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PHYSICAL SCIENCES: PAPER I

Time: 2 hours

130 marks

Examiner: K Mari

Moderator: J Morrison-Young

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PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This question paper consists of 15 pages, and a Data Sheet of 2 pages. Please check that your question paper is complete.
 2. Read the questions carefully.
 3. Answer ALL the questions.
 4. Start each question on a new page.
 5. Number your answers as the questions are numbered.
 6. Use the data and formulae whenever necessary.
 7. Show your working in all calculations.
 8. Units need not be included in the working calculations, but appropriate units should be shown in the answer.
 9. Answers must be expressed in decimal format, not left as proper fractions.
 10. Where appropriate, express answers to TWO decimal places.
 11. It is in your own interest to write legibly and to present your work neatly.
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Question 1

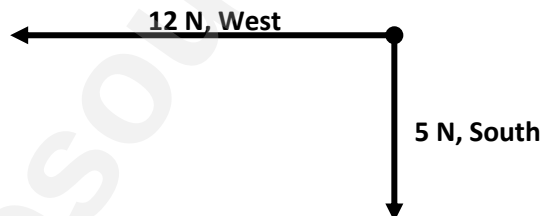
Answer these questions on the multiple-choice answer sheet below. Make a cross (X) in the box corresponding to the letter that you consider to be correct.

A	B	☒	D
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Here the option C has been marked as an example.

1.1	A	B	☒	D
1.2	A	☒	C	D
1.3	A	B	C	☒
1.4	A	B	☒	D
1.5	A	☒	C	D
1.6	☒	B	C	D
1.7	☒	B	C	D

1.1 Two forces act on an object as shown below:



Choose the correct option for the resultant of the two forces from the table below:

	Magnitude	Direction
A)	13	67,4° South of West
B)	17	22,6° South of West
C)	13	67,4° West of South
D)	13	22,6° West of South

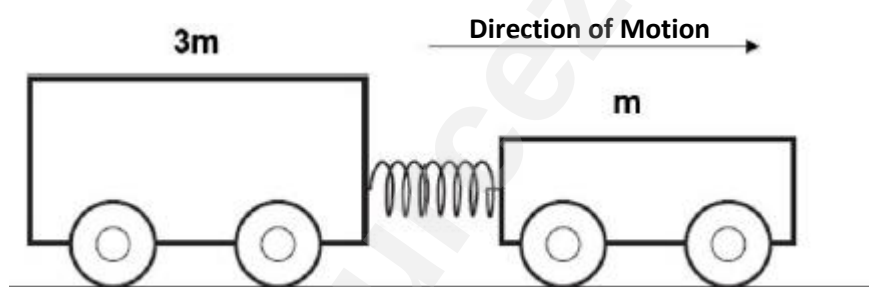
1.2 The table shows data from a high-jump competition. Which athlete jumps the highest?

	Weight of Athlete (N)	Increase in gravitational energy
A)	600	1320
B)	700	1610
C)	800	1760
D)	900	1800

- 1.3 Joash throws a ball vertically upwards. Which one of the following combinations indicates the direction of the net force, acceleration and velocity of the ball when it is halfway up after leaving the hand?

	F_{net}	a	v
A)	Up	Down	Up
B)	Down	Down	Down
C)	Up	Up	Up
D)	Down	Down	Up

- 1.4 Two trolleys of masses $3m$ and m are moving to the right across a horizontal frictionless surface. The speed of the trolleys is v and they are joined by means of a compressed spring. When the spring is released, the trolleys are pushed apart and separate.



The magnitude of the change in momentum of the trolley with mass $3m$ is x . What is the magnitude of the change of momentum of the trolley with mass m ?

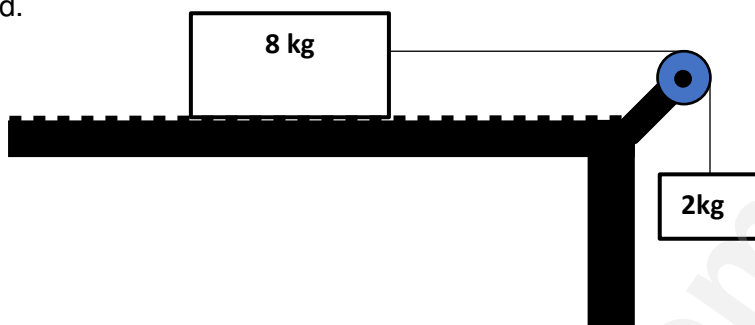
- A) $3x$ B) $4x$
 C) x D) $\frac{1}{3}x$
- 1.5 An object, of mass m , hangs at the end of a string from the ceiling of a lift cage. The lift is moving upward while slowing down uniformly.

The acceleration due to gravity is g .

Which ONE of the following statements regarding the tension (T) in the string is CORRECT? The tension T ...

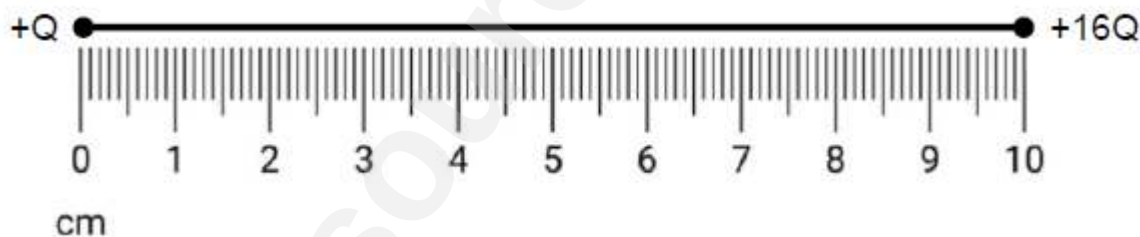
- A) will be equal to mg .
 B) will be less than mg .
 C) will be greater than mg .
 D) is zero.

- 1.6 A box of mass $8,0 \text{ kg}$ rests on a horizontal rough surface. A light inextensible string attached to the box passes over a smooth pulley and supports a $2,0 \text{ kg}$ mass at its other end.



When the box is released, a frictional force of $6,0 \text{ N}$ acts on it. What is the magnitude of the acceleration of the box?

- A) $1,4 \text{ m.s}^{-2}$ B) $1,7 \text{ m.s}^{-2}$
 C) $2,0 \text{ m.s}^{-2}$ D) $2,6 \text{ m.s}^{-2}$
- 1.7 Two point charges of $+Q$ and $+16Q$ are placed 10 cm apart as shown below. A ruler is used to determine the distance between the two charges.



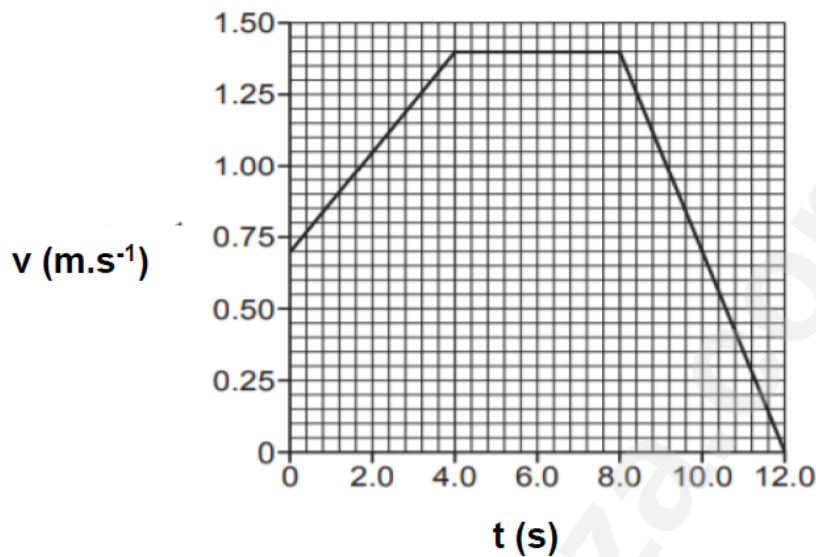
At which position between $+Q$ and $+16Q$ is the magnitude of the electric field strength zero?

- A) At 2 cm from $+Q$ B) At 4 cm from $+Q$
 C) At 5 cm from $+Q$ D) At 6 cm from $+Q$

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Question 2

The velocity versus time graph of a go-kart, initially travelling West is shown below.



- 2.1 State the initial velocity of the go-kart. (2)

$v = 0,7 \text{ m.s}^{-1}$ ✓ West ✓

- 2.2 Define acceleration. (2)

Rate of ✓ change of velocity ✓

- 2.3 Determine the acceleration of the go-kart between 8 and 12 seconds. (3)

$$a = \frac{1,4 - 0}{8 - 12} = -0,35 \text{ m.s}^{-2} \text{ ✓} = 0,35 \text{ m.s}^{-2} \text{ East ✓}$$

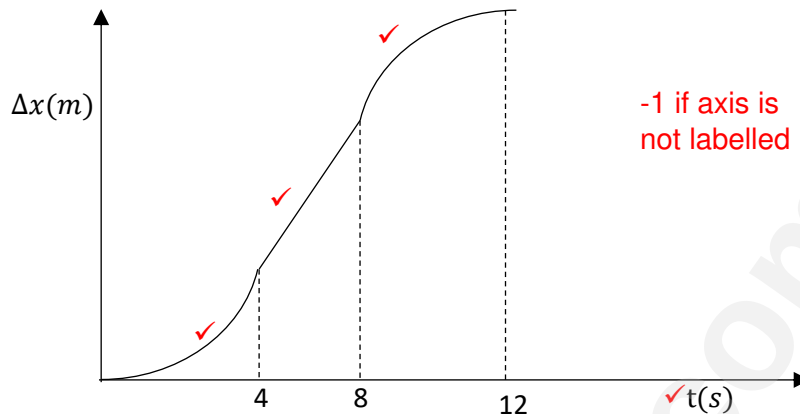
- 2.4 Use the graph to determine how far the go-kart moved during the 12 seconds. (4)

$$\Delta x = \frac{1}{2}(0,7 + 1,4)(4) \text{ ✓} + (4)(1,4) \text{ ✓} + \frac{1}{2}(4)(1,4) \text{ ✓} = 12,6 \text{ m ✓}$$

2.5 Draw sketch graphs (showing only the times) of:

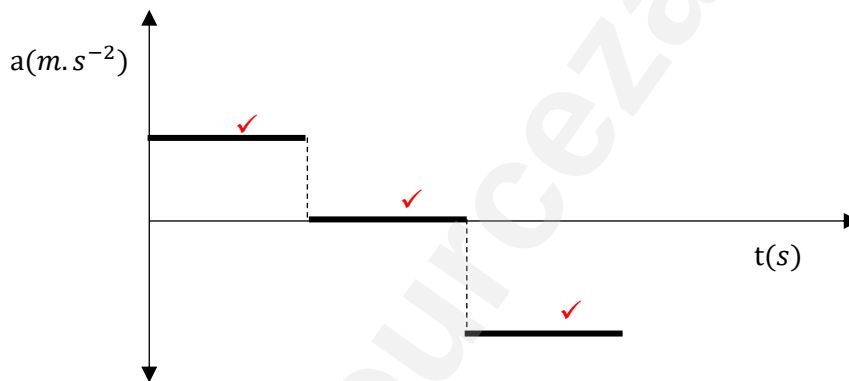
2.5.1 The displacement vs time for the 12 seconds.

(4)



2.5.2 The acceleration vs time for the 12 seconds.

(3)



2.6 In a pro go-kart, Presharin completes a 2 km race. The kart starts from rest and accelerates at $2,1 \text{ m.s}^{-2}$ until reaching its top speed of $75,6 \text{ km.h}^{-1}$. Presharin maintains this speed to complete the race.

How long does it take him to complete the 2 km race?

(6)

$$75,6 \text{ km.h}^{-1} = 21 \text{ m.s}^{-1}$$

$$v_f = v_i + at$$

$$21 = 0 + (2,1)t \quad \checkmark \quad t = 10s$$

$$v_f^2 = v_i^2 + 2a\Delta x \quad \checkmark$$

$$21^2 = 0^2 + 2(2,1)\Delta x \quad \checkmark \quad \Delta x = 105 \text{ m}$$

$$\Delta x = 2000 - 105 = 1895 \text{ m} \quad \checkmark$$

$$t = \frac{\Delta x}{v} = \frac{1895}{21} = 90,24 \text{ s} \quad \checkmark$$

$$t = 10 + 90,24 = 100,24 \text{ s} \quad \checkmark$$

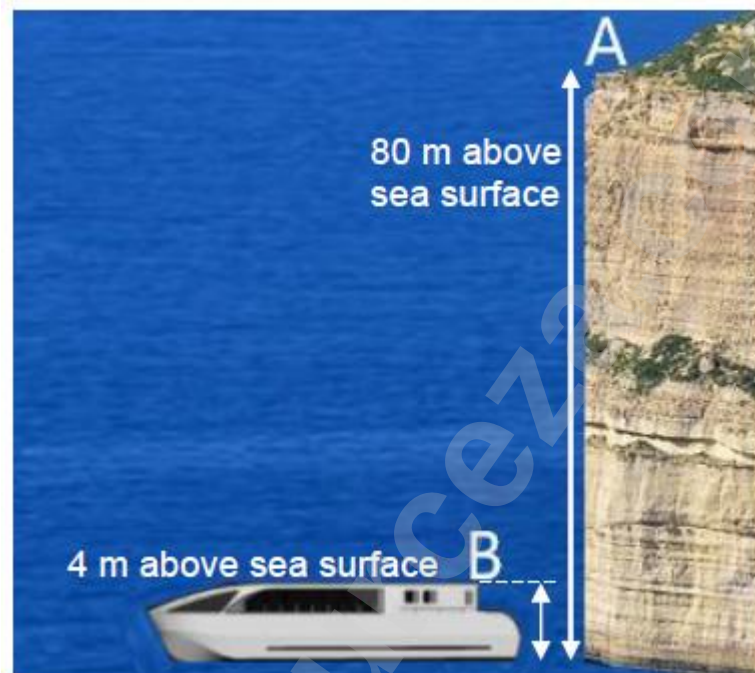
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Question 3

Priya stands on a cliff at point A which is 80 m above the sea surface.

Tim is on the roof of a sea ferry, at point B, which is 4 m above the sea surface, as shown in the picture (not to scale) below.

Priya fires a paintball upwards from the edge of the cliff, at 15 m.s^{-1} . Tim fires a pepperball upwards from the sea ferry, 0,8 s after Priya fired the paintball.



- 3.1 What is the acceleration of the paintball at its highest point of projection above the sea surface? (2)

$9,8 \text{ m.s}^{-2}$ ✓ down ✓

- 3.2 Define the term *displacement*. (2)

Change ✓ of position ✓

- 3.3 Determine the displacement of the paintball from the point that it is fired upward by Priya to the point where it strikes the sea surface. (2)

$\Delta x = 80 \text{ m}$ ✓ down ✓

3.4 Calculate the time taken for the paintball to reach Tim at point **B**. (5)

$$\Delta x = v_i t + \frac{1}{2} a t^2 \checkmark$$

$$-76 \checkmark = (15)t \checkmark + \frac{1}{2}(-9,8)t^2 \checkmark$$

$$4,9t^2 - 15t - 76 = 0$$

$$t = 5,76 \text{ s} \checkmark$$

3.5 Tim noticed that the paintball and the pepperball reach point **B** *at the same time* on the way down before they drop into the sea. Calculate the magnitude of the initial velocity of the pepperball. (5)

$$t = 5,76 - 0,8 = 4,96 \text{ s} \checkmark$$

$$\Delta x = v_i t + \frac{1}{2} a t^2$$

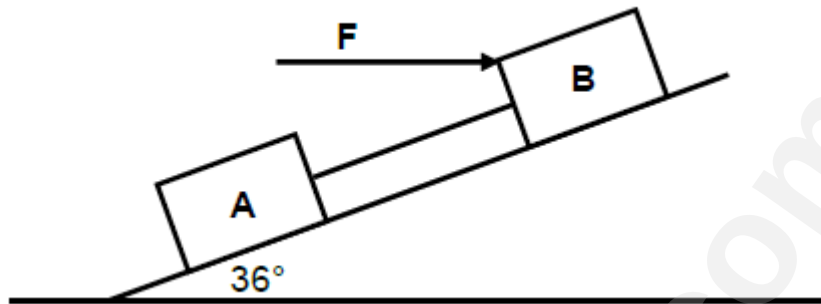
$$0 \checkmark = v_i(4,96) \checkmark + \frac{1}{2}(-9,8)(4,96)^2 \checkmark$$

$$v_i = 24,3 \text{ m} \cdot \text{s}^{-1} \text{ Up} \checkmark$$

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Question 4

Two blocks, A and B, are held at REST on a rough slope by a horizontal force F. The mass of each block is 8,5 kg and the rope connecting the two blocks is light and inextensible.



The coefficient of static friction between block B and the surface is 0,4 and block A experiences a static frictional force of 68 N. Block B is at the point of sliding up the slope.

4.1 Define *normal force*. (2)

Normal Force is the perpendicular force ✓ exerted by a surface on an object in contact with it. ✓

4.2 Calculate the magnitude of the normal force acting on block A. (3)

$$F_N = F_g \cos \theta = (8,5)(9,8) \cos 36^\circ = 67,39 \text{ N}$$

4.3 State *Newton's first law*. (2)

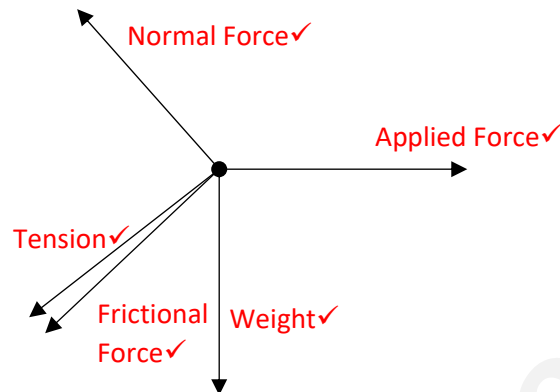
An object continues in a state of rest or uniform (moving with constant) velocity ✓ unless it is acted upon by a net or resultant force. ✓

4.4 Consider the forces acting on block A and calculate the magnitude of the tension in the string. (3)

$$F_{\text{net}} = T - F_g \sin \theta - F_f$$

$$0 = T - (8,5)(9,8) \sin 36^\circ - 68 \quad T = 116,96 \text{ N}$$

- 4.5 Draw a free-body diagram for the forces acting on block B. (5)



- 4.6 Calculate force F. (7)

$$F_{net} = F \cos 36 - F_g \sin \theta - T - F_f$$

$$0 = F \cos 36 - (8,5)(9,8) \sin 36 - 116,96 - 0,4[(8,5)(9,8) \cos 36 + F \sin 36]$$

$$0 = F \cos 36 - 48,96 - 116,96 - 26,96 - F \cdot 0,4 \sin 36$$

$$F(\cos 36 - 0,4 \sin 36) = 48,96 + 116,96 + 26,96$$

$$F = \frac{48,96 + 116,96 + 26,96}{\cos 36 - 0,4 \sin 36} = 336,08 \text{ Right}$$

- 4.7 The magnitude of force F is now decreased. For the following questions, state only INCREASES, DECREASES, or NO EFFECT.

- 4.7.1 How will this affect the normal force on block B? (2)

Decrease

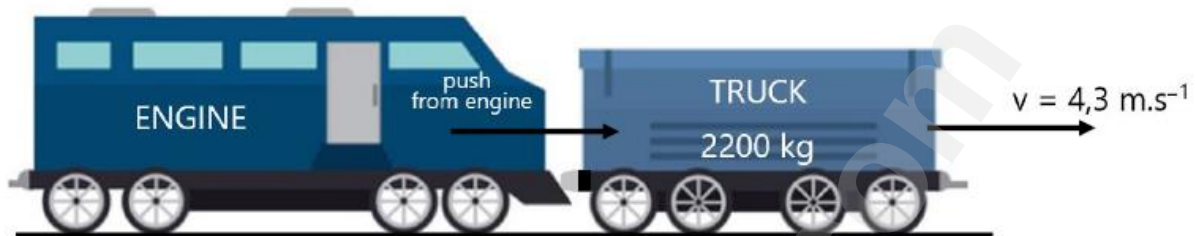
- 4.7.2 How will this affect the frictional force on block B? (2)

Decrease

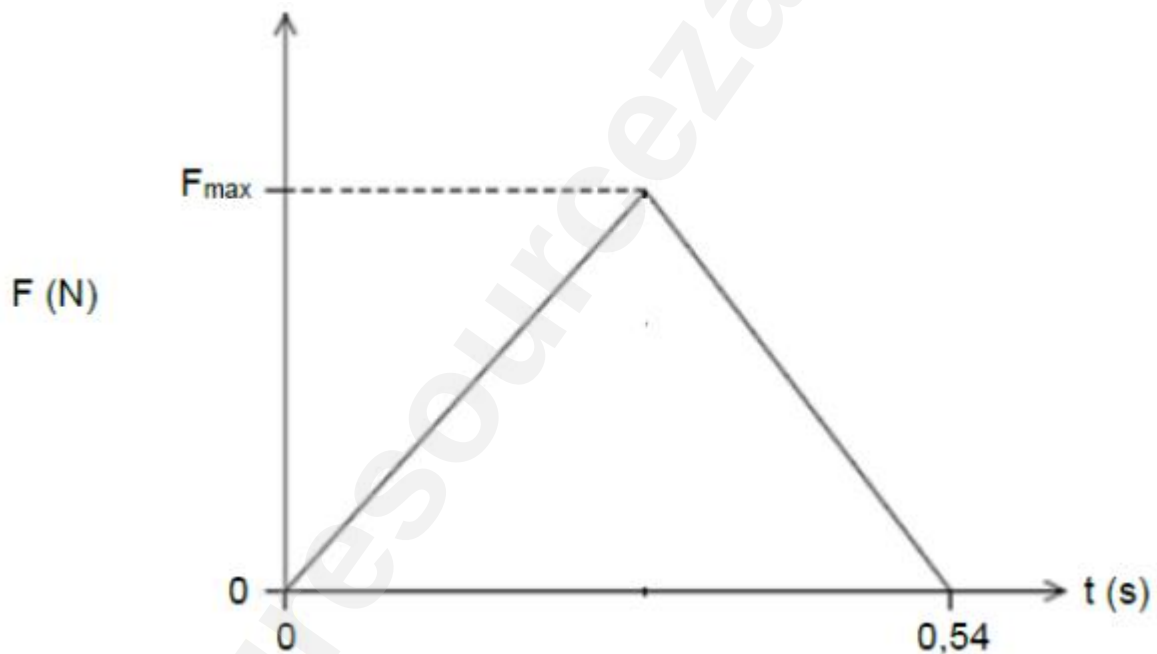
[26]

Question 5

A railway truck on a level, straight track is initially at rest. The truck, mass 2200 kg, is given a quick, horizontal push by an engine so that it now rolls along the track with a speed of $4,3 \text{ m.s}^{-1}$. The engine is in contact with the truck for a time $t = 0,54 \text{ s}$.



The sketch shows how the force exerted by the engine on the truck varies with contact time, t .



5.1 Define the term *impulse*. (2)

Impulse is the product ✓ of the net force and the contact time. ✓

5.2 Calculate the impulse of the force exerted by the engine on the truck. (4)

$$J = mv_f - mv_i \checkmark = (2200)(4,3) - (2200)(0) \checkmark = 9460 \text{ kg.m.s}^{-1} \checkmark \text{ Right} \checkmark$$

- 5.3 Determine the magnitude of the maximum force $F_{\max}$ exerted by the engine on the truck. (3)

$$J = \text{area under graph} \checkmark$$

$$9460 = \frac{1}{2} (0,54) F_{\max} \checkmark$$

$$F_{\max} = 35\,037,04 \text{ N} \checkmark$$

After contact with the engine ($t = 0,54 \text{ s}$), the truck moves 15 m along the track. After travelling this distance, the speed of the truck is $2,8 \text{ m.s}^{-1}$.



- 5.4 State the *work-energy theorem*. (2)

Work done by a net force on an object is equal $\checkmark$ to the change in the kinetic energy of the object. $\checkmark$

- 5.5 Calculate the work done on the truck by resistive forces as it travels 15 m. (4)

$$W_{\text{net}} = \Delta E_k \checkmark$$

$$W_{\text{net}} = \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2$$

$$W_{\text{net}} = \frac{1}{2} (2200) (2,8)^2 \checkmark - \frac{1}{2} (2200) (4,3)^2 \checkmark$$

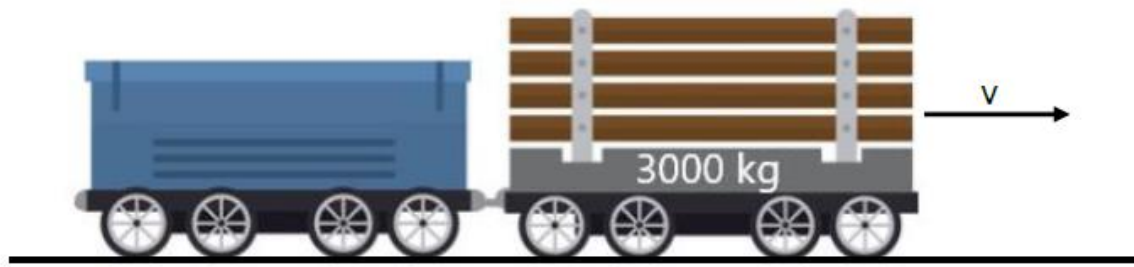
$$W_{ff} = W_{\text{net}} = -11715 \text{ J} \checkmark$$

- 5.6 When the speed of the truck is $2,8 \text{ m.s}^{-1}$ it collides with another truck of mass 3000 kg moving in the opposite direction at $0,8 \text{ m.s}^{-1}$. The two trucks stick together and move off with a speed v in the direction shown. Calculate the speed of the trucks immediately after the collision. (4)

$$\Sigma p_i = \Sigma p_f \checkmark$$

$$(2200)(2,8) + (3000)(-0,8) \checkmark = (2200 + 3000) v_f \checkmark$$

$$v_f = 0,72 \text{ m.s}^{-1} \checkmark$$



Once the two trucks eventually come to rest at the end of the track, a forklift lifts the cargo from the second truck with a force of 29 400 N at a **constant velocity** of 0,4 m.s⁻¹ to a height of 9 m. The forklift's engine is 90 % efficient. (The diagram alongside is not to scale)

5.7 Calculate the amount of work done by the forklift's engine to raise the load. (3)

$$W = F\Delta x \checkmark = (29400)(9) \checkmark = 264\,600\,J \checkmark$$

5.8 Calculate the power output of the engine. (3)

$$P = Fv \checkmark = (29400)(0,4) \checkmark = 11760\,W \checkmark$$

5.9 Calculate the power input of the engine. (3)

$$\text{Efficiency} = \frac{P_{out}}{P_{in}} \times 100 \checkmark$$

$$90\% = \frac{11760}{P_{in}} \checkmark \quad P_{in} = 13\,066,67\,W \checkmark$$

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Question 6

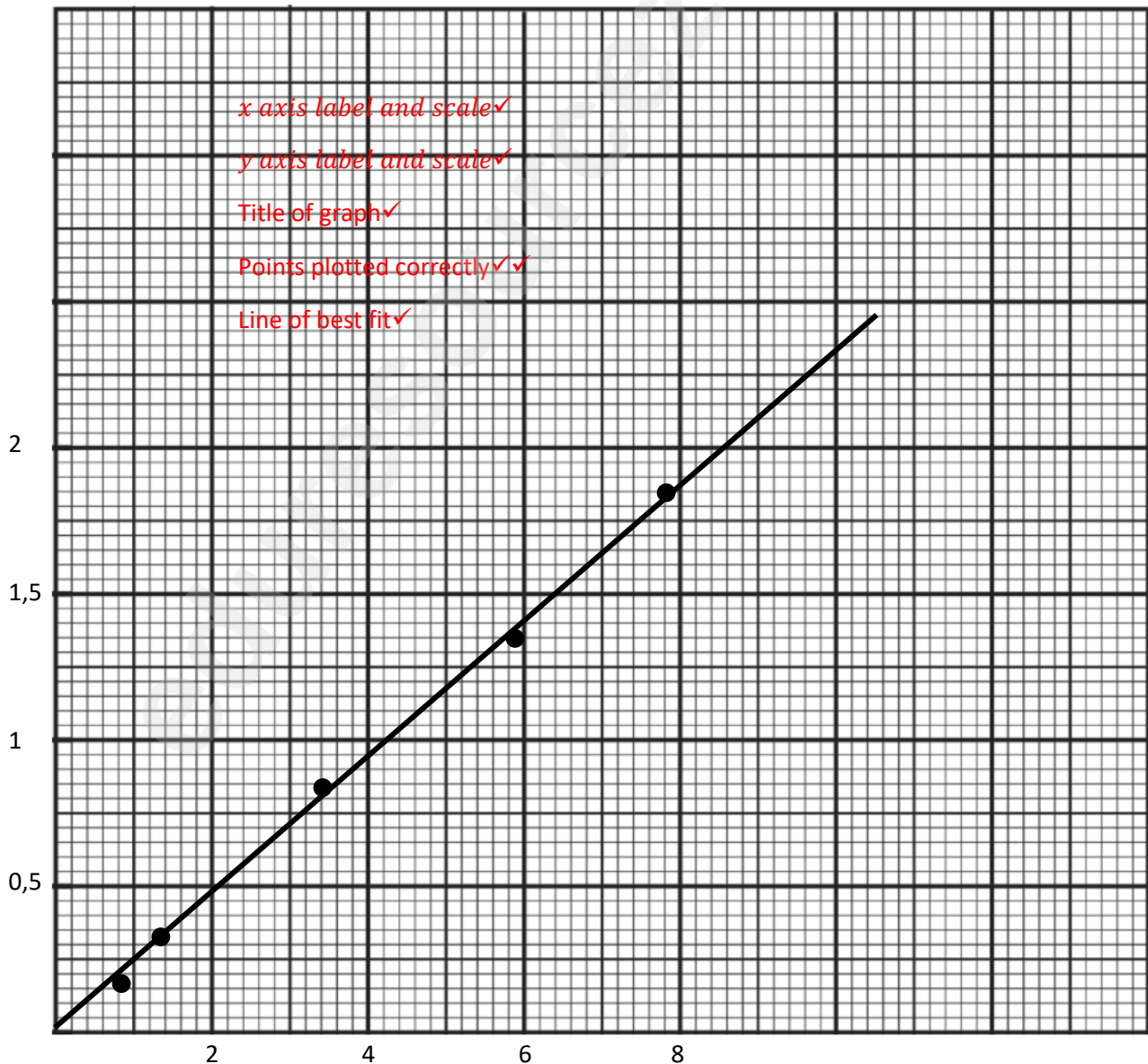
Space X wants to determine the size of Mars's gravitational field. They send probes that record the gravitational force (F) due to Mars on the probe at different distances (r) away from the planet.

The results for $\frac{1}{r^2}$ and F are given in the table below:

$\frac{1}{r^2} (\times 10^{-14} m^{-2})$	$F (\times 10^{-4} N)$
7,8	1,85
5,9	1,36
3,4	0,84
2,2	0,48
1,4	0,32
0,8	0,16

6.1 Plot a graph of F vs $\frac{1}{r^2}$. Include a line of best fit.

(6)



- 6.2 Calculate the gradient of your graph. Show the values you used on your graph. Give an appropriate unit for your gradient. (4)

$$\text{Gradient} = \frac{y_2 - y_1}{x_2 - x_1} = 0,239 \times \frac{10^{-4}}{10^{-14}} = 2,39 \times 10^9 \checkmark \text{ N} \cdot \text{m}^2 \checkmark$$

$$\text{Range: } 0,227 - 0,251$$

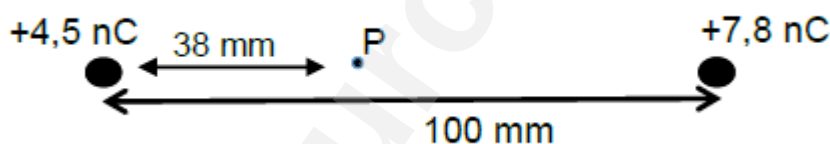
- 6.3 The probe has a mass of 5600 kg. Use an appropriate equation and your gradient calculated in 6.2 to determine the mass of Mars. (4)

$$F = \frac{Gm_1m_2}{r^2} \quad \text{Gradient} = Gm_1m_2 \checkmark$$

$$(6,7 \times 10^{-11})(5600)m_2 \checkmark = 2,39 \times 10^9 \checkmark$$

$$m = 6,37 \times 10^{15} \text{ kg} \checkmark \checkmark$$

- 6.4 Two small conducting spheres which carry charges of +4,5 nC and +7,8 nC are placed a distance of 100 mm apart as shown in the diagram below.



- 6.4.1 Define the term *magnitude of electric field*. (2)

The magnitude of the electric field at a point is the force per unit positive charge. ✓

- 6.4.2 Determine the resultant electric field strength at P. (6)

$$E_1 = \frac{kQ}{r^2} \checkmark = \frac{(9 \times 10^9)(4,5 \times 10^{-9})}{(0,038)^2} \checkmark = 28\,047,09 \text{ N} \cdot \text{C}^{-1}$$

$$E_2 = \frac{kQ}{r^2} = \frac{(9 \times 10^9)(7,8 \times 10^{-9})}{(0,062)^2} \checkmark = 18\,262,23 \text{ N} \cdot \text{C}^{-1}$$

$$E_{\text{net}} = 28\,047,09 - 18\,262,23 \checkmark = 9784,86 \text{ N} \cdot \text{C}^{-1} \checkmark \text{ right} \checkmark$$

[22]

TOTAL MARKS: 130