Topical Past Paper Questions Workbook

AS & A Level Mathematics (9709) Paper 6

[Probability & Statistics 2]

Exam Series: May 2015 – May 2022

Format Type A:
Answers to all questions are provided as an appendix

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Introduction

Each topical past paper questions workbook consists of hundreds of questions and their answer schemes, in the form of worksheets. Questions are assigned to each chapter according to their corresponding topic. Topics, in turn, are based on the items of the latest Cambridge IGCSE or AS/A level syllabus content. This book's specifications are as follows:

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Chapter 1

The Poisson distribution

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1. 9709_m22_qp_62 Q: 7

(a) Two ponds, A and B, each contain a large number of fish. It is known that 2.4% of fish in pond A are carp and 1.8% of fish in pond B are carp. Random samples of 50 fish from pond A and 60 fish from pond B are selected.

Use appropriate Poisson approximations to find the following probabilities.

(i) The samples contain at least 2 carp from pond A and at least 2 carp from pond B. [3]

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(ii) The samples contain at least 4 carp altogether. [3]

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(b) The random variables X and Y have the distributions $\text{Po}(\lambda)$ and $\text{Po}(\mu)$ respectively. It is given that

- $\text{P}(X = 0) = [\text{P}(Y = 0)]^2$,
- $\text{P}(X = 2) = k[\text{P}(Y = 1)]^2$, where k is a non-zero constant.

Find the value of k. [4]

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2. 9709_s22_qp_61 Q: 5

Cars arrive at a fuel station at random and at a constant average rate of 13.5 per hour.

(a) Find the probability that more than 4 cars arrive during a 20-minute period. [3]

(b) Use an approximating distribution to find the probability that the number of cars that arrive during a 12-hour period is between 150 and 160 inclusive. [4]

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Independently of cars, trucks arrive at the fuel station at random and at a constant average rate of 3.6 per 15-minute period.

(c) Find the probability that the total number of cars and trucks arriving at the fuel station during a 10-minute period is more than 3 and less than 7. [3]

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3. 9709_s22_qp_62 Q: 3

It is known that 1.8% of children in a certain country have not been vaccinated against measles. A random sample of 200 children in this country is chosen.

(a) Use a suitable approximating distribution to find the probability that there are fewer than 3 children in the sample who have not been vaccinated against measles. [4]

(b) Justify your approximating distribution. [2]

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4. 9709_s22_qp_62 Q: 7

X is a random variable with distribution Po(2.90). A random sample of 100 values of X is taken.

Find the probability that the sample mean is less than 2.88. [5]

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5. 9709_s22_qp_63 Q: 5

The number of clients who arrive at an information desk has a Poisson distribution with mean 2.2 per 5-minute period.

(a) Find the probability that, in a randomly chosen 15-minute period, exactly 6 clients arrive at the desk. [3]

(b) If more than 4 clients arrive during a 5-minute period, they cannot all be served.

Find the probability that, during a randomly chosen 5-minute period, not all the clients who arrive at the desk can be served. [2]

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(c) Use a suitable approximating distribution to find the probability that, during a randomly chosen 1-hour period, fewer than 20 clients arrive at the desk. [4]

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6. 9709_m21_qp_62 Q: 4

On average, 1 in 400 microchips made at a certain factory are faulty. The number of faulty microchips in a random sample of 1000 is denoted by X.

(a) State the distribution of X, giving the values of any parameters. [1]

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(b) State an approximating distribution for X, giving the values of any parameters. [2]

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(c) Use this approximating distribution to find each of the following.

(i) $P(X = 4)$. [2]

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(ii) $P(2 \leqslant X \leqslant 4)$. [2]

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(d) Use a suitable approximating distribution to find the probability that, in a random sample of 700 microchips, there will be at least 1 faulty one. [3]

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7. 9709_s21_qp_61 Q: 1

Accidents at two factories occur randomly and independently. On average, the numbers of accidents per month are 3.1 at factory A and 1.7 at factory B.

Find the probability that the total number of accidents in the two factories during a 2-month period is more than 3. [4]

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8. 9709_s21_qp_61 Q: 5

On average, 1 in 75 000 adults has a certain genetic disorder.

(a) Use a suitable approximating distribution to find the probability that, in a random sample of 10 000 people, at least 1 has the genetic disorder. [3]

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(b) In a random sample of n people, where n is large, the probability that no-one has the genetic disorder is more than 0.9.

Find the largest possible value of n. [4]

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9. 9709_s21_qp_62 Q: 7

Customers arrive at a particular shop at random times. It has been found that the mean number of customers who arrive during a 5-minute interval is 2.1.

(a) Find the probability that exactly 4 customers arrive during a 10-minute interval. [2]

(b) Find the probability that at least 4 customers arrive during a 20-minute interval. [2]

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(c) Use a suitable approximating distribution to find the probability that fewer than 40 customers arrive during a 2-hour interval. [4]

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10. 9709_s21_qp_63 Q: 1

The number of goals scored by a team in a match is independent of other matches, and is denoted by the random variable X, which has a Poisson distribution with mean 1.36. A supporter offers to make a donation of \$5 to the team for each goal that they score in the next 10 matches.

Find the expectation and standard deviation of the amount that the supporter will pay. [5]

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11. 9709_s21_qp_63 Q: 5

Most plants of a certain type have three leaves. However, it is known that, on average, 1 in 10 000 of these plants have four leaves, and plants with four leaves are called 'lucky'. The number of lucky plants in a random sample of 25 000 plants is denoted by X.

(a) State, with a justification, an approximating distribution for X, giving the values of any parameters. [2]

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Use your approximating distribution to answer parts **(b)** and **(c)**.

(b) Find $\mathrm{P}(X \leqslant 3)$. [2]

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(c) Given that $P(X = k) = 2P(X = k + 1)$, find k. [2]

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The number of lucky plants in a random sample of n plants, where n is large, is denoted by Y.

(d) Given that $P(Y \geqslant 1) = 0.963$, correct to 3 significant figures, use a suitable approximating distribution to find the value of n. [3]

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12. 9709_w21_qp_61 Q: 2

The number of enquiries received per day at a customer service desk has a Poisson distribution with mean 45.2. If more than 60 enquiries are received in a day, the customer service desk cannot deal with them all.

Use a suitable approximating distribution to find the probability that, on a randomly chosen day, the customer service desk cannot deal with all the enquiries that are received. [4]

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13. 9709_w21_qp_62 Q: 5

In a certain large document, typing errors occur at random and at a constant mean rate of 0.2 per page.

(a) Find the probability that there are fewer than 3 typing errors in 10 randomly chosen pages. [2]

(b) Use an approximating distribution to find the probability that there are more than 50 typing errors in 200 randomly chosen pages. [4]

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In the same document, formatting errors occur at random and at a constant mean rate of 0.3 per page.

(c) Find the probability that the total number of typing and formatting errors in 20 randomly chosen pages is between 8 and 11 inclusive. [3]

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14. 9709_w21_qp_63 Q: 2

The number of enquiries received per day at a customer service desk has a Poisson distribution with mean 45.2. If more than 60 enquiries are received in a day, the customer service desk cannot deal with them all.

Use a suitable approximating distribution to find the probability that, on a randomly chosen day, the customer service desk cannot deal with all the enquiries that are received. [4]

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15. 9709_m20_qp_62 Q: 1

The booklets produced by a certain publisher contain, on average, 1 incorrect letter per 30 000 letters, and these errors occur randomly. A randomly chosen booklet from this publisher contains 12 500 letters.

Use a suitable approximating distribution to find the probability that this booklet contains at least 2 errors. [3]

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16. 9709_m20_qp_62 Q: 4

The number of accidents on a certain road has a Poisson distribution with mean 0.4 per 50-day period.

(a) Find the probability that there will be fewer than 3 accidents during a year (365 days). [3]

(b) The probability that there will be no accidents during a period of n days is greater than 0.95.

Find the largest possible value of n. [4]

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17. 9709_s20_qp_61 Q: 5

Each week a sports team plays one home match and one away match. In their home matches they score goals at a constant average rate of 2.1 goals per match. In their away matches they score goals at a constant average rate of 0.8 goals per match. You may assume that goals are scored at random times and independently of one another.

(a) A week is chosen at random.

(i) Find the probability that the team scores a total of 4 goals in their two matches. [2]

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(ii) Find the probability that the team scores a total of 4 goals, with more goals scored in the home match than in the away match. [3]

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(b) Use a suitable approximating distribution to find the probability that the team scores fewer than 25 goals in 10 randomly chosen weeks. [4]

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(c) Justify the use of the approximating distribution used in part **(b)**. [1]

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18. 9709_s20_qp_62 Q: 3

In the data-entry department of a certain firm, it is known that 0.12% of data items are entered incorrectly, and that these errors occur randomly and independently.

(a) A random sample of 3600 data items is chosen. The number of these data items that are incorrectly entered is denoted by X.

(i) State the distribution of X, including the values of any parameters. [1]

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(ii) State an appropriate approximating distribution for X, including the values of any parameters.

Justify your choice of approximating distribution. [3]

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(iii) Use your approximating distribution to find $P(X > 2)$. [2]

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(b) Another large random sample of n data items is chosen. The probability that the sample contains no data items that are entered incorrectly is more than 0.1.

Use an approximating distribution to find the largest possible value of n. [3]

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19. 9709_s20_qp_62 Q: 5

(a) The random variable X has the distribution $\text{Po}(\lambda)$.

(i) State the values that X can take. [1]

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It is given that $\text{P}(X = 1) = 3 \times \text{P}(X = 0)$.

(ii) Find λ. [1]

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(iii) Find $\text{P}(4 \leqslant X \leqslant 6)$. [2]

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(b) The random variable Y has the distribution $\text{Po}(\mu)$ where μ is large. Using a suitable approximating distribution, it is found that $\text{P}(Y < 46) = 0.0668$, correct to 4 decimal places.

Find μ. [5]

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20. 9709_s20_qp_63 Q: 4

The random variable A has the distribution Po(1.5). A_1 and A_2 are independent values of A.

(a) Find $P(A_1 + A_2 < 2)$. [3]

(b) Given that $A_1 + A_2 < 2$, find $P(A_1 = 1)$. [4]

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(c) Give a reason why $A_1 - A_2$ cannot have a Poisson distribution. [1]

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21. 9709_w20_qp_61 Q: 1

(a) Use an appropriate approximating distribution to find the probability that more than 1 flower in the sample is white. [3]

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(b) Justify the approximating distribution used in part **(a)**. [1]

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The probability that a randomly chosen flower of another kind is white is 0.02. A random sample of 150 of these flowers is selected.

(c) Use an appropriate approximating distribution to find the probability that the total number of white flowers in the two samples is less than 4. [3]

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22. 9709_w20_qp_62 Q: 1

On average, 1 in 50 000 people have a certain gene.

Use a suitable approximating distribution to find the probability that more than 2 people in a random sample of 150 000 have the gene. [3]

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23. 9709_w20_qp_62 Q: 5

Customers arrive at a shop at a constant average rate of 2.3 per minute.

(a) State another condition for the number of customers arriving per minute to have a Poisson distribution. [1]

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It is now given that the number of customers arriving per minute has the distribution Po(2.3).

(b) Find the probability that exactly 3 customers arrive during a 1-minute period. [2]

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(c) Find the probability that more than 3 customers arrive during a 2-minute period. [3]

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(d) Five 1-minute periods are chosen at random. Find the probability that no customers arrive during exactly 2 of these 5 periods. [3]

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24. 9709_w20_qp_63 Q: 1

It is known that, on average, 1 in 300 flowers of a certain kind are white. A random sample of 200 flowers of this kind is selected.

(a) Use an appropriate approximating distribution to find the probability that more than 1 flower in the sample is white. [3]

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(b) Justify the approximating distribution used in part **(a)**. [1]

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The probability that a randomly chosen flower of another kind is white is 0.02. A random sample of 150 of these flowers is selected.

(c) Use an appropriate approximating distribution to find the probability that the total number of white flowers in the two samples is less than 4. [3]

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25. 9709_m19_qp_72 Q: 5

The number of eagles seen per hour in a certain location has the distribution Po(1.8). The number of vultures seen per hour in the same location has the independent distribution Po(2.6).

(i) Find the probability that, in a randomly chosen hour, at least 2 eagles are seen. [2]

(ii) Find the probability that, in a randomly chosen half-hour period, the total number of eagles and vultures seen is less than 5. [3]

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Alex wants to be at least 99% certain of seeing at least 1 eagle.

(iii) Find the minimum time for which she should watch for eagles. [3]

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26. 9709_s19_qp_71 Q: 5

(a) The random variable X has the distribution Po(2.3).

(i) Find $P(2 \leqslant X \leqslant 4)$. [2]

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(ii) Find the probability that the sum of two independent values of X is greater than 2. [3]

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(iii) The random variable S is the sum of 50 independent values of X. Use a suitable approximating distribution to find $P(S \leqslant 110)$. [4]

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(b) The random variable Y has the distribution $\text{Po}(\lambda)$. Given that $\text{P}(Y = 3) = \text{P}(Y = 5)$, find λ. [3]

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27. 9709_s19_qp_72 Q: 1

The random variable X has the distribution Po(5).

(i) Find $P(X = 2)$. [1]

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It is given that $P(X = n) = P(X = n + 1)$.

(ii) Write down an equation in n. [1]

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(iii) Hence or otherwise find the value of n. [1]

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28. 9709_s19_qp_73 Q: 7

Each day at a certain doctor's surgery there are 70 appointments available in the morning and 60 in the afternoon. All the appointments are filled every day. The probability that any patient misses a particular morning appointment is 0.04, and the probability that any patient misses a particular afternoon appointment is 0.05. All missed appointments are independent of each other.

Use suitable approximating distributions to answer the following.

(i) Find the probability that on a randomly chosen morning there are at least 3 missed appointments. [3]

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(ii) Find the probability that on a randomly chosen day there are a total of exactly 6 missed appointments. [3]

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(iii) Find the probability that in a randomly chosen 10-day period there are more than 50 missed appointments. [4]

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29. 9709_w19_qp_72 Q: 1

On average, 1 in 150 components made by a certain machine are faulty. The random variable X denotes the number of faulty components in a random sample of 500 components.

(i) Describe fully the distribution of X. [2]

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(ii) State a suitable approximating distribution for X, giving a justification for your choice. [2]

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(iii) Use your approximating distribution to find the probability that the sample will include at least 3 faulty components. [3]

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30. 9709_w19_qp_73 Q: 2

Cars arrive at a filling station randomly and at a constant average rate of 2.4 cars per minute.

(i) Calculate the probability that fewer than 4 cars arrive in a 2-minute period. [2]

(ii) Use a suitable approximating distribution to calculate the probability that at least 140 cars arrive in a 1-hour period. [4]

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31. 9709_w19_qp_73 Q: 5

(i) The random variable X has the distribution B(300, 0.01). Use a Poisson approximation to find $P(2 < X < 6)$. [3]

(ii) The random variable Y has the distribution Po(λ), and $P(Y = 0) = P(Y = 2)$. Find λ. [2]

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(iii) The random variable Z has the distribution Po(5.2) and it is given that $P(Z = n) < P(Z = n + 1)$.

(a) Write down an inequality in n. [1]

(b) Hence or otherwise find the largest possible value of n. [2]

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32. 9709_m18_qp_72 Q: 2

The number of phone calls arriving in a 10-minute period at a switchboard is modelled by the random variable X which has the distribution Po(4.1). Use an approximating distribution to find the probability that more than 90 calls arrive in a 4-hour period. [5]

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33. 9709_s18_qp_71 Q: 3

The number of e-readers sold in a 10-day period in a shop is modelled by the distribution Po(5.1). Use an approximating distribution to find the probability that fewer than 140 e-readers are sold in a 300-day period. [4]

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34. 9709_s18_qp_72 Q: 1

The numbers of alpha, beta and gamma particles emitted per minute by a certain piece of rock have independent distributions Po(0.2), Po(0.3) and Po(0.6) respectively. Find the probability that the total number of particles emitted during a 4-minute period is less than 4. [3]

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35. 9709_s18_qp_72 Q: 6

Accidents on a particular road occur at a constant average rate of 1 every 4.8 weeks.

(i) State, in context, one condition for the number of accidents in a given period to be modelled by a Poisson distribution. [1]

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Assume now that a Poisson distribution is a suitable model.

(ii) Find the probability that exactly 4 accidents will occur during a randomly chosen 12-week period. [2]

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(iii) Find the probability that more than 3 accidents will occur during a randomly chosen 10-week period. [3]

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(iv) Use a suitable approximating distribution to find the probability that fewer than 30 accidents will occur during a randomly chosen 2-year period ($104\frac{2}{7}$ weeks). [4]

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36. 9709_s18_qp_73 Q: 1

A random variable X has the distribution B(75, 0.03).

(i) Use the Poisson approximation to the binomial distribution to calculate $P(X < 3)$. [3]

(ii) Justify the use of the Poisson approximation. [1]

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37. 9709_s18_qp_73 Q: 4

The numbers, M and F, of male and female students who leave a particular school each year to study engineering have means 3.1 and 0.8 respectively.

(i) State, in context, one condition required for M to have a Poisson distribution. [1]

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Assume that M and F can be modelled by independent Poisson distributions.

(ii) Find the probability that the total number of students who leave to study engineering in a particular year is more than 3. [3]

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(iii) Given that the total number of students who leave to study engineering in a particular year is more than 3, find the probability that no female students leave to study engineering in that year. [3]

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38. 9709_w18_qp_71 Q: 4

Small drops of two liquids, A and B, are randomly and independently distributed in the air. The average numbers of drops of A and B per cubic centimetre of air are 0.25 and 0.36 respectively.

(i) A sample of 10 cm^3 of air is taken at random. Find the probability that the total number of drops of A and B in this sample is at least 4. [3]

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(ii) A sample of $100\,\text{cm}^3$ of air is taken at random. Use an approximating distribution to find the probability that the total number of drops of A and B in this sample is less than 60. [5]

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39. 9709_w18_qp_72 Q: 1

The random variable X has the distribution Po(2.3). Find $P(2 \leqslant X < 5)$. [3]

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40. 9709_w18_qp_73 Q: 4

Small drops of two liquids, A and B, are randomly and independently distributed in the air. The average numbers of drops of A and B per cubic centimetre of air are 0.25 and 0.36 respectively.

(i) A sample of 10 cm^3 of air is taken at random. Find the probability that the total number of drops of A and B in this sample is at least 4. [3]

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(ii) A sample of 100 cm^3 of air is taken at random. Use an approximating distribution to find the probability that the total number of drops of A and B in this sample is less than 60. [5]

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41. 9709_m17_qp_72 Q: 7

The number of planes arriving at an airport every hour during daytime is modelled by the random variable X with distribution Po(5.2).

(i) State two assumptions required for the Poisson model to be valid in this context. [2]

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(ii) **(a)** Find the probability that the number of planes arriving in a 15-minute period is greater than 1 and less than 4, [3]

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(b) Find the probability that more than 3 planes will arrive in a 40-minute period. [2]

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(iii) The airport has enough staff to deal with a maximum of 60 planes landing during a 10-hour day. Use a suitable approximation to find the probability that, on a randomly chosen 10-hour day, staff will be able to deal with all the planes that land. [4]

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42. 9709_s17_qp_71 Q: 1

On average, 1 clover plant in 10 000 has four leaves instead of three.

(i) Use an approximating distribution to calculate the probability that, in a random sample of 2000 clover plants, more than 2 will have four leaves. [3]

(ii) Justify your approximating distribution. [2]

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43. 9709_s17_qp_72 Q: 2

Javier writes an article containing 52 460 words. He plans to upload the article to his website, but he knows that this process sometimes introduces errors. He assumes that for each word in the uploaded version of his article, the probability that it contains an error is 0.000 08. The number of words containing an error is denoted by X.

(i) Find $\mathrm{E}(X)$ and $\mathrm{Var}(X)$, giving your answers correct to three decimal places. [2]

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Javier wants to use the Poisson distribution as an approximating distribution to calculate the probability that there will be fewer than 5 words containing an error in his uploaded article.

(ii) Explain how your answers to part **(i)** are consistent with the use of the Poisson distribution as an approximating distribution. [1]

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(iii) Use the Poisson distribution to calculate $\mathrm{P}(X < 5)$. [2]

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44. 9709_s17_qp_72 Q: 6

Old televisions arrive randomly and independently at a recycling centre at an average rate of 1.2 per day.

(i) Find the probability that exactly 2 televisions arrive in a 2-day period. [2]

(ii) Use an appropriate approximating distribution to find the probability that at least 55 televisions arrive in a 50-day period. [4]

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Independently of televisions, old computers arrive randomly and independently at the same recycling centre at an average rate of 4 per 7-day week.

(iii) Find the probability that the total number of televisions and computers that arrive at the recycling centre in a 3-day period is less than 4. [3]

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45. 9709_s17_qp_73 Q: 5

(i) A random variable X has the distribution Po(42).

(a) Use an appropriate approximating distribution to find $\mathrm{P}(X \geqslant 40)$. [4]

(b) Justify your use of the approximating distribution. [1]

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(ii) A random variable Y has the distribution B(60, 0.02).

(a) Use an appropriate approximating distribution to find $P(Y > 2)$. [3]

(b) Justify your use of the approximating distribution. [1]

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46. 9709_w17_qp_71 Q: 1

A random variable, X, has the distribution Po(31). Use the normal approximation to the Poisson distribution to find $P(X > 40)$. [3]

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47. 9709_w17_qp_71 Q: 2

An airline has found that, on average, 1 in 100 passengers do not arrive for each flight, and that this occurs randomly. For one particular flight the airline always sells 403 seats. The plane only has room for 400 passengers, so the flight is overbooked if the number of passengers who do not arrive is less than 3. Use a suitable approximation to find the probability that the flight is overbooked. [4]

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48. 9709_w17_qp_72 Q: 1

(a) **(i)** A random variable X has the distribution B(2540, 0.001). Use the Poisson approximation to the binomial distribution to find $P(X > 1)$. [3]

(ii) Explain why the Poisson approximation is appropriate in this case. [1]

(b) Two independent random variables, S and T, have distributions Po(2.1) and Po(3.5) respectively. Find the mean and standard deviation of $S + T$. [2]

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49. 9709_w17_qp_73 Q: 1

A random variable, X, has the distribution Po(31). Use the normal approximation to the Poisson distribution to find $P(X > 40)$. [3]

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50. 9709_w17_qp_73 Q: 2

An airline has found that, on average, 1 in 100 passengers do not arrive for each flight, and that this occurs randomly. For one particular flight the airline always sells 403 seats. The plane only has room for 400 passengers, so the flight is overbooked if the number of passengers who do not arrive is less than 3. Use a suitable approximation to find the probability that the flight is overbooked. [4]

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51. 9709_m16_qp_72 Q: 6

The battery in Sue's phone runs out at random moments. Over a long period, she has found that the battery runs out, on average, 3.3 times in a 30-day period.

(i) Find the probability that the battery runs out fewer than 3 times in a 25-day period. [3]

(ii) **(a)** Use an approximating distribution to find the probability that the battery runs out more than 50 times in a year (365 days). [4]

(b) Justify the approximating distribution used in part **(ii)(a)**. [1]

(iii) Independently of her phone battery, Sue's computer battery also runs out at random moments. On average, it runs out twice in a 15-day period. Find the probability that the total number of times that her phone battery and her computer battery run out in a 10-day period is at least 4. [3]

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52. 9709_s16_qp_71 Q: 7

(a) A large number of spoons and forks made in a factory are inspected. It is found that 1% of the spoons and 1.5% of the forks are defective. A random sample of 140 items, consisting of 80 spoons and 60 forks, is chosen. Use the Poisson approximation to the binomial distribution to find the probability that the sample contains

(i) at least 1 defective spoon and at least 1 defective fork, [3]

(ii) fewer than 3 defective items. [3]

(b) The random variable X has the distribution Po(λ). It is given that

$$\mathrm{P}(X = 1) = p \quad \text{and} \quad \mathrm{P}(X = 2) = 1.5p,$$

where p is a non-zero constant. Find the value of λ and hence find the value of p. [4]

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53. 9709_s16_qp_72 Q: 6

At a certain shop the demand for hair dryers has a Poisson distribution with mean 3.4 per week.

(i) Find the probability that, in a randomly chosen two-week period, the demand is for exactly 5 hair dryers. [3]

(ii) At the beginning of a week the shop has a certain number of hair dryers for sale. Find the probability that the shop has enough hair dryers to satisfy the demand for the week if

(a) they have 4 hair dryers in the shop, [2]

(b) they have 5 hair dryers in the shop. [2]

(iii) Find the smallest number of hair dryers that the shop needs to have at the beginning of a week so that the probability of being able to satisfy the demand that week is at least 0.9. [3]

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54. 9709_s16_qp_73 Q: 3

1% of adults in a certain country own a yellow car.

(i) Use a suitable approximating distribution to find the probability that a random sample of 240 adults includes more than 2 who own a yellow car. [4]

(ii) Justify your approximation. [2]

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55. 9709_w16_qp_71 Q: 3

Particles are emitted randomly from a radioactive substance at a constant average rate of 3.6 per minute. Find the probability that

(i) more than 3 particles are emitted during a 20-second period, [3]

(ii) more than 240 particles are emitted during a 1-hour period. [4]

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56. 9709_w16_qp_73 Q: 1

The random variable X has the distribution Po(3.5). Find $P(X < 3)$. [3]

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57. 9709_w16_qp_73 Q: 7

Men arrive at a clinic independently and at random, at a constant mean rate of 0.2 per minute. Women arrive at the same clinic independently and at random, at a constant mean rate of 0.3 per minute.

(i) Find the probability that at least 2 men and at least 3 women arrive at the clinic during a 5-minute period. [4]

(ii) Find the probability that fewer than 36 people arrive at the clinic during a 1-hour period. [5]

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58. 9709_s15_qp_71 Q: 6

A publishing firm has found that errors in the first draft of a new book occur at random and that, on average, there is 1 error in every 3 pages of a first draft. Find the probability that in a particular first draft there are

(i) exactly 2 errors in 10 pages, [2]

(ii) at least 3 errors in 6 pages, [3]

(iii) fewer than 50 errors in 200 pages. [4]

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59. 9709_s15_qp_72 Q: 3

In a golf tournament, the number of times in a day that a 'hole-in-one' is scored is denoted by the variable X, which has a Poisson distribution with mean 0.15. Mr Crump offers to pay \$200 each time that a hole-in-one is scored during 5 days of play. Find the expectation and variance of the amount that Mr Crump pays. [5]

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60. 9709_s15_qp_72 Q: 7

In a certain lottery, 10 500 tickets have been sold altogether and each ticket has a probability of 0.0002 of winning a prize. The random variable X denotes the number of prize-winning tickets that have been sold.

(i) State, with a justification, an approximating distribution for X. [3]

(ii) Use your approximating distribution to find $P(X < 4)$. [3]

(iii) Use your approximating distribution to find the conditional probability that $X < 4$, given that $X \geqslant 1$. [4]

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61. 9709_s15_qp_73 Q: 6

People arrive at a checkout in a store at random, and at a constant mean rate of 0.7 per minute. Find the probability that

(i) exactly 3 people arrive at the checkout during a 5-minute period, [2]

(ii) at least 30 people arrive at the checkout during a 1-hour period. [4]

People arrive independently at another checkout in the store at random, and at a constant mean rate of 0.5 per minute.

(iii) Find the probability that a total of more than 3 people arrive at this pair of checkouts during a 2-minute period. [4]

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62. 9709_w15_qp_71 Q: 1

Failures of two computers occur at random and independently. On average the first computer fails 1.2 times per year and the second computer fails 2.3 times per year. Find the probability that the total number of failures by the two computers in a 6-month period is more than 1 and less than 4. [4]

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63. 9709_w15_qp_71 Q: 5

On average, 1 in 2500 adults has a certain medical condition.

(i) Use a suitable approximation to find the probability that, in a random sample of 4000 people, more than 3 have this condition. [3]

(ii) In a random sample of n people, where n is large, the probability that none has the condition is less than 0.05. Find the smallest possible value of n. [4]

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64. 9709_w15_qp_72 Q: 1

Failures of two computers occur at random and independently. On average the first computer fails 1.2 times per year and the second computer fails 2.3 times per year. Find the probability that the total number of failures by the two computers in a 6-month period is more than 1 and less than 4. [4]

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65. 9709_w15_qp_72 Q: 5

On average, 1 in 2500 adults has a certain medical condition.

(i) Use a suitable approximation to find the probability that, in a random sample of 4000 people, more than 3 have this condition. [3]

(ii) In a random sample of n people, where n is large, the probability that none has the condition is less than 0.05. Find the smallest possible value of n. [4]

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66. 9709_w15_qp_73 Q: 2

The number of calls received per 5-minute period at a large call centre has a Poisson distribution with mean λ, where $\lambda > 30$. If more than 55 calls are received in a 5-minute period, the call centre is overloaded. It has been found that the probability of being overloaded during a randomly chosen 5-minute period is 0.01. Use the normal approximation to the Poisson distribution to obtain a quadratic equation in $\sqrt{\lambda}$ and hence find the value of λ. [5]

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Chapter 2

Linear combinations of random variables

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67. 9709_m22_qp_62 Q: 5

The heights of buildings in a large city are normally distributed with mean 18.3 m and standard deviation 2.5 m.

(a) Find the probability that the total height of 5 randomly chosen buildings in the city is more than 95 m. [4]

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(b) Find the probability that the difference between the heights of two randomly chosen buildings in the city is less than 1 m. [5]

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68. 9709_s22_qp_61 Q: 3

The lengths, in centimetres, of two types of insect, A and B, are modelled by the random variables $X \sim \mathrm{N}(6.2, 0.36)$ and $Y \sim \mathrm{N}(2.4, 0.25)$ respectively.

Find the probability that the length of a randomly chosen type A insect is greater than the sum of the lengths of 3 randomly chosen type B insects. [5]

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69. 9709_s22_qp_61 Q: 4

The independent random variables X and Y have distributions Po(2) and $\mathrm{B}\left(20, \frac{1}{4}\right)$ respectively.

(a) Find the mean and standard deviation of $X - 3Y$. [5]

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(b) Find $P(Y = 15X)$. [3]

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70. 9709_s22_qp_62 Q: 6

The masses, in kilograms, of large and small sacks of grain have the distributions N(53, 11) and N(14, 3) respectively.

(a) Find the probability that the mass of a randomly chosen large sack is greater than four times the mass of a randomly chosen small sack. [5]

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(b) A lift can safely carry a maximum mass of 1000 kg.

Find the probability that the lift can safely carry 12 randomly chosen large sacks and 25 randomly chosen small sacks. [5]

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71. 9709_s22_qp_63 Q: 1

The number of characters in emails sent by a particular company is modelled by the distribution $N(1250, 480^2)$.

Find the probability that the mean number of characters in a random sample of 100 emails sent by the company is more than 1300. [3]

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72. 9709_s22_qp_63 Q: 4

Each box of Seeds & Raisins contains S grams of seeds and R grams of raisins. The weight of a box, when empty, is B grams. S, R and B are independent random variables, where $S \sim N(300, 45)$, $R \sim N(200, 25)$ and $B \sim N(15, 4)$. A full box of Seeds & Raisins is chosen at random.

(a) Find the probability that the total weight of the box and its contents is more than 500 grams. [5]

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(b) Find the probability that the weight of seeds in the box is less than 1.4 times the weight of raisins in the box. [5]

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73. 9709_m21_qp_62 Q: 5

The volumes, in litres, of juice in large and small bottles have the distributions N(5.10, 0.0102) and N(2.51, 0.0036) respectively.

(a) Find the probability that the total volume of juice in 3 randomly chosen large bottles and 4 randomly chosen small bottles is less than 25.5 litres. [5]

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(b) Find the probability that the volume of juice in a randomly chosen large bottle is at least twice the volume of juice in a randomly chosen small bottle. [5]

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74. 9709_s21_qp_61 Q: 7

The masses, in kilograms, of large and small sacks of flour have the distributions $N(55, 3^2)$ and $N(27, 2.5^2)$ respectively.

(a) Some sacks are loaded onto a boat. The maximum load of flour that the boat can carry safely is 340 kg.

Find the probability that the boat can carry safely 3 randomly chosen large sacks of flour and 6 randomly chosen small sacks of flour. [5]

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(b) Find the probability that the mass of a randomly chosen large sack of flour is greater than the total mass of two randomly chosen small sacks of flour. [5]

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75. 9709_s21_qp_62 Q: 2

The random variable X has the distribution B(400, 0.01).

(a) Find Var$(4X + 2)$. [3]

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(b) **(i)** State an appropriate approximating distribution for X, giving the values of any parameters. Justify your choice of approximating distribution. [2]

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(ii) Use your approximating distribution to find P$(2 \leqslant X \leqslant 5)$. [2]

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76. 9709_s21_qp_62 Q: 4

Wendy's journey to work consists of three parts: walking to the train station, riding on the train and then walking to the office. The times, in minutes, for the three parts of her journey are independent and have the distributions $N(15.0, 1.1^2)$, $N(32.0, 3.5^2)$ and $N(8.6, 1.2^2)$ respectively.

(a) Find the mean and variance of the total time for Wendy's journey. [2]

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If Wendy's journey takes more than 60 minutes, she is late for work.

(b) Find the probability that, on a randomly chosen day, Wendy will be late for work. [3]

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(c) Find the probability that the mean of Wendy's journey times over 15 randomly chosen days will be less than 54.5 minutes. [3]

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77. 9709_m20_qp_62 Q: 6

The volumes, in millilitres, of large and small cups of tea are modelled by the distributions N(200, 30) and N(110, 20) respectively.

(a) Find the probability that the total volume of a randomly chosen large cup of tea and a randomly chosen small cup of tea is less than 300 ml. [4]

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(b) Find the probability that the volume of a randomly chosen large cup of tea is more than twice the volume of a randomly chosen small cup of tea. [6]

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78. 9709_s20_qp_61 Q: 3

The masses, in kilograms, of large sacks of flour and small sacks of flour have the independent distributions $N(40, 1.5^2)$ and $N(12, 0.7^2)$ respectively.

(a) Find the probability that the total mass of 6 randomly chosen large sacks of flour is more than 245 kg. [4]

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(b) Find the probability that the mass of a randomly chosen large sack of flour is less than 4 times the mass of a randomly chosen small sack of flour. [6]

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79. 9709_s20_qp_62 Q: 1

The masses, in grams, of plums of a certain type have the distribution $N(40.4, 5.2^2)$. The plums are packed in bags, with each bag containing 6 randomly chosen plums. If the total weight of the plums in a bag is less than 220 g the bag is rejected.

Find the percentage of bags that are rejected. [4]

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80. 9709_s20_qp_63 Q: 2

Each day at the gym, Sarah completes three runs. The distances, in metres, that she completes in the three runs have the independent distributions $W \sim N(1520, 450)$, $X \sim N(2250, 720)$ and $Y \sim N(3860, 1050)$.

Find the probability that, on a particular day, Y is less than the total of W and X. [5]

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81. 9709_w20_qp_61 Q: 3

The masses, in kilograms, of female and male animals of a certain species have the distributions $N(102, 27^2)$ and $N(170, 55^2)$ respectively.

Find the probability that a randomly chosen female has a mass that is less than half the mass of a randomly chosen male. [6]

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82. 9709_w20_qp_62 Q: 7

Before a certain type of book is published it is checked for errors, which are then corrected. For costing purposes each error is classified as either minor or major. The numbers of minor and major errors in a book are modelled by the independent distributions N(380, 140) and N(210, 80) respectively. You should assume that no continuity corrections are needed when using these models.

A book of this type is chosen at random.

(a) Find the probability that the number of minor errors is at least 200 more than the number of major errors. [5]

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The costs of correcting a minor error and a major error are 20 cents and 50 cents respectively.

(b) Find the probability that the total cost of correcting the errors in the book is less than \$190. [5]

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83. 9709_w20_qp_63 Q: 3

The masses, in kilograms, of female and male animals of a certain species have the distributions $N(102, 27^2)$ and $N(170, 55^2)$ respectively.

Find the probability that a randomly chosen female has a mass that is less than half the mass of a randomly chosen male. [6]

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84. 9709_m19_qp_72 Q: 2

The independent random variables X and Y have the distributions N(9.2, 12.1) and N(3.0, 8.6) respectively. Find $P(X > 3Y)$. [5]

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85. 9709_s19_qp_71 Q: 1

At an internet café, the charge for using a computer is 5 cents per minute. The number of minutes for which people use a computer has mean 23 and standard deviation 8.

(i) Find, in cents, the mean and standard deviation of the amount people pay when using a computer. [2]

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(ii) Each day, 15 people use computers independently. Find, in cents, the mean and standard deviation of the total amount paid by 15 people. [3]

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86. 9709_s19_qp_72 Q: 2

The random variable X has mean 372 and standard deviation 54.

(i) Describe fully the distribution of the mean of a random sample of 36 values of X. [3]

(ii) The distribution in part **(i)** might be either exact or approximate. State a condition under which the distribution is exact. [1]

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87. 9709_s19_qp_72 Q: 4

The heights of a certain variety of plant are normally distributed with mean 110 cm and variance 1050 cm^2. Two plants of this variety are chosen at random. Find the probability that the height of one of these plants is at least 1.5 times the height of the other. [7]

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88. 9709_s19_qp_73 Q: 4

A factory supplies boxes of children's bricks. Each box contains 10 randomly chosen large bricks and 20 randomly chosen small bricks. The masses, in grams, of large and small bricks have the distributions N(60, 1.2) and N(30, 0.7) respectively. The mass of an empty box is 8 g. Find the probability that the total weight of a box and its contents is less than 1200 g. [5]

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89. 9709_w19_qp_72 Q: 5

The masses, in grams, of large boxes of chocolates and small boxes of chocolates have the distributions N(325, 6.1) and N(167, 5.6) respectively.

(i) Find the probability that the total mass of 10 randomly chosen large boxes of chocolates is less than 3240 g. [4]

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(ii) Find the probability that the mass of a randomly chosen large box of chocolates is more than twice the mass of a randomly chosen small box of chocolates. [5]

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90. 9709_w19_qp_73 Q: 1

The random variable X has mean 2.4 and variance 3.1.

(i) The random variable Y is the sum of four independent values of X. Find the mean and variance of Y. [2]

(ii) The random variable Z is defined by $Z = 4X - 3$. Find the mean and variance of Z. [2]

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91. 9709_m18_qp_72 Q: 3

The heights of plants of type A have mean 1.2 m and standard deviation 0.03 m. A random sample of 5 plants of type A is selected. The sum of the heights of these 5 plants is denoted by H_A m.

(i) Find the mean and variance of H_A. [3]

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The heights of plants of type B have mean 0.6 m and standard deviation 0.02 m. A random sample of 5 plants of type B is selected. The sum of the heights of these 5 plants is denoted by H_B m.

(ii) Find the mean and variance of $H_A - 2H_B$. [4]

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92. 9709_s18_qp_71 Q: 4

The volume, in millilitres, of a small cup of coffee has the distribution N(103.4, 10.2). The volume of a large cup of coffee is 1.5 times the volume of a small cup of coffee.

(i) Find the mean and standard deviation of the volume of a large cup of coffee. [3]

(ii) Find the probability that the total volume of a randomly chosen small cup of coffee and a randomly chosen large cup of coffee is greater than 250 ml. [4]

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93. 9709_s18_qp_72 Q: 2

The random variable X has the distribution N(3, 1.2). The random variable A is defined by $A = 2X$. The random variable B is defined by $B = X_1 + X_2$, where X_1 and X_2 are independent random values of X. Describe fully the distribution of A and the distribution of B. [3]

Distribution of A: .....

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Distribution of B: .....

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94. 9709_s18_qp_73 Q: 6

The times, in minutes, taken to complete the two parts of a task are normally distributed with means 4.5 and 2.3 respectively and standard deviations 1.1 and 0.7 respectively.

(i) Find the probability that the total time taken for the task is less than 8.5 minutes. [4]

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(ii) Find the probability that the time taken for the first part of the task is more than twice the time taken for the second part. [5]

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95. 9709_w18_qp_71 Q: 5

The times, in months, taken by a builder to build two types of house, P and Q, are represented by the independent variables $T_1 \sim \mathrm{N}(2.2, 0.4^2)$ and $T_2 \sim \mathrm{N}(2.8, 0.5^2)$ respectively.

(i) Find the probability that the total time taken to build one house of each type is less than 6 months. [4]

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(ii) Find the probability that the time taken to build a type Q house is more than 1.2 times the time taken to build a type P house. [5]

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96. 9709_w18_qp_72 Q: 3

Sugar and flour for making cakes are measured in cups. The mass, in grams, of one cup of sugar has the distribution N(250, 10). The mass, in grams, of one cup of flour has the independent distribution N(160, 9). Each cake contains 2 cups of sugar and 5 cups of flour. Find the probability that the total mass of sugar and flour in one cake exceeds 1310 grams. [5]

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97. 9709_w18_qp_73 Q: 5

The times, in months, taken by a builder to build two types of house, P and Q, are represented by the independent variables $T_1 \sim N(2.2, 0.4^2)$ and $T_2 \sim N(2.8, 0.5^2)$ respectively.

(i) Find the probability that the total time taken to build one house of each type is less than 6 months. [4]

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(ii) Find the probability that the time taken to build a type Q house is more than 1.2 times the time taken to build a type P house. [5]

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98. 9709_m17_qp_72 Q: 6

The masses, in kilograms, of cartons of sugar and cartons of flour have the distributions $N(78.8, 12.6^2)$ and $N(62.0, 10.0^2)$ respectively.

(i) The standard load for a certain crane is 8 cartons of sugar and 3 cartons of flour. The maximum load that can be carried safely by the crane is 900 kg. Stating a necessary assumption, find the percentage of standard loads that will exceed the maximum safe load. [5]

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(ii) Find the probability that a randomly chosen carton of sugar has a smaller mass than a randomly chosen carton of flour. [5]

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99. 9709_s17_qp_71 Q: 5

Large packets of sugar are packed in cartons, each containing 12 packets. The weights of these packets are normally distributed with mean 505 g and standard deviation 3.2 g. The weights of the cartons, when empty, are independently normally distributed with mean 150 g and standard deviation 7 g.

(i) Find the probability that the total weight of a full carton is less than 6200 g. [5]

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Small packets of sugar are packed in boxes. The total weight of a full box has a normal distribution with mean 3130 g and standard deviation 12.1 g.

(ii) Find the probability that the weight of a randomly chosen full carton is less than double the weight of a randomly chosen full box. [5]

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100. 9709_s17_qp_72 Q: 7

(a) A random variable X is normally distributed with mean 4.2 and standard deviation 1.1. Find the probability that the sum of two randomly chosen values of X is greater than 10. [4]

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(b) Each candidate's overall score for an essay is calculated as follows. The mark for creativity is denoted by C, the penalty mark for spelling errors is denoted by S and the overall score is defined by $C - \frac{1}{2}S$. The variables C and S are independent and have distributions N(29, 105) and N(17, 15) respectively. Find the proportion of candidates receiving a negative overall score. [5]

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101. 9709_s17_qp_73 Q: 3

The mass, in tonnes, of iron ore produced per day at a mine is normally distributed with mean 7.0 and standard deviation 0.46. Find the probability that the total amount of iron ore produced in 10 randomly chosen days is more than 71 tonnes. [5]

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102. 9709_w17_qp_71 Q: 6

The numbers of barrels of oil, in millions, extracted per day in two oil fields A and B are modelled by the independent random variables X and Y respectively, where $X \sim \mathrm{N}(3.2, 0.4^2)$ and $Y \sim \mathrm{N}(4.3, 0.6^2)$. The income generated by the oil from the two fields is \$90 per barrel for A and \$95 per barrel for B.

(i) Find the mean and variance of the daily income, in millions of dollars, generated by field A. [3]

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(ii) Find the probability that the total income produced by the two fields in a day is at least \$670 million. [5]

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103. 9709_w17_qp_72 Q: 5

The marks in paper 1 and paper 2 of an examination are denoted by X and Y respectively, where X and Y have the independent continuous distributions $N(56, 6^2)$ and $N(43, 5^2)$ respectively.

(i) Find the probability that a randomly chosen paper 1 mark is more than a randomly chosen paper 2 mark. [5]

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(ii) Each candidate's overall mark is M where $M = X + 1.5Y$. The minimum overall mark for grade A is 135. Find the proportion of students who gain a grade A. [5]

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104. 9709_w17_qp_73 Q: 6

The numbers of barrels of oil, in millions, extracted per day in two oil fields A and B are modelled by the independent random variables X and Y respectively, where $X \sim \mathrm{N}(3.2, 0.4^2)$ and $Y \sim \mathrm{N}(4.3, 0.6^2)$. The income generated by the oil from the two fields is \$90 per barrel for A and \$95 per barrel for B.

(i) Find the mean and variance of the daily income, in millions of dollars, generated by field A. [3]

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(ii) Find the probability that the total income produced by the two fields in a day is at least \$670 million. [5]

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105. 9709_m16_qp_72 Q: 1

A fair six-sided die is thrown 20 times and the number of sixes, X, is recorded. Another fair six-sided die is thrown 20 times and the number of odd-numbered scores, Y, is recorded. Find the mean and standard deviation of $X + Y$. [5]

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106. 9709_m16_qp_72 Q: 4

The masses, in grams, of large bags of sugar and small bags of sugar are denoted by X and Y respectively, where $X \sim \mathrm{N}(5.1, 0.2^2)$ and $Y \sim \mathrm{N}(2.5, 0.1^2)$. Find the probability that the mass of a randomly chosen large bag is less than twice the mass of a randomly chosen small bag. [5]

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107. 9709_s16_qp_71 Q: 5

The thickness of books in a large library is normally distributed with mean 2.4 cm and standard deviation 0.3 cm.

(i) Find the probability that the total thickness of 6 randomly chosen books is more than 16 cm. [4]

(ii) Find the probability that the thickness of a book chosen at random is less than 1.1 times the thickness of a second book chosen at random. [5]

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108. 9709_s16_qp_72 Q: 1

The length of time, in minutes, taken by people to complete a task has mean 53.0 and standard deviation 6.2. Find the probability that the mean time taken to complete the task by a random sample of 50 people is more than 51 minutes. [4]

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109. 9709_s16_qp_72 Q: 5

Each box of Fruity Flakes contains X grams of flakes and Y grams of fruit, where X and Y are independent random variables, having distributions N(400, 50) and N(100, 20) respectively. The weight of each box, when empty, is exactly 20 grams. A full box of Fruity Flakes is chosen at random.

(i) Find the probability that the total weight of the box and its contents is less than 530 grams. [5]

(ii) Find the probability that the weight of flakes in the box is more than 4.1 times the weight of fruit in the box. [5]

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110. 9709_s16_qp_73 Q: 7

Bags of sugar are packed in boxes, each box containing 20 bags. The masses of the boxes, when empty, are normally distributed with mean 0.4 kg and standard deviation 0.01 kg. The masses of the bags are normally distributed with mean 1.02 kg and standard deviation 0.03 kg.

(i) Find the probability that the total mass of a full box of 20 bags is less than 20.6 kg. [5]

(ii) Two full boxes are chosen at random. Find the probability that they differ in mass by less than 0.02 kg. [5]

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111. 9709_w16_qp_71 Q: 4

Each week a farmer sells X litres of milk and Y kg of cheese, where X and Y have the independent distributions $N(1520, 53^2)$ and $N(175, 12^2)$ respectively.

(i) Find the mean and standard deviation of the total amount of milk that the farmer sells in 4 randomly chosen weeks. [2]

During a year when milk prices are low, the farmer makes a loss of 2 cents per litre on milk and makes a profit of 21 cents per kg on cheese, so the farmer's overall weekly profit is $(21Y - 2X)$ cents.

(ii) Find the probability that, in a randomly chosen week, the farmer's overall profit is positive. [5]

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112. 9709_w16_qp_73 Q: 3

A men's triathlon consists of three parts: swimming, cycling and running. Competitors' times, in minutes, for the three parts can be modelled by three independent normal variables with means 34.0, 87.1 and 56.9, and standard deviations 3.2, 4.1 and 3.8, respectively. For each competitor, the total of his three times is called the race time. Find the probability that the mean race time of a random sample of 15 competitors is less than 175 minutes. [5]

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113. 9709_s15_qp_71 Q: 3

The daily times, in minutes, that Yu Ming takes showering, getting dressed and having breakfast are independent and have the distributions $N(9, 2.2^2)$, $N(8, 1.3^2)$ and $N(17, 2.6^2)$ respectively. The total daily time that Yu Ming takes for all three activities is denoted by T minutes.

(i) Find the mean and variance of T. [2]

(ii) Yu Ming notes the value of T on each day in a random sample of 70 days and calculates the sample mean. Find the probability that the sample mean is between 33 and 35. [4]

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114. 9709_s15_qp_71 Q: 7

The independent variables X and Y are such that $X \sim \text{B}(10, 0.8)$ and $Y \sim \text{Po}(3)$. Find

(i) $\text{E}(7X + 5Y - 2)$, [2]

(ii) $\text{Var}(4X - 3Y + 3)$, [4]

(iii) $\text{P}(2X - Y = 18)$. [4]

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115. 9709_s15_qp_72 Q: 1

The independent random variables X and Y have standard deviations 3 and 6 respectively. Calculate the standard deviation of $4X - 5Y$. [3]

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116. 9709_w15_qp_71 Q: 6

The weights, in kilograms, of men and women have the distributions $\text{N}(78, 7^2)$ and $\text{N}(66, 5^2)$ respectively.

(i) The maximum load that a certain cable car can carry safely is 1200 kg. If 9 randomly chosen men and 7 randomly chosen women enter the cable car, find the probability that the cable car can operate safely. [5]

(ii) Find the probability that a randomly chosen woman weighs more than a randomly chosen man. [4]

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117. 9709_w15_qp_73 Q: 7

The diameter, in cm, of pistons made in a certain factory is denoted by X, where X is normally distributed with mean μ and variance σ^2. The diameters of a random sample of 100 pistons were measured, with the following results.

$$n = 100 \qquad \Sigma x = 208.7 \qquad \Sigma x^2 = 435.57$$

(i) Calculate unbiased estimates of μ and σ^2. [3]

The pistons are designed to fit into cylinders. The internal diameter, in cm, of the cylinders is denoted by Y, where Y has an independent normal distribution with mean 2.12 and variance 0.000 144. A piston will not fit into a cylinder if $Y - X < 0.01$.

(ii) Using your answers to part **(i)**, find the probability that a randomly chosen piston will not fit into a randomly chosen cylinder. [6]

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Chapter 3

Continuous random variables

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118. 9709_m22_qp_62 Q: 6

In a game a ball is rolled down a slope and along a track until it stops. The distance, in metres, travelled by the ball is modelled by the random variable X with probability density function

$$f(x) = \begin{cases} -k(x-1)(x-3) & 1 \leqslant x \leqslant 3, \\ 0 & \text{otherwise,} \end{cases}$$

where k is a constant.

(a) Without calculation, explain why $E(X) = 2$. [1]

(b) Show that $k = \frac{3}{4}$. [3]

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(c) Find Var(X). [3]

One turn consists of rolling the ball 3 times and noting the largest value of X obtained. If this largest value is greater than 2.5, the player scores a point.

(d) Find the probability that on a particular turn the player scores a point. [4]

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119. 9709_s22_qp_61 Q: 6

A random variable X has probability density function f. The graph of $f(x)$ is a straight line segment parallel to the x-axis from $x = 0$ to $x = a$, where a is a positive constant.

(a) State, in terms of a, the median of X. [1]

(b) Find $P(X > \frac{3}{4}a)$. [1]

(c) Show that $\text{Var}(X) = \frac{1}{12}a^2$. [5]

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(d) Given that $\mathrm{P}(X < b) = p$, where $0 < b < \frac{1}{2}a$, find $\mathrm{P}\left(\frac{1}{3}b < X < a - \frac{1}{3}b\right)$ in terms of p. [2]

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120. 9709_s22_qp_62 Q: 5

A random variable X has probability density function given by

$$f(x) = \begin{cases} \frac{3}{16}(4x - x^2) & 2 \leqslant x \leqslant 4, \\ 0 & \text{otherwise.} \end{cases}$$

(a) Show that $E(X) = \frac{11}{4}$. [3]

(b) Find $\text{Var}(X)$. [3]

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(c) Given that the median of X is m, find $\mathrm{P}(m < X < 3)$. [3]

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121. 9709_s22_qp_63 Q: 7

The random variables X and W have probability density functions f and g defined as follows:

$$\mathrm{f}(x) = \begin{cases} p(a^2 - x^2) & 0 \leqslant x \leqslant a, \\ 0 & \text{otherwise,} \end{cases}$$

$$\mathrm{g}(w) = \begin{cases} q(a^2 - w^2) & -a \leqslant w \leqslant a, \\ 0 & \text{otherwise,} \end{cases}$$

where a, p and q are constants.

(a) **(i)** Write down the value of $\mathrm{P}(X \geqslant 0)$. [1]

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(ii) Write down the value of $\mathrm{P}(W \geqslant 0)$. [1]

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(iii) Write down an expression for q in terms of p only. [1]

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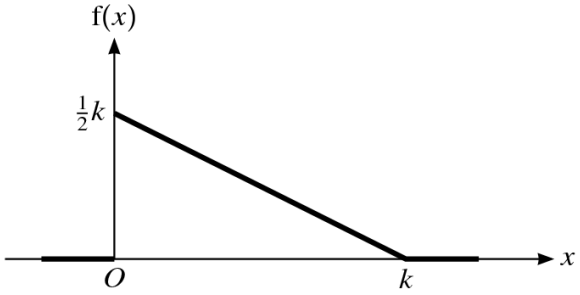
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(b) Given that $E(X) = 3$, find the value of a. [6]

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122. 9709_m21_qp_62 Q: 2



The diagram shows the graph of the probability density function, f, of a random variable X.

(a) Find the value of the constant k. [2]

(b) Using this value of k, find $f(x)$ for $0 \leqslant x \leqslant k$ and hence find $E(X)$. [3]

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(c) Find the value of p such that $P(p < X < 1) = 0.25$. [4]

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123. 9709_s21_qp_61 Q: 3

The graph of the probability density function of a random variable X is symmetrical about the line $x = 4$.

Given that $P(X < 5) = \frac{20}{27}$, find $P(3 < X < 5)$. [2]

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124. 9709_s21_qp_61 Q: 6

The probability density function, f, of a random variable X is given by

$$f(x) = \begin{cases} k(6x - x^2) & 0 \leqslant x \leqslant 6, \\ 0 & \text{otherwise,} \end{cases}$$

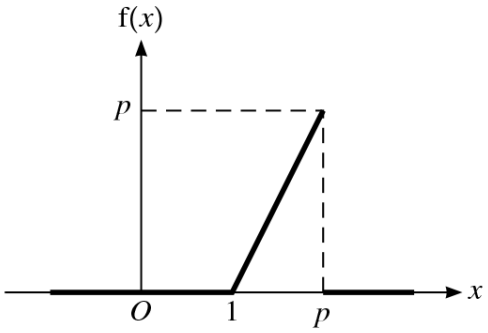
where k is a constant.

State the value of $E(X)$ and show that $\text{Var}(X) = \frac{9}{5}$. [6]

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125. 9709_s21_qp_62 Q: 3



The random variable X takes values in the range $1 \leqslant x \leqslant p$, where p is a constant. The graph of the probability density function of X is shown in the diagram.

(a) Show that $p = 2$. [2]

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(b) Find $\mathrm{E}(X)$. [5]

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126. 9709_s21_qp_63 Q: 6

Alethia models the length of time, in minutes, by which her train is late on any day by the random variable X with probability density function given by

$$f(x) = \begin{cases} \frac{3}{8000}(x-20)^2 & 0 \leqslant x \leqslant 20, \\ 0 & \text{otherwise.} \end{cases}$$

(a) Find the probability that the train is more than 10 minutes late on each of two randomly chosen days. [4]

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(b) Find E(X). [4]

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(c) The median of X is denoted by m.

Show that m satisfies the equation $(m - 20)^3 = -4000$, and hence find m correct to 3 significant figures. [4]

(d) State one way in which Alethia's model may be unrealistic. [1]

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127. 9709_w21_qp_61 Q: 4

A random variable X has probability density function given by

$$f(x) = \begin{cases} \frac{1}{18}(9 - x^2) & 0 \leqslant x \leqslant 3, \\ 0 & \text{otherwise.} \end{cases}$$

(a) Find $P(X < 1.2)$. [3]

(b) Find $E(X)$. [3]

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The median of X is m.

(c) Show that $m^3 - 27m + 27 = 0$. [3]

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128. 9709_w21_qp_62 Q: 7

(a) The probability density function of the random variable X is given by

$$f(x) = \begin{cases} kx(4-x) & 0 \leqslant x \leqslant 2, \\ 0 & \text{otherwise,} \end{cases}$$

where k is a constant.

(i) Show that $k = \frac{3}{16}$. [3]

(ii) Find $E(X)$. [3]

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(b) The random variable Y has the following properties.

- Y takes values between 0 and 5 only.
- The probability density function of Y is symmetrical.

Given that $P(Y < a) = 0.2$, find $P(2.5 < Y < 5 - a)$ illustrating your method with a sketch on the axes provided. [3]



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129. 9709_w21_qp_63 Q: 4

A random variable X has probability density function given by

$$f(x) = \begin{cases} \frac{1}{18}(9 - x^2) & 0 \leqslant x \leqslant 3, \\ 0 & \text{otherwise.} \end{cases}$$

(a) Find $P(X < 1.2)$. [3]

(b) Find $E(X)$. [3]

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The median of X is m.

(c) Show that $m^3 - 27m + 27 = 0$. [3]

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130. 9709_m20_qp_62 Q: 5

Bottles of Lanta contain approximately 300 ml of juice. The volume of juice, in millilitres, in a bottle is $300 + X$, where X is a random variable with probability density function given by

$$f(x) = \begin{cases} \frac{3}{4000}(100 - x^2) & -10 \leqslant x \leqslant 10, \\ 0 & \text{otherwise.} \end{cases}$$

(a) Find the probability that a randomly chosen bottle of Lanta contains more than 305 ml of juice. [3]

(b) Given that 25% of bottles of Lanta contain more than $(300 + p)$ ml of juice, show that

$$p^3 - 300p + 1000 = 0. \quad [4]$$

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(c) Given that $p = 3.47$, and that 50% of bottles of Lanta contain between $(300 - q)$ and $(300 + q)$ ml of juice, find q. Justify your answer. [2]

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131. 9709_s20_qp_61 Q: 6

The length of time, T minutes, that a passenger has to wait for a bus at a certain bus stop is modelled by the probability density function given by

$$f(t) = \begin{cases} \frac{3}{4000}(20t - t^2) & 0 \leqslant t \leqslant 20, \\ 0 & \text{otherwise.} \end{cases}$$

(a) Sketch the graph of $y = f(t)$. [1]

(b) Hence explain, without calculation, why $E(T) = 10$. [1]

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(c) Find $\text{Var}(T)$. [3]

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(d) It is given that $P(T < 10 + a) = p$, where $0 < a < 10$.

Find $P(10 - a < T < 10 + a)$ in terms of p. [2]

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(e) Find $P(8 < T < 12)$. [3]

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(f) Give one reason why this model may be unrealistic. [1]

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132. 9709_s20_qp_62 Q: 6

A random variable X has probability density function given by

$$f(x) = \begin{cases} \dfrac{k}{x^2} & 1 \leqslant x \leqslant a, \\ 0 & \text{otherwise,} \end{cases}$$

where k and a are positive constants.

(a) Show that $k = \dfrac{a}{a-1}$. [3]

(b) Find $E(X)$ in terms of a. [3]

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(c) Find the 60th percentile of X in terms of a. [4]

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133. 9709_s20_qp_63 Q: 6

The length, X centimetres, of worms of a certain type is modelled by the probability density function

$$f(x) = \begin{cases} \frac{6}{125}(10 - x)(x - 5) & 5 \leqslant x \leqslant 10, \\ 0 & \text{otherwise.} \end{cases}$$

(a) State the value of $E(X)$. [1]

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(b) Find $\text{Var}(X)$. [3]

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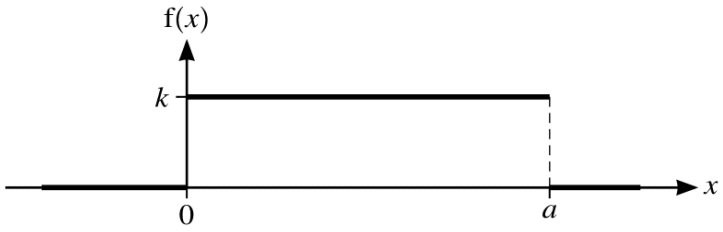
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(c) Two worms of this type are chosen at random.

Find the probability that exactly one of them has length less than 6 cm. [5]

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134. 9709_w20_qp_61 Q: 4



The diagram shows the probability density function, $f(x)$, of a random variable X. For $0 \leqslant x \leqslant a$, $f(x) = k$; elsewhere $f(x) = 0$.

(a) Express k in terms of a. [1]

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(b) Given that $\text{Var}(X) = 3$, find a. [4]

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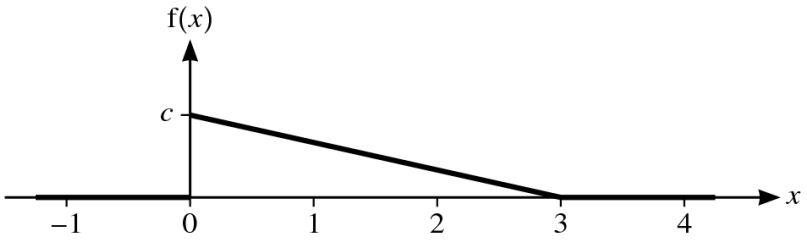
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135. 9709_w20_qp_62 Q: 3



A random variable X takes values between 0 and 3 only and has probability density function as shown in the diagram, where c is a constant.

(a) Show that $c = \frac{2}{3}$. [1]

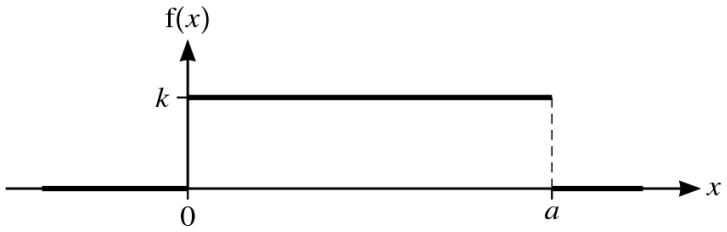
(b) Find $P(X > 2)$. [2]

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(c) Calculate E(X). [4]

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136. 9709_w20_qp_63 Q: 4



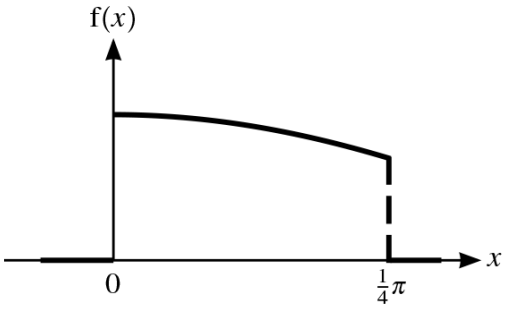
The diagram shows the probability density function, $f(x)$, of a random variable X. For $0 \leqslant x \leqslant a$, $f(x) = k$; elsewhere $f(x) = 0$.

(a) Express k in terms of a. [1]

(b) Given that $\text{Var}(X) = 3$, find a. [4]

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137. 9709_m19_qp_72 Q: 7



A random variable X has probability density function given by

$$f(x) = \begin{cases} (\sqrt{2})\cos x & 0 \leqslant x \leqslant \frac{1}{4}\pi, \\ 0 & \text{otherwise,} \end{cases}$$

as shown in the diagram.

(i) Find $P(X > \frac{1}{6}\pi)$. [2]

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(ii) Find the median of X. [4]

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(iii) Find $\mathrm{E}(X)$. [4]

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138. 9709_s19_qp_71 Q: 4

(a)



The diagram shows the graph of the probability density function, f, of a random variable X, where a is a constant greater than 0.5. The graph between $x = 0$ and $x = a$ is a straight line parallel to the x-axis.

(i) Find $P(X < 0.5)$ in terms of a. [2]

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(ii) Find $E(X)$ in terms of a. [1]

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(iii) Show that $Var(X) = \frac{1}{12}a^2$. [2]

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(b) A random variable T has probability density function given by

$$g(t) = \begin{cases} \dfrac{3}{2(t-1)^2} & 2 \leqslant t \leqslant 4, \\ 0 & \text{otherwise.} \end{cases}$$

Find the value of b such that $P(T \leqslant b) = \frac{3}{4}$. [4]

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139. 9709_s19_qp_72 Q: 6

X is a random variable with probability density function given by

$$f(x) = \begin{cases} \dfrac{a}{x^2} & 1 \leqslant x \leqslant b, \\ 0 & \text{otherwise,} \end{cases}$$

where a and b are constants.

(i) Show that $b = \dfrac{a}{a-1}$. [3]

(ii) Given that the median of X is $\frac{3}{2}$, find the values of a and b. [3]

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(iii) Use your values of a and b from part **(ii)** to find $\mathrm{E}(X)$. [3]

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140. 9709_s19_qp_73 Q: 6

A function f is defined by

$$f(x) = \begin{cases} \dfrac{3x^2}{a^3} & 0 \leqslant x \leqslant a, \\ 0 & \text{otherwise,} \end{cases}$$

where a is a constant.

(i) Show that f is a probability density function for all positive values of a. [3]

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The random variable X has probability density function f and the median of X is 2.

(ii) Show that $a = 2.52$, correct to 3 significant figures. [3]

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(iii) Find E(X). [3]

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141. 9709_w19_qp_72 Q: 4

A random variable X has probability density function given by

$$f(x) = \begin{cases} \frac{1}{2}x & 0 \leqslant x \leqslant a, \\ 0 & \text{otherwise,} \end{cases}$$

where a is a constant.

(i) Find a. [2]

(ii) Show that $E(X) = \frac{4}{3}$. [3]

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The median of X is denoted by m.

(iii) Find $\mathrm{P}\big(\mathrm{E}(X) < X < m\big)$. [4]

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142. 9709_w19_qp_73 Q: 6

A random variable X has probability density function given by

$$f(x) = \begin{cases} k(3x - x^2) & 0 \leqslant x \leqslant 3, \\ 0 & \text{otherwise.} \end{cases}$$

(i) Show that $k = \frac{2}{9}$. [3]

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(ii) Find $P(1 \leqslant X \leqslant 2)$. [2]

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(iii) Find Var(X). [5]

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143. 9709_m18_qp_72 Q: 6

A random variable X has probability density function given by

$$f(x) = \begin{cases} 6x(1-x) & 0 \leqslant x \leqslant 1, \\ 0 & \text{otherwise.} \end{cases}$$

(i) Find the probability that X does not lie between 0.3 and 0.7. [4]

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(ii) Sketch the graph of the probability density function and hence state the value of $\mathrm{E}(X)$. [2]

(iii) Find $\mathrm{Var}(X)$. [3]

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144. 9709_s18_qp_71 Q: 6

The time, in minutes, taken by people to complete a test is modelled by the continuous random variable X with probability density function given by

$$f(x) = \begin{cases} \dfrac{k}{x^2} & 5 \leqslant x \leqslant 10, \\ 0 & \text{otherwise,} \end{cases}$$

where k is a constant.

(i) Show that $k = 10$. [3]

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(ii) Show that $E(X) = 10 \ln 2$. [2]

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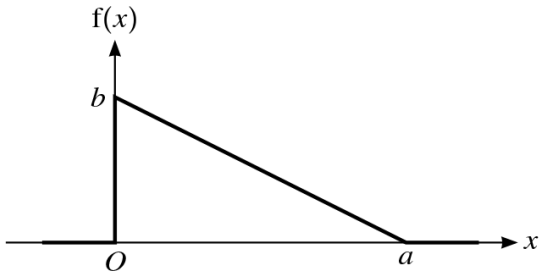
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(iii) Find $P(X > 9)$. [3]

(iv) Given that $P(X < a) = 0.6$, find a. [3]

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145. 9709_s18_qp_72 Q: 5



The diagram shows the probability density function, f, of a random variable X, in terms of the constants a and b.

(i) Find b in terms of a. [2]

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(ii) Show that $f(x) = \frac{2}{a} - \frac{2}{a^2}x$. [3]

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(iii) Given that $\mathrm{E}(X) = 0.5$, find a. [4]

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146. 9709_s18_qp_73 Q: 7

A random variable X has probability density function defined by

$$f(x) = \begin{cases} k\left(\frac{1}{x^2} + \frac{1}{x^3}\right) & 1 \leqslant x \leqslant 2, \\ 0 & \text{otherwise,} \end{cases}$$

where k is a constant.

(i) Show that $k = \frac{8}{7}$. [3]

(ii) Find $E(X)$. [3]

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(iii) Three values of X are chosen at random. Find the probability that one of these values is less than 1.5 and the other two are greater than 1.5. [5]

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147. 9709_w18_qp_71 Q: 6

The random variable X has probability density function given by

$$f(x) = \begin{cases} kx^{-1} & 2 \leqslant x \leqslant 6, \\ 0 & \text{otherwise,} \end{cases}$$

where k is a constant.

(i) Show that $k = \dfrac{1}{\ln 3}$. [2]

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(ii) Show that $E(X) = 3.64$, correct to 3 significant figures. [3]

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(iii) Given that the median of X is m, find $\mathrm{P}\big(m < X < \mathrm{E}(X)\big)$. [4]

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148. 9709_w18_qp_72 Q: 4

The time, X hours, taken by a large number of runners to complete a race is modelled by the probability density function given by

$$f(x) = \begin{cases} \dfrac{k}{(x+1)^2} & 0 \leqslant x \leqslant a, \\ 0 & \text{otherwise,} \end{cases}$$

where k and a are constants.

(i) Show that $k = \dfrac{a+1}{a}$. [3]

(ii) State what the constant a represents in this context. [1]

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Three quarters of the runners take half an hour or less to complete the race.

(iii) Find the value of a. [3]

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149. 9709_w18_qp_73 Q: 6

The random variable X has probability density function given by

$$f(x) = \begin{cases} kx^{-1} & 2 \leqslant x \leqslant 6, \\ 0 & \text{otherwise,} \end{cases}$$

where k is a constant.

(i) Show that $k = \dfrac{1}{\ln 3}$. [2]

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(ii) Show that $E(X) = 3.64$, correct to 3 significant figures. [3]

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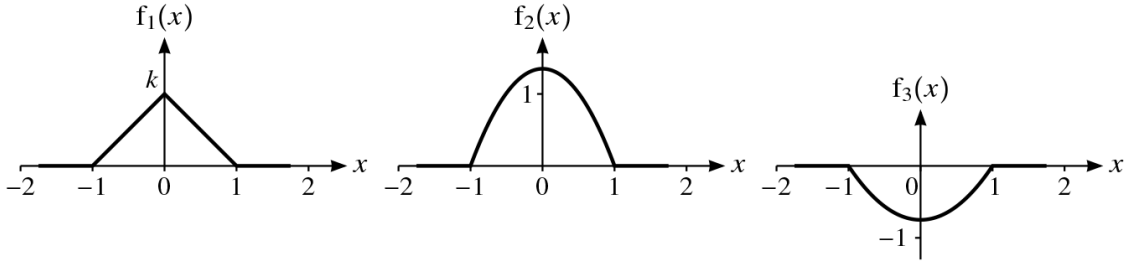
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(iii) Given that the median of X is m, find $\mathrm{P}\big(m < X < \mathrm{E}(X)\big)$. [4]

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150. 9709_m17_qp_72 Q: 5

(a)



The diagram shows the graphs of three functions, f_1, f_2 and f_3. The function f_1 is a probability density function.

(i) State the value of k. [1]

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(ii) For each of the functions f_2 and f_3, state why it cannot be a probability density function. [2]

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(b) The probability density function g is defined by

$$g(x) = \begin{cases} 6(a^2 - x^2) & -a \leqslant x \leqslant a, \\ 0 & \text{otherwise,} \end{cases}$$

where a is a constant.

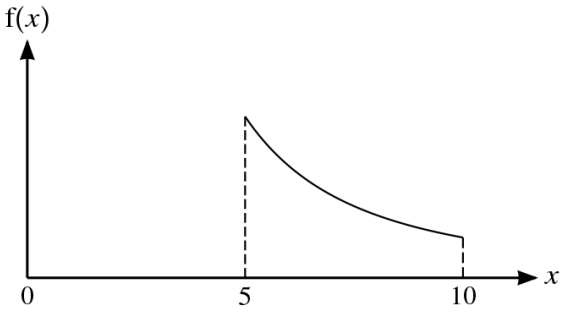
(i) Show that $a = \frac{1}{2}$. [3]

(ii) State the value of $E(X)$. [1]

(iii) Find $\text{Var}(X)$. [2]

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151. 9709_s17_qp_71 Q: 4



The time, X minutes, taken by a large number of runners to complete a certain race has probability density function f given by

$$f(x) = \begin{cases} \dfrac{k}{x^2} & 5 \leqslant x \leqslant 10, \\ 0 & \text{otherwise,} \end{cases}$$

where k is a constant, as shown in the diagram.

(i) Without calculation, explain how you can tell that there were more runners whose times were below 7.5 minutes than above 7.5 minutes. [1]

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(ii) Show that $k = 10$. [3]

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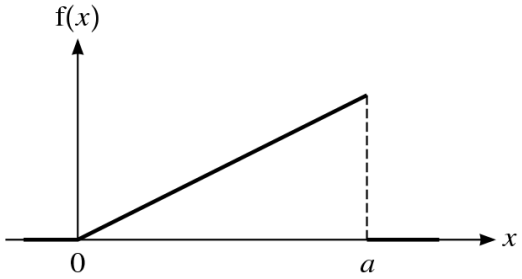
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(iii) Find E(X). [3]

(iv) Find Var(X). [2]

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152. 9709_s17_qp_72 Q: 5



The diagram shows the graph of the probability density function, f, of a random variable X which takes values between 0 and a only. It is given that $P(X < 1) = 0.25$.

(i) Find, in any order,

(a) $P(X < 2)$,

(b) the value of a,

(c) $f(x)$.

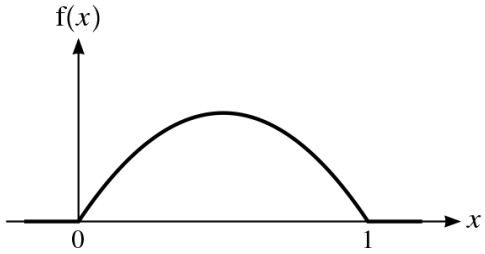
[5]

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(ii) Find the median of X. [3]

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153. 9709_s17_qp_73 Q: 6



The diagram shows the graph of the probability density function, f, of a continuous random variable X, where f is defined by

$$f(x) = \begin{cases} k(x - x^2) & 0 \leqslant x \leqslant 1, \\ 0 & \text{otherwise.} \end{cases}$$

(i) Show that the value of the constant k is 6. [3]

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(ii) State the value of $E(X)$ and find $Var(X)$. [4]

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(iii) Find $P(0.4 < X < 2)$. [3]

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154. 9709_w17_qp_71 Q: 5

A continuous random variable, X, has probability density function given by

$$f(x) = \begin{cases} \frac{1}{4}(x+1) & 0 \leqslant x \leqslant 2, \\ 0 & \text{otherwise.} \end{cases}$$

(i) Find $E(X)$. [3]

(ii) Find the median of X. [3]

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155. 9709_w17_qp_72 Q: 4

The random variable X has probability density function given by

$$f(x) = \begin{cases} \dfrac{k}{\sqrt{x}} & 0 < x \leqslant a, \\ 0 & \text{otherwise,} \end{cases}$$

where k and a are constants. It is given that $E(X) = 3$.

(i) Find the value of a and show that $k = \frac{1}{6}$. [7]

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(ii) Find the median of X. [3]

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156. 9709_w17_qp_73 Q: 5

A continuous random variable, X, has probability density function given by

$$f(x) = \begin{cases} \frac{1}{4}(x+1) & 0 \leqslant x \leqslant 2, \\ 0 & \text{otherwise.} \end{cases}$$

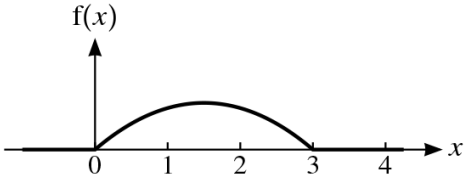
(i) Find $E(X)$. [3]

(ii) Find the median of X. [3]

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157. 9709_m16_qp_72 Q: 7

(a)



The diagram shows the graph of the probability density function, f, of a random variable X, where

$$f(x) = \begin{cases} \frac{2}{9}(3x - x^2) & 0 \leqslant x \leqslant 3, \\ 0 & \text{otherwise.} \end{cases}$$

(i) State the value of $E(X)$ and find $Var(X)$. [4]

(ii) State the value of $P(1.5 \leqslant X \leqslant 4)$. [1]

(iii) Given that $P(1 \leqslant X \leqslant 2) = \frac{13}{27}$, find $P(X > 2)$. [2]

(b) A random variable, W, has probability density function given by

$$g(w) = \begin{cases} aw & 0 \leqslant w \leqslant b, \\ 0 & \text{otherwise,} \end{cases}$$

where a and b are constants. Given that the median of W is 2, find a and b. [4]

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158. 9709_s16_qp_71 Q: 6

In each turn of a game, a coin is pushed and slides across a table. The distance, X metres, travelled by the coin has probability density function given by

$$f(x) = \begin{cases} kx^2(2 - x) & 0 \leqslant x \leqslant 2, \\ 0 & \text{otherwise,} \end{cases}$$

where k is a constant.

(i) State the greatest possible distance travelled by the coin in one turn. [1]

(ii) Show that $k = \frac{3}{4}$. [3]

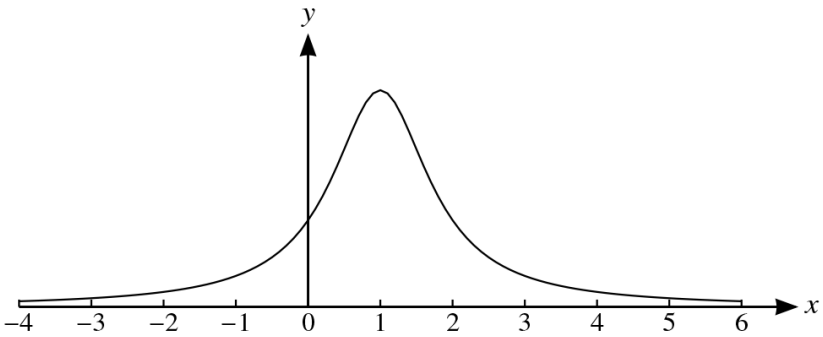
(iii) Find the mean distance travelled by the coin in one turn. [3]

(iv) Out of 400 turns, find the expected number of turns in which the distance travelled by the coin is less than 1 metre. [3]

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159. 9709_s16_qp_72 Q: 7

(a)



The diagram shows the graph of the probability density function of a variable X. Given that the graph is symmetrical about the line $x = 1$ and that $\mathrm{P}(0 < X < 2) = 0.6$, find $\mathrm{P}(X > 0)$. [2]

(b) A flower seller wishes to model the length of time that tulips last when placed in a jug of water. She proposes a model using the random variable X (in hundreds of hours) with probability density function given by

$$\mathrm{f}(x) = \begin{cases} k(2.25 - x^2) & 0 \leqslant x \leqslant 1.5, \\ 0 & \text{otherwise,} \end{cases}$$

where k is a constant.

(i) Show that $k = \frac{4}{9}$. [3]

(ii) Use this model to find the mean number of hours that a tulip lasts in a jug of water. [4]

The flower seller wishes to create a similar model for daffodils. She places a large number of daffodils in jugs of water and the longest time that any daffodil lasts is found to be 290 hours.

(iii) Give a reason why $\mathrm{f}(x)$ would not be a suitable model for daffodils. [1]

(iv) The flower seller considers a model for daffodils of the form

$$\mathrm{g}(x) = \begin{cases} c(a^2 - x^2) & 0 \leqslant x \leqslant a, \\ 0 & \text{otherwise,} \end{cases}$$

where a and c are constants. State a suitable value for a. (There is no need to evaluate c.) [1]

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160. 9709_s16_qp_73 Q: 5

The time, T minutes, taken by people to complete a test has probability density function given by

$$f(t) = \begin{cases} k(10t - t^2) & 5 \leqslant t \leqslant 10, \\ 0 & \text{otherwise,} \end{cases}$$

where k is a constant.

(i) Show that $k = \frac{3}{250}$. [3]

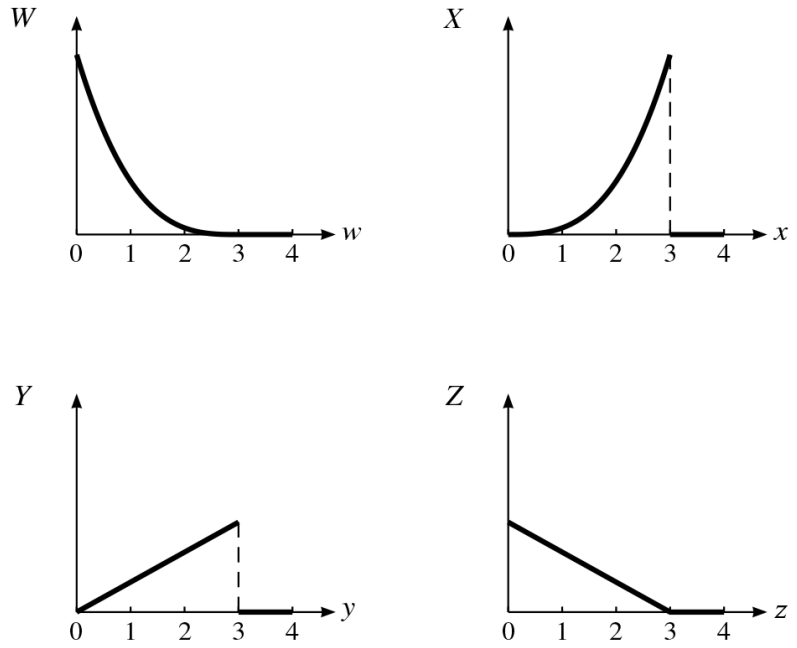
(ii) Find $E(T)$. [3]

(iii) Find the probability that a randomly chosen value of T lies between $E(T)$ and the median of T. [3]

(iv) State the greatest possible length of time taken to complete the test. [1]

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161. 9709_w16_qp_71 Q: 6



The diagrams show the probability density functions of four random variables W, X, Y and Z. Each of the four variables takes values between 0 and 3 only, and their medians are m_W, m_X, m_Y and m_Z respectively.

(i) List m_W, m_X, m_Y and m_Z in order of size, starting with the largest. [2]

(ii) The probability density function of X is given by

$$\mathrm{f}(x) = \begin{cases} \frac{4}{81}x^3 & 0 \leqslant x \leqslant 3, \\ 0 & \text{otherwise.} \end{cases}$$

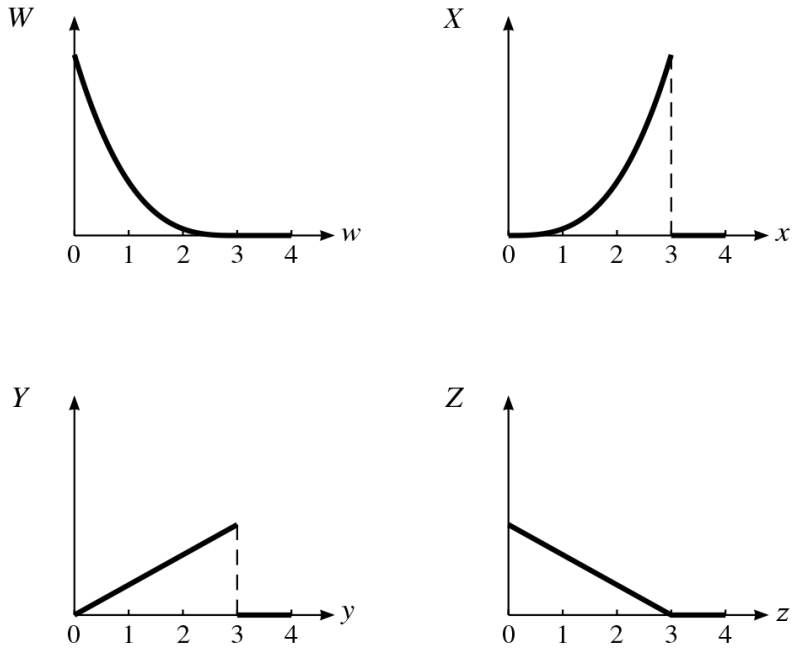
(a) Show that $\mathrm{E}(X) = \frac{12}{5}$. [3]

(b) Calculate $\mathrm{P}\big(X > \mathrm{E}(X)\big)$. [3]

(c) Write down the value of $\mathrm{P}\big(X < 2\mathrm{E}(X)\big)$. [1]

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162. 9709_w16_qp_72 Q: 6



The diagrams show the probability density functions of four random variables W, X, Y and Z. Each of the four variables takes values between 0 and 3 only, and their medians are m_W, m_X, m_Y and m_Z respectively.

(i) List m_W, m_X, m_Y and m_Z in order of size, starting with the largest. [2]

(ii) The probability density function of X is given by

$$\mathrm{f}(x) = \begin{cases} \frac{4}{81}x^3 & 0 \leqslant x \leqslant 3, \\ 0 & \text{otherwise.} \end{cases}$$

(a) Show that $\mathrm{E}(X) = \frac{12}{5}$. [3]

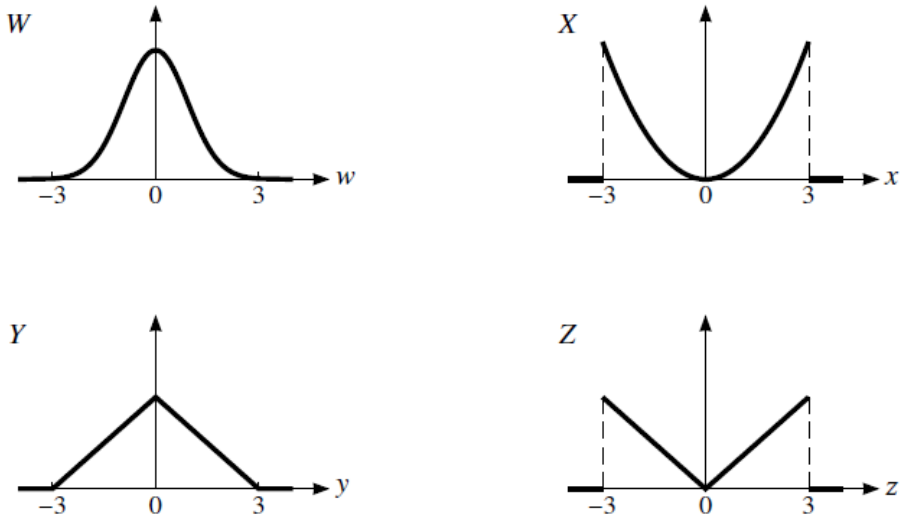
(b) Calculate $\mathrm{P}\big(X > \mathrm{E}(X)\big)$. [3]

(c) Write down the value of $\mathrm{P}\big(X < 2\mathrm{E}(X)\big)$. [1]

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163. 9709_w16_qp_73 Q: 8

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The diagrams show the probability density functions of four random variables W, X, Y and Z. Each of the four variables takes values between -3 and 3 only, and their standard deviations are σ_W, σ_X, σ_Y and σ_Z respectively.

(i) List σ_W, σ_X, σ_Y and σ_Z in order of size, starting with the largest. [2]

(ii) The probability density function of X is given by

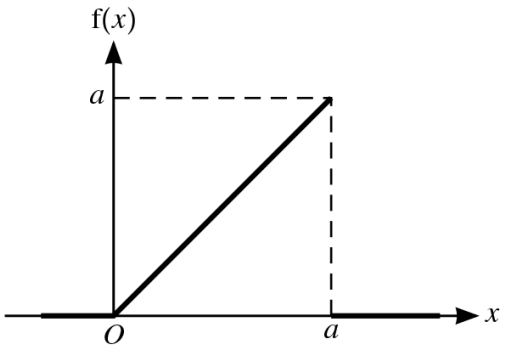
$$f(x) = \begin{cases} \frac{1}{18}x^2 & -3 \leqslant x \leqslant 3, \\ 0 & \text{otherwise.} \end{cases}$$

(a) Show that $\sigma_X = 2.32$ correct to 3 significant figures. [3]

(b) Calculate $P(X > \sigma_X)$. [3]

(c) Write down the value of $P(X > 2\sigma_X)$. [1]

164. 9709_s15_qp_71 Q: 1



The random variable X has probability density function, f, as shown in the diagram, where a is a constant. Find the value of a and hence show that $E(X) = 0.943$ correct to 3 significant figures. [5]

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165. 9709_s15_qp_72 Q: 6

The waiting time, T minutes, for patients at a doctor's surgery has probability density function given by

$$f(t) = \begin{cases} k(225 - t^2) & 0 \leqslant t \leqslant 15, \\ 0 & \text{otherwise,} \end{cases}$$

where k is a constant.

(i) Show that $k = \frac{1}{2250}$. [3]

(ii) Find the probability that a patient has to wait for more than 10 minutes. [3]

(iii) Find the mean waiting time. [4]

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166. 9709_s15_qp_73 Q: 7

The probability density function of the random variable X is given by

$$f(x) = \begin{cases} \frac{3}{4}x(c - x) & 0 \leqslant x \leqslant c, \\ 0 & \text{otherwise,} \end{cases}$$

where c is a constant.

(i) Show that $c = 2$. [3]

(ii) Sketch the graph of $y = f(x)$ and state the median of X. [3]

(iii) Find $P(X < 1.5)$. [4]

(iv) Hence write down the value of $P(0.5 < X < 1)$. [1]

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167. 9709_w15_qp_71 Q: 4

A random variable X has probability density function given by

$$f(x) = \begin{cases} k(3 - x) & 1 \leqslant x \leqslant 2, \\ 0 & \text{otherwise,} \end{cases}$$

where k is a constant.

(i) Show that $k = \frac{2}{3}$. [3]

(ii) Find the median of X. [4]

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168. 9709_w15_qp_73 Q: 4

A random variable X has probability density function given by

$$f(x) = \begin{cases} k(4 - x^2) & -2 \leqslant x \leqslant 2, \\ 0 & \text{otherwise,} \end{cases}$$

where k is a constant.

(i) Show that $k = \frac{3}{32}$. [3]

(ii) Sketch the graph of $y = f(x)$ and hence write down the value of $E(X)$. [2]

(iii) Find $P(X < 1)$. [3]

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Chapter 4

Sampling and estimation

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169. 9709_m22_qp_62 Q: 1

The lengths, in millimetres, of a random sample of 12 rods made by a certain machine are as follows.

200	201	198	202	200	199	199	201	197	202	200	199

(a) Find unbiased estimates of the population mean and variance. [3]

(b) Give a statistical reason why these estimates may not be reliable. [1]

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170. 9709_m22_qp_62 Q: 3

A random sample of 500 households in a certain town was chosen. Using this sample, a confidence interval for the proportion, p, of all households in that town that owned two or more cars was found to be $0.355 < p < 0.445$.

Find the confidence level of this confidence interval. Give your answer correct to the nearest integer. [5]

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171. 9709_s22_qp_61 Q: 1

The diameters, x millimetres, of a random sample of 200 discs made by a certain machine were recorded. The results are summarised below.

$$n = 200 \qquad \Sigma x = 2520 \qquad \Sigma x^2 = 31852$$

(a) Calculate a 95% confidence interval for the population mean diameter. [6]

(b) Jean chose 40 random samples and used each sample to calculate a 95% confidence interval for the population mean diameter.

How many of these 40 confidence intervals would be expected to include the true value of the population mean diameter? [1]

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172. 9709_s22_qp_62 Q: 1

(a) A javelin thrower noted the lengths of a random sample of 50 of her throws. The sample mean was 72.3 m and an unbiased estimate of the population variance was 64.3 m^2.

Find a 92% confidence interval for the population mean length of throws by this athlete. [3]

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(b) A discus thrower wishes to calculate a 92% confidence interval for the population mean length of his throws. He bases his calculation on his first 50 throws in a week.

Comment on this method. [1]

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173. 9709_s22_qp_63 Q: 6

A random sample of 5 values of a variable X is given below.

$$2 \quad 3 \quad 3 \quad 5 \quad a$$

(a) Find an expression, in terms of a, for the mean of these values. [1]

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It is given that an unbiased estimate of the population variance of X, using these values, is 4. It is also given that a is positive.

(b) Find and simplify a quadratic equation in terms of a and hence find the value of a. [3]

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174. 9709_m21_qp_62 Q: 1

A construction company notes the time, t days, that it takes to build each house of a certain design. The results for a random sample of 60 such houses are summarised as follows.

$$\Sigma t = 4820 \qquad \Sigma t^2 = 392\,050$$

(a) Calculate a 98% confidence interval for the population mean time. [6]

(b) Explain why it was necessary to use the Central Limit theorem in part **(a)**. [1]

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175. 9709_s21_qp_61 Q: 2

The time, in minutes, taken by students to complete a test has the distribution N(125, 36).

(a) Find the probability that the mean time taken to complete the test by a random sample of 40 students is less than 123 minutes. [3]

(b) Explain whether it was necessary to use the Central Limit theorem in the solution to part **(a)**. [1]

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176. 9709_s21_qp_61 Q: 4

100 randomly chosen adults each throw a ball once. The length, l metres, of each throw is recorded. The results are summarised below.

$$n = 100 \qquad \Sigma l = 3820 \qquad \Sigma l^2 = 182\,200$$

Calculate a 94% confidence interval for the population mean length of throws by adults. [6]

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177. 9709_s21_qp_62 Q: 6

The heights, h centimetres, of a random sample of 100 fully grown animals of a certain species were measured. The results are summarised below.

$$n = 100 \qquad \Sigma h = 7570 \qquad \Sigma h^2 = 588\,050$$

(a) Find unbiased estimates of the population mean and variance. [3]

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(b) Calculate a 99% confidence interval for the mean height of animals of this species. [3]

Four random samples were taken and a 99% confidence interval for the population mean, μ, was found from each sample.

(c) Find the probability that all four of these confidence intervals contain the true value of μ. [2]

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178. 9709_s21_qp_63 Q: 4

The masses, m kilograms, of flour in a random sample of 90 sacks of flour are summarised as follows.

$$n = 90 \qquad \Sigma m = 4509 \qquad \Sigma m^2 = 225\,950$$

(a) Find unbiased estimates of the population mean and variance. [3]

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(b) Calculate a 98% confidence interval for the population mean. [3]

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(c) Explain why it was necessary to use the Central Limit theorem in answering part **(b)**. [1]

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(d) Find the probability that the confidence interval found in part **(b)** is wholly above the true value of the population mean. [2]

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179. 9709_w21_qp_61 Q: 1

It is known that the height H, in metres, of trees of a certain kind has the distribution N(12.5, 10.24). A scientist takes a random sample of 25 trees of this kind and finds the sample mean, $\overline{H}$, of the heights.

(a) State the distribution of $\overline{H}$, giving the values of any parameters. [2]

(b) Find $P(12 < \overline{H} < 13)$. [3]

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180. 9709_w21_qp_61 Q: 3

A random sample of 75 students at a large college was selected for a survey. 15 of these students said that they owned a car. From this result an approximate $\alpha\%$ confidence interval for the proportion of all students at the college who own a car was calculated. The width of this interval was found to be 0.162.

Calculate the value of α correct to 2 significant figures. [5]

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181. 9709_w21_qp_61 Q: 6

The random variable T denotes the time, in seconds, for 100 m races run by Tania. T is normally distributed with mean μ and variance σ^2. A random sample of 40 races run by Tania gave the following results.

$$n = 40 \qquad \Sigma t = 560 \qquad \Sigma t^2 = 7850$$

(a) Calculate unbiased estimates of μ and σ^2. [3]

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The random variable S denotes the time, in seconds, for 100 m races run by Suki. S has the independent distribution N(14.2, 0.3).

(b) Using your answers to part **(a)**, find the probability that, in a randomly chosen 100 m race, Suki's time will be at least 0.1 s more than Tania's time. [5]

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182. 9709_w21_qp_62 Q: 1

The mass, in kilograms, of a block of cheese sold in a supermarket is denoted by the random variable M. The masses of a random sample of 40 blocks are summarised as follows.

$$n = 40 \qquad \Sigma m = 20.50 \qquad \Sigma m^2 = 10.7280$$

(a) Calculate unbiased estimates of the population mean and variance of M. [3]

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(b) The price, \$$P$, of a block of cheese of mass M kg is found using the formula $P = 11M + 0.50$.

Find estimates of the population mean and variance of P. [3]

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183. 9709_w21_qp_62 Q: 2

Andy and Jessica are doing a survey about musical preferences. They plan to choose a representative sample of six students from the 256 students at their college.

(a) Andy suggests that they go to the music building during the lunch hour and choose six students at random from the students who are there.

Give a reason why this method is unsatisfactory. [1]

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(b) Jessica decides to use another method. She numbers all the students in the college from 1 to 256. Then she uses her calculator and generates the following random numbers.

204393 162007 204028 587119 207395

From these numbers, she obtains six student numbers. The first three of her student numbers are 204, 162 and 7.

Continue Jessica's method to obtain the next three student numbers. [2]

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184. 9709_w21_qp_62 Q: 3

The probability that a certain spinner lands on red on any spin is p. The spinner is spun 140 times and it lands on red 35 times.

(a) Find an approximate 96% confidence interval for p. [3]

From three further experiments, Jack finds a 90% confidence interval, a 95% confidence interval and a 99% confidence interval for p.

(b) Find the probability that exactly two of these confidence intervals contain the true value of p. [3]

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185. 9709_w21_qp_63 Q: 1

It is known that the height H, in metres, of trees of a certain kind has the distribution N(12.5, 10.24). A scientist takes a random sample of 25 trees of this kind and finds the sample mean, $\overline{H}$, of the heights.

(a) State the distribution of $\overline{H}$, giving the values of any parameters. [2]

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(b) Find $P(12 < \overline{H} < 13)$. [3]

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186. 9709_w21_qp_63 Q: 3

A random sample of 75 students at a large college was selected for a survey. 15 of these students said that they owned a car. From this result an approximate $\alpha\%$ confidence interval for the proportion of all students at the college who own a car was calculated. The width of this interval was found to be 0.162.

Calculate the value of α correct to 2 significant figures. [5]

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187. 9709_w21_qp_63 Q: 6

The random variable T denotes the time, in seconds, for 100 m races run by Tania. T is normally distributed with mean μ and variance σ^2. A random sample of 40 races run by Tania gave the following results.

$$n = 40 \qquad \Sigma t = 560 \qquad \Sigma t^2 = 7850$$

(a) Calculate unbiased estimates of μ and σ^2. [3]

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The random variable S denotes the time, in seconds, for 100 m races run by Suki. S has the independent distribution N(14.2, 0.3).

(b) Using your answers to part **(a)**, find the probability that, in a randomly chosen 100 m race, Suki's time will be at least 0.1 s more than Tania's time. [5]

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188. 9709_m20_qp_62 Q: 2

Lengths of a certain species of lizard are known to be normally distributed with standard deviation 3.2 cm. A naturalist measures the lengths of a random sample of 100 lizards of this species and obtains an $\alpha\%$ confidence interval for the population mean. He finds that the total width of this interval is 1.25 cm.

Find α. [5]

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189. 9709_s20_qp_61 Q: 1

The lengths, X centimetres, of a random sample of 7 leaves from a certain variety of tree are as follows.

5.2 4.8 5.5 6.1 4.8 3.9 4.4

(a) Calculate unbiased estimates of the population mean and variance of X. [3]

It is now given that the true value of the population variance of X is 0.55, and that X has a normal distribution.

(b) Find a 95% confidence interval for the population mean of X. [3]

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190. 9709_s20_qp_63 Q: 1

A random sample of 100 values of a variable X is taken. These values are summarised below.

$$n = 100 \qquad \Sigma x = 1556 \qquad \Sigma x^2 = 29\,004$$

Calculate unbiased estimates of the population mean and variance of X. [3]

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191. 9709_s20_qp_63 Q: 5

Sunita has a six-sided die with faces marked 1, 2, 3, 4, 5, 6. The probability that the die shows a six on any throw is p. Sunita throws the die 500 times and finds that it shows a six 70 times.

(a) Calculate an approximate 99% confidence interval for p. [4]

(b) Sunita believes that the die is fair. Use your answer to part **(a)** to comment on her belief. [1]

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(c) Sunita uses the result of her 500 throws to calculate an $\alpha\%$ confidence interval for p. This interval has width 0.04.

Find the value of α. [5]

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192. 9709_w20_qp_61 Q: 2

In a survey, a random sample of 250 adults in Fromleigh were asked to fill in a questionnaire about their travel.

(a) It was found that 102 adults in the sample travel by bus. Find an approximate 90% confidence interval for the proportion of all the adults in Fromleigh who travel by bus. [3]

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(b) The survey included a question about the amount, x dollars, spent on travel per year. The results are summarised as follows.

$$n = 250 \qquad \Sigma x = 50\,460 \qquad \Sigma x^2 = 19\,854\,200$$

Find unbiased estimates of the population mean and variance of the amount spent per year on travel. [3]

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A councillor wanted to select a random sample of houses in Fromleigh. He planned to select the first house on each of the 143 streets in Fromleigh.

(c) Explain why this would not provide a random sample. [1]

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193. 9709_w20_qp_62 Q: 2

A six-sided die has faces marked 1, 2, 3, 4, 5, 6. When the die is thrown 300 times it shows a six on 56 throws.

(a) Calculate an approximate 96% confidence interval for the probability that the die shows a six on one throw. [3]

(b) Maroulla claims that the die is biased.

Use your answer to part **(a)** to comment on this claim. [1]

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194. 9709_w20_qp_63 Q: 2

In a survey, a random sample of 250 adults in Fromleigh were asked to fill in a questionnaire about their travel.

(a) It was found that 102 adults in the sample travel by bus. Find an approximate 90% confidence interval for the proportion of all the adults in Fromleigh who travel by bus. [3]

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(b) The survey included a question about the amount, x dollars, spent on travel per year. The results are summarised as follows.

$$n = 250 \qquad \Sigma x = 50\,460 \qquad \Sigma x^2 = 19\,854\,200$$

Find unbiased estimates of the population mean and variance of the amount spent per year on travel. [3]

A councillor wanted to select a random sample of houses in Fromleigh. He planned to select the first house on each of the 143 streets in Fromleigh.

(c) Explain why this would not provide a random sample. [1]

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195. 9709_m19_qp_72 Q: 1

The masses of a certain variety of plums are known to have standard deviation 13.2 g. A random sample of 200 of these plums is taken and the mean mass of the plums in the sample is found to be 62.3 g.

(i) Calculate a 98% confidence interval for the population mean mass. [3]

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(ii) State with a reason whether it was necessary to use the Central Limit theorem in the calculation in part **(i)**. [1]

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196. 9709_m19_qp_72 Q: 4

The lifetimes, X hours, of a random sample of 50 batteries of a certain kind were found. The results are summarised by $\Sigma x = 420$ and $\Sigma x^2 = 27\,530$.

(i) Calculate an unbiased estimate of the population mean of X and show that an unbiased estimate of the population variance is 490, correct to 3 significant figures. [3]

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(ii) The lifetimes of a further large sample of n batteries of this kind were noted, and the sample mean, $\bar{X}$, was found. Use your estimates from part **(i)** to find the value of n such that $P(\bar{X} > 5) = 0.9377$. [4]

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197. 9709_s19_qp_71 Q: 6

Ramesh plans to carry out a survey in order to find out what adults in his town think about local sports facilities. He chooses a random sample from the adult members of a tennis club and gives each of them a questionnaire.

(i) Give a reason why this will not result in Ramesh having a random sample of adults who live in the town. [1]

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(ii) Describe briefly a valid method that Ramesh could use to choose a random sample of adults in the town. [2]

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Ramesh now uses a valid method to choose a random sample of 350 adults from the town. He finds that 47 adults think that the local sports facilities are good.

(iii) Calculate an approximate 90% confidence interval for the proportion of all adults in the town who think that the local sports facilities are good. [4]

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(iv) Ramesh calculates a confidence interval whose width is 1.25 times the width of this 90% confidence interval. Ramesh's new interval is an x% confidence interval. Find the value of x. [3]

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198. 9709_s19_qp_73 Q: 1

A coin is thrown 100 times and it shows heads 60 times. Calculate an approximate 98% confidence interval for the probability, p, that the coin shows heads on any throw. [3]

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199. 9709_s19_qp_73 Q: 2

The length of worms is denoted by X cm. The lengths of a random sample of 50 worms were measured. Some of the results were lost, but the following results are available.

- $\Sigma x^2 = 4361$
- An unbiased estimate of the population variance of X is 9.62.

Calculate the mean length of the 50 worms. [3]

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200. 9709_s19_qp_73 Q: 3

Luis has to choose one person at random from four people, A, B, C and D. He throws a fair six-sided die. If the score is 1, he will choose A. If the score is 2 he will choose B. If the score is 3, he will choose C. If the score is 4 or more he will choose D.

(i) Explain why the choice made by this method is not random. [1]

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(ii) Describe how Luis could use a single throw of the die to make a random choice. [1]

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On another day, Luis has to choose two people at random from the same four people, A, B, C and D.

(iii) List the possible choices of two people and hence describe how Luis could use a single throw of the die to make this random choice. [2]

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201. 9709_w19_qp_72 Q: 3

The masses, in grams, of bags of flour are normally distributed with mean μ. The masses, m grams, of a random sample of 50 bags are summarised by $\Sigma m = 25\,110$ and $\Sigma m^2 = 12\,610\,300$.

(i) Calculate a 96% confidence interval for μ, giving the end-points correct to 1 decimal place. [6]

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Another random sample of 50 bags of flour is taken and a 99% confidence interval for μ is calculated.

(ii) Without calculation, state whether this confidence interval will be wider or narrower than the confidence interval found in part **(i)**. Give a reason for your answer. [1]

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202. 9709_w19_qp_73 Q: 3

The times, in minutes, taken by competitors to complete a puzzle have mean μ and standard deviation 3. The times taken by a random sample of 10 competitors are noted and the results are given below.

25.2 26.8 18.5 25.5 30.1 28.9 27.0 26.1 26.0 24.9

(i) Stating a necessary assumption, calculate a 97% confidence interval for μ. [5]

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(ii) Two more random samples, each of 10 competitors, are taken. Their times are used to calculate two more 97% confidence intervals for μ. Find the probability that neither of these intervals contains the true value of μ. [1]

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203. 9709_m18_qp_72 Q: 1

X is a random variable with mean 4.9 and standard deviation 2.21. A random sample of 75 values of X is taken. Find the probability that the sample mean is greater than 5.0. [3]

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204. 9709_m18_qp_72 Q: 7

A nutritionist wishes to investigate the mean sugar content in some cereal bars. He takes a random sample of 10 of the bars and measures the mass, in grams, of sugar in each bar. His results are shown below.

11.9	11.7	11.8	11.9	11.6	12.1	11.7	11.9	11.8	11.9

Assume that the mass, in grams, of sugar in bars of this type has the distribution $N(\mu, 0.01)$.

(i) Calculate a 99% confidence interval for μ. [4]

(ii) Explain whether it was necessary to use the Central Limit theorem in the calculation in part **(i)**. [1]

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(iii) The manufacturer claims that the mean mass of sugar in bars of this type is 11.7 g. Explain why your answer to part **(i)** does not support this claim. [1]

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(iv) The manufacturer suggests that a 95% confidence interval would be more likely to support his claim than a 99% confidence interval. **Without doing a calculation**, explain whether this suggestion is correct. [1]

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(v) It is thought that the value of 0.01 for the population variance may not be correct. Use the values in the sample to calculate an unbiased estimate of the population variance. [3]

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205. 9709_s18_qp_71 Q: 1

A random sample of 75 values of a variable X gave the following results.

$$n = 75 \qquad \Sigma x = 153.2 \qquad \Sigma x^2 = 340.24$$

Find unbiased estimates for the population mean and variance of X. [3]

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206. 9709_s18_qp_71 Q: 2

A six-sided die is suspected of bias. The die is thrown 100 times and it is found that the score is 2 on 20 throws. It is given that the probability of obtaining a score of 2 on any throw is p.

(i) Find an approximate 94% confidence interval for p. [3]

(ii) Use your answer to part **(i)** to comment on whether the die may be biased. [1]

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207. 9709_s18_qp_72 Q: 3

The management of a factory wished to find a range within which the time taken to complete a particular task generally lies. It is given that the times, in minutes, have a normal distribution with mean μ and standard deviation 6.5. A random sample of 15 employees was chosen and the mean time taken by these employees was found to be 52 minutes.

(i) Calculate a 95% confidence interval for μ. [3]

Later another 95% confidence interval for μ was found, based on a random sample of 30 employees.

(ii) State, with a reason, whether the width of this confidence interval was less than, equal to or greater than the width of the previous interval. [1]

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208. 9709_s18_qp_73 Q: 2

Amy has to choose a random sample from the 265 students in her year at college. She numbers the students from 1 to 265 and then uses random numbers generated by her calculator. The first two random numbers produced by her calculator are 0.213 165 448 and 0.073 165 196.

(i) Use these figures to find the numbers of the first four students in her sample. [2]

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There were 25 students in Amy's sample. She asked each of them how much money, $\$x$, they earned in a week, on average. Her results are summarised below.

$$n = 25 \qquad \Sigma x = 510 \qquad \Sigma x^2 = 13\,225$$

(ii) Find unbiased estimates of the population mean and variance. [3]

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(iii) Explain briefly what is meant by 'population' in this question. [1]

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209. 9709_s18_qp_73 Q: 3

A researcher wishes to estimate the proportion, p, of houses in London Road that have only one occupant. He takes a random sample of 64 houses in London Road and finds that 8 houses in the sample have only one occupant. Using this sample, he calculates that an approximate $\alpha\%$ confidence interval for p has width 0.130. Find α correct to the nearest integer. [5]

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210. 9709_w18_qp_71 Q: 1

The standard deviation of the heights of adult males is 7.2 cm. The mean height of a sample of 200 adult males is found to be 176 cm.

(i) Calculate a 97.5% confidence interval for the mean height of adult males. [3]

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(ii) State a necessary condition for the calculation in part **(i)** to be valid. [1]

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211. 9709_w18_qp_71 Q: 3

A population has mean 12 and standard deviation 2.5. A large random sample of size n is chosen from this population and the sample mean is denoted by $\overline{X}$. Given that $P(\overline{X} < 12.2) = 0.975$, correct to 3 significant figures, find the value of n. [4]

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212. 9709_w18_qp_72 Q: 2

The standard deviation of the volume of drink in cans of Koola is 4.8 centilitres. A random sample of 180 cans is taken and the mean volume of drink in these 180 cans is found to be 330.1 centilitres.

(i) Calculate a 95% confidence interval for the mean volume of drink in all cans of Koola. Give the end-points of your interval correct to 1 decimal place. [3]

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(ii) Explain whether it was necessary to use the Central Limit theorem in your answer to part **(i)**. [1]

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213. 9709_w18_qp_72 Q: 7

The independent random variables X and Y have the distributions Po(2.1) and Po(3.5) respectively.

(i) Find $\mathrm{P}(X + Y = 3)$. [2]

(ii) Given that $X + Y = 3$, find $\mathrm{P}(X = 2)$. [3]

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(iii) A random sample of 100 values of X is taken. Find the probability that the sample mean is more than 2.2. [6]

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214. 9709_w18_qp_73 Q: 1

The standard deviation of the heights of adult males is 7.2 cm. The mean height of a sample of 200 adult males is found to be 176 cm.

(i) Calculate a 97.5% confidence interval for the mean height of adult males. [3]

(ii) State a necessary condition for the calculation in part **(i)** to be valid. [1]

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215. 9709_w18_qp_73 Q: 3

A population has mean 12 and standard deviation 2.5. A large random sample of size n is chosen from this population and the sample mean is denoted by $\overline{X}$. Given that $P(\overline{X} < 12.2) = 0.975$, correct to 3 significant figures, find the value of n. [4]

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216. 9709_m17_qp_72 Q: 1

In a survey, 36 out of 120 randomly selected voters in Hungton said that if there were an election next week they would vote for the Alpha party. Calculate an approximate 90% confidence interval for the proportion of voters in Hungton who would vote for the Alpha party. [4]

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217. 9709_m17_qp_72 Q: 3

The length, in centimetres, of a certain type of snake is modelled by the random variable X with mean 52 and standard deviation 6.1. A random sample of 75 snakes is selected, and the sample mean, $\overline{X}$, is found.

(i) Find $P(51 < \overline{X} < 53)$. [4]

(ii) Explain why it was necessary to use the Central Limit theorem in the solution to part **(i)**. [1]

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218. 9709_s17_qp_71 Q: 3

(a) The waiting time at a certain bus stop has variance 2.6 minutes^2. For a random sample of 75 people, the mean waiting time was 7.1 minutes. Calculate a 92% confidence interval for the population mean waiting time. [3]

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(b) A researcher used 3 random samples to calculate 3 independent 92% confidence intervals. Find the probability that all 3 of these confidence intervals contain only values that are greater than the actual population mean. [2]

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(c) Another researcher surveyed the first 75 people who waited at a bus stop on a Monday morning. Give a reason why this sample is unsuitable for use in finding a confidence interval for the mean waiting time. [1]

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219. 9709_s17_qp_72 Q: 1

In a survey of 2000 randomly chosen adults, 1602 said that they owned a smartphone. Calculate an approximate 95% confidence interval for the proportion of adults in the whole population who own a smartphone. [4]

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220. 9709_s17_qp_73 Q: 1

A residents' association has 654 members, numbered from 1 to 654. The secretary wishes to send a questionnaire to a random sample of members. In order to choose the members for the sample she uses a table of random numbers. The first line in the table is as follows.

1096 4357 3765 0431 0928 9264

The numbers of the first two members in the sample are 109 and 643. Find the numbers of the next three members in the sample. [3]

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221. 9709_s17_qp_73 Q: 2

In a random sample of 200 shareholders of a company, 103 said that they wanted a change in the management.

(i) Find an approximate 92% confidence interval for the proportion, p, of all shareholders who want a change in the management. [3]

(ii) State the probability that a 92% confidence interval does not contain p. [1]

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222. 9709_w17_qp_71 Q: 3

After an election 153 adults, from a random sample of 200 adults, said that they had voted. Using this information, an $\alpha\%$ confidence interval for the proportion of all adults who voted in the election was found to be 0.695 to 0.835, both correct to 3 significant figures. Find the value of α, correct to the nearest integer. [4]

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223. 9709_w17_qp_71 Q: 4

The lengths, in millimetres, of rods produced by a machine are normally distributed with mean μ and standard deviation 0.9. A random sample of 75 rods produced by the machine has mean length 300.1 mm.

(i) Find a 99% confidence interval for μ, giving your answer correct to 2 decimal places. [3]

The manufacturer claims that the machine produces rods with mean length 300 mm.

(ii) Use the confidence interval found in part **(i)** to comment on this claim. [1]

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224. 9709_w17_qp_72 Q: 2

The number of words in History essays by students at a certain college has mean μ and standard deviation 1420.

(i) The mean number of words in a random sample of 125 History essays was found to be 4820. Calculate a 98% confidence interval for μ. [3]

(ii) Another random sample of n History essays was taken. Using this sample, a 95% confidence interval for μ was found to be 4700 to 4980, both correct to the nearest integer. Find the value of n. [3]

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225. 9709_w17_qp_73 Q: 3

After an election 153 adults, from a random sample of 200 adults, said that they had voted. Using this information, an $\alpha\%$ confidence interval for the proportion of all adults who voted in the election was found to be 0.695 to 0.835, both correct to 3 significant figures. Find the value of α, correct to the nearest integer. [4]

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226. 9709_w17_qp_73 Q: 4

The lengths, in millimetres, of rods produced by a machine are normally distributed with mean μ and standard deviation 0.9. A random sample of 75 rods produced by the machine has mean length 300.1 mm.

(i) Find a 99% confidence interval for μ, giving your answer correct to 2 decimal places. [3]

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The manufacturer claims that the machine produces rods with mean length 300 mm.

(ii) Use the confidence interval found in part **(i)** to comment on this claim. [1]

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227. 9709_m16_qp_72 Q: 5

The 150 oranges in a random sample from a certain supplier were weighed and the masses, X grams, were recorded. The results are summarised below.

$$n = 150 \qquad \Sigma x = 14\,910 \qquad \Sigma x^2 = 1\,525\,000$$

(i) Calculate a 99% confidence interval for the population mean of X. [6]

(ii) The supplier claims that the mean mass of his oranges is 100 grams. Use your answer to part **(i)** to explain whether this claim should be accepted. [1]

(iii) State briefly why the sample should be random. [1]

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228. 9709_s16_qp_71 Q: 2

A researcher is investigating the lengths, in kilometres, of the journeys to work of the employees at a certain firm. She takes a random sample of 10 employees.

(i) State what is meant by 'random' in this context. [1]

The results of her sample are as follows.

1.5 2.0 3.6 5.9 4.8 8.7 3.5 2.9 4.1 3.0

(ii) Find unbiased estimates of the population mean and variance. [3]

(iii) State what is meant by 'population' in this context. [1]

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229. 9709_s16_qp_71 Q: 3

Based on a random sample of 700 people living in a certain area, a confidence interval for the proportion, p, of all people living in that area who had travelled abroad was found to be $0.5672 < p < 0.6528$.

(i) Find the proportion of people in the sample who had travelled abroad. [1]

(ii) Find the confidence level of this confidence interval. Give your answer correct to the nearest integer. [4]

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230. 9709_s16_qp_72 Q: 3

(i) Give a reason for using a sample rather than the whole population in carrying out a statistical investigation. [1]

(ii) Tennis balls of a certain brand are known to have a mean height of bounce of 64.7 cm, when dropped from a height of 100 cm. A change is made in the manufacturing process and it is required to test whether this change has affected the mean height of bounce. 100 new tennis balls are tested and it is found that their mean height of bounce when dropped from a height of 100 cm is 65.7 cm and the unbiased estimate of the population variance is 15 cm^2.

(a) Calculate a 95% confidence interval for the population mean. [3]

(b) Use your answer to part **(ii)(a)** to explain what conclusion can be drawn about whether the change has affected the mean height of bounce. [1]

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231. 9709_s16_qp_73 Q: 1

The time taken for a particular type of paint to dry was measured for a sample of 150 randomly chosen points on a wall. The sample mean was 192.4 minutes and an unbiased estimate of the population variance was 43.6 $minutes^2$. Find a 98% confidence interval for the mean drying time. [3]

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232. 9709_s16_qp_73 Q: 6

X and Y are independent random variables with distributions Po(1.6) and Po(2.3) respectively.

(i) Find $P(X + Y = 4)$. [3]

A random sample of 75 values of X is taken.

(ii) State the approximate distribution of the sample mean, $\bar{X}$, including the values of the parameters. [2]

(iii) Hence find the probability that the sample mean is more than 1.7. [3]

(iv) Explain whether the Central Limit theorem was needed to answer part **(ii)**. [1]

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233. 9709_w16_qp_71 Q: 1

The weights, in kilograms, of a random sample of eight 16-year old males are given below.

58.9 63.5 62.7 59.4 66.9 68.0 60.4 68.2

Find unbiased estimates of the population mean and variance of the weights of all 16-year old males. [3]

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234. 9709_w16_qp_71 Q: 5

(a) The masses, in grams, of certain tomatoes are normally distributed with standard deviation 9 grams. A random sample of 100 tomatoes has a sample mean of 63 grams. Find a 90% confidence interval for the population mean mass of these tomatoes. [3]

(b) The masses, in grams, of certain potatoes are normally distributed with known population standard deviation but unknown population mean. A random sample of potatoes is taken in order to find a confidence interval for the population mean. Using a sample of size 50, a 95% confidence interval is found to have width 8 grams.

(i) Using another sample of size 50, an α% confidence interval has width 4 grams. Find α. [3]

(ii) Find the sample size n, such that a 95% confidence interval has width 4 grams. [2]

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235. 9709_w16_qp_72 Q: 1

The weights, in kilograms, of a random sample of eight 16-year old males are given below.

58.9 63.5 62.7 59.4 66.9 68.0 60.4 68.2

Find unbiased estimates of the population mean and variance of the weights of all 16-year old males. [3]

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236. 9709_w16_qp_72 Q: 5

(a) The masses, in grams, of certain tomatoes are normally distributed with standard deviation 9 grams. A random sample of 100 tomatoes has a sample mean of 63 grams. Find a 90% confidence interval for the population mean mass of these tomatoes. [3]

(b) The masses, in grams, of certain potatoes are normally distributed with known population standard deviation but unknown population mean. A random sample of potatoes is taken in order to find a confidence interval for the population mean. Using a sample of size 50, a 95% confidence interval is found to have width 8 grams.

(i) Using another sample of size 50, an α% confidence interval has width 4 grams. Find α. [3]

(ii) Find the sample size n, such that a 95% confidence interval has width 4 grams. [2]

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237. 9709_w16_qp_73 Q: 2

Dominic wishes to choose a random sample of five students from the 150 students in his year. He numbers the students from 1 to 150. Then he uses his calculator to generate five random numbers between 0 and 1. He multiplies each random number by 150 and rounds up to the next whole number to give a student number.

(i) Dominic's first random number is 0.392. Find the student number that is produced by this random number. [1]

(ii) Dominic's second student number is 104. Find a possible random number that would produce this student number. [1]

(iii) Explain briefly why five random numbers may not be enough to produce a sample of five student numbers. [1]

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238. 9709_w16_qp_73 Q: 6

A variable X takes values 1, 2, 3, 4, 5, and these values are generated at random by a machine. Each value is supposed to be equally likely, but it is suspected that the machine is not working properly. A random sample of 100 values of X, generated by the machine, gives the following results.

$$n = 100 \qquad \Sigma x = 340 \qquad \Sigma x^2 = 1356$$

(i) Find a 95% confidence interval for the population mean of the values generated by the machine. [6]

(ii) Use your answer to part **(i)** to comment on whether the machine may be working properly. [2]

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239. 9709_s15_qp_71 Q: 5

The masses, m grams, of a random sample of 80 strawberries of a certain type were measured and summarised as follows.

$$n = 80 \qquad \Sigma m = 4200 \qquad \Sigma m^2 = 229\,000$$

(i) Find unbiased estimates of the population mean and variance. [3]

(ii) Calculate a 98% confidence interval for the population mean. [3]

50 random samples of size 80 were taken and a 98% confidence interval for the population mean, μ, was found from each sample.

(iii) Find the number of these 50 confidence intervals that would be expected to include the true value of μ. [1]

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240. 9709_s15_qp_72 Q: 5

The volumes, v millilitres, of juice in a random sample of 50 bottles of Cooljoos are measured and summarised as follows.

$$n = 50 \qquad \Sigma v = 14\,800 \qquad \Sigma v^2 = 4\,390\,000$$

(i) Find unbiased estimates of the population mean and variance. [3]

(ii) An α% confidence interval for the population mean, based on this sample, is found to have a width of 5.45 millilitres. Find α. [4]

Four random samples of size 10 are taken and a 96% confidence interval for the population mean is found from each sample.

(iii) Find the probability that these 4 confidence intervals all include the true value of the population mean. [2]

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241. 9709_s15_qp_73 Q: 1

Jyothi wishes to choose a representative sample of 5 students from the 82 members of her school year.

(i) She considers going into the canteen and choosing a table with five students from her year sitting at it, and using these five people as her sample. Give two reasons why this method is unsatisfactory. [2]

(ii) Jyothi decides to use another method. She numbers all the students in her year from 1 to 82. Then she uses her calculator and generates the following random numbers.

231492 762305 346280

From these numbers, she obtains the student numbers 23, 14, 76, 5, 34 and 62. Explain how Jyothi obtained these student numbers from the list of random numbers. [3]

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242. 9709_s15_qp_73 Q: 3

A die is biased so that the probability that it shows a six on any throw is p.

(i) In an experiment, the die shows a six on 22 out of 100 throws. Find an approximate 97% confidence interval for p. [4]

(ii) The experiment is repeated and another 97% confidence interval is found. Find the probability that exactly one of the two confidence intervals includes the true value of p. [2]

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243. 9709_s15_qp_73 Q: 4

The marks, x, of a random sample of 50 students in a test were summarised as follows.

$$n = 50 \qquad \Sigma x = 1508 \qquad \Sigma x^2 = 51\,825$$

(i) Calculate unbiased estimates of the population mean and variance. [3]

(ii) Each student's mark is scaled using the formula $y = 1.5x + 10$. Find estimates of the population mean and variance of the scaled marks, y. [3]

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244. 9709_w15_qp_71 Q: 2

The mean and standard deviation of the time spent by people in a certain library are 29 minutes and 6 minutes respectively.

(i) Find the probability that the mean time spent in the library by a random sample of 120 people is more than 30 minutes. [4]

(ii) Explain whether it was necessary to assume that the time spent by people in the library is normally distributed in the solution to part **(i)**. [2]

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245. 9709_w15_qp_71 Q: 3

Jagdeesh measured the lengths, x minutes, of 60 randomly chosen lectures. His results are summarised below.

$$n = 60 \qquad \Sigma x = 3420 \qquad \Sigma x^2 = 195\,200$$

(i) Calculate unbiased estimates of the population mean and variance. [3]

(ii) Calculate a 98% confidence interval for the population mean. [3]

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246. 9709_w15_qp_72 Q: 2

The mean and standard deviation of the time spent by people in a certain library are 29 minutes and 6 minutes respectively.

(i) Find the probability that the mean time spent in the library by a random sample of 120 people is more than 30 minutes. [4]

(ii) Explain whether it was necessary to assume that the time spent by people in the library is normally distributed in the solution to part **(i)**. [2]

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247. 9709_w15_qp_72 Q: 3

Jagdeesh measured the lengths, x minutes, of 60 randomly chosen lectures. His results are summarised below.

$$n = 60 \qquad \Sigma x = 3420 \qquad \Sigma x^2 = 195\,200$$

(i) Calculate unbiased estimates of the population mean and variance. [3]

(ii) Calculate a 98% confidence interval for the population mean. [3]

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248. 9709_w15_qp_73 Q: 1

It is known that the number, N, of words contained in the leading article each day in a certain newspaper can be modelled by a normal distribution with mean 352 and variance 29. A researcher takes a random sample of 10 leading articles and finds the sample mean, $\overline{N}$, of N.

(i) State the distribution of $\overline{N}$, giving the values of any parameters. [2]

(ii) Find $P(\overline{N} > 354)$. [3]

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249. 9709_w15_qp_73 Q: 3

From a random sample of 65 people in a certain town, the proportion who own a bicycle was noted. From this result an $\alpha\%$ confidence interval for the proportion, p, of all people in the town who own a bicycle was calculated to be $0.284 < p < 0.516$.

(i) Find the proportion of people in the sample who own a bicycle. [1]

(ii) Calculate the value of α correct to 2 significant figures. [4]

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Chapter 5

Hypothesis tests

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250. 9709_m22_qp_62 Q: 2

Harry has a five-sided spinner with sectors coloured blue, green, red, yellow and black. Harry thinks the spinner may be biased. He plans to carry out a hypothesis test with the following hypotheses.

$$H_0: \text{ P(the spinner lands on blue)} = \frac{1}{5}$$
$$H_1: \text{ P(the spinner lands on blue)} \neq \frac{1}{5}$$

Harry spins the spinner 300 times. It lands on blue on 45 spins.

Use a suitable approximation to carry out Harry's test at the 5% significance level. [5]

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251. 9709_m22_qp_62 Q: 4

In the past the time, in minutes, taken by students to complete a certain challenge had mean 25.5 and standard deviation 5.2. A new challenge is devised and it is expected that students will take, on average, less than 25.5 minutes to complete this challenge. A random sample of 40 students is chosen and their mean time for the new challenge is found to be 23.7 minutes.

(a) Assuming that the standard deviation of the time for the new challenge is 5.2 minutes, test at the 1% significance level whether the population mean time for the new challenge is less than 25.5 minutes. [5]

(b) State, with a reason, whether it is possible that a Type I error was made in the test in part **(a)**. [1]

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252. 9709_s22_qp_61 Q: 2

Arvind uses an ordinary fair 6-sided die to play a game. He believes he has a system to predict the score when the die is thrown. Before each throw of the die, he writes down what he thinks the score will be. He claims that he can write the correct score more often than he would if he were just guessing. His friend Laxmi tests his claim by asking him to write down the score before each of 15 throws of the die. Arvind writes the correct score on exactly 5 out of 15 throws.

Test Arvind's claim at the 10% significance level. [5]

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253. 9709_s22_qp_61 Q: 7

In the past, the mean time for Jenny's morning run was 28.2 minutes. She does some extra training and she wishes to test whether her mean time has been reduced. After the training Jenny takes a random sample of 40 morning runs. She decides that if the sample mean run time is less than 27 minutes she will conclude that the training has been effective. You may assume that, after the training, Jenny's run time has a standard deviation of 4.0 minutes.

(a) State suitable null and alternative hypotheses for Jenny's test. [1]

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(b) Find the probability that Jenny will make a Type I error. [3]

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(c) Jenny found that the sample mean run time was 27.2 minutes.

Explain briefly whether it is possible for her to make a Type I error or a Type II error or both. [2]

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254. 9709_s22_qp_62 Q: 2

In the past, the mean height of plants of a particular species has been 2.3 m. A random sample of 60 plants of this species was treated with fertiliser and the mean height of these 60 plants was found to be 2.4 m. Assume that the standard deviation of the heights of plants treated with fertiliser is 0.4 m.

Carry out a test at the 2.5% significance level of whether the mean height of plants treated with fertiliser is greater than 2.3 m. [5]

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255. 9709_s22_qp_62 Q: 4

The number of cars arriving at a certain road junction on a weekday morning has a Poisson distribution with mean 4.6 per minute. Traffic lights are installed at the junction and a council officer wishes to test at the 2% significance level whether there are now fewer cars arriving. He notes the number of cars arriving during a randomly chosen 2-minute period.

(a) State suitable null and alternative hypotheses for the test. [1]

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(b) Find the critical region for the test. [4]

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The officer notes that, during a randomly chosen 2-minute period on a weekday morning, exactly 5 cars arrive at the junction.

(c) Carry out the test. [2]

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(d) State, with a reason, whether it is possible that a Type I error has been made in carrying out the test in part **(c)**. [1]

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The number of cars arriving at another junction on a weekday morning also has a Poisson distribution with mean 4.6 per minute.

(e) Use a suitable approximating distribution to find the probability that more than 300 cars will arrive at this junction in an hour. [3]

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256. 9709_s22_qp_63 Q: 2

Anton believes that 10% of students at his college are left-handed. Aliya believes that this is an underestimate. She plans to carry out a hypothesis test of the null hypothesis $p = 0.1$ against the alternative hypothesis $p > 0.1$, where p is the actual proportion of students at the college that are left-handed. She chooses a random sample of 20 students from the college. She will reject the null hypothesis if at least 5 of these students are left-handed.

(a) Explain what is meant by a Type I error in this context. [1]

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(b) Find the probability of a Type I error in the test. [3]

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(c) Given that the true value of p is 0.3, find the probability of a Type II error in the test. [2]

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257. 9709_s22_qp_63 Q: 3

Batteries of type A are known to have a mean life of 150 hours. It is required to test whether a new type of battery, type B, has a shorter mean life than type A batteries.

(a) Give a reason for using a sample rather than the whole population in carrying out this test. [1]

A random sample of 120 type B batteries are tested and it is found that their mean life is 147 hours, and an unbiased estimate of the population variance is 225 hours^2.

(b) Test, at the 2% significance level, whether type B batteries have a shorter mean life than type A batteries. [5]

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(c) Calculate a 94% confidence interval for the population mean life of type B batteries. [3]

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258. 9709_m21_qp_62 Q: 3

An architect wishes to investigate whether the buildings in a certain city are higher, on average, than buildings in other cities. He takes a large random sample of buildings from the city and finds the mean height of the buildings in the sample. He calculates the value of the test statistic, z, and finds that $z = 2.41$.

(a) Explain briefly whether he should use a one-tail test or a two-tail test. [1]

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(b) Carry out the test at the 1% significance level. [3]

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259. 9709_m21_qp_62 Q: 6

It is known that 8% of adults in a certain town own a Chantor car. After an advertising campaign, a car dealer wishes to investigate whether this proportion has increased. He chooses a random sample of 25 adults from the town and notes how many of them own a Chantor car.

(a) He finds that 4 of the 25 adults own a Chantor car.

Carry out a hypothesis test at the 5% significance level. [5]

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(b) Explain which of the errors, Type I or Type II, might have been made in carrying out the test in part **(a)**. [2]

Later, the car dealer takes another random sample of 25 adults from the town and carries out a similar hypothesis test at the 5% significance level.

(c) Find the probability of a Type I error. [3]

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260. 9709_s21_qp_61 Q: 8

At a certain large school it was found that the proportion of students not wearing correct uniform was 0.15. The school sent a letter to parents asking them to ensure that their children wear the correct uniform. The school now wishes to test whether the proportion not wearing correct uniform has been reduced.

(a) It is suggested that a random sample of the students in Grade 12 should be used for the test.

Give a reason why this would not be an appropriate sample. [1]

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A suitable sample of 50 students is selected and the number not wearing correct uniform is noted. This figure is used to carry out a test at the 5% significance level.

(b) State suitable null and alternative hypotheses. [1]

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(c) Use a binomial distribution to find the probability of a Type I error. You must justify your answer fully. [5]

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(d) In fact 4 students out of the 50 are not wearing correct uniform.

State the conclusion of the test, explaining your answer. [2]

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(e) State, with a reason, which of the errors, Type I or Type II, may have been made. [2]

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261. 9709_s21_qp_62 Q: 1

In a game, a ball is thrown and lands in one of 4 slots, labelled A, B, C and D. Raju wishes to test whether the probability that the ball will land in slot A is $\frac{1}{4}$.

(a) State suitable null and alternative hypotheses for Raju's test. [1]

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The ball is thrown 100 times and it lands in slot A 15 times.

(b) Use a suitable approximating distribution to carry out the test at the 2% significance level. [5]

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262. 9709_s21_qp_62 Q: 5

The time, in minutes, spent by customers at a particular gym has the distribution N(μ, 38.2). In the past the value of μ has been 42.4. Following the installation of some new equipment the management wishes to test whether the value of μ has changed.

(a) State what is meant by a Type I error in this context. [1]

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(b) The mean time for a sample of 20 customers is found to be 45.6 minutes.

Test at the 2.5% significance level whether the value of μ has changed. [5]

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263. 9709_s21_qp_63 Q: 2

In the past, the time, in hours, for a particular train journey has had mean 1.40 and standard deviation 0.12. Following the introduction of some new signals, it is required to test whether the mean journey time has decreased.

(a) State what is meant by a Type II error in this context. [1]

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(b) The mean time for a random sample of 50 journeys is found to be 1.36 hours.

Assuming that the standard deviation of journey times is still 0.12 hours, test at the 2.5% significance level whether the population mean journey time has decreased. [5]

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(c) State, with a reason, which of the errors, Type I or Type II, might have been made in the test in part **(b)**. [2]

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264. 9709_s21_qp_63 Q: 3

The local council claims that the average number of accidents per year on a particular road is 0.8. Jane claims that the true average is greater than 0.8. She looks at the records for a random sample of 3 recent years and finds that the total number of accidents during those 3 years was 5.

(a) Assume that the number of accidents per year follows a Poisson distribution.

(i) State null and alternative hypotheses for a test of Jane's claim. [1]

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(ii) Test at the 5% significance level whether Jane's claim is justified. [4]

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(b) Jane finds that the number of accidents per year has been gradually increasing over recent years.

State how this might affect the validity of the test carried out in part **(a)(ii)**. [1]

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265. 9709_w21_qp_61 Q: 5

(a) The proportion of people having a particular medical condition is 1 in 100 000. A random sample of 2500 people is obtained. The number of people in the sample having the condition is denoted by X.

(i) State, with a justification, a suitable approximating distribution for X, giving the values of any parameters. [2]

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(ii) Use the approximating distribution to calculate $P(X > 0)$. [2]

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(b) The percentage of people having a different medical condition is thought to be 30%. A researcher suspects that the true percentage is less than 30%. In a medical trial a random sample of 28 people was selected and 4 people were found to have this condition.

Use a binomial distribution to test the researcher's suspicion at the 2% significance level. [5]

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266. 9709_w21_qp_61 Q: 7

The masses, in grams, of apples from a certain farm have mean μ and standard deviation 5.2. The farmer says that the value of μ is 64.6. A quality control inspector claims that the value of μ is actually less than 64.6. In order to test his claim he chooses a random sample of 100 apples from the farm.

(a) The mean mass of the 100 apples is found to be 63.5 g.

Carry out the test at the 2.5% significance level. [5]

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(b) Later another test of the same hypotheses at the 2.5% significance level, with another random sample of 100 apples from the same farm, is carried out.

Given that the value of μ is in fact 62.7, calculate the probability of a Type II error. [5]

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267. 9709_w21_qp_62 Q: 4

A certain kind of firework is supposed to last for 30 seconds, on average, after it is lit. An inspector suspects that the fireworks actually last a shorter time than this, on average. He takes a random sample of 100 fireworks of this kind. Each firework in the sample is lit and the time it lasts is noted.

(a) Give a reason why it is necessary to take a sample rather than testing all the fireworks of this kind. [1]

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It is given that the population standard deviation of the times that fireworks of this kind last is 5 seconds.

(b) The mean time lasted by the 100 fireworks in the sample is found to be 29 seconds.

Test the inspector's suspicion at the 1% significance level. [5]

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(c) State with a reason whether the Central Limit theorem was needed in the solution to part **(b)**. [1]

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268. 9709_w21_qp_62 Q: 6

A machine is supposed to produce random digits. Bob thinks that the machine is not fair and that the probability of it producing the digit 0 is less than $\frac{1}{10}$. In order to test his suspicion he notes the number of times the digit 0 occurs in 30 digits produced by the machine. He carries out a test at the 10% significance level.

(a) State suitable null and alternative hypotheses. [1]

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(b) Find the rejection region for the test. [4]

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(c) State the probability of a Type I error. [1]

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It is now given that the machine actually produces a 0 once in every 40 digits, on average.

(d) Find the probability of a Type II error. [3]

(e) Explain the meaning of a Type II error in this context. [1]

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269. 9709_w21_qp_63 Q: 5

(a) The proportion of people having a particular medical condition is 1 in 100 000. A random sample of 2500 people is obtained. The number of people in the sample having the condition is denoted by X.

(i) State, with a justification, a suitable approximating distribution for X, giving the values of any parameters. [2]

(ii) Use the approximating distribution to calculate $P(X > 0)$. [2]

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(b) The percentage of people having a different medical condition is thought to be 30%. A researcher suspects that the true percentage is less than 30%. In a medical trial a random sample of 28 people was selected and 4 people were found to have this condition.

Use a binomial distribution to test the researcher's suspicion at the 2% significance level. [5]

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270. 9709_w21_qp_63 Q: 7

The masses, in grams, of apples from a certain farm have mean μ and standard deviation 5.2. The farmer says that the value of μ is 64.6. A quality control inspector claims that the value of μ is actually less than 64.6. In order to test his claim he chooses a random sample of 100 apples from the farm.

(a) The mean mass of the 100 apples is found to be 63.5 g.

Carry out the test at the 2.5% significance level. [5]

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(b) Later another test of the same hypotheses at the 2.5% significance level, with another random sample of 100 apples from the same farm, is carried out.

Given that the value of μ is in fact 62.7, calculate the probability of a Type II error. [5]

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271. 9709_m20_qp_62 Q: 3

In the past, the mean time taken by Freda for a particular daily journey was 39.2 minutes. Following the introduction of a one-way system, Freda wishes to test whether the mean time for the journey has decreased. She notes the times, t minutes, for 40 randomly chosen journeys and summarises the results as follows.

$$n = 40 \qquad \Sigma t = 1504 \qquad \Sigma t^2 = 57\,760$$

(a) Calculate unbiased estimates of the population mean and variance of the new journey time. [3]

(b) Test, at the 5% significance level, whether the population mean time has decreased. [5]

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272. 9709_m20_qp_62 Q: 7

A national survey shows that 95% of year 12 students use social media. Arvin suspects that the percentage of year 12 students at his college who use social media is less than the national percentage. He chooses a random sample of 20 students at his college and notes the number who use social media. He then carries out a test at the 2% significance level.

(a) Find the rejection region for the test. [4]

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(b) Find the probability of a Type I error. [1]

(c) Jimmy believes that the true percentage at Arvin's college is 70%. Assuming that Jimmy is correct, find the probability of a Type II error. [3]

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273. 9709_s20_qp_61 Q: 2

In the past the yield of a certain crop, in tonnes per hectare, had mean 0.56 and standard deviation 0.08. Following the introduction of a new fertilizer, the farmer intends to test at the 2.5% significance level whether the mean yield has increased. He finds that the mean yield over 10 years is 0.61 tonnes per hectare.

(a) State two assumptions that are necessary for the test. [2]

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(b) Carry out the test. [5]

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274. 9709_s20_qp_61 Q: 4

A fair spinner has five sides numbered 1, 2, 3, 4, 5. The score on one spin is denoted by X.

(a) Show that $\text{Var}(X) = 2$. [1]

Fiona has another spinner, also with five sides numbered 1, 2, 3, 4, 5. She suspects that it is biased so that the expected score is less than 3. In order to test her suspicion, she plans to spin her spinner 40 times. If the mean score is less than 2.6 she will conclude that her spinner is biased in this way.

(b) Find the probability of a Type I error. [4]

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(c) State what is meant by a Type II error in this context. [1]

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275. 9709_s20_qp_62 Q: 2

A shop obtains apples from a certain farm. It has been found that 5% of apples from this farm are Grade A. Following a change in growing conditions at the farm, the shop management plan to carry out a hypothesis test to find out whether the proportion of Grade A apples has increased. They select 25 apples at random. If the number of Grade A apples is more than 3 they will conclude that the proportion has increased.

(a) State suitable null and alternative hypotheses for the test. [1]

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(b) Find the probability of a Type I error. [3]

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In fact 2 of the 25 apples were Grade A.

(c) Which of the errors, Type I or Type II, is possible? Justify your answer. [2]

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276. 9709_s20_qp_62 Q: 4

The score on one spin of a 5-sided spinner is denoted by the random variable X with probability distribution as shown in the table.

x	0	1	2	3	4
$P(X = x)$	0.1	0.2	0.4	0.2	0.1

(a) Show that $\text{Var}(X) = 1.2$. [2]

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The spinner is spun 200 times. The score on each spin is noted and the mean, $\overline{X}$, of the 200 scores is found.

(b) Given that $P(\overline{X} > a) = 0.1$, find the value of a. [4]

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(c) Explain whether it was necessary to use the Central Limit theorem in your answer to part **(b)**. [1]

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(d) Johann has another, similar, spinner. He suspects that it is biased so that the mean score is less than 2. He spins his spinner 200 times and finds that the mean of the 200 scores is 1.86.

Given that the variance of the score on one spin of this spinner is also 1.2, test Johann's suspicion at the 5% significance level. [5]

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277. 9709_s20_qp_63 Q: 3

The number of customers who visit a particular shop between 9.00 am and 10.00 am has the distribution Po(λ). In the past the value of λ was 5.2. Following some new advertising, the manager wishes to test whether the value of λ has increased. He chooses a random sample of 20 days and finds that the total number of customers who visited the shop between 9.00 am and 10.00 am on those days is 125.

Use an approximating distribution to test at the 2.5% significance level whether the value of λ has increased. [6]

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278. 9709_s20_qp_63 Q: 7

A market researcher is investigating the length of time that customers spend at an information desk. He plans to choose a sample of 50 customers on a particular day.

(a) He considers choosing the first 50 customers who visit the information desk.

Explain why this method is unsuitable. [1]

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The actual lengths of time, in minutes, that customers spend at the information desk may be assumed to have mean μ and variance 4.8. The researcher knows that in the past the value of μ was 6.0. He wishes to test, at the 2% significance level, whether this is still true. He chooses a random sample of 50 customers and notes how long they each spend at the information desk.

(b) State the probability of making a Type I error and explain what is meant by a Type I error in this context. [2]

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(c) Given that the mean time spent at the information desk by the 50 customers is 6.8 minutes, carry out the test. [5]

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(d) Give a reason why it was necessary to use the Central Limit theorem in your answer to part **(c)**. [1]

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279. 9709_w20_qp_61 Q: 5

The number of absences per week by workers at a factory has the distribution Po(2.1).

(a) Find the standard deviation of the number of absences per week. [1]

(b) Find the probability that the number of absences in a 2-week period is at least 2. [3]

(c) Find the probability that the number of absences in a 3-week period is more than 4 and less than 8. [2]

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Following a change in working conditions, the management wished to test whether the mean number of absences has decreased. They found that, in a randomly chosen 3-week period, there were exactly 2 absences.

(d) Carry out the test at the 10% significance level. [5]

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(e) State, with a reason, which of the errors, Type I or Type II, might have been made in carrying out the test in part **(d)**. [2]

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280. 9709_w20_qp_61 Q: 6

The time, in minutes, for Anjan's journey to work on Mondays has mean 38.4 and standard deviation 6.9.

(a) Find the probability that Anjan's mean journey time for a random sample of 30 Mondays is between 38 and 40 minutes. [5]

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Anjan wishes to test whether his mean journey time is different on Tuesdays. He chooses a random sample of 30 Tuesdays and finds that his mean journey time for these 30 Tuesdays is 40.2 minutes. Assume that the standard deviation for his journey time on Tuesdays is 6.9 minutes.

(b) **(i)** State, with a reason, whether Anjan should use a one-tail or a two-tail test. [1]

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(ii) Carry out the test at the 10% significance level. [5]

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(iii) Explain whether it was necessary to use the Central Limit theorem in part **(b)(ii)**. [1]

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281. 9709_w20_qp_62 Q: 4

The areas, X cm^2, of petals of a certain kind of flower have mean μ cm^2. In the past it has been found that $\mu = 8.9$. Following a change in the climate, a botanist claims that the mean is no longer 8.9. The areas of a random sample of 200 petals from this kind of flower are measured, and the results are summarized by

$$\Sigma x = 1850, \qquad \Sigma x^2 = 17\,850.$$

Test the botanist's claim at the 2.5% significance level. [8]

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282. 9709_w20_qp_62 Q: 6

A biscuit manufacturer claims that, on average, 1 in 3 packets of biscuits contain a prize offer. Gerry suspects that the proportion of packets containing the prize offer is less than 1 in 3. In order to test the manufacturer's claim, he buys 20 randomly selected packets. He finds that exactly 2 of these packets contain the prize offer.

(a) Carry out the test at the 10% significance level. [5]

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(b) Maria also suspects that the proportion of packets containing the prize offer is less than 1 in 3. She also carries out a significance test at the 10% level using 20 randomly selected packets. She will reject the manufacturer's claim if she finds that there are 3 or fewer packets containing the prize offer.

Find the probability of a Type II error in Maria's test if the proportion of packets containing the prize offer is actually 1 in 7. [3]

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(c) Explain what is meant by a Type II error in this context. [1]

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283. 9709_w20_qp_63 Q: 5

The number of absences per week by workers at a factory has the distribution Po(2.1).

(a) Find the standard deviation of the number of absences per week. [1]

(b) Find the probability that the number of absences in a 2-week period is at least 2. [3]

(c) Find the probability that the number of absences in a 3-week period is more than 4 and less than 8. [2]

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Following a change in working conditions, the management wished to test whether the mean number of absences has decreased. They found that, in a randomly chosen 3-week period, there were exactly 2 absences.

(d) Carry out the test at the 10% significance level. [5]

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(e) State, with a reason, which of the errors, Type I or Type II, might have been made in carrying out the test in part **(d)**. [2]

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284. 9709_w20_qp_63 Q: 6

The time, in minutes, for Anjan's journey to work on Mondays has mean 38.4 and standard deviation 6.9.

(a) Find the probability that Anjan's mean journey time for a random sample of 30 Mondays is between 38 and 40 minutes. [5]

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Anjan wishes to test whether his mean journey time is different on Tuesdays. He chooses a random sample of 30 Tuesdays and finds that his mean journey time for these 30 Tuesdays is 40.2 minutes. Assume that the standard deviation for his journey time on Tuesdays is 6.9 minutes.

(b) **(i)** State, with a reason, whether Anjan should use a one-tail or a two-tail test. [1]

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(ii) Carry out the test at the 10% significance level. [5]

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(iii) Explain whether it was necessary to use the Central Limit theorem in part **(b)(ii)**. [1]

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285. 9709_m19_qp_72 Q: 3

At factory A the mean number of accidents per year is 32. At factory B the records of numbers of accidents before 2018 have been lost, but the number of accidents during 2018 was 21. It is known that the number of accidents per year can be well modelled by a Poisson distribution. Use an approximating distribution to test at the 2% significance level whether the mean number of accidents at factory B is less than at factory A. [6]

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286. 9709_m19_qp_72 Q: 6

The time taken by volunteers to complete a certain task is normally distributed. In the past the time, in minutes, has had mean 91.4 and standard deviation 6.4. A new, similar task is introduced and the times, t minutes, taken by a random sample of 6 volunteers to complete the new task are summarised by $\Sigma t = 568.5$. Andrea plans to carry out a test, at the 5% significance level, of whether the mean time for the new task is different from the mean time for the old task.

(i) Give a reason why Andrea should use a two-tail test. [1]

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(ii) State the probability that a Type I error is made, and explain the meaning of a Type I error in this context. [2]

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You may assume that the times taken for the new task are normally distributed.

(iii) Stating another necessary assumption, carry out the test. [7]

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287. 9709_s19_qp_71 Q: 2

The time, in minutes, that John takes to travel to work has a normal distribution. Last year the mean and standard deviation were 26.5 and 4.8 respectively. This year John uses a different route and he finds that the mean time for his first 150 journeys is 27.5 minutes.

(i) Stating a necessary assumption, test at the 1% significance level whether the mean time for his journey to work has increased. [6]

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(ii) State, with a reason, whether it was necessary to use the Central Limit theorem in your answer to part **(i)**. [1]

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288. 9709_s19_qp_71 Q: 3

Sumitra has a six-sided die. She suspects that it is biased so that it shows a six less often than it would if it were fair. She decides to test the die by throwing it 30 times and noting the number of throws on which it shows a six.

(i) It shows a six on exactly 2 throws. Use a binomial distribution to carry out the test at the 5% significance level. [5]

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(ii) Later, Sumitra repeats the test at the 5% significance level by throwing the die 30 times again. Find the probability of a Type I error in this second test. [2]

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289. 9709_s19_qp_72 Q: 3

It is claimed that, on average, a particular train journey takes less than 1.9 hours. The times, t hours, taken for this journey on a random sample of 50 days were recorded. The results are summarised below.

$$n = 50 \qquad \Sigma t = 92.5 \qquad \Sigma t^2 = 175.25$$

(i) Calculate unbiased estimates of the population mean and variance. [3]

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(ii) Test the claim at the 5% significance level. [5]

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290. 9709_s19_qp_72 Q: 5

The manufacturer of a certain type of biscuit claims that 10% of packets include a free offer printed on the packet. Jyothi suspects that the true proportion is less than 10%. He plans to test the claim by looking at 40 randomly selected packets and, if the number which include the offer is less than 2, he will reject the manufacturer's claim.

(i) State suitable hypotheses for the test. [1]

(ii) Find the probability of a Type I error. [3]

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On another occasion Jyothi looks at 80 randomly selected packets and finds that exactly 6 include the free offer.

(iii) Calculate an approximate 90% confidence interval for the proportion of packets that include the offer. [3]

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(iv) Use your confidence interval to comment on the manufacturer's claim. [1]

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291. 9709_s19_qp_72 Q: 7

All the seats on a certain daily flight are always sold. The number of passengers who have bought seats but fail to arrive for this flight on a particular day is modelled by the distribution B(320, 0.005).

(i) Explain what the number 320 represents in this context. [1]

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(ii) The total number of passengers who have bought seats but fail to arrive for this flight on 2 randomly chosen days is denoted by X. Use a suitable approximating distribution to find $P(2 < X < 6)$. [3]

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(iii) Justify the use of your approximating distribution. [2]

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After some changes, the airline wishes to test whether the mean number of passengers per day who fail to arrive for this flight has decreased.

(iv) During 5 randomly chosen days, a total of 2 passengers failed to arrive. Carry out the test at the 2.5% significance level. [5]

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292. 9709_s19_qp_73 Q: 5

The amount of money, in dollars, spent by a customer on one visit to a certain shop is modelled by the distribution N(μ, 1.94). In the past, the value of μ has been found to be 20.00, but following a rearrangement in the shop, the manager suspects that the value of μ has changed. He takes a random sample of 6 customers and notes how much they each spend, in dollars. The results are as follows.

17.60 23.50 17.30 22.00 31.00 15.50

The manager carries out a hypothesis test using a significance level of α%. The test does not support his suspicion. Find the largest possible value of α. [6]

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293. 9709_s19_qp_73 Q: 8

The four sides of a spinner are A, B, C, D. The spinner is supposed to be fair, but Sonam suspects that the spinner is biased so that the probability, p, that it will land on side A is greater than $\frac{1}{4}$. He spins the spinner 10 times and finds that it lands on side A 6 times.

(i) Test Sonam's suspicion using a 1% significance level. [5]

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Later Sonam carries out a similar test at the 1% significance level, using another 10 spins of the spinner.

(ii) Calculate the probability of a Type I error. [2]

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(iii) Assuming that the value of p is actually $\frac{3}{5}$, calculate the probability of a Type II error. [3]

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294. 9709_w19_qp_72 Q: 2

The heights of a certain species of animal have been found to have mean 65.2 cm and standard deviation 7.1 cm. A researcher suspects that animals of this species in a certain region are shorter on average than elsewhere. She takes a large random sample of n animals of this species from this region and finds that their mean height is 63.2 cm. She then carries out an appropriate hypothesis test.

(i) She finds that the value of the test statistic z is –2.182, correct to 3 decimal places.

(a) Stating a necessary assumption, calculate the value of n. [4]

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(b) Carry out the hypothesis test at the 4% significance level. [3]

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(ii) Explain why it was necessary to use the Central Limit theorem in carrying out the test. [1]

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295. 9709_w19_qp_72 Q: 6

The number of accidents per month, X, at a factory has a Poisson distribution. In the past the mean has been 1.1 accidents per month. Some new machinery is introduced and the management wish to test whether the mean has increased. They note the number of accidents in a randomly chosen month and carry out a hypothesis test at the 1% significance level.

(i) Show that the critical region for the test is $X \geqslant 5$. Given that the number of accidents is 6, carry out the test. [6]

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Later they carry out a similar test, also at the 1% significance level.

(ii) Explain the meaning of a Type I error in this context and state the probability of a Type I error. [2]

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(iii) Given that the mean is now 7.0, find the probability of a Type II error. [2]

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296. 9709_w19_qp_73 Q: 4

A train company claims that 92% of trains on a particular line arrive on time. Sanjeep suspects that the true percentage is less than 92%. He chooses a random sample of 20 trains on this line and finds that exactly 16 of them arrive on time. Making an assumption that should be stated, test at the 5% significance level whether Sanjeep's suspicion is justified. [6]

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297. 9709_w19_qp_73 Q: 7

Bob is a self-employed builder. In the past his weekly income had mean \$546 and standard deviation \$120. Following a change in Bob's working pattern, his mean weekly income for 40 randomly chosen weeks was \$581. You should assume that the standard deviation remains unchanged at \$120.

(i) Test at the 2.5% significance level whether Bob's mean weekly income has increased. [5]

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Bob finds his mean weekly income for another random sample of 40 weeks and carries out a similar test at the 2.5% significance level.

(ii) Given that Bob's mean weekly income is now in fact \$595, find the probability of a Type II error. [5]

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298. 9709_m18_qp_72 Q: 4

A store sells two types of computer, laptops and tablets. The number of laptops sold per hour is modelled by a random variable with distribution Po(0.9). The number of tablets sold per hour is modelled by an independent random variable with distribution Po(1.5).

(i) Find the probability that, during a randomly chosen hour, the total number of laptops and tablets sold in the store is less than 4. [3]

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(ii) The manager claims that on sunny Saturdays fewer laptops than usual are sold. In order to test this claim, an employee notes the number of laptops sold during a 4-hour period on a randomly chosen sunny Saturday. In fact only 1 laptop is sold during this period. Test the manager's claim at the 10% significance level. [5]

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299. 9709_m18_qp_72 Q: 5

Packets of Frugums contain 30 sweets. The manufacturer claims that, on average, 17% of the sweets are orange flavoured. Angela suspects that the average is actually less than 17%. In order to test the manufacturer's claim, she buys a packet of Frugums. If there are fewer than 3 orange flavoured sweets in the packet, she will conclude that the claim is false.

(i) State appropriate null and alternative hypotheses. [1]

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(ii) Explain what is meant by a Type I error in this situation. [1]

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(iii) Calculate the probability of a Type I error. [3]

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(iv) Given that the true percentage of orange flavoured sweets is 5%, calculate the probability of a Type II error. [3]

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300. 9709_s18_qp_71 Q: 5

The mass, in kilograms, of rocks in a certain area has mean 14.2 and standard deviation 3.1.

(i) Find the probability that the mean mass of a random sample of 50 of these rocks is less than 14.0 kg. [3]

(ii) Explain whether it was necessary to assume that the population of the masses of these rocks is normally distributed. [1]

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(iii) A geologist suspects that rocks in another area have a mean mass which is less than 14.2 kg. A random sample of 100 rocks in this area has sample mean 13.5 kg. Assuming that the standard deviation for rocks in this area is also 3.1 kg, test at the 2% significance level whether the geologist is correct. [5]

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301. 9709_s18_qp_71 Q: 7

The number of absences by girls from a certain class on any day is modelled by a random variable with distribution Po(0.2). The number of absences by boys from the same class on any day is modelled by an independent random variable with distribution Po(0.3).

(i) Find the probability that, during a randomly chosen 2-day period, the total number of absences is less than 3. [3]

(ii) Find the probability that, during a randomly chosen 5-day period, the number of absences by boys is more than 3. [2]

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(iii) The teacher claims that, during the football season, there are more absences by boys than usual. In order to test this claim at the 5% significance level, he notes the number of absences by boys during a randomly chosen 5-day period during the football season.

(a) State what is meant by a Type I error in this context. [1]

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(b) State appropriate null and alternative hypotheses and find the probability of a Type I error. [3]

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(c) In fact there were 4 absences by boys during this period. Test the teacher's claim at the 5% significance level. [3]

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302. 9709_s18_qp_72 Q: 4

The mean mass of packets of sugar is supposed to be 505 g. A random sample of 10 packets filled by a certain machine was taken and the masses, in grams, were found to be as follows.

500 499 496 495 498 490 492 501 494 494

(i) Find unbiased estimates of the population mean and variance. [3]

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The mean mass of packets produced by this machine was found to be less than 505 g, so the machine was adjusted. Following the adjustment, the masses of a random sample of 150 packets from the machine were measured and the total mass was found to be 75 660 g.

(ii) Given that the population standard deviation is 3.6 g, test at the 2% significance level whether the machine is still producing packets with mean mass less than 505 g. [5]

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(iii) Explain why the use of the normal distribution is justified in carrying out the test in part **(ii)**. [1]

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303. 9709_s18_qp_72 Q: 7

A ten-sided spinner has edges numbered 1, 2, 3, 4, 5, 6, 7, 8, 9, 10. Sanjeev claims that the spinner is biased so that it lands on the 10 more often than it would if it were unbiased. In an experiment, the spinner landed on the 10 in 3 out of 9 spins.

(i) Test at the 1% significance level whether Sanjeev's claim is justified. [5]

(ii) Explain why a Type I error cannot have been made. [1]

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In fact the spinner is biased so that the probability that it will land on the 10 on any spin is 0.5.

(iii) Another test at the 1% significance level, also based on 9 spins, is carried out. Calculate the probability of a Type II error. [6]

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304. 9709_s18_qp_73 Q: 5

The time taken for a particular train journey is normally distributed. In the past, the time had mean 2.4 hours and standard deviation 0.3 hours. A new timetable is introduced and on 30 randomly chosen occasions the time for this journey is measured. The mean time for these 30 occasions is found to be 2.3 hours.

(i) Stating any assumption(s), test, at the 5% significance level, whether the mean time for this journey has changed. [6]

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(ii) A similar test at the 5% significance level was carried out using the times from another randomly chosen 30 occasions.

(a) State the probability of a Type I error. [1]

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(b) State what is meant by a Type II error in this context. [1]

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305. 9709_w18_qp_71 Q: 2

A headteacher models the number of children who bring a 'healthy' packed lunch to school on any day by the distribution B(150, p). In the past, she has found that $p = \frac{1}{3}$. Following the opening of a fast food outlet near the school, she wishes to test, at the 1% significance level, whether the value of p has decreased.

(i) State the null and alternative hypotheses for this test. [1]

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On a randomly chosen day she notes the number, N, of children who bring a 'healthy' packed lunch to school. She finds that $N = 36$ and then, assuming that the null hypothesis is true, she calculates that $P(N \leqslant 36) = 0.0084$.

(ii) State, with a reason, the conclusion that the headteacher should draw from the test. [2]

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(iii) According to the model, what is the largest number of children who might bring a packed lunch to school? [1]

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306. 9709_w18_qp_71 Q: 7

A mill owner claims that the mean mass of sacks of flour produced at his mill is 51 kg. A quality control officer suspects that the mean mass is actually less than 51 kg. In order to test the owner's claim she finds the mass, x kg, of each of a random sample of 150 sacks and her results are summarised as follows.

$$n = 150 \qquad \Sigma x = 7480 \qquad \Sigma x^2 = 380\,000$$

(i) Carry out the test at the 2.5% significance level. [7]

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You may now assume that the population standard deviation of the masses of sacks of flour is 6.856 kg. The quality control officer weighs another random sample of 150 sacks and carries out another test at the 2.5% significance level.

(ii) Given that the population mean mass is 49 kg, find the probability of a Type II error. [5]

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307. 9709_w18_qp_72 Q: 5

The numbers of basketball courts in a random sample of 70 schools in South Mowland are summarised in the table.

Number of basketball courts	0	1	2	3	4	>4
Number of schools	2	28	26	10	4	0

(i) Calculate unbiased estimates for the population mean and variance of the number of basketball courts per school in South Mowland. [4]

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The mean number of basketball courts per school in North Mowland is 1.9.

(ii) Test at the 5% significance level whether the mean number of basketball courts per school in South Mowland is less than the mean for North Mowland. [5]

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(iii) State, with a reason, which of the errors, Type I or Type II, might have been made in the test in part **(ii)**. [1]

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308. 9709_w18_qp_72 Q: 6

In the past, Angus found that his train was late on 15% of his daily journeys to work. Following a timetable change, Angus found that out of 60 randomly chosen days, his train was late on 6 days.

(i) Test at the 10% significance level whether Angus' train is late less often than it was before the timetable change. [5]

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Angus used his random sample to find an $\alpha\%$ confidence interval for the proportion of days on which his train is late. The upper limit of his interval was 0.150, correct to 3 significant figures.

(ii) Calculate the value of α correct to the nearest integer. [5]

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309. 9709_w18_qp_73 Q: 2

A headteacher models the number of children who bring a 'healthy' packed lunch to school on any day by the distribution B(150, p). In the past, she has found that $p = \frac{1}{3}$. Following the opening of a fast food outlet near the school, she wishes to test, at the 1% significance level, whether the value of p has decreased.

(i) State the null and alternative hypotheses for this test. [1]

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On a randomly chosen day she notes the number, N, of children who bring a 'healthy' packed lunch to school. She finds that $N = 36$ and then, assuming that the null hypothesis is true, she calculates that $P(N \leqslant 36) = 0.0084$.

(ii) State, with a reason, the conclusion that the headteacher should draw from the test. [2]

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(iii) According to the model, what is the largest number of children who might bring a packed lunch to school? [1]

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310. 9709_w18_qp_73 Q: 7

A mill owner claims that the mean mass of sacks of flour produced at his mill is 51 kg. A quality control officer suspects that the mean mass is actually less than 51 kg. In order to test the owner's claim she finds the mass, x kg, of each of a random sample of 150 sacks and her results are summarised as follows.

$$n = 150 \qquad \Sigma x = 7480 \qquad \Sigma x^2 = 380\,000$$

(i) Carry out the test at the 2.5% significance level. [7]

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You may now assume that the population standard deviation of the masses of sacks of flour is 6.856 kg. The quality control officer weighs another random sample of 150 sacks and carries out another test at the 2.5% significance level.

(ii) Given that the population mean mass is 49 kg, find the probability of a Type II error. [5]

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311. 9709_m17_qp_72 Q: 2

Karim has noted the lifespans, in weeks, of a large random sample of certain insects. He carries out a test, at the 1% significance level, for the population mean, μ. Karim's null hypothesis is $\mu = 6.4$.

(i) Given that Karim's test is two-tail, state the alternative hypothesis. [1]

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Karim finds that the value of the test statistic is $z = 2.43$.

(ii) Explain what conclusion he should draw. [2]

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(iii) Explain briefly when a one-tail test is appropriate, rather than a two-tail test. [1]

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312. 9709_m17_qp_72 Q: 4

At a doctors' surgery, the number of missed appointments per day has a Poisson distribution. In the past the mean number of missed appointments per day has been 0.9. Following some publicity, the manager carries out a hypothesis test to determine whether this mean has decreased. If there are fewer than 3 missed appointments in a randomly chosen 5-day period, she will conclude that the mean has decreased.

(i) Find the probability of a Type I error. [3]

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(ii) State what is meant by a Type I error in this context. [1]

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(iii) Find the probability of a Type II error if the mean number of missed appointments per day is 0.2. [3]

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313. 9709_s17_qp_71 Q: 2

Past experience has shown that the heights of a certain variety of plant have mean 64.0 cm and standard deviation 3.8 cm. During a particularly hot summer, it was expected that the heights of plants of this variety would be less than usual. In order to test whether this was the case, a botanist recorded the heights of a random sample of 100 plants and found that the value of the sample mean was 63.3 cm. Stating a necessary assumption, carry out the test at the 2.5% significance level. [6]

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314. 9709_s17_qp_71 Q: 6

The number of sports injuries per month at a certain college has a Poisson distribution. In the past the mean has been 1.1 injuries per month. The principal recently introduced new safety guidelines and she decides to test, at the 2% significance level, whether the mean number of sports injuries has been reduced. She notes the number of sports injuries during a 6-month period.

(i) Find the critical region for the test and state the probability of a Type I error. [6]

(ii) State what is meant by a Type I error in this context. [1]

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(iii) During the 6-month period there are a total of 2 sports injuries. Carry out the test. [3]

(iv) Assuming that the mean remains 1.1, calculate the probability that there will be fewer than 30 sports injuries during a 36-month period. [4]

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315. 9709_s17_qp_72 Q: 3

Household incomes, in thousands of dollars, in a certain country are represented by the random variable X with mean μ and standard deviation σ. The incomes of a random sample of 400 households are found and the results are summarised below.

$$n = 400 \qquad \Sigma x = 923 \qquad \Sigma x^2 = 3170$$

(i) Calculate unbiased estimates of μ and σ^2. [3]

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(ii) A random sample of 50 households in one particular region of the country is taken and the sample mean income, in thousands of dollars, is found to be 2.6. Using your values from part **(i)**, test at the 5% significance level whether household incomes in this region are greater, on average, than in the country as a whole. [5]

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316. 9709_s17_qp_72 Q: 4

It is claimed that 1 in every 4 packets of certain biscuits contains a free gift. Marisa and André both suspect that the true proportion is less than 1 in 4.

(i) Marisa chooses 20 packets at random. She decides that if fewer than 3 contain free gifts, she will conclude that the claim is not justified. Use a binomial distribution to find the probability of a Type I error. [2]

(ii) André chooses 25 packets at random. He decides to carry out a significance test at the 1% level, using a binomial distribution. Given that only 1 of the 25 packets contains a free gift, carry out the test. [5]

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317. 9709_s17_qp_73 Q: 4

Last year the mean level of a certain pollutant in a river was found to be 0.034 grams per millilitre. This year the levels of pollutant, X grams per millilitre, were measured at a random sample of 200 locations in the river. The results are summarised below.

$$n = 200 \qquad \Sigma x = 6.7 \qquad \Sigma x^2 = 0.2312$$

(i) Calculate unbiased estimates of the population mean and variance. [3]

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(ii) Test, at the 10% significance level, whether the mean level of pollutant has changed. [5]

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318. 9709_s17_qp_73 Q: 7

In the past the number of accidents per month on a certain road was modelled by a random variable with distribution Po(0.47). After the introduction of speed restrictions, the government wished to test, at the 5% significance level, whether the mean number of accidents had decreased. They noted the number of accidents during the next 12 months. It is assumed that accidents occur randomly and that a Poisson model is still appropriate.

(i) Given that the total number of accidents during the 12 months was 2, carry out the test. [6]

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(ii) Explain what is meant by a Type II error in this context. [1]

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It is given that the mean number of accidents per month is now in fact 0.05.

(iii) Using another random sample of 12 months the same test is carried out again, with the same significance level. Find the probability of a Type II error. [4]

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319. 9709_w17_qp_71 Q: 7

In the past the number of cars sold per day at a showroom has been modelled by a random variable with distribution Po(0.7). Following an advertising campaign, it is hoped that the mean number of sales per day will increase. In order to test at the 10% significance level whether this is the case, the total number of sales during the first 5 days after the campaign is noted. You should assume that a Poisson model is still appropriate.

(i) Given that the total number of cars sold during the 5 days is 5, carry out the test. [6]

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The number of cars sold per day at another showroom has the independent distribution Po(0.6). Assume that the distribution for the first showroom is still Po(0.7).

(ii) Find the probability that the total number of cars sold in the two showrooms during 3 days is exactly 2. [3]

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320. 9709_w17_qp_71 Q: 8

In order to test the effect of a drug, a researcher monitors the concentration, X, of a certain protein in the blood stream of patients. For patients who are not taking the drug the mean value of X is 0.185. A random sample of 150 patients taking the drug was selected and the values of X were found. The results are summarised below.

$$n = 150 \qquad \Sigma x = 27.0 \qquad \Sigma x^2 = 5.01$$

The researcher wishes to test at the 1% significance level whether the mean concentration of the protein in the blood stream of patients taking the drug is less than 0.185.

(i) Carry out the test. [7]

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(ii) Given that, in fact, the mean concentration for patients taking the drug is 0.175, find the probability of a Type II error occurring in the test. [5]

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321. 9709_w17_qp_72 Q: 3

The masses, m kg, of packets of flour are normally distributed. The mean mass is supposed to be 1.01 kg. A quality control officer measures the masses of a random sample of 100 packets. The results are summarised below.

$$n = 100 \qquad \Sigma m = 98.2 \qquad \Sigma m^2 = 104.52$$

(i) Test at the 5% significance level whether the population mean mass is less than 1.01 kg. [7]

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(ii) Explain whether it was necessary to use the Central Limit theorem in your answer to part **(i)**.
[1]

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322. 9709_w17_qp_72 Q: 6

In a certain factory the number of items per day found to be defective has had the distribution Po(1.03). After the introduction of new quality controls, the management wished to test at the 10% significance level whether the mean number of defective items had decreased. They noted the total number of defective items produced in 5 randomly chosen days. It is assumed that defective items occur randomly and that a Poisson model is still appropriate.

(i) Given that the total number of defective items produced during the 5 days was 2, carry out the test. [6]

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(ii) Using another random sample of 5 days the same test is carried out again, with the same significance level. Find the probability of a Type I error. [3]

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(iii) Explain what is meant by a Type I error in this context. [1]

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323. 9709_w17_qp_73 Q: 7

In the past the number of cars sold per day at a showroom has been modelled by a random variable with distribution Po(0.7). Following an advertising campaign, it is hoped that the mean number of sales per day will increase. In order to test at the 10% significance level whether this is the case, the total number of sales during the first 5 days after the campaign is noted. You should assume that a Poisson model is still appropriate.

(i) Given that the total number of cars sold during the 5 days is 5, carry out the test. [6]

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The number of cars sold per day at another showroom has the independent distribution Po(0.6). Assume that the distribution for the first showroom is still Po(0.7).

(ii) Find the probability that the total number of cars sold in the two showrooms during 3 days is exactly 2. [3]

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324. 9709_w17_qp_73 Q: 8

In order to test the effect of a drug, a researcher monitors the concentration, X, of a certain protein in the blood stream of patients. For patients who are not taking the drug the mean value of X is 0.185. A random sample of 150 patients taking the drug was selected and the values of X were found. The results are summarised below.

$$n = 150 \qquad \Sigma x = 27.0 \qquad \Sigma x^2 = 5.01$$

The researcher wishes to test at the 1% significance level whether the mean concentration of the protein in the blood stream of patients taking the drug is less than 0.185.

(i) Carry out the test. [7]

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(ii) Given that, in fact, the mean concentration for patients taking the drug is 0.175, find the probability of a Type II error occurring in the test. [5]

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325. 9709_m16_qp_72 Q: 2

Jill shoots arrows at a target. Last week, 65% of her shots hit the target. This week Jill claims that she has improved. Out of her first 20 shots this week, she hits the target with 18 shots. Assuming shots are independent, test Jill's claim at the 1% significance level. [5]

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326. 9709_m16_qp_72 Q: 3

In the past, Arvinder has found that the mean time for his journey to work is 35.2 minutes. He tries a different route to work, hoping that this will reduce his journey time. Arvinder decides to take a random sample of 25 journeys using the new route. If the sample mean is less than 34.7 minutes he will conclude that the new route is quicker. Assume that, for the new route, the journey time has a normal distribution with standard deviation 5.6 minutes.

(i) Find the probability that a Type I error occurs. [4]

(ii) Arvinder finds that the sample mean is 34.5 minutes. Explain briefly why it is impossible for him to make a Type II error. [1]

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327. 9709_s16_qp_71 Q: 1

A six-sided die shows a six on 25 throws out of 200 throws. Test at the 10% significance level the null hypothesis: P(throwing a six) = $\frac{1}{6}$, against the alternative hypothesis: P(throwing a six) < $\frac{1}{6}$. [5]

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328. 9709_s16_qp_71 Q: 4

In the past, the time spent by customers in a certain shop had mean 12.5 minutes and standard deviation 4.2 minutes. Following a change of layout in the shop, the mean time spent in the shop by a random sample of 50 customers is found to be 13.5 minutes.

(i) Assuming that the standard deviation remains at 4.2 minutes, test at the 5% significance level whether the mean time spent by customers in the shop has changed. [5]

(ii) Another random sample of 50 customers is chosen and a similar test at the 5% significance level is carried out. State the probability of a Type I error. [1]

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329. 9709_s16_qp_72 Q: 2

Jacques is a chef. He claims that 90% of his customers are satisfied with his cooking. Marie suspects that the true percentage is lower than 90%. She asks a random sample of 15 of Jacques' customers whether they are satisfied. She then performs a hypothesis test of the null hypothesis $p = 0.9$ against the alternative hypothesis $p < 0.9$, where p is the population proportion of customers who are satisfied. She decides to reject the null hypothesis if fewer than 12 customers are satisfied.

(i) In the context of the question, explain what is meant by a Type I error. [1]

(ii) Find the probability of a Type I error in Marie's test. [3]

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330. 9709_s16_qp_72 Q: 4

At a certain company, computer faults occur randomly and at a constant mean rate. In the past this mean rate has been 2.1 per week. Following an update, the management wish to determine whether the mean rate has changed. During 20 randomly chosen weeks it is found that 54 computer faults occur. Use a suitable approximation to test at the 5% significance level whether the mean rate has changed. [6]

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331. 9709_s16_qp_73 Q: 2

In the past, the mean annual crop yield from a particular field has been 8.2 tonnes. During the last 16 years, a new fertiliser has been used on the field. The mean yield for these 16 years is 8.7 tonnes. Assume that yields are normally distributed with standard deviation 1.2 tonnes. Carry out a test at the 5% significance level of whether the mean yield has increased. [5]

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332. 9709_s16_qp_73 Q: 4

The number of sightings of a golden eagle at a certain location has a Poisson distribution with mean 2.5 per week. Drilling for oil is started nearby. A naturalist wishes to test at the 5% significance level whether there are fewer sightings since the drilling began. He notes that during the following 3 weeks there are 2 sightings.

(i) Find the critical region for the test and carry out the test. [5]

(ii) State the probability of a Type I error. [1]

(iii) State why the naturalist could not have made a Type II error. [1]

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333. 9709_w16_qp_71 Q: 2

A die has six faces numbered 1, 2, 3, 4, 5, 6. Manjit suspects that the die is biased so that it shows a six on fewer throws than it would if it were fair. In order to test her suspicion, she throws the die a certain number of times and counts the number of sixes.

(i) State suitable null and alternative hypotheses for Manjit's test. [1]

(ii) There are no sixes in the first 15 throws. Show that this result is not significant at the 5% level. [2]

(iii) Find the smallest value of n such that, if there are no sixes in the first n throws, this result is significant at the 5% level. [2]

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334. 9709_w16_qp_71 Q: 7

In the past the time, in minutes, taken for a particular rail journey has been found to have mean 20.5 and standard deviation 1.2. Some new railway signals are installed. In order to test whether the mean time has decreased, a random sample of 100 times for this journey are noted. The sample mean is found to be 20.3 minutes. You should assume that the standard deviation is unchanged.

(i) Carry out a significance test, at the 4% level, of whether the population mean time has decreased. [5]

Later another significance test of the same hypotheses, using another random sample of size 100, is carried out at the 4% level.

(ii) Given that the population mean is now 20.1, find the probability of a Type II error. [5]

(iii) State what is meant by a Type II error in this context. [1]

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335. 9709_w16_qp_72 Q: 2

A die has six faces numbered 1, 2, 3, 4, 5, 6. Manjit suspects that the die is biased so that it shows a six on fewer throws than it would if it were fair. In order to test her suspicion, she throws the die a certain number of times and counts the number of sixes.

(i) State suitable null and alternative hypotheses for Manjit's test. [1]

(ii) There are no sixes in the first 15 throws. Show that this result is not significant at the 5% level. [2]

(iii) Find the smallest value of n such that, if there are no sixes in the first n throws, this result is significant at the 5% level. [2]

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336. 9709_w16_qp_72 Q: 7

In the past the time, in minutes, taken for a particular rail journey has been found to have mean 20.5 and standard deviation 1.2. Some new railway signals are installed. In order to test whether the mean time has decreased, a random sample of 100 times for this journey are noted. The sample mean is found to be 20.3 minutes. You should assume that the standard deviation is unchanged.

(i) Carry out a significance test, at the 4% level, of whether the population mean time has decreased. [5]

Later another significance test of the same hypotheses, using another random sample of size 100, is carried out at the 4% level.

(ii) Given that the population mean is now 20.1, find the probability of a Type II error. [5]

(iii) State what is meant by a Type II error in this context. [1]

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337. 9709_w16_qp_73 Q: 4

The manufacturer of a tablet computer claims that the mean battery life is 11 hours. A consumer organisation wished to test whether the mean is actually greater than 11 hours. They invited a random sample of members to report the battery life of their tablets. They then calculated the sample mean. Unfortunately a fire destroyed the records of this test except for the following partial document.

Test of the mean batter the table	
Sample size, n	
Sample mean (hours)	11.8
Is the result significant at the 5% level?	Yes
Is the result significant at the 2.5% level?	No

Given that the population of battery lives is normally distributed with standard deviation 1.6 hours, find the set of possible values of the sample size, n. [5]

338. 9709_w16_qp_73 Q: 5

It is claimed that 30% of packets of Froogum contain a free gift. Andre thinks that the actual proportion is less than 30% and he decides to carry out a hypothesis test at the 5% significance level. He buys 20 packets of Froogum and notes the number of free gifts he obtains.

(i) State null and alternative hypotheses for the test. [1]

(ii) Use a binomial distribution to find the probability of a Type I error. [5]

Andre finds that 3 of the 20 packets contain free gifts.

(iii) Carry out the test. [2]

339. 9709_s15_qp_71 Q: 2

Sami claims that he can read minds. He asks each of 50 people to choose one of the 5 letters A, B, C, D or E. He then tells each person which letter he believes they have chosen. He gets 13 correct. Sami says "This shows that I can read minds, because 13 is more than I would have got right if I were just guessing."

(i) State null and alternative hypotheses for a test of Sami's claim. [1]

(ii) Test at the 10% significance level whether Sami's claim is justified. [5]

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340. 9709_s15_qp_71 Q: 4

In the past, the time taken by vehicles to drive along a particular stretch of road has had mean 12.4 minutes and standard deviation 2.1 minutes. Some new signs are installed and it is expected that the mean time will increase. In order to test whether this is the case, the mean time for a random sample of 50 vehicles is found. You may assume that the standard deviation is unchanged.

(i) The mean time for the sample of 50 vehicles is found to be 12.9 minutes. Test at the 2.5% significance level whether the population mean time has increased. [4]

(ii) State what is meant by a Type II error in this context. [2]

(iii) State what extra piece of information would be needed in order to find the probability of a Type II error. [1]

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341. 9709_s15_qp_72 Q: 2

Cloth made at a certain factory has been found to have an average of 0.1 faults per square metre. Suki claims that the cloth made by her machine contains, on average, more than 0.1 faults per square metre. In a random sample of 5 m^2 of cloth from Suki's machine, it was found that there were 2 faults. Assuming that the number of faults per square metre has a Poisson distribution,

(i) state null and alternative hypotheses for a test of Suki's claim, [1]

(ii) test at the 10% significance level whether Suki's claim is justified. [4]

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342. 9709_s15_qp_72 Q: 4

In the past, the flight time, in hours, for a particular flight has had mean 6.20 and standard deviation 0.80. Some new regulations are introduced. In order to test whether these new regulations have had any effect upon flight times, the mean flight time for a random sample of 40 of these flights is found.

(i) State what is meant by a Type I error in this context. [2]

(ii) The mean time for the sample of 40 flights is found to be 5.98 hours. Assuming that the standard deviation of flight times is still 0.80 hours, test at the 5% significance level whether the population mean flight time has changed. [4]

(iii) State, with a reason, which of the errors, Type I or Type II, might have been made in your answer to part **(ii)**. [2]

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343. 9709_s15_qp_73 Q: 2

Marie claims that she can predict the winning horse at the local races. There are 8 horses in each race. Nadine thinks that Marie is just guessing, so she proposes a test. She asks Marie to predict the winners of the next 10 races and, if she is correct in 3 or more races, Nadine will accept Marie's claim.

(i) State suitable null and alternative hypotheses. [1]

(ii) Calculate the probability of a Type I error. [3]

(iii) State the significance level of the test. [1]

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344. 9709_s15_qp_73 Q: 5

The mean breaking strength of cables made at a certain factory is supposed to be 5 tonnes. The quality control department wishes to test whether the mean breaking strength of cables made by a particular machine is actually less than it should be. They take a random sample of 60 cables. For each cable they find the breaking strength by gradually increasing the tension in the cable and noting the tension when the cable breaks.

(i) Give a reason why it is necessary to take a sample rather then testing all the cables produced by the machine. [1]

(ii) The mean breaking strength of the 60 cables in the sample is found to be 4.95 tonnes. Given that the population standard deviation of breaking strengths is 0.15 tonnes, test at the 1% significance level whether the population mean breaking strength is less than it should be. [4]

(iii) Explain whether it was necessary to use the Central Limit theorem in the solution to part **(ii)**. [2]

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345. 9709_w15_qp_71 Q: 7

At a certain hospital it was found that the probability that a patient did not arrive for an appointment was 0.2. The hospital carries out some publicity in the hope that this probability will be reduced. They wish to test whether the publicity has worked.

(i) It is suggested that the first 30 appointments on a Monday should be used for the test. Give a reason why this is not an appropriate sample. [1]

A suitable sample of 30 appointments is selected and the number of patients that do not arrive is noted. This figure is used to carry out a test at the 5% significance level.

(ii) Explain why the test is one-tail and state suitable null and alternative hypotheses. [2]

(iii) State what is meant by a Type I error in this context. [1]

(iv) Use the binomial distribution to find the critical region, and find the probability of a Type I error. [5]

(v) In fact 3 patients out of the 30 do not arrive. State the conclusion of the test, explaining your answer. [2]

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346. 9709_w15_qp_72 Q: 7

At a certain hospital it was found that the probability that a patient did not arrive for an appointment was 0.2. The hospital carries out some publicity in the hope that this probability will be reduced. They wish to test whether the publicity has worked.

(i) It is suggested that the first 30 appointments on a Monday should be used for the test. Give a reason why this is not an appropriate sample. [1]

A suitable sample of 30 appointments is selected and the number of patients that do not arrive is noted. This figure is used to carry out a test at the 5% significance level.

(ii) Explain why the test is one-tail and state suitable null and alternative hypotheses. [2]

(iii) State what is meant by a Type I error in this context. [1]

(iv) Use the binomial distribution to find the critical region, and find the probability of a Type I error. [5]

(v) In fact 3 patients out of the 30 do not arrive. State the conclusion of the test, explaining your answer. [2]

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347. 9709_w15_qp_73 Q: 5

(a) Narika has a die which is known to be biased so that the probability of throwing a 6 on any throw is $\frac{1}{100}$. She uses an approximating distribution to calculate the probability of obtaining no 6s in 450 throws. Find the percentage error in using the approximating distribution for this calculation. [4]

(b) Johan claims that a certain six-sided die is biased so that it shows a 6 less often than it would if the die were fair. In order to test this claim, the die is thrown 25 times and it shows a 6 on only 2 throws. Test at the 10% significance level whether Johan's claim is justified. [5]

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348. 9709_w15_qp_73 Q: 6

Parcels arriving at a certain office have weights W kg, where the random variable W has mean μ and standard deviation 0.2. The value of μ used to be 2.60, but there is a suspicion that this may no longer be true. In order to test at the 5% significance level whether the value of μ has increased, a random sample of 75 parcels is chosen. You may assume that the standard deviation of W is unchanged.

(i) The mean weight of the 75 parcels is found to be 2.64 kg. Carry out the test. [4]

(ii) Later another test of the same hypotheses at the 5% significance level, with another random sample of 75 parcels, is carried out. Given that the value of μ is now 2.68, calculate the probability of a Type II error. [5]

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Appendix A

Answers

1. 9709_m22_ms_62 Q: 7

Question	Answer	Marks	Guidance
(a)(i)	0.024×50 [= 1.2] and 0.018×60 [= 1.08]	**B1**	
	$(1 - e^{-1.2}(1 + 1.2)) \times (1 - e^{-1.08}(1 + 1.08))$	**M1**	For $(1 - e^{-\lambda}(1+\lambda)) \times (1 - e^{-\mu}(1+\mu))$ any λ, μ ($\lambda \neq \mu$) Allow one end error on either or both terms
	= 0.0991 (3 sf)	**A1**	Unsupported answer scores maximum **SC** B1 B1 **SC** Use of binomial 0.0994 scores B1 only
		3	
(a)(ii)	$\lambda = 0.024 \times 50 + 0.018 \times 60$	**M1**	or *their* 1.2 + 1.08 (NB 0.024+0.018 is M0)
	$1 - e^{-2.28} \times \left(1 + 2.28 + \frac{2.28^2}{2!} + \frac{2.28^3}{3!}\right)$	**M1**	any λ and allow one end error
	= 0.197 (3 sf)	**A1**	Unsupported answer scores maximum **SC** B2
		3	
(b)	$e^{-\lambda} = \left[e^{-\mu}\right]^2 = e^{-2\mu}$	**M1**	
	$e^{-\lambda} \times \frac{\lambda^2}{2} = k\left[e^{-\mu} \times \mu\right]^2$	**M1**	
	$e^{-2\mu} \times 2\mu^2 = k \times e^{-2\mu} \times \mu^2$	**M1**	OE. Use of $\lambda = 2\mu$ to find equation in μ and k only (or λ and k only)
	$k = 2$	**A1**	
		4	

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2. 9709_s22_ms_61 Q: 5

Question	Answer	Marks	Guidance
(a)	$\lambda = 4.5$	**B1**	
	$1 - e^{-4.5}(1 + 4.5 + \frac{4.5^2}{2!} + \frac{4.5^3}{3!} + \frac{4.5^4}{4!})$	**M1**	Allow one end error Allow any λ. Poisson expressions must be seen
	= 0.468 (3 sf)	**A1**	If M0 awarded allow SC B1 for 0.468
		3	
(b)	$\lambda = 162$ ($X \sim$ Po(162) $\Rightarrow X \sim$ N(162, 162))	**B1**	
	$\frac{149.5 - \text{'162'}}{\sqrt{\text{'162'}}}$ and $\frac{160.5 - \text{'162'}}{\sqrt{\text{'162'}}}$ (= –0.982 and –0.118)	**M1**	One of these; allow with incorrect or no continuity correction
	Φ('0.982') – ϕ('0.118') oe	**M1**	Area consistent with *their* values (both standardisations must be seen)
	= 0.290 (3 sf)	**A1**	Allow 0.29
		4	

Question	Answer	Marks	Guidance
(c)	$\lambda = \frac{13.5}{6} + 3.6 \times \frac{2}{3}$ OE or 4.65	**M1**	Attempt to find λ
	$e^{-4.65}(\frac{4.65^4}{4!} + \frac{4.65^5}{5!} + \frac{4.65^6}{6!})$	**M1**	Allow any λ Allow one end error Poisson terms not be seen
	0.494 (3 sf)	**A1**	If M0 allow SC B1 for 0.494
		3	

3. 9709_s22_ms_62 Q: 3

Question	Answer	Marks	Guidance
(a)	Poisson	**B1**	SOI
	Mean = 3.6	**B1**	Can be awarded for N(3.6, …)
	$e^{-3.6}(1 + 3.6 + \frac{3.6^2}{2})$	**M1**	Allow any λ Allow one end error Expression must be seen
	0.303 (3 s.f.)	**A1**	If M0 awarded allow SC B1 for 0.303 SC Use of binomial: B1 for answer 0.300 (3 sf)
		4	
(b)	[Binomial with] 200 > 50	**B1**	
	[200 × 0.018 =] 3.6 < 5 or [p =] 0.018 < 0.1	**B1**	If B0 B0 then SC n large, p small: B1 or n large $np < 5$: B1 or $n > 50$ and either $np < 5$ or $p < 0.1$: B1
		2	

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4. 9709_s22_ms_62 Q: 7

Question	Answer	Marks	Guidance
	$\bar{X} \sim N(2.9, \frac{2.9}{100})$ OR Totals method N(290, 290)	B1	B1 for N(2.9, …) OR N(290, …)
		B1	B1 for Var = $\frac{2.9}{100}$ OR for var = 290 SOI
	$\frac{2.88-2.90}{\sqrt{\frac{2.9}{100}}}$ [= –0.1174] OR $\frac{288-290}{\sqrt{290}}$	M1	Standardising with *their* values Allow without –ve sign AND/OR with incorrect continuity correction No mixed methods
	1– Φ('0.1174')	M1	For area consistent with *their* values
	0.453 (3 sf)	A1	As final answer
	Alternative method for question 7		
	$\bar{X} \sim N(2.9, \frac{2.9}{100})$ OR Totals method N(290, 290)	B1	B1 for N(2.9, …) OR N(290, …)
		B1	B1 for Var = $\frac{2.9}{100}$ OR Var = 290 stated or implied
	$\frac{(2.88-\frac{1}{200})-2.90}{\sqrt{\frac{2.9}{100}}}$ [= –0.1468] OR (287.5 – 290)/√290	M1	Standardising with *their* values Allow without –ve sign AND/OR with incorrect continuity correction No mixed methods
	1 – ϕ('0.1468')	M1	For area consistent with *their* values
	0.442 (3 sf)	A1	As final answer
		5	

5. 9709_s22_ms_63 Q: 5

Question	Answer	Marks	Guidance
(a)	$\lambda = 6.6$	B1	
	$e^{-6.6} \times \frac{6.6^6}{6!}$	M1	Any λ
	0.156 (3 s.f.)	A1	If M0 awarded SC B1 for 0.156
		3	
(b)	$1 - e^{-2.2}(1 + 2.2 + \frac{2.2^2}{2} + \frac{2.2^3}{3!} + \frac{2.2^4}{4!})$	M1	Allow one end error. Need 1 – … Any λ
	0.0725 (3 s.f.)	A1	If M0 awarded SC B1 for 0.0725
		2	

Question	Answer	Marks	Guidance
(c)	N(26.4, 26.4)	B1	Give at early stage 2.2 × 12
	$\frac{19.5-'26.4'}{\sqrt{'26.4'}}$ [= –1.343]	M1	Standardising with *their* values. Allow wrong or no continuity correction
	ϕ('–1.343') = 1 – ϕ('1.343')	M1	Area consistent with *their* working
	0.0897 or 0.0896 (3 s.f.)	A1	
		4	

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6. 9709_m21_ms_62 Q: 4

Question	Answer	Marks	Guidance
(a)	B(1000, $\frac{1}{400}$)	**B1**	Accept Bin and $n = 1000$, $p = \frac{1}{400}$.
		1	
(b)	Po(2.5)	**B2**	B1 for Po. B1 for $\lambda = 2.5$.
		2	
(c)(i)	$e^{-2.5} \times \frac{2.5^4}{4!}$	**M1**	FT *their* **(b)** for Normal must have a continuity correction. Allow any λ
	0.134 (3 sf)	**A1**	CWO
		2	
(c)(ii)	$e^{-2.5}(\frac{2.5^2}{2!} + \frac{2.5^3}{3!} + \frac{2.5^4}{4!})$	**M1**	FT *their* **(b)** for Normal must have a continuity correction. Allow with one term extra or omitted or wrong. Allow any λ.
	0.604 (3 sf)	**A1**	CWO
		2	
(d)	$\lambda = 2.5 \times 0.7$ or $\lambda = 700 \times \frac{1}{400}$ [= 1.75]	**M1**	Must see λ or use of Poisson.
	$1 - e^{-1.75}$	**M1**	Allow any λ. Allow 1 – P(0,1).
	0.826	**A1**	**SC B1** Use of B(700,0.0025) leading to 0.826.
		3	

7. 9709_s21_ms_61 Q: 1

Question	Answer	Marks	Guidance
	$\lambda = (3.1 + 1.7) \times 2$	M1	Attempt combined mean. Allow 3.1 + 1.7 for M1
	= 9.6	A1	Correct mean
	$1 - e^{-9.6}(1 + 9.6 + \frac{9.6^2}{2} + \frac{9.6^3}{3!})$	M1	Allow incorrect mean. Allow one end error.
	= 0.986 (3 sf)	A1	**SC** If 9.6 seen and unsupported 0.986 M1A1B1. **SC** Unsupported correct answer of 0.986 only if 9.6 also not seen scores B2 only.
		4	

8. 9709_s21_ms_61 Q: 5

Question	Answer	Marks	Guidance
(a)	$\text{Po}\left(\frac{2}{15}\right)$	M1	SOI. Allow Po(0.133).
	$P(X \geqslant 1) = 1 - e^{-\frac{2}{15}}$	M1	Allow incorrect λ allow one end error
	= 0.125 (3 sf)	A1	**SC** Partially unsupported final answer: $\text{Po}\left(\frac{2}{15}\right)$ stated B1 then unsupported 0.125 B1 **SC** Use of Binomial (0.1248) B1 only Use of Normal scores M0
		3	

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Question	Answer	Marks	Guidance
(b)	$\lambda = \frac{n}{75000}$	B1	
	$e^{-\frac{n}{75000}} > 0.9$	M1	Allow '=' Allow incorrect λ
	$-\frac{n}{75000} > \ln 0.9 \quad [n < 7902.04]$	M1	Attempt ln both sides
	Largest value of n is 7902	A1	CWO. Must be an integer.
	Alternative method for Question 5(b)		
	$e^{-\mu} > 0.9$	M1	Allow '='
	$-\mu > \ln 0.9 \quad [\mu < 0.10536]$	M1	Attempt ln both sides
	$n = \mu \times 75000$	B1	
	Largest value of n is 7902	A1	CWO. Must be an integer.
	Alternative method for Question 5(b)		
	$\frac{74999}{75000}$	B1	
	$\left(\frac{74999}{75000}\right)^n > 0.9$	M1	
	$n\ln\frac{74999}{75000} > \ln 0.9$	M1	Attempt ln or log both sides
	Largest value of n is 7901	A1	CWO Must be an integer
		4	

9. 9709_s21_ms_62 Q: 7

Question	Answer	Marks	Guidance
(a)	$e^{-4.2} \times \frac{4.2^4}{4!}$	M1	P(4), allow any λ
	0.194 (3 sf)	A1	As final answer. **SC** Unsupported correct answer scores B1 only.
		2	
(b)	$1 - e^{-8.4}\left(1 + 8.4 + \frac{8.4^2}{2} + \frac{8.4^3}{3!}\right)$	M1	Allow M1 with incorrect λ. Accept one end error.
	0.968 (3 sf)	A1	As final answer. **SC** Unsupported correct answer scores B1 only.
		2	
(c)	N(50.4, 50.4)	M1	SOI
	$\frac{39.5 - 50.4}{\sqrt{50.4}}$ [= –1.535]	M1	Allow wrong or no continuity correction. Must have √
	Φ('–1.535') = 1 – Φ('1.535')	M1	For correct probability area consistent with *their* working.
	0.0624 (3 sf) or 0.0623	A1	
		4	

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10. 9709_s21_ms_63 Q: 1

Question	Answer	Marks	Guidance
	$\lambda = 10 \times 1.36$ [= 13.6]	**M1**	
	E(amount) = 5×13.6 = [$]68	**A1**	
	Var(amount) = $5^2 \times 13.6$ [= 340]	**M1**	$5^2 \times \ldots$
		M1	$\ldots \times$ *their* λ
	Standard Deviation = [$]18.4(4) (3 s.f.)	**A1**	CAO condone $2\sqrt{85}$
		5	

11. 9709_s21_ms_63 Q: 5

Question	Answer	Marks	Guidance
(a)	Po(2.5)	**B1**	Accept Poisson with mean = 2.5 not just np = 2.5
	n = 25 000 > 50 and np (or λ) = 2.5 which is < 5 or n = 25 000 > 50 and p = 0.0001 < 0.1	**B1**	Must see 2.5 (or 0.0001) and 25000 OE, not just $np < 5$ (or $p < 0.1$) and $n > 50$
		2	
(b)	$e^{-2.5}(1 + 2.5 + \frac{2.5^2}{2} + \frac{2.5^3}{3!})$	**M1**	Any λ, accept one end error. FT binomial from part **(a)** scores M1 only for equivalent binomial expressions FT normal from part **(a)** must use correct continuity correction and tables scores M1 only for complete method
	0.758 (3 sf)	**A1**	Unsupported answer of 0.758 scores B1 instead of M1A1
		2	
(c)	$e^{-2.5} \times \frac{2.5^k}{(k)!} = 2e^{-2.5} \times \frac{2.5^{k+1}}{(k+1)!}$	**M1**	Any λ FT binomial from **(a)** scores M1 only for equivalent binomial expression FT from **(a)** normal for equivalent expressions continuity correction must be included
	$k = 4$	**A1**	No errors seen **SC** $k = 4$ unsupported scores B1 only, but see full Poisson expressions for P(4) and P(5) and 0.134 scores M1A1
		2	

Question	Answer	Marks	Guidance
(d)	$1 - e^{-\lambda} = 0.963$	**M1**	Accept *their* attempt at λ
	$\lambda = -\ln 0.037$ (= 3.2968 or 3.30 or 3.3)	**M1**	Correct use of lns
	n = 33 000 (3 sf)	**A1**	Allow n = 32 950 to 33 050 (must be an integer) **SC** use of binomial leading to 32 967 scores B1 for $(0.9999)^n = 0.037$ B1 for 33 000 to 3sf (32 967)
		3	

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12. 9709_w21_ms_61 Q: 2

Question	Answer	Marks	Guidance
	N(45.2, 45.2)	**B1**	SOI
	$\frac{60.5-45.2}{\sqrt{45.2}}$ [= 2.276]	**M1**	Allow with wrong or no continuity correction.
	1 –Φ('2.276')	**M1**	
	0.0114	**A1**	
		4	

13. 9709_w21_ms_62 Q: 5

Question	Answer	Marks	Guidance
(a)	$e^{-2}(1 + 2 + \frac{2^2}{2!})$	**M1**	P($X < 3$) any λ. Allow one end error.
	0.677 (3sf)	**A1**	Unsupported correct answer scores SC **B1** only.
		2	
(b)	N(40, 40)	**M1**	SOI
	$\frac{50.5-40}{\sqrt{40}}$ [= 1.660]	**M1**	For standardising with *their* values. Allow with wrong or no cc must have square root.
	P($z >$ '1.660') = 1 – Φ('1.660')	**M1**	Correct area consistent with *their* working.
	0.0485 or 0.0484 (3sf)	**A1**	
		4	
(c)	$\lambda = 10$	**B1**	Condone mean = 10.
	$e^{-10}\left(\frac{10^8}{8!}+\frac{10^9}{9!}+\frac{10^{10}}{10!}+\frac{10^{11}}{11!}\right)$	**M1**	Allow any λ (allow one end error).
	0.477 (3sf)	**A1**	Unsupported correct answer scores SC **B2** only.
		3	

14. 9709_w21_ms_63 Q: 2

Question	Answer	Marks	Guidance
	N(45.2, 45.2)	**B1**	SOI
	$\frac{60.5-45.2}{\sqrt{45.2}}$ [= 2.276]	**M1**	Allow with wrong or no continuity correction.
	1 –Φ('2.276')	**M1**	
	0.0114	**A1**	
		4	

15. 9709_m20_ms_62 Q: 1

Question	Answer	Marks	Guidance
	($\lambda =$) $\frac{5}{12}$ = 0.417 or better	**B1**	
	$1 - e^{-\frac{5}{12}}(1 + \frac{5}{12})$	**M1**	1 – P(X = 0 or 1), by Poisson, using any λ, allow 1 – P(X = 0 or 1 or 2) for M1
	= 0.0661 or 0.0662 (3 sf)	**A1**	Final answer **SC** use of Binomial (from 0.06607…) B1 only
		3	

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16. 9709_m20_ms_62 Q: 4

Question	Answer	Marks	Guidance
(a)	λ (= 0.4 × 365 ÷ 50) = 2.92	**B1**	
	$e^{-2.92}(1 + 2.92 + \frac{2.92^2}{2})$	**M1**	Any λ. Allow one end error
	= 0.441 (3 sf)	**A1**	
		3	
(b)	$e^{-\lambda} > 0.95$	**M1**	Allow '=' throughout
	$-\lambda > \ln 0.95$ or $\lambda < 0.051293$ OE	**M1**	Attempt ln both sides
	'0.051293' × 50 ÷ 0.4 (= 6.411)	**M1**	
	Largest n is 6 (3 sf) Allow $n = 6$ or $n \leqslant 6$ (NOT $n < 6$ or $n \geqslant 6$ as final answer)	**A1**	**SC** Trial and Improvement M1 for $e^{-\lambda} > 0.95$ SOI; M1 for $\lambda = n \times \frac{0.4}{50}$; M1 for use of both $n = 6$ giving 0.9531 and $n = 7$ giving 0.9455; A1 $n = 6$
		4	

17. 9709_s20_ms_61 Q: 5

Question	Answer	Marks
(a)(i)	$e^{-2.9} \times \frac{2.9^4}{4!}$	**M1**
	0.162 (3 sf)	**A1**
		2
(a)(ii)	$e^{-2.1} \times \frac{2.1^4}{4!} \times e^{-0.8} + e^{-2.1} \times \frac{2.1^3}{3!} \times e^{-0.8} \times 0.8$	**B1**
	(**B1** for either expression correct, **M1** for P(4, 0) + P(3, 1))	**M1**
	0.113 (3 sf)	**A1**
		3
(b)	N(29, 29)	**M1**
	$\frac{24.5 - 29}{\sqrt{29}} (= -0.83563)$	**M1**
	1 – Φ("0.836")	**M1**
	0.202 (3sf)	**A1**
		4
(c)	29 is large or 29 > 15	**B1**
		1

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18. 9709_s20_ms_62 Q: 3

Question	Answer	Marks
(a)(i)	B(3600, 0.0012)	**B1**
		1
(a)(ii)	Po(4.32) (**B1** for Po. **B1** for $\lambda = 4.32$)	**B2**
	$n = 3600$ which is large, $p = 0.12$ which is small and $np = 4.32$ which is < 5	**B1**
		3
(a)(iii)	$1 - e^{-4.32}\left(1 + 4.32 + \frac{4.32^2}{2}\right)$	**M1**
	0.805 (3 sf)	**A1**
		2
(b)	$e^{-\lambda} > 0.1$	**M1**
	$(-\lambda > \ln 0.1)$ $(\lambda < \ln 10)$ $0.0012n < \ln 10$	**A1**
	$(n < 1918.8)$ largest n is 1918	**A1**
		3

19. 9709_s20_ms_62 Q: 5

Question	Answer	Marks
(a)(i)	0, 1, 2, 3, ...	**B1**
		1
(a)(ii)	3	**B1**
		1
(a)(iii)	$e^{-3}\left(\frac{3^4}{4!} + \frac{3^5}{5!} + \frac{3^6}{6!}\right)$	**M1**
	0.319 (3 sf)	**A1**
		2
(b)	$\Phi^{-1}(0.0668)$ $(= -1.500)$	**M1**
	$N(\mu, \mu)$	**M1**
	$\frac{45.5 - \mu}{\sqrt{\mu}} =$ "-1.500"	**M1**
	$\mu -$ "1.500" $\sqrt{\mu} - 45.5 = 0$ $\sqrt{\mu} = \frac{"1.5" \pm \sqrt{("-1.5")^2 + 4 \times 45.5}}{2} (= 7.5369)$	**M1**
	$\mu = 56.8$ (3 sf)	**A1**
		5

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20. 9709_s20_ms_63 Q: 4

Question	Answer	Marks
(a)	$\lambda = 3$	B1
	$e^{-3}(1+3)$	M1
	= 0.199 (3 sf)	A1
		3

Question	Answer	Marks
(b)	$P(A_1 = 1 \text{ and } A_1 + A_2 < 2) = P(A_1 = 1) \times P(A_2 = 0)$	M1
	$e^{-1.5} \times 1.5 \times e^{-1.5} = 0.0747$	A1
	$P(A_1 = 1 \mid A_1 + A_2 < 2) = \frac{P(A1 = 1 \text{ and } A1 + A2 < 2)}{P(A1 + A2 < 2)}$ $= \frac{1.5 \times \left(e^{-1.5}\right)^2}{4e^{-3}} = \frac{'0.0747'}{'0.199'}$	M1
	$\frac{3}{8}$ or 0.375 (3 sf)	A1
		4
(c)	Takes negative values	B1
		1

21. 9709_w20_ms_61 Q: 1

Question	Answer	Marks	Guidance
(a)	$\text{Po}\left(\frac{2}{3}\right)$	B1	Poisson with correct mean stated (to at least 3 sf) or implied in working.
	$1 - e^{-\frac{2}{3}}\left(1 + \frac{2}{3}\right)$	M1	1 – P(X = 0 or 1); allow incorrect λ; allow one end error
	= 0.144 (3 sf)	A1	**SC** B1 for use of binomial or no working shown leading to correct final answer.
		3	
(b)	$n > 50$ and $np = \frac{2}{3} < 5$ **or** $n > 50$ and $p = \frac{1}{300} < 0.1$	B1	Accept p or np clearly stated in part **(a)**. Do not accept n is large and p is small.
		3	
(c)	$\text{Po}\left(\frac{11}{3}\right)$	B1	Poisson with correct mean stated (to at least 3sf) or implied in working.
	$e^{-\frac{11}{3}}\left(1 + \frac{11}{3} + \frac{\left(\frac{11}{3}\right)^2}{2!} + \frac{\left(\frac{11}{3}\right)^3}{3!}\right)$	M1	P(X = 0, 1, 2, 3); allow incorrect λ; allow one end error. Must not be multiplied by any additional values.
	= 0.501 (3 sf)	A1	As final answer.
		3	

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22. 9709_w20_ms_62 Q: 1

Question	Answer	Marks	Guidance
	Poisson, any λ	**M1**	Used
	$1-e^{-3}\left(1+3+\frac{3^2}{2}\right)$	**M1**	Allow one end error
	= 0.577 (3sf)	**A1**	**SC** Use of Binomial (or unsupported correct answer) scores B1 only
		3	

23. 9709_w20_ms_62 Q: 5

Question	Answer	Marks	Guidance
(a)	Customers arrive independently or singly or at random	**B1**	Any one of these in context
		1	
(b)	$e^{-2.3}\times\frac{2.3^3}{3!}$	**M1**	Attempt correct expression seen
	= 0.203 (3sf)	**A1**	
		2	
(c)	Po(4.6)	**B1**	SOI
	$1-e^{-4.6}\left(1+4.6+\frac{4.6^2}{2!}+\frac{4.6^3}{3!}\right)$	**M1**	Correct expression, with any λ, allow one end error
	= 0.674 (3sf)	**A1**	As final answer.
		3	
(d)	P(none arrive) = $e^{-2.3}$ (= 0.10026)	**M1**	Must be clearly *their* P(none arrive)
	${}^5C_2(e^{-2.3})^2(1-e^{-2.3})^3$	**M1**	FT *their* $e^{-2.3}$
	= 0.0732 or 0.0733 (3sf)	**A1**	
		3	

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24. 9709_w20_ms_63 Q: 1

Question	Answer	Marks	Guidance
(a)	$\text{Po}\left(\frac{2}{3}\right)$	**B1**	Poisson with correct mean stated (to at least 3 sf) or implied in working.
	$1-\text{e}^{-\frac{2}{3}}\left(1+\frac{2}{3}\right)$	**M1**	$1 - \text{P}(X = 0 \text{ or } 1)$; allow incorrect λ; allow one end error
	= 0.144 (3 sf)	**A1**	**SC** B1 for use of binomial or no working shown leading to correct final answer.
		3	
(b)	$n > 50$ and $np = \frac{2}{3} < 5$ **or** $n > 50$ and $p = \frac{1}{300} < 0.1$	**B1**	Accept p or np clearly stated in part **(a)**. Do not accept n is large and p is small.
		3	
(c)	$\text{Po}\left(\frac{11}{3}\right)$	**B1**	Poisson with correct mean stated (to at least 3sf) or implied in working.
	$\text{e}^{-\frac{11}{3}}\left(1+\frac{11}{3}+\frac{\left(\frac{11}{3}\right)^2}{2!}+\frac{\left(\frac{11}{3}\right)^3}{3!}\right)$	**M1**	$\text{P}(X = 0, 1, 2, 3)$; allow incorrect λ; allow one end error. Must not be multiplied by any additional values.
	= 0.501 (3 sf)	**A1**	As final answer.
		3	

25. 9709_m19_ms_72 Q: 5

Question	Answer	Marks	Guidance
(i)	$1 - \text{e}^{-1.8}(1 + 1.8)$	**M1**	Accept any λ. Accept 1–P(0,1,2)
	= 0.537 (3 sf)	**A1**	
		2	
(ii)	$\lambda = 2.2$	**B1**	
	$\text{e}^{-2.2}(1 + 2.2 + \frac{2.2^2}{2!} + \frac{2.2^3}{3!} + \frac{2.2^4}{4!})$	**M1**	Attempt expr'n for $\text{P}(X \leqslant 4)$,allow one end error, allow any λ
	= 0.928 (3 sf) or 0.927	**A1**	
		3	

Question	Answer	Marks	Guidance
(iii)	$1 - e^{-1.8t} \geqslant 0.99$ or $1 - e^{-\lambda} \geqslant 0.99$	**M1**	Condone = signs/incorrect inequality signs
	$e^{-1.8t} \leqslant 0.01$ or $e^{-\lambda} \leqslant 0.01$ $-1.8t \leqslant \ln 0.01$	**M1**	Valid attempt take logs (must have single term on each side)
	$t \geqslant 2.56$ She must watch for at least 2.56 (hours)	**A1**	or 2 hours, 34 mins or better. No errors seen
		3	

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26. 9709_s19_ms_71 Q: 5

Question	Answer	Marks	Guidance
(a)(i)	$e^{-2.3}(\frac{2.3^2}{2}+\frac{2.3^3}{3!}+\frac{2.3^4}{4!}$	**M1**	Allow one end error
	= 0.585	**A1**	
		2	
(a)(ii)	$(\lambda) = 4.6$	**B1**	
	$1 - e^{-4.6}(1 + 4.6 + \frac{4.6^2}{2})$	**M1**	any λ, Allow one end error
	= 0.837 (3 sf)	**A1**	
		3	
(a)(iii)	$S \sim N(115, 115)$	**B1**	May be implied
	$\frac{110.5-115}{\sqrt{115}}$ (= –0.420)	**M1**	Allow with wrong or no cc OR no √
	1 – Φ('0.420') (= 1 – 0.663)	**M1**	
	= 0.337	**A1**	Accept alternative method using N(2.3, 2.3) no mixed methods.
		4	
(b)	$e^{-\lambda} \times \frac{\lambda^3}{3!} = e^{-\lambda} \times \frac{\lambda^5}{5!}$	**M1**	
	$\lambda^3 = \frac{\lambda^5}{4\times5}$ or $\lambda^2 = 20$ oe	**A1**	any correct simplification without $e^{-\lambda}$ or !
	$\lambda = \sqrt{20}$ or $2\sqrt{5}$ or 4.47 (3 sf)	**A1**	
		3	

27. 9709_s19_ms_72 Q: 1

Question	Answer	Marks	Guidance
(i)	0.0842 (3 sf)	**B1**	
		1	
(ii)	$e^{-5} \times \frac{5^n}{n!} = e^{-5} \times \frac{5^{n+1}}{(n+1)!}$	**B1**	or $\frac{5^n}{n!} = \frac{5^{n+1}}{(n+1)!}$ or better ISW
		1	
(iii)	$1=\frac{5}{n+1}$ $n = 4$	**B1**	
		1	

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28. 9709_s19_ms_73 Q: 7

Question	Answer	Marks	Guidance
(i)	Use of Po(2.8)	**M1**	May be implied
	$1 - e^{-2.8}(1 + 2.8 + \frac{2.8^2}{2})$)	**M1**	Any λ allowing one end error
	= 0.531or 0.53(0) (3 sf)	**A1**	SC Binomial 0.534 B1
		3	
(ii)	Use of Po(5.8)	**M1**	May be implied
	$e^{-5.8} \times \frac{5.8^6}{6!}$	**M1**	Any λ
	= 0.16(0) (3 sf)	**A1**	
		3	

Question	Answer	Marks	Guidance
(iii)	Use of N(58, 58)	**M1**	May be implied or N(58, 55.38)
	$\frac{50.5 - '58'}{\sqrt{'58'}}$ (= -0.985)	**M1**	Standardised with their values, allow wrong or incorrect cc
	Φ('0.985')	**M1**	Correct area consistent with their working or Φ("1.008")
	= 0.838 (3 sf)	**A1**	or 0.843
		4	

29. 9709_w19_ms_72 Q: 1

Question	Answer	Marks	Guidance
(i)	Binomial	**B1**	
	$n = 500$ **and** $p = \frac{1}{150}$ or 0.00667	**B1**	Or $B\left(500, \frac{1}{150}\right)$ for B1B1
		2	
(ii)	Poisson	**B1**	
	n large and mean = $\frac{10}{3}$ or 3.3 or better, which is < 5	**B1**	Accept $n > 50$
		2	
(iii)	$1 - e^{-\frac{10}{3}} \times \left(1 + \frac{10}{3} + \frac{\left(\frac{10}{3}\right)^2}{2}\right)$	**M1**	1-P(X = 0, 1, 2)
	= 1 – 0.353	**A1**	Correct expression with λ=3.3 or better
	= 0.647 (3 sf)	**A1**	**SC** Use of Binomial scores B1 for 0.648. Use of Normal scores B1 for 0.67(0) to 0.677
		3	

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30. 9709_w19_ms_73 Q: 2

Question	Answer	Marks	Guidance
(i)	$(\lambda(=2\times2.4)=4.8)$ $e^{-4.8}\left(1+4+\frac{4.8^2}{2}+\frac{4.8^3}{3!}\right)$	**M1**	Any λ
	0.294 (3 sf)	**A1**	
		2	
(ii)	$(\lambda(=60\times2.4)=144)$ N('144', '144')	**M1**	N and $\sigma^2=\mu$ SOI
	$\frac{139.5-'144'}{\sqrt{'144'}}(=-0.375)$	**M1**	Allow with no continuity correction
	ϕ('0.375')	**M1**	Correct area consistent with their working
	0.646 (3 sf)	**A1**	
		4	

31. 9709_w19_ms_73 Q: 5

Question	Answer	Marks	Guidance
(i)	Po(3)	**B1**	SOI
	$e^{-3}\left(\frac{3^3}{3!}+\frac{3^4}{4!}+\frac{3^5}{5!}\right)$	**M1**	Allow one or two extra terms (2 or 6 or both)
	0.493 (3 sf)	**A1**	
		3	
(ii)	A correct equation from $P(0)=P(2)$ $\left(\text{leading to } 1=\frac{\lambda^2}{2}\right)$	**M1**	
	$\lambda=\sqrt{2}$ or 1.41 (3 sf)	**A1**	CWO
		2	

Question	Answer	Marks	Guidance
(iii)(a)	Correct inequality $\left(\text{leading to } \frac{5.2^n}{n!}<\frac{5.2^{n+1}}{(n+1)!}\right)$	**B1**	
		1	
(iii)(b)	$n+1<5.2$ or $1<\frac{5.2}{n+1}$	**M1**	Simplify to a stage without exponentials, powers or factorials.
	Largest n is 4	**A1**	
		2	

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32. 9709_m18_ms_72 Q: 2

Question	Answer	Marks	Guidance
	$\lambda = 98.4$	**B1**	
	N(98.4, 98.4) seen or implied	**B1**	
	$\frac{90.5-"98.4"}{\sqrt{"98.4"}}$ (= –0.796)	**M1**	allow with wrong or no cc. No sd/var mix.
	$\phi("0.796")$	**M1**	Correct area consistent with working
	= 0.787 (3 sf)	**A1**	
		5	

33. 9709_s18_ms_71 Q: 3

Question	Answer	Marks	Guidance
	N(153, 153)	**B1**	Seen or implied
	$\frac{139.5-153}{\sqrt{"153"}}$ (= –1.091)	**M1**	Allow with wrong or no cc
	$\phi("-1.091") = 1 - \phi("1.091")$	**M1**	For area consistent with their working
	= 0.138 (3 sf)	**A1**	
		4	

34. 9709_s18_ms_72 Q: 1

Question	Answer	Marks	Guidance
	$\lambda = 4.4$	**B1**	
	$P(X<4) = e^{-4.4}(1 + 4.4 + \frac{4.4^2}{2} + \frac{4.4^3}{3!})$	**M1**	Allow any λ allow one end error
	= 0.359	**A1**	
		3	

35. 9709_s18_ms_72 Q: 6

Question	Answer	Marks	Guidance
(i)	Accidents occur independently or randomly	**B1**	In context. Allow 'singly'.
		1	
(ii)	$e^{-2.5} \times \frac{2.5^4}{4!}$	**M1**	Poisson P(4), allow any λ
	= 0.134 (3 sfs)	**A1**	
		2	

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Question	Answer	Marks	Guidance
(iii)	$\lambda = \frac{25}{12}$ or 2.08(333)	**B1**	
	$1 - e^{\frac{-25}{12}}(1 + \frac{25}{12} + \frac{\frac{25}{12}^2}{2!} + \frac{\frac{25}{12}^3}{3!})$	**M1**	1 – Poisson P(0, 1, 2, 3), allow any λ allow one end error
	= 0.158 (3 sfs)	**A1**	As final answer
		3	
(iv)	$N(\frac{1825}{84}, \frac{1825}{84})$ or N(21.7(26), 21.7(26))	**B1**	Stated or implied
	$\frac{29.5-\frac{1825}{84}}{\sqrt{\frac{1825}{84}}}$	**M1**	Allow with wrong or no cc with their mean/sd
	Φ("1.668")	**M1**	Correct area consistent with their working
	= 0.952 (3 sfs)	**A1**	
		4	

36. 9709_s18_ms_73 Q: 1

Question	Answer	Marks	Guidance
(i)	Po(2.25)	**B1**	Stated or implied
	$e^{-2.25}(1 + 2.25 + \frac{2.25^2}{2})$	**M1**	Allow any λ, one end error
	= 0.609 (3 sf)	**A1**	SC B1 Use of B(75,0.03) leading to 0.608
		3	
(ii)	μ = 2.25, which is less than 5; n large	**B1**	Allow np<5 and n large or p<0.1 and n>50, no contradictions
		1	

37. 9709_s18_ms_73 Q: 4

Question	Answer	Marks	Guidance
(i)	No of males leaving (to do eng) each yr has const mean or Males leave (to do eng) indep of other males leaving (to do eng) or Males leave (to do eng) at random	**B1**	One of these or any equiv statement in context.
		1	
(ii)	$\lambda = 3.9$	**B1**	
	$1 - e^{-3.9}(1 + 3.9 + \frac{3.9^2}{2!} + \frac{3.9^3}{3!})$	**M1**	Any λ. Allow one end error or extra term.
	0.546753 or 0.547 (3 sf)	**A1**	
		3	
(iii)	$P(F = 0 \text{ and } M > 3) = e^{-0.8} \times \left[1 - e^{-3.1}\left(1 + 3.1 + \frac{3.1^2}{2!} + \frac{3.1^3}{3!}\right)\right]$ (= 0.16857)	**M1**	Attempt $P(F = 0) \times P(M > 3)$ allow one end error for $P(M > 3)$ provided $\lambda = 3.1$
	$\frac{P(F=0 \text{ and } M>3)}{P(M+F>3)}$ $\frac{"0.16857"}{"0.54675"}$	**M1**	Attempted, allow any probability/their **(ii)** provided the answer is <1
	= 0.308 (3 sf)	**A1**	
		3	

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38. 9709_w18_ms_71 Q: 4

Question	Answer	Marks	Guidance
(i)	$\lambda = 10\times0.25 + 10\times0.36 \quad (= 6.1)$	**B1**	
	$1 - e^{-6.1}\left(1 + 6.1 + \frac{6.1^2}{2} + \frac{6.1^3}{3!}\right)$	**M1**	$1 - P(X \leqslant 3)$, any λ Allow one end error
	$= 0.857$	**A1**	Allow 0.858
		3	
(ii)	$\lambda = 61$	**B1 ft**	Ft from (i)
	N('61', '61')	**M1**	N with $\mu = \lambda$, any λ. May be implied
	$\frac{59.5-61}{\sqrt{'61'}} \quad (= -0.192)$	**M1**	Standardise with their mean and variance Allow no or wrong cc. not 61/100
	$\Phi('-0.192') = 1 - \Phi('0.192')$	**M1**	Correct area consistent with their working
	$= 0.424$	**A1**	
		5	

39. 9709_w18_ms_72 Q: 1

Question	Answer	Marks	Guidance
	$e^{-2.3}\left(\frac{2.3^2}{2} + \frac{2.3^3}{3!} + \frac{2.3^4}{4!}\right)$	**M2**	M1 for one term wrong or one end error or 1 – P(2, 3, 4)
	= 0.585 (3 sf)	**A1**	
		3	

40. 9709_w18_ms_73 Q: 4

Question	Answer	Marks	Guidance
(i)	$\lambda = 10\times0.25 + 10\times0.36 \quad (= 6.1)$	**B1**	
	$1 - e^{-6.1}\left(1 + 6.1 + \frac{6.1^2}{2} + \frac{6.1^3}{3!}\right)$	**M1**	$1 - P(X \leqslant 3)$, any λ Allow one end error
	$= 0.857$	**A1**	Allow 0.858
		3	
(ii)	$\lambda = 61$	**B1 ft**	Ft from (i)
	N('61', '61')	**M1**	N with $\mu = \lambda$, any λ. May be implied
	$\frac{59.5-61}{\sqrt{'61'}} \quad (= -0.192)$	**M1**	Standardise with their mean and variance Allow no or wrong cc. not 61/100
	$\Phi('-0.192') = 1 - \Phi('0.192')$	**M1**	Correct area consistent with their working
	$= 0.424$	**A1**	
		5	

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41. 9709_m17_ms_72 Q: 7

Question	Answer	Marks	Guidance
(i)	Planes arrive at constant mean rate	**B1**	
	Planes arrive at random	**B1**	or Planes arrive independently Must be in context
	Total:	**2**	
(ii)(a)	($\lambda =$) $5.2 \div 4$	**M1**	
	$e^{-1.3}(\frac{1.3^2}{2} + \frac{1.3^3}{3!})$	**M1**	Allow any λ , allow one end error
	= 0.330 (3 sfs)	**A1**	Accept 0.33
	Total:	**3**	
(ii)(b)	$1 - e^{-3.467} \times (1 + 3.467 + \frac{3.467^2}{2!} + \frac{3.467^3}{3!})$	**M1**	Allow any λ except 5.2 or 1.3, allow one end error
	= 0.456 (3 sfs)	**A1**	
	Total:	**2**	
(iii)	N(52, 52) stated or implied	**B1**	
	$\frac{60.5-52}{\sqrt{52}}$ (= 1.179)	**M1**	ft their mean and var. Allow wrong or no cc or no √
	Φ("1.179")	**M1**	
	= 0.881 (3 sf)	**A1**	
	Total:	**4**	

42. 9709_s17_ms_71 Q: 1

Question	Answer	Marks	Guidance
(i)	Poisson with $\lambda = 0.2$	**B1**	
	$1 - e^{-0.2}(1 + 0.2 + \frac{0.2^2}{2})$	**M1**	1 – Poisson P(0, 1, 2, 3) attempted, any λ, allow one end error
	= 0.00115 (3 sf)	**A1**	SR: using Bin, ans 0.00115: **B1**
	Total:	**3**	
(ii)	n large ($n > 50$)	**B1**	
	$np = 0.2 < 5$ or p small	**B1**	
	Total:	**2**	

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43. 9709_s17_ms_72 Q: 2

Question	Answer	Marks	Guidance
(i)	E(X) = 4.197	B1	
	Var (X) = 4.196	B1	Both to 3dp or better
	Total:	4	
(ii)	E(X) ≈ Var(X)	B1	Condone =
(iii)	$e^{-4.1968}\left(1+4.1968+\frac{4.1968^2}{2}+\frac{4.1968^3}{3!}+\frac{4.1968^4}{4!}\right)$	M1	Any λ. Allow with one end error
	= 0.59(0) (3 sfs)	A1	Allow 0.591
	Total:	2	

44. 9709_s17_ms_72 Q: 6

Question	Answer	Marks	Guidance
(i)	$e^{-2.4}\times\frac{2.4^2}{2!}$	M1	Allow incorrect λ
	= 0.261 (3 sfs)	A1	
	Total:	2	
(ii)	N(60, 60)	B1	seen or implied
	$\frac{54.5-60}{\sqrt{60}}$ (= −0.710)	M1	allow with wrong or missing cc
	1− ϕ("−0.710") = ϕ("0.710")	M1	For area consistent with their working
	= 0.761 (3 sf)	A1	
	Total:	4	
(iii)	λ = 3.6 + 12 ÷ 7 (= 186/35) (= 5.314)	M1	
	$e^{-5.314}\left(1+5.314+\frac{5.314^2}{2}+\frac{5.314^3}{3!}\right)$	M1	Allow incorrect λ. Allow one end error.
	= 0.224 (3 sfs)	A1	
	Total:	3	

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45. 9709_s17_ms_73 Q: 5

Question	Answer	Marks	Guidance
(i)(a)	$X \sim N(42, 42)$	**B1**	stated or implied
	$\frac{39.5-"42"}{\sqrt{"42"}}$ (= −0.386)	**M1**	allow with wrong or no cc
	1 − ϕ ("−0.386") = ϕ ("0.386")	**M1**	correct area consistent with their working
	= 0.65(0) (3 sf)	**A1**	
	Total:	**4**	
(i)(b)	42 > (e.g. 15) or mean is large	**B1**	$\lambda > 15$ or higher, λ = large ignore subsequent work if not undermining what already written
	Total:	**1**	
(ii)(a)	$Y \sim Po(1.2)$	**B1**	stated or implied
	$1 - e^{-1.2}(1 + 1.2 + \frac{1.2^2}{2})$	**M1**	allow any λ allow one end error
	= 0.121 (3 sf)	**A1**	Using binomial: 0.119 SR **B1**
	Total:	**3**	
(ii)(b)	60 × 0.02 = 1.2 < 5 or mean is small	**B1FT**	or large n small p FT Poisson only
	Total:	**1**	

46. 9709_w17_ms_71 Q: 1

Question	Answer	Marks	Guidance
	$\frac{40.5-31}{\sqrt{31}}$ (= 1.706)	**M1**	standn correct but allow with no or incorrect cc
	1 – ϕ("1.706")	**M1**	indep correct area consistent with working
	= 0.0441 (3 sf) or 0.0440	**A1**	not 0.044
		3	

47. 9709_w17_ms_71 Q: 2

Question	Answer	Marks	Guidance
	Poisson	**B1**	seen or implied
	$\lambda = 4.03$	**B1**	seen or implied
	$e^{-4.03}(1 + 4.03 + \frac{4.03^2}{2!})$	**M1**	any λ; e.g. allow $\lambda = 4$ no extra or missing terms
	= 0.234 (3 sf)	**A1**	
		4	

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48. 9709_w17_ms_72 Q: 1

Question	Answer	Marks	Guidance
(a)(i)	Po(2.54)	M1	seen or implied Po(2540 × 0.001)
	$1 - e^{-2.54}(1 + 2.54)$	M1	any λ Allow 1 end error
	= 0.721 (3 sf)	A1	
		3	
(a)(ii)	n large and p small (or np (= 2.54) < 5)	B1	$n > 50$, $p < 0.1$
		1	
(b)	$\mu = 5.6$	B1	
	$\sigma = 2.37$ (3 sf)	B1	Accept $\sqrt{5.6}$
		2	

49. 9709_w17_ms_73 Q: 1

Question	Answer	Marks	Guidance
	$\frac{40.5-31}{\sqrt{31}}$ (= 1.706)	M1	standn correct but allow with no or incorrect cc
	1 – ϕ("1.706")	M1	indep correct area consistent with working
	= 0.0441 (3 sf) or 0.0440	A1	not 0.044
		3	

50. 9709_w17_ms_73 Q: 2

Question	Answer	Marks	Guidance
	Poisson	B1	seen or implied
	$\lambda = 4.03$	B1	seen or implied
	$e^{-4.03}(1 + 4.03 + \frac{4.03^2}{2!})$	M1	any λ; e.g. allow $\lambda = 4$ no extra or missing terms
	= 0.234 (3 sf)	A1	
		4	

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51. 9709_m16_ms_72 Q: 6

Q	Answer	Mark	Notes
(i)	$\lambda = 3.3 \times \frac{25}{30} = 2.75$	B1	
	$e^{-2.75}(1 + 2.75 + \frac{2.75^2}{2})$	M1	Allow any λ Allow one end error
	= 0.481 (3 sf)	A1 [3]	As final answer. Accept 0.482
(ii) (a)	$\lambda\ (= 3.3 \times \frac{365}{30}) = 40.15$	B1	Accept 40.1 or 40.2
	$(X \sim \text{Po}(40.15) \Rightarrow X \sim \text{N}(40.15, 40.15))$		
	$\frac{50.5-"40.15"}{\sqrt{"40.15"}}$ (= 1.633)	M1	Allow with incorrect or no cc OR no √ sign
	1 – Φ("1.633")	M1	For correct area consistent with their working
	= 0.0513 (3 sf)	A1 [4]	Accept 0.0512
(b)	$\lambda > 15$	B1 [1]	or similar
(iii)	$\lambda = \frac{73}{30}$ oe or 1.1+1.33= 2.43 (3 sf)	B1	
	$1 - e^{-2.43}(1 + 2.43 + \frac{2.43^2}{2} + \frac{2.43^3}{3!})$	M1	Allow any λ. Allow one end error
	= 0.228 (3 sf)	A1 [3]	

52. 9709_s16_ms_71 Q: 7

Q	Answer	Mark	Notes
(a) (i)	0.01 × 80 and 0.015 × 60	M1	$(1 - e^{-\lambda}) \times (1 - e^{-\mu})$ any λ, μ $(\lambda \neq \mu)$
	$(1 - e^{-0.8}) \times (1 - e^{-0.9})$	M1	allow one end error
	= 0.327 (3 sf)	A1 [3]	
(ii)	$\lambda = 0.02 \times 40 + 0.015 \times 60$	M1	or their 0.8 + 0.9
	$e^{-1.7} \times (1 + 1.7 + \frac{1.7^2}{2})$	M1	
	= 0.757 (3 sf)	A1 [3]	
(b)	$e^{-\lambda} \times \lambda = p$ and $e^{-\lambda} \times \frac{\lambda^2}{2} = 1.5p$	M1	or $e^{-\lambda} \times \frac{\lambda^2}{2} = 1.5 \times e^{-\lambda} \times \lambda$ seen or implied
	$\lambda = 3$	A1	
	$p = e^{-3} \times 3$	M1	their λ
	= 0.149 (3 sf)	A1 [4]	

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53. 9709_s16_ms_72 Q: 6

Q	Answer	Mark	Notes
(i)	$\lambda = 6.8$	B1	
	$e^{-6.8} \times \frac{6.8^5}{5!}$	M1	any λ
	= 0.135 (3 sf)	A1 [3]	
(ii) (a)	$e^{-3.4}(1 + 3.4 + \frac{3.4^2}{2} + \frac{3.4^3}{3!} + \frac{3.4^4}{4!})$	M1	any λ, allow one end-error
	= 0.744 (3 sf)	A1 [2]	
(b)	'0.744' + $e^{-3.4} \times \frac{3.4^5}{5!}$	M1	or complete method, any λ, allow one end-error
	= 0.87(0) (3 sf) or 0.871	A1 [2]	
(iii)	$P(X \leqslant 6)$ = '0.870' + $e^{-3.4} \times \frac{3.4^6}{6!}$	M1	or complete method, any λ
	= 0.94	A1	fully correct un-simplified expression or better
	Need 6 hair driers	A1 [3]	dep M1A1 with numerical justification (0.94 or better)

54. 9709_s16_ms_73 Q: 3

Q	Answer	Mark	Notes
(i)	Use of Poisson	B1	
	Mean = 2.4	B1	
	$1 - e^{-2.4}(1 + 2.4 + \frac{2.4^2}{2})$	M1	Allow any λ *(Allow one end error)*
	= 0.43(0) (3 sf)	A1 [4]	Final answer SR Use of binomial: B1 for ans 0.431 (3 sf)
(ii)	240 > 50 or n>50	B1	
	240 × 0.01 = 2.4 < 5 or np<5 or p<0.1	B1 [2]	SR *n* large, *p* small: B1

55. 9709_w16_ms_71 Q: 3

Q	Answer	Mark		Notes
(i)	$(\lambda) = 3.6 \div 3 = 1.2$	B1		1.2 seen
	$1 - e^{-1.2}\left(1 + 1.2 + \frac{1.2^2}{2} + \frac{1.2^3}{3!}\right)$	M1		Allow any λ
	= 0.0338 (3 sf)	A1	[3]	As final answer
(ii)	N(60 × 3.6, 60 × 3.6)	M1		Stated or implied
	$\frac{240.5 - '216'}{\sqrt{'216'}}$ (= 1.667)	M1		Allow with no or wrong cc (no sd/var mixes)
	1 – Φ('1.667')	M1		Area consistent with their working
	= 0.0478 (3 sf)	A1	[4]	SR use of Poisson 0.0497 scores 4/4

56. 9709_w16_ms_73 Q: 1

Q	Answer	Mark		Notes
	$e^{-3.5}(1 + 3.5 + \frac{3.5^2}{2!})$			
	= 0.321 (3 sf)	M2		Allow M1 if extra term $e^{-3.5} \times \frac{3.5^3}{3!}$ or " 1 - . " or omit P(0)
		A1	[3]	

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57. 9709_w16_ms_73 Q: 7

Q	Answer	Mark		Notes
(i)	$1 - e^{-1}(1 + 1)$ (= 0.26424) $1 - e^{-1.5}(1 + 1.5 + \frac{1.5^2}{2!})$ (= 0.19115)	B1 B1		B1 for either λ correct. B1 for either correct expression with correct λ
	'0.26424' × '0.19115'	M1		product of their values for ⩽ 2 and ⩽ 3 from Poisson, need correct form " 1 - .. " , but allow incorrect λ values and end errors
	= 0.0505 (3 sf)	A1	[4]	accept 0.0504

Q	Answer	Mark		Notes
(ii)	λ = 30 N(30, 30)	B1 B1√		seen or implied, need N(λ,λ)
	$\frac{35.5-30}{\sqrt{30}}$ (= 1.004)	M1		allow with wrong or no cc or no √
	Φ ('1.004')	M1		consistent with their working
	= 0.842 (3 sf)	A1	[5]	

58. 9709_s15_ms_71 Q: 6

Q	Answer	Mark		Notes
(i)	$e^{-\frac{10}{3}} \times \frac{\left(\frac{10}{3}\right)^2}{2}$	M1		P(2), allow any λ
	= 0.198 (3 sf)	A1	[2]	
(ii)	$1 - e^{-2}\left(1 + 2 + \frac{2^2}{2}\right)$	M1 M1		M1 allow any λ and/or 1end error Correct expression , correct λ
	= 0.323 (3 sf)	A1	[3]	
(iii)	$N\left(\frac{200}{3}, \frac{200}{3}\right)$	M1		seen or implied
	$\frac{49.5 - \frac{200}{3}}{\sqrt{\frac{200}{3}}}$ (= –2.102)	M1		For standardising allow either wrong or no cc No sd/var mix
	Φ('–2.102') = 1 – Φ('2.102') = 0.0178 (3 sf)	M1 A1	[4]	For finding area consistent with their working
		[Total: 9]		

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59. 9709_s15_ms_72 Q: 3

Q	Answer	Mark	Notes
	$\lambda = 5\times0.15$ (= 0.75) E(amount) = 200×0.75 = 150 Var(weekly no of hole–in–ones) = 0.75 Var(amount) = $200^2 \times 0.75$ = 30,000	M1 A1 B1√ M1 A1 5	 Allow 200^2 × their variance (with nothing added/subtracted at any stage) (SR probability table can score M1A0 srB1 if var rounds to 30,000 (2sf))
	Total	**5**	

60. 9709_s15_ms_72 Q: 7

Q	Answer	Mark	Notes
(i)	Poisson (Actually binomial with) $n > 50$ and np (or λ) (= 2.1) which is < 5	B1 B1 B1 3	 Allow without "binomial" Accept n large Accept p small (p < 0.1)
(ii)	$\lambda = 2.1$ $e^{-2.1}\left(1+2.1+\frac{2.1^2}{2}+\frac{2.1^3}{3!}\right)$ = 0.839 (3 sf)	B1 M1 A1 3	 Attempt P(0,1,2,3) any λ allow 1 end error SR_1 Ft Normal N(2.1,2.1) B1 standardising M1 0.833 A1 SR_2 Ft Binomial B(10500,0.0002) B1 calculating binomial prob P(0,1,2,3) M1 = 0.8386 A1
(iii)	$P(X \geqslant 1) = 1 - e^{-2.1}$ (= 0. 87754) $P(X = 1,2,3) = e^{-2.1}\left(2.1+\frac{2.1^2}{2}+\frac{2.1^3}{3!}\right)$ (= 0.71619) $\frac{P(X=1,2,3)}{P(X>1)}$ $\left(=\frac{0.71619}{0.87754}\right)$ = 0.816 (3 sf)	M1 M1 M1 A1 4	Any λ Or '0.839' – $e^{-2.1}$ Any λ Allow any attempted $\frac{P(X=1,2,3)}{P(X>1)}$ Any λ SR_1 Ft Normal P(>0.5)=0.86523 M1 P(1,2,3)=0.698 M1 0.698/0.86523 = 0.807 M1A1 SR_2 FT Binomial M1 M1 M1 A1
	Total	**10**	
	Total for paper	**50**	

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61. 9709_s15_ms_73 Q: 6

Q	Answer	Mark	Notes
(i)	$e^{-3.5} \times \frac{3.5^3}{3!}$	M1	P($X = 3$) any λ
	= 0.216 (3 sf)	A1 [2]	
(ii)	N(42, 42) stated or implied	B1	
	$\frac{29.5 - 42}{\sqrt{42}}$ (= –1.929)	M1	Allow with wrong or no cc OR without √
	P(z > '–1.929') = Φ('1.929') = 0.973 (3 sf)	M1 A1 [4]	For correct area consistent with their working
(iii)	(λ) = 2.4	B1	
	$1 - e^{-2.4}\left(1 + 2.4 + \frac{2.4^2}{2} + \frac{2.4^3}{3!}\right)$	M1 M1	for 1 – P($X \leqslant 3$), any λ allow one end error Correct expression any λ
	= 0.221 (3 sf)	A1 4	NB For combination method B1 attempting 10 combinations with λ=1, λ=1.4 M1 6 expressions M1 10 expressions 0.221 A1
		Total 10	

62. 9709_w15_ms_71 Q: 1

Q	Answer	Mark	Notes
	λ= (1.2 + 2.3) ÷ 2 = 1.75	**M1** **A1**	Attempt combined mean, allow 1.2 + 2.3 Correct mean
	$e^{-1.75}\left(\frac{1.75^2}{2} + \frac{1.75^3}{3!}\right)$	**M1**	Allow incorrect mean. Allow end errors (1 and/or 4)
	= 0.421 (3 sf)	**A1** [4]	
		Total: 4	

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63. 9709_w15_ms_71 Q: 5

Q	Answer	Mark	Notes	
(i)	Po(1.6) stated or implied	M1		
	$P(X > 3) = 1 - e^{-1.6}\left(1 + 1.6 + \frac{1.6^2}{2} + \frac{1.6^3}{3!}\right)$	M1	Allow M1 for 1 – P($X \leqslant 3$), incorrect λ and allow one end error	
	= 0.0788 (3 sf)	A1 [3]	SR Use of Bin scores B1 only for 0.0788	
(ii)	$\lambda = \frac{n}{2500}$	B1	or $e^{-\mu} < 0.05$ M1	or $\frac{2499}{2500}$ B1
	$e^{-\frac{n}{2500}} < 0.05$ Allow = Allow incorrect λ	M1		$\left(\frac{2499}{2500}\right)^n < 0.05$ M1
	$-\frac{n}{2500} < \ln 0.05$ Attempt ln bs	M1	$-\mu < \ln 0.05$ M1 ($\mu > 2.9957$)	$n \ln \frac{2499}{2500} < \ln 0.05$ M1
	$n > 7489.3$ (1 dp) Smallest $n = 7490$	A1 [4]	$n = \mu \times 2500$ B1 Smallest $n = 7490$ A1	Smallest $n = 7488$ A1
		Total: 7		

64. 9709_w15_ms_72 Q: 1

Q	Answer	Mark	Notes
	$\lambda = (1.2 + 2.3) \div 2$	M1	Attempt combined mean, allow 1.2 + 2.3
	= 1.75	A1	Correct mean
	$e^{-1.75}\left(\frac{1.75^2}{2} + \frac{1.75^3}{3!}\right)$	M1	Allow incorrect mean. Allow end errors (1 and/or 4)
	= 0.421 (3 sf)	A1 [4]	
		Total: 4	

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65. 9709_w15_ms_72 Q: 5

Q	Answer	Mark	Notes	
(i)	Po(1.6) stated or implied	M1		
	$P(X>3)=1-e^{-1.6}\left(1+1.6+\frac{1.6^2}{2}+\frac{1.6^3}{3!}\right)$	M1	Allow M1 for 1 – P($X \leqslant 3$), incorrect λ and allow one end error	
	= 0.0788 (3 sf)	A1 [3]	SR Use of Bin scores B1 only for 0.0788	
(ii)	$\lambda = \frac{n}{2500}$	B1	or $e^{-\mu} < 0.05$ M1	or $\frac{2499}{2500}$ B1
	$e^{-\frac{n}{2500}} < 0.05$ Allow = Allow incorrect λ	M1		$\left(\frac{2499}{2500}\right)^n < 0.05$ M1
	$-\frac{n}{2500} < \ln 0.05$ Attempt ln bs	M1	$-\mu < \ln 0.05$ M1 ($\mu > 2.9957$)	$n \ln \frac{2499}{2500} < \ln 0.05$ M1
	$n > 7489.3$ (1 dp) Smallest $n = 7490$	A1 [4]	$n = \mu \times 2500$ B1 Smallest $n = 7490$ A1	Smallest $n = 7488$ A1
		Total: 7		

66. 9709_w15_ms_73 Q: 2

Q	Answer	Mark		Notes
	($\Phi^{-1}(0.99) =$) 2.326 seen	B1		must be Φ^{-1}, not Φ
	N(λ, λ) seen or implied	M1		
	$\frac{55.5-\lambda}{\sqrt{\lambda}} =$ + "2.326"	M1		allow with wrong or no cc & Φ(0.99) (= 0.8389) must = " z " or attempt at z (0.99 / 0.01 M0)
	$\lambda +$ "2.326" $\sqrt{\lambda} - 55.5 = 0$			
	$\sqrt{\lambda} = \frac{-\text{"2.326"} \pm \sqrt{\text{"2.326"}^2 + 4 \times 55.5}}{2}$ (= 6.377.. or – 8.703..))	M1		for correct method of solving their quad in $\sqrt{\lambda}$ and squaring to find λ
	$\lambda = 40.7$ (3 sf)	A1	[5]	cao, one ans only Without cc, $\lambda = 40.2$: lose final A1
Total			**[5]**	

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67. 9709_m22_ms_62 Q: 5

Question	Answer	Marks	Guidance
(a)	Mean = 5×18.3 and Variance = 5×2.5^2 [= N(91.5, 31.25)]	B1	SOI
	$\frac{95-'91.5}{\sqrt{'31.25'}}$ [= 0.626]	M1	FT *their* mean and variance
	1 – Φ('0.626')	M1	For finding area consistent with *their* values
	0.266 (3 sf)	A1	
		4	
(b)	E(D) = 0	B1	Or E(D – 1) = –1
	Var(D) = $2.5^2 \times 2$ [= 12.5]	B1	
	$\frac{1-0}{\sqrt{'12.5'}}$ [= 0.283] or $\frac{-1-0}{\sqrt{'12.5'}}$ [= –0.283]	M1	FT *their* E and Var
	Φ('0.283') – (1 – ϕ(0.283)) [= 0.6115 – 0.3885]	M1	For finding area consistent with *their* values
	0.223 (3 sf)	A1	
		5	

68. 9709_s22_ms_61 Q: 3

Question	Answer	Marks	Guidance
	$D = X – (Y_1 + Y_2 + Y_3)$ OE E(D) = 6.2 -2.4 × 3 [= –1] OE	B1	Give at early stage
	Var(D) = 0.36 + 3 × 0.25 [= 1.11]	B1	Give at early stage
	$\frac{0-(-1)}{\sqrt{'1.11'}}$ [= 0.949]	M1	No standard deviation/variance mixes Var must come from a combination attempt
	1 – Φ('0.949')	M1	Area consistent with *their* values
	= 0.171 (3 s.f.)	A1	
		5	

69. 9709_s22_ms_61 Q: 4

Question	Answer	Marks	Guidance
(a)	$E(Y) = \frac{20}{4}[=5]$, $Var(Y) = 20\times\frac{1}{4}\times\frac{3}{4}\left[=\frac{15}{4}\right]$	B1	Both OE, SOI
	Var(X) = 2	B1	SOI or standard deviation = $\sqrt{2}$
	E($X – 3Y$) = –13	B1	
	Var($X – 3Y$) = 2 + 9 × '$\frac{15}{4}$' [= 35.75]	M1	Correct formula using *their* values
	Standard deviation of ($X – 3Y$) = 5.98 (3 s.f.) or $\frac{1}{2}\sqrt{143}$	A1	CWO
		5	

Question	Answer	Marks	Guidance
(b)	(0, 0) and (1, 15)	M1	
	$e^{-2} \times (\frac{3}{4})^{20} + e^{-2} \times 2 \times {}^{20}C_{15}(\frac{3}{4})^5 (\frac{1}{4})^{15}$	M1	
	0.000430 (3 sf)	A1	CWO (must have evidence of addition) Allow 0.00043 or $4.3(0) \times 10^{-4}$
		3	

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70. 9709_s22_ms_62 Q: 6

Question	Answer	Marks	Guidance
(a)	$E(D) = 53 - (4 \times 14) = -3$	**B1**	OE Give at early stage
	$Var(D) = 11 + 4^2 \times 3$ [= 59]	**B1**	or $\sqrt{(11 + 4^2 \times 3)}$ (= 7.68 (3 s.f.)) Give at early stage
	$\frac{0-(-3)}{\sqrt{59}}$ [= 0.391]	**M1**	For standardising with *their* values (var must be from a combination attempt) Ignore continuity correction attempts
	1 – Φ('0.391')	**M1**	For area consistent with *their* values
	0.348 (3 s.f.)	**A1**	As final answer
		5	
(b)	$E(T) = 12 \times 53 + 25 \times 14$ [= 986]	**B1**	Give at early stage (N.B. accept $E(T - 1000) = -14$)
	$Var(T) = 12 \times 11 + 25 \times 3$ [= 207]	**B1**	Or $\sqrt{(12 \times 11 + 25 \times 3)}$ (= 14.4 (3sf)) Give at early stage
	$\frac{1000-986}{\sqrt{207}}$ [= 0.973]	**M1**	For standardising with *their* values (var must be from a combination attempt) Ignore continuity correction attempts
	Φ('0.973')	**M1**	For area consistent with *their* values
	0.835 (3 sf)	**A1**	As final answer
		5	

71. 9709_s22_ms_63 Q: 1

Question	Answer	Marks	Guidance
	$\frac{1300 + \frac{1}{200} - 1250}{\frac{480}{10}}$ or $\frac{1300-1250}{\frac{480}{10}}$ [= 1.042]	**M1**	Allow with incorrect or omitted continuity correction Must have 10 Accept totals method
	1 – Φ('1.042')	**M1**	For area consistent with *their* values
	0.149 (3 s.f.)	**A1**	
		3	

72. 9709_s22_ms_63 Q: 4

Question	Answer	Marks	Guidance
(a)	$T \sim N(515, 74)$	**B1**	B1 for N(515, ..) give at early stage
		B1	B1 for Var = 45 + 25 + 4 = 74 give at early stage
	$\frac{500-'515'}{\sqrt{'74'}}$ [= –1.744]	**M1**	Standardise with *their* values. No standard deviation/variance mix Need combination for variance. Allow continuity correction.
	Φ('1.744')	**M1**	Area consistent with *their* working
	0.959 or 0.96[0] (3 s.f.)	**A1**	
		5	

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Question	Answer	Marks	Guidance
(b)	E(S – 1.4R) = 300-1.4x200 =20	**B1**	Give at early stage
	Var(S – 1.4R) = 45 + 1.4^2×25 = 94	**B1**	Give at early stage SC: if B0B0 awarded allow SC B1 for 14 and 105.84
	$\frac{0-(20)}{\sqrt{'94'}}$ [= –2.063]	**M1**	Standardise with *their* values. No standard deviation/variance mix. Need combination for variance.
	1 – Φ(‘2.063’)	**M1**	Area consistent with *their* working
	0.0196 (3 s.f.)	**A1**	
		5	

73. 9709_m21_ms_62 Q: 5

Question	Answer	Marks	Guidance
(a)	E(L_1+L_2+L_3+S_1+S_2+S_3+S_4) = 3×5.10 + 4×2.51 [= 25.34]	**B1**	OE (E(3L + 4S – 25.5) = -0.16)
	Var(L_1+L_2+L_3+S_1+S_2+S_3+S_4) = 3×0.0102 + 4×0.0036 [= 0.045]	**B1**	or SD = $\frac{3\sqrt{2}}{20}$ = 0.2121.
	$\frac{25.5-'25.34'}{\sqrt{'0.045'}}$ [= 0.754]	**M1**	No SD/variance mix. Standardising with *their* values (must be from a combination attempt).
	Φ(‘0.754’)	**M1**	For the correct area consistent with *their* working.
	0.775 (3 sf)	**A1**	
		5	
(b)	E(L – 2S) = 5.10 – 2×2.51 [= 0.08]	**B1**	OE
	Var(L – 2S) = 0.0102 + 2^2 ×0.0036 [= 0.0246]	**B1**	Or SD = 0.1568.
	$\frac{0-'0.08'}{\sqrt{'0.0246'}}$ [= –0.510]	**M1**	No SD/variance mix. Standardising with *their* values (must be from a combination attempt).
	P(Z > '–0.510') = ϕ(‘0.510’)	**M1**	For the correct area consistent with *their* working.
	0.695 (3 sf)	**A1**	
		5	

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74. 9709_s21_ms_61 Q: 7

Question	Answer	Marks	Guidance
(a)	$E(T)=3\times55+6\times27[=327]$	B1	OE. Accept unsimplified.
	$Var(T) = 3\times3^2 + 6\times2.5^2$ [= 64.5]	B1	Accept unsimplified.
	$\frac{340-'327'}{\sqrt{'64.5'}}$ [= 1.619]	M1	Must have √
	P(z < '1.619') = Φ('1.619')	M1	Correct probability area consistent with *their* working.
	0.947 (3 sf)	A1	
		5	
(b)	$E(L–S_1–S_2) = 55 – 2 \times 27$ [=1]	B1	OE e.g. $E(S_1+S_2 – L)= –1$. Accept unsimplified.
	$Var(L– S_1–S_2) = 3^2 + 2 \times 2.5^2$ [= 21.5]	B1	Accept unsimplified.
	$\frac{0-'1'}{\sqrt{'21.5'}}$ [= –0.216]	M1	Standardising with *their* values. Must come from a combination attempt.
	P($L–S_1–S_2 > 0$) = Φ(‘0.216’)	M1	Correct probability area consistent with *their* working.
	0.586 or 0.585 (3 sf)	A1	
		5	

75. 9709_s21_ms_62 Q: 2

Question	Answer	Marks	Guidance
(a)	$Var(X) = 400 \times 0.01 \times 0.99$ (= 3.96)	M1	
	$Var(4X + 2) = 16 \times Var(X)$	M1	For 16 × *their* Var(X)
	63.36	A1	Accept 63.4
		3	
(b)(i)	Po(4)	B1	
	$n = 400 > 50$ and either $np = 4 < 5$ or p=0.01 < 0.1	B1	Must quote values 400 and 4 or clearly see n=400 and np=4 (or p=0.01) in working
		2	
(b)(ii)	$e^{-4}\left(\frac{4^2}{2!}+\frac{4^3}{3!}+\frac{4^4}{4!}+\frac{4^5}{5!}\right)$	M1	FT *their* ‘4’ Allow one end error FT from **(b)(i)** Use of Normal allow M1 for attempt at standardising (with correct continuity correction) using *their* N(4,3.96) and attempt at probability. FT from **(b)(i)** Use of Binomial allow M1 for attempt at P(2,3,4,5) Binomial terms clearly seen and added
	0.694 (3 sf)	A1	CWO **SCB1** only for unsupported answer of 0.694
		2	

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76. 9709_s21_ms_62 Q: 4

Question	Answer	Marks	Guidance
(a)	Mean = 15.0+32.0+8.6 [= 55.6]	B1	Allow unsimplified
	Var = $1.1^2+3.5^2+1.2^2$ [= 14.9]	B1	Allow unsimplified
		2	
(b)	$\frac{60-"55.6"}{\sqrt{"14.9"}}$ [= 1.140]	M1	FT *their* 55.6 and 14.9 Ignore continuity correction
	1 – ϕ("1.140")	M1	For correct probability area consistent with *their* working
	0.127 (3 sf)	A1	CWO
		3	
(c)	$\frac{54.5-"55.6"}{\sqrt{\frac{"14.9"}{15}}}$ or $\frac{817.5-834}{\sqrt{223.5}}$ [= –1.104]	**M1**	FT *their* 55.6 and 14.9 No mixed methods
	1 – ϕ("1.104")	**M1**	For correct probability area consistent with their working
	0.135 (3 sf)	**A1**	As final answer
		3	

77. 9709_m20_ms_62 Q: 6

Question	Answer	Marks	Guidance
(a)	N(310, 50)	**B1**	SOI
	$\frac{300-'310'}{\sqrt{'50'}}$ (= –1.414)	**M1**	Standardise using their values
	Φ('–1.414') = 1 – ϕ('1.414')	**M1**	Area consistent with their values
	= 0.0786 or 0.0787 (3 sf)	**A1**	As final answer
		4	

Question	Answer	Marks	Guidance
(b)	P($L - 2S > 0$)	**M1**	OE SOI
	E(X) = 200-2x110 or = – 20	**B1**	OE seen
	Var = $30 + 2^2 \times 20$ or = 110	**B1**	Seen
	N(–20, 110) $\frac{0-('-20')}{\sqrt{'110'}}$ (= 1.907)	**M1**	Standardising with their values. Mean and variance must come from a combination attempt.
	1 – Φ('1.907')	**M1**	Correct area consistent with their working
	= 0.0283 (3 sf)	**A1**	Final answer
		6	

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78. 9709_s20_ms_61 Q: 3

Question	Answer	Marks
(a)	N(240, 6×1.5^2) or N(240, 13.5)	M1
	$\frac{245 - "240"}{\sqrt{"13.5"}}$ (= 1.361)	M1
	$1 - \Phi$("1.361")	M1
	0.0867 (3 sf)	A1
		4
(b)	Use of $L - 4S$ or similar	M1
	E($L - 4S$) = –8	B1
	Var($L - 4S$) = $1.5^2 + 16 \times 0.7^2$ or 10.09	B1
	$\frac{0 - ("-8")}{\sqrt{"10.09"}} (= 2.519)$	M1
	Φ("2.519")	M1
	0.994 (3 sf)	A1
		6

79. 9709_s20_ms_62 Q: 1

Question	Answer	Marks
	N(242.4, 162.24)	B1
	$\frac{220 - '242.4'}{\sqrt{'162.24'}}$ (= –1.759)	M1
	ϕ ('–1.759) = 1 – ϕ ('1.759') = 0.0393	M1
	3.93%	A1
		4

80. 9709_s20_ms_63 Q: 2

Question	Answer	Marks
	$Y - W - X \sim$ N(90, …)	B1
	Var($Y - W - X$) = 1050 + 450 + 720 or 2220	B1
	$\frac{0 - 90}{\sqrt{'2220'}}$ (= –1.910)	M1
	Φ('–1.910') = 1 – Φ('1.910')	M1
	0.0281	A1
		5

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81. 9709_w20_ms_61 Q: 3

Question	Answer	Marks	Guidance
	F – 0.5M	M1	SOI
	$\sim N(17, 27^2 + 0.25 \times 55^2)$	B1	for 102 – 0.5(170) (= 17) or 34
		B1	for $27^2 + 0.25 \times 55^2$ (= 1485.25) or $2^2 \times 27^2 + 55^2$ (= 5941)
	$\frac{0-'17'}{\sqrt{'1485.25'}}$ (= –0.4411)	M1	Must have an attempt at combining F and M. No standard deviation/variance errors.
	P(F – 0.5M < 0) = Φ('-0.4411') = 1 – Φ('0.4411')	M1	Correct area consistent with *their* figures.
	= 0.330 (3 sf)	A1	Allow 0.33 if no greater accuracy given
	Alternative method for question 3		
	2F – M		
	$\sim N(34, 2^2 \times 27^2 + 55^2)$	B1	for 102 – 0.5(170) (= 17) or 34
		B1	for $27^2 + 0.25 \times 55^2$ (= 1485.25) or $2^2 \times 27^2 + 55^2$ (= 5941)
	$\frac{0-'34'}{\sqrt{'5941'}}$ (= –0.4411)	M1	Must have an attempt at combining F and M. No standard deviation/variance errors.
	P(2F – M < 0) = Φ('-0.4411') = 1 – Φ('0.4411')	M1	Correct area consistent with *their* figures.
	= 0.330 (3 sf)	A1	Allow 0.33 if no greater accuracy given
		6	

82. 9709_w20_ms_62 Q: 7

Question	Answer	Marks	Guidance
(a)	P(S > L + 200) = P(S – L > 200) E(S – L) = 380–210 (=170) or E(S–L–200)= 380–210–200 (=–30)	B1	These may be implied by next line
	Var(S – L) = 140+80 (=220) or Var(S–L–200)= 140+80 (=220)	B1	
	$\frac{200-"170"}{\sqrt{"220"}}$ or $\frac{0-"-30"}{\sqrt{"220"}}$ (= 2.023)	M1	Standardising with *their* values (must be from a combination attempt) Allow with attempted continuity correction.
	1 – Φ("2.023")	M1	Area consistent with their values
	= 0.0216 (3sf)	A1	(0.0234 with continuity correction)
		5	

Question	Answer	Marks	Guidance
(b)	E(total cost) = 380 × 20 + 210 × 50 (= 18 100)	B1	or $181
	Var(total cost) = 140 × 20^2 + 80 × 50^2 (= 256 000)	B1	or 25.6 (dollar^2) These may be implied by next line
	$\frac{19000-"18100"}{\sqrt{"256000"}}$ or $\frac{190-"181"}{\sqrt{"25.6"}}$ (= 1.778)	M1	Standardising with *their* values (must be from a combination attempt). No mixed methods. Allow with attempted continuity correction.
	Φ("1.778")	M1	Area consistent with *their* values
	= 0.962 or 0.963 (3 sf)	A1	(0.953 or 0.954 with continuity correction)
		5	

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83. 9709_w20_ms_63 Q: 3

Question	Answer	Marks	Guidance
	F – 0.5M	**M1**	SOI
	~ N(17, $27^2 + 0.25 \times 55^2$)	**B1**	for 102 – 0.5(170) (= 17) or 34
		B1	for $27^2 + 0.25 \times 55^2$ (= 1485.25) or $2^2 \times 27^2 + 55^2$ (= 5941)
	$\frac{0-'17'}{\sqrt{'1485.25'}}$ (= –0.4411)	**M1**	Must have an attempt at combining F and M. No standard deviation/variance errors.
	P(F – 0.5M < 0) = ϕ('-0.4411') = 1 – ϕ('0.4411')	**M1**	Correct area consistent with *their* figures.
	= 0.330 (3 sf)	**A1**	Allow 0.33 if no greater accuracy given
	Alternative method for question 3		
	2F – M		
	~ N(34, $2^2 \times 27^2 + 55^2$)	**B1**	for 102 – 0.5(170) (= 17) or 34
		B1	for $27^2 + 0.25 \times 55^2$ (= 1485.25) or $2^2 \times 27^2 + 55^2$ (= 5941)
	$\frac{0-'34'}{\sqrt{'5941'}}$ (= –0.4411)	**M1**	Must have an attempt at combining F and M. No standard deviation/variance errors.
	P(2F – M < 0) = ϕ('-0.4411') = 1 – ϕ('0.4411')	**M1**	Correct area consistent with *their* figures.
	= 0.330 (3 sf)	**A1**	Allow 0.33 if no greater accuracy given
		6	

84. 9709_m19_ms_72 Q: 2

Question	Answer	Marks	Guidance
	E(X – 3Y) = 0.2	**B1**	oe
	Var(X – 3Y) = 12.1 + 9 × 8.6 (= 89.5)	**B1**	
	$\frac{0-0.2}{\sqrt{"89.5"}}$ (= –0.021)	**M1**	For area consistent with their working
	Φ(‘0.021’)	**M1**	
	= 0.508 (3 sfs)	**A1**	
		5	

85. 9709_s19_ms_71 Q: 1

Question	Answer	Marks	Guidance
(i)	Mean = 115	**B1**	
	SD = 40	**B1**	
		2	
(ii)	Mean = 15 × ‘115’ = 1725	**B1ft**	
	15 × ‘40’^{2} (= 24000)	**M1**	or SD = √15 × ‘40’. ft their **(i)**
	SD = √24000 SD = 155 (cents) (3 sf)	**A1**	Accept √24000 SC: Allow correct answers in dollars
		3	

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86. 9709_s19_ms_72 Q: 2

Question	Answer	Marks	Guidance
(i)	Normal with mean 372	**B1**	
	sd = $\frac{54}{\sqrt{36}}$	**M1**	or variance = $\frac{54^2}{36}$ M1
	(= 9)	**A1**	(= 81) A1
		3	
(ii)	Pop normal	**B1**	Allow X is normal
		1	

87. 9709_s19_ms_72 Q: 4

Question	Answer	Marks	Guidance
	Use of $1.5X_1 - X_2$ or similar	**B1**	
	$E(1.5X_1 - X_2) = 1.5(110) - 110$ (= 55)	**B1**	or $E(X_1 - 1.5X_2) = 110 - 1.5(110)$ (= –55)
	$Var(1.5X_1 - X_2) = 1.5^2 \times 1050 + 1050$ (or 3412.5)	**M1**	Correct expression or result
	$\frac{0-55}{\sqrt{'3412.5'}}$ or $\frac{0-(-55)}{\sqrt{'3412.5'}}$ (= ± 0.942)	**M1**	Their '55'. Allow incorrect var (dep > 0 and ≠ 1050)
	1 – Φ('0.942')	**M1**	Area consistent with their working
	= 0.173	**A1**	
	Ans 0.346 (3 sf)	**B1**	**FT** double their prob (must be <1)
		7	

88. 9709_s19_ms_73 Q: 4

Question	Answer	Marks	Guidance
	Total ~ N(1208, ...)	**B1**	
	Var(total) (= 10×1.2 + 20×0.7 (+ 0)) = 26	**B1**	May be implied by next line
	± $\frac{1200-"1208"}{\sqrt{"26"}}$ (= –1.569)	**M1**	**FT** their mean and var of total mass, e.g. allow 1200 and 11.24 (from $10 \times 1.2^2 + 20 \times 0.7^2$)
	1 – Φ("1.569")	**M1**	Correct area consistent with their working
	= 0.0583 (3 sf)	**A1**	
		5	

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89. 9709_w19_ms_72 Q: 5

Question	Answer	Marks	Guidance
(i)	mean = 3250 var. = 61	**B1**	Or mean = 325 var. $= \frac{6.1}{10}$
	$\frac{3240-3250}{\sqrt{61}}(=-1.280)$	**M1**	Standardise with their values (no mixed methods)
	$\phi('-1.280') = 1 - \phi('1.280')$	**M1**	Area consistent with their figures
	0.100	**A1**	Allow 0.1
		4	
(ii)	$E(D) = 325 - 2 \times 167 = -9$	**B1**	Accept ±9
	$Var(D) = 6.1 + 2^2 \times 5.6 (= 28.5)$	**B1**	
	$\frac{0-(-9)}{\sqrt{28.5}}(=1.686)$	**M1**	Standardising with *their* values. Must have a combination attempt on denominator and $\sqrt{}$
	$1 - \phi('1.686')$	**M1**	Area consistent with their figures
	0.0459	**A1**	
		5	

90. 9709_w19_ms_73 Q: 1

Question	Answer	Marks	Guidance
(i)	9.6, 12.4	**B1 B1**	
		2	
(ii)	6.6, 49.6	**B1 B1**	
		2	

91. 9709_m18_ms_72 Q: 3

Question	Answer	Marks	Guidance
(i)	$E(H_A) = 6$	**B1**	
	$Var(H_A) = 5 \times 0.03^2$	**M1**	
	= 0.0045 or 9/2000	**A1**	
		3	
(ii)	$E(H_A - 2H_B) = 0$	**B1**	From 6–6
	$Var(H_A - 2H_B) = '0.0045' + 4\times5\times0.02^2$	**M2**	Allow **M1** for $'0.0045' - 4\times5\times0.02^2$ *or* $'0.0045' + 2\times5\times0.02^2$ *or* $'0.0045' + 4\times0.02^2$ *or* $'0.0045' + 4\times5^2\times0.02^2$
	= 0.0125 (3 sf) or 1/80	**A1**	
		4	

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92. 9709_s18_ms_71 Q: 4

Question	Answer	Marks	Guidance
(i)	mean= 155.1	**B1**	
	var = $1.5^2 \times 10.2$ (= 22.95) sd = √"22.95"	**M1**	or $1.5 \times \sqrt{10.2}$
	= 4.79	**A1**	
		3	

Question	Answer	Marks	Guidance
(ii)	mean = 103.4 + "155.1" (= 258.5) var = 10.2 + "22.95" (=33.15)	**B1ft**	Both. ft their 155.1 and 22.95. Accept sd.
	$\frac{250-"258.5"}{\sqrt{"33.15"}}$ (= –1.476)	**M1**	Standardising – no sd/var mix. Their mean/sd must be from an attempt at combination
	1– ϕ(–1.476) = ϕ(1.476)	**M1**	For area consistent with their working
	= 0.930 (3 sf)	**A1**	Allow 0.93
		4	

93. 9709_s18_ms_72 Q: 2

Question	Answer	Marks	Guidance
	A: N(6, 4.8)	**B1 B1**	B1 for N(6, ..) for either A or B. B1 for 4.8 (or 2.19^2) (or SD=2.19)
	B: N(6, 2.4)	**B1**	B1 For 2.4 (or 1.55^2) (or SD=1.55) (SR 3/3 but error seen withhold B1 so 2/3 scored)
		3	

94. 9709_s18_ms_73 Q: 6

Question	Answer		Marks	Guidance
(i)	E(T) = 4.5 + 2.3 Var(T) = $1.1^2 + 0.7^2$	(= 6.8) (= 1.7)	**M1**	Both methods seen or implied
	$\frac{8.5-"6.8"}{\sqrt{"1.7"}}$	(= 1.304)	**M1**	Correct stand'n using their μ and σ^2 must be a combination of the two variables
	ϕ("1.304")		**M1**	Area consistent with their working
	= 0.904 (3 sf)		**A1**	
			4	
(ii)	E(D) = 4.5 – 2 × 2.3	or –0.1	**M1**	
	Var(D) = $1.1^2 + 2^2 \times 0.7^2$	or 3.17	**M1**	Both can seen or implied
	$\frac{0-('-0.1')}{\sqrt{'3.17'}}$	(= 0.056)	**M1**	Correct stand'n using their μ and σ^2 must be a Combination of the two variables
	1 – ϕ("0.056")		**M1**	Area consistent with their working
	= 0.478 (3 sf)		**A1**	
			5	

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95. 9709_w18_ms_71 Q: 5

Question	Answer	Marks	Guidance
(i)	$T_1 + T_2 \sim N(5, 0.4^2 + 0.5^2)$	**B1**	or N(5, 0.41)
	$\frac{6-5}{\sqrt{'0.41'}}$ (= 1.562)	**M1**	Allow cc
	Φ('1.562')	**M1**	Correct area consistent with their working
	= 0.941	**A1**	
		4	
(ii)	$\text{Var}(T_2 - 1.2T_1) = 0.5^2 + 1.2^2 \times 0.4^2$ (= 0.4804)	**B1**	Or similar using $1.2T_1 - T_2$
	$T_2 - 1.2T_1 - N(0.16, 0.4804)$	**B1 ft**	Only ft attempt at combination. no ft for neg var.
	$\frac{0-'0.16'}{\sqrt{'0.4804'}}$ (= -0.231)	**M1**	Standardise with their mean and variance. Allow cc
	$P(T_2 - 1.2T_1) > 0$		
	= Φ('0.231')	**M1**	Correct area consistent with their working
	= 0.591 (3 sfs)	**A1**	
		5	

96. 9709_w18_ms_72 Q: 3

Question	Answer	Marks	Guidance
	$E(T) = 2 \times 250 + 5 \times 160$ (= 1300)	**B1**	
	$\text{Var}(T) = 2 \times 10 + 5 \times 9$ (= 65)	**B1**	
	$\frac{1310-'1300'}{\sqrt{'65'}}$ (= 1.240)	**M1**	Standardise using their values (must come from a combination attempt). Ignore cc
	1 – ϕ('1.240')	**M1**	Correct area consistent with their working
	= 0.1075	**A1**	Allow 0.107 to 0.108 (no errors seen)
		5	

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97. 9709_w18_ms_73 Q: 5

Question	Answer	Marks	Guidance
(i)	$T_1 + T_2 \sim N(5, 0.4^2 + 0.5^2)$	**B1**	or N(5, 0.41)
	$\frac{6-5}{\sqrt{'0.41'}}$ (= 1.562)	**M1**	Allow cc
	Φ('1.562')	**M1**	Correct area consistent with their working
	= 0.941	**A1**	
		4	
(ii)	$\text{Var}(T_2 - 1.2T_1) = 0.5^2 + 1.2^2 \times 0.4^2$ (= 0.4804)	**B1**	Or similar using $1.2T_1 - T_2$
	$T_2 - 1.2T_1 - N(0.16, 0.4804)$	**B1 ft**	Only ft attempt at combination. no ft for neg var.
	$\frac{0-'0.16'}{\sqrt{'0.4804'}}$ (= -0.231)	**M1**	Standardise with their mean and variance. Allow cc
	$P(T_2 - 1.2T_1) > 0$		
	= Φ('0.231')	**M1**	Correct area consistent with their working
	= 0.591 (3 sfs)	**A1**	
		5	

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98. 9709_m17_ms_72 Q: 6

Question	Answer	Marks	Guidance
(i)	Assume cartons are random sample(s)	**B1**	or masses of cartons are independent of each other oe
	E(T) = 816.4 Var(T) = 1570.08	**B1**	Both
	$z = \frac{900-"816.4"}{\sqrt{"1570.08"}}$ (= 2.110)	**M1**	
	1 – Φ(“2.110”)	**M1**	
	= 0.0174 = 1.74% (3 sfs)	**A1**	% only (accept 1.7% if 0.0174 seen)
	Total:	**5**	
(ii)	P($F – S > 0$) stated or implied	**M1**	P($S – F < 0$)
	62.0 – 78.8 (= –16.8) & $10.0^2 + 12.6^2$ (= 258.76)	**B1**	78.8 – 62.0 (= 16.8) & $12.6^2 + 10.0^2$ (= 258.76)
	$z = \frac{0-("-16.8")}{\sqrt{"258.76"}}$ (= 1.044)	**M1**	$z = \frac{0-"16.8"}{\sqrt{"258.76"}}$ (= –1.044)
	1 – Φ(“1.044”)	**M1**	Φ(“–1.044”) = 1 – Φ(“1.044”)
	(= 1 – 0.8517) = 0.148 (3 sfs)	**A1**	
	Total:	**5**	

99. 9709_s17_ms_71 Q: 5

Question	Answer	Marks	Guidance
(i)	$W \sim$ N(6210, 171.88)	**B2**	seen or implied. **B1** each parameter
	$\frac{6200-"6210"}{\sqrt{"171.88"}}$ (= – 0.763)	**M1**	Standardising with their values. No sd / var mix
	1 – Φ(“0.763”)	**M1**	For area consistent with their mean
	= 0.223 (3 sfs)	**A1**	
	Total:	**5**	

Question	Answer	Marks	Guidance
(ii)	E(C – 2B) = −50	**M1**	“6210”–2(3130) (or E(2B–C)=50
	Var(C – 2B) = "171.88" + $2^2 \times 12.1^2$ (= 757.52)	**M1**	
	$\frac{0-(-50)}{\sqrt{"757.52"}}$ (= 1.817)	**M1**	Standardising with their values
	Φ(“1.817”)	**M1**	For area consistent with their mean
	= 0.965 (3 sfs)	**A1**	
	Total:	**5**	

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100. 9709_s17_ms_72 Q: 7

Question	Answer	Marks	Guidance
(a)	$E(X_1+X_2) = 2 \times 4.2 = 8.4$ $Var(X_1+X_2) = 2 \times 1.1^2 = 2.42$	**B1**	Both. Seen or implied (or sd = 1.56)
	$\frac{10-8.4}{\sqrt{2.42}}$ (= 1.029)	**M1**	Standardising with their mean and var (no sd / var mix)
	1 − ϕ("1.029")	**M1**	For area consistent with their working
	= 0.152 (3 sf)	**A1**	
	Total:	**4**	
(b)	$E(X) = 20.5$	**B1**	
	$Var(X) = 105 + 0.5^2 \times 15$ (= 108.75)	**M1**	correct expression oe
	$\frac{0-"20.5"}{\sqrt{"108.75"}}$ (= −1.966)	**M1**	correct standardisation using their E & V (no sd/var mix) ignore any attempted cc
	ϕ("−1.966") = 1− ϕ("1.966") (= (1 − 0.9754))	**M1**	For area consistent with their working
	= 0.0246 or 2.46% (3 sf)	**A1**	Accept 0.0247
	Total:	**5**	

101. 9709_s17_ms_73 Q: 3

Question	Answer	Marks	Guidance
	10×0.46^2 (= 2.116) or $\frac{0.46}{\sqrt{10}}$	**B1**	SOI
	Total mass of ore ~ N(70, 2.116) or $\sim N\left(7, \left(\frac{0.46}{\sqrt{10}}\right)^2\right)$	**B1**	
	$\pm\frac{71-"70"}{\sqrt{"2.116"}}$ or $\pm\frac{7.1-"7.0"}{0.46/\sqrt{10}}$ (= 0.687)	**M1**	correct, using their sd or √(their var) e.g. allow $\frac{71-"70"}{4.6}$ for **M1**
	1 − ϕ("0.687")	**M1**	for correct area consistent with their working
	= 0.246 (3 sf)	**A1**	
	Total:	**5**	

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102. 9709_w17_ms_71 Q: 6

Question	Answer	Marks	Guidance
(i)	Mean = $3.2 \times 90 = 288$	**B1**	
	Variance = $0.4^2 \times 90^2$	**M1**	
	$= 1296$	**A1**	
		3	
(ii)	Mean = '288' + $4.3 \times 95 = 696.5$	**B1 FT**	
	Variance = '1296' + $0.6^2 \times 95^2 = 4545$	**B1 FT**	FT their **(i)**
	$\frac{670-696.5}{\sqrt{4545}}$ (= -0.393)	**M1**	FT Var provided both given Vars used standardising (ignore cc) no sd / Var mix
	$1 - \phi('-0.393') = \phi('0.393')$	**M1**	correct area consistent with their working (i.e. their mean)
	= 0.653 (3 sf)	**A1**	
		5	

103. 9709_w17_ms_72 Q: 5

Question	Answer	Marks	Guidance
(i)	$E(X - Y) = 56-43$ (= 13)	**B1**	
	$\text{Var}(X - Y) = 6^2 + 5^2$ (= 61)	**M1**	
	$\frac{0-13}{\sqrt{'61'}}$ (= −1.664)	**M1**	Ignore any attempted cc/no SD/var mixes. var must be attempt at a combination
	$1 - \phi('-1.664') = \phi('1.664')$	**M1**	For area consistent with their working
	= 0.952 (3 sf)	**A1**	Similar scheme for use of $Y - X$
		5	

Question	Answer	Marks	Guidance
(ii)	$E(M) = 56 + 1.5(43)$ (= 120.5)	**B1**	
	$\text{Var}(M) = 6^2 + 1.5^2 \times 5^2$ (= 92.25)	**M1**	
	$\frac{135-120.5}{\sqrt{'92.25}}$ (= 1.510)	**M1**	Ignore any attempted cc/no SD/var mixes. var must be attempt at a combination
	$1 - \phi('1.510')$	**M1**	For area consistent with their working
	= 0.0655 or 0.0656 or 6.55% or 6.56% (3 sf) As final answer	**A1**	Allow 6.6% or 6.5% or 7% if correct working seen
		5	

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104. 9709_w17_ms_73 Q: 6

Question	Answer	Marks	Guidance
(i)	Mean = $3.2 \times 90 = 288$	**B1**	
	Variance = $0.4^2 \times 90^2$	**M1**	
	$= 1296$	**A1**	
		3	
(ii)	Mean = '288' + $4.3 \times 95 = 696.5$	**B1 FT**	
	Variance = '1296' + $0.6^2 \times 95^2 = 4545$	**B1 FT**	FT their **(i)**
	$\frac{670-696.5}{\sqrt{4545}}$ (= -0.393)	**M1**	FT Var provided both given Vars used standardising (ignore cc) no sd / Var mix
	$1 - \phi(\text{'}-0.393\text{'}) = \phi(\text{'}0.393)$	**M1**	correct area consistent with their working (i.e. their mean)
	= 0.653 (3 sf)	**A1**	
		5	

105. 9709_m16_ms_72 Q: 1

Q	Answer	Mark	Notes
	$E(X) = \frac{10}{3}$ oe $\quad$ $Var(X) = \frac{25}{9}$ oe	**B1**	For $E(X)$ and $Var(X)$
	$E(Y) = 10$ $\quad$ $Var(Y) = 5$	**B1**	For $E(Y)$ and $Var(Y)$ OR For $E(X)$ and $E(Y)$ For $Var(X)$ and $Var(Y)$
	$E(X + Y) = \frac{40}{3}$ oe $\quad$ or 13.3 (3 sf)	**B1**	
	Var $(X + Y)$ = "$\frac{25}{9}$" + "5"	**M1**	For adding 2 (appropriate) variances
	sd = $\frac{\sqrt{70}}{3}$ oe $\quad$ or 2.79 (3 sf)	**A1** [5]	or sd = or $\sqrt{2} \times \frac{5}{3}$

106. 9709_m16_ms_72 Q: 4

Q	Answer	Mark	Notes
	$X - 2Y \sim N(0.1, 0.2^2 + 4 \times 0.1^2)$ soi (= N(0.1, 0.08))	**B1 B1**	**B1** for ± 0.1 **B1** for $0.2^2 + 4 \times 0.1^2$
	$\frac{0-0.1}{\sqrt{"0.08"}}$ (= –0.354)	**M1**	For standardising. Allow without √ sign
	Φ("–0.354 ") = 1 – Φ("0.354") = 0. 362 (3 sf)	**M1** **A1** [5]	For correct area consistent with their working

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107. 9709_s16_ms_71 Q: 5

Q	Answer	Mark	Notes
(i)	$T \sim N(6 \times 2.4, 6 \times 0.3^2)$		
	$(= N(14.4, 0.54)$	**M1**	seen or implied
	$\frac{16-'14.4'}{\sqrt{'0.54'}}$ $(= 2.177)$	**M1**	ft their E and Var; allow without √ (Accept alternative method $N(2.4,(0.3^2)/6)$)
	$1 -$ ('2.177')	**M1**	correct area consistent with their working
	$= 0.0147$ (3 sf)	**A1** [4]	
(ii)	$D = X_1 - 1.1X_2$		
	$E(D) = -0.24$	**B1**	
	$Var(D) = 0.3^2 + 1.1^2 \times 0.3^2$ $(= 0.1989)$	**M1**	
	$\frac{0-(-0.24)}{\sqrt{'0.1989'}}$ $(= 0.538)$	**M1**	ft their E and Var; allow without √
	('0.538')	**M1**	correct area consistent with their working
	$= 0.705$ (3 sf)	**A1** [5]	

108. 9709_s16_ms_72 Q: 1

Q	Answer	Mark	Notes
	$\frac{6.2}{\sqrt{50}}$ or $\frac{6.2^2}{50}$	**B1**	seen or implied
	$\frac{51-53}{6.2 \div \sqrt{50}}$ $(= -2.281)$	**M1**	allow without $\div\sqrt{50}$
	$P(z >$ '-2.281') $= \phi$('2.281')	**M1**	for finding correct area consistent with working
	$= 0.989$ (3 sf)	**A1** [4]	as final answer

109. 9709_s16_ms_72 Q: 5

Q	Answer	Mark	Notes
(i)	$T \sim N(520, 70)$	**B1**	for N(520,..) or N(500,..) if standardising with 510
	$\frac{530-520}{\sqrt{'70'}}$ $(= 1.195)$	**B1**	for Var = 70 seen or implied
	('1.195')	**M1**	ft their E and Var; allow without √
	$= 0.884$ (3 sf)	**M1**	finding correct area consistent with working
		A1 [5]	CWO
(ii)	$E(T) = -10$	**B1**	or +10 for $T < 0$
	$Var(T) = 50 + 4.1^2 \times 20$ $(= 386.2)$	**B1**	Seen or implied
	$\frac{0-(-10)}{\sqrt{'386.2'}}$ $(= 0.509)$	**M1**	ft their E and Var; allow without √
	$1 -$ ('0.509')	**M1**	finding correct area consistent with working
	$= 0.305$ (3 sf)	**A1** [5]	CWO

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110. 9709_s16_ms_73 Q: 7

Q	Answer	Mark	Notes
(i)	E(T) =20.8	B1	
	Var(T)= $20 \times 0.03^2 + 0.01^2$(= 0.0181)	B1	or $\sqrt{(20 \times 0.03^2 + 0.01^2)} = 0.135$ (3sf)
	$\frac{20.6-20.8}{\sqrt{"0.0181"}}$ (= –1.487)	M1	For standardising (σ must come from combination)
	1 – Φ("1.487")	M1	Area consistent with their working
	= 0.0684 to 0.686	A1 [5]	Any answer within range
(ii)	E(D) = 0		
	Var(D) = 2×0.0181(= 0.0362)	B1√	Both (Seen or implied)
	$\frac{0.02-0}{\sqrt{"0.0362)}}$ (= 0.105)	M1	Allow without √
	Φ("0.105") = 0.5418 or 1-Φ(0.015) =0.4582	A1	Allow to 3sf
	Φ("0.105") – (1 – Φ("0.105") (= 0.5418 – 0.4582)	M1	or 1 – 2(1 – Φ("0.105")) (= 1 – 2 × 0.4582)
	= 0.0836/0.0837	A1 [5]	

111. 9709_w16_ms_71 Q: 4

Q	Answer	Mark		Notes
(i)	6080 (litres)	B1		
	106 (litres)	B1	[2]	
(ii)	E($21Y – 2X$) = 635	B1		
	Var($21Y – 2X$) = $21^2 \times 12^2 + 2^2 \times 53^2$ (= 74740)	B1		correct expression or result or sd = 273 seen
	$\frac{0-635}{\sqrt{'74740'}}$ (= –2.323)	M1		no sd/var mixes
	1–Φ('–2.323') = Φ('2.323')	M1		Area consistent with their working
	= 0.99(0) (3 sf)	A1	[5]	No errors seen

112. 9709_w16_ms_73 Q: 3

Q	Answer	Mark		Notes
	N(178, …)	B1		stated or implied
	Var = $3.2^2 + 4.1^2 + 3.8^2$ or 41.49	B1		or sd = 6.44 stated or implied
	$\frac{175-'178'}{\sqrt{'41.49'} \div \sqrt{15}}$ (= '–1.804')	M1		need √15 but allow var / sd mix for "41.49" allow cc for method marks
	Φ('–1.804') = 1 – Φ ('1.804')	M1		independent M1 for area / prob
	= 0.0356 (3 sf)	A1	[5]	consistent with working

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113. 9709_s15_ms_71 Q: 3

Q	Answer	Mark	Notes
(i)	34 $2.2^2 + 1.3^2 + 2.6^2$ (=13.29)	B1 B1 [2]	Accept 13.3 or 3.65^2 Allow at early stage
(ii)	$\frac{33-'34'}{\sqrt{\frac{'13.29'}{70}}}$ (= –2.295) $\frac{35-'34'}{\sqrt{\frac{'13.29'}{70}}}$ (= 2.295) Φ('2.295') – Φ('–2.295') = Φ('2.295') – (1 – Φ('2.295')) oe = 0.978 (3 sf)	M1 M1 M1 A1 [4]	correct standardisation method for either For attempt to use tables to find the probability between two z values ,may be implied by next line For a correct method to find the area between their two z values
		[Total: 6]	

114. 9709_s15_ms_71 Q: 7

Q	Answer	Mark	Notes
(i)	$7E(X) + 5E(Y) – 2$ $(= 7 \times 8 + 5 \times 3) – 2$ = 69	M1 A1 [2]	allow incorrect means
(ii)	Var(X) = 1.6, Var(Y) = 3 $16\text{Var}(X) + 9\text{Var}(Y)$ $(= 16\times1.6 + 9 \times 3)$ = 52.6	B1 M1 M1 A1 [4]	both M1 for mult by 16 and 9; allow with '+ 3' M1 for add without '+ 3'; allow incorrect multipliers
(iii)	$X = 10$, $Y = 2$ and $X = 9$, $Y = 0$ $0.8^{10} \times e^{-3} \times \frac{3^2}{2}$ or $10\times0.8^9 \times 0.2 \times e^{-3}$ $0.8^{10} \times e^{-3} \times \frac{3^2}{2} + 10\times0.8^9 \times 0.2 \times e^{-3}$ = 0.0374/5	B1 M1 M1 A1 [4]	both pairs seen or implied or 0.0241 or 0.0134 (3sf) one correct product all correct
		[Total: 10]	

115. 9709_s15_ms_72 Q: 1

Q	Answer	Mark	Notes
	Var = 16×9 + 25×36 (= 1044) sd = 32.3 or 6√29 or √1044	B1 M1 A1	M1 for 16 (or 4^2) & 25 (or 5^2) used M1 for add any multiples of 9 and 36 only
	Total	**3**	

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116. 9709_w15_ms_71 Q: 6

Q	Answer	Mark	Notes
(i)	$E(T) = 9 \times 78 + 7 \times 66$ (= 1164)	B1	Or $9 \times 78 + 7 \times 66 - 1200$
	$Var(T) = 9 \times 7^2 + 7 \times 5^2$ (= 616)	B1	
	$\frac{1200-'1164'}{\sqrt{'616'}}$ (= 1.450)	M1	± Allow without √
	$P(z < 1.450) = \Phi(1.450)$ = 0.927 (3 sf)	M1 A1 [5]	Correct tail consistent with their mean
(ii)	$E(D) = 66 - 78$ (= –12)	B1	Both needed
	$Var(D) = 7^2 + 5^2$ (= 74)		
	$\frac{0-('-12')}{\sqrt{74}}$ (= 1.395)	M1	± Allow without √
	$P(D > 0) = 1 - \Phi$ ('1.395') 0.0815 (3 sf)	M1 A1 [4]	Correct tail consistent with their mean Similar scheme for P(M – W) < 0
		Total: 9	

117. 9709_w15_ms_73 Q: 7

Q	Answer	Mark		Notes
(i)	est $\mu = 2.087$	B1		allow 2.09
	est $\sigma^2 = \frac{100}{99}\left(\frac{435.57}{100} - 2.087^2\right)$	M1		$1/99\ (435.57 - 208.7^2/100)$
	= 0.000132(3232) or 131/990000	A1	[3]	without $\frac{100}{99}$: 0.000131 M0A0
(ii)	$E(Y - X) = 2.12 - 2.087$ (= 0.033)	B1		or 2.12 – 2.087 – 0.01 for Y – X – 0.01 < 0 allow 2.09 for 2.087
	$Var(Y - X) = 0.000144 + '0.00013232'$ = 0.000276(32)	M1 A1		or $\sqrt{(0.012^2 + '0.00013232')}$ M1 = 0.016623 A1
	$\frac{0.01-'0.033'}{\sqrt{'0.00027632'}}$ (= –1.384)	M1		√their $E(Y - X)$ & $Var(Y - X)$ var must be a combination of the two vars
	$\Phi('-1.384') = 1 - \Phi('1.384')$	M1		correct area/prob consistent with their working
	= 0.0832	A1	[6]	SR use of biased var (0.000131) in (i) and (ii) scores in (ii) B1M1 A1 for 0.000275 and M1M1 A1 for 0.0827 (6/6 available)
Total			[9]	
	Total for paper		[50]	

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118. 9709_m22_ms_62 Q: 6

Question	Answer	Marks	Guidance
(a)	Quadratic curve, hence symmetrical	**B1**	OE. Allow sketch and 'symmetrical' or just 'curve symmetrical'
		1	
(b)	$-k\int_1^3 (x^2-4x+3)\mathrm{d}x = 1$	**M1**	Attempt to integrate f(x) and '= 1'. Ignore limits at this stage
	$-k\left[\frac{x^3}{3}-2x^2+3x\right]_1^3$	**A1**	Fully correct expression (correct integration and limits)
	$-k\times\left[0-\frac{4}{3}\right]=1$ or $k\times\frac{4}{3}=1$ $\left[k=\frac{3}{4}\right]$	**A1**	AG, OE. Correctly substitute limits and '= 1' and correctly obtain result with no errors seen.
		3	
(c)	$-\frac{3}{4}\int_1^3 \left(x^4-4x^3+3x^2\right)\mathrm{d}x$	**M1**	Attempt to integrate x^2 f(x) from 1 to 3
	$-\frac{3}{4}\times\left[\frac{x^5}{5}-x^4+x^3\right]_1^3$ $\left[=\frac{3}{4}\times\frac{28}{5}=\frac{21}{5}\right]$	**A1**	Correct integration and limits
	$\left[\frac{21}{5}-2^2\right]=0.2$	**A1**	
		3	

Question	Answer	Marks	Guidance
(d)	$-\frac{3}{4}\int_{2.5}^{3}\left(x^2-4x+3\right)\mathrm{d}x$	**M1**	OE. Attempt to integrate f(x), from 2.5 to 3 (or 1 to 2.5)
	$=-\frac{3}{4}\times\left[\frac{x^3}{3}-2x^2+3x\right]_{2.5}^{3}=\frac{5}{32}$ or 0.15625	**A1**	
	$1-\left(1-'\frac{5}{32}'\right)^3$	**M1**	OE. FT *their* $\frac{5}{32}$.
	= 0.399 (3 sf)	**A1**	
		4	

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119. 9709_s22_ms_61 Q: 6

Question	Answer	Marks	Guidance
(a)	$\frac{a}{2}$	**B1**	
		1	
(b)	$\frac{1}{4}$	**B1**	
		1	
(c)	$f(x) = \frac{1}{a}$	**B1**	SOI (may be seen in part **(a)** or part **(b)**)
	$E(X) = \frac{a}{2}$	**B1**	SOI
	$\int_0^a \frac{1}{a} x^2 dx$	**M1**	Attempt integrate *their* $f(x) \times x^2$ with correct limits
	$= \left[\frac{x^3}{3a}\right]_0^a = \frac{a^2}{3}$	**A1**	
	$\frac{a^2}{3} - (\frac{a}{2})^2$ or $\frac{a^2}{3} - \frac{a^2}{4}$ [$= \frac{a^2}{12}$ **AG**]	**A1**	Must see previous line and answer No errors seen
		5	

Question	Answer	Marks	Guidance
(d)	$P(X < \frac{b}{3}) = \frac{p}{3}$	**M1**	SOI (could be on a diagram) OR by integration: prob = 1-(2/3)(b/a)
	$P(\frac{b}{3} < X < a - \frac{b}{3}) = 1 - \frac{2p}{3}$	**A1**	
		2	

120. 9709_s22_ms_62 Q: 5

Question	Answer	Marks	Guidance
(a)	$\frac{3}{16}\int_2^4 (4x^2 - x^3) dx$	**M1**	Attempt to integrate $xf(x)$ Ignore limits (must see a power increase for attempted integration)
	$= \frac{3}{16}\left[\frac{4x^3}{3} - \frac{x^4}{4}\right]_2^4$	**M1**	Attempt integrate $xf(x)$ with correct limits (must see a power increase for attempted integration)
	$= \frac{3}{16}(\frac{256}{3} - 64 - (\frac{32}{3} - 4)) = \frac{11}{4}$ **(AG)**	**A1**	Correct substitution of correct limits (at least 2 terms seen) and answer seen. No errors seen i.e. NO recovery of errors and no non-exact decimals (e.g. 21.33) seen
		3	

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Question	Answer	Marks	Guidance
(b)	$\frac{3}{16}\int_2^4(4x^3-x^4)\mathrm{d}x$	*M1	Attempt to integrate x^2 f(x) with correct limits (integration must be seen not implied. Must see a power increase for attempted integration)
	$=\frac{3}{16}\left[x^4-\frac{x^5}{5}\right]_2^4$ [$=\frac{39}{5}$ or 7.8] Var(X) = '$\frac{39}{5}$' $-(\frac{11}{4})^2$	DM1	*their* $\int x^2\mathrm{f}(x)\mathrm{d}x-(\frac{11}{4})^2$, with $\int x^2\mathrm{f}(x)\mathrm{d}x$ evaluated, not necessarily simplified
	$=\frac{19}{80}$ or 0.2375 (or 0.238 (3 sf))	A1	SC If M0 then score B1 for $\frac{39}{5}$ and B1 for $\frac{19}{80}$
		3	
(c)	$\frac{3}{16}\int_2^3(4x-x^2)\mathrm{d}x$	M1	Attempt to integrate correct integral and limits must see a power increase for attempted integration Oe (Integrate 3 to 4) OR ALTERNATIVE METHOD integrate from m to 4 or 2 to m and equate to 0.5 to obtain cubic (m^3 -$6m^2$ + 24 = 0 oe) (NB Integrating from m to 3 and equating to 0.5M0)
	$=\frac{3}{16}\left[2x^2-\frac{x^3}{3}\right]_2^3$ $\left[=\frac{3}{16}\left(18-9-\left(8-\frac{8}{3}\right)\right)\right]\left[=\frac{11}{16}\right]$ '$\frac{11}{16}$' $-\frac{1}{2}$	M1	*Their* $\int\mathrm{f}(x)\mathrm{d}x-\frac{1}{2}$ oe (1/2 – 5/16) OR ALTERNATIVE METHOD m obtained from cubic (m = 2.69459) and attempt to integrate f(x) from '*their m*' (2 < m < 4) to 3 must see a power increase for attempted integration and limits substituted
	$\frac{3}{16}$ or 0.1875	A1	Condone 0.187 or 0.188
		3	

121. 9709_s22_ms_63 Q: 7

Question	Answer	Marks	Guidance
(a)(i)	1	B1	no ambiguity
		1	
(a)(ii)	$\frac{1}{2}$	B1	No ambiguity
		1	
(a)(iii)	[q =] $\frac{1}{2}p$	B1	Accept $2q = p$
		1	
(b)	$p\int_0^a(a^2-x^2)\mathrm{d}x=1$	M1	Attempt to integrate f(x) and equated to 1
	$\frac{2}{3}a^3p=1$	A1	OE, simplified
	"$\frac{3}{2a^3}$"$\int_0^a(a^2x-x^3)\mathrm{d}x=3$ or "$\frac{3}{2a^3}$"$\int_0^a(a^2x-x^3)\mathrm{d}x=3$	M1	Attempt to integrate xf(x), with multiplier p or $\frac{3}{2a^3}$ or *their p*, and equate to 3
	$p\times\frac{a^4}{4}=3$	A1	May be implied by next line
	"$\frac{3}{2a^3}$"$\times\frac{a^4}{4}=3$	M1	OE. Substitute from one equation into the other. FT *their* equations
	a = 8	A1	
		6	

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122. 9709_m21_ms_62 Q: 2

Question	Answer	Marks	Guidance
(a)	$\frac{1}{2}\times\frac{1}{2}k\times k = 1$	**M1**	Or use of $\int_0^k\left(-\frac{1}{2}x+\frac{1}{2}k\right)\mathrm{d}x=1$ and attempt at integral.
	$k = 2$	**A1**	Unsupported answers M0 A0. Do not accept ± 2.
		2	
(b)	$\mathrm{f}(x) = -\frac{1}{2}x + 1$	**B1 FT**	FT *their k* from $y=-\frac{1}{2}x+\frac{1}{2}k$.
	$\int_0^2(-\frac{1}{2}x^2+x)\mathrm{d}x = \left[-\frac{x^3}{6}+\frac{x^2}{2}\right]_0^2$	**M1**	Attempt integration of $x\mathrm{f}(x)$ limits 0 to k. FT *their* $\mathrm{f}(x)$. Could be in terms of k.
	$\frac{2}{3}$ or 0.667 (3 sf)	**A1**	
		3	

Question	Answer	Marks	Guidance
(c)	$\int_p^1(-\frac{1}{2}x+1)\mathrm{d}x$ [= 0.25]	**M1**	FT their equation of **line**; correct integral and limits (could be reversed) stated or $\frac{1}{2}(1-p)(1-\frac{1}{2}p+\frac{1}{2})$[= 0.25].
	$\left[-\frac{x^2}{4}+x\right]_p^1 = 0.25$ $-\frac{1}{4}+1+\frac{p^2}{4}-p = 0.25$	**M1**	Attempt substitution of correct limits (not reversed) into their integral or attempt expand must equal 0.25. OE
	$p^2 - 4p + 2 = 0$	**M1**	Obtain 3-term quadratic set equal to 0, obtain at least 1 solution.
	$p = 2 - \sqrt{2}$ or 0.586	**A1**	CAO
		4	

123. 9709_s21_ms_61 Q: 3

Question	Answer	Marks	Guidance
	$1-\frac{20}{27}$ or $\frac{20}{27}-\frac{1}{2}$ $\frac{20}{27}-\left(1-\frac{20}{27}\right)$ or $\left(\frac{20}{27}-\frac{1}{2}\right)$	M1	For either expression seen.
	$\frac{13}{27}$	A1	OE. Accept 0.481 or 0.482.
		2	

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124. 9709_s21_ms_61 Q: 6

Question	Answer	Marks	Guidance
	E(X) = 3	B1	N.B. E(X)=108k is B0 until correct k substituted in.
	$k\int_0^6(6x-x^2)\mathrm{d}x = 1$ $k\left[3x^2-\frac{x^3}{3}\right]_0^6$ [= 1]	M1	Attempt integration of f(x) and =1. Ignore limits at this stage.
	$k\left(108-\frac{216}{3}\right) = 1$ $k = \frac{3}{108}$ or $\frac{1}{36}$	A1	
	$'\frac{3}{108}'\int_0^6(6x^3-x^4)\mathrm{d}x$ $= \frac{3}{108}\left[\frac{3x^4}{2}-\frac{x^5}{5}\right]_0^6 = 10.8$	*M1	Attempt integration of *their* $k \times x^2$f(x). Ignore limits at this stage. Accept in terms of k.
	'10.8' – '3'^{2}	DM1	*Their* 10.8 (from use of limits 0 and 6) minus *their* (E(X))^2. Accept in terms of k: $388.8k-(108k)^2$
	$\frac{9}{5}$ or 1.8	A1	CWO. Must be convincingly obtained as AG.
		6	

125. 9709_s21_ms_62 Q: 3

Question	Answer	Marks	Guidance
(a)	$\frac{1}{2}p(p-1) = 1$	M1	For area =1 For verification methods accept $\frac{1}{2}\times 2\times 1 = 1$ or $\frac{1}{2}\times 2\times(p-1) = 1$ or $\frac{1}{2}\times 1\times p = 1$ as indication that area=1
	$p = 2$	A1	AG - Convincing method and answer. Must see quadratic rearranged to =0 and no errors seen. N.B. Accept convincing verification methods (e.g. statement such as 'assume p = 2' or 'if p = 2' or 'using p = 2' or showing by clear substitution that p = 2 fits $\frac{1}{2}p(p-1) = 1$ with clear conclusion)
		2	
(b)	Gradient = 2 equation of line is $y = 2x + c$ line passes through (1, 0), hence $c = -2$	M1	Award for attempting equation of line $y=mx+c$ with m = 2, -2, $\frac{1}{2}$ or $-\frac{1}{2}$ and numerical c ($c\neq 0$)
	$y = 2x - 2$	A1	May be seen in **(a)** M1 can be implied by correct answer
	$2\int_1^2(x^2-x)\mathrm{d}x$	M1	For attempting $\int x\mathrm{f}(x)\mathrm{d}x$. Ignore limits, FT *their* equation.
	$2\left[\frac{x^3}{3}-\frac{x^2}{2}\right]_1^2$	A1 FT	Correct integration FT *their* f(x)and correct limits
	$\frac{5}{3}$ or 1.67 (3 sf)	A1	
		5	

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126. 9709_s21_ms_63 Q: 6

Question	Answer	Marks	Guidance
(a)	$P(X > 10) = \int_{10}^{20} \frac{3}{8000}(x-20)^2 dx$	**M1**	Attempt integration of f(x), ignore limits.
	$= \left[\frac{3}{8000} \times \frac{(x-20)^3}{3}\right]_{10}^{20}$ or $\frac{3}{8000}\left[\frac{x^3}{3} - \frac{40x^2}{2} + 400x\right]_{10}^{20}$ $= \frac{1}{8000}\left[0 - (-10)^3\right]$	**M1**	Substitute correct limits 10 to 20 or 1 – … limits 0 to 10 in *their* integral
	$\frac{1}{8}$ or 0.125	**A1**	**SC** Unsupported answer of $\frac{1}{8}$ scores B1 only
	$(\frac{1}{8})^2 = \frac{1}{64}$ or 0.0156 (3 sf)	**B1 FT**	FT *their* P($X > 10$) dependent on first M1 gained
		4	

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Question	Answer	Marks	Guidance
(b)	$\int_0^{20} \frac{3}{8000}(x^3 - 40x^2 + 400x)dx$	**M1**	Attempt integration of xf(x). Ignore limits.
	$\frac{3}{8000}\left[\frac{x^4}{4} - \frac{40x^3}{3} + \frac{400x^2}{2}\right]_0^{20}$ or $\left(\frac{3x}{8000} \times \frac{(x-20)^3}{3}\right) - \frac{1}{8000}\left(\frac{(x-20)^4}{4}\right)$	**A1**	Correct integral (by expanding or by parts)
	$\frac{3}{8000}\left[\frac{160000}{4} - \frac{40 \times 8000}{3} + 200 \times 400\right]$	**M1**	Subst correct limits in their (4th degree) integral
	5	**A1**	
		4	
(c)	$\int_0^m \frac{3}{8000}(x-20)^2 dx = 0.5$	**M1**	Attempt to integrate f(x) and equate to 0.5. Ignore limits.
	$\left[\frac{3}{8000} \times \frac{(x-20)^3}{3}\right]_0^m = 0.5$ or $\frac{3}{8000}\left[\frac{x^3}{3} - \frac{40x^2}{2} + 400x\right]_0^m = 0.5$ $\frac{1}{8000}\left[(m-20)^3 - (-20)^3\right] = 0.5$	**M1**	Attempt integral and substitute limits 0 and m or m and 20 and = 0.5
	$(m - 20)^3 = -4000$	**A1**	AG. Found convincingly.
	$(m = 20 + \sqrt[3]{-4000})$ $m = 4.13$ (3 sf)	**B1**	
		4	

Question	Answer	Marks	Guidance
(d)	Doesn't allow for trains > 20 mins late or Doesn't allow for trains being early	**B1**	or any relevant comment e.g. trains on Sun may be different to trains on Mon
		1	

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127. 9709_w21_ms_61 Q: 4

Question	Answer	Marks	Guidance
(a)	$\frac{1}{18}\int_0^{1.2}(9-x^2)\mathrm{d}x$	**M1**	Attempt to integrate f(x), ignore limits. Must see an increase of power.
	$\frac{1}{18}\left[9x-\frac{x^3}{3}\right]_0^{1.2}$	**A1**	Correct integration and correct limits.
	$\frac{71}{125}$ or 0.568	**A1**	SC unsupported answer scores **B2** only.
		3	

Question	Answer	Marks	Guidance
(b)	$\frac{1}{18}\int_0^3(9x-x^3)\mathrm{d}x$	**M1**	Attempt to integrate xf(x), ignore limits. Must see an increase of power.
	$\frac{1}{18}\left[\frac{9x^2}{2}-\frac{x^4}{4}\right]_0^3$	**A1**	Correct integration and correct limits.
	$\frac{9}{8}$ or 1.125	**A1**	SC unsupported answer scores **B2** only.
		3	
(c)	$\frac{1}{18}\left[9x-\frac{x^3}{3}\right]_0^m=0.5$	**M1**	Attempt to integrate f(x) with correct limits and = 0.5. OE. Accept limits m to 3. Allow x instead of m.
	$\frac{1}{18}\left[9m-\frac{m^3}{3}\right]-0.5=0$	**A1**	Any correct cubic equation in m or x.
	$m^3-27m+27=0$	**A1**	AG. Correctly obtain this equation. No errors seen.
		3	

128. 9709_w21_ms_62 Q: 7

Question	Answer	Marks	Guidance
(a)(i)	$k\int_0^2(4x-x^2)\mathrm{d}x=1$	**M1**	Attempt integral f(x) and = 1. Ignore limits (must see a power increase for attempted integration).
	$k\left[\frac{4x^2}{2}-\frac{x^3}{3}\right]_0^2=1$	**A1**	Correct integration and correct limits.
	$k\times\frac{16}{3}=1\left[k=\frac{3}{16}\right]$	**A1**	OE AG Convincingly obtained. At least one interim step. No errors seen.
		3	

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Question	Answer	Marks	Guidance
(a)(ii)	$\frac{3}{16}\int_0^2 (4x^2 - x^3)\mathrm{d}x$	**M1**	Attempt integral $x\mathrm{f}(x)$. Ignore limits. (must see a power increase for attempted integration). Condone missing k.
	$\frac{3}{16}\left[\frac{4x^2}{2} - \frac{x^3}{3}\right]_0^2$	**A1**	Correct integration and correct limits. Condone missing k.
	$\frac{5}{4}$	**A1**	Unsupported correct answer scores **SC B2** only.
		3	
(b)	Symmetrical frequency density graph, 0 to 5, showing area 0.2 to left of a	**B1**	With a to the left of centre.
	Either 0.2 between $5–a$ and 5-or 0.8 between 0 and $5–a$	**B1**	Shown on graph or stated ($5–a$ seen or implied). a must be non-numerical.
	$[P(2.5<Y<5–a)] = 0.3$	**B1**	Must be clearly final answer. a must be non-numerical.
		3	

129. 9709_w21_ms_63 Q: 4

Question	Answer	Marks	Guidance
(a)	$\frac{1}{18}\int_0^{1.2} (9 - x^2)\mathrm{d}x$	**M1**	Attempt to integrate f(x), ignore limits. Must see an increase of power.
	$\frac{1}{18}\left[9x - \frac{x^3}{3}\right]_0^{1.2}$	**A1**	Correct integration and correct limits.
	$\frac{71}{125}$ or 0.568	**A1**	SC unsupported answer scores **B2** only.
		3	

Question	Answer	Marks	Guidance
(b)	$\frac{1}{18}\int_0^3 (9x - x^3)\mathrm{d}x$	**M1**	Attempt to integrate $x\mathrm{f}(x)$, ignore limits. Must see an increase of power.
	$\frac{1}{18}\left[\frac{9x^2}{2} - \frac{x^4}{4}\right]_0^3$	**A1**	Correct integration and correct limits.
	$\frac{9}{8}$ or 1.125	**A1**	SC unsupported answer scores **B2** only.
		3	
(c)	$\frac{1}{18}\left[9x - \frac{x^3}{3}\right]_0^m = 0.5$	**M1**	Attempt to integrate f(x) with correct limits and = 0.5. OE. Accept limits m to 3. Allow x instead of m.
	$\frac{1}{18}\left[9m - \frac{m^3}{3}\right] - 0.5 = 0$	**A1**	Any correct cubic equation in m or x.
	$m^3 - 27m + 27 = 0$	**A1**	AG. Correctly obtain this equation. No errors seen.
		3	

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130. 9709_m20_ms_62 Q: 5

Question	Answer	Marks	Guidance
(a)	$\frac{3}{4000}\int_5^{10}(100-x^2)\mathrm{d}x$ $=\frac{3}{4000}[100x - \frac{x^3}{3}]_5^{10}$	**M1**	Attempt integration of f(x), ignore limits. Condone omission of $\frac{3}{4000}$
	$=\frac{3}{4000}(1000 - \frac{1000}{3} - 500 + \frac{125}{3})$	**M1**	Correct limits 5 and 10. OE SOI
	$= 0.156$ (3 sf) or $\frac{5}{32}$	**A1**	For fully correct working seen including substitution of limits
		3	
(b)	$\frac{3}{4000}\int_p^{10}(100-x^2)\mathrm{d}x = \frac{1}{4}$	**M1**	Attempt integration of f(x) with any limits and $=\frac{1}{4}$ or $=\frac{3}{4}$ seen. Condone omission of $\frac{3}{4000}$
	$\frac{3}{4000}[100x - \frac{x^3}{3}]_p^{10} = \frac{1}{4}$	**A1**	Correct integration with correct limits seen (or implied for limits p and 10) and $=\frac{1}{4}$ OE Condone omission of $\frac{3}{4000}$
	$\frac{3}{4000}(1000 - \frac{1000}{3} - 100p + \frac{p^3}{3}) = \frac{1}{4}$	**M1**	Attempt substitution correct limits in their integration of f(x). Accept limits 0 to p if clearly seen, accept limits –10 and p. Substitution must be seen.
	e.g. $\frac{2000}{3} - 100p + \frac{p^3}{3} = \frac{1000}{3}$ $p^3 - 300p + 1000 = 0$	**A1**	AG No errors seen
		4	

Question	Answer	Marks	Guidance
(c)	Curve is symmetrical about $x = 0$	**B1**	May be implied by sketch. No contradictions or integrate f(x) between $-q$ and $+q$ and equate to 0.5 leading to $q^3 - 300q + 1000 = 0$ oe
	$q = 3.47$	**B1**	
		2	

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131. 9709_s20_ms_61 Q: 6

Question	Answer	Marks
(a)	'Tails down' parabola only from $x = 0$ to 20 shown	B1
		1
(b)	Symmetrical	B1
		1
(c)	$\frac{3}{4000}\int_0^{20}\left(20t^3 - t^4\right)\mathrm{d}x = \frac{3}{4000}\left[20\frac{t^4}{4} - \frac{t^5}{5}\right]_0^{20}$	M1
	$\mathrm{Var}(T) = \frac{3}{4000}\times 160000 - 10^2$	M1
	20	A1
		3
(d)	$(p - 0.5)\times 2$ or $1 - 2(1 - p)$	M1
	$2p - 1$	A1
		2

Question	Answer	Marks
(e)	$\frac{3}{4000}\int_8^{12}\left(20t - t^2\right)\mathrm{d}x$	M1
	$\frac{3}{4000}\left[20\frac{t^2}{2} - \frac{t^3}{3}\right]_8^{12} = \frac{3}{4000}\left(1440 - 576 - 640 + \frac{512}{3}\right)$	A1
	$\frac{37}{125}$ or 0.296	A1
		3
(f)	Does not allow times greater than 20 minutes	B1
		1

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132. 9709_s20_ms_62 Q: 6

Question	Answer	Marks
(a)	$\int_1^a \frac{k}{x^2}\,dx = 1$	M1
	$k\left[-\frac{1}{x}\right]_1^a = 1$ $k\left[1-\frac{1}{a}\right] = 1$	A1
	$k\left[\frac{a-1}{a}\right] = 1$ $\left(k = \frac{1}{a-1}\right)$ **AG**	A1
		3
(b)	$\frac{a}{a-1}\int_1^a \frac{1}{x}\,dx$	M1
	$\frac{a}{a-1}\left[\ln x\right]_1^a$	A1
	$\frac{a\ln a}{a-1}$	A1
		3

Question	Answer	Marks
(c)	$\frac{a}{a-1}\int_1^m \frac{1}{x^2}\,dx = \frac{3}{5}$	M1
	$\frac{a}{a-1}\left[-\frac{1}{x}\right]_1^m = \frac{3}{5}$ $\frac{a}{a-1}\left[1-\frac{1}{m}\right] = \frac{3}{5}$	A1
	$\frac{1}{m} = 1 - \frac{3(a-1)}{5a}$ or $\frac{1}{m} = \frac{2a+3}{5a}$	A1
	$m = \frac{5a}{2a+3}$	A1
		4

133. 9709_s20_ms_63 Q: 6

Question	Answer	Marks
(a)	7.5	B1
		1
(b)	$\frac{6}{125}\int_5^{10}(-x^4+15x^3-50x^2)\,dx$	M1
	$\frac{6}{125}\left[-\frac{x^5}{5}+15\frac{x^4}{4}-50\frac{x^3}{3}\right]_5^{10}$ – '7.5'²	M1
	1.25 (3 sf)	A1
		3

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Question	Answer	Marks
(c)	$\frac{6}{125}\int_5^6(-x^2+15x-50)\mathrm{d}x$ $\frac{6}{125}\left[-\frac{x^3}{3}+15\frac{x^2}{2}-50x\right]_5^6$	**M1**
	$\frac{6}{125}(-102+\frac{625}{6})$ oe	**M1**
	0.104	**A1**
	$2\times('0.104'\times(1-'0.104')$	**M1**
	0.186 (3 sf)	**A1ft**
		5

134. 9709_w20_ms_61 Q: 4

Question	Answer	Marks	Guidance
(a)	$(k=)\ \frac{1}{a}$	**B1**	
		1	
(b)	(Mean =) *their* $k\times\frac{a^2}{2}\ \left(=\frac{a}{2}\right)$	**B1 FT**	OE seen. FT *their k*
	$\frac{1}{a}\int_0^a x^2\mathrm{d}x\left(=\frac{'a^2'}{3}\right)$	**M1**	Attempt at correct integral and use of limits. Accept in terms of *k* or incorrect *k*.
	$-\left(\frac{'a'}{2}\right)^2\left(=\frac{a^2}{12}\right)$	**M1**	For subtracting mean^2, allow if integration not complete. FT incorrect values of *k*.
	$\left(\frac{a^2}{12}=3\right)\ a=6$	**A1**	Can be in terms of *k*.
		4	

135. 9709_w20_ms_62 Q: 3

Question	Answer	Marks	Guidance
(a)	$\frac{1}{2}\times3\times c=1$ ($c=\frac{2}{3}$ **AG**)	**B1**	Must see this line, oe, and result (Alternative method involving equation of line $\left(y=\left(\frac{-c}{3}\right)x+c\right)$ must have all relevant working shown)
		1	
(b)	$\left(\frac{1}{3}\right)^2$	**M1**	Allow M1 for $\frac{1}{3}$ seen as a linear scale factor or Attempt to find equation of line (of form y = mx + c where c ≠ 0) and interval from 2 to 3 OE or Attempt to find the point (2, $\frac{2}{9}$) using the equation of the line (of form y = mx +c where c ≠ 0) and then use area of triangle
	$=\frac{1}{9}$ or 0.111(3sf)	**A1**	
		2	

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Question	Answer	Marks	Guidance
(c)	Equation of line is $y = \frac{2}{3} - \left(\frac{2}{3} \div 3\right)x$	*M1	OE Must be of form y = mx + c (c ≠ 0).
	$E(X) = \int_0^3 \left(\frac{2}{3}x - \frac{2}{9}x^2\right) dx$	DM1	Attempt integration $x \times$ *their* f(x), ignore limits
	$= \left[\frac{x^2}{3} - \frac{2x^3}{27}\right]_0^3$	A1 FT	Correct integration and limits. FT *their* equation of line
	= 1	A1	
		4	

136. 9709_w20_ms_63 Q: 4

Question	Answer	Marks	Guidance
(a)	$(k =) \frac{1}{a}$	B1	
		1	
(b)	(Mean =) *their* $k \times \frac{a^2}{2}$ $\left(= \frac{a}{2}\right)$	B1 FT	OE seen. FT *their k*
	$\frac{1}{a}\int_0^a x^2 dx \left(= \frac{'a^2'}{3}\right)$	M1	Attempt at correct integral and use of limits. Accept in terms of k or incorrect k.
	$-\left(\frac{'a}{2}'\right)^2 \left(= \frac{a^2}{12}\right)$	M1	For subtracting mean^2, allow if integration not complete. FT incorrect values of k.
	$\left(\frac{a^2}{12} = 3\right)$ $a = 6$	A1	Can be in terms of k.
		4	

137. 9709_m19_ms_72 Q: 7

Question	Answer	Marks	Guidance
(i)	$\sqrt{2}\int_{\frac{\pi}{6}}^{\frac{\pi}{4}} \cos x dx$ $= \sqrt{2}\,[\sin x]_{\frac{\pi}{6}}^{\frac{\pi}{4}}$	M1	Attempt integ f(x) with correct limits
	$= \frac{2-\sqrt{2}}{2}$ oe or 0.293 (3 sf)	A1	SC Final answer of 0.707 scores B1sc
		2	
(ii)	$\sqrt{2}\int_0^m \cos x dx = 0.5$	M1	Attempt to integ f(x) & = 0.5. Ignore limits. Condone missing √2
	$\sqrt{2}\,[\sin x]_0^m = 0.5$ $\sqrt{2}\,\sin m = 0.5$	A1	Correct integral and limits 0 to unknown & = 0.5 Condone missing √2
	$\sin m = \frac{1}{2\sqrt{2}}$ oe	M1	For rearranging their expression to the form sin$m$=… (sin$m$ = 0.35355.... or 0.354) seen or implied
	m = 0.361 (3 sfs)	A1	No errors seen (Note 20.705 can score M1 A1 M1 A0)
		4	

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Question	Answer	Marks	Guidance
(iii)	$\sqrt{2}\int_0^{\frac{\pi}{4}} x\cos x\,dx$	M1	Attempt to integ $xf(x)$. Ignore limits. Condone missing $\sqrt{2}$
	$= \sqrt{2}\ \{[x(\sin x)]_0^{\frac{\pi}{4}} - \int_0^{\frac{\pi}{4}} \sin x\,dx\ \}$	M1	Attempt to integ by parts leading to expression of form $\pm x\sin x \pm \cos x$ with correct limits
	$= \sqrt{2}\ \{\frac{\pi}{4\sqrt{2}} - 0 - [-\cos x]_0^{\frac{\pi}{4}}\}$	A1	For $\sqrt{2}(x\sin x - (-\cos x))$ with correct limits
	$= \sqrt{2}\ \{\frac{\pi}{4\sqrt{2}} + \cos\frac{\pi}{4} - 1\}$ $= \frac{\pi}{4} + 1 - \sqrt{2}$ oe or 0.371 (3 sf)	A1	
		4	

138. 9709_s19_ms_71 Q: 4

Question	Answer	Marks	Guidance
(a)(i)	$0.5 \times 1/a = (\frac{0.5}{a})$	M1	Or attempt to integrate f(x) (=1/a) between 0 and 0.5
	$= \frac{1}{2a}$ oe	A1	Accept 0.5/a for A1
		2	
(a)(ii)	$\frac{a}{2}$	B1	
		1	
(a)(iii)	$\int_0^a \frac{x^2}{a}\,dx - (\text{`}\frac{a}{2}\text{'})^2$	M1	Integ their x^2f(x) from 0 to a and sub their mean^2
	$\text{Var}(X) = \frac{a^2}{3} - \frac{a^2}{4}$ $(\text{Var}(X) = \frac{a^2}{12}$ **AG**)	A1	Must see this line oe
		2	
(b)	$\int_2^b \frac{3}{2(t-1)^2}\,dt$	M1	Attempt integ g(t) ignore limits
	$\left[-\frac{3}{2(t-1)}\right]_2^b$	A1	Correct integral
	$-\frac{3}{2}(\frac{1}{(b-1)} - 1) = \frac{3}{4}$ $(1 - \frac{1}{(b-1)} = \frac{1}{2})$	M1	Attempt subst correct limits in their integ and = $\frac{3}{4}$
	$b = 3$	A1	
		4	

139. 9709_s19_ms_72 Q: 6

Question	Answer	Marks	Guidance
(i)	$a\int_1^b \frac{1}{x^2}dx = 1$	M1	Attempt int f(x) and = 1, ignore limits
	$a[-\frac{1}{x}]_1^b = 1$	A1	correct integ and limits = 1
	$a[1 - \frac{1}{b}] = 1$ or $a \times \frac{b-1}{b} = 1$ $b = \frac{a}{a-1}$ **AG**	A1	No errors seen
		3	

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Question	Answer	Marks	Guidance
(ii)	$a\int_1^{\frac{3}{2}} \frac{1}{x^2}dx = \frac{1}{2}$ $a\left[-\frac{1}{x}\right]_1^{\frac{3}{2}} = \frac{1}{2}$	**M1**	Attempt int f(x) with limits 1 to $\frac{3}{2}$ and = $\frac{1}{2}$
	$a\left[1-\frac{2}{3}\right] = \frac{1}{2}$	**A1**	oe correct equn in a
	$a = \frac{3}{2}$, $b = 3$	**A1**	Both
		3	
(iii)	$\frac{3}{2}\int_1^3 \frac{1}{x}dx$	**M1**	Attempt int xf(x), ignore limits – condone missing a
	$= \frac{3}{2}\left[\ln x\right]_1^3$	**A1**	**FT** Correct integ and *their* limits 1 to b – condone missing a
	$= \frac{3}{2}\ln 3$ or 1.65 (3 sf)	**A1**	**FT** *their a* and *b* (valid *b* i.e. >1)
		3	

140. 9709_s19_ms_73 Q: 6

Question	Answer	Marks	Guidance
(i)	$\frac{3}{a^3}\int_0^a x^2dx$ $(= \frac{3}{a^3}\left[\frac{x^3}{3}\right]_0^a)$	**M1**	Attempt to integrate f(x) with limits 0 and a (condone missing $\frac{3}{a^3}$)
	$= \frac{3a^3}{3a^3}$	**A1**	$\frac{3a^3}{3a^3} - 0$ or better seen
	= 1 Hence f is pdf for all a	**A1**	Answer = 1 and comment
		3	
(ii)	$\frac{3}{a^3}\int_0^2 x^2dx = 0.5$ $\frac{3}{a^3}\left[\frac{x^3}{3}\right]_0^2 = 0.5$	**M1**	Attempt to integrate f(x)=0.5, limits 0 and 2 oe, condone missing $\frac{3}{a^3}$
	$\frac{3}{a^3}\times\frac{8}{3} = 0.5$ oe	**A1**	$\frac{2^3}{3} - 0$ or better, condone missing $\frac{3}{a^3}$
	$a^3 = 16$ or $a = \sqrt[3]{16}$ (= 2.52 **AG**)	**A1**	Convincingly obtained Note: Attempt to verify 2.52, M1 as stated except not equated to 0.5.A1 as stated, A1 for evaluation to 0.499..apprx 0.5
		3	

Question	Answer	Marks	Guidance
(iii)	$\frac{3}{16}\int_0^{2.52} x^3dx$ or $\frac{3}{16}\int_0^a x^3dx$ $= \frac{3}{16}\left[\frac{x^4}{4}\right]_0^{2.52}$ or $\frac{3}{16}\left[\frac{x^4}{4}\right]_0^a$	**M1**	Attempt integ xf(x), correct limits, condone missing $\frac{3}{a^3}$
	$= \frac{3}{16}\times\frac{40.317}{4}$	**A1**	$\frac{2.52^4}{4} - 0$ or better, condone missing $\frac{3}{a^3}$
	= 1.89 (3 sf)	**A1**	
		3	

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141. 9709_w19_ms_72 Q: 4

Question	Answer	Marks	Guidance
(i)	$\frac{1}{2}\times a\times\frac{a}{2}=1$ **or** $\frac{1}{2}\int_0^a x\,dx=1$ $\frac{a^2}{4}=1$ OE	**M1**	Attempt at triangle area or integral f(x) **and** = 1,
	$a=2$	**A1**	
		2	
(ii)	$\frac{1}{2}\int_0^2 x^2\,dx$	**M1**	Attempt integral xf(x)
	$=\left[\frac{x^3}{6}\right]_0^2$	**M1**	Correct integral and limits 0 to their 'a'
	$\left(=\frac{8}{6}\right)=\frac{4}{3}$	**A1**	AG CWO
		3	

Question	Answer	Marks	Guidance
(iii)	$P\left(X<\frac{4}{3}\right)=\frac{1}{2}\int_0^{\frac{4}{3}} x\,dx$	**M1**	Attempt integral f(x) between correct limits
	$=\frac{4}{9}$	**A1**	or $\frac{5}{9}$
	$P(E(X)<X<m)=\frac{1}{2}-\text{'}\frac{4}{9}\text{'}$	**M1**	or $\frac{5}{9}-\frac{1}{2}$
	$\frac{1}{18}$	**A1**	
	Alternative method for question 4(iii)		
	Attempt to find m	**M1**	
	$m=\sqrt{2}$	**A1**	
	Integrate f(x) between $\frac{4}{3}$ and '$\sqrt{2}$'	**M1**	
	$\frac{1}{18}$	**A1**	
		4	

142. 9709_w19_ms_73 Q: 6

Question	Answer	Marks	Guidance
(i)	$k\int_0^3\left(3x-x^2\right)dx=1$	**M1**	Attempt to integrate f(x) and = 1
	$k\left[\frac{3}{2}x^2-\frac{x^3}{3}\right]_0^3$ $k\left(\frac{27}{2}-\frac{27}{3}\right)=1$	**A1**	Correct integral and limits
	$k=\frac{2}{9}$	**A1**	AG No errors seen
		3	

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Question	Answer	Marks	Guidance
(ii)	$\frac{2}{9}\int_1^2 (3x - x^2)\,dx = \frac{2}{9}\left[\frac{3}{2}x^2 - \frac{x^3}{3}\right]_1^2 = \frac{2}{9}\times\left(6 - \frac{8}{3} - \frac{3}{2} + \frac{1}{3}\right)$	**M1**	Attempt to integrate f(x) dx with limits 1 and 2 OE
	$\frac{13}{27}$ or 0.481 (3 sf)	**A1**	
		2	
(iii)	$y = 3x - x^2$ symmetrical about $x = \frac{3}{2}$	**M1**	Attempt $\frac{2}{9}\int_0^3 (3x^2 - x^3)\,dx$
	$E(X) = \frac{3}{2}$	**A1**	
	$\frac{2}{9}\int_0^3 (3x^3 - x^4)\,dx$	**M1**	Attempt to integrate x^2f(x)
	$= \frac{2}{9}\left[\frac{3x^4}{4} - \frac{x^5}{5}\right]_0^3 \left(= \frac{2}{9}\times\frac{243}{20} = \frac{27}{10}\right)$ $\frac{'27'}{10} - \left(\frac{'3'}{2}\right)^2$	**M1**	Subtract their $(E(X))^2$ from their integral x^2f(x) with correct limits substituted
	$\frac{9}{20}$ or 0.45	**A1**	
		5	

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143. 9709_m18_ms_72 Q: 6

Question	Answer	Marks	Guidance
(i)	$1 - 6\int_{0.3}^{0.7}\left(x - x^2\right)\mathrm{d}x$	**M1**	or $2 \times 6\int_{0}^{0.3}\left(x - x^2\right)\mathrm{d}x$ or similar correct expression before integration
	$1 - \left[6(\frac{x^2}{2} - \frac{x^3}{3})\right]_{0.3}^{0.7}$	**A1**	or similar correct expression after integration
	$1 - 6\left[\frac{0.7^2}{2} - \frac{0.7^3}{3} - \frac{0.3^2}{2} + \frac{0.3^3}{3}\right]$	**M1**	Attempt subst correct limits in this or other correct expression
	= 0.432 (or 54/125)	**A1**	(SR1 Omission of '1–' scores **B2** for 0.568 or 71/125) (SR2 Omission of '2x' scores **B2** for 0.216 or 27/125)
		4	
(ii)	Correct shape between $x = 0$ and 1	**B1**	No curve outside this range.
	E(X) = 0.5	**B1**	
		2	
(iii)	$6\int_0^1\left(x^3 - x^4\right)\mathrm{d}x$ $= \left[6\left(\frac{x^4}{4} - \frac{x^5}{5}\right)\right]_0^1$	**M1**	attempt int x^2f(x), ignore limits
	$6[\frac{1^4}{4} - \frac{1^5}{5}]$ (= 0.3)	**M1**	attempt subst correct limits in correct integ
	Var(X) = '0.3' – '0.5'^{2} = 0.05	**A1FT**	FT their mean, dep their Var(X) > 0
		3	

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144. 9709_s18_ms_71 Q: 6

Question	Answer	Marks	Guidance
(i)	$\int_5^{10} \frac{k}{x^2}\,dx = 1$	**M1**	Attempt integration f(x) and '= 1'; ignore limits
	$\left[-\frac{k}{x}\right]_5^{10} = 1$ oe $(\frac{k}{5} - \frac{k}{10} = 1)$	**A1**	Correct integration and limits and '= 1'
	$k = 10$ **AG**	**A1**	No errors seen
		3	
(ii)	$10\int_5^{10} \frac{1}{x}\,dx$ $10\left[\ln x\right]_5^{10}$	**M1**	Attempt integ xf(x); ignore limits. or 10(ln 10 – ln 5)
	$= 10\ln 2$ **AG**	**A1**	No errors seen
		2	
(iii)	$10\int_9^{10} \frac{1}{x^2}\,dx$ $(10\left[-\frac{1}{x}\right]_9^{10})$	**M1**	Attempt integ f(x) with correct limits
	$10\left[-\frac{1}{10} + \frac{1}{9}\right]$	**A1**	Substitute correct limits in correct integration
	$= \frac{1}{9}$ or 0.111 (3 sf)	**A1**	
		3	
(iv)	$\int_5^a \frac{k}{x^2}\,dx = 0.6$ $10\left[-\frac{1}{x}\right]_5^a = 0.6$	**M1**	Attempt integration of f(x) with correct limits and = 0.6
	$10[\frac{1}{5} - \frac{1}{a}] = 0.6$	**A1**	Substitute correct limits in correct integration
	$a = \frac{50}{7}$ or 7.14 (3 sf)	**A1**	
		3	

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145. 9709_s18_ms_72 Q: 5

Question	Answer	Marks	Guidance
(i)	$\frac{1}{2}\times a\times b = 1$	**M1**	Attempt Δ area = 1 or $\int(b–bx/a)\,dx = 1$ with correct limits
	$b = \frac{2}{a}$	**A1**	
		2	
(ii)	grad = $-\frac{2}{a^2}$ or $-\frac{b}{a}$	**B1**	allow without '–' sign (could be implied or seen in **(i)**)
	$y - (\frac{2}{a})$ = grad × x or y = grad × $(x – a)$	**M1**	correct use of $y = mx + c$ or $y - y_1 = m(x – x_1)$ with (0,b) or (a,0) including attempt at substitution of their b
	$y - (\frac{2}{a}) = -\frac{2}{a^2}x$ or $y = -\frac{2}{a^2}(x – a)$ and $y = \frac{2}{a} - \frac{2}{a^2}x$ **AG**	**A1**	No errors seen
		3	

Question	Answer	Marks	Guidance
(iii)	$\int_0^a (\frac{2}{a}x - \frac{2}{a^2}x^2)dx$	**M1**	Attempt int $xf(x)$ ignore limits
	$= [\frac{1}{a}x^2 - \frac{2}{3a^2}x^3]_0^a$	**A1**	Correct integration ignore limits
	$a - \frac{2}{3}a = 0.5$	**M1**	Sub correct limits into their integral and = 0.5
	$a = 1.5$	**A1**	
		4	

146. 9709_s18_ms_73 Q: 7

Question	Answer	Marks	Guidance
(i)	$k\int_1^2 (\frac{1}{x^2} + \frac{1}{x^3})\,dx = 1$	**M1**	Attempt integ f(x) & '= 1'; ignore limits
	$k\left[-\frac{1}{x} - \frac{1}{2x^2}\right]_1^2 = 1$	**A1**	Correct integral & limits & '= 1'
	$k\left[-\frac{1}{2} - \frac{1}{8} + 1 + \frac{1}{2}\right] = 1$ $k = \frac{8}{7}$ **AG**	**A1**	Sufficient working must be shown, no errors seen
		3	
(ii)	$\frac{8}{7}\int_1^2 (\frac{1}{x} + \frac{1}{x^2})\,dx$	**M1**	Attempt integ $xf(x)$, ignore limits
	$= \frac{8}{7}\left[\ln x - \frac{1}{x}\right]_1^2$	**A1**	Correct integral & limits, condone missing k
	$= \frac{8}{7}(\ln 2 + \frac{1}{2})$ or 1.36 (3 sf)	**A1**	
		3	

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Question	Answer	Marks	Guidance
(iii)	$\frac{8}{7}\int_1^{1.5}(\frac{1}{x^2}+\frac{1}{x^3})\,dx$ $=\frac{8}{7}\left[-\frac{1}{x}-\frac{1}{2x^2}\right]_1^{1.5}$	**M1**	Attempt integration f(x) between 1 and 1.5 or between 1.5 and 2
	$=\frac{44}{63}$ or 0.698.....	**A1**	Or $\frac{19}{63}$ or 0.302
	$'\frac{44}{63}'(1-'\frac{44}{63}')^2$	**M1**	FT their $\frac{44}{63}$
	× 3	**M1**	Independent provided answer is <1
	= 0.191	**A1**	
		5	

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147. 9709_w18_ms_71 Q: 6

Question	Answer	Marks	Guidance
(i)	$k\int_2^6 x^{-1}\mathrm{d}x = 1$	**M1**	Attempt integrate f(x) & = 1. Ignore limits
	$k\left[\ln x\right]_2^6 = 1$ $k(\ln 6 - \ln 2) = 1$ or $k\ln 3 = 1$ $k = \frac{1}{\ln 3}$ **AG**	**A1**	correct sub of correct limits in correct integral leading to correct ans. No errors seen.
		2	
(ii)	$\frac{1}{\ln 3}\int_2^6 1\ \mathrm{d}x$	**M1**	Attempt integ xf(x). Ignore limits
	$= \frac{1}{\ln 3}\left[x\right]_2^6$ $(= \frac{1}{\ln 3}(6-2))$	**A1**	Correct integral and limits
	$= \frac{4}{\ln 3} = 3.64$ **AG**	**A1**	No errors seen
		3	
(iii)	$\mathrm{P}(X < \mathrm{E}(X)) = \frac{1}{\ln 3}\int_2^{3.64} x^{-1}\mathrm{d}x$	**M1**	Attempt integ f(x) from 2 to $\frac{4}{\ln 3}$ or 3.64 oe
	$= \frac{1}{\ln 3}\left[\ln x\right]_2^{3.64}$ $= \frac{1}{\ln 3}(\ln 3.64 - \ln 2)$ $(= 0.545)$	**A1**	Correct sub correct limits into correct integral
	P($m < \mathrm{X} < \mathrm{E}(X)$) = "0.545" – 0.5	**M1**	Subt 0.5 from their P($X < \mathrm{E}(X)$) art 0.045 . ft their P($X < \mathrm{E}(X)$ (> 0.5)
	= 0.045 (2 sfs)	**A1**	equivalent method M1 method for median-need 0.5 and limits 2 to m or m to 6 A1 sqrt 12 or 3.464 M1 calc area from "3.464" to 3.64 A1 0.045 or better, not 0.046
		4	

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148. 9709_w18_ms_72 Q: 4

Question	Answer	Marks	Guidance
(i)	$\int_0^a \frac{k}{(x+1)^2}\mathrm{d}x = 1$	**M1**	Any attempt integ f(x) and = 1. Ignore limits
	$-\left[\frac{k}{(x+1)}\right]_0^a = 1$ $-k(\frac{1}{a+1}-1) = 1$	**M1**	Attempt subst correct limits into correct integral
	$k \times \frac{a}{a+1} = 1$ and $k = \frac{a+1}{a}$ **AG**	**A1**	No errors seen
		3	

Question	Answer	Marks	Guidance
(ii)	Max time allowed by model (for runners to finish)	**B1**	Allow: All runners finish in time a or less or Longest time (taken by any runner) oe
		1	
(iii)	$\frac{a+1}{a}\int_0^{0.5} \frac{1}{(x+1)^2}\mathrm{d}x = \frac{3}{4}$	**M1**	Attempt integ f(x) and = $\frac{3}{4}$; ignore limits oe. Condone missing / incorrect k
	$-\frac{a+1}{a}\left[\frac{1}{(x+1)}\right]_0^{0.5} = \frac{3}{4}$ $-\frac{a+1}{a}(\frac{2}{3}-1) = \frac{3}{4}$	**M1**	Attempt subst correct limits into correct integral. Condone missing / incorrect k
	$a = 0.8$ oe	**A1**	
		3	

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149. 9709_w18_ms_73 Q: 6

Question	Answer	Marks	Guidance
(i)	$k\int_2^6 x^{-1}\mathrm{d}x = 1$	**M1**	Attempt integrate f(x) & = 1. Ignore limits
	$k\left[\ln x\right]_2^6 = 1$ $k(\ln 6 - \ln 2) = 1$ or $k\ln 3 = 1$ $k = \frac{1}{\ln 3}$ **AG**	**A1**	correct sub of correct limits in correct integral leading to correct ans. No errors seen.
		2	
(ii)	$\frac{1}{\ln 3}\int_2^6 1\ \mathrm{d}x$	**M1**	Attempt integ xf(x). Ignore limits
	$= \frac{1}{\ln 3}\left[x\right]_2^6$ $(= \frac{1}{\ln 3}(6-2))$	**A1**	Correct integral and limits
	$= \frac{4}{\ln 3} = 3.64$ **AG**	**A1**	No errors seen
		3	
(iii)	$\mathrm{P}(X < \mathrm{E}(X)) = \frac{1}{\ln 3}\int_2^{3.64} x^{-1}\mathrm{d}x$	**M1**	Attempt integ f(x) from 2 to $\frac{4}{\ln 3}$ or 3.64 oe
	$= \frac{1}{\ln 3}\left[\ln x\right]_2^{3.64}$ $= \frac{1}{\ln 3}(\ln 3.64 - \ln 2)$ $(= 0.545)$	**A1**	Correct sub correct limits into correct integral
	P($m < \mathrm{X} < \mathrm{E}(X)$) = "0.545" – 0.5	**M1**	Subt 0.5 from their P($X < \mathrm{E}(X)$) art 0.045 . ft their P($X < \mathrm{E}(X)$ (> 0.5)
	= 0.045 (2 sfs)	**A1**	equivalent method M1 method for median-need 0.5 and limits 2 to m or m to 6 A1 sqrt 12 or 3.464 M1 calc area from "3.464" to 3.64 A1 0.045 or better, not 0.046
		4	

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150. 9709_m17_ms_72 Q: 5

Question	Answer	Marks	Guidance
(a)(i)	$k = 1$	**B1**	
	Total:	**1**	
(a)(ii)	f_2: area > 1 (area ≠ 1)	**B1**	oe
	f_3: includes negative values of f_3	**B1**	oe
	Total:	**2**	
(b)(i)	$6\int_{-a}^{a}(a^2 - x^2)\mathrm{d}x = 1$	**M1**	Integ f(x) = 1, ignore limits
	$6[a^2x - \frac{x^3}{3}]_{-a}^{a} = 1$	**A1**	Correct integral and limits
	$6(2a^3 - \frac{2a^3}{3}) = 1$ $\frac{24a^3}{3} = 1$ or $8a^3 = 1$ $a = 1/2$ **AG**	**A1**	Correctly obtained. No errors seen. (SR Verification scores M1A1 only max 2/3)
	Total:	**3**	

Question	Answer	Marks	Guidance
(b)(ii)	0	**B1**	
	Total:	**1**	
(b)(iii)	$6\int_{-0.5}^{0.5}(\frac{x^2}{4} - x^4)\mathrm{d}x$ $(= 6\left[\frac{x^3}{12} - \frac{x^5}{5}\right]_{-0.5}^{0.5} = 0.05)$ Var = $0.05 - 0^2$	**M1**	attempt int x^2f(x) & correct limits
	= 0.05 oe	**A1**	cao; allow omission of -0^2
	Total:	**2**	

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151. 9709_s17_ms_71 Q: 4

Question	Answer	Marks	Guidance
(i)	Greater area where $x < 7.5$ than $x > 7.5$	B1	Allow Graph higher for $x < 7.5$ than for $x > 7.5$ or Graph decreasing or equiv expl'n
	Total:	1	
(ii)	$\int_5^{10} \frac{k}{x^2}\,dx = 1$	M1	Attempt Integ f(x) = 1 ignore limits
	$k\left[-\frac{1}{x}\right]_5^{10} = 1$ $k \times \frac{1}{10} = 1$	A1	Correct integration and limits
	$k = 10$ AG	A1	No errors seen
	Total:	3	

Question	Answer	Marks	Guidance
(iii)	$10\int_5^{10} \frac{1}{x}\,dx$	M1	Attempt Integ xf(x) ignore limits
	$= 10\left[\ln x\right]_5^{10}$ $= 10(\ln 10 - \ln 5)$	M1	Correct integration and limits
	$= 10\ln 2$ or 6.93 (3 sf)	A1	OE
	Total:	3	
(iv)	$10\int_5^{10} 1\,dx$ – "6.93"^{2}	M1	Attempt (Integ x^2f(x)) – (E(x))^2. No limits **M0**
	= 1.95 (accept 1.96)	A1	*Use of 6.93 gives 1.97* **A0**
	Total:	2	

152. 9709_s17_ms_72 Q: 5

Question	Answer	Marks	Guidance
(i)	$0.5\times1\times h=0.25$ $h = 0.5$ grad = 0.5	M1	P($X < 2$) = 4 × P($X < 1$) **M1**
	f(x) = 0.5x	A1	P($X < 2$) = 1 **A1** $a = 2$ **A1**
	$0.5 \times a \times 0.5a = 1$	M1	$0.5 \times 2 \times h' = 1$ **M1** $h' = 1$
	$a = 2$	A1	grad = 0.5
	P($X < 2$) = 1	A1	f(x) = 0.5x **A1**
	Total:	5	
(ii)	$\int_0^m 0.5x\,dx = 0.5$	M1	Attempt $\int f(x)\,dx = 0.5$ Ignore limits
	$= \left[\frac{x^2}{4}\right]_0^m = 0.5$	A1FT	Correct integration (ft f(x)) & limits = 0.5
	$m = \sqrt{2}$ or 1.41 (3 sf)	A1	or by similarity $m = \frac{1}{\sqrt{2}} \times 2$ **M2** $= \sqrt{2}$ **A1**
	Total:	3	

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153. 9709_s17_ms_73 Q: 6

Question	Answer	Marks	Guidance
(i)	$k\int_0^1 (x-x^2)\,dx = 1$	M1	Attempt integ f(x) and "= 1", ignore limits
	$= k\left[\frac{x^2}{2} - \frac{x^3}{3}\right]_0^1 = 1$	A1	correct integration, limits 0 and 1
	$= k\left[\frac{1}{2} - \frac{1}{3}\right] = 1$ or $\frac{k}{6} = 1$	A1	correctly obtained, no errors seen
	Total:	3	
(ii)	E(X) = 0.5	B1	
	$6\int_0^1 (x^3 - x^4)\,dx$	M1	Attempt integ x^2f(x), limits 0 to 1
	$(= 6\left[\frac{1}{4} - \frac{1}{5}\right] = 0.3)$ "0.3" − "0.5"^{2}	M1	their int x^2f(x) – their (E(X))^2 dep +ve result
	= 0.05(= 1/20)	A1	
	Total:	4	
(iii)	$6\int_{0.4}^1 (x-x^2)\,dx$	M1	ignore limits, eg **M1**for $6\int_{0.4}^2 (x-x^2)\,dx$
	$= 6\{\frac{1}{2} - \frac{1}{3} - (\frac{0.4^2}{2} - \frac{0.4^3}{3})\}$	A1FT	subst correct limits into correct integration
	= 0.648(= 81/125)	A1	condone incorrect "k" for **A1**
	Total:	3	

154. 9709_w17_ms_71 Q: 5

Question	Answer	Marks	Guidance
(i)	$\frac{1}{4}\int_0^2 (x^2+x)\,dx \qquad (= \frac{1}{4}\left[\frac{x^3}{3} + \frac{x^2}{2}\right]_0^2)$	M1	Attempt integ xf(x), ignore limits
	$= \frac{1}{4}(\frac{8}{3}+2) \quad (-0)$	A1	Subst correct limits in correct integration
	$= \frac{7}{6}$ OE or 1.17 (3 sf)	A1	
		3	
(ii)	$\frac{1}{4}\int_0^m (x+1)\,dx = 0.5 \quad (= \frac{1}{4}\left[\frac{x^2}{2} + x\right]_0^m = 0.5)$	M1	attempt integ f(x), limits 0 to unknown (or unknown to 2) and = 0.5
	$\frac{1}{4}(\frac{m^2}{2} + m) = 0.5$ $m^2 + 2m - 4 = 0$ $m = \frac{-2 \pm \sqrt{4+16}}{2}$ OE	A1	a correct equation in m (any form) or $\sqrt{5} - 1$
	m = 1.24	A1	must reject the negative value if there
		3	

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155. 9709_w17_ms_72 Q: 4

Question	Answer	Marks	Guidance
(i)	$k\int_0^a \frac{1}{\sqrt{x}}\mathrm{d}x = 1$	**M1**	Attempt int f(x) and = 1 ignore limits
	$(2k[x^{0.5}]_0^a = 1)$ $2ka^{0.5} = 1$ or $a = \frac{1}{4k^2}$	**A1**	OE; a correct eqn in k & a after sub limits
	$k\int_0^a \frac{x}{\sqrt{x}}\mathrm{d}x = 3$	**M1**	Attempt int xf(x) and = 3
	e.g. $\frac{2}{3}ka^{1.5} = 3$ or $a^3 = \frac{81}{4k^2}$	**A1**	OE; a correct eqn in k and a after sub limits
	e.g. $a^2 = 81$ or e.g. $k^2 = \frac{81}{4\times 9^3}$	**M1**	Attempt eliminate one letter
	$a = 9$	**A1**	Convincingly obtained
	e.g. $k = \frac{9}{54}$ $k = \frac{1}{6}$ AG	**A1**	
		7	

Question	Answer	Marks	Guidance
(ii)	$\frac{1}{6}\int_0^m \frac{1}{\sqrt{x}}\mathrm{d}x = 0.5$ OE	**M1**	Attempt int f(x), unknown limit and = 0.5
	$\frac{1}{3}m^{0.5} = 0.5$	**A1**	a correct equn in m after sub limits
	$m = 2.25$	**A1**	
		3	

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156. 9709_w17_ms_73 Q: 5

Question	Answer	Marks	Guidance
(i)	$\frac{1}{4}\int_0^2 (x^2 + x)\,dx$ $\quad (= \frac{1}{4}\left[\frac{x^3}{3} + \frac{x^2}{2}\right]_0^2)$	**M1**	Attempt integ $xf(x)$, ignore limits
	$= \frac{1}{4}(\frac{8}{3} + 2)$ $\quad (- 0)$	**A1**	Subst correct limits in correct integration
	$= \frac{7}{6}$ OE or 1.17 (3 sf)	**A1**	
		3	
(ii)	$\frac{1}{4}\int_0^m (x+1)\,dx = 0.5$ $\quad (= \frac{1}{4}\left[\frac{x^2}{2} + x\right]_0^m = 0.5)$	**M1**	attempt integ f(x), limits 0 to unknown (or unknown to 2) and = 0.5
	$\frac{1}{4}(\frac{m^2}{2} + m) = 0.5$ $m^2 + 2m - 4 = 0$ $m = \frac{-2 \pm \sqrt{4+16}}{2}$ OE	**A1**	a correct equation in m (any form) or $\sqrt{5} - 1$
	$m = 1.24$	**A1**	must reject the negative value if there
		3	

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157. 9709_m16_ms_72 Q: 7

Q	Answer	Mark	Notes
(a) (i)	E(X) = 1.5	**B1**	
	$\frac{2}{9}\int_0^3 (3x^3 - x^4)\mathrm{d}x$	**M1**	Attempt integ x^2f(x) ignore limits
	$= \frac{2}{9}\left[\frac{3x^4}{4} - \frac{x^5}{5}\right]_0^3$		
	$= \frac{2}{9}\left[\frac{243}{4} - \frac{243}{5}\right]$ (= 2.7)	**M1**	Sub correct limits into correct integral
	Var(X) (= $2.7 - 1.5^2$) = 0.45 oe	**A1**√ [4]	Ft their E(X), but no ft for –ve Var.
(ii)	0.5	**B1** [1]	
(iii)	$(1 - \frac{13}{27}) \div 2$	**M1**	or $\frac{2}{9}\int_2^3 (3x - x^2)\,\mathrm{d}x$ oe
	$= \frac{7}{27}$ or 0.259	**A1** [2]	As final answer
(b)	$\frac{1}{2}\times 2\times 2a = \frac{1}{2}$ or $\int_0^2 ax\mathrm{d}x = \frac{1}{2}$	**M1**	Attempt correct equation in 'a'
	$a = \frac{1}{4}$	**A1**	
	$\frac{1}{2}\times b\times\frac{1}{4}b = 1$ or $\int_0^b \frac{1}{4}x\mathrm{d}x = 1$ or $b = 2\times\sqrt{2}$	**M1**	or $\frac{1}{2}\times b\times ab = 1$ or $\int_0^b ax\mathrm{d}x = 1$ attempt correct equation in (a and) b
	$b = 2\sqrt{2}$	**A1**√ [4]	Allow $b = \sqrt{8}$ or 2.83 (3 sf) Ft incorrect a, both **M**s needed
		Total for paper 50	

158. 9709_s16_ms_71 Q: 6

Q	Answer	Mark	Notes
(i)	2 m	**B1** [1]	allow without units
(ii)	$k\int_0^2 x^2(2-x)\mathrm{d}x = 1$	**M1**	attempt integ f(x) and '= 1'. Ignore limits
	$k\left[\frac{2x^3}{3} - \frac{x^4}{4}\right]_0^2$	**A1**	correct integration and limits
	$k\times\left[\frac{16}{3} - 4\right] = 1$ or $k\times\frac{4}{3} = 1$ oe		
	$k = \frac{3}{4}$ **AG**	**A1** [3]	No errors seen
(iii)	$\frac{3}{4}\int_0^2 x^3(2-x)\mathrm{d}x$	**M1**	attempt integ xf(x), condone missing k
	$= \frac{3}{4}\times\left[\frac{2x^4}{4} - \frac{x^5}{5}\right]_0^2$	**A1**	correct integration and limits, condone missing k
	1.2 m oe	**A1** [3]	allow without units

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Q	Answer	Mark	Notes
(iv)	$\frac{3}{4}\int_0^1 x^2(2-x)\mathrm{d}x$ $(=\frac{3}{4}\times(\frac{2}{3}-\frac{1}{4}))$ $=\frac{5}{16}$ or 0.3125 oe $400\times\frac{5}{16}=125$	**M1** **A1** **A1 ft** [3]	attempt integ f(x), 0 to 1, condone missing k ft their $\frac{5}{16}$

159. 9709_s16_ms_72 Q: 7

Q	Answer	Mark	Notes
(a)	0.3 or 1 – 0.6 or 0.4 or 0.2 seen 0.8	**M1** **A1** [2]	
(b) (i)	$k\int_0^{1.5}(2.25-x^2)\mathrm{d}x=1$	**M1**	attempt integ f(x) and '= 1'. Ignore limits
	$k\left[2.25x-\frac{x^3}{3}\right]_0^{1.5}=1$	**A1**	correct integration and limits
	$k\times\left[3.375-1.125\right]=1$ or $k\times\frac{9}{4}=1$ oe		
	$k=\frac{4}{9}$ **AG**	**A1** [3]	No errors seen

Q	Answer	Mark	Notes
(ii)	$\frac{4}{9}\int_0^{1.5}(2.25x-x^3)\mathrm{d}x$	**M1**	attempt integ xf(x), ignore limits, condone missing k
	$=\frac{4}{9}\left[2.25\frac{x^2}{2}-\frac{x^4}{4}\right]_0^{1.5}$	**A1**	correct integration and limits, condone missing k
	= 0.5625 or 0.563		
	Mean no. of hours = 56.25 or 56.3 56 hrs 15 mins	**A1** **A1** [4]	ft their 0.5625
(iii)	Max x is 1.5, less than 2.9 or $150 < 290$	**B1** [1]	Needs numerical justification
(iv)	any a such that $2.9 \leqslant a \leqslant 5$	**B1** [1]	
	Total for paper	**50**	

160. 9709_s16_ms_73 Q: 5

Q	Answer	Mark	Notes
(i)	$k\int_5^{10}(10t-t^2)\mathrm{d}t=1$	**M1**	Attempt to integrate, ignore limits
	$k\left[5t^2-\frac{t^3}{3}\right]_5^{10}=1$	**A1**	Correct integral and limits
	$k(500-\frac{1000}{3}-(125-\frac{125}{3}))=1$		
	$k\times\frac{250}{3}=1$		
	$(k=\frac{3}{250}$ **AG**$)$	**A1** [3]	No errors seen; No inexact decimals seen

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Q	Answer	Mark	Notes
(ii)	$\frac{3}{250}\int_5^{10}(10t^2-t^3)\mathrm{d}t$	M1	Attempt to integrate, ignore limits
	$=\frac{3}{250}\left[\frac{10t^3}{3}-\frac{t^4}{4}\right]_5^{10}$	A1	Correct integral and limit. Condone missing k
	$=\frac{3}{250}(\frac{10000}{3}-\frac{10000}{4}-(\frac{1250}{3}-\frac{625}{4})$		
	= 6.875 or 55/8	A1 [3]	Allow 6.88
(iii)	P(T < E(T) = $\frac{3}{250}\left[5t^2-\frac{t^3}{3}\right]_5^{"6.875"}$	M1*	ft their E(T)
	= 0.5361		
	"0.5361" – 0.5	DM1*	allow 0.036
	P(T between E(T) & median = 0.0361	A1 [3]	**Alternative Method** Integrate f(t)limits 5 and m equated to 0.5 M1* Integrate f(t)limits their 6.736 (provided between 5 and 10) and their 6.875DM1 Allow without "minutes"
(iv)	10 (minutes)	B1 [1]	

161. 9709_w16_ms_71 Q: 6

Q	Answer	Mark		Notes
(i)	m_X, m_Y, m_Z, m_W or X, Y, Z, W	B2	[2]	B1 if two adjacent means interchanged, i.e. m_Y, m_X, m_Z, m_W or m_X, m_Z, m_Y, m_W or m_X, m_Y, m_W, m_Z B1 for correct order reversed.
(ii) (a)	$\int_0^3 \frac{4}{81}x^4\mathrm{d}x$	M1		Attempt int xf(x). Ignore limits
	$=\left[\frac{4}{81}\frac{x^5}{5}\right]_0^3$	A1		Correct integration and limits (condone missing 4/81)
	$=\frac{4}{81}\times\frac{3^5}{5}$ or $\frac{4}{81}\times\frac{243}{5}$ or $\frac{972}{405}$ oe			Must see correct expression as well as $\frac{12}{5}$ or 2.4
	$=\frac{12}{5}$ or 2.4 AG	A1	[3]	No errors seen
(b)	$\int_{2.4}^3 \frac{4}{81}x^3\mathrm{d}x$ or $1-\int_0^{2.4}\frac{4}{81}x^3\mathrm{d}x$	M1		Attempt int f(x) ignore limits
	$=\left[\frac{4}{81}\frac{x^4}{4}\right]_{2.4}^3$ or $1-\left[\frac{4}{81}\frac{x^4}{4}\right]_0^{2.4}$	A1		Correct integration and limits (condone missing 4/81)
	$=1-\frac{4}{81}\times\frac{2.4^4}{4}$ oe			
	$=\frac{369}{625}$ or 0.59(0) (3 sf)	A1	[3]	As final answer
(c)	1	B1	[1]	

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162. 9709_w16_ms_72 Q: 6

Q	Answer	Mark		Notes
(i)	m_X, m_Y, m_Z, m_W or X, Y, Z, W	**B2**	[2]	B1 if two adjacent means interchanged, i.e. m_Y, m_X, m_Z, m_W or m_X, m_Z, m_Y, m_W or m_X, m_Y, m_W, m_Z B1 for correct order reversed.
(ii) (a)	$\int_0^3 \frac{4}{81}x^4 \mathrm{d}x$	**M1**		Attempt int $xf(x)$. Ignore limits
	$= \left[\frac{4}{81}\frac{x^5}{5}\right]_0^3$	**A1**		Correct integration and limits (condone missing 4/81)
	$= \frac{4}{81}\times\frac{3^5}{5}$ or $\frac{4}{81}\times\frac{243}{5}$ or $\frac{972}{405}$ oe			Must see correct expression as well as $\frac{12}{5}$ or 2.4
	$= \frac{12}{5}$ or 2.4 AG	**A1**	[3]	No errors seen
(b)	$\int_{2.4}^3 \frac{4}{81}x^3 \mathrm{d}x$ or $1 - \int_0^{2.4} \frac{4}{81}x^3 \mathrm{d}x$	**M1**		Attempt int f(x) ignore limits
	$= \left[\frac{4}{81}\frac{x^4}{4}\right]_{2.4}^3$ or $1 - \left[\frac{4}{81}\frac{x^4}{4}\right]_0^{2.4}$	**A1**		Correct integration and limits (condone missing 4/81)
	$= 1 - \frac{4}{81}\times\frac{2.4^4}{4}$ oe			
	$= \frac{369}{625}$ or 0.59(0) (3 sf)	**A1**	[3]	As final answer
(c)	1	**B1**	[1]	

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163. 9709_w16_ms_73 Q: 8

Q	Answer	Mark		Notes
(i)	σ_X, σ_Z, σ_Y, σ_W **or** X, Z, Y, W	**B2**	[2]	B1 if two adjacent sds interchanged, ie σ_Z, σ_X, σ_Y, σ_W **or** σ_X, σ_Y, σ_Z, σ_W **or** σ_X, σ_Z, σ_W, σ_Y B1 for correct order reversed
(ii) (a)	Mean = 0 stated or found or "– 0" seen	**B1**		
	$\frac{1}{18}\int_{-3}^{3} x^4 dx - 0$ $= \frac{1}{18}\left[\frac{x^5}{5}\right]_{-3}^{3}$ $= \frac{1}{18}\left[\frac{3^5}{5} + \frac{3^5}{5}\right]$ oe $= 5.4$	**M1**		Attempt integral ^{2} f(x). Ignore limits Allow without "– 0"
	sd = $\sqrt{5.4}$ or $\sqrt{\frac{1}{18}\left[\frac{3^5}{5} + \frac{3^5}{5}\right]}$ or 2.324 sd = 2.32 (3 sf) AG	**A1**	[3]	Must see $\sqrt{\text{correct expression or 5.4}}$ or 2.324 or better
(b)	$\frac{1}{18}\int_{'2.324'}^{3} x^2 dx$	**M1**		Attempt to integrate f(x), ignore limits
	$\frac{1}{18}\left[\frac{x^3}{3}\right]_{'2.324'}^{3} = \frac{1}{18}\left[\frac{3^3}{3} - \frac{'2.324'^3}{3}\right]$	**A1**		Sub correct limits into correct integral
	= 0.268 (3 sf)	**A1**	[3]	Allow 0.269
(c)	0	**B1**	[1]	

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164. 9709_s15_ms_71 Q: 1

Q	Answer	Mark	Notes
	$\frac{1}{2}a^2 = 1$	M1	or $\int_0^a x\mathrm{d}x = 1$
	$a = \sqrt{2}$	A1	Allow 1.41 or better
	$\int_0^{\sqrt{2}} x^2\mathrm{d}x$	M1	ignore limits
	$= \left[\frac{x^3}{3}\right]_0^{\sqrt{2}}$	A1f	correct integral and limits, but ft their a
	$= \frac{\left(\sqrt{2}\right)^3}{3} =$ or $\frac{2^{1.5}}{3}$ or $\frac{2.83}{3}$ or 0.9428 (= 0.943 **AG**)	A1 [5]	must see this numerical expression, or equiv SR Equating $\int x\ \mathrm{f}(x)$ to 0.943 scores M1 Solving to find a = 1.41 scores A1
		[Total 5]	

165. 9709_s15_ms_72 Q: 6

Q	Answer	Mark	Notes
(i)	$k\int_0^{15}(225 - t^2)\mathrm{d}t = 1$	M1	Attempt integ f(x) and = 1. Ignore limits
	$k\left[225t - \frac{t^3}{3}\right]_0^{15} = 1$	A1	Correct integration and limits
	$k\times[3375 - 1125\} = 1$ or $k\times 2250 = 1$ ($k = \frac{1}{2250}$ **AG**)	A1 3	No errors seen
(ii)	$\frac{1}{2250}\int_{10}^{15}(225 - t^2)\mathrm{d}t$	M1	Attempt integ, ignore limits
	$(= \frac{1}{2250}\left[225t - \frac{t^3}{3}\right]_{10}^{15})$	A1	Or $1 - \int_0^{10}$ Correct integration and limits. Condone missing k
	$= \frac{1}{2250}\ [2250 - (2250 - \frac{1000}{3})]$ $= \frac{4}{27}$ or 0.148 (3 sf)	A1 3	
(iii)	$\frac{1}{2250}\int_0^{15}(225t - t^3)\mathrm{d}t$	M1*	Attempt integ $x\mathrm{f}(x)$, ignore limits
	$= \frac{1}{2250}\left[\frac{225t^2}{2} - \frac{t^4}{4}\right]_0^{15}$	A1	Correct integration and limits. Condone missing k
	$= \frac{1}{2250}[\frac{50625}{2} - \frac{50625}{4}]$	M1*dep	Sub correct limits into their integral
	$= \frac{45}{8}$ or 5.625 or 5.63 (3 sf)	A1 4	Accept 5 mins 37 or 38 secs
	Total	**10**	

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166. 9709_s15_ms_73 Q: 7

Q	Answer	Mark	Notes
(i)	$\frac{3}{4}\int_0^c (cx - x^2)dx = 1$	M1	Attempt integ f(x) and = 1. Ignore limits
	$\frac{3}{4}\left[\frac{cx^2}{2} - \frac{x^3}{3}\right]_0^c = 1$	A1	Correct integration and limits (condone c = 2
	$\frac{3}{4}\left(\frac{c^3}{2} - \frac{c^3}{3}\right) = 1$ or $\frac{3}{4} \times \frac{c^3}{6} = 1$ or $\frac{c^3}{8} = 1$	A1 [3]	No errors seen
	($c = 2$ **AG**)		
(ii)	Inverted parabola Through (0, 0) and (2, 0) and zero elsewhere Median = 1	B1 B1 B1 [3]	Must not extend beyond [0,2]
(iii)	$\frac{3}{4}\int_0^{1.5} (2x - x^2)dx$	M1	Attempt integ f(x) ignore limits
	$= \frac{3}{4}\left[x^2 - \frac{x^3}{3}\right]_0^{1.5}$	A1	Correct integration ignore limits
	$\frac{3}{4}\left(1.5^2 - \frac{1.5^3}{3}\right)$	B1	Use of correct limits [0,1.5] or 1–[1.5,2]
	$= \frac{27}{32}$ or 0.844 (3 sf)	A1 [4]	

Q	Answer	Mark	Notes
(iv)	$\left(\frac{27}{32} - \frac{1}{2}$ or $0.844 - 0.5\right)$		
	$= \frac{11}{32}$ or 0.344 (3 sf)	B1f [1]	ft their (iii) For use of symmetry Note If do not use "hence" and start again B1 for cwo
		Total 11	

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167. 9709_w15_ms_71 Q: 4

Q	Answer	Mark	Notes
(i)	$k\int_1^2(3-x)dx=1$	M1	Attempt $\int f(x) = 1$, ignore limits or $\frac{k}{2}(h_1 + h_2) = 1$
	$k\left[3x-\frac{x^2}{2}\right]_1^2=1$	A1	Correct integration & limits or $\frac{k}{2}(2 + 1) = 1$
	$(k(6-2-(3-0.5))=1)$		
	$k\times 1.5=1$ or $k\times\frac{3}{2}=1$ or $k=\frac{1}{1.5}$ oe		
	$k=\frac{2}{3}$ **AG**	A1 [3]	No errors seen
(ii)	$\frac{2}{3}\int_1^m(3-x)dx=0.5$ oe $\int$ from m to 2	M1*	Attempt Int f(x) = 0.5, ignore limits oe Or use of area of trapezium
	$\left(\frac{2}{3}\left[3x-\frac{x^2}{2}\right]_1^m=0.5\right)$		
	$\frac{2}{3}\left[3m-\frac{m^2}{2}-2.5\right]=0.5$	dep M1*	Sub of correct limits into their integral. Or trapezium using 1 and m/m and 2 Any correct 3-term QE = 0 or $(m-3)^2 = 2.5$
	$m^2-6m+6.5=0$ oe	A1	
	$\left(m=\frac{6\pm\sqrt{36-4\times 6.5}}{2}=1.42 \text{ or } 4.58\right)$		
	$m = 1.42$ (3 sf)	A1 [4]	or $\frac{6-\sqrt{10}}{2}$ oe; single correct ans
		Total: 7	

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168. 9709_w15_ms_73 Q: 4

Q	Answer	Mark		Notes
(i)	$k\int_{-2}^{2}(4-x^2)\mathrm{d}x = 1$	M1		attempt Integral f(x) = 1, ignore limits
	$k[4x - \frac{x^3}{3}]_{-2}^{2} = 1$ $\left(k\left(8-\frac{8}{3}-\left(-8-\left(-\frac{8}{3}\right)\right)=1\right)\right)$	A1		correct integration & limits
	$k \times \frac{32}{3} = 1$ oe Not e.g. $k \times 10.7 = k$			
	$k = \frac{3}{32}$ **AG**	A1	[3]	exact answer correctly found
(ii)	Inverted parabola, vertex on y axis	B1		parabola must finish on x axis at ± 2, labelled (ignore markings on y axis)
	E(X) = 0	B1	[2]	
(iii)	$\frac{3}{32}\int_{-2}^{1}(4-x^2)\mathrm{d}x$	M1		or $1 - \frac{3}{32}\int_{1}^{2}(4-x^2)\mathrm{d}x$ ignore limits
	$\frac{3}{32}[4x - \frac{x^3}{3}]_{-2}^{1}$ $\frac{3}{32}(4 - \frac{1}{3} - (-8 - (-\frac{8}{3})))$	A1		or $1 - \frac{3}{32}[4x - \frac{x^3}{3}]_{1}^{2}$ correct integration and correct limits $= 1 - \frac{3}{32}(8 - \frac{8}{3} - (4 - \frac{1}{3}))$
	$= \frac{27}{32}$ or 0.844 (3 sf)	A1	[3]	
Total			**[8]**	

169. 9709_m22_ms_62 Q: 1

Question	Answer	Marks	Guidance
(a)	Est (μ) = $\frac{1199}{6}$ or 199.833 or 200 or $\frac{2398}{12}$ [mm]	B1	Accept in any form
	Est (σ^2) = $\frac{12}{11}\left(\frac{479226}{12} - \frac{'1199'^2}{6}\right)$ or $\frac{1}{11}\left('479226' - \frac{'2398'^2}{6}\right)$	M1	Use of their values in correct formula (may be implied)
	= 2.33 (3 sf) [mm^2]	A1	Accept $\frac{7}{3}$
		3	
(b)	Small sample	B1	Accept not 'not representative' unless qualified.
		1	

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170. 9709_m22_ms_62 Q: 3

Question	Answer	Marks	Guidance
	est(p) = 0.4	**B1**	
	$'0.4' + z\sqrt{\frac{'0.4'\times(1-'0.4')}{500}}$ [= 0.445]	**M1**	OE Use of *their* 0.4 in a correct expression
	$z\left[=0.045\div\sqrt{\frac{'0.4'\times(1-'0.4')}{500}}\right] = 2.054$	**A1**	Condone 2.053 and 2.05
	0.98 – (1 – 0.98)	**M1**	
	96% confidence	**A1**	CWO, must be integer
		5	

171. 9709_s22_ms_61 Q: 1

Question	Answer	Marks	Guidance
(a)	Est(μ) = $\frac{2520}{200}$ [= 12.6]	**B1**	OE
	Est(σ^2) = $\frac{200}{199}\left(\frac{31582}{200} - '12.6'^2\right)$ or $\frac{1}{199}\left(31852 - \frac{2520^2}{200}\right)$	**M1**	Allow M1 if $\frac{200}{199}$ omitted
	= 0.5025 or 0.503 or $\frac{100}{199}$	**A1**	CWO or σ = 0.7088 or 0.709
	z = 1.96	**B1**	
	'12.6' ± z × $\sqrt{'0.5025' \div 200}$	**M1**	For expression of correct form Any z but must be z
	CI = 12.5 to 12.7 (3 sf)	**A1**	CWO Must be an interval Note: Use of biased can score maximum B1 M1 A0 B1 M1 A0
		6	
(b)	0.95 × 40 [= 38]	**B1**	Give at early stage
		1	

172. 9709_s22_ms_62 Q: 1

Question	Answer	Marks	Guidance
(a)	$72.3 \pm z\sqrt{\frac{64.3}{50}}$	**M1**	Expression of correct form (allow only one side for M1). Must be a z value
	z = 1.751	**B1**	Accept 1.75 if nothing better seen
	CI is 70.3 to 74.3 metres (3 s.f.)	**A1**	Allow without units Must be an interval
		3	
(b)	Not random sample	**B1**	Need 'random' or 'not representative/biased because…' OE
		1	

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173. 9709_s22_ms_63 Q: 6

Question	Answer	Marks	Guidance
(a)	$\frac{13+a}{5}$	**B1**	Accept $\frac{2+3+3+5+a}{5}$. Do not ignore subsequent working
		1	
(b)	$\frac{5}{4}\left(\frac{47+a^2}{5}-\left(\frac{13+a}{5}\right)^2\right)=4$ or $\frac{1}{4}\left(47+a^2-\frac{(13+a)^2}{5}\right)=4$	**M1**	Use of correct formula using *their* value from **(a)**, in terms of a, and equate to 4
	$2a^2-13a-7=0$	**A1**	Any correct three-term quadratic equation rearranged to a form ready to solve
	$a=7$	**A1**	Condone the other value of a $(-\frac{1}{2})$
		3	

174. 9709_m21_ms_62 Q: 1

Question	Answer	Marks	Guidance
(a)	Est(μ) = $\frac{4820}{60}$ or $\frac{241}{3}$ or 80.3 (3 sf)	**B1**	
	Est(σ^2) = $\frac{60}{59}(\frac{392\,050}{60}-(\frac{4820}{60})^2)$	**M1**	Use of biased (80.72) score M0 A0.
	82.0904 $\left(\frac{14530}{177}\right)$ to 82.635 or SD = 9.0604 to 9.0904 (3sf)	**A1**	
	$z=2.326$	**B1**	
	$\frac{4820}{60}\pm z\times\sqrt{\frac{'82.0904'}{60}}$	**M1**	Expression of the correct form – must be z value.
	77.6 to 83.1 (3 sf)	**A1**	CWO Use of biased 77.6 to 83.0(3) can score B1M1A1 (max 4/6).
		6	
(b)	Population distribution of times unknown	**B1**	Accept 'not normal'.
		1	

175. 9709_s21_ms_61 Q: 2

Question	Answer	Marks	Guidance
(a)	$\pm\frac{123-125}{\frac{6}{\sqrt{40}}}$ [= –2.108...]	M1	Must have √40 No standard deviation/variance mix. Ignore any continuity correction attempts for this mark.
	P(z < '–2.108') = 1 – Φ('2.108')	M1	For correct probability area consistent with *their* working.
	= 0.0175 or 0.0176 (3 sf)	A1	
		3	
(b)	No, population is normal	B1	Need both.
		1	

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176. 9709_s21_ms_61 Q: 4

Question	Answer	Marks	Guidance
	$\frac{3820}{100}$ [= 38.2]	B1	
	$\frac{100}{99}\left(\frac{182200}{100}-'38.2'^2\right)$ or $\frac{1}{99}\left(182200-\frac{3820^2}{100}\right)$	M1	Use of biased (362.76) scores M0
	$=\frac{12092}{33}$ or 366.424 or 366 (3 sf)	A1	Accept SD=19.1422 or 19.1(3sf)
	'38.2' $\pm z\times\sqrt{\frac{'366.424'}{100}}$	M1	Expression of the correct form must be a z-value.
	z = 1.881 or 1.882	B1	Seen.
	34.6 to 41.8 (3 sf)	A1	Allow use of biased giving (34.6,41.8) Must be an interval.
		6	

177. 9709_s21_ms_62 Q: 6

Question	Answer	Marks	Guidance
(a)	est $(\mu)=\frac{7570}{100}$ (= 75.7)	B1	
	est$(\sigma^2)=\frac{100}{99}\left(\frac{\sum h^2}{100}-'75.7'^2\right)$ or $\frac{1}{99}\left(588050-\frac{7570^2}{100}\right)$ $=\frac{100}{99}\left(\frac{588050}{100}-'75.7'^2\right)$ [= 151.525]	M1	Attempted (**Note:** Biased variance (150.01) scores M0)
	= 152 (3 sf)	A1	Or $\frac{15001}{99}$
		3	
(b)	'75.7' $\pm z\sqrt{\frac{'151.525'}{100}}$	M1	For expression of correct form. Must be a z value. Condone just + or just -.
	z = 2.576	B1	Accept 2.574 to 2.579
	72.5 to 78.9	A1 FT	FT biased variance only Must be an interval
		3	
(c)	0.99^4	B1	
	0.961 (3 sf)	B1	
		2	

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178. 9709_s21_ms_63 Q: 4

Question	Answer	Marks	Guidance
(a)	$\frac{4509}{90}$ [= 50.1]	B1	
	$\frac{90}{89}\left(\frac{225950}{90} - '50.1'^2\right)$ or $\frac{1}{89}\left(225950 - \frac{4509^2}{90}\right)$	M1	Attempted. Use of biased = 0.5455 scores M0A0
	$\frac{491}{890}$ or 0.552 (3 sf)	A1	
		3	
(b)	'50.1' $\pm z\sqrt{\frac{'491'}{890}}$	M1	Expression of the correct form, allow any z-value but must be a z-value
	$z = 2.326$	B1	Accept 2.326 to 2.329
	49.9 to 50.3 (3 sf)	A1	FT from biased variance. Must be an interval.
		3	
(c)	Population of masses is unknown	B1	Accept population of masses is not normal
		1	
(d)	1 – 0.98	M1	0.02 seen
	0.02 ÷ 2 = 0.01	A1	As final answer
		2	

179. 9709_w21_ms_61 Q: 1

Question	Answer	Marks	Guidance
(a)	N(12.5, ….)	B1	
	Variance = 0.4096	B1	Accept 0.410 (3sf), condone $\frac{10.24}{25}$
		2	
(b)	$\frac{13 - '12.5'}{\sqrt{'0.4096'}}$ [= 0.781]	M1	For standardising with *their* values. Accept standardising with 12.
	ϕ('0.781') – (1 – Φ('0.781'))	M1	For attempting to find *their* central area.
	0.565 (3sf)	A1	
		3	

180. 9709_w21_ms_61 Q: 3

Question	Answer	Marks	Guidance
	est(p) = 0.2 accept $\frac{15}{75}$	B1	SOI
	$2 \times z \times \sqrt{\frac{0.2 \times 0.8}{75}} = 0.162$	M1	Expression of the correct form. Condone missing 2x.
	$z \left[= 0.081 \times \sqrt{\frac{75}{0.2 \times 0.8}}\right] = 1.754$	A1	Correct z. Condone 3sf accuracy.
	Φ('1.754') = 0.96[03] '0.96' – (1 – '0.96')	M1	OE. Using *their* z to find alpha.
	$\alpha = 92$	A1	Following correct working.
		5	

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181. 9709_w21_ms_61 Q: 6

Question	Answer	Marks	Guidance
(a)	est $\mu = 14$ accept $\frac{560}{40}$	**B1**	
	est $\sigma^2 = \frac{40}{39}\left(\frac{7850}{40} - 14^2\right)$ or $\frac{1}{39}\left(7850 - \frac{560^2}{40}\right)$	**M1**	
	0.25641 or 0.256 (3sf)	**A1**	Accept $\frac{10}{39}$ Without $\frac{40}{39}$ i.e. biased: est $\sigma^2 = 0.25$ **M0 A0**.
		3	
(b)	E($S - T$) = 14.2 – '14' [= 0.2]	**B1 FT**	FT *their* 14.
	Var($S - T$) = 0.3 + ` 0.256` [= 0.55641]	**B1 FT**	Accept $\frac{217}{390}$ FT *their* 0.256 including FT biased. Var($S - T$) = 0.55.
	$\frac{0.1 - '0.2'}{\sqrt{'0.55641'}}$ [= –0.134]	**M1**	Standardising with *their* values (note biased gives –0.135). FT *their* E & Var.
	P(S – T > 0.1) = 1 – Φ('–0.134') = Φ('0.134')	**M1**	Finding correct area consistent with *their* values.
	0.553 (3sf)	**A1**	Use of biased gives 0.554 (3sf) can score the **A1**. Similar scheme for P($T - S$) < –0.1. Similar scheme for S – T – 0.1 > 0. And T – S + 0.1 < 0.
		5	

182. 9709_w21_ms_62 Q: 1

Question	Answer	Marks	Guidance
(a)	$\frac{20.5}{40} = 0.5125$	**B1**	Accept 0.513 or $\frac{41}{80}$. Condone $\frac{20.5}{40}$.
	$\frac{40}{39}\left(\frac{10.728}{40} - \left('0.5125'^2\right)\right)$ or $\frac{1}{39}\left(10.728 - \frac{20.50^2}{40}\right)$	**M1**	Biased variance (0.005544 or $\frac{887}{160\,000}$) scores **M0 A0.**
	0.0056859 or 0.00569 (3 sf) or $\frac{887}{156\,000}$	**A1**	CAO
		3	
(b)	[11 × '0.5125' + 0.5]) = 6.1375 or $\frac{491}{80}$ or 6.14 (3sf)	**B1 FT**	FT *their* 0.5125
	11^2 × '0.0056859'	**M1**	With nothing added. Using *their* variance in **(a)** (no sd/var confusion)
	0.688 (3sf)	**A1**	CAO
		3	

183. 9709_w21_ms_62 Q: 2

Question	Answer	Marks	Guidance
(a)	E.g. Bias towards students who play instruments or only music students or e.g. the six will possibly be friends/have similar music preferences	**B1**	OE Or any reason that some are excluded e.g. because it is lunchtime or because the music building is chosen or any suggestion that opinions may not be independent. Note: 'not representative of all students' needs qualifying
		1	

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Question	Answer	Marks	Guidance
(b)	28, 119, 207	**B1**	**B1** for 28, 119 (condone 028).
		B1	**B1** for 207 and only 3 values stated.
		2	

184. 9709_w21_ms_62 Q: 3

Question	Answer	Marks	Guidance
(a)	$0.25 \pm z\sqrt{\frac{0.25\times0.75}{140}}$	**M1**	Expression of correct form (allow **M1** for just one side stated). Must be a z-value.
	$z = 2.054$ or 2.055	**B1**	
	0.175 to 0.325 (3sf)	**A1**	Must be an interval.
		3	
(b)	$0.90 \times 0.95 \times 0.01$ $+ 0.90 \times 0.05 \times 0.99$ $+ 0.10 \times 0.95 \times 0.99$	**M1 M1**	**M1** for one correct triple product. **M1** for all correct and added.
	0.147	**A1**	SC If zero scored award **B1** for a 2 or 3 term expression of the form 0.90×0.95 [$\times c$] OE. $(0 < c \leqslant 1)$
		3	

185. 9709_w21_ms_63 Q: 1

Question	Answer	Marks	Guidance
(a)	N(12.5, ….)	**B1**	
	Variance = 0.4096	**B1**	Accept 0.410 (3sf), condone $\frac{10.24}{25}$
		2	
(b)	$\frac{13-'12.5'}{\sqrt{'0.4096'}}$ [= 0.781]	**M1**	For standardising with *their* values. Accept standardising with 12.
	ϕ(‘0.781’) – (1 – Φ(‘0.781’))	**M1**	For attempting to find *their* central area.
	0.565 (3sf)	**A1**	
		3	

186. 9709_w21_ms_63 Q: 3

Question	Answer	Marks	Guidance
	est(p) = 0.2 accept $\frac{15}{75}$	**B1**	SOI
	$2 \times z \times \sqrt{\frac{0.2\times0.8}{75}} = 0.162$	**M1**	Expression of the correct form. Condone missing 2x.
	$z \left[= 0.081\times\sqrt{\frac{75}{0.2\times0.8}}\right] = 1.754$	**A1**	Correct z. Condone 3sf accuracy.
	Φ(‘1.754’) = 0.96[03] '0.96' – (1 – '0.96')	**M1**	OE. Using *their* z to find alpha.
	$\alpha = 92$	**A1**	Following correct working.
		5	

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187. 9709_w21_ms_63 Q: 6

Question	Answer	Marks	Guidance
(a)	est $\mu = 14$ accept $\frac{560}{40}$	**B1**	
	est $\sigma^2 = \frac{40}{39}\left(\frac{7850}{40} - 14^2\right)$ or $\frac{1}{39}\left(7850 - \frac{560^2}{40}\right)$	**M1**	
	0.25641 or 0.256 (3sf)	**A1**	Accept $\frac{10}{39}$ Without $\frac{40}{39}$ i.e. biased: est $\sigma^2 = 0.25$ **M0 A0**.
		3	
(b)	E($S - T$) = 14.2 – '14' [= 0.2]	**B1 FT**	FT *their* 14.
	Var($S - T$) = 0.3 + ` 0.256` [= 0.55641]	**B1 FT**	Accept $\frac{217}{390}$ FT *their* 0.256 including FT biased. Var($S - T$) = 0.55.
	$\frac{0.1 - '0.2'}{\sqrt{'0.55641'}}$ [= –0.134]	**M1**	Standardising with *their* values (note biased gives –0.135). FT *their* E & Var.
	P(S – T > 0.1) = 1 – Φ('–0.134') = Φ('0.134')	**M1**	Finding correct area consistent with *their* values.
	0.553 (3sf)	**A1**	Use of biased gives 0.554 (3sf) can score the **A1**. Similar scheme for P($T - S$) < –0.1. Similar scheme for S – T – 0.1 > 0. And T – S + 0.1 < 0.
		5	

188. 9709_m20_ms_62 Q: 2

Question	Answer	Marks	Guidance
	$2 \times z \times \frac{3.2}{10} = 1.25$	**M1**	OE Allow without '2 ×'
	$z = 1.953$	**A1**	SOI
	ϕ('*their* 1.953') (= 0.9746)	**M1**	
	= 1 – 2(1 – '0.9746') = 0.9492	**M1**	OE
	$\alpha = 94.9$ or 95	**A1**	CWO
		5	

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189. 9709_s20_ms_61 Q: 1

Question	Answer	Marks
(a)	$\frac{\Sigma x}{7} = \frac{34.7}{7} = 4.9571$ or 4.96 (3 sf) ($\Sigma x^2 = 175.15$)	B1
	$\frac{7}{6}\left(\frac{"175.15"}{7} - "4.9571"^2\right)$	M1
	0.523 (3 sf)	A1
		3
(b)	$'4.96' \pm z \times \sqrt{\frac{0.523}{7}}$ (**FT** *their* mean and standard deviation)	M1
	$z = 1.96$	B1
	4.42 to 5.49 (3 sf)	A1
		3

190. 9709_s20_ms_63 Q: 1

Question	Answer	Marks
	Est $\mu = 15.56$	B1
	Est $\sigma^2 = \frac{100}{99}\left(\frac{29004}{100} - "15.56"^2\right)$ or $= \frac{1}{99}\left(29004 - \frac{1556^2}{100}\right)$	M1
	$48.4105 = 48.4$ (3 sf)	A1
		3

191. 9709_s20_ms_63 Q: 5

Question	Answer	Marks
(a)	$p = \frac{70}{500}$ or 0.14	B1
	$z = 2.576$	B1
	$"0.14" \pm z \times \sqrt{\frac{"0.14"(1-"0.14")}{500}}$	M1
	0.100 to 0.180	A1
		4

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Question	Answer	Marks
(b)	0.1666... is within confidence interval Belief supported or justified	**B1**
		1
(c)	$z \times \sqrt{\frac{"0.14"(1-"0.14")}{500}} = 0.02$	**M1**
	$z = 1.289$	**A1**
	Φ('1.289') = 0.9013	**M1**
	α = '0.9013' – (1 – '0.9013')	**M1**
	80.3% (3 sf)	**A1**
		5

192. 9709_w20_ms_61 Q: 2

Question	Answer	Marks	Guidance
(a)	$\frac{\frac{102}{250} \times \frac{250-102}{250}}{250}$ (= 0.000966144) $\frac{102}{250} \pm z\sqrt{'0.00096614'}$	**M1**	Any z but must be a z value. One side of the interval scores M1.
	$z = 1.645$	**B1**	
	Confident Interval is 0.357 to 0.459 (3 sf)	**A1**	Must be an interval.
		3	
(b)	Estimate of mean $\left(\frac{50460}{250}\right)$ = \$201.84	**B1**	Allow without units. Allow 3s.f. \$202.
	$\frac{250}{249}\left(\frac{19854200}{250} - \left(\frac{50460}{250}\right)^2\right)$ or $\frac{1}{249}\left(19854200 - \frac{50460^2}{250}\right)$	**M1**	
	Estimate of variance = 38 832.75 dollars^2 or 38 800 (3 sf)	**A1**	Allow with missing units. (Calculation of biased gives 38 700 scores M0A0)
		3	
2(c)	e.g. Every house doesn't have an equal chance of being selected or most houses have no chance of being selected.	**B1**	Or other similar e.g. Houses in streets with few houses are more likely to be selected. Not just 'biased', OE, without explanation
		1	

193. 9709_w20_ms_62 Q: 2

Question	Answer	Marks	Guidance
(a)	$\frac{56}{300} \pm z \times \sqrt{\frac{\frac{56}{300} \times \frac{244}{300}}{300}}$	**M1**	For expression of the correct form. Must be a z value
	$z = 2.054$ or 2.055	**B1**	
	0.14(0) to 0.233 (3sf) or 0.141 to 0.233 (3sf)	**A1**	Must be an interval
		3	
(b)	$\frac{1}{6}$ (= 0.167) This is within confidence interval, so no reason to believe die is biased.	**B1 FT**	Note if confidence interval set up with $\frac{1}{6}, \frac{56}{300}$ it should be the value used here. FT *their* confidence interval. Not definite, e.g. not 'Die not biased'.
		1	

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194. 9709_w20_ms_63 Q: 2

Question	Answer	Marks	Guidance
(a)	$\frac{102}{250} \times \frac{250-102}{250}$ (= 0.000966144) $\frac{102}{250} \pm z\sqrt{'0.00096614'}$	M1	Any z but must be a z value. One side of the interval scores M1.
	$z = 1.645$	B1	
	Confident Interval is 0.357 to 0.459 (3 sf)	A1	Must be an interval.
		3	
(b)	Estimate of mean $\left(\frac{50460}{250}\right)$ = \$201.84	B1	Allow without units. Allow 3s.f. \$202.
	$\frac{250}{249}\left(\frac{19854200}{250} - \left(\frac{50460}{250}\right)^2\right)$ or $\frac{1}{249}\left(19854200 - \frac{50460^2}{250}\right)$	M1	
	Estimate of variance = 38 832.75 dollars^2 or 38 800 (3 sf)	A1	Allow with missing units. (Calculation of biased gives 38 700 scores M0A0)
		3	
(c)	e.g. Every house doesn't have an equal chance of being selected or most houses have no chance of being selected.	B1	Or other similar e.g. Houses in streets with few houses are more likely to be selected. Not just 'biased', OE, without explanation
		1	

195. 9709_m19_ms_72 Q: 1

Question	Answer	Marks	Guidance
(i)	$z = 2.326$	B1	
	$62.3 \pm z\frac{13.2}{\sqrt{200}}$	M1	Any z. Expression of correct form. Must be a 'z'
	60.1 to 64.5 (3 sfs)	A1	Must be an interval
		3	
(ii)	Yes, because pop not (given to be) normal, or pop distribution unknown	B1	No contradictions
		1	

196. 9709_m19_ms_72 Q: 4

Question	Answer	Marks	Guidance
(i)	$\bar{x} = \frac{420}{50} = 8.4$	B1	
	$s^2 = \frac{50}{49}\left(\frac{27530}{50} - \left(\frac{420}{50}\right)^2\right)$	M1	Or 1/49(27530 – (420)^2/50)
	= 489.8(36....)	A1	Must see ⩾ 4 sf
		3	

Question	Answer	Marks	Guidance
(ii)	$\Phi^{-1}(0.9377) = 1.536$	B1	
	$\frac{5-'8.4'}{\sqrt{\frac{490}{n}}} = -1.536$	M1	Attempting to standardise – must have correct form
	$n = \left(\frac{1.536}{3.4}\right)^2 \times 490$ (= 100.0048)	M1	Attempting numerical expression for n or √n (must have used a 'z' value) may be implied by answer
	$n = 100$	A1	No errors seen. Must be whole number
		4	

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197. 9709_s19_ms_71 Q: 6

Question	Answer	Marks	Guidance
(i)	Biased towards people who like tennis Excludes people who don't like tennis	**B1**	or other sensible
		1	
(ii)	Obtain a list of all people in the town	**B1**	
	Use random numbers	**B1**	or, e.g. pick numbers from a hat or other sensible
		2	
(iii)	Var(p) = $\frac{\frac{47}{350}(1-\frac{47}{350})}{350}$ (= 0.000332152)	**M1**	
	z = 1.645	**B1**	
	$\frac{47}{350} \pm z\sqrt{\frac{\frac{47}{350}(1-\frac{47}{350})}{350}}$	**M1**	Must be a z value
	0.104 to 0.164 (3 sf)	**A1**	Must be an interval
		4	
(iv)	1.25 × 1.645 (= 2.056)	**M1**	or 1.25 × their width ÷ 2 ÷ their $\sqrt{\frac{\frac{47}{350}(1-\frac{47}{350})}{350}}$ (Complete method)
	Φ('2.056') (= 0.980)	**M1**	Attempt Φ(their z)
	x = 96 (2 sf)	**A1**	Allow 0.96 (2 sf) CWO
		3	

198. 9709_s19_ms_73 Q: 1

Question	Answer	Marks	Guidance
	$0.6 \pm z\sqrt{\frac{0.4\times0.6}{100}}$	**M1**	Recognisable value of z
	z = 2.326	**B1**	2.326 to 2.329
	0.486 to 0.714 (3 sf)	**A1**	Must be an interval
		3	

199. 9709_s19_ms_73 Q: 2

Question	Answer	Marks	Guidance
	$\frac{50}{49}\left(\frac{4361}{50} - \bar{x}^2\right) = 9.62$	**M1**	or $\left(\frac{4361}{49} - \frac{(\Sigma x)^2}{50\times49}\right) = 9.62$ BOD regarding symbols used
	$\bar{x}^2 = \frac{4361}{50} - 9.62\times\frac{49}{50} = 77.7924$	**A1**	$(\Sigma x)^2 = 4361 \times 50 - 9.62 \times 50 \times 49 = 194481$or $\Sigma x = 441$ (Σx) or $(\bar{x})$ must be correctly identified
	$\bar{x}$ = 8.82 (3 sf)	**A1**	SC use of 'biased' leading to 8.81 B1
		3	

200. 9709_s19_ms_73 Q: 3

Question	Answer	Marks	Guidance
(i)	D more likely to be chosen	**B1**	oe, e.g. P(D) > P(A) e.g. P(A)=P(B)=P(C)=1/6 P(D)=1/2 no contradictions
		1	
(ii)	Reject scores of 5 or 6	**B1**	or other correct: choose D when the score is 4
		1	

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Question	Answer	Marks	Guidance
(iii)	AB AC AD BC BD CD	**B1**	
	Allocate as follows: 1: AB; 2: AC; 3: AD; 4: BC; 5: BD 6: CD	**B1**	or similar
		2	

201. 9709_w19_ms_72 Q: 3

Question	Answer	Marks	Guidance
(i)	$\text{est}(\mu) = \frac{25110}{50}$ (= 502.2)	**B1**	
	$\text{est}(\sigma^2) = \frac{50}{49}\left(\frac{12610300}{50} - \frac{25110}{50}\right)^2 \left(= \frac{50}{49} \times \frac{58}{50} = 1.1836\right)$	**M1**	OE
	1.18 (3 sf) or $\frac{58}{49}$	**A1**	Accept SD = 1.0879
	z = 2.054 or 2.055	**B1**	
	$502.2 \pm z \times \frac{\sqrt{'1.1836'}}{\sqrt{50}}$	**M1**	Must be of correct form.
	501.9 to 502.5 (1dp)	**A1**	CWO. Must be in interval. **SC** accept use of biased variance (1.16) for M1 A1
		6	
(ii)	More confident **or** z would be greater, Hence wider.	**B1**	OE Reason needed
		1	

202. 9709_w19_ms_73 Q: 3

Question	Answer	Marks	Guidance
(i)	Assume population is normally distributed	**B1**	
	$\bar{x} = 25.9$	**B1**	Allow $\frac{259}{10}$
	z =2.17	**B1**	
	$'25.9' \pm z \times \frac{3}{\sqrt{10}}$	**M1**	Must have correct form and z.
	23.8 to 28.0 (3 sf)	**A1**	CWO
		5	
(ii)	0.03^2 (=0.0009)	**B1**	
		1	

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203. 9709_m18_ms_72 Q: 1

Question	Answer	Marks	Guidance
	$\frac{5-4.9}{\frac{2.21}{\sqrt{75}}}$ (= 0.392)	**M1**	Correct stand'n. Must have √75
	1 – Φ("0.392")	**M1**	Correct area consistent with working
	= 0.348 (3 sfs)	**A1**	
		3	

204. 9709_m18_ms_72 Q: 7

Question	Answer	Marks	Guidance
(i)	$\bar{x} = 11.83$	**B1**	
	$11.83 \pm z \frac{0.1}{\sqrt{10}}$	**M1**	any z
	$z = 2.576$	**B1**	accept 2.574 to 2.579
	[11.75 to 11.91]	**A1**	or equiv. Accept 11.7 to 11.9
		4	
(ii)	No because pop normal (so $\bar{X}$ normally distr)	**B1**	
		1	
(iii)	11.7 not within CI	**B1FT**	
		1	
(iv)	No because 95% CI is narrower than 99% CI	**B1**	OE
		1	
(v)	Σx^2 (= 1399.67)	**M1**	attempted
	$\text{Est}(\sigma^2) = \frac{10}{9}\left(\frac{"1399.67"}{10} - \left(\frac{"118.3"}{10}\right)^2\right)$ OE	**M1**	correct sub of their Σs into correct formula
	= 0.0201 (3 sf) or 181/9000	**A1**	
		3	

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205. 9709_s18_ms_71 Q: 1

Question	Answer	Marks	Guidance
	est(μ) (= 153.2 ÷ 75) = 2.04 (3 sf)	**B1**	
	est(σ^2) = $\frac{75}{74}(\frac{340.24}{75} - "2.04267"^2)$ oe	**M1**	
	= 0.369 (3 sf)	**A1**	Accept 0.368
		3	

206. 9709_s18_ms_71 Q: 2

Question	Answer	Marks	Guidance
(i)	$\frac{20}{100} \pm z \times \sqrt{\frac{0.2\times(1-0.2)}{100}}$	**M1**	Any z
	z = 1.881 or 1.882	**B1**	
	= 0.125 to 0.275	**A1**	
		3	
(ii)	$\frac{1}{6}$ is within this range No evidence of bias concerning 2	**B1ft**	Both statements needed
		1	

207. 9709_s18_ms_72 Q: 3

Question	Answer	Marks	Guidance
(i)	$52 \pm z \times \frac{6.5}{\sqrt{15}}$	**M1**	Expression of the correct form. Any z
	z = 1.96	**B1**	Seen or used
	48.7 to 55.3 (3 sf)	**A1**	Must be an interval
		3	

Question	Answer	Marks	Guidance
(ii)	Narrower because more information or because $\frac{\sigma}{\sqrt{n}}$ smaller	**B1**	oe Accept 'sample size is larger' 'more employees' 'width inversely proportional to sq root of n' 'if n increases width decreases' '95% CI is 49.7 to 54.3' or similar. No contradictions
		1	

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208. 9709_s18_ms_73 Q: 2

Question	Answer	Marks	Guidance
(i)	213, 165, 73, 196 Allow 073	B1	For 3-digit no, < 265, consisting of three consecutive integers from given digits, backwards or forward. (73 or 073 counts as a 3-digit no.)
		B1	For another three such. Other answers may be valid. If other method used, method must be clear
		2	

Question	Answer	Marks	Guidance
(ii)	$\frac{510}{25} = \frac{102}{5}$ or 20.4	B1	
	$\frac{25}{24}\left[\frac{13225}{25} - \left(\frac{102}{5}\right)^2\right]$	M1	$\frac{1}{24}\left(13225 - \frac{510^2}{25}\right)$
	118 (3 sf) or $\frac{2821}{24}$	A1	
		3	
(iii)	(Average) weekly earnings of all students in Amy's year	B1	Not 'All students in Amy's year'
		1	

209. 9709_s18_ms_73 Q: 3

Question	Answer	Marks	Guidance
	$\frac{\frac{8}{64} \times (1 - \frac{8}{64})}{64}$ (= $\frac{7}{4096}$ or 0.00171)	M1	OE, e.g. $\frac{\frac{1}{8} \times \frac{7}{8}}{64}$
	$2 \times z \sqrt{"\frac{7}{4096}"} = 0.130$	M1	Correct equation using their variance
	$z = 1.572$	A1	
	ϕ("1.572") (= 0.942) (0.942 – (1 – 0.942) = 0.884)	M1	2ϕ(their z) -1
	$\alpha = 88$	A1	CAO
		5	

210. 9709_w18_ms_71 Q: 1

Question	Answer	Marks	Guidance
(i)	$176 \pm z \times \frac{7.2}{\sqrt{200}}$	M1	need correct form must be z
	$z = 2.24$	B1	allow 2.241 and 2.242
	175 to 177	A1	cwo
		3	
(ii)	Sample random	B1	oe. both words essential
		1	

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211. 9709_w18_ms_71 Q: 3

Question	Answer	Marks	Guidance
	$\frac{12.2-12}{2.5/\sqrt{n}}$	**M1**	Standardisation. Allow cc. need correct form incl sqrt
	(=) 1.96	**B1**	Correct z
	$\sqrt{n} = 1.96 \times 2.5 \div 0.2$	**M1**	Rearrange equation in n or sqrt n with numerical z to the stage n= or sqrt n = allow arithmetical slips only
	$n = 600$	**A1**	accept 601 SR whole number ans from 595 to 605 can score full marks if fully justified
		4	

212. 9709_w18_ms_72 Q: 2

Question	Answer	Marks	Guidance
(i)	$z = 1.96$	**B1**	seen
	$330.1 \pm z \times \frac{4.8}{\sqrt{180}}$	**M1**	Must be of correct form. Any z
	= 329.4 to 330.8 (1 dp)	**A1**	Must be to 1 dp. Must be an interval.
		3	
(ii)	Yes, because vol of all cans not stated to be normal	**B1**	Or Yes, population not stated to be normal
		1	

213. 9709_w18_ms_72 Q: 7

Question	Answer	Marks	Guidance
(i)	$e^{-5.6} \times \frac{5.6^3}{3!}$	**M1**	Allow any λ
	= 0.108 (3 sf)	**A1**	
		2	
(ii)	$P(X=2 \ \& \ Y=1) = e^{-2.1} \times \frac{2.1^2}{2} \times e^{-3.5} \times 3.5$ $(0.2700 \times 0.10569 = 0.028538)$	**M1**	
	$\frac{P(X=2 \ \& \ Y=1)}{P(X+Y=3)}$ attempted $= \frac{'0.028538'}{'0.108234}$	**M1**	For attempt at fraction with their **(i)** as denominator or $\frac{2.1^2}{2} \times 3.5 \div \frac{5.6^3}{3}$ M2
	= 0.264 (3 sf)	**A1**	
		3	

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Question	Answer	Marks	Guidance
(iii)	Var(X) = 2.1	**B1**	soi
	$\bar{X} \sim N(2.1, \frac{2.1}{100})$ or $N(210,210)$	**B1**	soi B1 for N(2.1, ...)
		B1	B1 for $\frac{2.1}{100}$ oe Standardise with their values. Allow with or without cc or with incorrect cc
	$\frac{2.2-2.1}{\frac{\sqrt{2.1}}{\sqrt{100}}}$ oe $(220 - 210)/\sqrt{210}$ (= 0.690)	**M1**	or $\frac{2.2+0.5\div100-2.1}{\frac{\sqrt{2.1}}{\sqrt{100}}}$ or $(220.5 - 210)/\sqrt{210})$ (= 0.725) no mixed methods
	$1 - \phi$('0.690')	**M1**	Correct area consistent with their working or $1 - \phi$('0.725')
	= 0.245 (3 sf)	**A1**	= 0.234 (3 sf)
		6	

214. 9709_w18_ms_73 Q: 1

Question	Answer	Marks	Guidance
(i)	$176 \pm z \times \frac{7.2}{\sqrt{200}}$	**M1**	need correct form must be z
	$z = 2.24$	**B1**	allow 2.241 and 2.242
	175 to 177	**A1**	cwo
		3	
(ii)	Sample random	**B1**	oe. both words essential
		1	

215. 9709_w18_ms_73 Q: 3

Question	Answer	Marks	Guidance
	$\frac{12.2-12}{2.5/\sqrt{n}}$	**M1**	Standardisation. Allow cc. need correct form incl sqrt
	(=) 1.96	**B1**	Correct z
	$\sqrt{n} = 1.96 \times 2.5 \div 0.2$	**M1**	Rearrange equation in n or sqrt n with numerical z to the stage n= or sqrt n = allow arithmetical slips only
	$n = 600$	**A1**	accept 601 SR whole number ans from 595 to 605 can score full marks if fully justified
		4	

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216. 9709_m17_ms_72 Q: 1

Question	Answer	Marks	Guidance
	$\text{Var}(Ps) = \frac{0.3(1-0.3)}{120}$ (= 0.00175)	**M1**	Attempt correct values in correct formula
	$0.3 \pm z\sqrt{"0.00175"}$	**M1**	must be a z-value, not a prob
	$z = 1.645$	**B1**	
	CI = 0.231 to 0.369 (3 sf)	**A1**	
	Total:	**4**	

217. 9709_m17_ms_72 Q: 3

Question	Answer	Marks	Guidance
(i)	$\frac{53-52}{6.1\div\sqrt{75}}$ (= 1.420)	**M1**	
	$\frac{51-52}{6.1\div\sqrt{75}}$ (= –1.420)	**M1**	or –"1.420" seen
	Φ("1.420") – Φ("–1.420")	**M1**	
	= 0.844 (3 sfs)	**A1**	
	Total:	**4**	
(ii)	Need to assume $\overline{X}$ (approx.) normally distributed	**B1**	or X not stated to be normally distributed
	Total:	**1**	

218. 9709_s17_ms_71 Q: 3

Question	Answer	Marks	Guidance
(a)	$7.1 \pm z \times \sqrt{\frac{2.6}{75}}$	**M1**	Expression of correct form must be z (note MR var = 2.6^2 can score **M1**) seen
	$z = 1.751$	**B1**	
	6.77 to 7.43 (3 sfs)	**A1**	Must be an interval
	Total:	**3**	
(b)	0.04^3	**M1**	Allow 0.08^3 for **M1**
	= 0.000064	**A1**	
	Total:	**2**	
(c)	e.g. Particular day or time of day	**B1**	Allow "Not random"
	Total:	**1**	

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219. 9709_s17_ms_72 Q: 1

Question	Answer	Marks	Guidance
	$\frac{0.801\times(1-0.801)}{2000}$ (= 0.0000797)	M1	
	$0.801\pm z\times\sqrt{"0.0000797"}$	M1	Allow any z-value
	$z = 1.96$	B1	
	0.784 to 0.818 (3 sf)	A1	As final answer. Must be an interval Allow 0.783 to 0.819
	Total:	**4**	

220. 9709_s17_ms_73 Q: 1

Question	Answer	Marks	Guidance
	573, 43 (or 043), 289	B1B1B1	Ignore incorrect numbers. But allow other correct use of table (i.e. 573, 650, 431)
	Total:	**3**	

221. 9709_s17_ms_73 Q: 2

Question	Answer	Marks	Guidance
(i)	$z = 1.751$	B1	
	$\frac{103}{200}\pm z\sqrt{\frac{\frac{103}{200}\times(1-\frac{103}{200})}{200}}$ oe	M1	all correct except for recognisable value of z, allow for one side only
	= 0.453 to 0.577 (3 sf) as final answer	A1	must be an interval
	Total:	**3**	
(ii)	0.08 oe 8%, 8/100	B1	

222. 9709_w17_ms_71 Q: 3

Question	Answer	Marks	Guidance
	$\frac{153}{200}+z\times\sqrt{\frac{\frac{153}{200}\times\frac{200-153}{200}}{200}}=0.835$ ($\text{Var}(P_s) = 0.000898875$) (s.d. 0.02998)	M1	
	$z = 2.335$	A1	allow 2.33 or 2.34
	$2\Phi(z)-1$	M1	or equivalent method indep
	$\alpha = 98$	A1	allow 98.0 but not e.g. 98.04
		4	

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223. 9709_w17_ms_71 Q: 4

Question	Answer	Marks	Guidance
(i)	$300.1 \pm z \times \frac{0.9}{\sqrt{75}}$	**M1**	allow any value of z
	$z = 2.576$	**B1**	allow 2.574 to 2.579
	299.83 to 300.37 (2 dps)	**A1**	answer must be seen to 2 dps need an interval
		3	
(ii)	CI includes 300 so claim supported or justified or probably true	**B1 FT**	or equivalent FT from CI in **(i)**
		1	

224. 9709_w17_ms_72 Q: 2

Question	Answer	Marks	Guidance
(i)	$4820 \pm z \times \frac{1420}{\sqrt{125}}$	**M1**	Must be a z value
	$z = 2.326$	**B1**	Accept 2.326 - 2.329
	4524/4525 to 5115/5116 or 4520 to 5120 (3 sf)	**A1**	Must be an interval
		3	

Question	Answer	Marks	Guidance
(ii)	$\bar{x} = 4840$	**B1**	or width = 280 or half width = 140
	$4840 + 1.96 \times \frac{1420}{\sqrt{n}} = 4980$ OE	**M1**	or $140 = 1.96 \times \frac{1420}{\sqrt{n}}$ OE
	$n = 395$	**A1**	CAO must be an integer
		3	

225. 9709_w17_ms_73 Q: 3

Question	Answer	Marks	Guidance
	$\frac{153}{200} + z \times \sqrt{\frac{\frac{153}{200} \times \frac{200-153}{200}}{200}} = 0.835$ $(\text{Var}(P_s) = 0.000898875)$ (s.d. 0.02998)	**M1**	
	$z = 2.335$	**A1**	allow 2.33 or 2.34
	$2\Phi(z) - 1$	**M1**	or equivalent method indep
	$\alpha = 98$	**A1**	allow 98.0 but not e.g. 98.04
		4	

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226. 9709_w17_ms_73 Q: 4

Question	Answer	Marks	Guidance
(i)	$300.1 \pm z \times \frac{0.9}{\sqrt{75}}$	**M1**	allow any value of z
	$z = 2.576$	**B1**	allow 2.574 to 2.579
	299.83 to 300.37 (2 dps)	**A1**	answer must be seen to 2 dps need an interval
		3	
(ii)	CI includes 300 so claim supported or justified or probably true	**B1 FT**	or equivalent FT from CI in **(i)**
		1	

227. 9709_m16_ms_72 Q: 5

Q	Answer	Mark	Notes
(i)	Est(μ) = $\frac{14\,910}{150}$ (= 99.4)	**B1**	
	Est(σ^2) = $\frac{150}{149}(\frac{1525000}{150} - \text{"99.4"}^2)$	**M1**	Allow **M1** if $\frac{150}{149}$ omitted
	= 288.228	**A1**	
	$z = 2.576$	**B1**	Accept 2.574–2.579
	"99.4" $\pm z \times \sqrt{288.228 \div 150}$	**M1**	Any z
	CI = 95.8 to 103 (3 sf)	**A1** [6]	(NB Use of biased Var can score 5/6 max)
(ii)	100 lies within this CI Hence yes	**B1**√ [1]	Both needed, ft their CI

Q	Answer	Mark	Notes
(iii)	To avoid bias or Necessary to enable statistical inference	**B1** [1]	Or any equivalent

228. 9709_s16_ms_71 Q: 2

Q	Answer	Mark	Notes
(i)	Each employee has an equal chance of being chosen	**B1** [1]	oe
(ii)	Est (μ) = 4	**B1**	
	Est (σ^2) = $\frac{10}{9}(\frac{199.22}{10} - \text{'4'}^2)$	**M1**	sub in correct formula attempted
	= 4.36 (3 sf)	**A1** [3]	working may not be seen
(iii)	Distances travelled by all employees at the firm	**B1** [1]	oe

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229. 9709_s16_ms_71 Q: 3

Q	Answer	Mark	Notes
(i)	((0.5672 + 0.6528) ÷ 2) = 0.61	B1 [1]	
(ii)	'0.61' + $z\sqrt{\frac{\text{'0.61'}\times(1-\text{'0.61'})}{350}}$ = 0.6528	M1	oe
	$z = 0.0428 \times \sqrt{\frac{700}{\text{'0.61'}\times(1-\text{'0.61'})}}$ oe	M1	correct rearrangement of correct equn, ft '0.61'
	= 2.321 98% confidence	A1 A1 ft [4]	ft their z (dep on both Ms)

230. 9709_s16_ms_72 Q: 3

Q	Answer	Mark	Notes
(i)	Pop too big or takes too long oe or testing destroys articles oe	B1 [1]	or too expensive oe or pop inaccessible oe
(ii) (a)	$z = 1.96$	B1	seen
	$65.7 \pm z \times \frac{\sqrt{15}}{10}$	M1	Expression of correct form (must be 'z' must be 65.7)
	= 64.9 to 66.5 (3 sf)	A1 [3]	Must be an interval
(b)	CI does not include 64.7 Probably has affected (or increased) mean bounce ht.	B1✓ [1]	allow 64.7 not within CI both needed. ft their CI ft 65.7/64.7 mix

231. 9709_s16_ms_73 Q: 1

Q	Answer	Mark	Notes
	$192.4 \pm z\sqrt{\frac{43.6}{150}}$	M1	Allow $\frac{43.6}{\sqrt{150}}$ Allow one side for M1
	z = 2.326 to 2.329 191 to 194 (3 sf)	B1 A1 [3]	Condone √(43.6/149) oe CWO

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232. 9709_s16_ms_73 Q: 6

Q	Answer	Mark	Notes
(i)	$\lambda = 3.9$	B1	
	$e^{-3.9} \times \frac{3.9^4}{4!}$	M1	M1 allow any λ
	= 0.195	A1 [3]	SR Combination method B1 for λ =1.6 AND λ =2.3 used in combination method (at least 3 combinations) M1 All correctly combined and added
(ii)	$\bar{X} \sim N(1.6, \frac{1.6}{75})$	B1 B1 [2]	B1 for N(1.6, ….)stated B1 for Var = $\frac{1.6}{75}$ stated SR, not stated but all implied in (iii): B1
(iii)	$\frac{1.7-1.6}{\sqrt{\frac{1.6}{75}}}$ (= 0.685)	M1	For standardising (using their values or correct values .Ignore cc
	1– Φ("0.685") = 0.247 (3 sf)	M1 A1 [3]	Correct area consistent with their working Accept use of 1/2n correction leading to 0.233. NB Use of Poisson sum Po(120) and N(120,120) with μ=127.5 leads to 0.247, or 0.233 with cc
(iv)	*X* not normally distr. So CLT needed	B1 [1]	Not "it"

233. 9709_w16_ms_71 Q: 1

Q	Answer	Mark		Notes
	$\left(\frac{508}{8}\right) = 63.5$	B1		
	$(\Sigma x^2 = 32360.12)$			
	$\frac{8}{7}\left(\frac{'32360.12'}{8} - '63.5'^2\right)$	M1		oe
	= 14.6 (3 sf) or 2553/175	A1	[3]	From correct working

234. 9709_w16_ms_71 Q: 5

Q	Answer	Mark		Notes
(a)	$63 \pm z \times \frac{9}{\sqrt{100}}$	M1	B1	Expression of correct form, any *z*
	$z = 1.645$	B1		Seen
	61.5 to 64.5 (3 sf)	A1	[3]	Must be an interval

Q	Answer	Mark		Notes
(b) (i)	$z = \frac{1.96}{2}$ (= 0.98)	M1		Allow $\frac{\text{any } z}{2}$
	Φ("0.98") (= 0.8365)			
	"0.8365" – (1 – "0.8365")	M1		
	(= 0.673)			
	α = 67.3 (3 sf)	A1	[3]	Allow 67 from correct working
(ii)	$4=(2x'z'x'\sigma')/\sqrt{n}$	M1		Attempt to solve equ of correct form
	n = 200	A1	[2]	SR B1 for n = 100

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235. 9709_w16_ms_72 Q: 1

Q	Answer	Mark		Notes
	$\left(\frac{508}{8}\right) = 63.5$ $(\Sigma x^2 = 32360.12)$ $\frac{8}{7}\left(\frac{'32360.12'}{8} - '63.5'^2\right)$ $= 14.6$ (3 sf) or 2553/175	**B1** **M1** **A1**	 [3]	 oe From correct working

236. 9709_w16_ms_72 Q: 5

Q	Answer	Mark		Notes
(a)	$63 \pm z \times \frac{9}{\sqrt{100}}$ $z = 1.645$ 61.5 to 64.5 (3 sf)	**M1** **B1** **A1**	B1 [3]	Expression of correct form, any z Seen Must be an interval

Q	Answer	Mark		Notes
(b) (i)	$z = \frac{1.96}{2}$ (= 0.98) Φ("0.98") (= 0.8365) "0.8365" – (1 – "0.8365") (= 0.673) $\alpha = 67.3$ (3 sf)	**M1** **M1** **A1**	 [3]	Allow $\frac{\text{any } z}{2}$ Allow 67 from correct working
(ii)	$4=(2x'z'x'\sigma')/\sqrt{n}$ $n = 200$	**M1** **A1**	 [2]	Attempt to solve equ of correct form SR B1 for $n = 100$

237. 9709_w16_ms_73 Q: 2

Q	Answer	Mark		Notes
(i)	59	**B1**	[1]	
(ii)	Any x such that $0.687 \leqslant x \leqslant 0.693$ (3 sf)	**B1**	[1]	or 0.69 or " ... 0.686.. < 0.693 rec "
(iii)	Possible repeats	**B1**	[1]	

238. 9709_w16_ms_73 Q: 6

Q	Answer	Mark		Notes
(i)	est(μ) = 3.4 est(σ^2)= $\frac{100}{99}\left(\frac{1356}{100} - '3.4'^2\right)$ = 2.02(0202) $z = 1.96$ $3.4 \pm z \times \sqrt{\frac{'2.020202'}{100}}$ = 3.12 to 3.68 (3 sf)	**B1** **M1** **A1** **B1** **M1** **A1**	 [6]	1 / 99 (1356 – $340^2/100$) or 200/99 correct working only allow from unbiased or biased variance
(ii)	Mean should be 3 CI does not include 3 Machine probably not working properly	**B1*** **DB1**√	 [2]	stated or implied √ their CI or evidence that….

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239. 9709_s15_ms_71 Q: 5

Q	Answer	Mark	Notes
(i)	4200/80 (=52.5)	B1	
	$=\frac{80}{79}\left(\frac{229\,000}{80}-'52.5'^2\right)$ (= 107.595)	M1	
	= 108 (3 sf)	A1 [3]	
(ii)	$'52.5'\pm z\sqrt{\frac{'107.595'}{80}}$	M1	Correct form – must be z-value – allow one side only
	z = 2.326	B1	Seen
	49.8 to 55.2	A1f [3]	ft their 52.5 and 107.595. Must be an interval
(iii)	49	B1 [1]	
		[Total: 7]	

240. 9709_s15_ms_72 Q: 5

Q	Answer	Mark	Notes
(i)	14800/50 or 296	B1	
	$\frac{50}{49}\left(\frac{4390000}{50}-'296'^2\right)$ (= 187.755)	M1	Oe
	= 188 (3 sf)	A1 3	
(ii)	$2\times z\times\sqrt{\frac{'187.755'}{50}}=5.45$ oe	M1	If '2 ×' omitted: $z\times\sqrt{\frac{'187.755'}{50}}=5.45$ M1
	z = 1.406 or 1.405	A1	z = 2.812 or 2.810 A0
	Φ('1.406') (= 0.92 or 0.9199)		Φ('2.812') (= 0.9975)
	α = 84 (2 sf) allow 83.98	M1	α = 99.5 or 99 or 100 M1 A0
		A1 4	For complete method to find α
			SR use of biased var(184) scores M1A1(1.4205) A=84.5 M1A1
(iii)	0.96^4	M1	
	= 0.849 (3 sf)	A1 2	
	Total	**9**	

241. 9709_s15_ms_73 Q: 1

Q	Answer	Mark	Notes
(i)	Eg: Only students who use canteen	B1	or any reason that some are excluded
	The five will probably be friends	B1 [2]	B1 each sensible reason must be in context
(ii)	2–digits	B1	
	ignore > 82 (anything too big)	B1	
	Ignore repeats	B1 [3]	
		[Total 5]	

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242. 9709_s15_ms_73 Q: 3

Q	Answer	Mark	Notes
(i)	$\text{Var}(p_s) = \dfrac{0.22 \times (1 - 0.22)}{100}$	M1	pq/100
	$\left(= \dfrac{429}{250\,000} \text{ or } 0.001716\right)$		
	$0.22 \pm z\sqrt{'\dfrac{429}{250\,000}'}$	M1	Expression of correct form with their variance Any z (must be a z value) accept one side only
	$z = 2.17$ or 2.168/9 or 2.171	B1	Seen
	0.13(0) to 0.31(0) (2 sf)	A1 [4]	Must be an interval
(ii)	'2' × (1 – 0.97) × 0.97 = 0.0582	M1 A1 [2]	
		Total 6	

243. 9709_s15_ms_73 Q: 4

Q	Answer	Mark	Notes
(i)	$\left(\dfrac{1508}{50}\right) = 30.16\,(30.2)$	B1	Allow any form
	$\dfrac{50}{49}\left(\dfrac{51\,825}{50} - \left('30.16'^2\right)\right)$	M1	(129.46367)
	= 129 (3 sf) Or 130	A1 [3]	
(ii)	(1.5 × '30.16' + 10) = 55.24	B1ft	ft their 30.16
	(1.5^2 × '129….')	M1	1.5^2 × their(129) with nothing added at any stage
	= 291 (3 sf)	A1ft [3]	Allow 290
		Total 6	

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244. 9709_w15_ms_71 Q: 2

Q	Answer	Mark	Notes
(i)	$\frac{6}{\sqrt{120}}$ oe seen	B1	Or $6^2/120$ oe seen
	$\frac{30-29}{\left(\frac{6}{\sqrt{120}}\right)}$ (= 1.826)	M1	± Allow without √120. No sd/var mix
	P(z > '1.826') = 1 – Φ('1.826') = 0.034 (2 sf)	M1 A1 [4]	Correct tail consistent with their working 0.0339
(ii)	No n is large (⩾30)	B1	1st B1 for either comment
	Sample mean is (appr) normally distrib or The CLT applies oe	B1 [2]	2nd B1 for'No'with 2nd comment (No mark for 'No' alone)
		Total: 6	

245. 9709_w15_ms_71 Q: 3

Q	Answer	Mark	Notes
(i)	$\frac{3420}{60}(=57)$	B1	
	$\frac{60}{59}\left(\frac{195200}{60}-'57'^2\right)$ (= 4.40678) = 4.41 (3 sf)	M1	Oe
		A1 [3]	As final answer
(ii)	$'57'\pm z\sqrt{\frac{'4.40678'}{60}}$	M1	
	z = 2.326	B1	2.326 – 2.329 (accept 2.33 if no better seen)
	[56.4 to 57.6] (3 sf)	A1 [3]	NB: use of biased variance in (ii) can score in full
		Total: 6	

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246. 9709_w15_ms_72 Q: 2

Q	Answer	Mark	Notes
(i)	$\frac{6}{\sqrt{120}}$ oe seen	B1	Or $6^2/120$ oe seen
	$\frac{30-29}{\left(\frac{6}{\sqrt{120}}\right)}$ (= 1.826)	M1	± Allow without √120. No sd/var mix
	P(z > '1.826') = 1 – Φ('1.826') = 0.034 (2 sf)	M1 A1 [4]	Correct tail consistent with their working 0.0339
(ii)	No n is large (⩾30)	B1	1st B1 for either comment
	Sample mean is (appr) normally distrib or The CLT applies oe	B1 [2]	2nd B1 for'No'with 2nd comment (No mark for 'No' alone)
		Total: 6	

247. 9709_w15_ms_72 Q: 3

Q	Answer	Mark	Notes
(i)	$\frac{3420}{60}(=57)$	B1	
	$\frac{60}{59}\left(\frac{195200}{60}-'57'^2\right)$ (= 4.40678) = 4.41 (3 sf)	M1	Oe
		A1 [3]	As final answer
(ii)	$'57'\pm z\sqrt{\frac{'4.40678'}{60}}$	M1	
	z = 2.326	B1	2.326 – 2.329 (accept 2.33 if no better seen)
	[56.4 to 57.6] (3 sf)	A1 [3]	NB: use of biased variance in (ii) can score in full
		Total: 6	

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248. 9709_w15_ms_73 Q: 1

Q	Answer	Mark		Notes
(i)	N(352, …) Variance = 2.9	B1 B1	[2]	no recovery in (ii) for each B mark accept sd = √ 2.9 = 1.70(29) stated
(ii)	$\frac{354-352}{\sqrt{2.9}}$ (= 1.174) 1 – Φ('1.174') = 0.120 (3 sf)	M1 M1 A1	[3]	with their mean and var Or $\frac{354.05-352}{\sqrt{2.9}}$ or correct restart (= 1.204) (accept sd/var mix)1 – Φ('1.204') = 0.114 (3 sf) Incorrect cc can score M1M1A0
Total			**[5]**	

249. 9709_w15_ms_73 Q: 3

Q	Answer	Mark		Notes
(i)	0.4 or 2/5 or 26/65	B1	[1]	no recovery in (ii) for the B mark
(ii)	" 0.4 " + $z \times \sqrt{\frac{0.4\times0.6}{65}}$ = 0.516 oe $z = \left(0.116 \times \sqrt{\frac{65}{0.4\times0.6}}\right) = 1.909$ (Φ('1.909') = 0.97(18)) 2 ('0.97' – 1) $\alpha = 94$	M1 A1 M1 A1	[4]	or " 0.4 " – $z \times \sqrt{\frac{0.4\times0.6}{65}}$ = 0.284 or $z \times \sqrt{\frac{0.4\times0.6}{65}}$ = 0.116 oe for fully correct method to find α from their z allow 94.36 or 94.4 or 94.374
Total			**[5]**	

250. 9709_m22_ms_62 Q: 2

Question	Answer	Marks	Guidance
	B(300, $\frac{1}{5}$) → N(60,48)	B1	SOI
	$\frac{45.5-60}{\sqrt{48}}$	M1	Condone with wrong or no continuity correction
	= –2.093	A1	
	'2.093' > 1.96	M1	Valid comparison Note: ϕ('–2.093') (= 0.0182), 0.0182< 0.025
	[Evidence to reject H_0] There is evidence that P(landing on blue) ≠ $\frac{1}{5}$	A1 FT	Allow 'There is evidence that the spinner is biased.' In context, not definite, no contradictions Condone critical values method (critical value 46.42 M1 A1 and 45.5 < '46.42' M1 for valid comparison A1 for correct conclusion)
			SC: 0.0182 unsupported: 0.0182 < 0.025 And there is evidence that the spinner is biased. In context, not definite B1 only
		5	

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251. 9709_m22_ms_62 Q: 4

Question	Answer	Marks	Guidance
(a)	H_0: $\mu = 25.5$ H_1: $\mu < 25.5$	**B1**	
	$\frac{23.7 - 25.5}{5.2 \div \sqrt{40}}$	**M1**	Must have $\sqrt{40}$
	$= -2.189$	**A1**	
	'2.189' < 2.326	**M1**	For valid comparison For two-tailed test: allow compare 2.576 if H_1: $\mu \neq 25.5$
	[Accept H_0] No evidence that mean time has decreased	**A1 FT**	In context, not definite, no contradictions FT *their* 2.189 but no FT for two-tailed test **N.B.** Use of two-tailed test can score max B0 M1 A1 M1 A0 Condone use of critical value method (23.59 M1 A1 and 23.7 > 23.59 M1 A1 correct conclusion or 25.612 M1 A1 and 25.5 < 25.612 M1 A1 with correct conclusion)
		5	
(b)	No, because H_0 was not rejected	**B1 FT**	FT *their* conclusion in **(a)**
		1	

252. 9709_s22_ms_61 Q: 2

Question	Answer	Marks	Guidance
	H_0: P(correct) = $\frac{1}{6}$ H_1: P(correct) > $\frac{1}{6}$	**B1**	Allow $p = \frac{1}{6}$ Allow $p > \frac{1}{6}$
	$1 - ({}^{15}C_4 \times (\frac{5}{6})^{11} \times (\frac{1}{6})^4 + {}^{15}C_3 \times (\frac{5}{6})^{12} \times (\frac{1}{6})^3 + {}^{15}C_2 \times (\frac{5}{6})^{13} \times (\frac{1}{6})^2 + 15 \times (\frac{5}{6})^{14} \times \frac{1}{6} + (\frac{5}{6})^{15})$	**M1**	Expression must be seen Allow one end error
	0.0898 or 0.0897 (3 sf)	**A1**	SC if M0 scored allow SCB1 for 0.0898 or 0.0897
	0.0898 < 0.1	**M1**	Valid comparison For valid comparison with 0.9 (0.9102 > 0.9 seen the previous M1and A1 can be recovered
	[Reject H_0] There is evidence (at the 10% level) that Arvind can predict scores	**FTA1**	Not definite, e.g. not 'He can predict' or 'Claim true' In context and no contradictions
		5	

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253. 9709_s22_ms_61 Q: 7

Question	Answer	Marks	Guidance
(a)	H_0: pop mean run time = 28.2 mins H_1: pop mean run time < 28.2 mins	**B1**	Allow 'μ'. Not 'mean journey time'
		1	
(b)	$\frac{27-28.2}{4/\sqrt{40}}$ [= –1.897]	**M1**	For standardising Must have √40
	Φ(< '–1.897') = 1 – Φ('1.897')	**M1**	For correct area consistent with these values
	0.0289 (3 sf)	**A1**	
		3	
(c)	H_0 is not rejected so…	**M1**	
	Type II error can be made and Type I error cannot be made	**A1**	Both needed (accept 'only a Type II error could be made')
		2	

254. 9709_s22_ms_62 Q: 2

Question	Answer	Marks	Guidance
	H_0: Pop mean height = 2.3 H_1: Pop mean height > 2.3	**B1**	Not just 'mean' Allow μ
	$\frac{2.4-2.3}{\frac{0.4}{\sqrt{60}}}$	**M1**	For standardising, must have $\sqrt{60}$
	1.936 or 1.937 or 1.94	**A1**	
	'1.936' < 1.96	**M1**	Valid comparison with 1.96 Or 2.64% > 2.5% OE Accept 1.936 < 2.24 or 2.64% > 1.25% OE if $H_1 \mu \neq 2.3$
	[Do not reject H_0] No evidence that (mean) height (with fertiliser) is more than without	**A1 FT**	FT *their z* In context, not definite. E.g. not 'Mean height is not greater' with no contradictions No FT for 2 tail test (max B0 M1 A1 M1 A0 3/5) Accept critical values method 2.401 (M1 A1) 2.4 < 2.401 (M1) Condone 2.299 (M1 A1) < 2.3 (M1) A1 conclusion
		5	

255. 9709_s22_ms_62 Q: 4

Question	Answer	Marks	Guidance
(a)	H_0: Pop mean = 4.6 [or 9.2] H_1: Pop mean < 4.6 [or 9.2]	**B1**	or $\lambda = 4.6$ or μ (Not just 'mean') or $\lambda < 4.6$
		1	

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Question	Answer	Marks	Guidance
(b)	Use of Poisson with $\lambda = 9.2$	**B1**	SOI
	$P(X \leqslant 3) = e^{-9.2}(1 + 9.2 + \frac{9.2^2}{2} + \frac{9.2^3}{3!}) = 0.0184$ or 0.018 [< 0.02] $P(X \leqslant 4) = 0.0184 + e^{-9.2} \times \frac{9.2^4}{4!} = 0.0486$ or 0.049 [> 0.02]	**M1**	At least one of these attempted correct λ (with Poisson expression seen not implied)
		***A1**	Both correct SC Use of $\lambda = 4.6$ scores B1 for P(X = 0) = 0.01[0][1] and P(X ⩽ 1) = 0.056[3]only
	CR is $X \leqslant 3$	**DA1**	From CWO and at least one comparison seen SC If M0 awarded allow *B1 for both 0.018 and 0.049 or better and DB1 for correct critical region from CWO and at least one comparison seen.
		4	
(c)	5 is not in critical region OR $P(X \leqslant 5) = 0.104 > 0.02$ so [not reject H_0] no evidence that number of cars arriving is now fewer	**M1** **A1 FT**	For a comparison (i.e. 5 > 3) OE In context, not definite No contradictions e.g. not 'No. of cars arriving is not fewer' ft *their* critical region if used (but must be from Poisson and integers)
		2	
(d)	No, because H_0 was not rejected	**B1 FT**	OE, FT *their* **(c)**
		1	

Question	Answer	Marks	Guidance
(e)	N(276, 276)	**B1**	SOI
	$\frac{300.5 - 276}{\sqrt{276}}$ [= 1.475]	**M1**	Standardising with *their* values Allow with wrong or no continuity correction
	1 – ϕ('1.475') = 0.0701 (3 s.f.)	**A1**	SC Use of Poisson: B1 for answer 0.0727 (3 sf)
		3	

256. 9709_s22_ms_63 Q: 2

Question	Answer	Marks	Guidance
(a)	Conclude more than 10% of the students are left handed when this is not true	**B1**	OE. Must be in context (accept use of p). Need the context of one tail test.
		1	
(b)	$1 - (0.9^{20} + 20 \times 0.9^{19} \times 0.1 + {}^{20}C_2 \times 0.9^{18} \times 0.1^2 + {}^{20}C_3 \times 0.9^{17} \times 0.1^3 + {}^{20}C_4 \times 0.9^{16} \times 0.1^4)$	**M2**	M2: fully correct M1: attempt 1 – P(X = 0, 1, 2, 3, 4); allow 1 – P(X = 0,1,2,3,4,5) or 1 – P(X = 0,1,2,3) need 1 – … the method mark cannot be implied
	0.0432 (3 s.f.)	**A1**	If M0 awarded allow SC B2 for 0.0432
		3	

Question	Answer	Marks	Guidance
(c)	$0.7^{20} + 20 \times 0.7^{19} \times 0.3 + {}^{20}C_2 \times 0.7^{18} \times 0.3^2 + {}^{20}C_3 \times 0.7^{17} \times 0.3^3 + {}^{20}C_4 \times 0.7^{16} \times 0.3^4$	**M1**	Attempt to find $P(\leqslant 4)$ using B(20,0.3) Allow one end error The method mark cannot be implied
	0.238 or 0.237 (3 s.f.)	**A1**	If M0 awarded allow SC B1for 0.238 or 0.237
		2	

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257. 9709_s22_ms_63 Q: 3

Question	Answer	Marks	Guidance
(a)	Batteries unusable after testing or Population too big or too costly or too time consuming to use the whole population oe	**B1**	
		1	
(b)	H_0: $\mu = 150$ H_1: $\mu < 150$	**B1**	Or population mean = 150; not just 'mean' = 150
	$\frac{147-150}{\sqrt{225} \div \sqrt{120}}$	**M1**	Allow with continuity correction Need $\sqrt{120}$
	–2.191	**A1**	Condone – 2.19
	–2.191 < –2.054 [or –2.055]	**M1**	OE. For valid comparison with 2.054 or 2.055 Or 0.0143 (or 0.0142) < 0.02 For two tail test allow comp –2.326 OE if H_1: $\mu \neq 150$ (can score B0M1A1M1A0 max 3/5)
	[Reject Ho] There is evidence that the (mean) life of type *B* is less than type *A* (or less than 150)	**A1 FT**	In context, not definite with no contradictions Accept critical value method 147.19 M1A1 147 < 147.19 M1 conclusion A1 Or 150 > 149.81
		5	

Question	Answer	Marks	Guidance
(c)	$147 \pm z \times \frac{15}{\sqrt{120}}$	**M1**	Expression of correct form must be a z value
	$z = 1.881$ [or 1.882]	**B1**	
	144 to 150 (3 s.f.)	**A1**	Must be an interval Incorrect z value can only score M1B0A0
		3	

258. 9709_m21_ms_62 Q: 3

Question	Answer	Marks	Guidance
(a)	One-tail because investigating whether "higher"	**B1**	OE. Must have both parts.
		1	
(b)	H_0: Population mean (or μ) in city same as for others H_1: Population mean (or μ) in city greater than for others	**B1 FT**	If **(a)** two-tail: H_0: Pop mean (or μ) in city same as for others. H_1: Pop mean (or μ) in region different from others.
	2.41 > 2.326 or 0.008 < 0.01 or 0.992 > 0.99	**M1**	If **(a)** two-tail: 2.41 < 2.576 or 0.992 < 0.995.
	There is evidence that buildings are higher [on average].	**A1 FT**	In context, not definite. No contradictions. If **(a)** two-tail: There is no evidence that the [average] height of buildings is different.
		3	

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259. 9709_m21_ms_62 Q: 6

Question	Answer	Marks	Guidance
(a)	H_0: population proportion = 0.08 OE H_1: population proportion > 0.08 OE	**B1**	Allow 'p = 0.08' etc.
	$P(X \geq 4) = 1 - P(X \leq 3) =$ $1 - (0.92^{25} + 25\times0.92^{24}\times0.08 + {}^{25}C_2\times0.92^{23}\times0.08^2 + {}^{25}C_3\times0.92^{22}\times0.08^3)$	**M1**	Allow 1 – (one term omitted or extra or wrong).
	0.135 (3 sf)	**A1**	
	0.135 > 0.05	**M1**	Valid comparison. Note: '0.865'<0.95 can score M1 A1 and can recover previous M1 A1 for 0.865.
	There is no evidence that proportion owning Chantor has increased	**A1 FT**	In context. Not definite, e.g. not 'Proportion not increased'. No contradictions.
		5	
(b)	H_0 was not rejected.	***B1 FT**	H_0 was rejected (consistent with **(a)**).
	Hence Type II might have been made.	**DB1 FT**	Type I error.
		2	
(c)	$P(X \geq 5) = 1 - P(X \leq 4)$ $= 1-\left((1-0.1351) + {}^{25}C_4\times0.92^{21}\times0.08^4\right)$ [= 0.0451]	***M1**	Attempted. Note: If critical region method used in **(a)** marks can be awarded here.
	0.0451 < 0.05	**A1**	Comparison of 0.045[1] with 0.05. Note: If critical region method used in **(a)** marks can be awarded here.
	P(Type I error) = 0.0451 or 0.0452	**A1**	Dependent on M1* only. **SC** Unsupported answers score: **B1** for 0.0451<0.05 and **B1** for final answer 0.0451 only.
		3	

260. 9709_s21_ms_61 Q: 8

Question	Answer	Marks	Guidance
(a)	Not representative (of all students in the school)	**B1**	OE idea of 'not being representative' e.g. different grades in the school have different characteristics/proportions.... Don't accept 'not random' or 'biased' without further explanation.
		1	
(b)	H_0: P(not correct uniform) = 0.15 H_1: P(not correct uniform) < 0.15	**B1**	Allow "p"
		1	
(c)	Any two probs attempted using B(50,0.15)	**M1**	
	$P(X \leqslant 3) = 0.85^{50} + 50\times0.85^{49}\times0.15 + {}^{50}C_2\times0.85^{48}\times0.15^2 + {}^{50}C_3\times0.85^{47}\times0.15^3$	**M1**	Attempt the tail probability P(0,1,2,3) with B(50,0.15) must be added.
	$P(X \leqslant 4) = 0.04605 + {}^{50}C_4\times0.85^{46}\times0.15^4$	**M1**	OE. *Their* $P(X \leqslant 3) + P(X = 4)$ or P(0,1,2,3,4) with B(50,0.15) must be added.
	$P(X \leqslant 3) = 0.0460$ or 0.0461 [<0.05] $P(X \leqslant 4) = 0.112$ or [>0.05]	**A1**	Both correct. OR if $P(X \leqslant 4)$ not seen; P(4)=0.06606 **and** 0.06606>0.05 **and** $P(X \leqslant 3)$=0.0460 scores M1 A1
	P(Type I) = 0.0460 or 0.0461 (3 sf)	**A1**	Dependent on second M1. **SC** If M1M1M1A0 scored allow A1FT for incorrect $P(X \leqslant 3)$ as long as <0.05
		5	

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Question	Answer	Marks	Guidance
(d)	4 is outside critical region ($\leqslant 3$) OE or P($X \leqslant 4$) = 0.112 which is > 0.05	**M1**	FT working from **(c)**.
	No evidence that proportion not wearing the correct uniform has decreased (Accept Ho)	**A1**	In context not definite, e.g. not 'Proportion has not decreased'. No contradiction.
		2	
(e)	Not rejected H_0	***B1 FT**	FT If Reject H_0 in **(d)**
	Type II	**DB1 FT**	FT Type I
		2	

261. 9709_s21_ms_62 Q: 1

Question	Answer	Marks	Guidance
(a)	$H_0: p = \frac{1}{4}$ $H_1: p \neq \frac{1}{4}$	B1	or $H_0: \mu = 25$ or $H_1: \mu \neq 25$
		1	
(b)	$N\left(25, \frac{75}{4}\right)$	B1	SOI. Allow B1 for $N\left(25, \frac{75}{4}\right)$ or N(0.25,0.001875) SOI.
	$\pm \frac{15.5-25}{\sqrt{\frac{75}{4}}}$ or $\frac{\frac{15.5}{100}-0.25}{\sqrt{\frac{0.25\times 0.75}{100}}}$	M1	Standardise with *their* N(25,…) Allow with no or wrong continuity correction.
	$\pm$ –2.194 (2.19)	A1	
	–2.326 < –2.194 or 0.0141 > 0.01 or 0.9859 < 0.99	M1	For valid comparison (accept 2.326 to 2.329)
	No evidence to reject that the probability is $\frac{1}{4}$	A1 FT	OE must be in context and not definite, e.g. not 'Claim untrue'. No contradictions. FT *their z* ; dependent on two–tailed test (one-tailed test can score B1 M1 A1 M1 A0) **SC** for use of Binomial B(100,0.25) P = 0.0111 for B1 and then comparison with 0.01 and correct conclusion for B1, maximum 2 out of 5 marks.
		5	

262. 9709_s21_ms_62 Q: 5

Question	Answer	Marks	Guidance
(a)	Conclude that (population) mean time has changed (or is not 42.4) although μ has not changed (or is still 42.4)	B1	OE. In context.
		1	
(b)	H_0: population mean (or μ) = 42.4 H_1: population mean (or μ) $\neq$ 42.4	B1	Not just 'mean'. (could be seen in **(a)**)
	$\pm \frac{45.6-42.4}{\sqrt{38.2 \div 20}}$	M1	For standardising (must have $\sqrt{20}$)
	$\pm$ 2.315	A1	
	2.240 < '2.315'	M1	For valid comparison (accept 2.241) or P(z > 2.315) = 0.0103 < 0.0125 oe
	There is evidence that μ or mean time has changed	A1 FT	FT *their z* In context, not definite. No contradictions. **Note:** Accept correct alternative methods **SC**: One tail test no FT. Can score B0 M1 A1 M1 (comparison with 1.96) A0 (maximum 3 out of 5)
		5	

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263. 9709_s21_ms_63 Q: 2

Question	Answer	Marks	Guidance
(a)	Conclude (mean) (journey) time has not decreased when in fact it has.	**B1**	OE in context
		1	
(b)	H_0: Pop mean (or μ) = 1.4 H_1: Pop mean (or μ) < 1.4	**B1**	May be seen in **(a)**
	$\frac{1.36-1.4}{\frac{0.12}{\sqrt{50}}}$	**M1**	Accept totals method $\frac{68-70}{\sqrt{50}\times 0.12}$ No mixed methods or no standard deviation/variance mixes
	–2.357 or – 2.36	**A1**	Correct z or correct area if used
	–2.357 < –1.96 or 0.0092 < 0.025 or 0.9908 > 0.975 Or CV method 1.36 < 1.367	**M1**	valid comparison
	There is evidence that (mean) (journey) times have decreased	**A1 FT**	in context not definite no contradictions NB use of two tail test scores max B0M1A1M1A0 no ft for two tail test
		5	
(c)	H_0 was rejected OE	***B1 FT**	FT H_0 was accepted OE
	Type I	**DB1 FT**	FT Type II
		2	

264. 9709_s21_ms_63 Q: 3

Question	Answer	Marks	Guidance
(a)(i)	H_0: $\lambda = 2.4$ H_1: $\lambda > 2.4$	**B1**	Accept λ or μ Accept 2.4 or 0.8 (per year)
		1	
(a)(ii)	$1 - e^{-2.4}(1 + 2.4 + \frac{2.4^2}{2} + \frac{2.4^3}{3!} + \frac{2.4^4}{4!})$	**M1**	Any λ; allow one end error
	0.0959 (3 sf)	**A1**	**SC** unsupported answer 0.0959 scores B1 only not M1A1
	0.0959 > 0.05	**M1**	Valid comparison Use of 0.9041 < 0.95 can recover either M1A1 or B1
	There is evidence that Jane's claim not justified or There is insufficient evidence to support Jane's claim	**A1 FT**	OE. In context, not definite, e.g. not 'Jane is wrong', no contradictions. Condone omission of Jane.
		4	
(b)	Mean not constant so Poisson model not valid	**B1**	
		1	

265. 9709_w21_ms_61 Q: 5

Question	Answer	Marks	Guidance
(a)(i)	Po(0.025)	**B1**	For Poisson and correct parameter.
	$n = 2500 > 50$, $np = 0.025 < 5$	**B1**	Must show 2500 and 0.025. Accept p = $\frac{1}{100000}$ < 0.1 in place of $np = 0.025 < 5$.
		2	

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Question	Answer	Marks	Guidance
(a)(ii)	$1 - e^{-0.025}$	**M1**	Allow any λ. FT *their* **(a)(i)** if normal; must have continuity correction.
	0.0247 (3sf)	**A1**	Must be from Poisson. Unsupported correct answer scores **B1** instead of **M1 A1**.
		2	
(b)	H_0: $p = 0.3$ H_1: $p < 0.3$	**B1**	
	$0.7^{28} + 28 \times 0.7^{27} \times 0.3 + {}^{28}C_2 \times 0.7^{26} \times 0.3^2 + {}^{28}C_3 \times 0.7^{25} \times 0.3^3 + {}^{28}C_4 \times 0.7^{24} \times 0.3^4$	**M1**	Use of B(28, 0.3). Addition of terms must be intended. Allow one term wrong or omitted or extra.
	0.0474	**A1**	Unsupported correct answer scores **B1** instead of **M1 A1**.
	0.0474 > 0.02 [Not reject H_0]	**M1**	Valid comparison.
	No evidence that suspicion is true.	**A1 ft**	Not definite e.g. not 'Suspicion is not true', in context, no contradictions. SC use of N(8.4, 5.88) leading to 0.054 > 0.2 OE can score **B1** only for comparison and correct conclusion. Correct hypotheses with p will also score B1.
		5	

266. 9709_w21_ms_61 Q: 7

Question	Answer	Marks	Guidance
(a)	H_0: $\mu = 64.6$ H_1: $\mu < 64.6$	**B1**	Allow population mean, not just 'mean'.
	$[\pm]\frac{63.5 - 64.6}{5.2 \div \sqrt{100}}$	**M1**	Standardising. Must have $\sqrt{100}$.
	$[\pm]-2.115$	**A1**	Accept -2.12 (3sf)
	'2.115' > 1.96 or '–2.115' < –1.96 [do not accept H_0]	**M1**	Valid comparison (0.0172 < 0.025 for area comparison).
	There is evidence that $\mu < 64.6$	**A1 FT**	Not definite, e.g. not '$\mu < 64.6$'. in context. No contradictions. Accept critical value method leading to 63.5 < 63.58 or 64.6 > 64.52.
		5	
(b)	$\frac{m - 64.6}{5.2 \div \sqrt{100}} = -1.96$	**M1**	Finding the critical value using $N\left(64.6, \frac{5.2}{\sqrt{100}}\right)$ and a z value.
	$m = 63.5808$	**A1**	
	$\frac{63.5808 - 62.7}{5.2 \div \sqrt{100}}$ [= 1.694]	**M1**	Standardising using $N\left(62.7, \frac{5.2}{\sqrt{100}}\right)$ and a critical value.
	1 – Φ('1.694')	**M1**	For area consistent with *their* values.
	0.0451	**A1**	Accept answers that round to 0.045.
		5	

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267. 9709_w21_ms_62 Q: 4

Question	Answer	Marks	Guidance
(a)	Fireworks are destroyed when tested.	**B1**	
		1	
(b)	H_0: Pop mean time lasted (or μ) = 30 H_1: Pop mean time lasted (or μ) < 30	**B1**	Not just 'mean'.
	$\pm \frac{29-30}{\frac{5}{\sqrt{100}}}$	**M1**	For standardising. Must have $\sqrt{100}$. Use of totals N(3000,2500) giving $\frac{(2900-3000)}{\sqrt{2500}}$ scores **M1**. No mixed methods.
	± -2	**A1**	
	$-2 > -2.326$ [Do not reject H_0]	**M1**	Accept –2.326 to –2.329. Valid comparison or area comparison 0.0228>0.01 or 0.9772<0.99. Accept CR method 28.837<29 or 30.163>30.
	There is not enough evidence that mean time lasted is less than 30 seconds OR Not enough evidence to support the inspector's suspicion	**A1 FT**	In context (if used need mean or time / condone average instead of mean), not definite, e.g. not 'mean time lasted is not less than 30 seconds'. No contradictions. **Note** 2 tailed test can score **B0 M1 A1 M1** (comparison with 2.574–2.579) **A0** (no FT).
		5	
(c)	Yes. Because population distribution is unknown [condone not Normal].	**B1**	Both needed. Condone X for parent population.
		1	

268. 9709_w21_ms_62 Q: 6

Question	Answer	Marks	Guidance
(a)	H_0: P(0) = $\frac{1}{10}$ H_1: P(0) < $\frac{1}{10}$	**B1**	Accept p.
		1	
(b)	For B(30,0.1)	**M1**	Used not just stated.
	$P(X = 0) = 0.9^{30}$ [= 0.0424] [<0.1]	**M1**	
	$P(X = 0 \text{ or } 1) = 0.9^{30} + 30\times0.9^{29}\times0.1$=0.184 [>0.1]	**B1**	Accept 0.184 or 0.183.
	Rejection region is 0 zeros	**A1**	Dependent on **M1 M1** and at least one comparison, no errors seen. **SC** One unsupported correct answer 0.0424/0.184(or 0.183) and correct rejection region scores **B1**; with comparison with 0.1 scores **B2**. Two unsupported correct answers 0.0424 and 0.184(or 0.183) and correct rejection region scores **B2** or if with one comparison with 0.1 scores **B3**.
		4	
(c)	0.0424	**B1**	FT *their* **(b)** must have a critical region (only follow though Binomial), dependent on answer < 0.1.
		1	

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Question	Answer	Marks	Guidance
(d)	Bin(30, $\frac{1}{40}$)	**B1**	SOI
	$1 - 0.975^{30}$	**M1**	FT *their* rr and with Bin(30, 1/40)).
	0.532 (3dp)	**A1**	SC Unsupported correct answer scores **B2** only.
		3	
(e)	Not concluding that the probability is less than $\frac{1}{10}$, when in fact it is.	**B1**	In context.
		1	

269. 9709_w21_ms_63 Q: 5

Question	Answer	Marks	Guidance
(a)(i)	Po(0.025)	**B1**	For Poisson and correct parameter.
	$n = 2500 > 50$, $np = 0.025 < 5$	**B1**	Must show 2500 and 0.025. Accept p = $\frac{1}{100000} < 0.1$ in place of $np = 0.025 < 5$.
		2	

Question	Answer	Marks	Guidance
(a)(ii)	$1 - e^{-0.025}$	**M1**	Allow any λ. FT *their* **(a)(i)** if normal; must have continuity correction.
	0.0247 (3sf)	**A1**	Must be from Poisson. Unsupported correct answer scores **B1** instead of **M1 A1**.
		2	
(b)	H_0: $p = 0.3$ H_1: $p < 0.3$	**B1**	
	$0.7^{28} + 28 \times 0.7^{27} \times 0.3 + {}^{28}C_2 \times 0.7^{26} \times 0.3^2 + {}^{28}C_3 \times 0.7^{25} \times 0.3^3 + {}^{28}C_4 \times 0.7^{24} \times 0.3^4$	**M1**	Use of B(28, 0.3). Addition of terms must be intended. Allow one term wrong or omitted or extra.
	0.0474	**A1**	Unsupported correct answer scores **B1** instead of **M1 A1**.
	0.0474 > 0.02 [Not reject H_0]	**M1**	Valid comparison.
	No evidence that suspicion is true.	**A1 ft**	Not definite e.g. not 'Suspicion is not true', in context, no contradictions. SC use of N(8.4, 5.88) leading to 0.054 > 0.2 OE can score **B1** only for comparison and correct conclusion. Correct hypotheses with p will also score B1.
		5	

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270. 9709_w21_ms_63 Q: 7

Question	Answer	Marks	Guidance
(a)	H_0: $\mu = 64.6$ H_1: $\mu < 64.6$	**B1**	Allow population mean, not just 'mean'.
	$[\pm]\frac{63.5-64.6}{5.2\div\sqrt{100}}$	**M1**	Standardising. Must have $\sqrt{100}$.
	$[\pm]-2.115$	**A1**	Accept -2.12 (3sf)
	'2.115' > 1.96 or '–2.115' < –1.96 [do not accept H_0]	**M1**	Valid comparison (0.0172 < 0.025 for area comparison).
	There is evidence that $\mu < 64.6$	**A1 FT**	Not definite, e.g. not '$\mu < 64.6$'. in context. No contradictions. Accept critical value method leading to 63.5 < 63.58 or 64.6 > 64.52.
		5	
(b)	$\frac{m-64.6}{5.2\div\sqrt{100}} = -1.96$	**M1**	Finding the critical value using $N\left(64.6, \frac{5.2}{\sqrt{100}}\right)$ and a z value.
	$m = 63.5808$	**A1**	
	$\frac{63.5808-62.7}{5.2\div\sqrt{100}}$ [= 1.694]	**M1**	Standardising using $N\left(62.7, \frac{5.2}{\sqrt{100}}\right)$ and a critical value.
	1 – Φ('1.694')	**M1**	For area consistent with *their* values.
	0.0451	**A1**	Accept answers that round to 0.045.
		5	

271. 9709_m20_ms_62 Q: 3

Question	Answer	Marks	Guidance
(a)	est (μ) = 37.6 or $\frac{1504}{40}$ or $\frac{188}{5}$	**B1**	
	est (σ^2) $= \frac{40}{39}\left[\frac{57760}{40} - 37.6^2\right] = 31.0154 = \frac{2016}{65}$	**M1**	Correct substitution in any correct formula $\frac{1}{39}\left[57760 - \frac{1504^2}{40}\right]$
	= 31.(0) (3 sf)	**A1**	Accept $\frac{2016}{65}$ or $31\frac{1}{65}$
		3	
(b)	H_0: Pop mean (or μ) = 39.2 H_1: Pop mean (or μ) < 39.2	**B1**	Both. Not just 'mean'
	$\frac{'37.6'-39.2}{\frac{\sqrt{'31.0154'}}{\sqrt{40}}}$	**M1**	Allow use of biased variance (30.2), must have √40
	= –1.817	**A1**	**SC** FT use of biased = –1.840 for A1
	'1.817' > 1.645 OE	**M1**	Valid comparison '*their* 1.817' with 1.645 or valid area comparison 0.0346 < 0.05 OE
	There is evidence that mean time has decreased	**A1FT**	FT *their* 1.817; in context, not definite, no contradictions **SC** For 2 tail test: H_1: $\mu \neq 39.2$ and comp 1.96, max B0M1A1M1A0 (no FT for final mark)
		5	

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272. 9709_m20_ms_62 Q: 7

Question	Answer	Marks	Guidance
(a)	P($X \leqslant n$) ($n \leqslant 20$) attempted, using B(20, 0.95)	**M1**	OE
	P($X \leqslant 17$) or P($X \leqslant 16$) attempted, using B(20, 0.95)	**M1**	OE
	(P($X \leqslant 17$)) = 0.0755 and (P($X \leqslant 16$)) = 0.0159	**A1**	OE (0.925 and 0.984) both correct
	Rej region is $X \leqslant 16$ or X < 17	**A1**	Dependent on M1M1 and previous answers correct to at least 0.075/0.076 and 0.016 **or** 0.92/0.93 and 0.98 Correct unsupported answers of 0.0755 and 0.0159 OE scores M1 M1 A0
		4	

Question	Answer	Marks	Guidance
(b)	0.0159	**B1**	FT *their* rejection region, from Binomial in a, if P(X in rejection region) < 0.025
		1	
(c)	Use of B(20, 0.7)	**M1**	
	P($X > 16 \mid p = 0.7$)	**M1**	Correct method using B(20, 0.7)
	= 0.107	**A1**	
		3	

273. 9709_s20_ms_61 Q: 2

Question	Answer	Marks
(a)	Assume standard deviation unchanged or standard deviation = 0.08	**B1**
	Assume yields normally distributed	**B1**
		2
(b)	H_0: Population mean yield (or μ) = 0.56 H_1: Population mean yield (or μ) > 0.56	**B1**
	$\frac{0.61-0.56}{\frac{0.08}{\sqrt{10}}}$	**M1**
	1.976	**A1**
	Comp 1.96	**M1**
	There is evidence that mean yield has increased	**A1**
		5

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274. 9709_s20_ms_61 Q: 4

Question	Answer	Marks
(a)	$(1^2+2^2+3^2+4^2+5^2) \div 5 - 3^2$ (= 2 **AG**)	**B1**
		1
(b)	N(3, 2)	**M1**
	$\frac{2.6-"3"}{\sqrt{\frac{2}{40}}} (=-1.789)$	**M1**
	Φ("–1.789") = 1 – Φ("1.789")	**M1**
	0.0367 to 0.0368	**A1**
		4
(c)	Concluding that spinner is unbiased when it is biased	**B1**
		1

275. 9709_s20_ms_62 Q: 2

Question	Answer	Marks
(a)	H_0: Proportion = 0.05 H_1: Proportion > 0.05	**B1**
		1
(b)	$1 - (0.95^{25} + 25 \times 0.95^{24} \times 0.05 + {}^{25}C_2 \times 0.95^{23} \times 0.05^2 + {}^{25}C_3 \times 0.95^{22} \times 0.05^3)$	**M1**
	Completely correct expression	**A1**
	0.0341	**A1**
		3
(c)	Type II	**B1**
	Will conclude proportion not increased	**B1**
		2

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276. 9709_s20_ms_62 Q: 4

Question	Answer	Marks
(a)	$E(X) = 2$	B1
	$0.2 \times 1 + 0.4 \times 2^2 + 0.2 \times 3^2 + 0.1 \times 4^2 - 2^2 (= 1.2)$ **AG**	B1
		2
(b)	$\frac{a-2}{\sqrt{1.2 \div 200}} = \phi^{-1}(0.9)$ (**M1** for LHS, **M1** for RHS)	M1 M1
	$a = 2 + \sqrt{1.2 \div 200} \times 1.282$	M1
	2.10 (3 sf)	A1
		4
(c)	Yes, because X is not normally distributed.	B1
		1
(d)	H_0: pop mean = 2 H_1: pop mean < 2	B1
	$\frac{1.86-2}{\sqrt{1.2 \div 200}}$	M1
	1.807	A1
	comp $z = 1.645$	M1
	There is evidence that the spinner is biased so that mean is less than 2	A1
		5

277. 9709_s20_ms_63 Q: 3

Question	Answer	Marks
	H_0: $\lambda = 104$ (or 5.2) H_1: $\lambda > 104$ (or 5.2)	B1
	N(104, 104) stated or implied	B1
	$\frac{124.5-104}{\sqrt{104}}$	M1
	2.010	A1
	$2.010 > 1.96$	M1
	There is evidence that λ has increased	A1
		6

278. 9709_s20_ms_63 Q: 7

Question	Answer	Marks
(a)	Later customers might spend times different from first ones	B1
		1
(b)	0.02	B1
	Concluding that $\mu \neq 6.0$, when actually $\mu = 6.0$	B1
		2

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Question	Answer	Marks
(c)	$H_0: \mu = 6.0$ $H_1: \mu \neq 6.0$	**B1**
	$\frac{6.8-6.0}{\sqrt{\frac{4.8}{50}}}$	**M1**
	2.582	**A1**
	comp 2.326	**M1**
	Evidence that $\mu \neq 6.0$	**A1**
		5
(d)	Population distribution unknown	**B1**
		1

279. 9709_w20_ms_61 Q: 5

Question	Answer	Marks	Guidance
(a)	$\sqrt{2.1}$ or 1.45 (3 sf)	**B1**	
		1	
(b)	$\lambda = 4.2$	**B1**	
	$1 - e^{-4.2}(1 + 4.2)$	**M1**	$1 - P(X \leqslant 1)$ any λ, allow one end error.
	= 0.922 (3 sf)	**A1**	
		3	
(c)	$\lambda = 6.3$ $e^{-6.3}\left(\frac{6.3^5}{5!}+\frac{6.3^6}{6!}+\frac{6.3^7}{7!}\right)$	**M1**	$P(X = 5, 6, 7)$ any λ, allow one end error.
	= 0.455 (3 sf)	**A1**	
		2	
(d)	$H_0: \lambda = 6.3$ $H_1: \lambda < 6.3$	**B1**	Accept μ, accept 2.1 (per week)
	$P(X \leqslant 2) = e^{-6.3}\left(1+6.3+\frac{6.3^2}{2!}\right)$	**M1**	
	= 0.0498 or 0.0499	**A1**	Accept 0.0499
	'0.0498' < 0.1	**M1**	For valid comparison. For CV method the comparison can be '2 lies in CR of $X \leqslant 2$'
	There is evidence that mean number of absences has decreased.	**A1 FT**	In context, not definite, e.g. not 'Mean number of absences has decreased.' No contradictions.
		5	

Question	Answer	Marks	Guidance
(e)	H_0 rejected	***B1 FT**	OE
	Hence Type I error possible	**DB1 FT**	
		2	

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280. 9709_w20_ms_61 Q: 6

Question	Answer	Marks	Guidance
(a)	$\frac{40-38.4}{\frac{6.9}{\sqrt{30}}} = 1.270$ $\frac{38-38.4}{\frac{6.9}{\sqrt{30}}} = -0.3175$	**M1**	M1 for either correct expression must have √30 (condone continuity correction)
		A1	A1 for ±1.270 or for 1.27 or AWRT
		A1	A1 for ± (–0.3175) must be opposite sign or for 0.317 or 0.318 or AWRT
	Φ('1.270') – (1 – ϕ('0.3175')	**M1**	For correct method consistent with *their* values
	= 0.523 (3 sf) or 0.522	**A1**	
		5	
(b)(i)	2-tail because looking for 'change', not decrease or increase	**B1**	OE
		1	

Question	Answer	Marks	Guidance
(b)(ii)	H_0: Population mean journey time (or μ) = 38.4 H_1: Population mean journey time (or μ) ≠ 38.4	**B1**	Not just 'mean journey time'
	$\frac{40.2-38.4}{\frac{6.9}{\sqrt{30}}}$	**M1**	For standardising (must have √30)
	= 1.429	**A1**	
	'1.429' < 1.645	**M1**	For valid comparison (area comparison 0.0765 > 0.05)
	There is no evidence that mean journey time has changed.	**A1 FT**	In context. Not definite (e.g. not 'mean journey time has not changed'). No contradictions. FT *their* '1.429' (Note use of 1-tail test scores B0 M1A1M1(comparison with 1.282) A0 max)
	Alternative method for question 6(b)(ii) – critical values method		
	H_0: Population mean journey time (or μ) = 38.4 H_1: Population mean journey time (or μ) ≠ 38.4	**B1**	Not just 'mean journey time'
	$38+1.645\left(\frac{6.9}{\sqrt{30}}\right)$	**M1**	
	= 40.47	**A1**	
	40.2 < 40.47	**M1**	For valid comparison
	There is no evidence that mean journey time has changed.	**A1 FT**	In context. Not definite (e.g. not 'mean journey time has not changed'). No contradictions.
		5	

Question	Answer	Marks	Guidance
(b)(iii)	Yes, because population distribution unknown.	**B1**	Allow: Yes, because population distribution not normal.
		1	

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281. 9709_w20_ms_62 Q: 4

Question	Answer	Marks	Guidance
	$\text{est}(\mu) = \frac{1850}{200}$ or 9.25	**B1**	
	$\text{est}(\sigma^2) = \frac{200}{199}\left(\frac{17850}{200} - \left(\frac{1850}{200}\right)^2\right)$ or $\frac{1}{199}\left(17850 - \frac{1850^2}{200}\right)$	**M1**	
	= 3.71 or 3.7060 or $\frac{1475}{398}$	**A1**	
	H_0: $\mu = 8.9$ H_1: $\mu \neq 8.9$	**B1**	Accept Population mean (not just mean)
	$\frac{\frac{1850}{200} - 8.9}{\sqrt{\frac{"3.706"}{200}}}$	**M1**	Use of biased variance (3.6875) still scores M1
	= 2.57(3sf) (or using areas 0.00507 – 0.0051)	**A1**	Accept 2.58 (3sf) or using areas 0.0049–0.005 where biased variance used.
	2.24 < 2.57 or 0.00507 < 0.0125	**M1**	For valid comparison with 2.240 or 2.241 or valid comparison with 0.0125 Accept 2.24 < 2.58 or 0.00496 < 0.0125 where biased variance used
	(Reject H_0) There is evidence that μ is not 8.9	**A1 FT**	Not definite, e.g. NOT '$\mu \neq 8.9$' Must be in context. No contradictions. (Accept cv method) (**Note:** Use of 1 tail test scores Max B1M1A1B0M1A1M1A0, max 6 out of 8)
		8	

282. 9709_w20_ms_62 Q: 6

Question	Answer	Marks	Guidance
(a)	H_0: P(contains offer) = $\frac{1}{3}$ H_1: P(contains offer) < $\frac{1}{3}$	**B1**	Allow p for P(contains offer) but not just proportion
	P(0,1 or 2 offers in 20 | H_0) $= \left(\frac{2}{3}\right)^{20} + 20\left(\frac{2}{3}\right)^{19}\left(\frac{1}{3}\right) + {}^{20}C_2\left(\frac{2}{3}\right)^{18}\left(\frac{1}{3}\right)^2$	**M1**	
	= 0.0176 (3sf)	**A1**	
	'0.0176' < 0.1	**M1**	For valid comparison. **SC** comparison of 0.982(4) > 0.9 scores M1 and recovers the previous M1 A1
	(Reject H_0) No evidence (at 10% level) to support manufacturers claim	**A1 FT**	In context. Not definite. No contradictions. (Note 2 tail test scores max B0M1A1M1A0, max 3 out of 5) Accept critical region method: M1 A1 for correctly finding critical region of < 4 ; 2 in critical region M1; A1 conclusion **SC** Use of Normal approximation $N\left(\frac{20}{3}, \frac{40}{9}\right)$ scores B1 M1 A0 M1 A1 max; the first M1 for $\frac{\left(2.5 - \frac{20}{3}\right)}{\sqrt{\left(\frac{40}{9}\right)}}$ requires use of correct continuity correction and the comparison 0.024 < 0.1 OE must be a valid comparison
		5	

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Question	Answer	Marks	Guidance
(b)	$1 - P(X \leqslant 3)$	**M1**	M1 for 1 – (one term omitted or extra or incorrect) or omit '1 −'
	$=1-\left[\left(\frac{6}{7}\right)^{20}+20\left(\frac{6}{7}\right)^{19}\left(\frac{1}{7}\right)+{}^{20}C_2\left(\frac{6}{7}\right)^{18}\left(\frac{1}{7}\right)^{2}+{}^{20}C_3\left(\frac{6}{7}\right)^{17}\left(\frac{1}{7}\right)^{3}\right]$	**A1**	for all correct expression
	= 0.318 (3sf)	**A1**	As final answer.
		3	
(c)	Concluding that prop is 1 in 3 when it is actually less(1 in 7)	**B1**	OE, in context.
		1	

283. 9709_w20_ms_63 Q: 5

Question	Answer	Marks	Guidance
(a)	$\sqrt{2.1}$ or 1.45 (3 sf)	**B1**	
		1	
(b)	$\lambda = 4.2$	**B1**	
	$1 - e^{-4.2}(1 + 4.2)$	**M1**	$1 - P(X \leqslant 1)$ any λ, allow one end error.
	= 0.922 (3 sf)	**A1**	
		3	
(c)	$\lambda = 6.3$ $e^{-6.3}\left(\frac{6.3^5}{5!}+\frac{6.3^6}{6!}+\frac{6.3^7}{7!}\right)$	**M1**	$P(X = 5, 6, 7)$ any λ, allow one end error.
	= 0.455 (3 sf)	**A1**	
		2	
(d)	H_0: $\lambda = 6.3$ H_1: $\lambda < 6.3$	**B1**	Accept μ, accept 2.1 (per week)
	$P(X \leqslant 2) = e^{-6.3}\left(1+6.3+\frac{6.3^2}{2!}\right)$	**M1**	
	= 0.0498 or 0.0499	**A1**	Accept 0.0499
	'0.0498' < 0.1	**M1**	For valid comparison. For CV method the comparison can be '2 lies in CR of $X \leqslant 2$'
	There is evidence that mean number of absences has decreased.	**A1 FT**	In context, not definite, e.g. not 'Mean number of absences has decreased.' No contradictions.
		5	

Question	Answer	Marks	Guidance
(e)	H_0 rejected	***B1 FT**	OE
	Hence Type I error possible	**DB1 FT**	
		2	

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284. 9709_w20_ms_63 Q: 6

Question	Answer	Marks	Guidance
(a)	$\frac{40-38.4}{\frac{6.9}{\sqrt{30}}} = 1.270 \quad \frac{38-38.4}{\frac{6.9}{\sqrt{30}}} = -0.3175$	**M1**	M1 for either correct expression must have √30 (condone continuity correction)
		A1	A1 for ±1.270 or for 1.27 or AWRT
		A1	A1 for ± (–0.3175) must be opposite sign or for 0.317 or 0.318 or AWRT
	Φ('1.270') – (1 – Φ('0.3175')	**M1**	For correct method consistent with *their* values
	= 0.523 (3 sf) or 0.522	**A1**	
		5	
(b)(i)	2-tail because looking for 'change', not decrease or increase	**B1**	OE
		1	

Question	Answer	Marks	Guidance
(b)(ii)	H_0: Population mean journey time (or μ) = 38.4 H_1: Population mean journey time (or μ) ≠ 38.4	**B1**	Not just 'mean journey time'
	$\frac{40.2-38.4}{\frac{6.9}{\sqrt{30}}}$	**M1**	For standardising (must have √30)
	= 1.429	**A1**	
	'1.429' < 1.645	**M1**	For valid comparison (area comparison 0.0765 > 0.05)
	There is no evidence that mean journey time has changed.	**A1 FT**	In context. Not definite (e.g. not 'mean journey time has not changed'). No contradictions. FT *their* '1.429' (Note use of 1-tail test scores B0 M1A1M1(comparison with 1.282) A0 max)
	Alternative method for question 6(b)(ii) – critical values method		
	H_0: Population mean journey time (or μ) = 38.4 H_1: Population mean journey time (or μ) ≠ 38.4	**B1**	Not just 'mean journey time'
	$38+1.645\left(\frac{6.9}{\sqrt{30}}\right)$	**M1**	
	= 40.47	**A1**	
	40.2 < 40.47	**M1**	For valid comparison
	There is no evidence that mean journey time has changed.	**A1 FT**	In context. Not definite (e.g. not 'mean journey time has not changed'). No contradictions.
		5	

Question	Answer	Marks	Guidance
(b)(iii)	Yes, because population distribution unknown.	**B1**	Allow: Yes, because population distribution not normal.
		1	

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285. 9709_m19_ms_72 Q: 3

Question	Answer	Marks	Guidance
	H_0: $\lambda = 32$ H_1: $\lambda < 32$	**B1**	Accept 'population mean' (μ)
	$X \sim N(32, 32)$	**B1**	seen or implied
	$\frac{21.5 - 32}{\sqrt{32}}$	**M1**	Standardise with their values. Allow with no or wrong cc
	$= -1.856$ cv of $z = -2.054$ (or -2.055 or -2.053)	**A1**	
	'1.856' < 2.054	**M1**	Valid comparison or comp ϕ("1.856") with 0.98 i.e. 0.9682 < 0.98 oe
	No evidence that fewer accidents at B than at A	**A1f**	No contradictions Note Use of CV method x = 20.38 M1 A1 comparison 21.5 > 20.38 M1 conc A1
		6	

286. 9709_m19_ms_72 Q: 6

Question	Answer	Marks	Guidance
(i)	Test is for "difference" oe	**B1**	Test is not for 'increase' or 'decrease' oe No contradictions
		1	
(ii)	0.05	**B1**	
	Conclude mean time is different when it is not	**B1**	oe, in context
		2	

Question	Answer	Marks	Guidance
(iii)	Assume $\sigma = 6.4$	**B1**	
	H_0: pop mean = 91.4 H_1: pop mean ≠ 91.4	**B1**	Allow μ, but not 'mean'
	$\bar{x} = \frac{568.5}{6}$ (= 94.75)	**B1**	
	$\frac{'94.75' - 91.4}{\frac{6.4}{\sqrt{6}}}$	**M1**	Must have √6
	$= 1.282$ cv of $z = 1.96$	**A1**	
	'1.282' < 1.96	**M1**	Valid comparison or comp ϕ("1.282") with 0.975 0.9(001) < 0.975 or 0.0999 (or 0.1) > 0.025 consistent use of one tail test can score M1 for comparison with 1.645oe but not A1ft oe. No contradictions. ft their z.
	No evidence mean time different	**A1 ft**	CV method x = 96.52 M1 A1 94.75 < 96.52 M1 Conc A1
		7	

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287. 9709_s19_ms_71 Q: 2

Question	Answer	Marks	Guidance
(i)	Assume sd still 4.8 or is unchanged	**B1**	or Assume the 150 times can be treated as a random sample / are independent
	H_0: Pop mean = 26.5 H_1: Pop mean > 26.5	**B1**	Allow 'μ' but not just 'mean'
	$\frac{27.5-26.5}{\frac{4.8}{\sqrt{150}}}$	**M1**	Standardise, with √ Accept CV method
	= 2.552	**A1**	
	Comp with z-value '2.552' > 2.326	**M1**	or comp 1 – Φ('2.552') with 0.01 1 – 0.9946 = 0.0054 < 0.01
	There is evidence time has increased	**A1ft**	oe No contradictions (2 tail test scores max. B1 B0 M1 A1 M1 (for comparison with 2.576) A0 no ft)
		6	

Question	Answer	Marks	Guidance
(ii)	No because pop is normal so distr of $\bar{X}$ is normal	**B1**	Condone just 'No because pop is normal'
		1	

288. 9709_s19_ms_71 Q: 3

Question	Answer	Marks	Guidance
(i)	H_0: P(6) = $\frac{1}{6}$ H_1: P(6) < $\frac{1}{6}$	**B1**	
	$(\frac{5}{6})^{30} + 30(\frac{1}{6}) \times (\frac{5}{6})^{29} + {}^{30}C_2(\frac{1}{6})^2 \times (\frac{5}{6})^{28}$	**M1**	Allow one term incorrect, omitted or extra
	= 0.103	**A1**	
	'0.103' > 0.05	**M1**	
	No evidence (at 5% level) that die biased	**A1ft**	oe No contradictions
		5	
(ii)	$(\frac{5}{6})^{30} + 30(\frac{1}{6}) \times (\frac{5}{6})^{29}$	**M1**	
	P(Type I) = 0.0295	**A1**	
		2	

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289. 9709_s19_ms_72 Q: 3

Question	Answer	Marks	Guidance
(i)	Est(μ) = 1.85	**B1**	
	Est(σ^2) = $\frac{50}{49}\left(\frac{175.25}{50} - '1.85'^2\right)$	**M1**	Allow $\sqrt{\frac{50}{49}\left(\frac{175.25}{150} - '1.85'^2\right)}$ or 0.0290 for M1
	= 0.0842 (3 sf) or $\frac{33}{392}$	**A1**	Cao If $\frac{50}{49}$ omitted (giving var = 0.0825 or sd = 0.287) M0A0
		3	
(ii)	H_0: Pop mean time = 1.9 (h) H_1: Pop mean time < 1.9 (h)	**B1**	Allow 'μ' but not just 'mean'
	$\pm\frac{1.85-1.9}{\sqrt{\frac{'0.0842'}{50}}}$	**M1**	$\pm\frac{1.85-1.9}{\frac{'0.290'}{\sqrt{50}}}$ Accept totals method (92.5–95) / $\sqrt{4.21}$
	= –1.22	**A1**	= –1.22
	comp z = –1.645	**M1**	Or other valid comparison 0.888 or 0.889 < 0.95 OR 0.111 or 0.112>0.05
	No evidence that mean time < 1.9 h	**A1**	**FT** their z. Correct conclusion. No contradictions If $\frac{50}{49}$ not used in (1): var = 0.8225, sd = 0.907, cr = 1.17 can score all marks in **(ii)** Note- 2 tail test can score B0 M1 A1 M1 (comparison with 1.96) A0 (no ft) max3/5
		5	

290. 9709_s19_ms_72 Q: 5

Question	Answer	Marks	Guidance
(i)	H_0: p = 0.1 H_1: p < 0.1	**B1**	
		1	
(ii)	B(40, 0.1) stated or implied by use of	**B1**	e.g. by ${}^{40}C_x$ or $0.9^p \times 0.1^q$ ($p + q = 40$)
	$0.9^{40} + 40\times0.9^{39}\times0.1$	**M1**	Correct working (if seen). If working not seen, M1 may be implied by 0.0805
	= 0.0805	**A1**	
		3	

Question	Answer	Marks	Guidance
(iii)	z = 1.645	**B1**	seen
	$\frac{6}{80} \pm z\sqrt{\frac{\frac{6}{80}\times\frac{(80-6)}{80}}{80}}$	**M1**	Formula of correct form. Must be a 'z'
	= 0.0266 to 0.123 (3 sfs)	**A1**	Allow 0.03 to 0.12 or better Must be an interval
		3	
(iv)	10% (or manufacturer's claim) is within CI Hence no reason to question claim	**B1**	**FT** Allow '10% is within CI, accept claim' oe Must include both parts. No contradictions. **FT** their CI Note if CI is centred on 0.1 allow ft 0.075 is within CI, accept claim
		1	

291. 9709_s19_ms_72 Q: 7

Question	Answer	Marks	Guidance
(i)	Max no. of passengers plane can take oe	**B1**	oe e.g. No of passengers who bought tickets
		1	

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Question	Answer	Marks	Guidance
(ii)	$\lambda = 3.2$	**B1**	
	$e^{-3.2}(\frac{3.2^3}{3!} + \frac{3.2^4}{4!} + \frac{3.2^5}{5!})$	**M1**	Any λ. Allow one end error
	= 0.5146 = 0.515 (3 sfs)	**A1**	SR Use of Bin(640,0.005) scores B1 (only) for 0.516
		3	
(iii)	$n > 50$	**B1**	Accept n is large
	np = 1.6, which is < 5 or p=0.005 which is <0.1	**B1**	Allow np = 3.2
		2	
(iv)	H_0: Pop mean (for 5 days) = 8 H_1: Pop mean (for 5 days) < 8	**B1**	or Pop mean (for 1 day) = 1.6 Pop mean (for 1 day) < 1.6 Allow λ or μ but not just 'mean'
	$e^{-8}(1 + 8 + \frac{8^2}{2!})$	**M1**	Any λ ($\neq$ 1.6) No end errors. Accept use of Bin(1600,0.005) P(0,1,2)=0.0136
	= 0.0138	**A1**	
	Comp 0.025	**M1**	Valid comparison
	Evidence that mean no. failing to arrive has decreased	**A1**	**FT** their '0.0138' or '0.0136'. No contradictions
		5	

292. 9709_s19_ms_73 Q: 5

Question	Answer	Marks	Guidance
	H_0: Pop mean = 20 H_1: Pop mean $\neq$ 20	**B1**	Accept μ
	$\frac{\Sigma x}{6}$ $(= \frac{126.9}{6} = 21.15)$	**M1**	Attempted or 126.9 and 11.64 attempted
	$\frac{'21.15'-20}{\sqrt{\frac{1.94}{6}}}$	**M1**	Must have $\sqrt{6}$ or $\frac{120-126.9}{\sqrt{11.64}}$ no mixed method
	= 2.022	**A1**	
	2(1 - ϕ('2.022')) 2 (1 – '0.9784)' = 0.0432)	**M1**	**FT** $2\times(1-'.9784')$
	α = 4.32 (3 sf)	**A1**	**FT** Allow 4.3 or 4, if correct working seen, or clearly implied, as far as 0.0216 **FT** their z, no error seen One-tail test scores maximum 3/6
		6	

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293. 9709_s19_ms_73 Q: 8

Question	Answer	Marks	Guidance
(i)	$H_0: p = \frac{1}{4}$ $H_1: p > \frac{1}{4}$	**B1**	
	${}^{10}C_6(\frac{1}{4})^6(\frac{3}{4})^4 + {}^{10}C_7(\frac{1}{4})^7(\frac{3}{4})^3 + {}^{10}C_8(\frac{1}{4})^8(\frac{3}{4})^2 + 10(\frac{1}{4})^9(\frac{3}{4}) + (\frac{1}{4})^{10}$	**M1**	Correct terms, allow one term incorrect or omitted or extra or summing all correct terms from 0 to 5 allow one term incorrect or omitted or extra
	= 0.0197	**A1**	or 0.9803
	comp '0.0197' with 0.01	**M1**	Valid comparison with 0.01 or valid comparison with 0.99
	No evidence to conclude $p > \frac{1}{4}$	**A1**	**FT** No contradictions Use of two-tail test can score BOM1A1M1(comparison with 0.005) A0
		5	
(ii)	${}^{10}C_7(\frac{1}{4})^7(\frac{3}{4})^3 + {}^{10}C_8(\frac{1}{4})^8(\frac{3}{4})^2 + 10(\frac{1}{4})^9(\frac{3}{4}) + (\frac{1}{4})^{10}$	**M1**	Their $P(X \geqslant 6) - {}^{10}C_6(0.25)^6(0.75)^4$
	P(Type I) = 0.00351 (3 sf)	**A1**	Accept 0.00348 to 0.00351
		2	
(iii)	C.R is $X \geqslant 7$ P(Type II) = 1 – P($X \geqslant 7 \mid p = \frac{3}{5}$) =	**M1**	May be implied
	$1 - ({}^{10}C_7(\frac{3}{5})^7(\frac{2}{5})^3 + {}^{10}C_8(\frac{3}{5})^8(\frac{2}{5})^2 + 10(\frac{3}{5})^9(\frac{2}{5}) + (\frac{3}{5})^{10})$	**M1**	Accept 1 – P($X \geqslant 8 \mid p = \frac{3}{5}$) or 1 – P($X \geqslant 6 \mid p = \frac{3}{5}$)
	= 0.618	**A1**	
		3	

294. 9709_w19_ms_72 Q: 2

Question	Answer	Marks	Guidance
(i)(a)	Assume standard deviation for the region is 7.1	**B1**	Or standard deviation is same as for whole population OE
	$\frac{63.2 - 65.2}{\frac{7.1}{\sqrt{n}}} = -2.182$	**M1**	Attempt to find correct equation (accept +2.182)
	$n = \{-2.182 \times 7.1 \div (-2)\}^2$	**A1**	Any correct expression for n or $\sqrt{n}$. SOI
	$n = 60$	**A1**	CWO. Must be an integer
		4	
(i)(b)	H_0: population mean (or μ) = 65.2 H_1: population mean (or μ) < 65.2	**B1**	Not just 'mean'
	2.182 > 1.751	**M1**	Or valid area comparison.
	There is evidence that animals are shorter in this region	**A1**	CWO. No contradictions
		3	
(ii)	Population unknown or population not given as normal	**B1**	Allow population not normal. Accept distribution of X unknown.
		1	

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295. 9709_w19_ms_72 Q: 6

Question	Answer	Marks	Guidance
(i)	H_0: Pop mean (or λ or μ) is 1.1 H_1: Pop mean (or λ or μ) is more than 1.1	**B1**	
	$P(X \geqslant 4) = 1 - e^{-1.1}\left(1 + 1.1 + \frac{1.1^2}{2} + \frac{1.1^3}{3!}\right)$	**M1**	Correct expression for either $P(X \geqslant 4)$ or $P(X \geqslant 5)$
	0.0257	**A1**	Correct value of either $P(X \geqslant 4)$ or $P(X \geqslant 5)$
	$P(X \geqslant 5) = 0.0257 - e^{-1.1} \times \frac{1.1^4}{4!} = 0.00544$	**B1**	B1 for the other value (Note use of $P(X < 4) = 0.9743$ and $P(X < 5) = 0.99456$ can score only if comparison with 0.99 seen)
	$0.00544 < 0.01 < 0.0257$	**M1**	OE stated (valid comparison)
	There is evidence mean has increased	**B1**	**SC** $P(X \geqslant 6) = 0.000968$ M1A1 Conclusion B1
		6	
(ii)	Concluding mean has increased when it has not	**B1**	In context
	'0.00544'	**B1FT**	FT *their* $P(X \geqslant 5)$, dep < 0.01
		2	
(iii)	$e^{-7.0}\left(1 + 7 + \frac{7^2}{2} + \frac{7^3}{3!} + \frac{7^4}{4!}\right)$	**M1**	Correct expression for $P(X \leqslant 4 \mid \lambda = 7.0)$
	0.173 (3 sf)	**A1**	
		2	

296. 9709_w19_ms_73 Q: 4

Question	Answer	Marks	Guidance
	Assume trains are independent OR probability of being on time is constant	**B1**	Must be in context
	H_0: P(on time)=0.92 H_1: P(on time)<0.92	**B1**	Both. Allow 'p' or π
	$1 - \left({}^{20}C_{17} \times 0.92^{17} \times 0.08^3 + {}^{20}C_{18} \times 0.92^{18} \times 0.08^2 + 20 \times 0.92^{19} \times 0.08 + 0.92^{20}\right)$	**M1**	Allow one end error Must have 1 – …
	=0.0706 (3 sf)	**A1**	
	Compare with 0.05	**M1**	Valid comparison needed
	No evidence that percentage less than 92%	**A1FT**	OE No contradictions. Method using normal approximation: If the first B1B1 is earned then: $CV - 1.566\left(\text{from } \frac{16.5 - 20 \times 0.92}{\sqrt{20 \times 0.92 \times 0.08}}, \text{with continuity correction}\right)$ **or** CV=1.978 (without continuity correction) comp z=1.645 No evidence that % decreased (1.566) or evidence that % decreased (1.978) is awarded **SC2** after B marks
		6	

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297. 9709_w19_ms_73 Q: 7

Question	Answer	Marks	Guidance
(i)	H_0: Pop mean=546 H_1: Pop mean>546	**B1**	Both. Allow just μ, but not just 'mean'
	$\frac{581-546}{\frac{120}{\sqrt{40}}}$	**M1**	Standardising. Need $\frac{120}{\sqrt{40}}$
	=1.845 allow 1.844	**A1**	Allow 1.84 or 1.85 AWRT
	1.845<1.96	**M1**	OE. Or area comparison 0.0325>0.025 or large probabilities
	No evidence that mean weekly income has increased	**A1FT**	No contradictions. If H_1: ≠, and 2.241 used, max B0M1A1M1A0
		5	
(ii)	$\frac{a-546}{\frac{120}{\sqrt{40}}}=1.96$	**M1**	Standardise to find a. Need $\frac{120}{\sqrt{40}}$ **and** 546 **and** a value of z
	a = 583.19	**A1**	Allow 583 to 3sf
	$\frac{'583.19'-595}{\frac{120}{\sqrt{40}}}(=-0.622)$	**M1**	Standardise. Need $\frac{120}{\sqrt{40}}$ and 595
	ϕ('−0.622')=1 − ϕ('0.622')	**M1**	Consistent area
	0.267	**A1**	
		5	

298. 9709_m18_ms_72 Q: 4

Question	Answer	Marks	Guidance
(i)	(Po)(2.4)	**B1**	seen or implied
	$e^{-2.4}(1+2.4+\frac{2.4^2}{2}+\frac{2.4^3}{3!})$	**M1**	allow + P(4)/one end error. Allow wrong λ
	= 0.779 (3 sfs)	**A1**	Final answer (Note: accept combination method)
		3	
(ii)	H_0: λ (or mean) = 3.6 (or 0.9) H_1: λ (or mean) < 3.6 (or 0.9)	**B1**	Accept μ for both
	$e^{-3.6}(1+3.6)$	**M1**	Allow any λ
	= 0.126	**A1**	
	0.126 > 0.1	**M1**	Valid comparison. (Comparison with 0.9 could recover previous **M1A1**)
	No evidence that fewer than usual sold	**A1FT**	Correct conclusion. No contradictions
		5	

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299. 9709_m18_ms_72 Q: 5

Question	Answer	Marks	Guidance
(i)	H_0: P(Orange) = 0.17 H_1: P(Orange) < 0.17	**B1**	or H_0: $p = 0.17$ H_1:$p < 0.17$
(ii)	Wrongly concluding that % age is less than 17%	**B1**	OE in context allow "fewer than 3 orange in packet even though average 17% is correct"
		1	
(iii)	B(30, 0.17) stated or implied	**M1**	eg by $0.17^p \times 0.83^q$ ($p + q = 30$) or ${}^{30}C_r$ ($r < 30$)
	$(1 – 0.17)^{30} + 30(1 – 0.17)^{29} \times 0.17 + {}^{30}C_2(1–0.17)^{28} \times 0.17^2$	**M1**	correct, but allow + ${}^{30}C_3(1–0.17)^{27}\times 0.17^3$
	= 0.0949 (3 sf)	**A1**	(SR: use of N(5.1,4.233) **M1** standardising (with or without cc) **M1** max 2/3)
		3	

Question	Answer	Marks	Guidance
(iv)	P(⩾ 3 orange | $p = 0.05$)	**M1**	stated or attempted; can be implied
	$= 1– [(0.95)^{30} + 30(0.95)^{29} \times 0.05 + {}^{30}C_2(0.95)^{28} \times 0.05^2]$	**M1**	allow + ${}^{30}C_3(0.95)^{27} \times 0.05^3$ in bracket, or ans 0.0608
	= 0.188 (3 sfs)	**A1**	
		3	

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300. 9709_s18_ms_71 Q: 5

Question	Answer	Marks	Guidance
(i)	$\frac{14-14.2}{\frac{3.1}{\sqrt{50}}}$ (= – 0.456)	**M1**	For stand'n; must have √50
	1 – Φ("0.456")	**M1**	for area consistent with their working
	= 0.324 (3 sfs)	**A1**	
		3	
(ii)	No because *n* large	**B1**	Accept n > 30
		1	
(iii)	H_0: $\mu = 14.2$ H_1: $\mu < 14.2$	**B1**	or 'pop mean', but not just 'mean'
	$\frac{13.5-14.2}{\frac{3.1}{\sqrt{100}}}$	**M1**	For stand'n; must have √100
	= –2.258	**A1**	
	comp –2.054 (or –2.055)	**M1**	Valid comparison of z values or areas (0.0119 < 0.02)
	There is evidence (at 2% level) that mean mass in this area < 14.2	**A1ft**	Ft their z. Correct conclusion no contradictions
		5	

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301. 9709_s18_ms_71 Q: 7

Question	Answer	Marks	Guidance
(i)	Po(1.0)	**B1**	Seen or implied
	$e^{-1}(1 + 1 + \frac{1^2}{2})$	**M1**	Allow any λ. Allow one end error.
	= 0.920 (3 sfs)	**A1**	
		3	
(ii)	$P(X > 3) = 1 - e^{-1.5}(1+1.5+ \frac{1.5^2}{2} + \frac{1.5^3}{3!})$	**M1**	Allow any λ. Allow one end error
	= 0.0656	**A1**	
		2	
(iii)(a)	Incorrectly concluding that more absences than usual when there are not oe	**B1**	In context
		1	
(iii)(b)	H_0: λ = 1.5 (or 0.3) H_1: λ > 1.5 (or 0.3)	**B1**	Or μ Both
	$P(X > 4)$ = "0.0656" – $e^{-1.5} \times \frac{1.5^4}{4!}$ = 0.0186 (3 sf)	**M1**	or $1 - e^{-1.5}(1+1.5+ \frac{1.5^2}{2} + \frac{1.5^3}{3!} + \frac{1.5^4}{4!})$
	P(Type I) = 0.0186 or 0.0185	**A1ft**	Ft their $P(X > 4)$ if less than 0.05
		3	
(iii)(c)	$P(X > 3)$ = "0.0656"	**B1ft**	Ft their **(ii)**
	0.0656 > 0.05	**M1**	
	No evidence of more than usual male absences	**A1ft**	Ft their P(X>3). Correct conclusion. No contradictions.
		3	

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302. 9709_s18_ms_72 Q: 4

Question	Answer	Marks	Guidance
(i)	Est(μ) = 495.9	**B1**	Accept 496
	Est(σ^2) = $\frac{10}{9}(\frac{2459283}{10} - "495.9"^2)$	**M1**	Attempt Σx^2 and subst in correct formula (1/9("2459283" – "4959"^{2}/10)). May be implied by correct answer
	= 12.8 (3 sf) or 383/30	**A1**	(Note: Biased var "11.49" scores M0 A0)
		3	
(ii)	H_0: $\mu = 505$ H_1: $\mu < 505$ $\frac{75660 - 505}{\frac{150}{3.6 \div \sqrt{150}}}$	**B1**	Allow 'Pop mean' but not just 'mean'
	= –2.04	**M1**	Correct stand'n; must have √150. No sd/var mixes. Condone sample SD (3.58/3.39) Accept standardisation of totals ((75660-75750)/44.091) Accept CV method
		A1	Accept +2.04 (Note: if valid area comparison done 0.0207/0.0206 or 0.979 needed for A1)
	comp z = –2.054	**M1**	Valid comparison of z's or area (0.0207/6>0.02; 0.979(3)<0.98)
	No evidence (at 2%) that machine pkts mean mass < 505	**A1ft**	oe No contradictions. SC Two tail test can score B0 M1 A1 M1 for comparison with 2.326 A0 (max 3/5)
		5	

Question	Answer	Marks	Guidance
(iii)	Large sample, so sample mean approx normally distr'd	**B1**	Allow just 'Sample is large' or 'n is large' n>30
		1	

303. 9709_s18_ms_72 Q: 7

Question	Answer	Marks	Guidance
(i)	H_0: P(10) = 0.1 H_1: P(10) > 0.1	**B1**	Both. Allow 'p' for P(10)
	B(9,0.1) P($X \geqslant 3$) = $1 - (0.9^9 + 9 \times 0.9^8 \times 0.1 + {}^9C_2 \times 0.9^7 \times 0.1^2)$	**M1**	Allow one extra term in bracket
	= 0.05297... or 0.053(0)	**A1**	
	comp 0.01	**M1**	Valid comparison. (comparison with 0.99 can recover previous M1 A1 for 0.9470)
	No evidence (at 1% level) to reject H_0 Claim not justified	**A1ft**	No contradictions
		5	
(ii)	H_0 not rejected oe	**B1**	
		1	
(iii)	P($X \geqslant 4$) $= "0.05297" - {}^9C_3 \times 0.9^6 \times 0.1^3$	**M1**	or $1-(0.9^9 + 9 \times 0.9^8 \times 0.1 + {}^9C_2 \times 0.9^7 \times 0.1^2 + {}^9C_3 \times 0.9^6 \times 0.1^3)$
	= 0.00833	**A1**	Note: 0.05297 and 0.00833 both needed in **(i)** or **(iii)** to justify CV
	Hence crit value is 4	**B1**	Allow without working. Or in **(i)** May be implied by attempt at P($X < 4$) below
	B(9,0.5) P($X < 4$)	**M1**	stated or implied
	$= 0.5^9 + 9 \times 0.5^8 \times 0.5 + {}^9C_2 \times 0.5^7 \times 0.5^2 + {}^9C_3 \times 0.5^6 \times 0.5^3$	**M1**	Attempt P($X < 4$) with $p = 0.5$
	P(Type II) = 0.254 (3 sf)	**A1**	
		6	

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304. 9709_s18_ms_73 Q: 5

Question	Answer	Marks	Guidance
(i)	Assume (pop) sd same (0.3) H_0: Pop mean = 2.4	**B1**	
	H_1: Pop mean $\neq$ 2.4	**B1**	Allow 'μ' but not just 'mean'
	$\pm\frac{2.3-2.4}{\frac{0.3}{\sqrt{30}}}$	**M1**	Must have $\sqrt{30}$, Critical region approach (2.293, 2.507) or (2.193, 2.407)
	= ±1.826	**A1**	
	comp z = ±1.96	**M1**	Valid comparison (e.g. compare 0.034 with 0.025)
	No evidence that mean time changed	**A1f**	In context, allow accept H_0 if correctly defined, no contradictions. One-tail test can score B1, B0, M1, A1, M1, A0 Max 4/6
		6	
(ii)(a)	0.05	**B1**	
		1	
(ii)(b)	Concluding mean time has not changed when it has.	**B1**	OE, must have e.g. conclude/accept SR Allow mean has decreased if a one tailed test in Part **(i)**
		1	

305. 9709_w18_ms_71 Q: 2

Question	Answer	Marks	Guidance
(i)	H_0: $p = \frac{1}{3}$ H_1: $p < \frac{1}{3}$	**B1**	
		1	
(ii)	0.0084 < 0.01	**B1**	Allow P(N $\leqslant$ 36) < 0.01 or 1%
	There is evidence that p has decreased	**B1 dep**	Allow 'p has decreased' or $p < \frac{1}{3}$
		2	
(iii)	150	**B1**	
		1	

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306. 9709_w18_ms_71 Q: 7

Question	Answer	Marks	Guidance
(i)	$H_0: \mu = 51$ $H_1: \mu < 51$	**B1**	Or popn mean …
	$\bar{x} = \frac{7480}{150} = 49.8667 = 49.9$	**B1**	
	$s^2 = \frac{150}{149}(\frac{380000}{150} - (\frac{748}{15})^2)$ $= 46.9620 = 47.0$ or $s = 6.85$	**M1**	Correct subst in s^2 or $\sqrt{s^2}$ formula Biased var scores M0
	$\frac{49.8667-51}{\sqrt{\frac{46.962}{150}}}$ allow $\frac{49.9-51}{\sqrt{\frac{47}{150}}}$	**M1**	Allow 49.8667 to 49.9 in numerator Need sqrt 150
	$= (-)\ 2.025 = (-)\ 1.965$	**A1**	Accept 2.02 or 2.03 Accept –2.0264 –1.9651 provided correct working
	comp $z = 1.96$	**M1**	or comp $1 - \phi(2.025)$ with 0.025
	There is evidence that $\mu < 51$	**A1 ft**	no contradictions biased var B1B1M0M1A0M1A1ft (max 5/7) accept cv method $x_{crit} = 49.9028$ M1A1 49 867 < 49.9… M1A1
		7	
(ii)	$\frac{\bar{x}-51}{\frac{6.856}{\sqrt{150}}} = -1.96$	**M1**	Need 51 and sqrt 150 and correct form
	$\bar{x} = 51 - 1.097 = 49.9$ Rejection region is $\bar{x} < 49.9$	**A1**	This may have been found in part (i)
	$\frac{49.9-49}{\frac{6.856}{\sqrt{150}}}$ (= 1.608 to 1.614)	**M1**	Need 49 and sqrt 150 and correct form
	$P(\bar{x} > 49.9 \mid \mu = 49) = 1 - \Phi(\text{'1.608'})$	**M1**	
	P(Type II error) = 0.0539	**A1**	Allow 0.0533 to 0.0539
		5	

307. 9709_w18_ms_72 Q: 5

Question	Answer	Marks	Guidance
(i)	$\hat{\mu} = \frac{126}{70}$ or $\frac{9}{5}$ or 1.8 oe	**B1**	
	$\Sigma x^2 f = 286$	**B1**	Seen or implied
	$\text{Est}(\sigma^2) = \frac{70}{69}(\frac{\Sigma x^2 f}{70} - \text{'1.8'}^2)$	**M1**	oe attempted
	= 0.858 or 296 / 345	**A1**	Note: Final answer for var 0.846 (biased) and no working implies B1 for 286
		4	

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Question	Answer	Marks	Guidance
(ii)	H_0: $\mu = 1.9$ H_1: $\mu < 1.9$	**B1**	Or 'pop mean'; not just 'mean'
	$\frac{1.8-1.9}{\sqrt{\frac{'0.858'}{70}}}$	**M1**	Standardise with their values from **(i)**. Must have sqr 70. No SD / Var mix
	= –0.903	**A1**	Accept ±
	0.903 < 1.645	**M1**	comp 1.645 allow comp 1.96 if H_1: $\mu \neq 1.9$ or comp 1 – ϕ('0.903')=0.182 or 0.183 with 0.05 (or 0.025 if H_1: $\mu \neq 1.9$)
	No evidence that mean no courts in S is less than in N	**A1ft**	No contradictions. ft their 0.903, but not comp 1.96 i.e. no ft for a 2 tail test Accept cv method: cv = 1.718 M1A1 1.718 < 1.8 M1 conclusion A1 (cv centred on 1.8 gives 1.982 M1A1 and M1 for 1.982 > 1.9 A1 conclusion)
		5	
(iii)	Type II because H_0 was not rejected	**B1ft**	ft their conclusion, i.e. if H_0 rejected, 'Type I because H_0 rejected' B1 Answer must be consistent with their conclusion. No conclusion in **(ii)** will score B0
		1	

308. 9709_w18_ms_72 Q: 6

Question	Answer	Marks	Guidance
(i)	H_o: $p = 0.15$ H_1: $p < 0.15$ (N(60 × 0.15, 60 × 0.15 × 0.85)) = N(9, 7.65)	**B1**	Accept H_0: μ = 9 H_1: μ < 9 Use of Normal approximation: (N(0.15, $\frac{0.15\times0.85}{60}$)) = N(0.15, 0.002125)
	$\frac{6.5-'9'}{\sqrt{'7.65'}}$	**M1**	For standardising (or $\frac{\frac{6}{60}+\frac{0.5}{60}-'0.15'}{\sqrt{'0.002125'}}$ = –0.904) Allow wrong or no cc
	= –0.904	**A1**	Accept ±
	'0.904' < 1.282	**M1**	Valid comparison of z values or ϕ('–0.904')= 0.183 > 0.1 ft their 0.904
	No evidence train late less often	**A1ft**	Use of Bin (60,0.15) to give Pr (< = 6) = 0.1848 M1A1 Valid comparison with 0.1 M1 Conclusion A1ft
		5	
(ii)	$0.1 + z \times \sqrt{\frac{0.1\times0.9}{60}} = 0.150$	**M1**	For √ (0.1 × 0.9 / 60) seen
		M1	for $0.1 + z \times ... = 0.150$ or 2z… = 0.1
	$z = 1.291$	**A1**	
	ϕ('1.291') (= 0.90(16))	**M1**	for correct method to find α
	$\alpha = 80$	**A1ft**	ft their z. Must be a +ve non-zero integer < 100
		5	

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309. 9709_w18_ms_73 Q: 2

Question	Answer	Marks	Guidance
(i)	$H_0: p = \frac{1}{3}$ $H_1: p < \frac{1}{3}$	**B1**	
		1	
(ii)	0.0084 < 0.01	**B1**	Allow P(N ⩽ 36) < 0.01 or 1%
	There is evidence that p has decreased	**B1 dep**	Allow 'p has decreased' or $p < \frac{1}{3}$
		2	
(iii)	150	**B1**	
		1	

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310. 9709_w18_ms_73 Q: 7

Question	Answer	Marks	Guidance
(i)	$H_0: \mu = 51$ $H_1: \mu < 51$	**B1**	Or popn mean …
	$\bar{x} = \frac{7480}{150} = 49.8667 = 49.9$	**B1**	
	$s^2 = \frac{150}{149}(\frac{380000}{150} - (\frac{748}{15})^2)$ $= 46.9620 = 47.0$ or $s = 6.85$	**M1**	Correct subst in s^2 or $\sqrt{s^2}$ formula Biased var scores M0
	$\frac{49.8667-51}{\sqrt{\frac{'46.962'}{150}}}$ allow $\frac{49.9-51}{\sqrt{\frac{'47'}{150}}}$	**M1**	Allow 49.8667 to 49.9 in numerator Need sqrt 150
	$= (-) 2.025 = (-) 1.965$	**A1**	Accept 2.02 or 2.03 Accept –2.0264 –1.9651 provided correct working
	comp $z = 1.96$	**M1**	or comp $1 - \phi(2.025)$ with 0.025
	There is evidence that $\mu < 51$	**A1 ft**	no contradictions biased var B1B1M0M1A0M1A1ft (max 5/7) accept cv method $x_{crit} = 49.9028$ M1A1 49 867 < 49.9… M1A1
		7	
(ii)	$\frac{\bar{x}-51}{\frac{6.856}{\sqrt{150}}} = -1.96$	**M1**	Need 51 and sqrt 150 and correct form
	$\bar{x} = 51 - 1.097 = 49.9$ Rejection region is $\bar{x} < 49.9$	**A1**	This may have been found in part (i)
	$\frac{49.9-49}{\frac{6.856}{\sqrt{150}}}$ (= 1.608 to 1.614)	**M1**	Need 49 and sqrt 150 and correct form
	$P(\bar{x} > 49.9 \mid \mu = 49) = 1 - \Phi(\text{'1.608'})$	**M1**	
	P(Type II error) = 0.0539	**A1**	Allow 0.0533 to 0.0539
		5	

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311. 9709_m17_ms_72 Q: 2

Question	Answer	Marks	Guidance
(i)	(H_1): $\mu \neq 6.4$	**B1**	
	Total:	**1**	
(ii)	comp 2.43 with a z-value $z = 2.576$ AND	**M1**	oe valid comparison
	No evidence that μ is not 6.4 or do not reject $\mu = 6.4$	**A1**	Allow "Accept $\mu = 6.4$" Must mention μ, not just "H_0" or "H_1"
	Total:	**2**	
(iii)	Testing for an increase in μ, or for a decrease in μ, rather than a change	**B1**	Any equiv statement

312. 9709_m17_ms_72 Q: 4

Question	Answer	Marks	Guidance
(i)	($\lambda =$) 4.5	**B1**	
	$e^{-4.5}(1 + 4.5 + \frac{4.5^2}{2!})$	**M1**	Allow any λ. Allow one end error
	= 0.174	**A1**	
	Total:	**3**	
(ii)	Accept reduction in mean no. of missed appts although untrue	**B1**	or Mean is 0.9 (or 4.5) but < 3 missed appts. In context
	Total:	**1**	
(iii)	$P(X \geqslant 3)$	**M1**	Attempted
	$= 1 - e^{-1}(1 + 1 + \frac{1^2}{2!})$	**M1**	Allow any λ except 4.5 or 0.9, Allow one end error
	= 0.0803 (3 sfs)	**A1**	
	Total:	**3**	

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313. 9709_s17_ms_71 Q: 2

Question	Answer	Marks	Guidance
	Assume sd still = 3.8	**B1**	or sd unchanged
	H_0: $\mu = 64.0$ H_1: $\mu < 64.0$	**B1**	
	$\frac{63.3-64.0}{\frac{3.8}{\sqrt{100}}}$	**M1**	Standardising with their values (no sd / var mixes) Must have $\sqrt{100}$
	= –1.842	**A1**	
	comp "1.842" with z-value "1.842" < 1.96	**M1**	comp +ve with +ve or –ve with –ve or comp Φ ("1.842") with 0.975 0.9672 < 0.975 OE
	No evidence that heights are shorter	**A1FT**	OE FT their z_{calc}
	Total:	**6**	

314. 9709_s17_ms_71 Q: 6

Question	Answer	Marks	Guidance
(i)	mean = 6.6	**B1**	**B1** for 6.6 (could be scored in iii)
	$P(X \leqslant 1) = e^{-6.6}(1 + 6.6) = 0.0103$	**M1**	Allow incorrect λ in both probs
	$P(X \leqslant 2) = e^{-6.6}(1 + 6.6 + \frac{6.6^2}{2}) = 0.0400$	**M1A1**	**A1** for both values
	CR is $X \leqslant 1$	**DA1**	Dep on at least one **M**
	P(Type I error) = $P(X \leqslant 1) = 0.0103$	**B1FT**	FT their $P(X \leqslant 1)$
	Total:	**6**	
(ii)	Wrongly concluding that (mean) no of (sports) injuries has decreased	**B1**	Must be in context
	Total:	**1**	

Question	Answer	Marks	Guidance
(iii)	H_0: $\lambda = 6.6$ H_1: $\lambda < 6.6$	**B1**	Can be scored in (i). Allow μ or λ / 1.1 or 6.6 or $P(X \leqslant 2) = 0.0400 > 0.02$
	2 not in CR	**M1**	
	No evidence mean no. of injuries has decreased	**A1FT**	
	Total:	**3**	
(iv)	N(39.6, 39.6)	**B1**	May be implied
	$\frac{29.5-39.6}{\sqrt{39.6}}$ (= −1.605)	**M1**	Allow with wrong or no cc
	Φ("–1.605") = 1 – Φ("1.605")	**M1**	For area consistent with their mean
	= 0.0543 (3 sfs)	**A1**	
	Total:	**4**	

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315. 9709_s17_ms_72 Q: 3

Question	Answer	Marks	Guidance
(i)	Est (μ) = 923/400 or 2.3075 or 2.31 (3 sf)	**B1**	
	Est(σ^2) = $\frac{400}{399}\left(\frac{3170}{400} - "2.3075"^2\right)$ OE	**M1**	
	= 2.60696 or 2.61 (3 sf)	**A1**	(Note: Biased Var= 2.600 scores **M0**)
	Total:	**3**	
(ii)	H_0: Pop mean (or μ) = "2.31" or "2310" H_1: Pop mean (or μ) > "2.31" or "2310"	**B1 FT**	
	$\pm \frac{2.6-"2.310"}{\sqrt{2.60696\div 50}} = 1.27$	**M1 A1**	Standardising using their values, Accept 1.28
	Comp 1.645 (OE)	**M1**	Valid comparison z values or areas
	No evidence that incomes in the region greater	**A1 FT**	OE FT their z. No contradictions (No FT for 2 tail test – max score **B0 M1 A1 M1** for comp 1.96 **A0**) **Note:** Accept alternative CV method
	Total:	**5**	

316. 9709_s17_ms_72 Q: 4

Question	Answer	Marks	Guidance
(i)	$0.75^{20} + 20 \times 0.75^{19} \times 0.25 + {}^{20}C_2 \times 0.75^{18} \times 0.25^2$	**M1**	No end errors
	= 0.0913	**A1**	As final answer
	Total:	**2**	
(ii)	H_0: Pop proportion=0.25 H_1: Pop proportion<0.25	**B1**	Allow p or π, not "proportion" (Accept anywhere in the question)
	$0.75^{25} + 25 \times 0.75^{24} \times 0.25$	**M1**	Must be B(25,0,25) No end errors
	= 0.00702	**A1**	
	comp 0.01	**M1**	Valid comparison
	There is evidence that the claim is not justified	**A1 FT**	OE. No contradictions
	Total:	**5**	

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317. 9709_s17_ms_73 Q: 4

Question	Answer	Marks	Guidance
(i)	$\bar{x} = 6.7/200$ (= 67/2000 = 0.0335)	B1	
	$s^2 = \frac{200}{199} \times \left(\frac{0.2312}{200} - "0.0335"^2 \right)$	M1	$s^2 = \frac{0.2312}{200} - 0.0335^2$ M0
	= 0.0000339(2) = 27/796000	A1	= 0.00003375 A0
	Total:	**3**	
(ii)	H_0: Pop mean level = 0.034 H_1: Pop mean level ≠ 0.034	B1	not just "mean", but allow just "μ"
	$\frac{"030335" - 0.034}{\frac{\sqrt{"0.00003392"}}{\sqrt{200}}}$	M1	must have $\sqrt{200}$ $\frac{0.0335 - 0.034}{\frac{\sqrt{"0.00003375"}}{\sqrt{200}}}$ M1
	= –1.21(4) (3 sfs) (–1.22 ↔ –1.21)	A1	= –1.217 (3 sfs) A1
	Comp with $z = -1.645$ (or 0.1124>0.05)	M1	0.112 > 0.05 valid comparison z or areas
	No evidence that (mean) pollutant level has changed, accept H_0 (if correctly defined)	A1FT	correct conclusion no contradictions SR: One tail test: **B0**, **M1A1** as normal, **M1** (comparison with 1.282 consistent signs) **A0**
	Total:	**5**	

318. 9709_s17_ms_73 Q: 7

Question	Answer	Marks	Guidance
(i)	H_0: Pop mean no. accidents = 5.64 H_1: Pop mean no. accidents < 5.64	B1	or "= 0.47 (per month)" not just "mean", but allow just "λ" or "μ"
	Use of $\lambda = 5.64$	B1	used in a Poisson calculation
	$= e^{-5.64}(1 + 5.64 + \frac{5.64^2}{2})$	M1	Allow incorrect λ in otherwise correct
	= 0.08(0)	A1	
	Comp with 0.05	M1	Valid comparison (Poisson only), no contradictions.
	No evidence to believe mean no. of accidents has decreased; accept H_0 (if correctly defined)	A1FT	Normal distribution: **M0M0**
	Total:	**6**	
(ii)	Mean < 0.47 but conclude that this is not so	B1	(Mean) no. of accidents **reduced**, but conclude not reduced. Must be in context.
	Total:	**1**	
(iii)	(Need greatest x such that $P(X \leqslant x) < 0.05$) $P(X \leqslant 1) = e^{-5.64}(1 + 5.64) = 0.024$ $P(X \leqslant 2) = 0.08$	B1	Both, could be seen in (i)
	Hence rejection region is $X \leqslant 1$	B1	Can be implied
	With $\lambda = 12 \times 0.05 = 0.6$, $1 - P(X \leqslant 1) = 1 - e^{-0.6}(1 + 0.6)$	M1	λ=0.6 and $1 - P(X \leqslant 1)$
	= 0.122 (3 sf)	A1	Normal scores 0
	Total:	**4**	

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319. 9709_w17_ms_71 Q: 7

Question	Answer	Marks	Guidance
(i)	H_0: mean no. sales = 3.5	**B1**	or " ... = 0.7 (per day)"
	H_1: mean no. sales > 3.5	**M1**	allow 'λ' or 'μ' but not just 'mean'
	$P(X \geqslant 5) = 1 - e^{-3.5}(1 + 3.5 + \frac{3.5^2}{2!} + \frac{3.5^3}{3!} + \frac{3.5^4}{4!})$	**M1**	
	= 0.275	**A1**	allow 0.274
	Comp with 0.10	**M1**	valid comparison using Poisson
	No evidence (at 10%) to believe that sales per day have increased	**A1 FT**	correct conclusion FT no contradictions
		6	

Question	Answer	Marks	Guidance
(ii)	$\lambda = 3.9$	**B1**	
	$e^{-3.9} \times \frac{3.9^2}{2!}$	**M1**	any λ ($\neq$ 0.7 or 0.6), single term
	= 0.154 (3 sf)	**A1**	
		3	

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320. 9709_w17_ms_71 Q: 8

Question	Answer	Marks	Guidance
(i)	$\bar{x} = 27/150$ (= 0.18)	**B1**	
	$s = \sqrt{\frac{150}{149}} \times \sqrt{\frac{5.01}{150} - 0.18^2}$ or variance (= 0.031729) (var = 3/2980 = 0.0010067)	**M1**	or var = $1/149(5.01 - 27.0^2/150)$
	H_0: Pop mean = 0.185 H_1: Pop mean < 0.185	**B1**	allow just 'μ'
	$\frac{0.18 - 0.185}{\frac{'0.031729'}{\sqrt{150}}}$	**M1**	standardising, need $\sqrt{150}$
	= (–) 1.930 (3 sfs) or 1.93	**A1**	
	Comp with z = (–) 2.326	**M1**	consistent signs or using probs 0.0268 > 0.01 or 0.9732 < 0.99 or using x_{crit} 0.18 > 0.17897
	There is no evidence (at 1% level) that concentration with drug is less than without drug	**A1 FT**	conclusion FT no contradictions
		7	

Question	Answer	Marks	Guidance
(ii)	$\frac{cv - 0.185}{\frac{'0.031729'}{\sqrt{150}}}$ (= – 2.326)	**M1**	must use 0.185 and $\sqrt{150}$
	= 0.17897 or 0.179	**A1**	acceptance region (for H_0) is > 0.179
	$\frac{"0.17897" - 0.175}{\frac{'0.031729'}{\sqrt{150}}}$ (=1.534)	**M1**	must use 0.175 and $\sqrt{150}$
	1 – ϕ("1.534")	**M1**	indep mark
	= 0.0625 (3 sf)	**A1**	Accept 0.0610 to 0.0628
		5	

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321. 9709_w17_ms_72 Q: 3

Question	Answer	Marks	Guidance
(i)	$\overline{m} = \frac{98.2}{100} = 0.982$	**B1**	Accept either
	$s = \sqrt{\frac{100}{99}} \times \sqrt{\frac{104.52}{100} - 0.982^2}$ (= 0.28582) or var = 0.08169	**M1**	
	H_0: Pop mean mass = 1.01 H_1: Pop mean mass < 1.01	**B1**	not just 'mean', but allow just 'μ'
	$\pm\frac{0.982 - 1.01}{\frac{0.28582}{\sqrt{100}}}$	**M1**	$\pm\frac{0.982 - 1.01}{\frac{0.284387}{\sqrt{100}}}$ **M1**
	= −0.980 (3 sf) accept ±	**A1**	= –0.985 (3 sfs) accept ± **A1**
	Comp with z = − 1.645 (or areas 0.1635 > 0.05)	**M1**	Valid comparison of z's or area's
	No evidence that (mean) mass is less than 1.01	**A1 FT**	Correct conclusion FT their z
		7	

Question	Answer	Marks	Guidance
(ii)	Distr of X normal (so distr of $\overline{X}$ normal) Must state or imply No	**B1**	X/parent population
		1	

322. 9709_w17_ms_72 Q: 6

Question	Answer	Marks	Guidance
(i)	H_0: Pop mean no. defectives = 5.15 H_1: Pop mean no. defectives < 5.15	**B1**	or '= 1.03 (per day)' not just 'mean', but allow just 'λ' or 'μ'
	P($X \leqslant 2$)	**M1**	Attempted. Any one term error/end error/incorrect λ/expression 1–…
	$= e^{-5.15}(1 + 5.15 + \frac{5.15^2}{2})$	**M1**	Correct expression attempted
	= 0.113	**A1**	
	Comp with 0.1	**M1**	Valid comparison
	No evidence to believe mean no. of defectives has decreased	**A1 FT**	Correct conclusion (FT their value) No contradictions
		6	

Question	Answer	Marks	Guidance
(ii)	BOTH P($X \leqslant 1$) = $e^{-5.15}$ (1 + 5.15) (= 0.0357) AND P($X \leqslant 2$) = = $e^{-5.15}(1 + 5.15 + \frac{5.15^2}{2})$= (0.113)	**B1***	(Could be seen in **(i)**)
	Comp either with 0.1	**DB1**	One comparison with 0.01 (could be seen in **(i)**)
	P(Type I error) = 0.0357 (3 sf)	**B1**	
		3	
(iii)	Actually mean = 1.03 but conclude that mean < 1.03	**B1**	Mean no. of defectives not reduced, but conclude that it is reduced.
		1	

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323. 9709_w17_ms_73 Q: 7

Question	Answer	Marks	Guidance
(i)	H_0: mean no. sales = 3.5	**B1**	or " ... = 0.7 (per day)"
	H_1: mean no. sales > 3.5	**M1**	allow 'λ' or 'μ' but not just 'mean'
	$P(X \geqslant 5) = 1 - e^{-3.5}(1 + 3.5 + \frac{3.5^2}{2!} + \frac{3.5^3}{3!} + \frac{3.5^4}{4!})$	**M1**	
	= 0.275	**A1**	allow 0.274
	Comp with 0.10	**M1**	valid comparison using Poisson
	No evidence (at 10%) to believe that sales per day have increased	**A1 FT**	correct conclusion FT no contradictions
		6	

Question	Answer	Marks	Guidance
(ii)	$\lambda = 3.9$	**B1**	
	$e^{-3.9} \times \frac{3.9^2}{2!}$	**M1**	any λ ($\neq$ 0.7 or 0.6), single term
	= 0.154 (3 sf)	**A1**	
		3	

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324. 9709_w17_ms_73 Q: 8

Question	Answer	Marks	Guidance
(i)	$\bar{x} = 27/150$ (= 0.18)	**B1**	
	$s = \sqrt{\frac{150}{149}} \times \sqrt{\frac{5.01}{150} - 0.18^2}$ or variance (= 0.031729) (var = 3/2980 = 0.0010067)	**M1**	or var = $1/149(5.01 - 27.0^2/150)$
	H_0: Pop mean = 0.185 H_1: Pop mean < 0.185	**B1**	allow just 'μ'
	$\frac{0.18 - 0.185}{\frac{'0.031729'}{\sqrt{150}}}$	**M1**	standardising, need $\sqrt{150}$
	= (–) 1.930 (3 sfs) or 1.93	**A1**	
	Comp with z = (–) 2.326	**M1**	consistent signs or using probs 0.0268 > 0.01 or 0.9732 < 0.99 or using x_{crit} 0.18 > 0.17897
	There is no evidence (at 1% level) that concentration with drug is less than without drug	**A1 FT**	conclusion FT no contradictions
		7	

Question	Answer	Marks	Guidance
(ii)	$\frac{cv - 0.185}{\frac{'0.031729'}{\sqrt{150}}}$ (= – 2.326)	**M1**	must use 0.185 and $\sqrt{150}$
	= 0.17897 or 0.179	**A1**	acceptance region (for H_0) is > 0.179
	$\frac{"0.17897" - 0.175}{\frac{'0.031729'}{\sqrt{150}}}$ (=1.534)	**M1**	must use 0.175 and $\sqrt{150}$
	1 – ϕ("1.534")	**M1**	indep mark
	= 0.0625 (3 sf)	**A1**	Accept 0.0610 to 0.0628
		5	

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325. 9709_m16_ms_72 Q: 2

Q	Answer	Mark	Notes
	H_0: P(hit target) = 0.65 H_1: P(hit target) > 0.65	**B1**	Allow $p = 0.65$ Allow $p > 0.65$
	$^{20}C_2 \times 0.35^2 \times 0.65^{18} + 19 \times 0.35 \times 0.65^{19} + 0.65^{20}$ = 0.0121 (3 sf)	**M1** **A1**	Allow one end error. Allow p/q mix. Allow (1–) for **M** mark **A** mark recovered following valid comparison
	Comp 0.01 There is no evidence (at the 1% level) that she has improved	**M1** **A1**√ [5]	For valid comparison She has probably not improved. No contradictions. (SR Use of Normal **M0**, but **M1A1** for valid comparison could be awarded)

326. 9709_m16_ms_72 Q: 3

Q	Answer	Mark	Notes
(i)	H_0: pop mean journey time = 35.2 mins H_1: pop mean journey time < 35.2 mins	**B1**	Allow "μ". Not "mean journey time"
	$\frac{34.7-35.2}{5.6/\sqrt{25}}$ (= –0.446)	**M1**	For standardising (√25 needed)
	Φ(< "–0.446") = 1 – Φ("0.446") = 0.328 (3 sf)	**M1** **A1** [4]	For correct area consistent with their working As final answer
(ii)	H_0 *is* rejected but Type II error can only be made if H_0 is *not* rejected	**B1** [1]	Allow just "H_0 is rejected." oe

327. 9709_s16_ms_71 Q: 1

Q	Answer	Mark	Notes
	B(200, $\frac{1}{6}$) → N($\frac{100}{3}$, $\frac{250}{9}$)	**B1**	seen or implied
	$\frac{25.5-\frac{100}{3}}{\sqrt{\frac{250}{9}}}$	**M1**	allow with wrong or no cc
	= –1.486	**A1**	(Accept alternative correct methods)
	comp '1.486' with 1.282	**M1**	or comp ('1.486') with 0.1
	Evidence to reject H_0 There is some evidence that $p < \frac{1}{6}$ or, e.g. It is likely that $p < \frac{1}{6}$ oe	**A1 ft** [5]	No contradictions

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328. 9709_s16_ms_71 Q: 4

Q	Answer	Mark	Notes
(i)	H_0: $\mu = 12.5$ H_1: $\mu \neq 12.5$	**B1**	
	$\frac{13.5-12.5}{4.2\div\sqrt{50}}$	**M1**	allow 4.2 ÷ 50
	= 1.68(4)	**A1**	
	'1.684' < 1.96	**M1**	comp 1.96 allow comp 1.645 if H1: μ > 12.5 or comp 1 – ('1.684') with 0.025
	No evidence that mean time has changed	**A1 ft** [5]	No contradictions ft their 1.684, but not comp 1.645
(ii)	0.05	**B1** [1]	

329. 9709_s16_ms_72 Q: 2

Q	Answer	Mark	Notes
(i)	Conclude less than 90% satisfied when this is not true oe	**B11**	In context
(ii)	$1-(0.9^{15}+15\times0.9^{14}\times0.1$ $+{}^{15}C_2\times0.9^{13}\times0.1^2+{}^{15}C_3\times0.9^{12}\times0.1^3)$ = 0.0556 (3 sf) or 0.0555	**M1** **M1** **A1** [3]	Attempt (1–)P(X = 15,14,13,12) allow 1 end error Attempt fully correct expression

330. 9709_s16_ms_72 Q: 4

Q	Answer	Mark	Notes
	H_0: λ (or μ) = 42 H_1: λ (or μ) ≠ 42	**B1**	Or pop weekly mean = 2.1 etc. allow 'population mean' not just 'mean'
	Po(42) ~ N(42, 42) stated or implied	**B1**√	ft their '42' (Accept alt method N(2.1,2.1/20)
	$\frac{53.5-42}{\sqrt{42}}$	**M1**	
	= 1.77(4) (or 0.038 for area comparison)	**A1**	allow with wrong or no cc. Accept alt method using N(2.1,2.1/20) with or without cc
	comp 1.96	**M1**	Valid comp z or 1 – ('1.774') with 0.025 seen
	No evidence that mean has changed	**A1**√ [6]	allow comp 1.645 if H_1: λ (or μ) > 42 No contradictions. No ft for H_1: λ (or μ) > 42 Note – accept other valid methods(e.g. cv method)

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331. 9709_s16_ms_73 Q: 2

Q	Answer	Mark	Notes
	H_0: Pop mean yield = 8.2 H_1: Pop mean yield > 8.2 $(\pm)\frac{8.7-8.2}{1.2/\sqrt{16}}$ $= (\pm)1.667$ Comp z = 1.645 Or Area comparison 0.0475-0.0478) Reject H_0 Evidence that mean yield has increased	 **B1** **M1** **A1** **M1** **A1**√ [5]	or μ = 8.2(not just "mean") $\mu > 8.2$ Allow without √ sign (Allow cc) Or comp 1 - Φ('1.667') with 0.05 Valid Comparison z-values (same sign) or areas No Contradictions No follow through for 2 tail test

332. 9709_s16_ms_73 Q: 4

Q	Answer	Mark	Notes
(i)	H_0: Pop mean = 2.5 (or 7.5) H_0: Pop mean < 2.5 (or 7.5) $\lambda = 7.5$ $P(X \leqslant 2) = e^{-7.5}(1+7.5+\frac{7.5^2}{2}) = 0.0203$ $P(X \leqslant 3)=0.0203 + e^{-7.5}\times\frac{7.5^3}{3!} = 0.0591$ CR is $X \leqslant 2$ Reject H_0 Evidence that no of sightings fewer	 **B1** **M1** **A1** **A1** **A1**√ [5]	or λ = 2.5(Not just "mean") Allow μ or $\lambda < 2.5$ Either P(X⩽2) or P(X⩽3) , allow any λ *Both Correct* *Clear statement* *Follow through their CR/their P(X⩽2)*
(ii)	P(Type I) = 0.0203 (3 sf)	**B1**√ [1]	ft their $P(X \leqslant 2)$
(iii)	H_0 was rejected oe	**B1** [1]	or Type II is P(not reject H_0)oe

333. 9709_w16_ms_71 Q: 2

Q	Answer	Mark		Notes
(i)	H_0: $P(6) = 1/6$ H_1: $P(6) < 1/6$	**B1**	[1]	Allow H_0: $p = 1/6$ H_1: $p < 1/6$
(ii)	$\left(\frac{5}{6}\right)^{15}$ = 0.065 > 0.05	**M1** **A1**	[2]	Correct result and comparison needed for A1 SR if 2 tail test followed allow A1 for 0.065 > 0.025
(iii)	$\left(\frac{5}{6}\right)^{16} = 0.054$ and $\left(\frac{5}{6}\right)^{17} = 0.045$ Smallest n is 17 **OR** $\left(\frac{5}{6}\right)^{n} < 0.05$ and attempt to solve $n\ln\left(\frac{5}{6}\right) < \ln 0.05$ smallest n is 17	**M1** **A1** **M1** **A1**	[2]	both No errors seen

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334. 9709_w16_ms_71 Q: 7

Q	Answer	Mark		Notes
(i)	H_0: Pop mean time (or μ) = 20.5 H_1: Pop mean time (or μ) < 20.5	B1		Not just "mean"
	$\frac{20.3-20.5}{1.2\div\sqrt{100}}$	M1		Allow without √ sign
	= –1.667 or 0.0478/0.952 if areas compared	A1		(accept ±1.667/1.67)
	'1.667' < 1.751 (or '–1.667' > –1.751) No evidence that (pop) mean time has decreased	M1 A1ft	[5]	Correct comparison of their z_{calc} with 1.751/1.75 oe valid comparison of areas (0.0478 > 0.04) No contradictions (ft their z)
(ii)	$\frac{cv-20.5}{1.2\div\sqrt{100}} = -1.751$	M1*		
	cv = 20.29 or 20.3	A1		
	$\frac{'20.29'-20.1}{1.2\div\sqrt{100}}$ (= 1.583 or 1.582)	DM1		Allow $\frac{20.3-20.1}{1.2\div\sqrt{100}}$ (= 1.667) M1
	1 – Φ('1.583') = 0.0567 – 0.0569 (3 sf)	M1 A1	[5]	1 – Φ('1.667') M1 = 0.0478 (3 sf) A1
(iii)	Concluding (mean) time not decreased when in fact it has.	B1	[1]	Must be in context oe

335. 9709_w16_ms_72 Q: 2

Q	Answer	Mark		Notes
(i)	H_0: P(6) = $^1/_6$ H_1: P(6) < $^1/_6$	B1	[1]	Allow H_0: $p = {}^1/_6$ H_1: $p < {}^1/_6$
(ii)	$\left(\frac{5}{6}\right)^{15}$	M1		
	= 0.065 > 0.05	A1	[2]	Correct result and comparison needed for A1 SR if 2 tail test followed allow A1 for 0.065 > 0.025
(iii)	$\left(\frac{5}{6}\right)^{16} = 0.054$ and $\left(\frac{5}{6}\right)^{17} = 0.045$	M1		both
	Smallest n is 17	A1	[2]	No errors seen
	OR $\left(\frac{5}{6}\right)^{n} < 0.05$ and attempt to solve $n\ln\left(\frac{5}{6}\right) < \ln 0.05$ smallest n is 17	M1 A1		

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336. 9709_w16_ms_72 Q: 7

Q	Answer	Mark		Notes
(i)	H_0: Pop mean time (or μ) = 20.5 H_1: Pop mean time (or μ) < 20.5	B1		Not just "mean"
	$\frac{20.3-20.5}{1.2\div\sqrt{100}}$	M1		Allow without √ sign
	= –1.667 or 0.0478/0.952 if areas compared	A1		(accept ±1.667/1.67)
	'1.667' < 1.751 (or '–1.667' > –1.751) No evidence that (pop) mean time has decreased	M1 A1ft	[5]	Correct comparison of their z_{calc} with 1.751/1.75 oe valid comparison of areas (0.0478 > 0.04) No contradictions (ft their z)
(ii)	$\frac{cv-20.5}{1.2\div\sqrt{100}} = -1.751$	M1*		
	cv = 20.29 or 20.3	A1		
	$\frac{'20.29'-20.1}{1.2\div\sqrt{100}}$ (= 1.583 or 1.582)	DM1		Allow $\frac{20.3-20.1}{1.2\div\sqrt{100}}$ (= 1.667) M1
	1 – Φ('1.583') = 0.0567 – 0.0569 (3 sf)	M1 A1	[5]	1 – Φ('1.667') M1 = 0.0478 (3 sf) A1
(iii)	Concluding (mean) time not decreased when in fact it has.	B1	[1]	Must be in context oe

337. 9709_w16_ms_73 Q: 4

Q	Answer	Mark		Notes
	$\frac{11.8-11}{1.6\div\sqrt{n}} = 1.645$	M1		M1 for $\frac{11.8-11}{1.6\div\sqrt{n}}$ = any z
	$\frac{11.8-11}{1.6\div\sqrt{n}} = 1.96$			allow var / sd mix for 1.6 but need √n
	n = 10.8 (allow 11) n = 15.4 (allow 15)	B1 B1		B1 for each correct z
		A1		for both
	Possible values are 11, 12, 13, 14, 15	A1	[5]	not for just $11 \leqslant n \leqslant 15$ oe

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338. 9709_w16_ms_73 Q: 5

Q	Answer	Mark		Notes
(i)	H_0: P(free gift) = 0.3 or $p = 0.3$ H_1: P(free gift) < 0.3 or $p < 0.3$	**B1**	[1]	
(ii)	$P(X \leqslant 2) =$ $0.7^{20} + 20 \times 0.7^{19} \times 0.3 + {}^{20}C_2 \times 0.7^{18} \times 0.3^2$ = 0.03548 or 0.0355	**M1*** **A1**		$P(X \leqslant 2)$ attempted
	$P(X \leqslant 3) =$ '0.03548' + ${}^{20}C_3 \times 0.7^{17} \times 0.3^3$ (= 0.107)	**M1***		$P(X \leqslant 3)$ attempted
	One comparison with 0.05 seen	**M1***		or implied by fully correct methods for $P(X \leqslant 2)$ and $P(X \leqslant 3)$
	P(Type I error) = 0.0355 (3 sf)	**DA1** √	[5]	dep on all 3 Ms
(iii)	$P(X \leqslant 3)$ = '0.107' '0.107' > 0.05 **or** cv = 2 and compare 3 >2	**M1**		Compare their $P(X \leqslant 3)$ with 0.05
	No evidence to reject claim oe	**A1** √	[2]	No evidence that 30% is not correct oe ft their 0.107

339. 9709_s15_ms_71 Q: 2

Q	Answer	Mark	Notes
(i)	H_0: $p = 0.2$ or $\mu = 10$ H_1: $p > 0.2$ or $\mu > 10$	B1 [1]	
(ii)	N(10, 8) seen or implied	B1	or $N\left(0.2, \frac{0.2 \times 0.8}{50}\right)$
	$\frac{125-10}{\sqrt{8}}$ or $\frac{\frac{125}{50} - 02}{\sqrt{\frac{0.2 \times 0.8}{50}}}$	M1	For standardising allow with no or wrong cc
	= 0.884	A1	
	comp 1.282	M1f	Allow area comparison with 0.188 or comp 1.645 if H_1 $p \neq 0.2$
	Claim not justified or No evidence to support claim	A1f [5]	Allow accept H_0 provided correctly defined. Follow through their test statistic ;dep 1–tail test No Contradictions SR; Use of B(50,0.2) scores B1 provided at least two probabilities calculated. M1 For finding $P(X \geqslant 13)$ allow one end error. A1 for 0.186
		[Total: 6]	

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340. 9709_s15_ms_71 Q: 4

Q	Answer	Mark	Notes
(i)	H_0: pop mean (or μ) = 12.4 H_1: pop mean (or μ) > 12.4	B1	not just "mean"
	$\frac{12.9-12.4}{2.1+\sqrt{50}}$	M1	Allow with 50 instead of √50
	1.684	A1	
	comp cv z = 1.96 No evidence that pop mean time has increased	B1f [4]	or P(z > 1.684) = 0.0461 > 0.025 Allow accept H_0 if correctly defined. Ft their test statistic. No contradictions
(ii)	Not reject (or accept) that mean time is unchanged (or is 12.4) oe	B1	
	although mean time has increased (or is more than 12.4) oe	B1 [2]	
(iii)	True (or new) mean	B1 [1]	
		[Total: 7]	

341. 9709_s15_ms_72 Q: 2

Q	Answer	Mark	Notes
(i)	H_0: λ = 0.5		or Pop mean = 0.5, not just Mean = 0.5 or Pop mean (per m^2)= 0.1
	H_1: λ >0.5	B1 1	Accept μ instead of λ
(ii)	$1 - e^{-0.5}(1 + 0.5)$ = 0.0902 (3 sf) comp 0.1 Claim justified or there is evidence to support claim	M1 A1 M1 A1√ 4	1 – P(X = 0,1) attempted, any λ. Allow 1 end error Allow 0.09 Valid comparison NB 0.9098>0.9 recovers M1A1 M1 oe Accept 'Reject H_0' if correctly defined No contradictions.
	Total	**5**	

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342. 9709_s15_ms_72 Q: 4

Q	Answer	Mark	Notes
(i)	Conclude flight times affected when in fact they have not been.	B1 B1 2	Or accept pop mean changed from 6.2 although pop mean has not changed from 6.2
(ii)	H_0: Pop mean (or μ) = 6.2 H_0: Pop mean (or μ) ≠ 6.2 $\frac{5.98 - 6.2}{\frac{0.8}{\sqrt{40}}}$ = –1.739 (±) Accept (±)1.74 comp z = 1.96 No evidence that flight times affected	B1 M1 A1 B1√ 4	 Allow with 40 instead of √40 Allow SD/Var mix (CV method 5.952 or 6.2279 M1 A1) For valid comparison or P(z < –1.739) = 0.041 > 0.025 or 5.98 > 5.952 or 6.2 < 6.228 and correct conclusion
(iii)	H_0 was not rejected oe Type II	B1* B1*dep 2	If in (ii) H_0 was rejected, then: H_0 rejected B1; Type I B1dep
	Total	**8**	

343. 9709_s15_ms_73 Q: 2

Q	Answer	Mark	Notes
(i)	H_0: P(correct) = $\frac{1}{8}$ H_1: P(correct) > $\frac{1}{8}$	 B1 [1]	Or H_0 p = 1/8 H_1p > 1/8
(ii)	$1-\left(\left(\frac{1}{8}\right)^{10}+10\left(\frac{1}{8}\right)^{9}\left(\frac{7}{8}\right)+{}^{10}C_2\left(\frac{1}{8}\right)^{8}\left(\frac{7}{8}\right)^{2}\right)$ = 0.120 (3 sf) or 0.119	M1 A1 A1 [3]	M1 for attempt at correct expression accept 1 error only, e.g. 1 term extra, omitted or wrong, or omit "1–" or incorrect p/q Correct expression Note Use of Poisson in (ii) could score M1 only for expression 1 –P(0,1,2) λ =1.25
(iii)	12%	B1f [1]	ft their (ii) Must be a probability
		Total 5	

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344. 9709_s15_ms_73 Q: 5

Q	Answer	Mark	Notes
(i)	Cables broken or not all cables can be accessed oe or Too many cables oe or too time consuming oe	B1 [1]	e.g. previous days' stocks may have gone
(ii)	H_0: Pop mean brk str (or μ) = 5 H_1: Pop mean brk str (or μ) < 5 $(\pm)\frac{4.95-5}{\frac{0.15}{\sqrt{60}}}$ (= ±2.582) comp ±2.326 There is evidence that mean breaking strength is less than it should be Or reject H_0 (H_0 correctly defined)	B1 M1 A1 B1 ft [4]	Not just "mean" Allow 60 instead of √60 Ft their –2.582 (No ft 2 tailed test) Correct comparison shown, no errors seen. Accept area comparison 0.0049 with 0.01 [CR method $(x-5)/(0.15/\sqrt{60})$ = –2.326 M1 A1 leading to x = 4.955 compared to 4.95and correct conclusion B1ft OR $((x-4.95)/0.15/\sqrt{60})$ leading to 4.995 M1 A1 compared to 5and correct conclusion B1ft]
(iii)	Population not necessarily normal so yes	B1 B1dep [2]	SR B1 For "it" is not necc normal (no mention of population) AND Yes
		Total 7	

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345. 9709_w15_ms_71 Q: 7

Q	Answer	Mark	Notes
(i)	Prob could be different later in day or on a different day oe	**B1** [1]	or any explanation why not random or "Not random" or "Not representative"
(ii)	Looking for decrease (or improvement) H_0: P(not arrive) = 0.2 H_1: P(not arrive) < 0.2	**B1** **B1** [2]	oe Allow "$p = 0.2$"
(iii)	Concluding that prob has decreased (or publicity has worked) when it hasn't oe	**B1** [1]	In context
(iv)	P($X = 0$) and P($X = 1$) attempted P($X \leqslant 2$) = $0.8^{30} + 30 \times 0.8^{29} \times 0.2 + {}^{30}C_2 \times 0.8^{28} \times 0.2^2$ (= 0.0442) P($X \leqslant 3$) = $0.8^{30} + 30 \times 0.8^{29} \times 0.2 + {}^{30}C_2 \times 0.8^{28} \times 0.2^2 + {}^{30}C_3 \times 0.8^{27} \times 0.2^3$ = 0.123 cr is $X \leqslant 2$ P(Type I) = 0.0442 (3 sf)	**M1** **M1** **B1** **A1** **A1** [5]	B(30, 0.2) Not nec'y added May be implied by calc P($X \leqslant 2$) or P($X \leqslant 3$) Attempt P($X \leqslant 2$) Or '0.0442' + ${}^{30}C_3 \times 0.8^{27} \times 0.2^3 = 0.123$
(v)	3 is outside cr No evidence that p has decreased (or that publicity has worked)	**M1** **A1** √ [2]	Comparison of 3 with their cr or P($X \leqslant 3$) = 0.123 which is > 0.05 Correct conclusion. No contradictions
		Total: 11	
		Total for paper: 50	

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346. 9709_w15_ms_72 Q: 7

Q	Answer	Mark	Notes
(i)	Prob could be different later in day or on a different day oe	**B1** [1]	or any explanation why not random or "Not random" or "Not representative"
(ii)	Looking for decrease (or improvement) H_0: P(not arrive) = 0.2 H_1: P(not arrive) < 0.2	**B1** **B1** [2]	oe Allow "$p = 0.2$"
(iii)	Concluding that prob has decreased (or publicity has worked) when it hasn't oe	**B1** [1]	In context
(iv)	P($X = 0$) and P($X = 1$) attempted P($X \leqslant 2$) = $0.8^{30} + 30 \times 0.8^{29} \times 0.2 + {}^{30}C_2 \times 0.8^{28} \times 0.2^2$ (= 0.0442) P($X \leqslant 3$) = $0.8^{30} + 30 \times 0.8^{29} \times 0.2 + {}^{30}C_2 \times 0.8^{28} \times 0.2^2 + {}^{30}C_3 \times 0.8^{27} \times 0.2^3$ = 0.123 cr is $X \leqslant 2$ P(Type I) = 0.0442 (3 sf)	**M1** **M1** **B1** **A1** **A1** [5]	B(30, 0.2) Not nec'y added May be implied by calc P($X \leqslant 2$) or P($X \leqslant 3$) Attempt P($X \leqslant 2$) Or '0.0442' + ${}^{30}C_3 \times 0.8^{27} \times 0.2^3 = 0.123$
(v)	3 is outside cr No evidence that p has decreased (or that publicity has worked)	**M1** **A1** √ [2]	Comparison of 3 with their cr or P($X \leqslant 3$) = 0.123 which is > 0.05 Correct conclusion. No contradictions
		Total: 11	
		Total for paper: 50	

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347. 9709_w15_ms_73 Q: 5

Q	Answer	Mark		Notes
(a)	$\lambda = 4.5$	**B1**		
	$e^{-4.5}$ (= 0.011109)	**M1**		alone allow any λ
	$\left(\frac{99}{100}\right)^{450}$ (= 0.010860)	**M1**		
	$\left(\frac{'0.011109' - '0.010860'}{'0.010860'} \times 100\right)$			
	= 2.29% (3 sf)	**A1**	[4]	
(b)	H_0: $P(6) = \frac{1}{6}$ or $p = \frac{1}{6}$			
	H_1: $P(6) < \frac{1}{6}$ or $p < \frac{1}{6}$	**B1**		Both needed
	$\left(\frac{5}{6}\right)^{25} + 25\left(\frac{5}{6}\right)^{24} \times \frac{1}{6} + {}^{25}C_2\left(\frac{5}{6}\right)^{23} \times \left(\frac{1}{6}\right)^2$	**M1**		allow one error (extra term / missing term / incorrect term) CR method: attempt at least P(0) and P(0 and 1) (0.010... and 0.06... < 0.1)
	= 0.189 (3 sf)	**A1**		CR is 0,1 and must see 0.189 for A1
	comp 0.1	**M1**		valid comp '0.189' with 0.1 oe valid comparison of 2 with CR
	No reason to believe die biased	**A1**	[5]	correct conclusion, √ their 0.189 no contradictions
Total			**[9]**	

348. 9709_w15_ms_73 Q: 6

Q	Answer	Mark		Notes
(i)	Ho: $\mu = 2.60$ H_1: $\mu > 2.60$	**B1**		allow pop mean, not just 'mean'
	$\pm \frac{2.64 - 2.6}{0.2 \div \sqrt{75}}$	**M1**		
	$= \pm 1.732$	**A1**		accept ± 1.73 (3 sf)
	'1.732' > 1.645 Reject Ho. There is evidence that μ has increased	**B1** √	[4]	valid comparison with 1.645 (or 0.0416 < 0.05) and correct conclusion √ their 1.732 no contradictions (or CV method x_{crit} = 2.638 M1A1 comp 2.64 > 2.638 and concln B1 √) SR two tail test, using 1.96 (or using 0.025) can score B0M1A1B1ft max 3/4

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Q	Answer	Mark		Notes
(ii)	$\frac{x-2.6}{0.2\div\sqrt{75}} = 1.645$ $(x = 2.638)$	**M1**		
	$\pm\frac{'2.638'-2.68}{0.2\div\sqrt{75}}$	**M1**		for standardising with their " 2.638 " using 2.68
	$= \pm 1.819$	**A1**		accept 1.82 (3 sf)
	$\Phi('-1.819') = 1 - \Phi('1.819')$	**M1**		indep M mark, calculate correct area / prob consistent with their working
	$= 0.0345$ or 0.0344	**A1**	[5]	
Total			**[9]**	

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