

Term 3 Assessment – Preliminary Examination**Grade 12****Accelerated Programme****Name:** _____**Time: 3 hours****200 marks**

INSTRUCTIONS

1. This question paper consists of 33 pages. Please check that your question paper is complete.
2. Read the questions carefully.
3. Use the data and formulae whenever necessary.
4. An extra graph paper (page 32) has been included at the end of the test paper. If you use this extra graph paper, make sure that you indicate this clearly at the question to ensure that your answer is marked in full.
5. A blank page (page 33) has been included at the end of the test paper. If you run out of space for a question, use this page. If you use this extra space, make sure that you indicate this clearly at the question to ensure that your answer is marked in full.
6. Diagrams are not necessarily drawn to scale.
7. You may use an approved non-programmable and non-graphical calculator.
8. Clearly show ALL calculations, diagrams, graphs, equations etc. that you have used in determining your answers. Final answers only will NOT necessarily be awarded full marks.
9. Answers must be expressed using the correct significant figures.
10. Units need not be included in the working of the calculations, but appropriate units should be shown in the final answer.
11. It is in your own interest to write legibly and to present your work neatly.

Question 1 [20 marks]

Answer these questions on the multiple-choice answer grid below. Make a clear cross (X) in the box corresponding to the letter that you consider to be correct.

1.1.	A	B	C	D
1.2.	A	B	C	D
1.3.	A	B	C	D
1.4.	A	B	C	D
1.5.	A	B	C	D

1.6.	A	B	C	D
1.7.	A	B	C	D
1.8.	A	B	C	D
1.9.	A	B	C	D
1.10.	A	B	C	D

1.1. Which quantity has the fundamental SI units of $\text{kg}\cdot\text{m}^2\cdot\text{s}^{-2}$? (2 marks)

- A. Energy
- B. Force
- C. Momentum
- D. Pressure

1.2. Which family of particles does the tau belong to? (2 marks)

- A. Charged leptons
- B. Neutrinos
- C. Quarks of the type “down”
- D. Leptons from the first generation

1.3. Which of the stars below has a HOTTER surface temperature than a star of spectral class F6? (2 marks)

- i. M0
- ii. A9
- iii. F2

- A. ii only
- B. iii only
- C. i and ii
- D. ii and iii

1.4. An ant walks from the edge of a rotating turntable to its centre. How will the ant's angular velocity and its angular displacement change for each half-turn? (2 marks)

	Angular Velocity	Angular Displacement
A.	Decrease	Stay the same
B.	Decrease	Decrease
C.	Stay the same	Stay the same
D.	Stay the same	Decrease

1.5. A stone is thrown upward from the ground at an angle of 45° above the horizontal with an initial speed v . The stone takes a time t to reach the ground again. If the same stone is thrown at the same angle with an initial speed of $2v$, how long will it take the stone to reach the ground again? (2 marks)

- A. t
- B. $2t$
- C. $\sqrt{2} \cdot t$
- D. $4t$

1.6. A physics student wants to hit a target with a rubber band ball from 1,8 meters away. If she throws the ball at a speed of $6 \text{ m}\cdot\text{s}^{-1}$ and the target (2 marks)

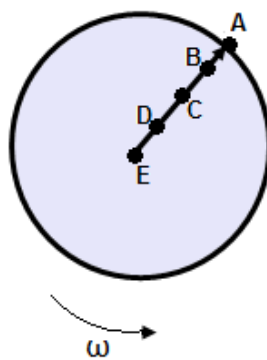
is at the exact same height as where the ball is thrown, what angle from the horizontal must she throw the ball to hit the target?

- A. 0°
- B. 15°
- C. 30°
- D. 40°

1.7. Which law is also called the law of equal areas? (2 marks)

- A. Kepler's first law
- B. Kepler's second law
- C. Kepler's third law
- D. Newton's universal law of gravitation

1.8. A solid disk with a radius R rotates at a constant rate ω . Which of the following points has the greater angular displacement? (2 marks)



- A. A
- B. B
- C. C
- D. All points have the same angular displacement.

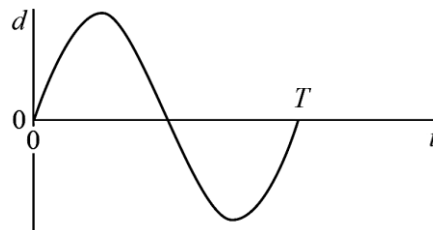
1.9. A mass hanging vertically on a spring has a position given by: (2 marks)

$$x = (50 \text{ mm}) \cos(4,8)t$$

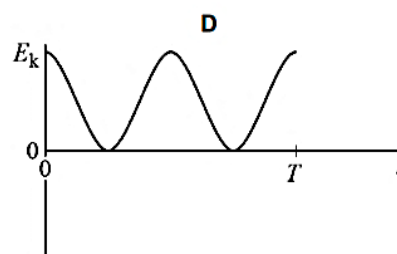
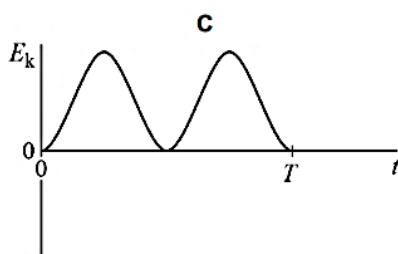
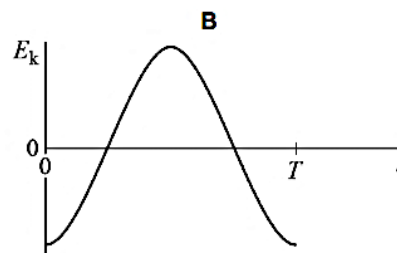
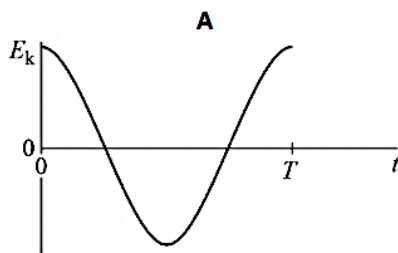
What is the angular frequency, position and speed of the mass at $t = 0,6$ seconds?

	$\omega / \text{rad}\cdot\text{s}^{-1}$	x / mm	$v / \text{mm}\cdot\text{s}^{-1}$
A.	4,8	+49,9	12,1
B.	4,8	-48,3	232
C.	1,3	+49,9	12,1
D.	4,8	-48,3	62,1

- 1.10. The graph below shows the variation of displacement d with time t for a particle moving with simple harmonic motion of period T . (2 marks)



Which graph shows the variation of kinetic energy E_k of the particle with time?



Question 2 [21 marks]

- 2.1. An electrical heater is placed into an insulated container holding 100 g of ice at a temperature $-14\text{ }^{\circ}\text{C}$. The heater supplies energy at a rate of 98 joules per second and the heat capacity of the container may be ignored. (4 marks)

After an interval of 30 seconds, all of the ice has reached a temperature of $0\text{ }^{\circ}\text{C}$. Calculate the specific heat capacity of ice.

- 2.2. Cola of mass 0,200 kg in a glass beaker of mass 0,250 kg are at the same temperature of $2,0\text{ }^{\circ}\text{C}$. The cola and beaker are now cooled to a temperature of $-1,0\text{ }^{\circ}\text{C}$ by the addition of cola ice at a temperature of $-50,0\text{ }^{\circ}\text{C}$.

Specific heat capacity of glass = $840\text{ J}\cdot\text{kg}^{-1}\cdot\text{K}^{-1}$

Specific heat capacity of liquid cola = $4\,200\text{ J}\cdot\text{kg}^{-1}\cdot\text{K}^{-1}$

Specific heat capacity of cola ice = $2\,000\text{ J}\cdot\text{kg}^{-1}\cdot\text{K}^{-1}$

Specific latent heat of fusion for cola ice = $330\text{ kJ}\cdot\text{kg}^{-1}$

Assume no heat exchange with the environment.

- a. Calculate the combined heat lost from the liquid cola and glass as they are cooled to 0°C . (4 marks)

- b. Calculate the mass of cola ice added. (5 marks)

- 2.3. A steel bridge spanning a river experiences a temperature variation of $24\text{ }^{\circ}\text{C}$ throughout a summer day. The bridge has a (5 marks)

length of 75,00 m at the coldest time of the day. Calculate the length of the bridge at the hottest time of the day.

$$\alpha_{steel} = 11 \times 10^{-6} \text{ }^{\circ}\text{C}^{-1}$$

2.4. Railway tracks are made with gaps in between the rails as shown below. (3 marks)



Explain why this is done.

Question 3 [39 marks]

- 3.1. Particle Y is produced in the collision of a proton with a K^- in the following reaction:



The quark content of some of the particles involved are:

$$K^- = \bar{u}s \quad K^0 = d\bar{s}$$

- a. K^+ is the antiparticle of K^- . State the quark composition for K^+ . (1 mark)

Identify, for particle Y, the:

- b. charge (1 mark)
- c. strangeness (1 mark)
- d. Give the collective name for baryons and mesons. (1 mark)

Classify the following particles as either a baryon or a meson:

- e. K^- (1 mark)
- f. p^+ (1 mark)
- g. Describe a *lepton*. (2 marks)
- h. Explain why a lepton is an unlikely product in this reaction. (2 marks)

3.2. Compare and contrast the possible fundamental forces that may be experienced by a neutrino and by a proton. (4 marks)

3.3. The lambda-zero baryon, Λ^0 , has a charge of zero and strangeness of -1 . Suggest the quark composition of Λ^0 . (2 marks)

3.4. A pure sample of copper-64 has a mass of 28 mg. The decay constant of copper-64 is $5,5 \times 10^{-2} \text{ h}^{-1}$.

a. Define *half-life*. (2 marks)

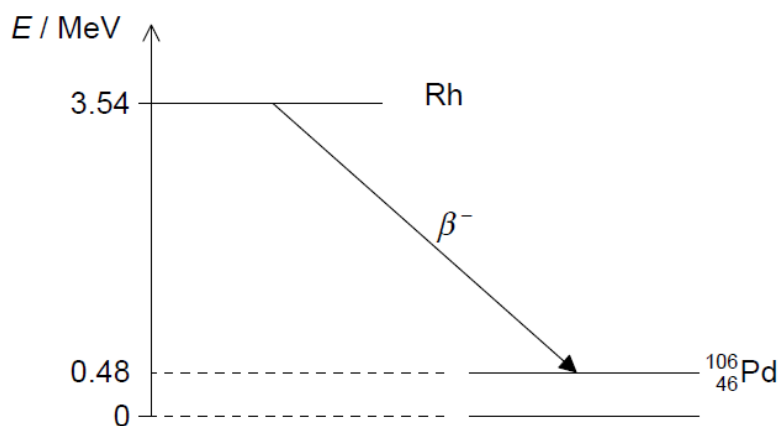
b. Calculate the half-life of copper-64. (3 marks)

c. Estimate the initial activity of the sample. (4 marks)

d. Calculate, in hours, the time at which the mass of copper-64 decreases to 9 mg. (4 marks)

- 3.5. A rhodium nucleus decays into palladium-106 ($^{106}_{46}\text{Pd}$) by beta minus decay.

The diagram shows some of the nuclear energy levels of the rhodium and palladium-106 nuclei. The arrow represents the beta decay.



- Write a nuclear equation for this decay process. (2 marks)
- Determine the energy (in MeV) of the beta particle emitted. (1 mark)
- Suggest why the beta decay is followed by a gamma ray photon. (1 mark)
- This decay is mediated by a gauge boson. From the options below, suggest the likely boson responsible. (1 mark)

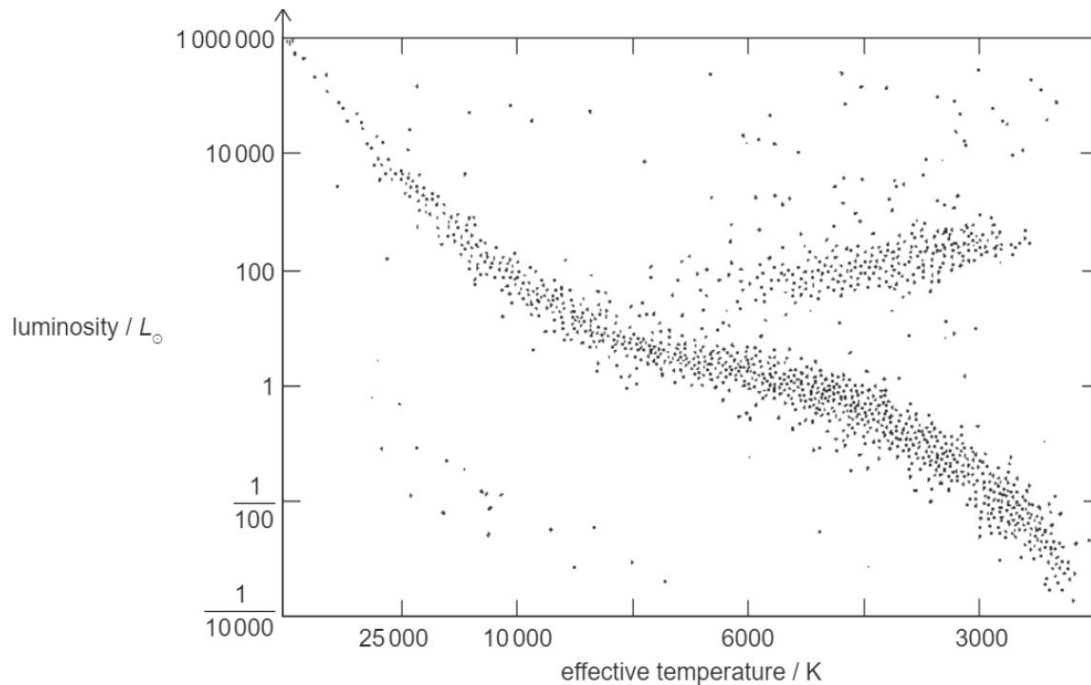
Tick the correct option:

γ		W^-		W^+		g	
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- e. Calculate the mass defect for a palladium-106 nucleus, given that the nucleus has a mass of 105,90 u. (5 marks)

Question 4 [24 marks]

- 4.1. The Hertzsprung-Russell (HR) diagram shows several star types.
The luminosity of the Sun is $L_{\odot}$.



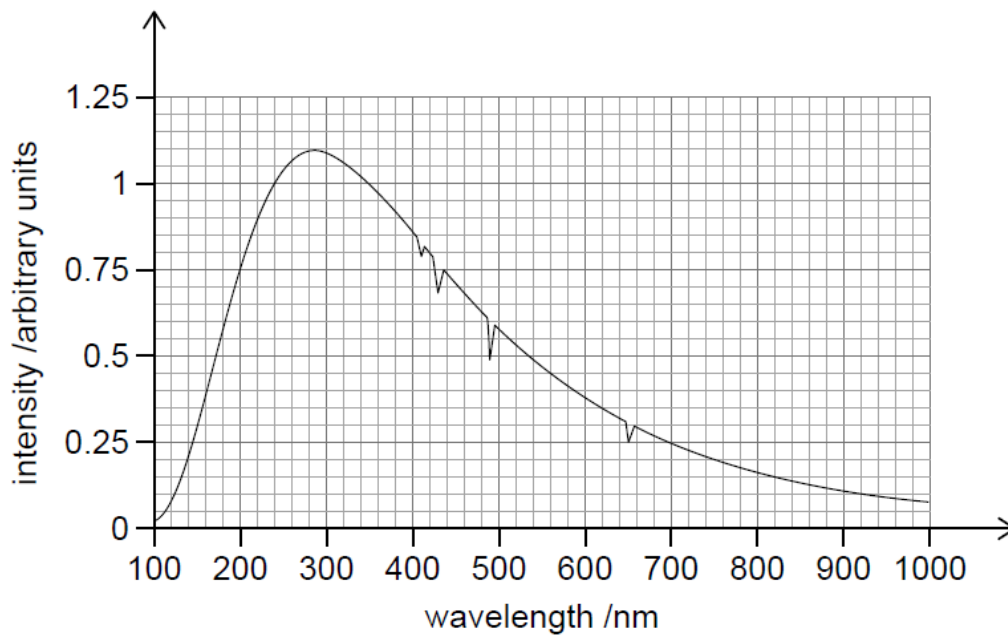
- Identify, on the HR diagram, the position of the Sun. Label the position S. (1 mark)
- Suggest the condition that will cause the Sun to start its transition into a red giant. (1 mark)
- Identify, on the HR diagram, the position of the red giant that the Sun will become. Label the position R. (1 mark)
- Describe the changes the Sun will undergo when moving from position S to position R. (4 marks)

- e. The Sun will become a white dwarf eventually. As a white dwarf, what will prevent the Sun from collapsing under its own gravity? (1 mark)
- f. As a white dwarf, the Sun will continue to emit energy into space as electromagnetic radiation. What is the origin of this radiation? (1 mark)
- g. As a red giant, the Sun is likely to have a surface temperature of around 3 000 K and a luminosity of $10^4 L_{\odot}$. As a white dwarf, the Sun is likely to have a surface temperature of around 10 000 K and a luminosity of $10^{-4} L_{\odot}$. Calculate the ratio
$$\frac{\text{radius of the Sun as a white dwarf}}{\text{radius of the Sun as a red giant}}.$$
 (3 marks)

Star **X** is a much more massive star of 15 solar masses.

- h. Identify, on the HR diagram, the approximate position of star **X** on the main sequence. Label the position X. (1 mark)
- i. With reference to the Oppenheimer-Volkoff limit, describe the eventual fate of star **X**. (2 marks)

The graph below shows the observed spectrum from star Y. Star Y is a stable star.



j. Explain what is meant by a *stable star*. (2 marks)

k. Show that the surface temperature of the star is approximately 10 000 K. (2 marks)

4.2. Deuterium, ${}^2_1\text{H}$, undergoes fusion according to the following equation:

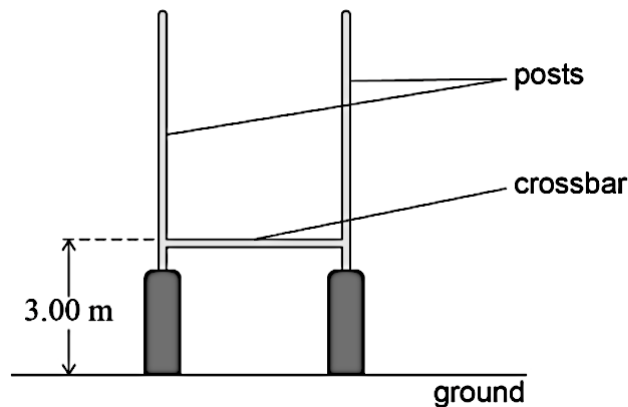
a. Identify particle **G**. (1 mark)

b. Suggest why the temperature in the core of a star must be very high. (1 mark)

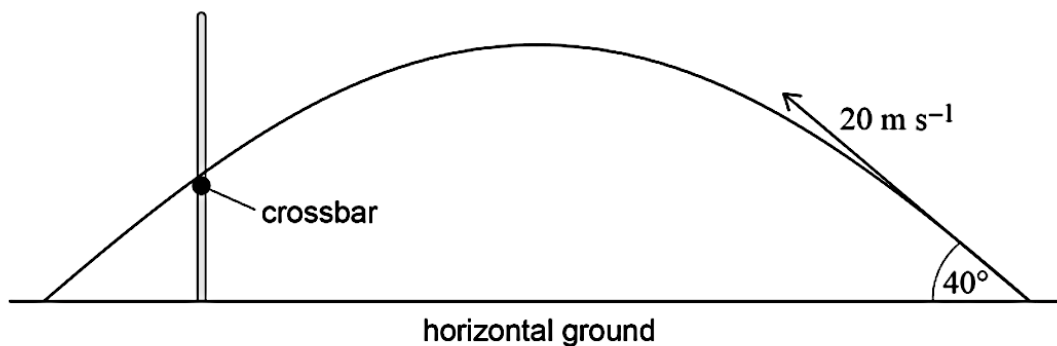
4.3. Outline why a hypothesis of dark energy has been developed. (3 marks)

Question 5 [42 marks]

5.1. The figure below shows the H-shaped posts used in a game of rugby.



Below shows the path of a ball that is kicked and just passes over the crossbar. The initial velocity of the ball is $20,0 \text{ m}\cdot\text{s}^{-1}$ at an angle of $40,0^\circ$ to the ground. Consider air resistance as negligible and treat the ball as a simple projectile.



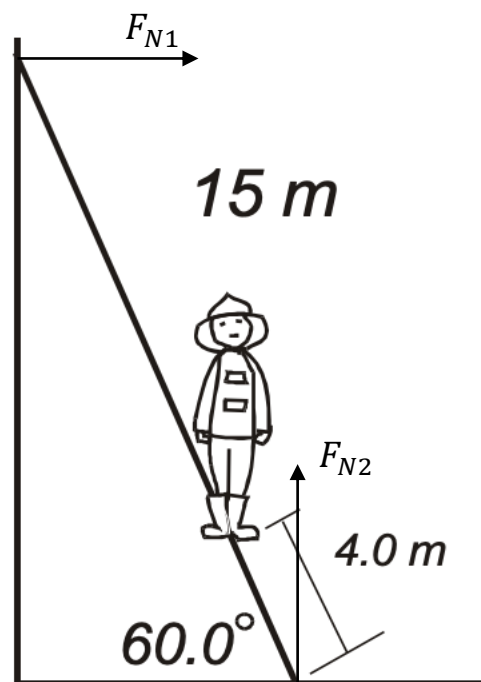
The top of the crossbar is 3,00 m above the horizontal ground.

- Calculate the horizontal speed of the ball. (2 marks)
- Calculate the time that the ball takes to pass over the crossbar. (4 marks)

c. How far from the posts was the kick taken from?

(4 marks)

- 5.2. A 15 m long uniform ladder of weight 500 N rests against a frictionless wall. It makes a 60° angle with the horizontal. A firefighter of weight 800 N is standing 4,0 m from the bottom.



a. Determine the vertical normal force F_{N2} .

(3 marks)

b. Define *torque*. (2 marks)

c. Calculate the horizontal normal force F_{N1} . (6 marks)

- 5.3. Hammer throw is a sport that uses a metal sphere attached to a chain of negligible mass. The athlete holds the chain and then spins around to give the sphere a large angular velocity.

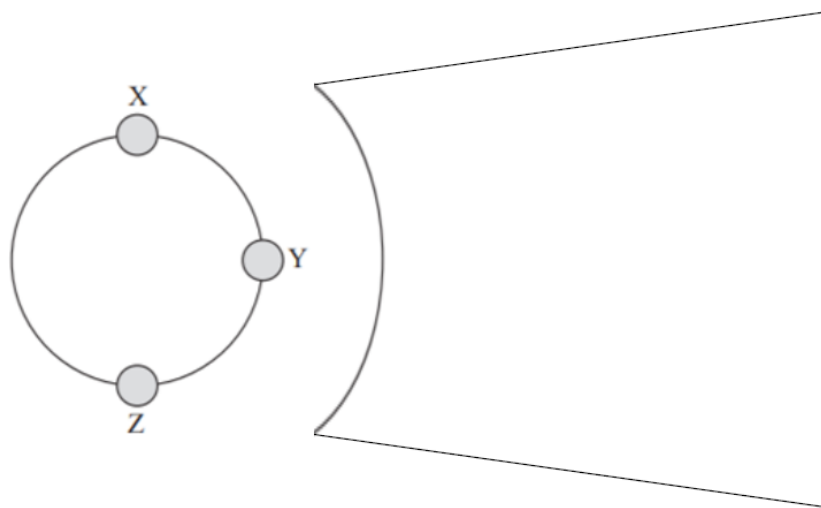


The mass of the sphere is 7,3 kg and the athlete moves the sphere ANTICLOCKWISE (as viewed from above) through a horizontal circle of radius 1,6 m. The sphere moves at a constant speed of $18 \text{ m}\cdot\text{s}^{-1}$.

- a. Explain why the sphere is accelerating, even though it is moving at a constant speed. (2 marks)
- b. Determine the angular velocity of the sphere. (3 marks)

- c. Calculate the centripetal force acting on the sphere in the position shown in the picture above. (4 marks)

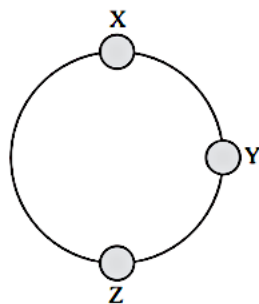
- d. The diagram below shows the sphere at three different positions, as viewed from above. Also shown is the area where the sphere is allowed to land in order for the throw to be legal. (2 marks)



At which position(s), **X**, **Y**, or **Z**, can the sphere be released, in order to make a legal throw?

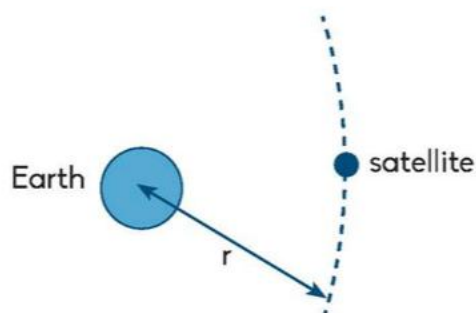
- e. The athlete tries to throw the same sphere at twice the speed. By what factor must she increase the force used? (2 marks)

- f. The athlete now moves the sphere in a VERTICAL circle. The diagram below shows three positions; **X** is the highest position and **Z** is the lowest position. (1 mark)



The tension in the chain must now vary as the sphere moves. At which position, **X**, **Y**, or **Z**, will the tension in the chain be the greatest?

5.4. A satellite is in a circular orbit of radius r around Earth of mass M , as illustrated below.

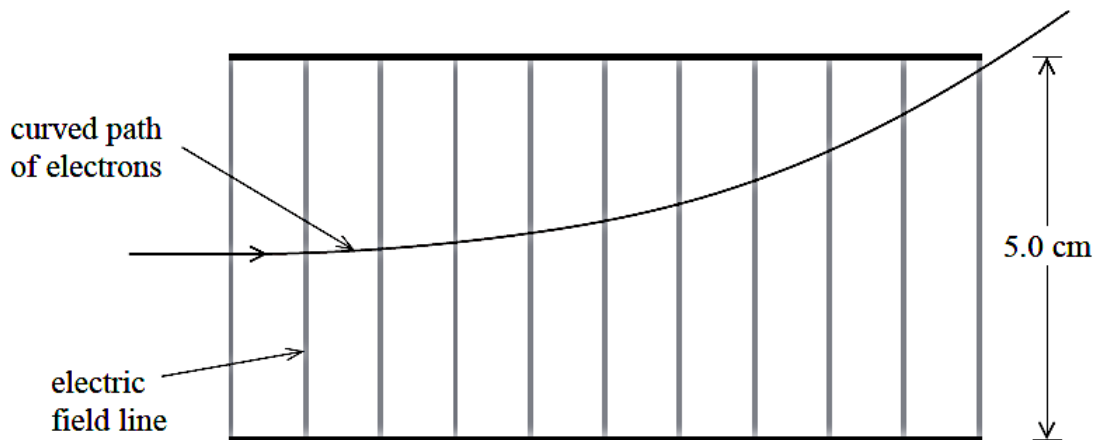


- a. Show that the period T of the orbit of the satellite is given by the expression $T^2 = \frac{4\pi^2 r^3}{GM}$ where G is the gravitational constant. (3 marks)

- b. The mass M of Earth is $6,0 \times 10^{24}$ kg. Determine the radius of a geostationary orbit. (4 marks)

Question 6 [17 marks]

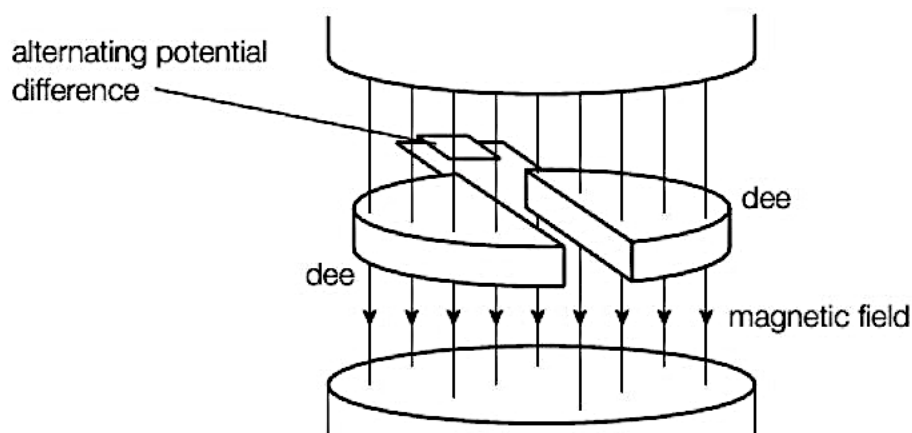
6.1. A teacher uses an electron beam tube to demonstrate the behaviour of electrons in an electric field. The diagram shows the path of an electron in a uniform electric field between two parallel conducting plates.



- Mark on the diagram the direction of the electric field. (1 mark)
- The potential difference across the conducting plates is 160 V. Calculate the force on the electron due to the electric field. (4 marks)
- Explain why the path of the electron is curved between the plates and straight when it has left the plates. (3 marks)

- d. The electric field is adjusted so that the electron leaves the plates with a velocity of $1,2 \times 10^7 \text{ m}\cdot\text{s}^{-1}$ to the right and enters a region of uniform magnetic field out of the page of 0,48 T. Calculate the magnitude and direction of the Lorentz force on the electron. (5 marks)

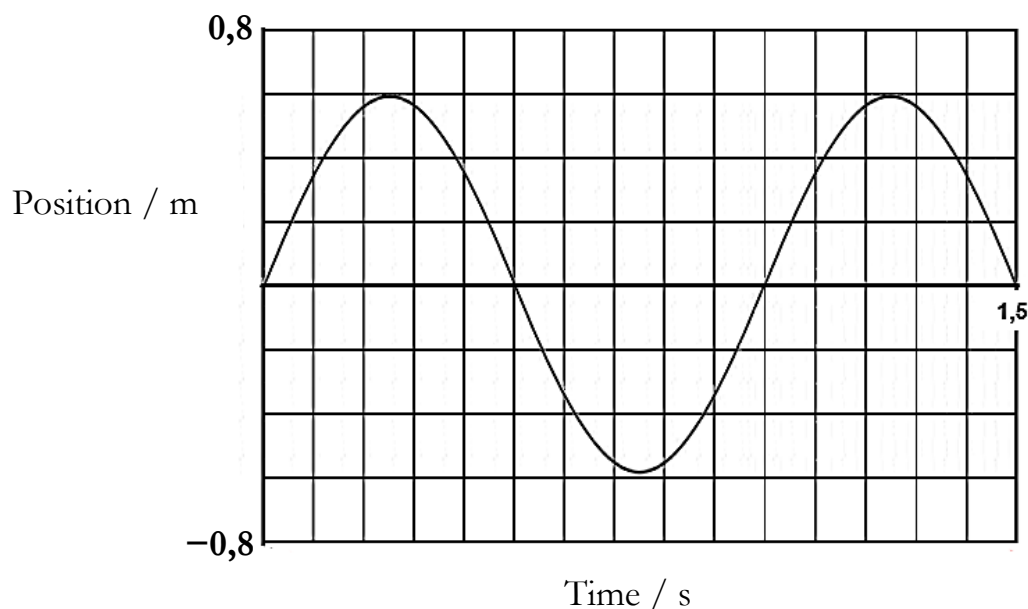
6.2. A cyclotron, shown below, can be used to accelerate particles.



- a. Explain the purpose of the magnetic field in the cyclotron. (2 marks)
- b. When a beam of low-speed protons is introduced into a cyclotron the potential difference across the two dees is alternated to increase the energy of the protons. Explain why the potential difference that is used is alternated. (2 marks)

Question 7 [37 marks]

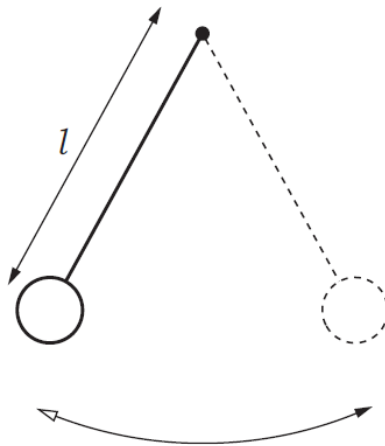
7.1. A metronome can be seen as a simple pendulum. The graph below shows the position vs time graph for a faulty metronome's oscillations.



- From the graph, determine the period of the pendulum's oscillation. (2 marks)
- From the graph, determine the angular frequency of the pendulum's oscillation. (2 marks)
- Explain the meaning of the negative sign in the defining equation for simple harmonic oscillation. (2 marks)

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- d. Determine the acceleration of the pendulum at 1,25 s. Show clearly on the graph how you obtained any values. (5 marks)
- e. If the tension in the string is 18 N at its lowest point, calculate the mass of the pendulum bob attached to the string of the pendulum system. (3 marks)

- 7.2. A student is investigating how the period T of a simple pendulum depends on its length l as shown below.



The time t for 10 oscillations is recorded for a pendulum of length l . The period T of the pendulum is determined. The procedure is then repeated for different lengths.

It is suggested that T and l are related by the equation:

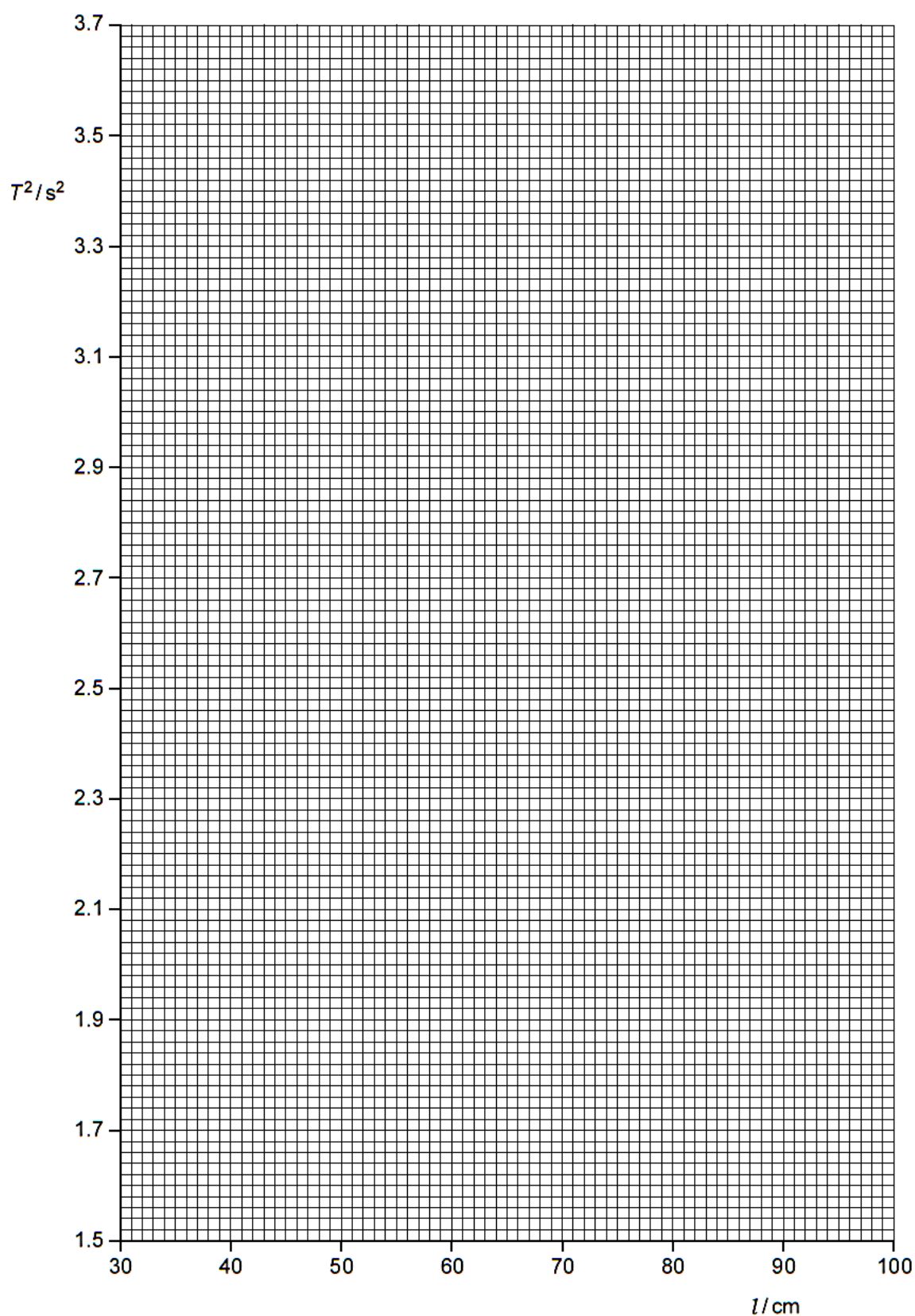
$$T = 2\pi \sqrt{\frac{l}{g}}$$

- a. A graph is plotted of T^2 on the y -axis against l on the x -axis. (2 marks)
Express the gradient in terms of g .
- b. Values of l and t are given below. Calculate and record the values of T and T^2 . Include the absolute uncertainties in T^2 . (5 marks)

l / cm	t / s		
90,0	$18,9 \pm 0,1$		
80,0	$17,9 \pm 0,1$		
70,0	$16,7 \pm 0,1$		
60,0	$15,5 \pm 0,1$		
50,0	$14,1 \pm 0,1$		

40,0	$12,6 \pm 0,1$		
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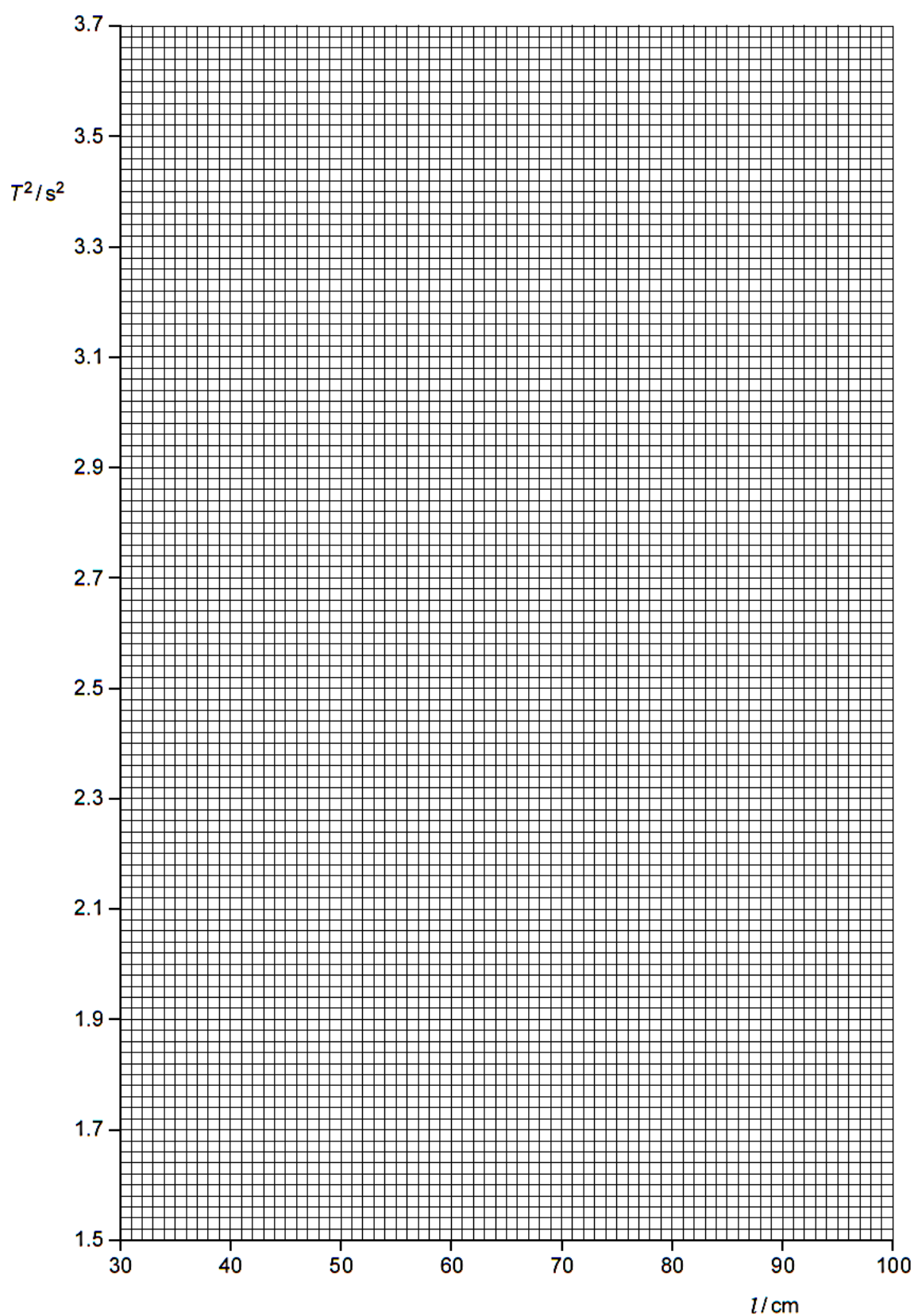
- c. On the graph paper provided below, plot a graph of T^2 against l . (6 marks)
Include error bars for T^2 . Draw the lines of best fit and the line of maximum gradient.



- d. Determine the gradient of the line of best fit. Include the uncertainty in your answer. (6 marks)

- e. Use your gradient calculated in question 7.2 d. to determine the value of g . (4 marks)
- Do NOT calculate the uncertainty in your answer.**

Extra Graph Paper



Extra Working Space