

AQA A-LEVEL PHYSICS • 7408

PHYSICS



EXAM QUESTION PACK

3.4.1 FORCE, ENERGY AND MOMENTUM • PACK 3

SCORE

/158

PERCENTAGE

%

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1.

A body of constant mass falls freely due to gravity.

The rate of change of momentum of the body is equal to its

A kinetic energy.

☐

B mass.

☐

C gravitational potential energy.

☐

D weight.

☐

(Total 1 mark)

2.

An electric vehicle is driven by a motor which produces a constant driving force.

The vehicle travels from rest along a straight horizontal road.

Friction and air resistance are negligible.

Which statement describes the variation with time of the power developed by the motor?

A It stays constant.

☐

B It increases linearly from zero.

☐

C It increases non-linearly from zero.

☐

D It increases from zero to a maximum and then decreases.

☐

(Total 1 mark)

3.

Immediately after take-off from the surface of the Earth, a rocket of mass 12 000 kg accelerates vertically upwards at 1.4 m s^{-2}

What is the thrust produced by the rocket motor?

A $1.7 \times 10^4 \text{ N}$

☐

B $1.0 \times 10^5 \text{ N}$

☐

C $1.3 \times 10^5 \text{ N}$

☐

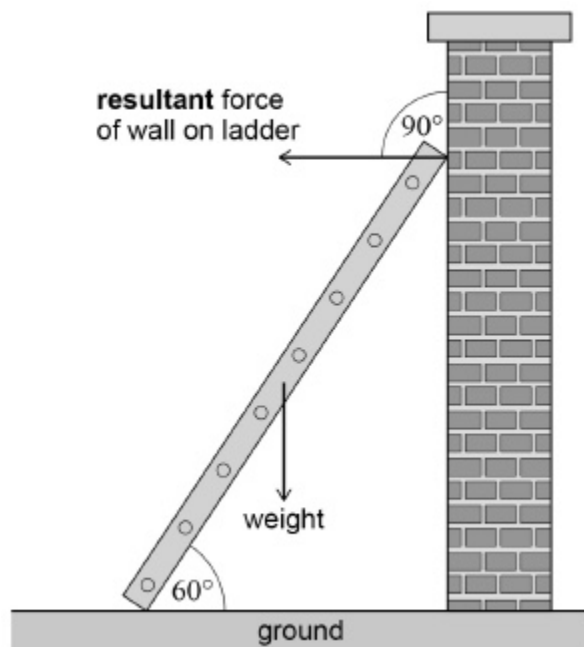
D $1.6 \times 10^5 \text{ N}$

☐

(Total 1 mark)

4.

The diagram shows two of the forces acting on a uniform ladder resting against a vertical wall. The ladder is at an angle of 60° to the ground.



- (a) Explain how the diagram shows that the friction between the ladder and the wall is negligible.

(1)

- (b) The forces acting on the ladder are in equilibrium.

Draw an arrow on the diagram to show the direction of the resultant force from the ground acting on the ladder. Label your arrow **G**.

(2)

- (c) The ladder is 8.0m long and weighs 390N.

Calculate the magnitude of the resultant force from the wall on the ladder.

resultant force = _____ N

(2)

- (d) Suggest the changes to the forces acting on the ladder that occur when someone climbs the ladder.

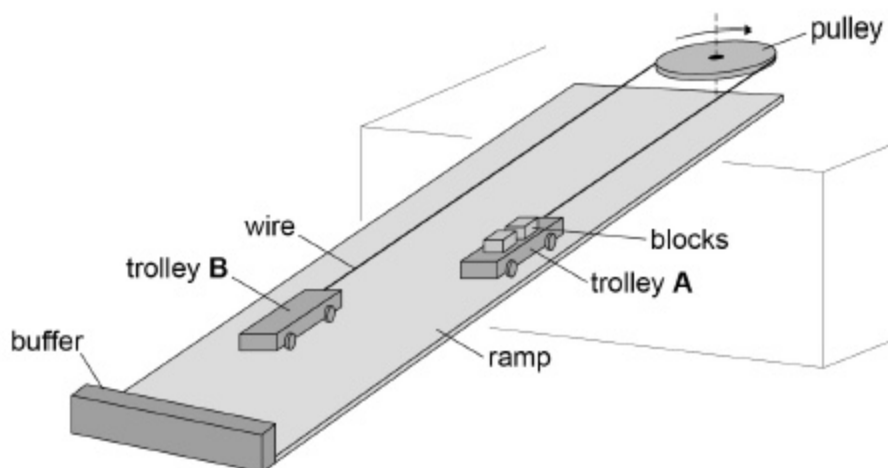
(3)

(Total 8 marks)

5.

Figure 1 shows a model of a system being designed to move concrete building blocks from an upper to a lower level.

Figure 1

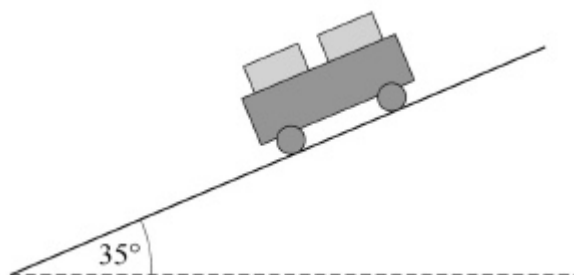


The model consists of two identical trolleys of mass M on a ramp which is at 35° to the horizontal. The trolleys are connected by a wire that passes around a pulley of negligible mass at the top of the ramp.

Two concrete blocks each of mass m are loaded onto trolley **A** at the top of the ramp. The trolley is released and accelerates to the bottom of the ramp where it is stopped by a flexible buffer. The blocks are unloaded from trolley **A** and two blocks are loaded onto trolley **B** that is now at the top of the ramp. The trolleys are released and the process is repeated.

Figure 2 shows the side view of trolley **A** when it is moving **down** the ramp.

Figure 2



- (a) The tension in the wire when the trolleys are moving is T .

Draw and label arrows on **Figure 2** to represent the magnitudes and directions of any forces and components of forces that act on trolley **A** parallel to the ramp as it travels down the ramp.

(1)

- (b) Assume that no friction acts at the axle of the pulley or at the axles of the trolleys and that air resistance is negligible.

Show that the acceleration a of trolley **B** along the ramp is given by

$$a = \frac{mg \sin 35^\circ}{M + m}$$

(2)

- (c) Compare the momentum of loaded trolley **A** as it moves downwards with the momentum of loaded trolley **B**.

(2)

- (d) In practice, for safety reasons there is a friction brake in the pulley that provides a resistive force to reduce the acceleration to 25% of the maximum possible acceleration.

The distance travelled for each journey down the ramp is 9.0 m.

The following data apply to the arrangement.

Mass of a trolley $M = 95\text{ kg}$

Mass of a concrete block $m = 30\text{ kg}$

Calculate the time taken for a loaded trolley to travel down the ramp.

time = _____ s

(3)

- (e) It takes 12s to remove the blocks from the lower trolley and reload the upper trolley.

Calculate the number of blocks that can be transferred to the lower level in 30 minutes.

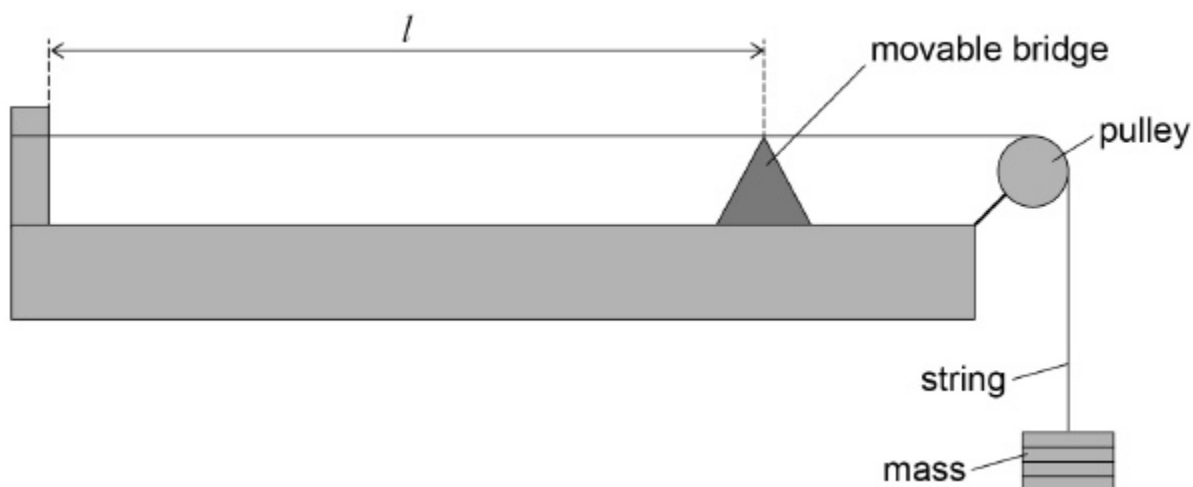
number = _____

(2)

(Total 10 marks)

6.

The diagram shows an arrangement used by a student to investigate vibrations in a stretched nylon string of fixed length l . He measures how the frequency f of first-harmonic vibrations for the string varies with the mass m suspended from it.



The table shows the results of the experiment.

m / kg	f / Hz
0.50	110
0.80	140
1.20	170

- (a) Show that the data in the table are consistent with the relationship

$$f \propto \sqrt{T}$$

where T is the tension in the nylon string.

(2)

- (b) The nylon string used has a density of 1150 kg m^{-3} and a uniform diameter of $5.0 \times 10^{-4} \text{ m}$.

Determine the length l of the string used.

$$l = \text{_____ m}$$

(3)

- (c) The student uses the relationship in question (a) to predict frequencies for tensions that are much larger than those used in the original experiment.

Explain how the actual frequencies produced would be different from those that the student predicts.

(2)

(Total 7 marks)

7.

Two identical balls, **X** and **Y**, are at the same height and a horizontal distance of 25 cm apart.

X is projected horizontally with a velocity of 0.10 m s^{-1} towards **Y** at the same time that **Y** is released from rest. Both **X** and **Y** move freely in the absence of air resistance.

What is the distance between the balls 1.0 s later?

A 0.15 m

☐

B 0.25 m

☐

C 2.4 m

☐

D 4.9 m

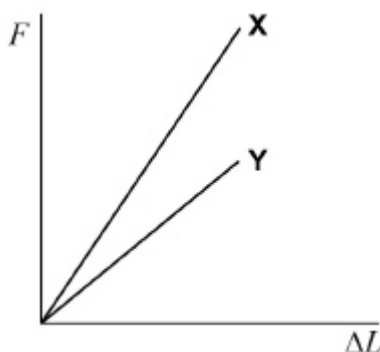
☐

(Total 1 mark)

8.

Two separate wires **X** and **Y** have the same original length and cross-sectional area.

The graph shows the extension ΔL produced in **X** and **Y** when the tensile force F applied to the wires is increased up to the point where they break.



Which statement is **incorrect**?

A For a given extension more energy is stored in **X** than in **Y**.
☐
B The Young modulus of the material of wire **Y** is greater than that of wire **X**.
☐
C Both wire **X** and wire **Y** obey Hooke's law.
☐
D Wire **X** has a greater breaking stress than wire **Y**.
☐

(Total 1 mark)

9.

Two bodies of different masses undergo an elastic collision in the absence of any external force.

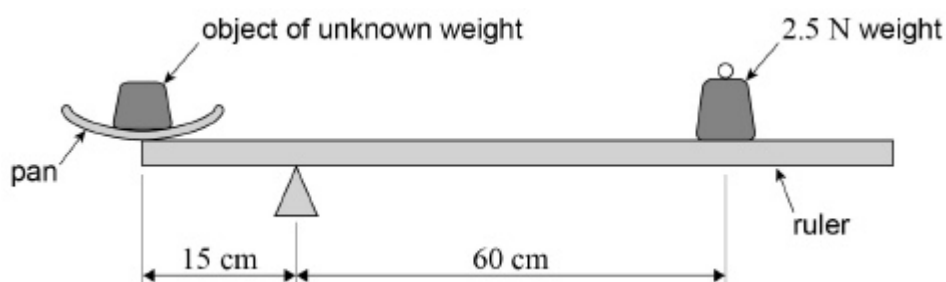
Which row gives the effect on the total kinetic energy of the masses and the magnitudes of the forces exerted on the masses during the collision?

	Total kinetic energy	Magnitudes of forces	
A	remains unchanged	same on both masses	☐
B	remains unchanged	greater on the smaller mass	☐
C	decreases	same on both masses	☐
D	decreases	greater on the smaller mass	☐

(Total 1 mark)

10.

The diagram shows a uniform metre ruler of weight 1.5 N pivoted 15 cm from one end for use as a simple balance.



A scale pan of weight 0.5 N is placed at the end of the ruler and an object of unknown weight is placed in the pan. The ruler moves to a steady horizontal position when a weight of 2.5 N is added at a distance of 60 cm from the pivot as shown.

What is the weight of the object?

A 9.5 N

☐

B 10.0 N

☐

C 13.0 N

☐

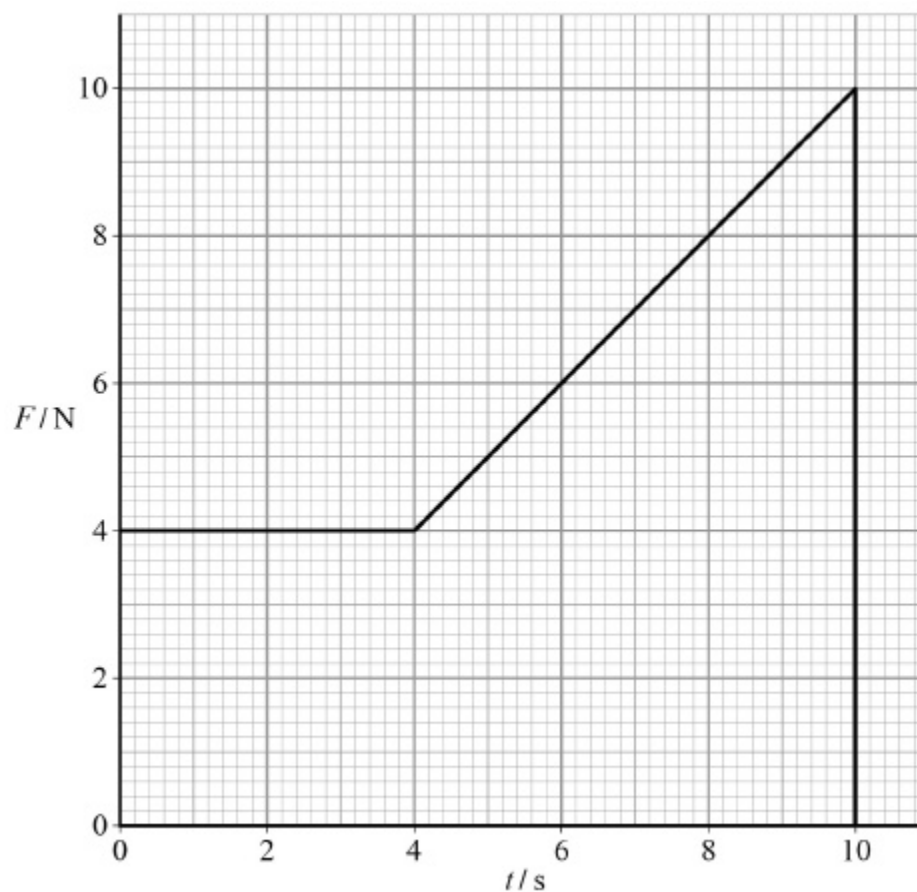
D 13.5 N

☐

(Total 1 mark)

11.

The graph shows how the force F applied to an object varies with time t .



What is the momentum gained by the object from $t = 0$ to $t = 10$ s?

A 18 kg m s⁻¹

☐

B 32 kg m s⁻¹

☐

C 40 kg m s⁻¹

☐

D 58 kg m s⁻¹

☐

(Total 1 mark)

12.

What is the name given to a material that breaks without deformation when a force is applied to it?

A Plastic

☐

B Brittle

☐

C Stiff

☐

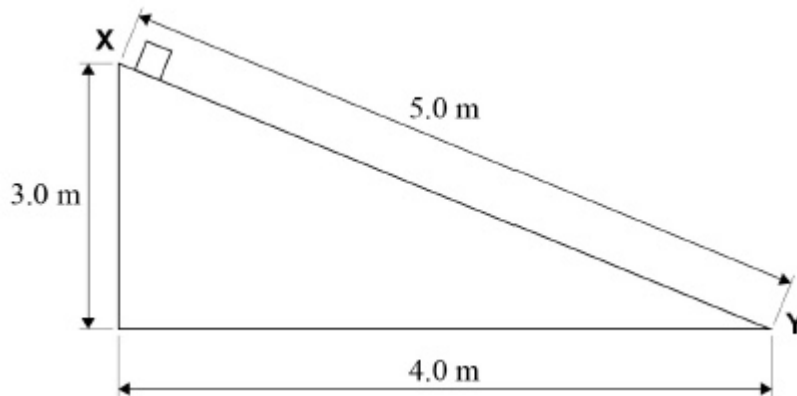
D Elastic

☐

(Total 1 mark)

13.

A mass of 2.5 kg is released from rest at **X** and slides down a ramp, of height 3.0 m, to point **Y** as shown.



When the mass reaches **Y** at the bottom of the ramp it has a velocity of 5.0 m s^{-1} .

What is the average frictional force between the mass and the ramp?

A 8.5 N

☐

B 10.6 N

☐

C 14.7 N

☐

D 24.5 N

☐

(Total 1 mark)

14. Which row correctly states whether momentum, mass and velocity are scalar or vector quantities?

	Momentum	Mass	Velocity	
A	scalar	scalar	vector	☐
B	vector	scalar	scalar	☐
C	scalar	vector	scalar	☐
D	vector	scalar	vector	☐

(Total 1 mark)

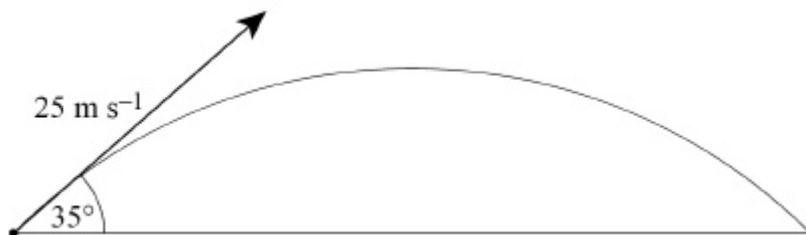
15. A bullet of mass 10 g is fired with a velocity of 100 m s^{-1} from a stationary rifle of mass 4.0 kg. Consider the rifle and bullet to be an isolated system.

What are the recoil velocity of the rifle and the total momentum of the rifle and bullet just after firing?

	Recoil velocity / m s^{-1}	Total momentum / kg m s^{-1}	
A	0.25	0	☐
B	0.25	1.0	☐
C	0.40	0	☐
D	0.40	1.0	☐

(Total 1 mark)

16. A projectile is launched with a speed of 25 m s^{-1} at an angle of 35° to the horizontal, as shown in the diagram.



Air resistance is negligible.

What is the time taken for the projectile to return to the ground?

A 1.5 s

☐

B 2.1 s

☐

C 2.9 s

☐

D 4.2 s

☐

(Total 1 mark)

17.

An electric wheelchair, powered by a battery, allows the user to move around independently.

One type of electric wheelchair has a mass of 55 kg. The maximum distance it can travel on level ground is 12 km when carrying a user of mass 65 kg and travelling at its maximum speed of 1.5 m s^{-1} .

The battery used has an emf of 12 V and can deliver $7.2 \times 10^4 \text{ C}$ as it discharges fully.

(a) Show that the average power output of the battery during the journey is about 100 W.

(3)

- (b) During the journey, forces due to friction and air resistance act on the wheelchair and its user.

Assume that all the energy available in the battery is used to move the wheelchair and its user during the journey.

Calculate the total mean resistive force that acts on the wheelchair and its user.

total mean resistive force = _____ N

(2)

The diagram below shows the wheelchair and its user travelling up a hill. The hill makes an angle of 4.5° to the horizontal.



- (c) Calculate the force that gravity exerts on the wheelchair and its user parallel to the slope.

force parallel to the slope = _____ N

(1)

- (d) Calculate the maximum speed of the wheelchair and its user when travelling up this hill when the power output of the battery is 100 W.

Assume that the resistive forces due to friction and air resistance are the same as in part (b).

maximum speed = _____ m s^{-1}

(2)

- (e) Explain how and why the maximum range of the wheelchair on level ground is affected by

- the mass of the user
- the speed at which the wheelchair travels.

Effect of mass _____

Effect of speed _____

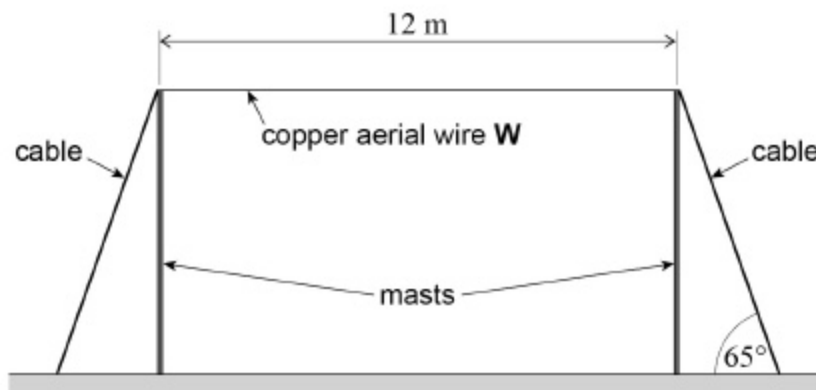
(4)

(Total 12 marks)

18.

Figure 1 shows a structure that supports a horizontal copper aerial wire **W** used for transmitting radio signals.

Figure 1



The copper aerial wire is 12 m long and its area of cross-section is $1.6 \times 10^{-5} \text{ m}^2$.
The tension in the copper aerial wire is $5.0 \times 10^2 \text{ N}$.

Young modulus of copper = $1.2 \times 10^{11} \text{ Pa}$

- (a) Show that the extension produced in a 12 m length of the aerial wire when the tension is $5.0 \times 10^2 \text{ N}$ is less than 4 mm.

(2)

- (b) The cables that support each mast are at an angle of 65° to the horizontal.

Calculate the tension in each supporting cable so that there is no resultant horizontal force on either mast.

tension = _____ N

(1)

- (c) When wind blows, stationary waves can be formed on the aerial wire.

Explain how stationary waves are produced and why only waves of specific frequencies can form on the aerial wire.

(4)

- (d) Calculate the mass of a 1.0 m length of the aerial wire.

Density of copper = 8900 kg m^{-3}

mass = _____ kg

(1)

- (e) Calculate the frequency of the wave when the third harmonic is formed on the aerial wire.

frequency = _____ Hz

(2)

- (f) Sketch, on **Figure 2**, the standing wave on the wire when the third harmonic is formed.

Figure 2



(1)

- (g) High winds produce large amplitudes of vibration of the aerial wire.

Explain why the wire may sag when the high wind stops.

(2)

(Total 13 marks)

19.

Which is a correct statement about mechanical power?

A It is a vector quantity.

☐

B It is measured in J.

☐

C In fundamental units, its unit is $\text{kg m}^2 \text{s}^{-3}$

☐

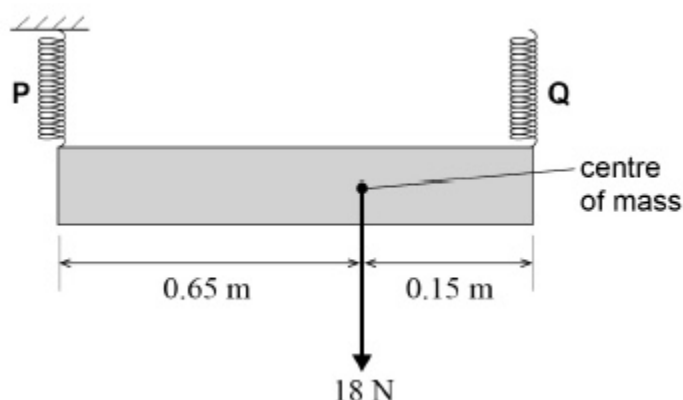
D It can be calculated from force $\times$ distance moved.

☐

(Total 1 mark)

20.

A non-uniform sign is 0.80 m long and has a weight of 18 N. It is suspended from two vertical springs **P** and **Q**. The springs obey Hooke's law and the spring constant of each spring is 240 N m^{-1} .



The top end of spring **P** is fixed and the top end of spring **Q** is adjusted until the sign is horizontal and in equilibrium.

What is the extension of spring **Q**?

A 0.014 m

☐

B 0.038 m

☐

C 0.049 m

☐

D 0.061 m

☐

(Total 1 mark)

21.

The diagram shows two railway trucks **A** and **B** travelling towards each other on the same railway line which is straight and horizontal.



The trucks are involved in an inelastic collision. They join when they collide and then move together.

The trucks move a distance of 15 m before coming to rest.

Truck **A** has a total mass of 16 000 kg and truck **B** has a total mass of 12 000 kg

Just before the collision, truck **A** was moving at a speed of 2.8 m s^{-1} and truck **B** was moving at a speed of 3.1 m s^{-1}

- (a) State the quantity that is **not** conserved in an inelastic collision.

(1)

- (b) Show that the speed of the joined trucks immediately after the collision is about 0.3 m s^{-1}

(3)

- (c) Calculate the impulse that acts on each truck during the collision.
Give an appropriate unit for your answer.

impulse = _____ unit _____

(2)

- (d) Explain, without doing a calculation, how the motion of the trucks immediately after the collision would be different for a collision that is perfectly elastic.

(2)

(Total 8 marks)

- 22.** Three coplanar forces F_1 , F_2 and F_3 act on a point object.

Which combination of forces can never produce a resultant force of zero?

	F_1 / N	F_2 / N	F_3 / N	
A	3	4	5	☐
B	8	8	8	☐
C	2	10	10	☐
D	3	6	10	☐

(Total 1 mark)

- 23.** What is a correct unit for the area under a force–time graph?

- A** N m ☐
- B** kg m s⁻¹ ☐
- C** kg m s⁻² ☐
- D** N s⁻¹ ☐

(Total 1 mark)

24.

Objects **P** and **Q** are initially at rest at time $t = 0$

The same resultant force F is applied to **P** and **Q** for time T .

The mass of **P** is 10 times greater than the mass of **Q**.

What is the ratio $\frac{\text{kinetic energy of P}}{\text{kinetic energy of Q}}$?

A 0.1

☐

B 1

☐

C 10

☐

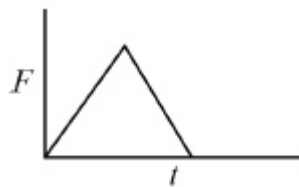
D 100

☐

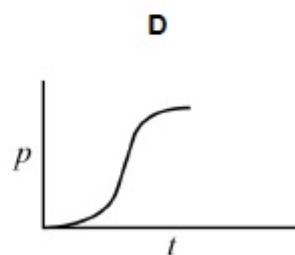
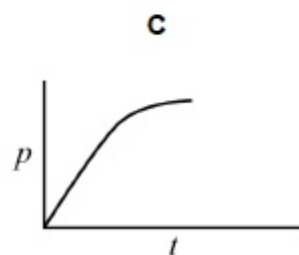
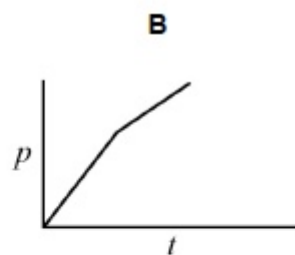
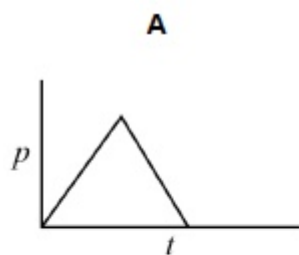
(Total 1 mark)

25.

The graph shows how the resultant force F on a football, which is initially at rest, varies with time t .



Which graph shows how the momentum p of the football varies with time t ?



A ☐

B ☐

C ☐

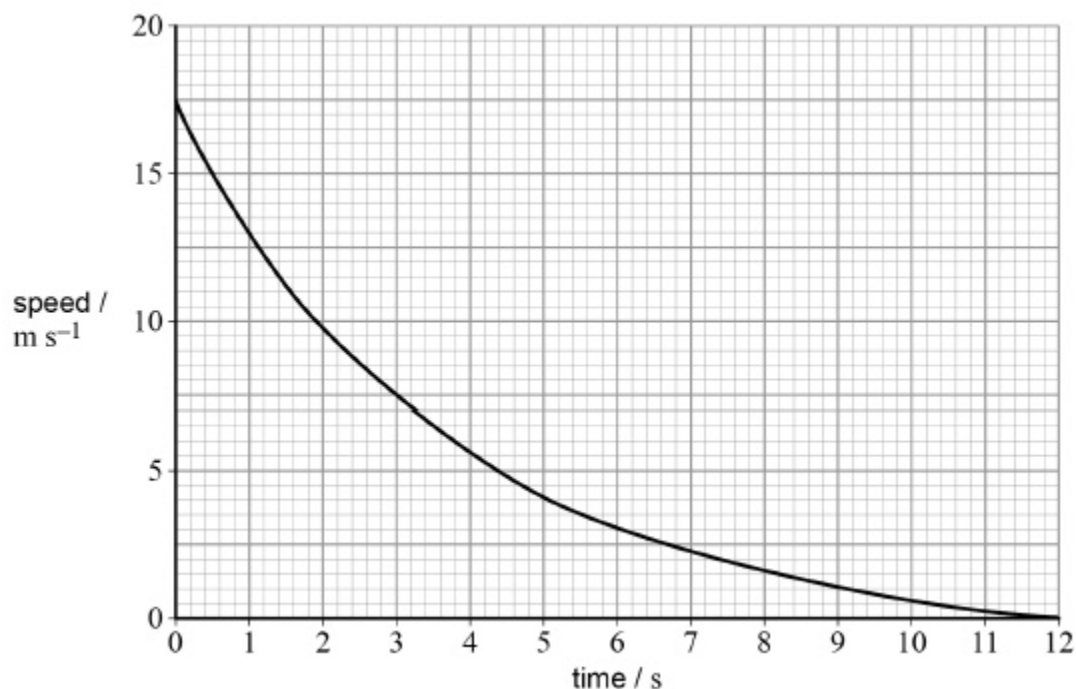
D ☐

(Total 1 mark)

26.

Horizontal escape lanes made of loose gravel have been constructed at the side of some roads on steep hills so that vehicles can stop safely when their brakes fail.

The graph shows an engineer's prediction of how the speed of an unpowered vehicle of mass 1.8×10^4 kg will vary with time as the vehicle comes to rest in an escape lane.



- (a) Determine the force decelerating the vehicle 2.0 s after entering the escape lane.

force decelerating the vehicle = _____ N

(3)

- (b) Deduce whether a lane of length 85 m is long enough to stop the vehicle, assuming that the engineer's graph is correct.

(3)

- (c) Discuss the energy transfers that take place when a vehicle is decelerated in an escape lane.

(2)

- (d) An alternative to an escape lane containing gravel is an escape lane that consists of a ramp. An escape ramp is a straight road with a concrete surface that has a constant upward gradient.

One escape ramp makes an angle of 25° to the horizontal and is 85 m long.

Deduce whether this escape ramp is sufficient to stop the vehicle.

Assume that any frictional forces and air resistance that decelerate the vehicle are negligible.

(3)

- (e) Discuss whether an escape lane containing gravel or an escape ramp would provide the safer experience for the driver of the vehicle as it comes to rest.

(1)

(Total 12 marks)

27.

A girl is bouncing on a trampoline.

Assuming that air resistance is negligible, her acceleration

A is zero when she is at maximum height.

☐

B is constant when she is in the air.

☐

C changes direction as she rises and then falls.

☐

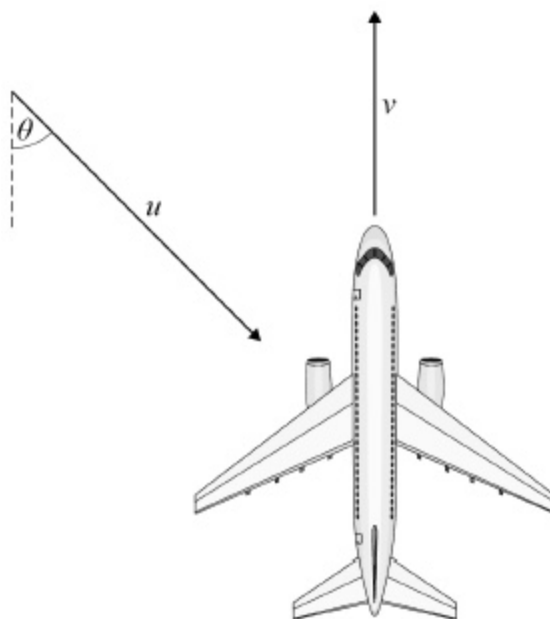
D is maximum just before she lands on the trampoline.

☐

(Total 1 mark)

28. An aircraft is flying due north through still air with a speed v

The aircraft enters a region where the wind is blowing with a speed u from a direction which makes an angle of θ with due south.



What is the time taken for the aircraft to fly a distance D due north of its current position in this windy region?

A $\frac{D}{v - u \cos \theta}$

☐

B $\frac{D}{v - u \sin \theta}$

☐

C $\frac{D}{v + u \cos \theta}$

☐

D $\frac{D}{v + u \sin \theta}$

☐

(Total 1 mark)

29. Two spheres, **P** and **Q**, have the same volume but **P** has a greater mass. The spheres fall in air at their terminal velocities v_P and v_Q respectively.

Which row states the relationship between v_P and v_Q and the reason?

	Relationship between v_P and v_Q	Reason	
A	$v_P = v_Q$	Terminal velocity is unaffected by mass	☐
B	$v_Q > v_P$	The mass of Q is less and it accelerates more	☐
C	$v_Q > v_P$	P reaches equilibrium at a lower terminal velocity	☐
D	$v_P > v_Q$	Q reaches equilibrium at a lower terminal velocity	☐

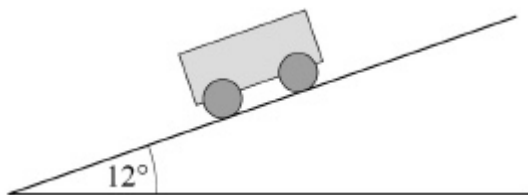
(Total 1 mark)

30.

A car's engine produces a useful output power of $6.5 \times 10^4 \text{ W}$

The car of mass 950 kg is moving up a hill at a steady speed.

The slope of the hill is 12° to the horizontal. Resistive forces on the car are negligible.



What is the steady speed of the car?

A 7.0 m s^{-1}

☐

B 12 m s^{-1}

☐

C 34 m s^{-1}

☐

D 68 m s^{-1}

☐

(Total 1 mark)

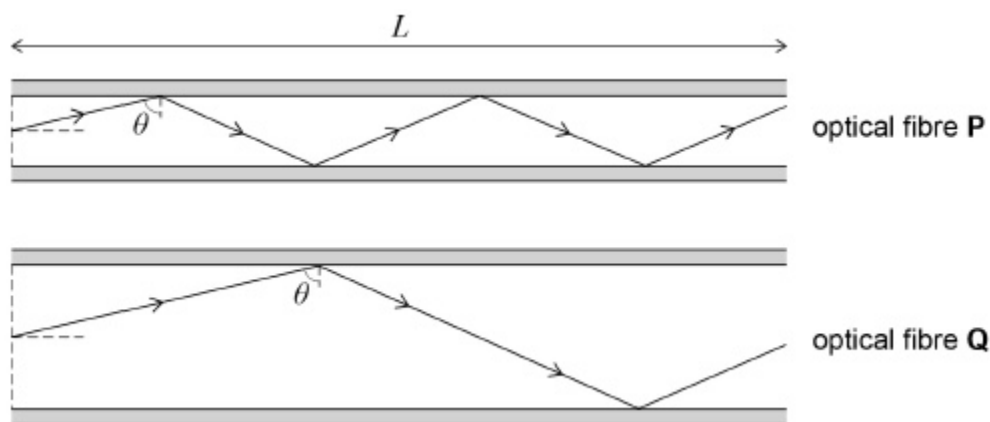
31.

Rays of light are incident at the same angle θ on the core–cladding boundary of optical fibres **P** and **Q**.

The cores of **P** and **Q** have the same refractive index n .

P and **Q** are the same length L .

The core diameter of **P** is half that of **Q**.



The time for the ray to travel along optical fibre **P** is

$$\frac{nL}{c \sin \theta}$$

where c is the speed of light in a vacuum.

What is the time for the ray to travel along optical fibre **Q**?

A $\frac{nL}{c \sin \theta}$ ☐

B $\frac{nL}{2c \sin \theta}$ ☐

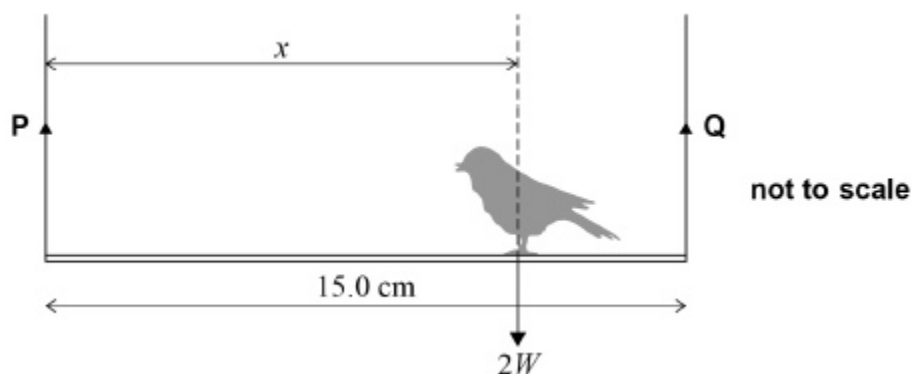
C $\frac{2nL}{c \sin \theta}$ ☐

D $\frac{4nL}{c \sin \theta}$ ☐

(Total 1 mark)

32.

A bird sits on a uniform rod suspended from vertical wires **P** and **Q**.



The rod has a weight W and is 15.0 cm long.

The weight of the bird is $2W$ and acts at a distance x from **P**.

What is the value of x when the tension in **P** is half the tension in **Q**?

A 7.50 cm

☐

B 10.0 cm

☐

C 11.3 cm

☐

D 15.0 cm

☐

(Total 1 mark)

33.

Which list puts the forces in order of increasing magnitude?

A 2 pN < 2 fN < 2 TN < 2 GN

☐

B 2 pN < 2 fN < 2 GN < 2 TN

☐

C 2 fN < 2 pN < 2 TN < 2 GN

☐

D 2 fN < 2 pN < 2 GN < 2 TN

☐

(Total 1 mark)

34.

A radioactive source emits alpha particles each with 8.1×10^{-13} J of kinetic energy.

- (a) Show that the velocity of an alpha particle with kinetic energy $8.1 \times 10^{-13} \text{ J}$ is approximately $2 \times 10^7 \text{ m s}^{-1}$

specific charge of an alpha particle = $4.81 \times 10^7 \text{ C kg}^{-1}$

(2)

- (b) The alpha particles travel through air in straight lines with a range of 3.5 cm
Calculate the average force exerted on an alpha particle as it is stopped by the air.

average force = _____ N

(2)

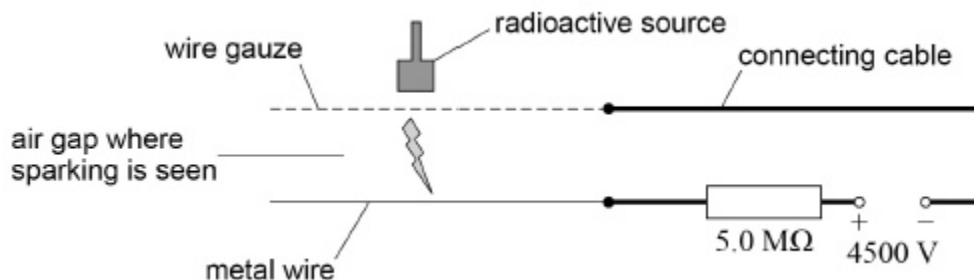
- (c) An alpha particle transfers all its kinetic energy to air molecules and produces 5.1×10^4 ions per centimetre over its range of 3.5 cm

Calculate the average ionisation energy, in eV, of a molecule of air.

ionisation energy = _____ eV

(3)

- (d) A spark counter consists of a wire gauze separated from a metal wire by a small air gap. A power supply with an output of 4500 V is connected in series with a $5.0\text{ M}\Omega$ resistor and the spark counter as shown in the diagram. When the radioactive source is moved close to the wire gauze, sparking is seen in the air gap.



Sparks are produced when alpha particles produce ionisation in the air gap.

One ionisation event produces a current of 0.85 mA for a time of 1.2 ns

Calculate the number of charge carriers that pass a point in the connecting cable during this ionisation event.

number of charge carriers = _____

(2)

- (e) The radioactive source was positioned 10 cm above the wire gauze before being moved slowly towards the wire gauze leading to the ionisation event in part **(d)**.

Discuss how the potential difference across the air gap varied as the radioactive source was moved over this distance.

Assume the power supply has negligible internal resistance.

This image shows a blank sheet of white paper with horizontal ruling lines. The lines are evenly spaced and extend across the width of the page. There are no margins, text, or other markings on the paper.

(3)

(Total 12 marks)

35.

An electric motor lifts a load of weight W through a vertical height h in time t . The potential difference across the motor is V and the current through it is I .

What is the efficiency of the motor?

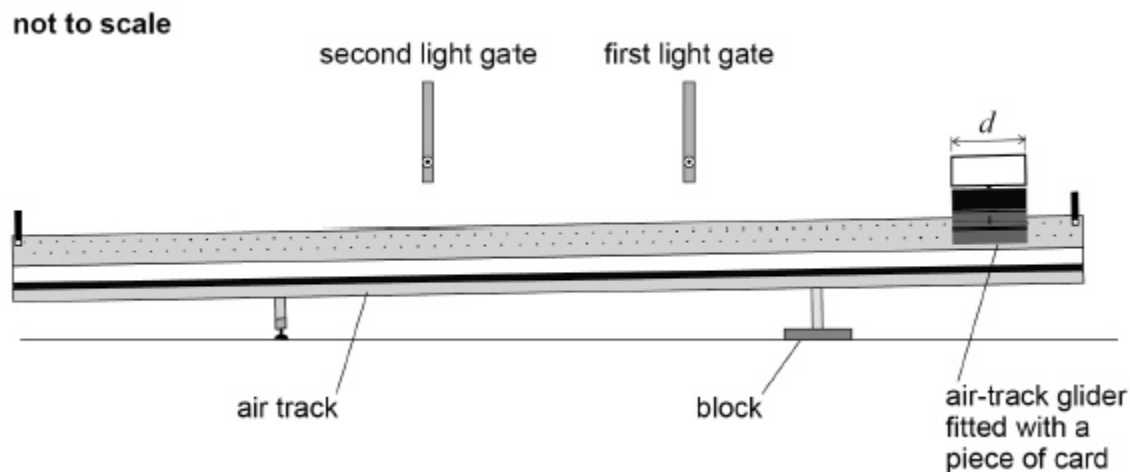
- A $\frac{Wh_t}{VI}$ 
- B $\frac{VI}{Wh_t}$ 
- C $\frac{Wh}{VI_t}$ 
- D $\frac{VI_t}{Wh}$ 

(Total 1 mark)

36.

Figure 1 shows the apparatus used by a student in an experiment to measure the acceleration due to gravity, g .

Figure 1



In the experiment:

- a block is used to raise one end of the air track as shown in **Figure 1**
- an air-track glider is released from rest near the raised end of the air track and passes through the first light gate and then through the second light gate
- a piece of card of length d fitted to the air-track glider interrupts a light beam as the air-track glider passes through each light gate
- a data logger records the time taken by the piece of card to pass through each light gate and also the time for the piece of card to travel from one light gate to the other.

(a) **Table 1** gives measurements made with the light gates as shown in **Figure 1**.

Table 1

Time to pass through first light gate / s	Time to pass through second light gate / s	Time to travel from first to second light gate / s
0.50	0.40	1.19

The length d of the piece of card is 10.0 cm

Assume there is negligible change in velocity while the air-track glider passes through a light gate.

Determine the acceleration a of the air-track glider.

$$a = \underline{\hspace{2cm}} \text{ m s}^{-2}$$

(3)

- (b) Two further sets of readings, **A** and **B**, are taken each with the light gates in different positions along the air track.

Assume the acceleration is the same in each set.

Table 2 shows these additional sets of results.

Table 2

Set	Time to pass through first light gate / s	Time to pass through second light gate / s	Time to travel from first to second light gate / s
A	0.61	0.42	1.77
B	0.55	0.37	2.11

Explain how the data in **Table 2** show that the distance between the light gates in set **B** is greater than in set **A**.

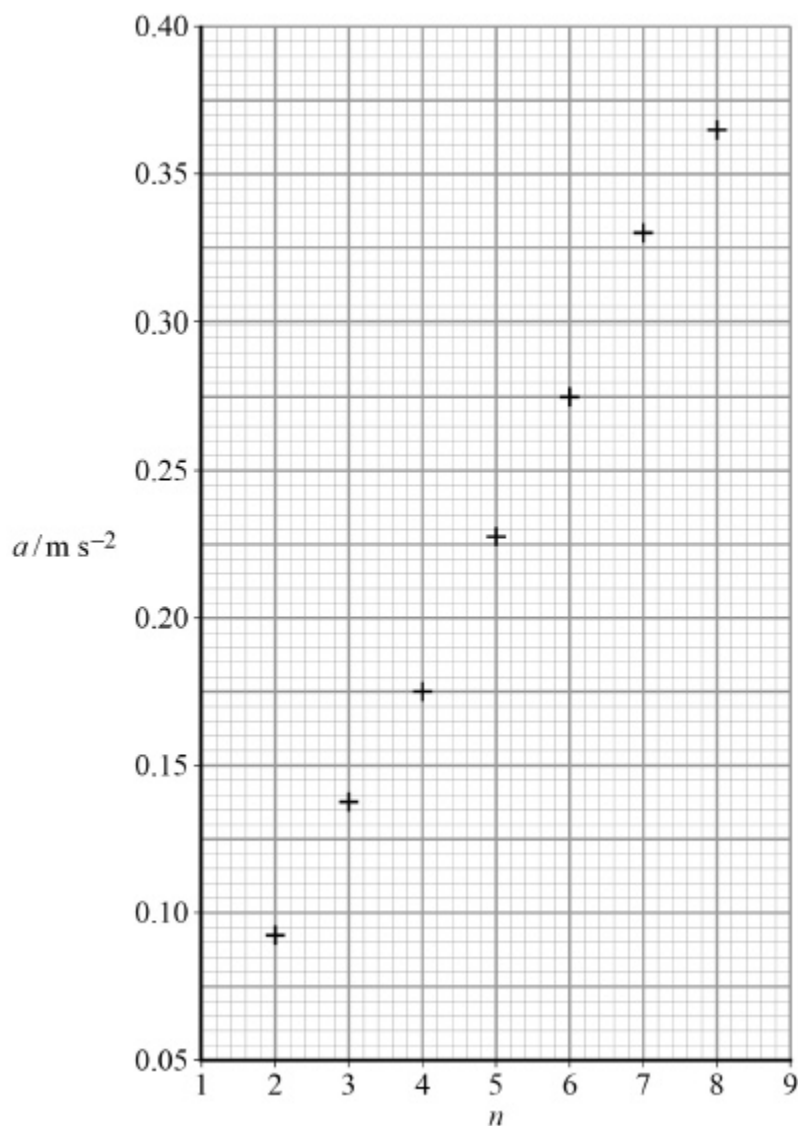
Assume there is negligible change in velocity while the air-track glider passes through a light gate.

(2)

- (c) Additional values for the acceleration of the air-track glider are obtained by further raising the end of the air track by using a stack consisting of identical blocks. Adding each block to the stack raises the end of the air track by the same distance.

Figure 2 is a graph of these results showing how a varies with n , the number of blocks in the stack.

Figure 2



Draw a suitable best-fit straight line on **Figure 2** and determine G , the gradient of your line.

$$G = \underline{\hspace{2cm}}$$

(2)

- (d) It can be shown that, for the apparatus used by the student, g is equal to $\frac{2G}{h}$ where h is the thickness of each block used in the experiment.

The student obtains a value for g of 9.8 m s^{-2}

Calculate h .

$$h = \text{_____ m}$$

(1)

- (e) Explain how you could find out, without drawing another graph, whether the data presented in the graph in **Figure 2** support the suggestion that a is directly proportional to n .

(1)

(Total 9 marks)

37.

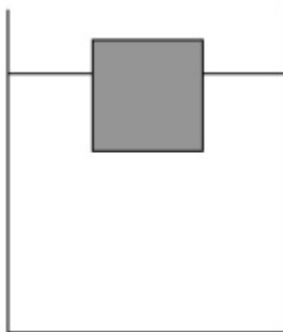
- (a) Calculate the weight of an ice cube that has volume $4.0 \times 10^{-6} \text{ m}^3$

density of ice = 920 kg m^{-3}

$$\text{weight} = \text{_____ N}$$

(2)

- (b) The diagram shows the ice cube floating in a beaker of water.



When the ice cube is placed in the beaker, it displaces a volume of water causing the water level to rise.

The weight of water displaced is equal to the weight of the ice cube.

Calculate the volume of water displaced by the ice cube.

$$\text{density of water} = 1000 \text{ kg m}^{-3}$$

$$\text{volume} = \text{_____} \text{ m}^3$$

(1)

- (c) The ice cube in the diagram is replaced by another cube also with volume $4.0 \times 10^{-6} \text{ m}^3$. This cube is made of ice containing a small piece of iron.
The mass of water now displaced is $3.9 \times 10^{-3} \text{ kg}$

Calculate the volume of the piece of iron.

$$\text{density of iron} = 7800 \text{ kg m}^{-3}$$

$$\text{volume} = \text{_____} \text{ m}^3$$

(3)

(Total 6 marks)

38.

An object of mass m moves in a circle of radius r . It completes n revolutions every second.

What is the kinetic energy of the object?

A $\frac{mn^2r^2}{8\pi^2}$

☐

B $\frac{mn^2r^2}{4\pi^2}$

☐

C $2m\pi^2n^2r^2$

☐

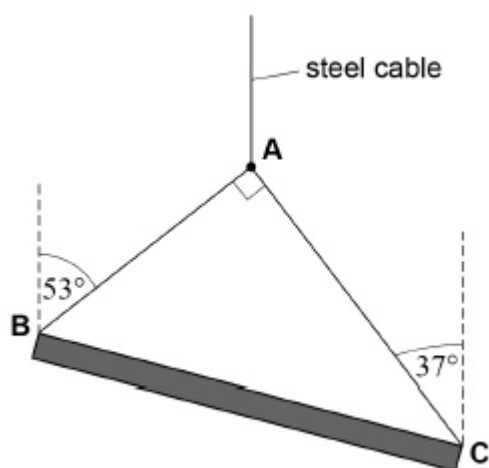
D $4m\pi^2n^2r^2$

☐

(Total 1 mark)

39.

The diagram shows a uniform beam supported by two light cables, **AB** and **AC**, which are attached to a single steel cable from a crane. The beam is stationary and in equilibrium.



(a) State **two** necessary conditions for the beam to be in equilibrium.

Condition 1 _____

Condition 2 _____

(2)

- (b) State what is meant by the centre of mass.

(1)

- (c) Explain why the centre of mass of the beam in the diagram must be vertically below **A**.

(2)

- (d) The weight of the beam is 12 000 N

Calculate the tension T_1 in cable **AB** and the tension T_2 in cable **AC**.

$$T_1 = \text{_____} \text{ N}$$

$$T_2 = \text{_____} \text{ N}$$

(4)

- (e) The steel cable from the crane has a circular cross-section of diameter 1.5×10^{-2} m
The cable is 12 m long.

Calculate the extension of the cable caused by the weight of the beam. You can assume that the weights of **all cables** are negligible.

Young modulus of steel = 2.0×10^{11} Pa

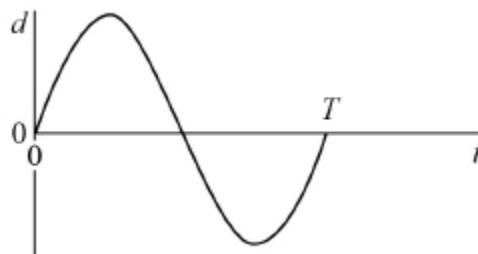
extension = _____ m

(3)

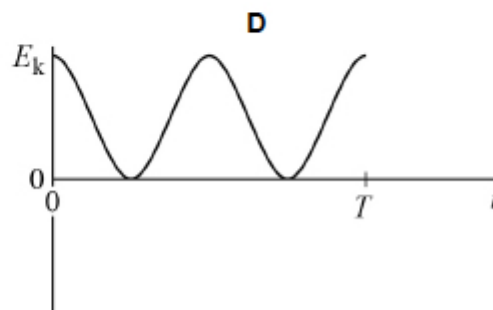
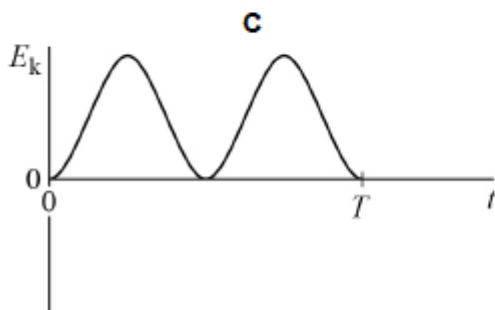
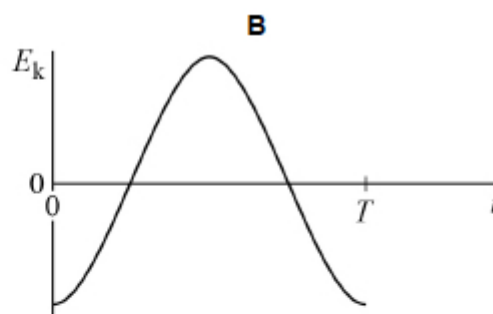
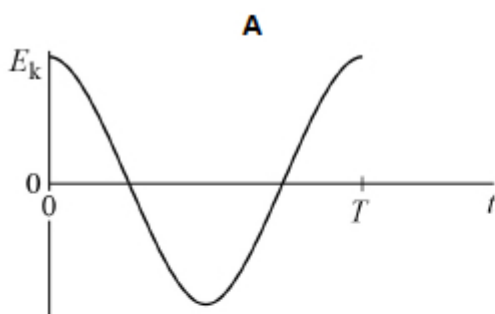
(Total 12 marks)

40.

The graph shows the variation of displacement d with time t for a particle moving with simple harmonic motion of period T .



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



A ☐

B ☐

C ☐

D ☐

(Total 1 mark)

41.

The frequency of oscillation of a vertical spring is f when the mass hanging from the spring is m .

What is the relationship between f and m ?

A $f \propto m^{-1/2}$

☐

B $f \propto m^{-2}$

☐

C $f \propto m^{1/2}$

☐

D $f \propto m^2$

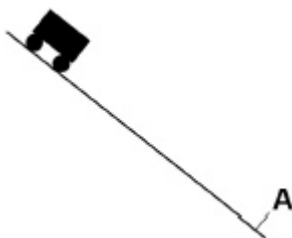
☐

(Total 1 mark)

42.

(a) **Figure 1** shows a truck moving freely down a ramp inclined at an angle to the horizontal.

Figure 1



The truck starts from rest at the top of the ramp and reaches point **A**. Friction and air resistance are negligible.

As the truck moves down the ramp to point **A**, its centre of mass has a total vertical displacement of 8.0 m

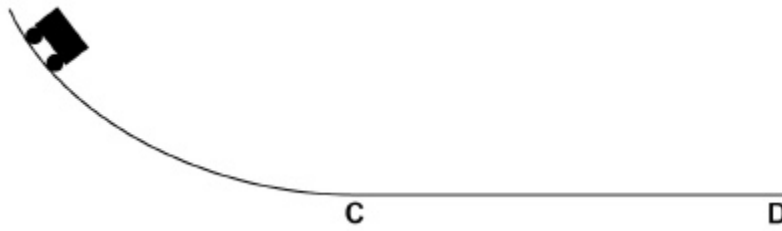
Calculate the speed of the truck at point **A**.

speed = _____ m s⁻¹

(2)

- (b) **Figure 2** shows the truck moving down a ramp with a varying slope.

Figure 2



The truck starts from rest and moves freely down the ramp. It reaches point **C** and then moves along the horizontal runway to **D**. Friction and air resistance are negligible.

Discuss how the acceleration of the truck in **Figure 2** differs from the acceleration of the truck in **Figure 1**.

This image shows a blank sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

(3)

- (c) The total vertical displacement of the centre of mass of the truck in **Figure 2** is also 8.0 m

The speed of the truck when it reaches the horizontal runway is the same as the speed of the truck in **Figure 1** when it reaches point **A**.

Explain why.

(1)

- (d) The horizontal runway in **Figure 2** has negligible friction and air resistance. As the truck moves along the runway, it starts to rain. The rain falls vertically and water collects in the truck.

Discuss whether there are any changes in the momentum of the truck and collected water.

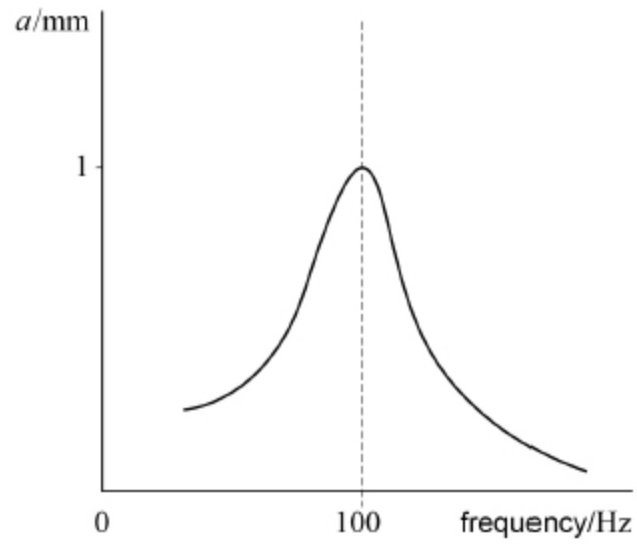
This image shows a single sheet of white paper with horizontal blue or grey ruling lines. The lines are evenly spaced and run across the width of the page. There are approximately 20 lines visible. The paper has a slight shadow on the right side, suggesting it's resting on a surface.

(3)

(Total 9 marks)

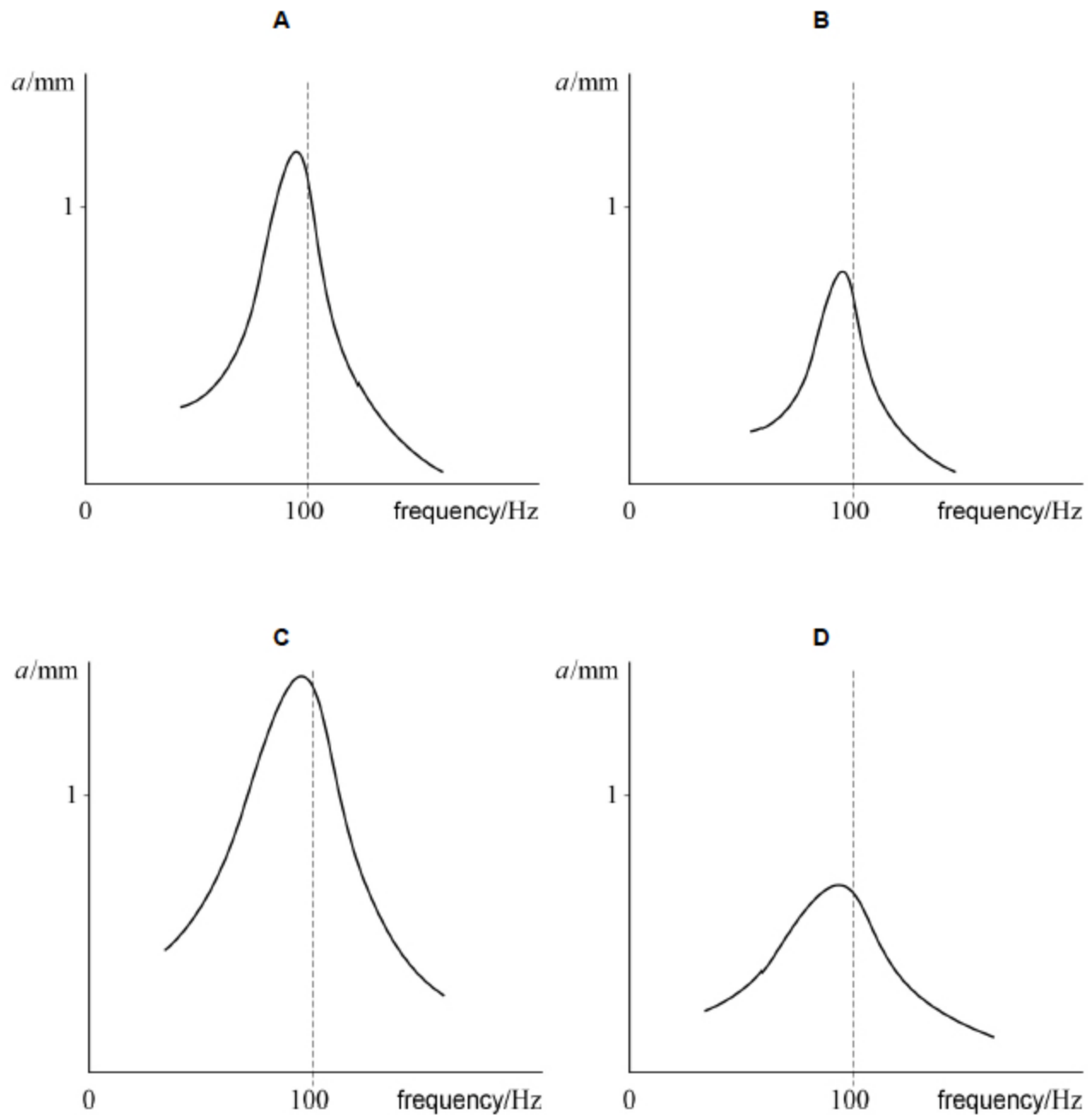
43.

A metal panel is driven to vibrate at different frequencies. The amplitude a of the vibration is measured at each frequency. The graph shows the variation of amplitude with driven frequency.



The damping of the metal panel is increased without changing the mass of the panel.

Which graph shows the variation of a with frequency with increased damping?



A ☐

B ☐

C ☐

D ☐

(Total 1 mark)

- 44.** Two pendulums **A** and **B** oscillate with simple harmonic motion. The time period of **A** is 2.00 s and the time period of **B** is 1.98 s.

A and **B** are released in phase.

What is the number of oscillations of **A** before **A** and **B** are next in phase?

A 49



B 50



C 99

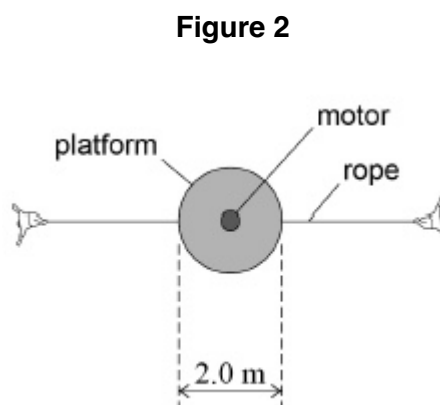
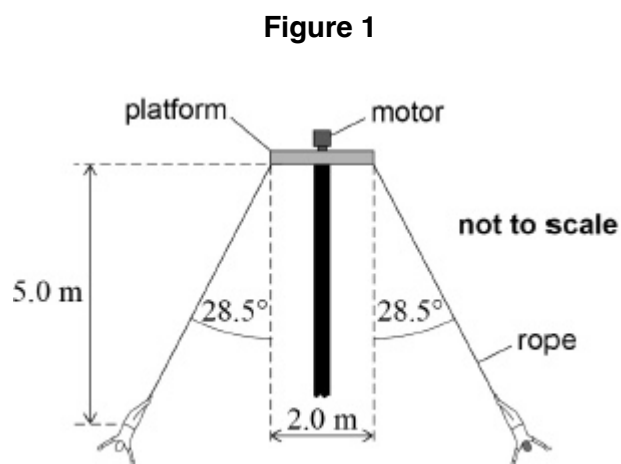


D 100



(Total 1 mark)

- 45.** **Figure 1** shows a side view of an act performed by two acrobats. **Figure 2** shows the view from above.



The acrobats, each of mass 85 kg, are suspended from ropes attached to opposite edges of a circular platform that is at the top of a vertical pole. The platform has a diameter of 2.0 m. A motor rotates the platform so that the acrobats move at a constant speed in a horizontal circle, on opposite sides of the pole.

When the period of rotation of the platform is 5.2 s, the centre of mass of each acrobat is 5.0 m below the platform and the ropes are at an angle of 28.5° to the vertical as shown in **Figure 1**.

- (a) Show that the linear speed of the acrobats is about 4.5 m s^{-1}

(2)

- (b) Determine the tension in each rope that supports the acrobats.

tension = _____ N

(3)

- (c) Discuss the consequences for the forces acting on the pole when one acrobat has a much greater mass than the other.

(3)

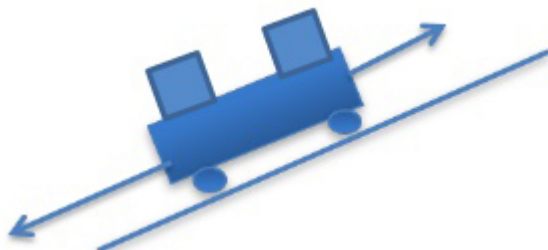
(Total 8 marks)

Mark schemes

1.	D	[1]
2.	B	[1]
3.	C	[1]
4.	(a) force is at right angles / horizontal to wall (and so no component along the wall) ✓ (b) arrow drawn upwards from point of contact with ground ✓ between ladder and vertical which when extended would pass through 'on ladder' part of label ✓ <i>Must be vertical or pointing to right for first mark</i> (c) (use of sum of clockwise moments = sum of anticlockwise moments) EITHER $F \times 8.0 \sin 60$ OR $390 \times 4.0 \cos 60$ ✓ $F = 390 \times 4.0 \cos 60 / 8.0 \sin 60 = 110$ (113) N ✓ <i>Either moment correct gets first mark (does not have to be evaluated)</i> (c) ANY 3 (vertical reaction) force from ground increases ✓ direction of arrow of resultant force from ground changes (as ladder is ascended) ✓ friction force / horizontal component of G between ladder and ground would increase ✓ the (reaction) force from the wall increases ✓ weight (of system) / load on ladder increases ✓ as person climbs they exert a force along the ladder ✓	1 1 1 1 1 MAX 3 [8]

5.

- (a) arrow parallel to slope labelled $(M+2m)g\sin 35$ and label parallel to slope labelled tension OR T ✓



Ignore arrows not parallel to ground e.g. weight

Ignore friction

W not acceptable for $(M + 2m)g$

1

- (b) $T - Mg\sin 35 = Ma$
AND $(M+2m)g\sin 35 - T = (M+2m)a$ ✓

add two equations

$$(M + 2m)g\sin 35 - Mg \sin 35 = Ma + (M + 2m)a$$
 ✓

HENCE

$$(a = mg\sin 35 / (M+m))$$

OR

$$(M + 2m)g\sin 35 - Mg\sin 35 = (2M+2m)a$$
 ✓

$$a = 2mg\sin 35 / (2M + 2m)$$
 ✓

HENCE

$$(a = mg\sin 35 / (M+m))$$

1

1

- (c) SECOND MARK CONDITIONAL ON FIRST
mass / impulse / acceleration (of trolleys) is the same ✓
momenta (trolley A and B) the same

SECOND MARK CONDITIONAL ON FIRST

both have same speed / magnitude of velocity but different masses

✓

(hence) momentum of A is greater / momenta in opposite directions

✓

1

1

(d) $\text{acceleration} = \frac{1}{4} \times \frac{30 \times 9.81 \times \sin 35^\circ}{(30 + 95)} = 0.338 \checkmark$

(use of $v^2 = 2as$)

$v = \sqrt{(2 \times 0.338 \times 9.0)} = 2.47 \checkmark$

$t = \frac{2.47}{0.338} = 7.3 \text{ s } \checkmark$

OR

(use of $s = \frac{1}{2}at^2$)

$9 = \frac{1}{2} \times 0.338 \times t^2 \checkmark$

$t = 7.3 \text{ s } \checkmark$

CE from acceleration calculation

If used g for acceleration then no marks awarded

1
1
1

(e) $\text{number of journeys} = (1800 / (12 + 7.3)) = 93 \text{ or } 94 \checkmark$

$\text{number of blocks} = 2 \times 93 = 186 \text{ or } 2 \times 94 = 188 \checkmark$

Allow CE from 06.4

Allow between 93 to 94

Allow CE from incorrect number of journeys

Allow 186 to 188

1
1

[10]

6.

(a) EITHER

calculate value for constant using two calculations ✓

calculate value for constant using three calculations and make a comment that they have same value ✓

need to see table to look for any working

OR

calculate ratio between masses and $\sqrt{T}$ for one pair of values ✓

calculate ratio between masses and $\sqrt{T}$ for two pairs of values and make comment about same value ✓

e.g. $0.5/0.8 = \sqrt{110}/\sqrt{140}$

OR

work out constant and use to predict one other frequency or mass ✓

work out constant and use to predict two other frequencies or mass ✓

no comment needed with this alternative

2

(b) $\mu = \rho A = 1150 \times \pi(5.0 \times 10^{-4}/2)^2$

$\mu = 2.258 \times 10^{-4} \text{ (kg m}^{-1}\text{)} \checkmark$

use of consistent m and f Substituted in $f = \frac{1}{2l} \sqrt{\frac{T}{\mu}}$ including g but

condone powers of 10 error ✓

Award second mark if T and f substituted correctly (ignore μ)

0.67 m ✓

If used diameter for radius incorrectly then lose first mark but can get third mark (answer 0.335 m)

3

(c) appreciation of reducing diameter when string is stretched. ✓

lower mass per unit length so (constant of proportionality and hence) frequency is higher (than would be predicted) ✓

2

[7]

7.

A

[1]

8.

B

[1]

- | | | | |
|------------|--|--|-----|
| 9. | A | | [1] |
| 10. | C | | [1] |
| 11. | D | | [1] |
| 12. | B | | [1] |
| 13. | A | | [1] |
| 14. | D | | [1] |
| 15. | A | | [1] |
| 16. | C | | [1] |
| 17. | <p>(a) Calculation of energy = $12 \times 7.2 \times 10^4 = 8.64 \times 10^5 \text{ J}$</p> <p>Or time = $12000 / 1.5 = 8000 \text{ s}$ ✓</p> <p>Calculation of other quantity and substitution in power = useful energy / time taken ✓</p> <p>Power = 110 (108 W) ✓</p> <p>Or</p> <p>Time = 8000 s ✓</p> <p style="padding-left: 40px;"><i>Allow ecf for current or time</i></p> <p>Current = charge / time = 9 A ✓</p> <p>Power = VI = 108 (W) ✓</p> | | |

- (b) Attempt to use Power / velocity ✓
 Allow use of 100W for P

73 N ✓

Ignore inclusion of KE in calculation
If 108 used then answer is 72 N
If 100 used then answer is 67 N

or

work done = $F \times 12000$ ✓

equates to 110×8000 so $F = 73 \text{ N}$ ✓
 allow ecf from 3.1

2

- (c) Force parallel to slope = $120 \times 9.81 \times \sin 4.5 = 92 \text{ N}$ ✓

1

- (d) Total resistive force = ans to (c) + ans to (b) (= 165 N) ✓
 Allow ecf for incorrect F

$$\text{Speed} = \left(\frac{100}{165} \right) 0.61 \text{ m s}^{-1}$$

Allow 0.66 / 0.67 if 108 W or 110 W used

2

- (e) **Increasing the mass**

Reward discussion of compression of tyres

Reduces the range ✓

increases the friction on the bearings/tyres

OR More energy / power is used accelerating the user to the final speed

OR user and wheelchair have higher KE/ more energy to move ✓

Increasing the speed

Reduces the range ✓

Air resistance increases with speed ✓

Treat as independent parts

If not explicit about increasing / decreasing lose the first mark in each part

Within each part, second mark is dependent on the first

Allow opposite answers for decreasing mass / speed

4

[12]

18.

- (a) Substitution of data in $Y = \frac{FL}{A\varepsilon}$

$$3.1 \times 10^{-3} \text{ (m)} \checkmark$$

2 marks can be awarded if 4mm used to show $T > 500 \text{ N}$ provided an explanation is provided, otherwise award zero.

2

- (b) $(500 = T \cos 65)$

$$T = 1200 \text{ N} \checkmark$$

1

- (c) Wind produces a wave / disturbance that travels along the wire $\checkmark$

Wave is reflected at each end / waves travel in opposite directions $\checkmark$

(Incident and reflected) waves interfere / superpose $\checkmark$

Only certain frequencies since fixed ends have to be nodes. $\checkmark$

4

- (d) Mass per m of the wire = $0.14(2) \text{ kg} \checkmark$

1

- (e) Use of $f = \frac{1}{2l} \sqrt{\frac{T}{\mu}}$ ($= 2.47$) to find fundamental

$$(\text{or } f = \frac{3}{2l} \sqrt{\frac{T}{\mu}})$$

$$\text{Third harmonic} = 7.4 \text{ (Hz)} \checkmark$$

*The second mark is for multiplying the fundamental frequency by 3
– allow ecf*

2

- (f) Diagram showing three approximately equally spaced loops

Condone single line

1

- (g) Copper may be stretched beyond elastic limit / may deform plastically $\checkmark$

Permanent deformation / Does not return to original length $\checkmark$

Allow 'will remain longer than original' or 'will be permanently deformed'

2

[13]**19.**

C

[1]

20.	D		[1]
21.	(a) (Total) <u>kinetic</u> energy ✓	1	
	(b) Attempt to apply conservation of momentum ✓ <i>NB This is a 'show that' so all stages must be seen</i>	1	
	$16\,000 \times 2.8 - 12\,000 \times 3.1 = 28\,000 v$ ✓ <i>Must see substitution</i>	1	
	$v = 0.27(1) \text{ (m s}^{-1}\text{)}$ ✓ <i>Correct equation (watch signs) gets first and second marks</i>	1	
	(c) Impulse = $16\,000(2.8 - 0.271)$ or $12\,000(3.1 + 0.271) = 4.0(5) \times 10^4$ ✓ <i>If 0.3 m s^{-1} used then impulse will be 4.0×10^4 or $4.08(4.1) \times 10^4$</i>	1	
	N s or kg m s^{-1} ✓	1	
	(d) Trucks move in opposite directions/rebound ✓	1	
	Velocity of B is greater than that of A because total momentum is to the right OR B has lower <u>mass</u> ✓		
	OR		
	Momentum of B after collision is same as that of A before the collision (and vice versa)	1	
			[8]
22.	D		[1]
23.	B		[1]
24.	A		[1]
25.	D		[1]

26.

- (a) Tangent drawn at $t = 2.0 \pm 1 \text{ s}$ ✓

Use of suvat loses first 2 marks

Guidance- take tangent point to be half-way between where the line clearly leaves the curve

1

Mean deceleration from use of tangent using correct coordinates (correct Δv and Δt) and answer in range $(-)2.5$ to $(-)2.9 \text{ (m s}^{-2})$ ✓

Ignore minus sign

$$= 15/5.5 = 2.7(3) \text{ m s}^{-2}$$

Allow if answer rounds to these values

1

Use of $F = ma$ using their a with answer

i.e. Force $= 1.8 \times 10^4 \times$ their a from an attempt at a tangent or trying to use suvat equation ✓

Answers from best attempts at tangent in range 4.7 to $4.9 \times 10^4 \text{ N}$

1

- (b) Attempt to estimate area under the graph ✓

Use of suvat equation = 0

1

Correct square count 21 to 23 10 mm squares

(525-575 small squares)

OR

distance per square = 2.5 m or 0.1 m ✓

For attempt to find area using trapezium rule expect use of 1 s intervals for this mark

1

Value in range 50 m to 60 m **and conclusion**

that escape lane would be long enough ✓

1

- (c) KE of lorry :

to KE of gravel (as it is pushed aside/moved) ✓

OR

PE of gravel (as it may be ejected upwards) ✓

Ignore losses due to friction

Not KE of the ground

1

transfer to thermal energy /internal energy/heating of gravel /ground/lorry

OR

work done on the gravel/vehicle increasing internal energy/raising temperature✓

Must refer to what is heated

1
Max 2

- (d) Appreciates that KE converted into PE

OR

May be stated or by attempt to use of $mgh = \frac{1}{2} mv^2$

OR

Calculates initial KE of lorry $\frac{1}{2} 1.8 \times 10^4 \times 17.5^2 = 2.76 \times 10^6$ (J) ✓

1

Height needed in escape lane = $2.76 \times 10^6 / (1.8 \times 10^4 \times 9.81) = 15.6$ m

OR

Length of lane required = $15.6 / \sin 25 = 37$ m (compare with 85 m)

OR

vertical height of ramp = 35.9 m (compare with height needed 15.6 m)

OR

maximum change in PE possible = $85 \sin 25 \times 9.81 \times 1.8 \times 10^4 = 6.3 \times 10^6$ (J)

(compare with initial KE) ✓

Allow max 2 if height = $85 \tan 25$

or length of lane = $15.6 / \tan 25$

i.e. allow these incorrect values when drawing conclusion

1

Comparison and conclusion that escape lane would be long enough. This must follow from correct working✓

.....

Deceleration produced by slope = $9.8(1) \sin 25$ or

4.15 (4.1 or 4.2) m s^{-2} seen✓

Distance to stop from $v^2 = 2as$ give $s = 37$ m (compare with 85 m)✓

Arriving at 37 m gets first two marks

OR

Minimum deceleration needed = $17.5^2/2 \times 85 = 1.8 \text{ m s}^{-2}$ (compare with 4.15 m s^{-2})

Comparison and conclusion that escape lane would be long enough This must follow from correct working✓

1

(e) The straight road of uniform gradient because:

The deceleration (condone acceleration) is uniform ✓

with the gravel the initial deceleration is larger/may vary ✓

Travelling through gravel could make the vehicle unstable/bounce erratically(owtte) ✓

Gravel because:

On the ramp the lorry would roll backwards after stopping (as it has no brakes)

Do not allow deceleration less when on gravel(It is greater initially)

Do not allow answers that (average) force using gravel lane is less than decelerating force on the ramp (due to increased stopping distance or stopping time)

Or because stopping time is longer

MAX 1

[12]

27.

B

[1]

28.

A

[1]

29.

D

[1]

30.

C

[1]

31.

A

[1]

32.

C

[1]

33.

D

[1]

34.

(a) Mass of alpha particle = $\frac{2 \times 1.6 \times 10^{-19}}{4.81 \times 10^7} = 6.6(53) \times 10^{-27} \text{ (kg)}$

Allow mass = $2 \times m_p + 2 \times m_n = 6.696 \times 10^{-27} \text{ kg}$

Allow mass = $4 \times 1.66 \times 10^{-27} \text{ kg} = 6.64 \times 10^{-27} \text{ kg}$

Allow mass = $4 \times 1.67 \times 10^{-27} \text{ kg} = 6.68 \times 10^{-27} \text{ kg}$

Allow slight rounding on mass (must be correct to 2 sf)

OR

Correctly re-arranged k.e. equation (with v^2 or v as subject) with $8.1 \times 10^{-13} \text{ (J)}$ substituted correctly $_1\checkmark$

1.56×10^7 seen $_2\checkmark$

Condone **incorrect mass** in otherwise correct substitution **with v** or **v^2 recognisable** as subject .

Alternative approaches are:

$$v = \sqrt{\frac{E_k \times \text{specific charge}}{e}}$$

$$v = \sqrt{\frac{2 \times E_k}{m_\alpha}}$$

Must see answer to at least 2 sf

Must see attempt to use one of the alternative approaches to support correct answer

2

(b) Use of $W = Fs$, $F = 8.1 \times 10^{-13} \div 3.5 \times 10^{-2} \text{ }_1\checkmark$

($F=$) $2.3 \times 10^{-11} \text{ (N)}$ $_2\checkmark$

Condone POT error

Correct answers gets 2 marks

OR

Use of an appropriate equation of motion to find a **and** $F = ma$

(allow their mass and their velocity in this sub) $_1\checkmark$

Condone POT error

($F=$) $2.3 \times 10^{-11} \text{ (N)}$ $_2\checkmark$

Condone POT

OR

Use of an appropriate equation of motion to find t **and** $F = \Delta mv/t$

(allow their mass and their velocity in this sub) $_1\checkmark$

(F=) 2.3×10^{-11} (N) $_2\checkmark$

[answer is

$$\frac{(\text{their speed})^2 \times (\text{their } m_e)}{0.070}$$

*Using $2 \times 10^7 \text{ m s}^{-1}$ yields($5.71 \times 10^{15} \times \text{their } m_e$) – allow 1 sf
answer in this case*

Expect to see 3.8×10^{-11} (N) or 4×10^{-11} (N)]

2

(c) (Number of ions formed over range =)

$5.1 \times 10^4 \times 3.5$ seen **or** 1.785×10^5 (ions) seen

OR

8.1×10^{-13} converted to eV seen $_1\checkmark$

$8.1 \times 10^{-13} \div 1.785 \times 10^5$

OR

$5.06 \times 10^6 \div 1.785 \times 10^5$ seen $_2\checkmark$

Condone POT error in first mark

Ignore units

$8.1 \times 10^{-13} \div (5.1 \times 10^4 \times 3.5)$ is worth 1st and 2nd marks

Condone POT errors in second mark

Correct answer obtains 3 marks

28 (.4) (eV) $_3\checkmark$

99(.3) (eV) scores 1 mark

3

(d) (Q =) $0.85 \times 10^{-3} \times 1.2 \times 10^{-9} = 1.02 \times 10^{-12}$

OR

$n = (\text{their } Q) \div 1.6 \times 10^{-19}$ $_1\checkmark$

$n = 6.4 \times 10^6$ (c.a.o.) $_2\checkmark$

Condone one POT error for one mark

2

(e) At 3.5 cm the pd drops / the current begins

OR

When the source is 10 cm away no ionisation occurs in the air gap (because the alpha particles have insufficient range to reach the air gap)

OR

When the radioactive source is close enough (approx. 5 cm) ionisation occurs ✓

OR

When beyond 3.5 cm no change in pd / current equals zero

Must be sense of abrupt change

MAX 3

When ionisation occurs / charge carriers are liberated in the air gap:

Allow more ionisation for second mark

resistance has decreased

OR

current increases (from zero)

OR

the potential difference decreases (with a maximum current) (to its minimum value) (across the air gap)✓

From 10 cm separation until 5 cm (approx) separation nothing changes / appreciates that pd is 4500 V / pd across gap = 4500 V until ionisation occurs ✓

Current is produced: the pd across 5 MΩ resistor is 4250 V / most pd is across the 5 MΩ resistor / small pd across air gap ✓

Current is produced and the pd across the air gap is 250 V✓

Current is produced and the pd across the air gap is 250 V✓

3

[12]

35.

C

[1]

36.

- (a) ($u = 0.2(0)$ or 20 or 200 **and** ($v = 0.25$ or 25 or 250) $\checkmark$;

Both velocities seen / allow seen in $(a =) \frac{v-u}{t_3}$ / condone (possible) powers of ten (POT) error for 1st mark and 2nd mark in their v and u and any substitution v and u into $(a =) \frac{v-u}{t_3}$

Where t_3 has been substituted must be $t_3 = 1.19$ (s)

substitution of their u and v in $(a =) \frac{v-u}{t_3} \checkmark$

Where t_3 has been substituted must be $t_3 = 1.19$ (s)

Values for:

u (0.20 (m s^{-1}) or 20 (cm s^{-1}) 200 (mm s^{-1})) and

v (0.25 (m s^{-1}) or 25 (cm s^{-1}) or 250 (mm s^{-1}))

Correctly combined with t_3 (1.19) will earn 1st and 2nd marks

Where u and v are not correct, they must be identifiable as their u and v (2nd mark is only mark available except where error is POT)

Allow their $\frac{\Delta v}{1.19} (= a)$ where clear it is their Δv

$$a = 4.2 \times 10^{-2} (\text{m s}^{-2}) \quad 3\checkmark$$

Correct result for a will earn three marks;

Accept 420 mm s^{-2} or 42 cm s^{-2} if m s^{-2} has been replaced on the answer line

2 sf answer only

3

- (b) (set **B** because) it has a greater time / takes longer (to travel between gates) (hence distance between gates is larger) $\checkmark$

(and) set **B**'s average velocity is greater / set **B**'s velocity at gate 1 is greater / Set **B**'s velocity is greater at both gates

Two calculations for gate separation s using either

OR

(and) set **A**'s average velocity is smaller / set **A**'s velocity at gate 1 is smaller/ Set **A**'s velocity is smaller at both gates $\checkmark$

Alternative Method

values of u and v are calculated (condone POT error) and corresponding values for each s determined; $\checkmark$

a comparison of their distances leading to conclusion that set **B** produced when s is largest

OR

ratio $(t_3 \times \frac{t_1 + t_2}{t_1 \times t_2})$ is proportional to distance s and B's ratio is greater 2✓

$$(s =) \left(\frac{u+v}{2} \right) \times t_3 \quad \text{OR} \quad (s =) \frac{v^2 - u^2}{2a}; \quad \text{OR} \quad (s =) t_3 \times \frac{t_1 + t_2}{t_1 \times t_2}$$

	u/ms^{-1}	v/ms^{-1}	s/m	$\frac{v^2 - u^2}{\text{m}^2\text{s}^{-2}}$
Set A	0.164	0.238	0.356	0.0297
Set B	0.181	0.270	0.476	0.0401

	$t_3 \times \frac{t_1 + t_2}{t_1 \times t_2}$
Set A	7.12
Set B	9.54

Allow ecf for acceleration where used to find s

Using $a = 0.042$: $s_A = 0.354$ and $s_B = 0.478$

Treat a larger change in velocity as neutral

2

- (c) Continuous, ruled straight best fit line through 1st and last points 1✓
n=4 point below and n=7 above, other points cut by line of best fit
Line must not be thicker than half a square grid
Line must have no variation in thickness
Do not accept more than one line drawn, do not accept discontinuities

Gradient from $\frac{\text{y step}}{\text{x step}}$ seen

and

$G = 0.045$ range (0.042 to 0.053) 2✓

Steps at least half the height and half the width of the grid; (at least 3 squares horizontally and at least 5 squares vertically)

Allow $\frac{\text{change in y}}{\text{change in x}}$ where points are on line and are at least half

drawn line apart ($\Delta x \geq 3$ and $\Delta y \geq 0.175$)

Ignore any units given for G

Allow 1 sf answers of 0.04 or 0.05 where correct working is shown

2

(d) $\frac{\text{their } G}{4.9} \checkmark$

$(h = 9.2 \times 10^{-3} \text{ m})$

Ecf from part (c)

Expect 2 sf normally. Penalise 3 or more sf

Condone 1 sf answers where correct working is shown in part (d)

and where their G is quoted to 1sf

In this case, allow use of their rounded G or full carry value

1

- (e) idea that the intercept can be found by calculating $a - Gn$ where a and n are values read-off (from a point on the line) and G is the gradient ; intercept compared to 0, 0 (OWTTE in a general $y=mx +c$ description)

Simply explaining how to find the intercept does not fully answer the question and gets no credit must describe the comparison aspect; do not accept idea of extrapolation off the grid or re-plotting on axes that include (0, 0)

OR

Read-off points (of line of best fit for) x_1 and x_2 compare with corresponding y_1 and y_2 , compares the ratio of the x terms to the ratio of the y terms; if equal then directly proportional

OR

Determine the constant of proportionality for at least two points (on line of best fit) and compare, where constant exists then directly proportional $\checkmark$

Idea that a and n will share a common factorial increase

1

[9]

37.

- (a) (use of $\rho = M/V$)

$M = 4.0 \times 10^{-6} \times 920 = 3.68 \times 10^{-3} \text{ (kg)} \checkmark$

weight = $3.68 \times 10^{-3} \times 9.81 = 3.6 \times 10^{-2} \text{ (N)} \checkmark$

Ecf for second mark

1 sig.fig. -1 mark

1

1

- (b) $V = 3.68 \times 10^{-3}/1000 = 3.7 \text{ (3.68)} \times 10^{-6} \text{ m}^3 \checkmark$

Ecf 5.1 from mass calculation

1

- (c) THREE FROM:
 any mass divided by 7800 ✓
 $V \times 7800 + (4.0 \times 10^{-6} - V) \times 920 = 3.9 \times 10^{-3}$ ✓
 $6880 V = 3.9 \times 10^{-3} - 3.68 \times 10^{-3}$ ✓
 $V = 3.2 \times 10^{-8} \text{ m}^3$ ✓
Ignore mass value if awarding first mark

1
1
1
(MAX 3)

[6]

38.

C

[1]

39.

- (a) resultant/overall/sum of force = 0 OR forces up equal forces down AND forces left equal forces right ✓
 (sum of) anticlockwise moments (about any point) = (sum of) clockwise moments/zero resultant moment/torque ✓

1
1

- (b) EITHER
 the point through which (the line of action of) a force has no turning effect/causes no rotation/ no torque ✓
 OR
 where the mass of the body can be considered to be concentrated OR where the weight can be considered to act ✓

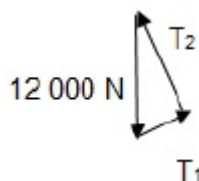
NOT where mass can be considered to act
Ignore reference to force of gravity

1

- (c) so there is not a resultant moment/turning effect / turning force OR moments do not balance OR (beam) does not rotate / oscillate / swing ✓
 about A / because A is pivot ✓

Allow moments balanced for no resultant moment

1
1



(d)

$$T_1 = 12\,000 \cos 53 \quad \checkmark$$

$$T_1 = 7200 \text{ (7221) (N)} \quad \checkmark$$

$$T_2 = 12\,000 \sin 53 \quad \checkmark$$

$$T_2 = 9600 \text{ (9583) (N)} \quad \checkmark$$

OR

$$T_1 \cos 53 + T_2 \cos 37 = 12\,000 \checkmark$$

$$T_1 \sin 53 = T_2 \sin 37 \checkmark$$

$$T_2 = T_1 \sin 53 / \sin 37$$

hence

$$T_1 \cos 53 + T_1 \sin 53 \cos 37 / \sin 37 = 12\,000$$

$$T_1 = 7200 \text{ (7221) (N)} \checkmark$$

$$T_2 = 7221 \sin 53 / \sin 37 = 9600 \text{ (9583) (N)} \checkmark$$

If T_1 and T_2 are the wrong way round get 3 out of 4

If scale drawing 2 max +/- 300(N)

If values out by a factor of 10 then -1 (i.e. confusion over g)

1
1
1
1

(e) (use of $\Delta l = Fl/AE$)

$$A = \pi \times (0.75 \times 10^{-2})^2 \checkmark (= 1.767 \times 10^{-4})$$

$$\Delta l = 12\,000 \times 12 / (1.767 \times 10^{-4} \times 200 \times 10^9) \checkmark$$

$$\Delta l = 4.1 \times 10^{-3} \text{ (m)} \checkmark$$

No attempt to calculate area scores zero

Wrong area (e.g. d^2 or $2\pi r$ or $2\pi rl$) maximum 1 mark unless diameter used for radius in πr^2 then maximum 2 marks

Accept 4.0×10^{-3}

If 4×10^{-3} then -1 as 1 sig. fig.

1
1
1

[12]

40.

D

[1]

41.

A

[1]

42.

(a) (use of gain in $E_k = \text{loss in } E_p$)

$$\frac{1}{2}mv^2 = mgh$$

$$\frac{1}{2}v^2 = 9.81 \times 8.0 \checkmark$$

$$(v = \sqrt{(2 \times 9.81 \times 8.0)}) = 13 \text{ (12.5) (m s}^{-1}\text{)} \checkmark$$

Bald correct answer scores 1 mark

If use $v^2 = u^2 + 2as$ then zero

Unless resolved g along slope

If use 10 for g (-1)

Gets second mark if answer rounds to 13

1
1

- (b) THREE FROM:
 acceleration of truck in Fig.1 is constant ✓
 In Fig.2
 acceleration is greater/greatest at start/top ✓
 acceleration decreases ✓
 reference to zero acceleration/uniform velocity between C and D ✓
 because the component of weight/acceleration parallel to the slope changes ✓

1
 1
 1
 (3 max)

- (c) the loss of (gravitational) potential energy is the same
 hence gain in kinetic energy is the same ✓

1

- (d) THREE FROM:
 rain has no (initial) horizontal momentum ✓
vertical momentum of rainwater decreases ✓
 there is no external (horizontal) impulse/force on the truck (and water system) ✓
 mass (of truck) increases but speed/velocity decreases ✓
horizontal momentum of water increases (but horizontal momentum of truck decreases by same amount) ✓
 (so) no change in (horizontal) momentum of truck and collected water/total momentum ✓
If say: 'vertical momentum/velocity of rain drops/water changes to horizontal (momentum/velocity)' score 2 marks
Cannot score last mark if stated that speed/velocity of truck does not change

1
 1
 1
 (3 max)

[9]

43. D

[1]

44. C

[1]

45. (a) Radius of orbit = $5 \tan 28.5 + 1 = 3.71 \text{ m}$ ✓

1

Speed = $2 \times 3.14 \times 3.71 / 5.2 = 4.49 \text{ ()}$ ✓

For second mark only allow

Use of $\sin 28.5$ gives orbit radius 3.39 m and speed = 4.1 m s^{-1}

Or

Forgets to add 1 giving radius 2.71 and speed 3.27 m s^{-1}

1

- (b) Centripetal force = $85 \times 4.49^2/3.71 = 460 \text{ N}$ ✓
 470 N if using 4.5 m s^{-1} leads to 1000 N

1

Centripetal force = $T \sin 28.5$ ✓

Allow the following as ecf:

Forgetting to add the 1 m (using $r = 2.71 \text{ m}$) leads to centripetal force = 630 N $T = 1300 \text{ N}$

Using $r = 3.39 \text{ m}$ as ecf from part (e) which leads to

Centripetal force = 510 N giving $T = 1070 \text{ N}$

1

$T = 950 - 970 \text{ N}$ ✓

1

OR

Weight = $85 \times 9.8(1)$ Or 834 N seen ✓

Weight = $T \cos 28.5$ ✓

$T = 950$ (949) (N) ✓

OR

Centripetal force = $85 \times 4.5^2/3.71 = 464 \text{ N}$ ✓

Weight = 834 N ✓

$T = \sqrt{464^2 + 834^2} = 950 - 970 \text{ N}$ ✓

Allow ecf for incorrect weight or centripetal force

Allow the following as ecf:

Forgetting to add the 1 m (using $r = 2.71 \text{ m}$) leads to

Centripetal force = 630 N, $T = 1050 \text{ N}$

Using $r = 3.39 \text{ m}$ leads to

Centripetal force = 510 N giving $T = 980 \text{ N}$

- (c) Vertical (compressive) force **on the pole** increases ✓

1

Increases mass increases weight and hence tension in the rope (for the same angle) ✓

1

Centripetal Force

on the acrobats/masses would be different/not equal

OR

Would be greater on the more massive acrobat(travelling at the same speed/same angle to vertical) ₁✓

Unbalanced (horizontal) forces/resultant force exists (on the pole) ✓

OR

Unbalanced moments acting (on pole)/resultant torque acting (on pole) ✓

Causing the pole to sway/bend/move/ or tilt/topple the platform toward more massive acrobat ₁✓

1
Max 3

[8]

Examiner reports

3.

56.7% correct

4.

Responses to this question on statics proved to be quite patchy.

Question (a) was generally well answered, with the majority appreciating that friction was negligible because the resultant force was a right angle to the wall.

Question (b) was less well done: very few students appreciated that the arrow for force G, the weight and the resultant force from the wall when extended would intersect at one point. G was often drawn vertically upwards or along the ladder; this did score 1 mark providing the arrow started from the point of contact with the ground. The calculation caused problems for over half of the students because they did not appreciate that they had to apply the principle of moments. The last part of the question generated some very good answers with some quite detailed analysis seen. Three-quarters of students were awarded at least two marks. There were some misconceptions such as that the force G decreases as the person climbs the ladder or that the resultant force from the wall only increases when the person is over half-way up the ladder.

5.

The responses to this question showed significant variation with students performing significantly better in the quantitative parts than they did in the qualitative.

The majority of students failed to identify the forces acting on the trolley that were parallel with the slope. It was rare to see the component of the combined weights of trolley and blocks identified. Also, the majority of diagrams included forces which were not required such as the reaction force.

Question (b) involved an algebraic derivation of the acceleration of the trolley – this proved quite a challenge for some and responses had to be scrutinised carefully to see if they were valid. Many provided a correct formula for the resultant force on trolley A but then incorrectly stated that the tension was equal to the component of trolley B's weight along the slope. The more successful answers treated the trollies as a system with a resultant force acting equal to $(M + 2m)g \sin 35^\circ - Mg \sin 35^\circ$ and a combined mass of $2M + 2m$.

There was a typographical error in question (c) which led candidates to assume that loaded trolley A was being compared with loaded trolley B. The question originally intended to ask students to compare loaded trolley A with unloaded trolley B (as shown in Figure 2). We judged that both interpretations should be allowed and revised the mark scheme to permit the two different approaches. Either approach could achieve 0, 1 or 2 marks according to the accuracy of the answer. Student responses to this question were carefully scrutinised to assess the impact of the typographical error, and there was no evidence that students were unable to generate meaningful responses to this question.

The conclusion mark of how the momenta compared was then conditional on the first mark being awarded. The multi-step calculations in (d) and (e) were well done, with a high proportion of students scoring at least 3 of the 5 marks available.

6. Question (a) required students to analyse the data given and demonstrate that it was consistent with the given relationship. Just over half of students were able to do this. Common errors were confusion between linear and proportional relationships, and attempts to derive the expression algebraically without using the data.

The calculation in question (b) proved to be one of the more challenging in the paper. The main reason for this was a lack of appreciation of how to find the mass per unit length of the nylon string; this did limit them although they were able to pick up a mark for a correct substitution of tension and frequency in the appropriate formula.

The explanation, required in (c), of why the result might be different if much larger masses were used, was not well answered. The majority did not appreciate that the nylon would get thinner and this would reduce the mass per unit length. Common responses tried to invoke Hooke's law notwithstanding the fact that nylon does not obey this law.

7. Less than 50% of students selected the correct answer. Distractor B was the most frequently selected incorrect response. In selecting distractor B, students did not take account of the horizontal motion of ball X.

8. Most students selected the correct answer. A significant number of students selected distractor D, believing this statement was incorrect. X has a greater breaking stress since the force applied to it is greater than the force applied to Y at the point of breaking.

9. Almost 50% of students selected distractor B. Students were unable to see that the force was the same on both masses. Students often have difficulty in distinguishing between force and acceleration, as was the case here. The smaller mass will experience a greater acceleration but this is due to its inertia and not the size of the force it experiences. As momentum is conserved, then the momentum lost by one object is equal to the momentum gained by the other. The magnitude of the momentum change is the same for both objects. The forces acting between the objects can only act while they are in contact, therefore the time over which the momentum change occurs is the same for each.

Momentum change = impulse = force $\times$ time

Same force = $\frac{\text{same momentum change}}{\text{same contact time}}$

Alternatively, these forces are internal forces in a two-body system, constituting an example of Newton's third law, and must be equal in magnitude.

10. This moments calculation proved to be very challenging, with only 17% of students selecting the correct answer. Distractors A and B were the most popular incorrect answers with each being selected by approximately 35% of students. This error was caused by students disregarding the weight of the uniform metre rule.

Students should be encouraged to read the question carefully and include all forces and their respective distances to the pivot before undertaking any moments calculation.

11. Most students were able to determine the momentum gained by the object. Each of the distractors gained about 15% of student responses.

12. 91% of students selected the correct answer.

13. 27% of students selected the correct answer here. Most students attempted to use equations of motion but failed to appreciate the direction of the acceleration and were unable to resolve to find the component of the weight parallel to the slope. Those who were successful most frequently used the principle of conservation of energy to find the work done by the frictional force.

14. This was an accessible question with 87% of students selecting the correct response. The most frequent incorrect response was distractor A, with weaker students unable to recognise the vector nature of momentum.

15. 45% of students selected the correct answer, with 33% of students incorrectly selecting distractor B. Students seemed unwilling to consider the total momentum as being zero despite this application of momentum conservation being clearly stated in the specification content.

16. 70.2% correct

17. This question required students to apply their knowledge and understanding of physics to a battery-powered wheelchair. It gave students an opportunity to demonstrate knowledge and understanding in a range of areas including electrical and mechanical energy, power and force.

- (a) This was a fairly accessible question with more than half of the students gaining all three marks. There was more than one route students could choose to answer this question, with the calculation of the current proving to be a popular alternative. ‘Show that’ questions provide students with an answer that can be used later should they be unable to do the calculation. It has become relatively common to see students attempting to use the value to perform the calculation backwards. It was more common to see answers that manipulated the numbers in the stem to obtain 100W. Students should be reminded that examiners will only give credit to the final answer in a ‘show that’ calculation if it is given to at least one more significant figure than the value in the question.
- (b) Students were given full credit if they chose to use the value of 100 W from 03.1. Despite this, many students were unable to make at least some attempt at an answer, with over 10% making no attempt at all. It may be that many students were unfamiliar with questions that move from one area (such as electricity) to another (such as force), which could have led to the confusion of v (velocity) with V (pd) that was seen. Teachers should understand that this combination of topics within a question is a requirement of this specification, and the full A-level, that is certain to continue to appear in the examination papers. Errors were also seen in the answers that were provided. For example, asking for a ‘mean’ value of a quantity inevitably encourages some students to divide their answer by 2, an error that was seen a surprising number of times.
- (c) Again, it may have been the context of this question that meant that this relatively straightforward calculation was only correctly performed by a minority of students. It may also have been partly due to the fact that only one mark is available and yet there are several opportunities for error, such as missing out ‘g’ and using the wrong trigonometrical function.
- (d) The fact that a large number of students did not attempt this question is partly related to the need to use information from 03.2, which was not well answered. It could also suggest that students expect calculations involving speed (or velocity) to require the use of the “suvat” equations, for example, and that they are therefore confused when none of the familiar information is provided. However, it is acknowledged that this is a conceptually demanding question, requiring students to appreciate that, at the maximum speed, the driving force = the total friction/drag force for example, and then apply that to $P = Fv$.

- (e) Another common feature of this new specification is the assessment of a student's ability to reach a reasoned judgement. In this question students were required to decide which effect (increase or decrease) they were going to consider, and whether this would increase or decrease the range. This was a point missed by many students. Fully correct answers were rare, with many students failing to make the link between the speed and drag forces for example.

18.

This question applied both the idea of standing waves and the behaviour of materials to the context of a radio aerial. Despite this combination of topics, several parts of the question proved to be very accessible.

- (a) It is clear from the large proportion of students who obtained both marks for this question that the application of the Young modulus is well understood. This question was made even more accessible by providing the area, and by giving all the data in units that did not require conversion.
- (b) This one mark calculation was poorly answered, with few students being able to obtain the correct value for the tension. It may be that many students missed the relevant data or could not picture which forces were needed. It would doubtless have helped some students had they drawn the forces on the diagram provided.
- (c) It is clear that many students learn about the formation of standing waves in general terms and answers focusing on this were incomplete in several respects. In particular, many students missed out the initial formation of the wave, and many failed to adequately explain the reason for production of specific frequencies. Consequently it was common to see answers obtaining only 2 of the 4 marks.
- (d) This calculation proved to be very accessible with a large majority of students obtaining the single mark for it.
- (e) However, this calculation proved to be less accessible despite an error for the mass per unit length in part (d) being carried forward. Credit was also given for students making it clear that the fundamental frequency had to be multiplied by 3.
- (f) The drawing of three 'loops' was generally awarded the mark, unless the length of each loop was too unequal to be acceptable.
- (g) Whilst it was common to see answers that made some attempt to describe what happens to the wire if it is stretched too much, poor use of the correct terminology, such as failure to mention an elastic limit or equivalent, tended to limit the mark awarded to many answers.

20.

43.0% correct

21.

- (a) That kinetic energy would be conserved in an elastic collision was well known (64.5% correct).
- (b) Most students knew how to arrive at the answer (75.3% fully correct), but responses were often completely unstructured and consisted of a mass of figures and calculations with no indication of what the calculation represented. In questions where the command word is 'calculate' this may often be accepted, but in 'show that' items communication of the processing of data needs to be clear.

- (c) The same impulse on each of the trucks is equal and opposite so students needed to focus on one or other of the trucks involved. There were many who misread the data and associated the initial velocities with the wrong trucks. Many gave the impulse as the difference between the final momenta of the two trucks.
- (d) It was necessary here to have a qualitative appreciation of the application of conservation of momentum and kinetic energy in the elastic collision. It is not possible to conserve both unless the trucks travel in opposite directions after the collision, and many appreciated this point. Many students, however, went on to state that the speed of each truck would be the same as before but in the opposite direction; others wrote that B would have the speed that A had and vice versa. The first conserves kinetic energy but not momentum (total momentum would be reversed) and the second would only be true if they had the same mass. If A were to stop, as suggested by many students, then to conserve momentum B would need to travel at a lower speed than either of the trucks (since the initial total momentum was 7600 Ns to the right, B's speed would need to be 0.63 Ns). This would not conserve kinetic energy. 38.5% of students were successful here.

22. 38.1% correct

23. 67.6% correct

24. Students found this question challenging; there was a success rate of just over 20%. The most common incorrect response seen was distractor C. Quite often this was selected without any evidence of supporting calculations.

25. This question was demanding, with only 18.8% of students able to select the correct answer. The most frequently selected incorrect answer was distractor A. The two approaches used were to realise the significance of the area under the force-time graph or alternatively to realise the significance of the gradient of the momentum-time graph.

26. (a) It was important to realise that this was not uniform deceleration so that application of the suvat equation was not appropriate. Many students unfortunately used this approach and therefore could only access the final mark for application of $F = ma$. A significant proportion used the instantaneous values at 2 s to find acceleration and these students were denied access to the final mark. Students who realised that a tangent was required were able to progress and were rewarded, provided that the tangent was not at a point too far from 2.0 s. The accepted range was determined to allow for the acceptable limits. Just over 30% of students scored all three marks.

(b) The use of the suvat equations led to no marks being awarded in this part. A majority of the students realised that the area under the graph was needed and there were many very sound responses (though 65% of students ultimately scored zero). Counting squares was the most popular approach. Use of the trapezium rule was often spoiled by choice of time intervals that were too large.

(c) Students here needed to think of the context and respond accordingly. There were many who produced the very low level response of 'heat and sound', which gained no credit. It was essential to state what was heated. Only the more thoughtful students commented on the transfer of KE of the lorry to KE of the gravel, or work done moving it, which contributed to the greatest energy transfer in the context. 4.6% of students gained both marks here.

- (d) There were a number of different routes that led to the conclusion that the escape lane was long enough and they were seen in fairly even numbers. The easiest and possibly most straightforward were a comparison of the initial KE of the lorry and height at which the KE would be totally transferred, or comparison of the initial KE with the PE of the lorry if it were to reach the top of the ramp. Whilst the appropriate calculations were often seen, it was disappointing that many did not provide any comments of what each calculation represented and final statements in conclusion were often not well argued. However, over a quarter of students were able to score maximum credit.
- (e) This was an open-ended question that could be argued either way with appropriate comment. The most common approach was to discuss the problem of rolling back down the slope after stopping on the ramp. Comments relating to comparisons of acceleration were not appropriate as this usually led to students writing that the deceleration was lower on the gravel. These were comparing the instantaneous deceleration at 2 s with the uniform deceleration on the ramp; the initial deceleration on the gravel was considerably larger. 52.5% of students answered this successfully.

27. Students demonstrated a limited understanding of the difference between acceleration and velocity, with the most popular answer selected being distractor A. Students found it difficult to realise that objects are still accelerating even when their instantaneous velocity is zero. 26.9% of students arrived at the correct answer.

28. A considerable number of students had difficulty in resolving vectors, with many choosing distractor B as their answer. Students who selected the correct answer (42.6%) had quite often drawn a vector triangle around the wind's velocity and this helped them to identify the correct component.

29. The most common incorrect response seen was distractor A. These students mixed up the acceleration of free-fall conditions with the conditions experienced under terminal velocity. There was a success rate of 38.7% on this item.

30. The most popular answer here was the correct answer (41% of students); certainly higher achieving candidates seemed confident with this calculation.

31. Most students thought that the transit time would either be halved or doubled, selecting B or C in almost equal numbers. Only 24% of students identified A as the correct answer and in doing so realised the transit time was unaffected by doubling the width of the core.

32. Almost 40% of students were able to select the correct answer. The most common wrong answer selected was B; here students used a simple 2:1 ratio approach for the distance based on the information provided about the tensions.

33. The majority of students (58.1%) were able to identify the correct ranking of the prefixes. The most common incorrect response was B showing these students were unable to recall the values for pico- and femto-.

34.

- (a) There were a number of stages to this “show that” question. Because of its level of demand the mark scheme was less stringent than usual about how “show that” calculations should be presented. However, students should be encouraged to ensure they have fully demonstrated how the answer is obtained. These pieces of advice should be considered:
- any equations used should be written with subjects seen at each stage of the calculation;
 - mid-calculation rounding should be avoided;
 - the answer should be quoted to more significant figures than the value they have been asked to find.
- (b) The main error seen, when using $F = ma$ and equations of motion, was not taking into account speed changing when calculating the time to stop. Students who identified the questions as being set up for a “work done = change in kinetic energy” generally obtained all marks (27.3%).
- (c) Good students were able successfully to complete this calculation (23.1%) whereas lower performing students appeared to have little appreciation of the problem and were able to make only limited progress, by perhaps finding the number of ions or converting the energy into electron volts.
- (d) Students failed to gain marks here for a number of the following common reasons: dividing the current by the time, using $2 \times 1.6 \times 10^{-19}$ for each charge carrier rather than 1.6×10^{-19} , and misremembering the prefix nano- as 10^{-12} .
- (e) This question proved to be inaccessible to all but the very best students. Only 10.7% of students managed to score anything on this item. The number of factors they had to consider proved too challenging for most. Where students realised that ionisation occurred when the alpha source was close enough, they often got confused about the effect this had on the current in the circuit and the resistance and potential difference across the air gap. Many students thought that an increase in current could only occur when the potential difference across the air gap increased.

36.

- (a) Many students incorrectly assumed the air-track glider’s velocity was zero at the first light gate. Other common mistakes seen included using the total travel time of 2.09 s rather than 1.19 s and assuming that the distance travelled was 10.0 cm. Nevertheless, nearly a quarter of students scored all three marks.
- (b) There were lots of undeveloped statements; students implied that a longer time equalled a greater distance. In many cases, the supporting arguments presented were flawed with many students stating that with the same acceleration a greater time would result in a larger distance. There was some good analysis of the data but such an approach was usually only taken by higher grade students. Only 12.8% of students gained both marks.
- (c) The lines of best fit seen were generally of good quality. Many students demonstrated best practice for determining the gradient. Large gradient triangles were drawn with the read-off co-ordinates and corresponding differences clearly seen. Mistakes that occurred most frequently included not taking the false origin into account and drawing a gradient triangle that was too small. Very nearly 90% of students scored at least one mark here.
- (d) Appropriate use of significant figures is particularly important in Section A. Calculated quantities should be shown to the number of significant figures of the data with the least number of significant figures. 53.4% of students gained this mark.

- (e) A significant number of students disregarded the instruction “without drawing another graph” and chose to describe how to test the relationship by drawing a graph. They did not appreciate the significance of the term “directly proportional” and could only apply it to descriptions of the graph one would expect for such a relationship. Students were unable to describe how such a relationship could be tested by non-graphical means. A common error presented was that a linear relationship was the same as a directly proportional one. This was evidenced by statements such as “constant gradient”, “straight line”, “as a increases, n increases”. Disappointingly, only 6.9% of students scored the mark.

37.

This question involved use of the density formula.

- (a) The majority of students (74.4%) had few problems with this calculation. Of those who did, conversion from mass to weight was the common problem.
- (b) As with the previous question, this was well answered. The only common issue was the use of weight rather than mass in the density formula.
- (c) Students found this question very challenging and only a small minority (4.3%) managed to come up with complete solutions. Setting up an expression that enabled the volume of iron to be calculated is clearly a procedure that is unfamiliar to many students. A reasonable proportion did appreciate that a mass needed to be divided by the density of iron and picked up the first mark, but got no further because they did not appreciate that the volume of the ice is less than the volume of the cube because part of the volume is occupied by the piece of iron.

39.

This question required students to understand the conditions for equilibrium and apply these in a multi-step calculation. They were also required to understand the significance of the centre of mass..

- (a) A pleasing proportion of students (nearly two-thirds) were able to identify one of the conditions for equilibrium; the resultant force being zero being the common answer. Only more able students were able to provide the second condition.
- (b) There was some confusion over how centre of mass is defined. A significant proportion of students stated what is meant by the centre of gravity. This was given credit but it is clear that the distinction between these two is not well understood.
- (c) Very few students (2.9%) managed to score both marks for this question. Nearly a quarter of students appreciated that this was to prevent rotation, but did not then give a complete explanation by referring to no resultant moment about A as the line of action of the forces passes through A when the beam is in equilibrium.
- (d) This is not an unusual calculation at this level but it was clear that a significant proportion of students were unsure how to analyse the forces on the beam. The best students managed complete solutions whilst weaker students did manage to access some of the intermediate marks.
- (e) The calculation in this question proved to be much more accessible and far more students were able to access the marks. Over half managed to score at least two marks. The most common error was failing to calculate the cross-sectional area correctly; the predominant mistake was using the diameter for radius. Weaker students often used surface area of the cable instead of cross-sectional area.

42. This question required an understanding of the vector nature of acceleration and momentum and also how using energy considerations can lead to a simpler analysis due to it being a scalar quantity.

- (a) This was a straightforward calculation but a lot of students were caught out because they used $v^2 = u^2 + 2as$ instead of energy considerations. This meant that they did not get credit for their answer unless they allowed for the different directions of v , a and s .
- (b) Some good responses were seen to this question although it was not uncommon for contradictory statements to be made. Most students were able to state that acceleration was constant in figure 1 but analysis of figure 2 proved more of a challenge. It was quite common to see answers that referred to speed rather than acceleration decreasing as the truck moved down the ramp. Also, a significant proportion of students thought that the truck decelerated between C and D. A quarter of students managed to gain all three marks.
- (c) Only more able students could give a satisfactory explanation for the speeds being the same (19.8% correct).
- (d) This was a challenging question that required a good understanding of momentum conservation in closed systems and also the importance of direction in momentum considerations. Very few students managed to give complete discussions. The commonest answer was that as mass went up momentum increased, with students failing to appreciate that with no external horizontal forces acting, this could not be the case. Better students did appreciate that the total horizontal momentum remains constant and so as mass increases speed must decrease. It was very rare for there to be a discussion of how the momentum of the rain water changes from vertical to horizontal. Nearly three-quarters of students failed to score on this question.

43. Most students correctly identified D as the correct answer here, but B also proved to be popular with about 25% of the students. They may have realised that the amplitude decreases with damping, without taking into account peak broadening.

44. This was answered correctly by less than half of the students. D was the most popular distractor, with some students probably calculating the number of oscillations of B. A and B were also relatively popular.

- 45.**
- (a) Many students (59%) completed this part fully successfully. This and part (b) exposed weaknesses in the understanding of some students when using sine, cosine and tangent. Many who arrived at 2.71 m did not add the extra metre for the platform to deduce the radius of the circular path followed by the acrobats.
 - (b) The simplest and most common route to the answer was to consider the vertical forces. There were other routes to the answer too. The most common of these was to realise that the horizontal force due to the tension provided the centripetal force. Examiners allowed the error carried forward from part (a) for the radius of the path for those who solved the problem this way.

- (c) There were some very good responses to this part and many students provided at least part of the necessary analysis. A high proportion of students wrote that there would be unbalanced forces on the acrobat, but in the subsequent explanation of how this imbalance occurred many answers were spoiled when students wrote about effects of weight when they should have referred to mass and vice versa. Most responses concentrated on the unbalanced horizontal force or considered the moments of the forces. Few made any comment of the increased vertical force on the pole.