

AQA A-LEVEL PHYSICS • 7408

PHYSICS



EXAM QUESTION PACK

3.4.1 FORCE, ENERGY AND MOMENTUM • PACK 4

SCORE

/428

PERCENTAGE

%

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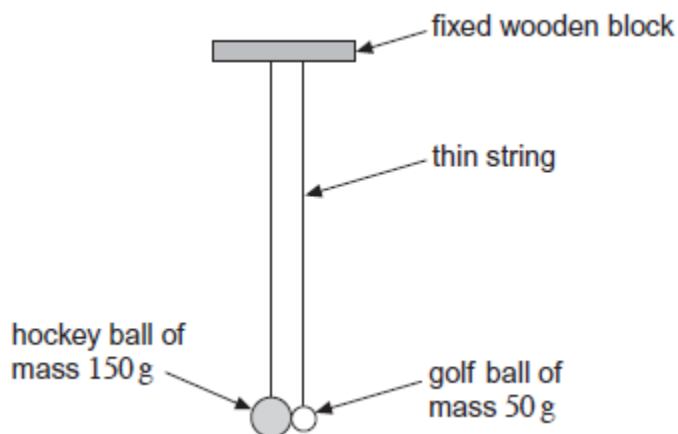
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1.

- (a) Explain what is meant by a **thermal** neutron.

(2)

- (b) A student sets up the arrangement, shown in the diagram below, to demonstrate the principle of moderation in a nuclear reactor.



A golf ball of mass 50 g is initially hanging vertically and just touching a hockey ball of mass 150 g. The golf ball is pulled up to the side and released. It has a speed of 1.3 m s^{-1} when it collides head-on with the hockey ball. After the collision the balls move in opposite directions with equal speeds of 0.65 m s^{-1} .

- (i) Calculate the height above its initial position from which the golf ball is released. Assume that there is no air resistance.

height _____ m

(2)

- (ii) Show that momentum is conserved in the collision and that the collision is perfectly elastic.

(4)

- (iii) Calculate the percentage of the kinetic energy of the golf ball transferred to the hockey ball during the collision.

percentage transferred _____ %

(2)

- (iv) Explain how this demonstration relates to the moderation process in a reactor and state **one** way in which the collisions in a reactor differ from the collision in the demonstration.

(2)

- (v) Name the substance used as the moderator in a pressurised water reactor (PWR).

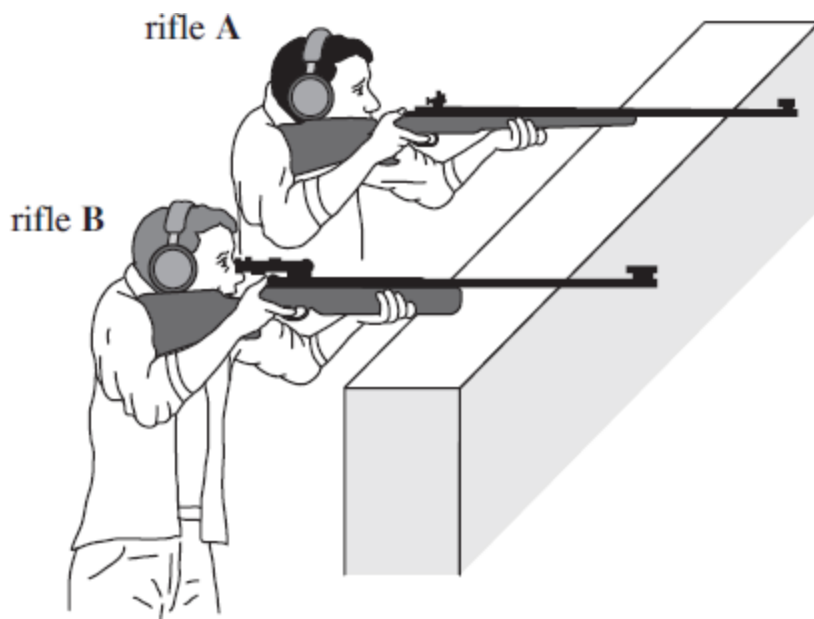
(1)

(Total 13 marks)

2.

The diagram below shows two different rifles being fired horizontally from a height of 1.5 m above ground level.

Assume the air resistance experienced by the bullets is negligible.



- (a) When rifle **A** is fired, the bullet has a horizontal velocity of 430 m s^{-1} as it leaves the rifle. Assume the ground is level.

- (i) Calculate the time that the bullet is in the air before it hits the ground.

time _____ s

(2)

- (ii) Calculate the horizontal distance travelled by the bullet before it hits the ground.

horizontal distance _____ m

(1)

- (b) Rifle **B** is fired and the bullet emerges with a smaller horizontal velocity than the bullet from rifle **A**.

Explain why the horizontal distance travelled by bullet **B** will be less than bullet **A**.

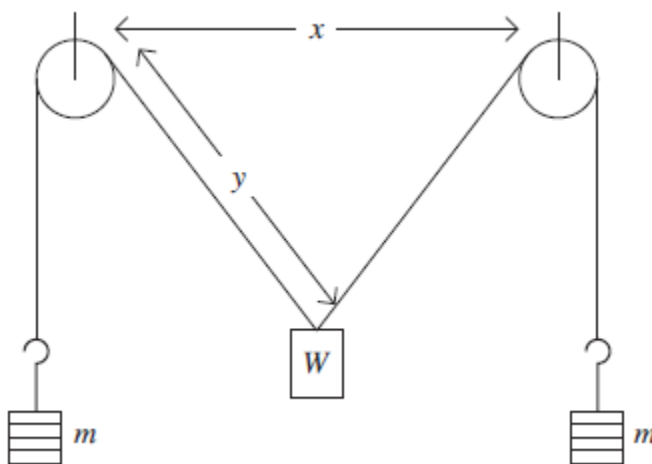
(3)

(Total 6 marks)

3.

In an experiment an unknown load, of weight, W , was supported by two strings kept in tension by equal masses, m , hung from their free ends, with each string passing over a frictionless pulley. The arrangement was symmetrical and is shown in **Figure 1**.

Figure 1

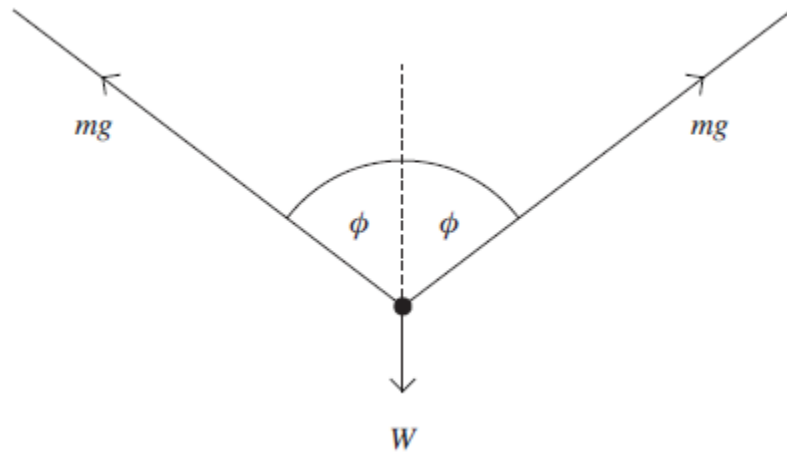


The distance x was kept constant throughout the experiment. The length y was measured for different values of m .

The distance between the strings at the pulleys, $x = 0.500\text{m}$

- (a) **Figure 2** shows the three forces acting through the point at which the strings are attached to the load. The weight of the load is W and the tension in each string is mg , where g is gravitational field strength.

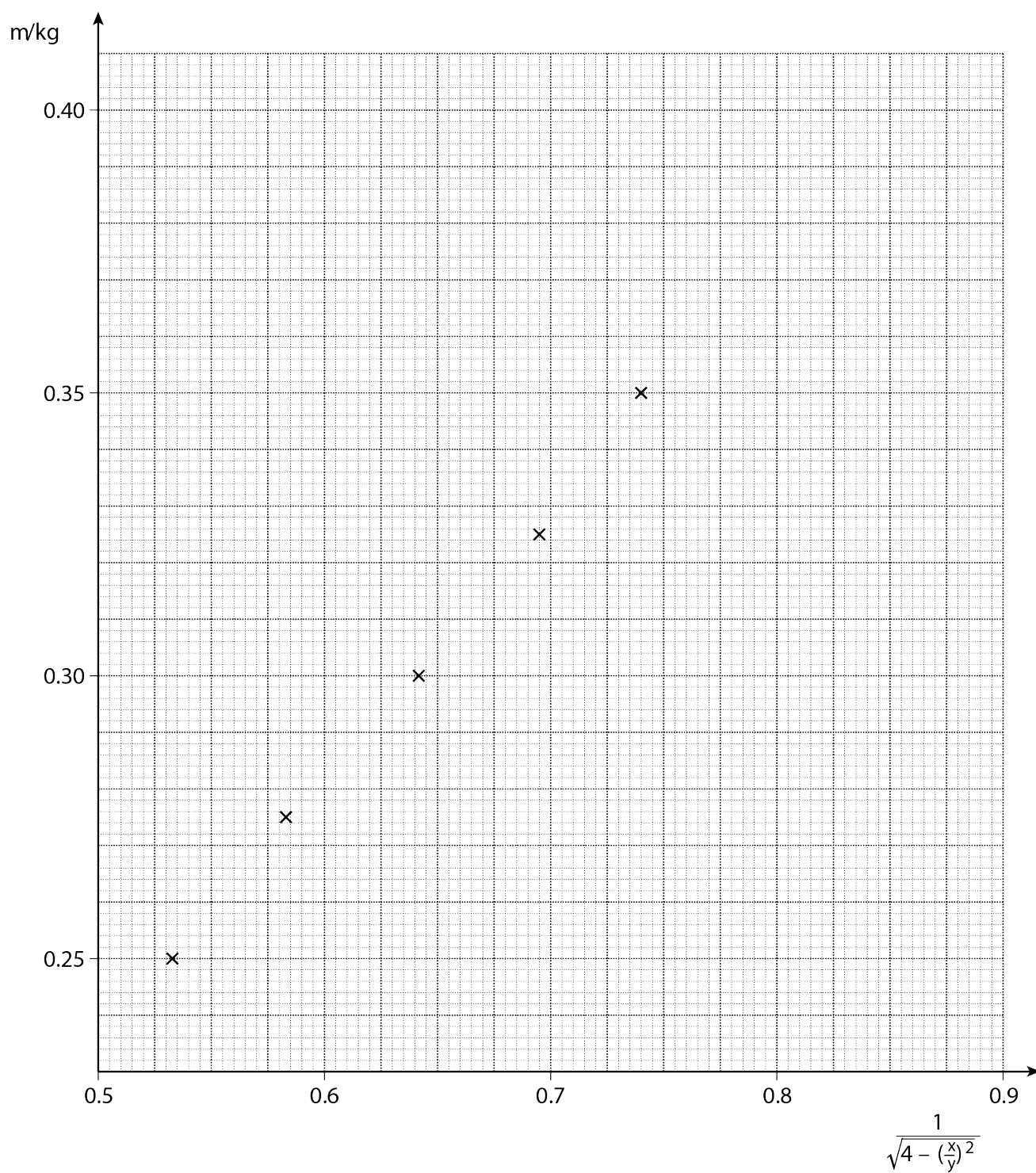
Figure 2



- (i) By resolving the forces vertically show that $m = \frac{W}{2g \cos \phi}$
where ϕ is the angle between each string and the vertical.

(1)

(ii) Draw the line of best fit through the points plotted on the graph.



(1)

- (b) (i) Determine the gradient of your graph.

(3)

- (ii) The equation for the straight line is $m = \frac{W}{g} \times \frac{1}{\sqrt{4 - \left(\frac{x}{y}\right)^2}}$

Given that $g = 9.81 \text{ N kg}^{-1}$, determine a value for W .

(2)

- (c) When m was 0.300 kg, y was 0.400 m.

Calculate the percentage uncertainty in $\left(\frac{x}{y}\right)^2$ for $m = 0.300 \text{ kg}$.

(3)

- (d) (i) Explain the term *systematic error*.

(1)

- (ii) In practice, there may be a systematic error in this experiment because of friction in the pulleys.

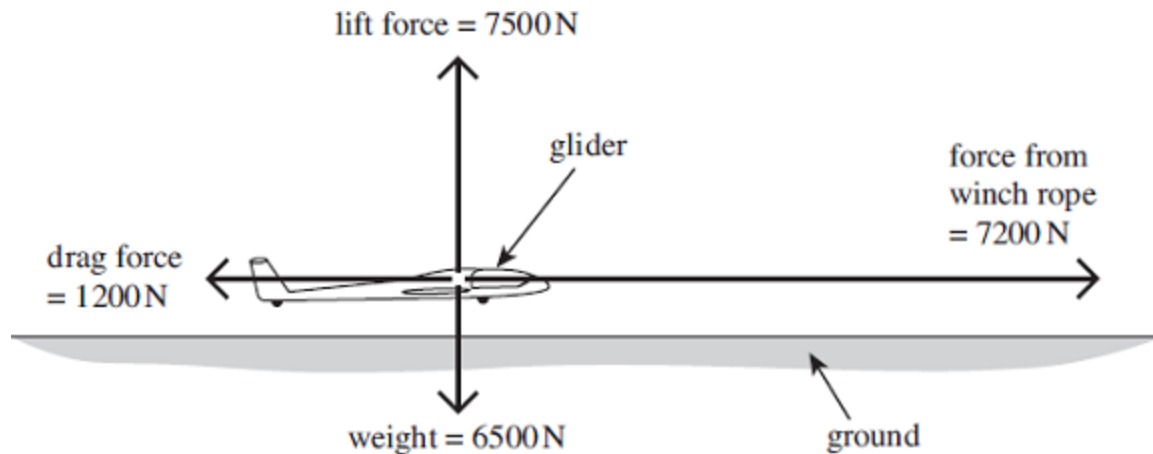
When the measurements were taken, increasing values of m were used. State and explain how friction in the pulleys would have affected the measured values of y .

(2)

(Total 13 marks)

4.

Gliders can be launched with a winch situated on the ground. The winch pulls a rope that is attached to the glider. The diagram below shows the forces acting on the glider at one instant during the launch.



- (a) The combined weight of the glider and pilot is 6500 N.
- (i) Show that the magnitude of the resultant force acting on the glider is about 6100 N.

(2)

- (ii) Calculate the angle between this resultant force and the horizontal.

angle _____ degrees

(2)

- (iii) Calculate the resultant acceleration of the glider in the diagram above.

resultant acceleration _____ m s^{-2}

(2)

- (b) The glider climbs a vertical distance of 600 m in 55 s. The average power input to the winch motor during the launch is 320 kW.

- (i) Calculate the gain in gravitational potential energy (gpe) of the glider.

gain in gpe _____ J

(2)

- (ii) Calculate the percentage efficiency of the winch system used to launch the glider. Assume the kinetic energy of the glider after the launch is negligible.

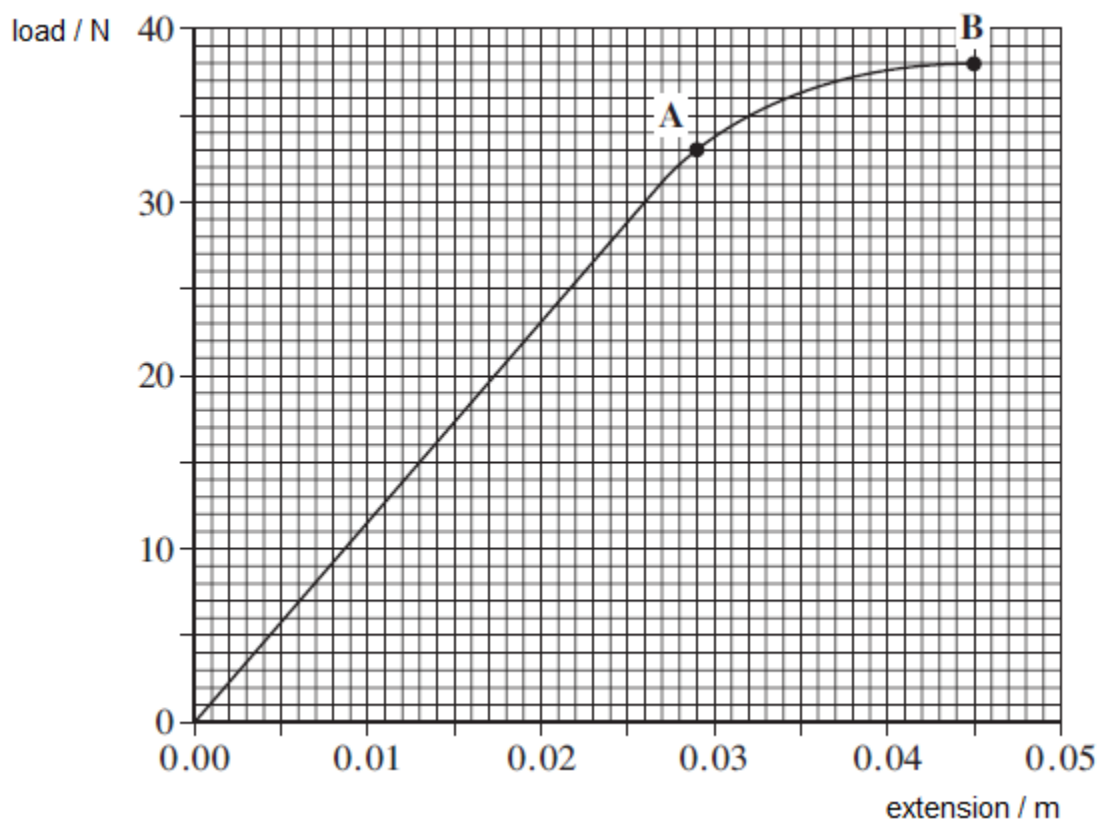
efficiency _____ %

(3)

(Total 11 marks)

5.

A manufacturer of springs tests the properties of a spring by measuring the load applied each time the extension is increased. The graph of load against extension is shown below.



(a) State Hooke's law.

(2)

(b) Calculate the spring constant, k , for the spring. State an appropriate unit.

spring constant _____ unit _____

(3)

- (c) Use the graph to find the work done in extending the spring up to point **B**.

work done _____ J

(3)

- (d) Beyond point **A** the spring undergoes *plastic deformation*.

Explain the meaning of the term plastic deformation.

(1)

- (e) When the spring reaches an extension of 0.045 m, the load on it is gradually reduced to zero. On the graph above sketch how the extension of the spring will vary with load as the load is reduced to zero.

(2)

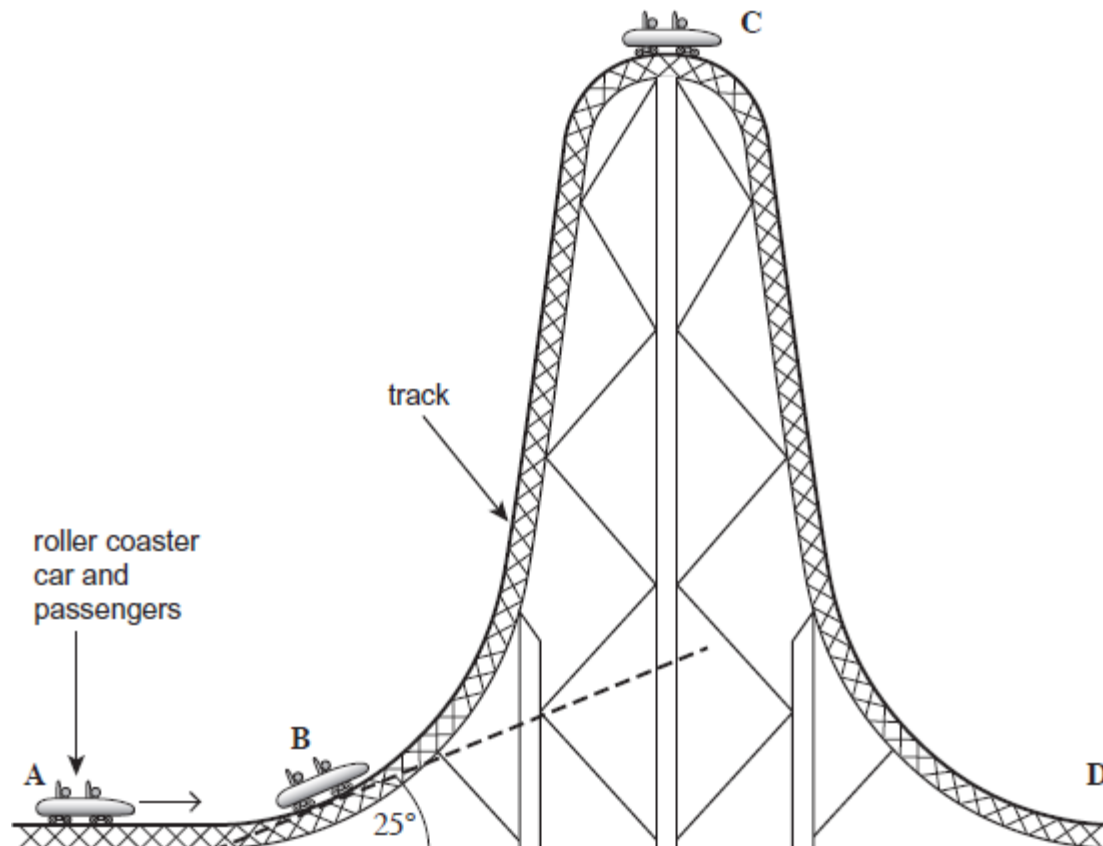
- (f) Without further calculation, compare the total work done by the spring when the load is removed with the work that was done by the load in producing the extension of 0.045 m.

(1)

(Total 12 marks)

6.

The following figure shows a roller coaster car which is accelerated from rest to a speed of 56 m s^{-1} on a horizontal track, **A**, before ascending the steep part of the track. The roller coaster car then becomes stationary at **C**, the highest point of the track. The total mass of the car and passengers is 8300 kg .



- (a) The angle of the track at **B** is 25° to the horizontal. Calculate the component of the weight of the car and passengers acting along the slope when the car and passengers are in position **B** as shown in the image above.

component of weight _____ N

(2)

- (b) (i) Calculate the kinetic energy of the car including the passengers when travelling at 56 m s^{-1} .

kinetic energy _____ J

(2)

- (ii) Calculate the maximum height above **A** that would be reached by the car and passengers if all the kinetic energy could be transferred to gravitational potential energy.

maximum height _____ m

(2)

- (c) The car does not reach the height calculated in part (b).

- (i) Explain the main reason why the car does not reach this height.

(2)

- (ii) The car reaches point **C** which is at a height of 140 m above **A**. Calculate the speed that the car would reach when it descends from rest at **C** to its original height from the ground at **D** if 87% of its energy at **C** is converted to kinetic energy.

speed _____ m s⁻¹

(2)

(Total 10 marks)

7.

- (a) (i) State the difference between a scalar quantity and a vector quantity.

(1)

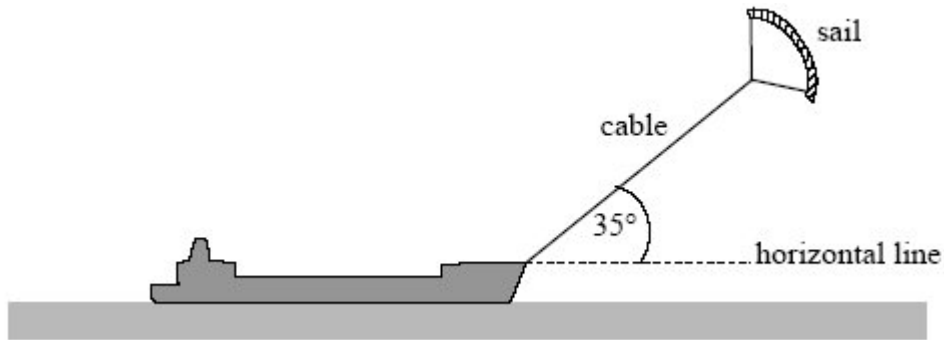
- (ii) State **two** examples of a scalar quantity and **two** examples of a vector quantity.

scalar quantities _____

vector quantities _____

(3)

- (b) The diagram below shows a ship fitted with a sail attached to a cable. The force of the wind on the sail assists the driving force of the ship's propellers.



The cable exerts a steady force of 2.8 kN on the ship at an angle of 35° above a horizontal line.

- (i) Calculate the horizontal and vertical components of this force.

horizontal component of force _____ kN

vertical component of force _____ kN

(2)

- (ii) The ship is moving at a constant velocity of 8.3 m s^{-1} and the horizontal component of the force of the cable on the ship acts in the direction in which the ship is moving. Calculate the power provided by the wind to this ship, stating an appropriate unit.

Answer _____

(3)

- (c) The cable has a diameter of 0.014 m. Calculate the tensile stress in the cable when it exerts a force of 2.8 kN on the ship, stating an appropriate unit. Assume the weight of the cable is negligible.

Answer _____

(5)

(Total 14 marks)

8.

The table below indicates some positions of a person carrying out a bungee jump from a high bridge.

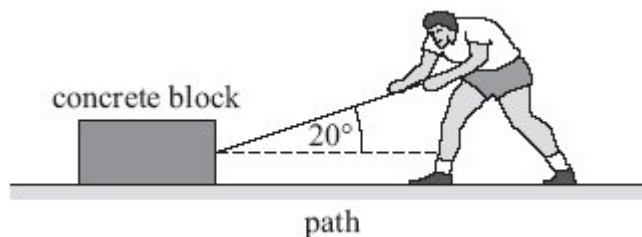
Tick the appropriate box(es) to show the forms that the jumper's energy takes at the different stages of the jump.

Energy forms Position	kinetic energy	gravitational potential energy	elastic potential energy
at the instant the jumper steps off the bridge			
at the instant the elastic bungee rope just becomes taut			
at the instant the jumper reaches the lowest point of the jump			

(Total 3 marks)

9.

The diagram below shows a man participating in a 'strong man' competition. The event requires the man to haul a concrete block along a horizontal path for a distance of 15 m. The frictional force between the block and the path is 2800 N.



- (a) The rope is inclined at an angle of 20° to the horizontal.
Calculate the minimum force that the man must exert on the rope to move the block.

force _____ N

(1)

- (b) Calculate the minimum work that the man has to do to complete the event.

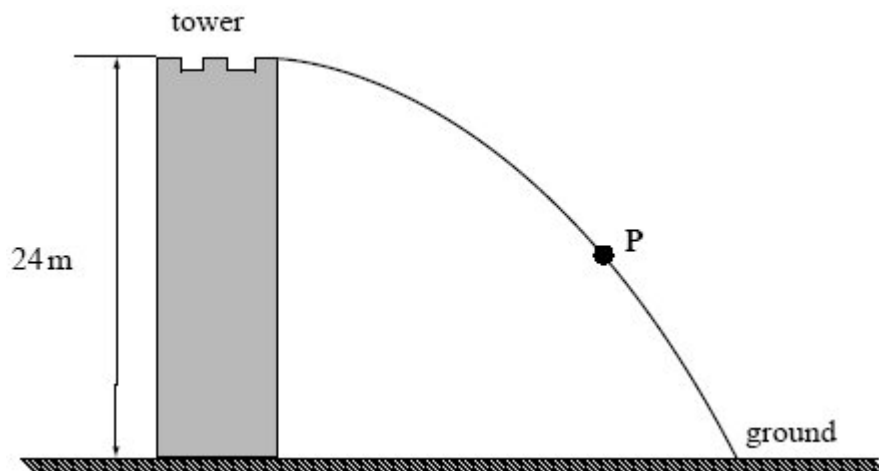
work done _____ J

(1)

(Total 2 marks)

10.

The diagram below shows the path of a ball thrown horizontally from the top of a tower of height 24 m which is surrounded by level ground.



- (a) Using two labelled arrows, show on the diagram above the direction of the velocity, v , and the acceleration, a , of the ball when it is at point **P**.

(2)

- (b) (i) Calculate the time taken from when the ball is thrown to when it first hits the ground. Assume air resistance is negligible.

Answer _____ s

(2)

- (ii) The ball hits the ground 27 m from the base of the tower. Calculate the speed at which the ball is thrown.

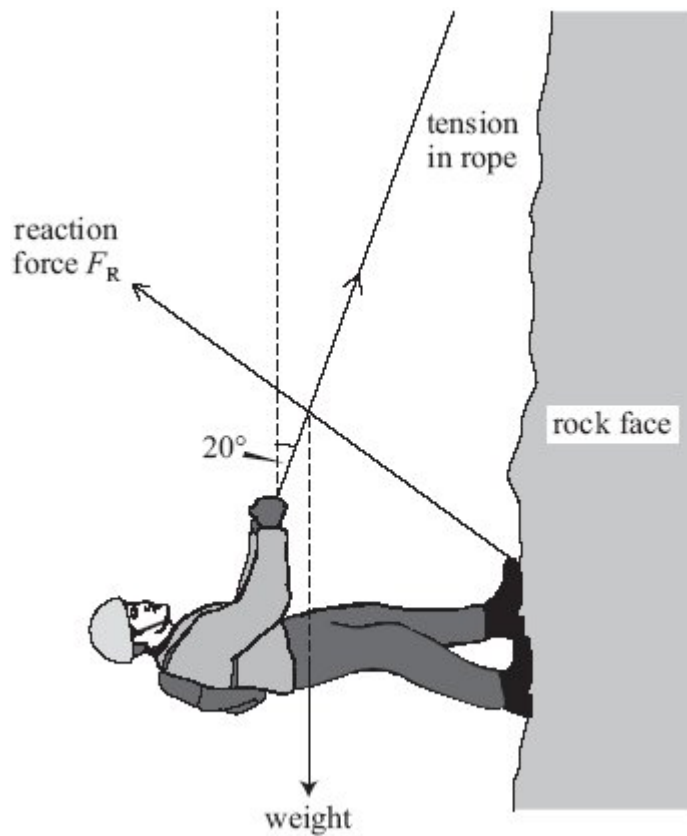
Answer _____ m s^{-1}

(2)

(Total 6 marks)

11.

The diagram below shows a rock climber abseiling down a rock face. At the instant shown the climber is stationary and in equilibrium. The forces acting on the climber are shown in the diagram below.



The tension in the rope is 610 N and it acts at 20° to the vertical.
The weight of the climber is 590 N.

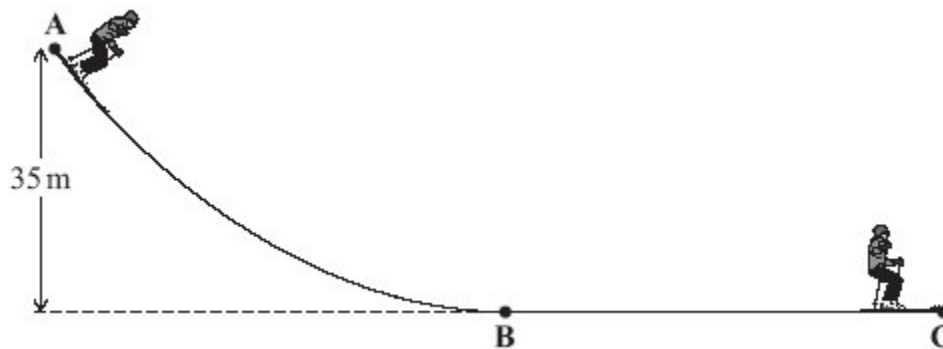
Calculate the vertical component of the reaction force, F_R , between the feet of the climber and the rock.

vertical component _____ N
(Total 3 marks)

12. A weightlifter lifts a weight of 1500 N through a height of 0.35 m in a time of 0.85 s. Calculate the mean power developed by the weightlifter.

power _____ W
(Total 2 marks)

13. The diagram below shows the path of a skier who descends a slope **AB**.



The skier starts from rest at **A** and eventually comes to rest again at **C** on the horizontal surface **BC**.

- (a) (i) The slope **AB** has a vertical height of 35 m. The total mass of the skier is 65 kg.

Show that the skier's loss in gravitational potential energy is about 20 kJ.

(1)

- (ii) The kinetic energy of the skier at point **B** is 11 000 J.
Show that the skier's speed at point **B** is about 18 m s^{-1} .

(2)

- (iii) The average retarding force acting on the skier is 140 N.
Calculate the distance travelled between **A** and **B**.

distance travelled _____ m

(2)

- (iv) Describe **two** ways in which the retarding force may arise.

(3)

(b) The skier decelerates uniformly between **B** and **C** at 2.8 m s^{-2} .

(i) Calculate the time taken to travel from **B** to **C**.

time _____ s

(2)

(ii) Calculate the distance **BC**.

distance _____ m

(2)

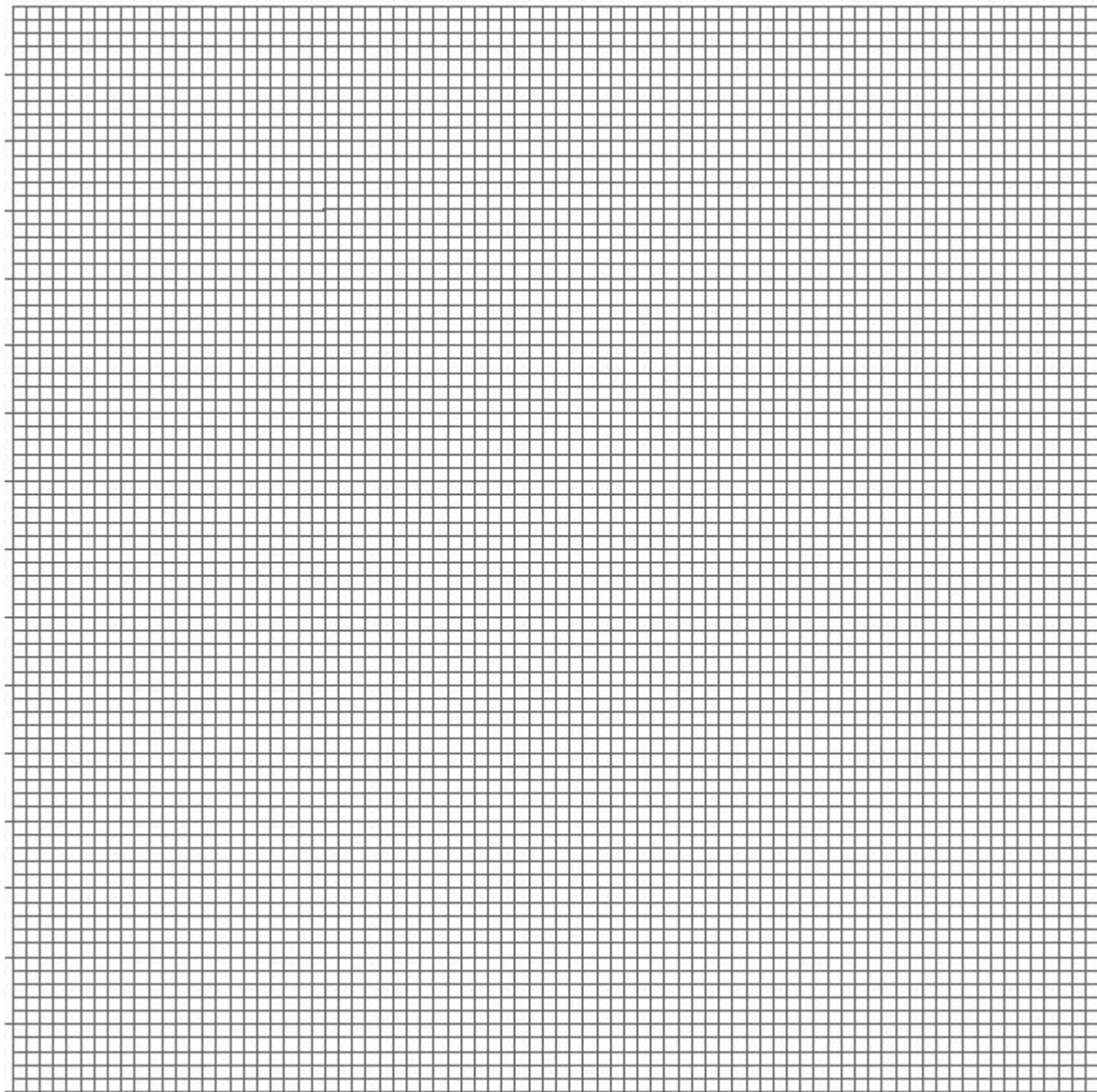
(Total 12 marks)

14.

A car is travelling on a level road at a speed of 15.0 m s^{-1} towards a set of traffic lights when the lights turn red. The driver applies the brakes 0.5 s after seeing the lights turn red and stops the car at the traffic lights. The table below shows how the speed of the car changes from when the traffic lights turn red.

time/s	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5
speed/ m s^{-1}	15.0	15.0	12.5	10.0	7.5	5.0	2.5	0.0

- (a) Draw a graph of speed on the y-axis against time on the x-axis on the grid provided.



(5)

- (b) (i) State and explain what feature of the graph shows that the car's deceleration was uniform.

(2)

- (ii) Use your graph to calculate the distance the car travelled after the lights turned red to when it stopped.

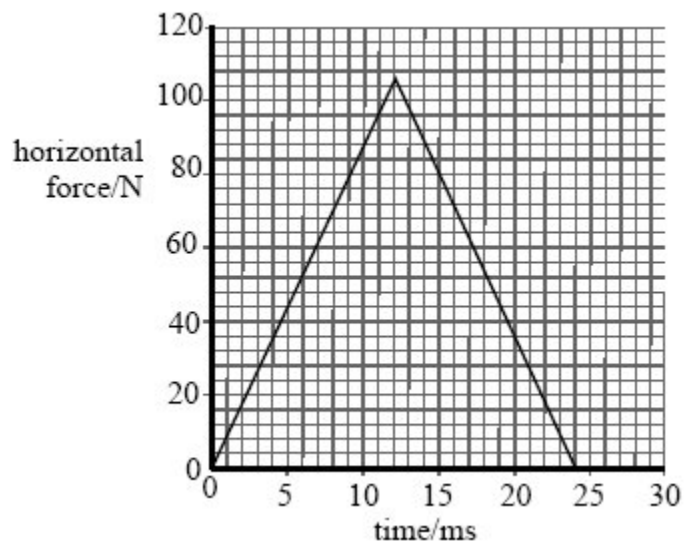
Answer _____ m

(4)

(Total 11 marks)

15.

The graph shows the variation in the horizontal force acting on a tennis ball with time whilst the ball is being served.



- (a) (i) Use the graph to show that the magnitude of the impulse that acts on the tennis ball is about 1.3 N s.

(2)

- (ii) The mass of the tennis ball is 0.057 kg. Show that the impulse in part (a)(i) gives the ball a speed of about 20 m s^{-1} horizontally as the ball leaves the racquet. Assume that the ball had no horizontal speed before the impulse was applied.

(2)

- (b) During flight the ball accelerates due to gravity. When it reaches the ground the vertical component of the velocity is 6.1 m s^{-1} . Calculate the speed and the angle between the direction of travel of the ball and the horizontal as it reaches the ground. Assume that air resistance is negligible.

speed _____ m s^{-1}

angle _____ degree

(3)

(Total 7 marks)

16.

A car of mass 1300 kg is stopped by a constant horizontal braking force of 6.2 kN.

- (a) Show that the deceleration of the car is about 5 m s^{-2} .

(3)

- (b) The initial speed of the car is 27 m s^{-1} .
Calculate the distance travelled by the car as it decelerates to rest.

distance travelled _____ m

(3)

(Total 6 marks)

17.

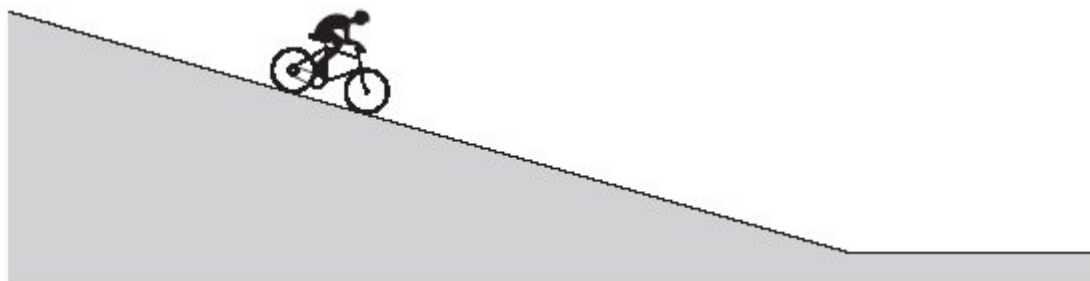
Water of density 1000 kg m^{-3} flows out of a garden hose of cross-sectional area $7.2 \times 10^{-4} \text{ m}^2$ at a rate of $2.0 \times 10^{-4} \text{ m}^3$ per second. How much momentum is carried by the water leaving the hose per second?

- A** $5.6 \times 10^{-5} \text{ N s}$
B $5.6 \times 10^{-2} \text{ N s}$
C 0.20 N s
D 0.72 N s

(Total 1 mark)

18.

A cyclist **pedals** downhill on a road, as shown in the diagram below, from rest at the top of the hill and reaches a horizontal section of the road at a speed of 16 m s^{-1} . The total mass of the cyclist and the cycle is 68 kg .



- (a) (i) Calculate the total kinetic energy of the cyclist and the cycle on reaching the horizontal section of the road.

answer _____ J

(2)

- (ii) The height difference between the top of the hill and the horizontal section of road is 12 m .
Calculate the loss of gravitational potential energy of the cyclist and the cycle.

answer _____ J

(2)

- (iii) The work done by the cyclist when pedalling downhill is 2400 J. Account for the difference between the loss of gravitational potential energy and the gain of kinetic energy of the cyclist and the cycle.

(3)

- (b) The cyclist stops pedalling on reaching the horizontal section of the road and slows to a standstill 160 m further along this section of the road. Assume the deceleration is uniform.

- (i) Calculate the time taken by the cyclist to travel this distance.

answer _____ s

(3)

- (ii) Calculate the average horizontal force on the cyclist and the cycle during this time.

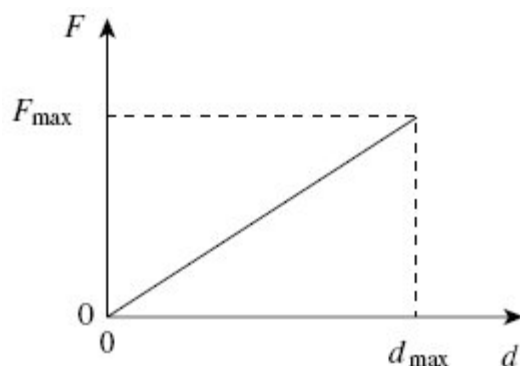
answer _____ N

(3)

(Total 13 marks)

19.

English longbows from the time of Henry VIII were found on board a sunken Tudor warship. The diagram below shows how the horizontal force, F , exerted by an archer on the bow string varies with the horizontal displacement, d , of the arrow as the bow is drawn.



- (a) (i) Show that the energy stored in the bow is

$$\frac{1}{2} F_{\max} d_{\max}$$

where $F_{\max}$ is the maximum force in the bow and $d_{\max}$ is the maximum displacement of the bow string.

(2)

- (ii) Show that the maximum speed, v , with which an arrow can leave the bow is given by

$$v = \sqrt{\frac{F_{\max} d_{\max}}{m}}$$

where m is the mass of the arrow.

(2)

- (b) Each arrow had a mass of 0.060 kg and the bow string was displaced by a maximum of 0.60 m before releasing the arrow. The archers needed to exert a maximum force of 650 N.

- (i) Show that the maximum speed of the arrow as it leaves the bow is about 80 m s^{-1} .

(2)

- (ii) State **one** reason why the speed of the arrow as it leaves the bow is likely to be less than 80 m s^{-1} .

(1)

- (c) The initial speed of an arrow as it leaves a bow is 65 m s^{-1} . When leaving the bow the arrow travels at an angle of 55° to the horizontal. Assume that the air resistance is negligible.

- (i) Show that the vertical component of the initial speed of the arrow is about 53 m s^{-1} .

(1)

- (ii) The arrow is fired from ground level across a flat, level field. Show that the arrow is in flight for about 11 s.

(3)

- (iii) Calculate the horizontal distance travelled by the arrow when fired from level ground.

horizontal distance travelled _____ m

(2)

(Total 13 marks)

20.

Which row, **A** to **D**, in the table correctly shows the quantities conserved in an inelastic collision?

	mass	momentum	kinetic energy	total energy
A	conserved	not conserved	conserved	conserved
B	not conserved	conserved	conserved	not conserved
C	conserved	conserved	conserved	conserved
D	conserved	conserved	not conserved	conserved

(Total 1 mark)

21.

A mountain walker of weight 750 N climbs a height of 300 m in 40 minutes.

- (a) Calculate the average power required due to the gravitational force on the walker during the climb.

average power _____ W

(3)

- (b) The walker uses a spring loaded walking pole that changes in length by 15 mm when the full weight of the walker is applied to it.

Calculate the stiffness of the spring in the pole.

Give an appropriate unit for your answer.

spring stiffness _____

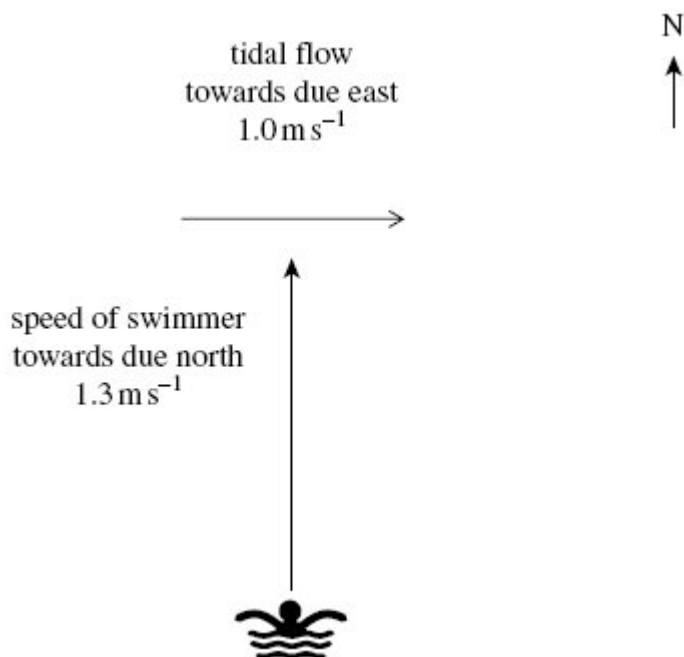
unit _____

(3)

(Total 6 marks)

22.

The diagram below shows a long-distance swimmer swimming due north at 1.3 m s^{-1} in a tide that flows at 1.0 m s^{-1} due east.



- (a) Calculate the magnitude of the resultant velocity of the swimmer.

magnitude of resultant velocity _____ m s^{-1}

(2)

- (b) Calculate the angle the resultant velocity of the swimmer makes with due north.

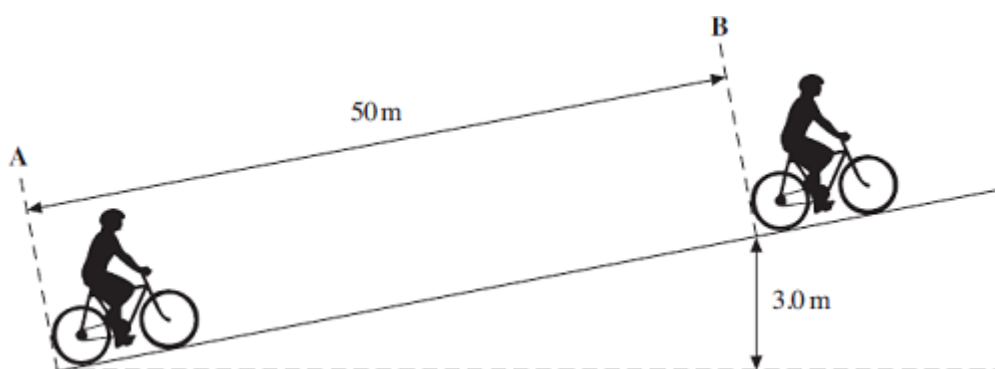
angle _____ degrees

(2)

(Total 4 marks)

23.

An 'E-bike' is a bicycle that is assisted by an electric motor. The figure below shows an E-bike and rider with a total mass of 83 kg moving up an incline.



- (a) (i) The cyclist begins at rest at **A** and accelerates uniformly to a speed of 6.7 m s^{-1} at **B**. The distance between **A** and **B** is 50 m. Calculate the time taken for the cyclist to travel this distance.

_____ s

(2)

- (ii) Calculate the kinetic energy of the E-bike and rider when at **B**. Give your answer to an appropriate number of significant figures.

_____ J

(2)

- (iii) Calculate the gravitational potential energy gained by the E-bike and rider between **A** and **B**.

_____ J

(2)

- (b) Between **A** and **B**, the work done by the electric motor is 3700 J, and the work done by the cyclist pedalling is 5300 J.

- (i) Calculate the wasted energy as the cyclist travels from **A** to **B**.

_____ J

(2)

- (ii) State **two** causes of this wasted energy.

Cause 1 _____

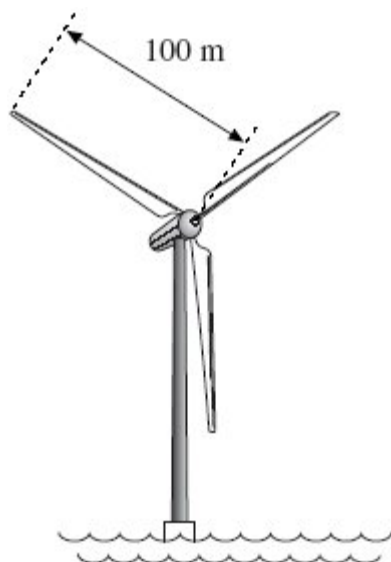
Cause 2 _____

(2)

(Total 10 marks)

24.

It has been predicted that in the future large offshore wind turbines may have a power output ten times that of the largest ones currently in use. These turbines could have a blade length of 100 m or more. A turbine such as this is shown in the diagram below.



- (a) At a wind speed of 11 m s^{-1} the volume of air passing through the blades each second is $3.5 \times 10^5 \text{ m}^3$.

- (i) Show that the mass of air that would pass through the blades each second is about $4 \times 10^5 \text{ kg}$.

The density of air is 1.2 kg m^{-3}

(2)

- (ii) Calculate the kinetic energy of the air that would enter the turbine each second.

answer = _____ J

(2)

- (iii) It has been predicted that the turbine would produce an electrical power output of 10 MW in these wind conditions. Calculate the percentage efficiency of the turbine in converting this kinetic energy into electrical energy.

answer = _____ %

(2)

- (b) State **one** advantage and **one** disadvantage of wind power in comparison to fossil fuel.

Advantage _____

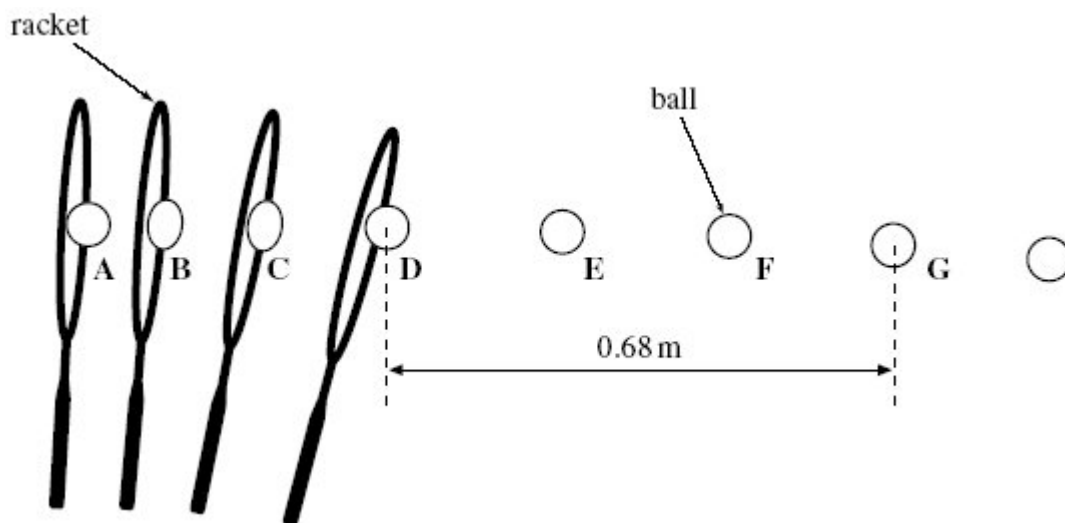
Disadvantage _____

(2)

(Total 8 marks)

25.

A digital camera was used to obtain a sequence of images of a tennis ball being struck by a tennis racket. The camera was set to take an image every 5.0 ms. The successive positions of the racket and ball are shown in the diagram below.



- (a) The ball has a horizontal velocity of zero at **A** and reaches a constant horizontal velocity at **D** as it leaves the racket. The ball travels a horizontal distance of 0.68 m between **D** and **G**.
- (i) Show that the horizontal velocity of the ball between positions **D** and **G** in the diagram above is about 45 m s^{-1} .

(3)

- (ii) Calculate the horizontal acceleration of the ball between **A** and **D**.

answer = _____ m s^{-2}

(1)

- (b) At **D**, the ball was projected horizontally from a height of 2.3 m above level ground.

- (i) Show that the ball would fall to the ground in about 0.7 s.

(3)

- (ii) Calculate the horizontal distance that the ball will travel after it leaves the racket before hitting the ground. Assume that only gravity acts on the ball as it falls.

answer = _____ m

(2)

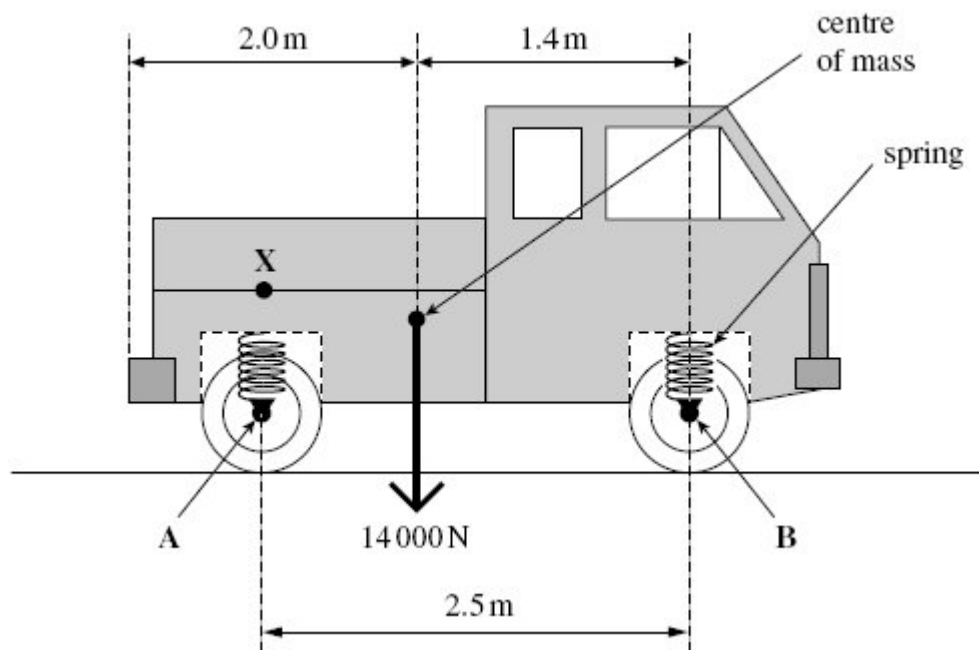
- (iii) Explain why, in practice, the ball will not travel this far before hitting the ground.

(2)

(Total 11 marks)

26.

Heavy duty coil springs are used in vehicle suspensions. The pick-up truck shown in the diagram below has a weight of 14 000 N and length of 4.5 m. When carrying no load, the centre of mass is 2.0 m from the rear end. The part of the vehicle shown shaded in grey is supported by four identical springs, one near each wheel.



- (a) (i) Define the moment of a force about a point.

(2)

- (ii) State and explain which pair of springs, front or rear, will be compressed the most.

(2)

- (iii) By taking moments about axle **B**, calculate the force exerted on the truck by each rear spring.

answer = _____ N

(4)

- (b) The spring constant for each of these springs is $100\,000\text{ N m}^{-1}$.

Calculate the distance that each of these rear springs is compressed by this vehicle as shown in the diagram above.

answer = _____ m

(2)

- (c) The springs must not be compressed by more than an additional 0.065 m. Calculate the maximum load that could be placed at point **X**, which is directly above the centre of the rear axle **A**, as shown in the diagram above.

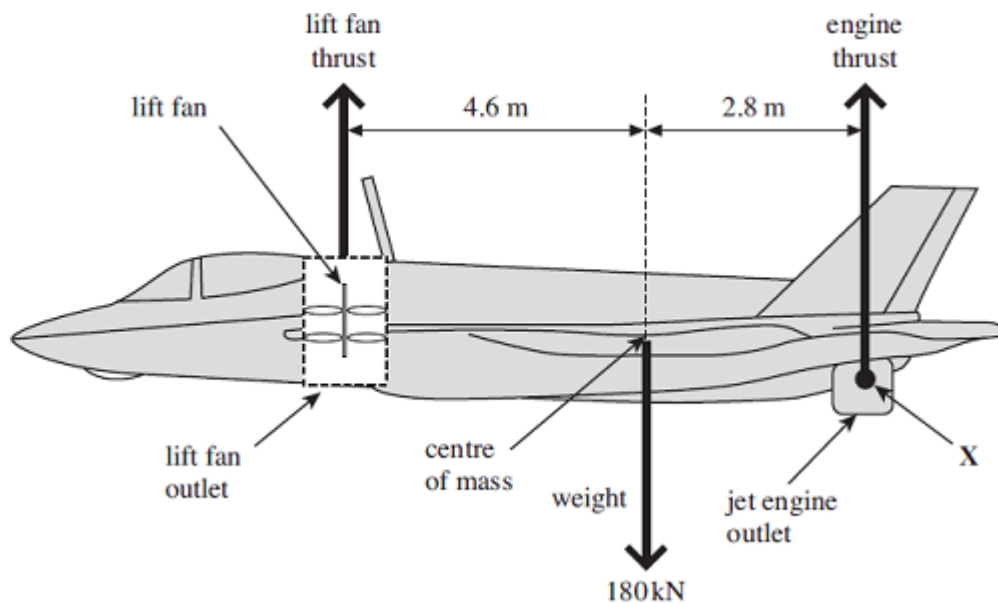
answer = _____ N

(2)

(Total 12 marks)

27.

The figure below shows an aircraft designed to take off and land vertically and also to hover without horizontal movement. In order to achieve this, upward lift is produced by directing the jet engine outlet downwards. The engine also drives a vertical lift fan near the front of the aircraft. The weight of the aircraft is 180 kN. The distance between the lift fan and the centre of mass is 4.6 m and the distance between the jet engine outlet and the centre of mass is 2.8 m.



- (a) (i) Calculate the moment caused by the weight of the aircraft about the point **X**.

answer = _____ Nm

(2)

- (ii) By taking moments about **X**, calculate the lift fan thrust if the aircraft is to remain horizontal when hovering.

answer = _____ N

(3)

- (iii) Calculate the engine thrust in the figure above.

answer = _____ N

(1)

- (b) Having taken off vertically, the jet engine outlet is turned so that the engine thrust acts horizontally. The aircraft accelerates horizontally to a maximum velocity. The forward thrust produced by the jet is 155 kN. The weight of the aircraft is 180 kN.

- (i) When the resultant horizontal force is 155 kN, calculate the horizontal acceleration of the aircraft.

answer = _____ ms^{-2}

(2)

- (ii) State and explain **one** characteristic of the aircraft that limits its maximum horizontal velocity.

(2)

- (iii) On the axes below, sketch the velocity-time graph for the horizontal motion of the aircraft as it accelerates from zero to its maximum horizontal velocity.



(2)

- (c) State how a velocity-time graph could be used to find the maximum acceleration.

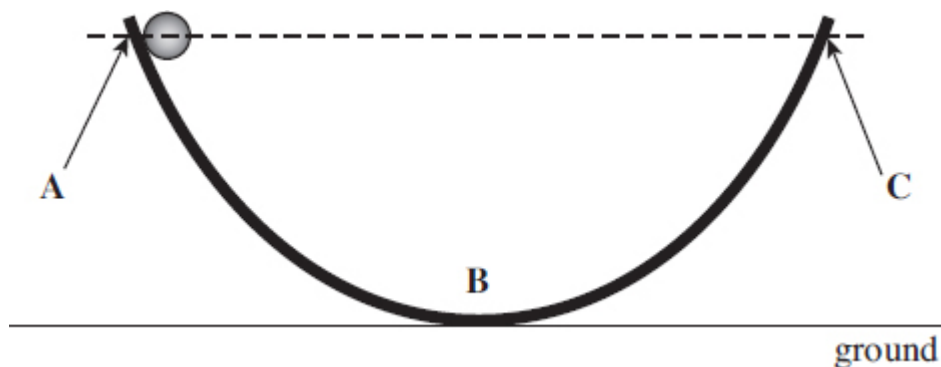
(1)

(Total 13 marks)

28.

In the 17th century, when thinking about forces, Galileo imagined a ball moving in the absence of air resistance on a frictionless track as shown in **Figure 1**.

Figure 1



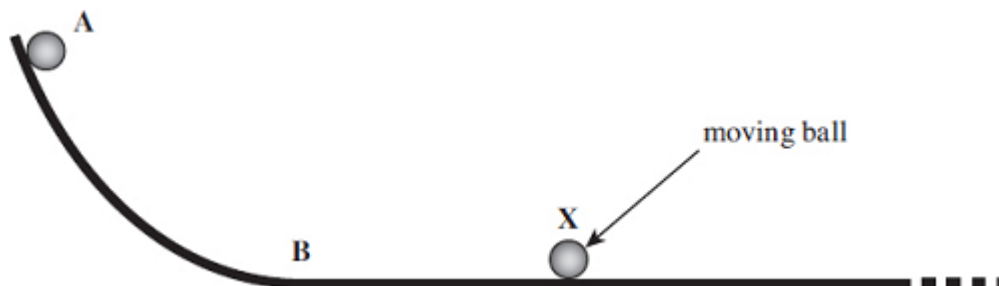
- (a) Galileo thought that, under these circumstances, the ball would reach position **C** if released from rest at position **A**. Position **C** is the same height above the ground as **A**.

Using ideas about energy, explain why Galileo was correct.

(3)

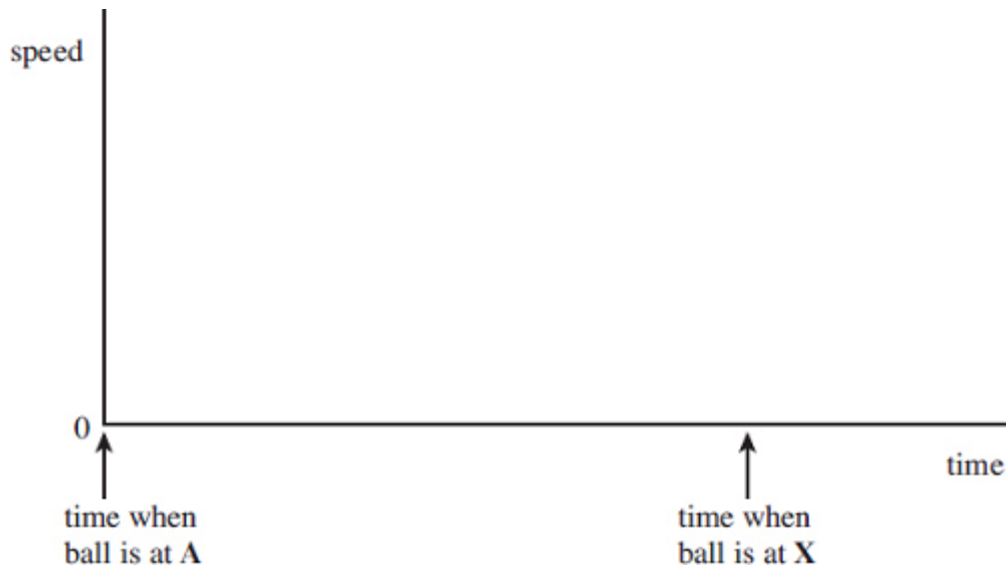
- (b) Galileo then imagined that the track was changed, as shown in **Figure 2**.

Figure 2



The slope beyond **B** was now horizontal.

On the axes below, sketch a speed – time graph for the ball from its release at **A** until it reaches the position **X** shown in **Figure 2**. Indicate on your graph the time when the ball is at **B**.



(3)

- (c) Newton later published his three laws of motion.

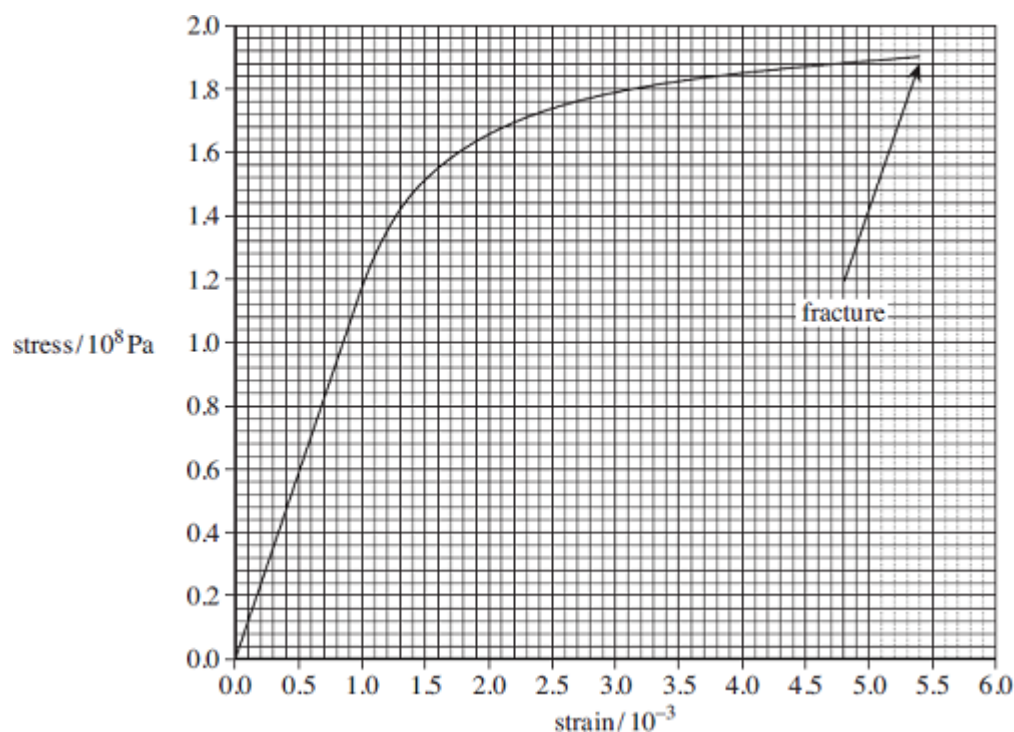
Explain how Newton's first law of motion is illustrated by the motion of the ball between **B** and **X**.

(2)

(Total 8 marks)

29.

The figure below shows a stress-strain graph for a copper wire.



- (a) Define tensile strain.

(1)

- (b) State the breaking stress of this copper wire.

answer = _____ Pa

(1)

- (c) Mark on the figure above a point on the line where you consider plastic deformation may start.

Label this point **A**.

(1)

- (d) Use the graph to calculate the Young modulus of copper. State an appropriate unit for your answer.

answer = _____

(3)

- (e) The area under the line in a stress-strain graph represents the work done per unit volume to stretch the wire.
- (i) Use the graph to find the work done per unit volume in stretching the wire to a strain of 3.0×10^{-3} .

answer = _____ J m^{-3}

(2)

- (ii) Calculate the work done to stretch a 0.015 kg sample of this wire to a strain of 3.0×10^{-3} .

The density of copper = 8960 kg m^{-3} .

answer = _____ J

(2)

- (f) A certain material has a Young modulus greater than copper and undergoes brittle fracture at a stress of 176 MPa .

On the figure above draw a line showing the possible variation of stress with strain for this material.

(2)

(Total 12 marks)

30.

Sail systems are being developed to reduce the running costs of cargo ships. The sail and ship's engines work together to power the ship. One of these sails is shown in the figure below pulling at an angle of 40° to the horizontal.



- (a) The average tension in the cable is 170 kN .
Show that, when the ship travels 1.0 km , the work done by the sail on the ship is $1.3 \times 10^8 \text{ J}$.

(2)

(b) With the sail and the engines operating, the ship is travelling at a steady speed of 7.0 ms^{-1} .

(i) Calculate the power developed by the sail.

answer = _____ W

(2)

(ii) Calculate the percentage of the ship's power requirement that is provided by the wind when the ship is travelling at this speed.

The power output of the engines is 2.1 MW.

answer = _____ %

(2)

(c) The angle of the cable to the horizontal is one of the factors that affects the horizontal force exerted by the sail on the ship. State **two** other factors that would affect this force.

Factor 1 _____

Factor 2 _____

(2)

(Total 8 marks)

31.

Figure 1 shows car **A** being towed at a steady speed up a slope which is inclined at 5.0° to the horizontal. Assume that the resistive forces acting on car **A** are negligible.

Figure 1

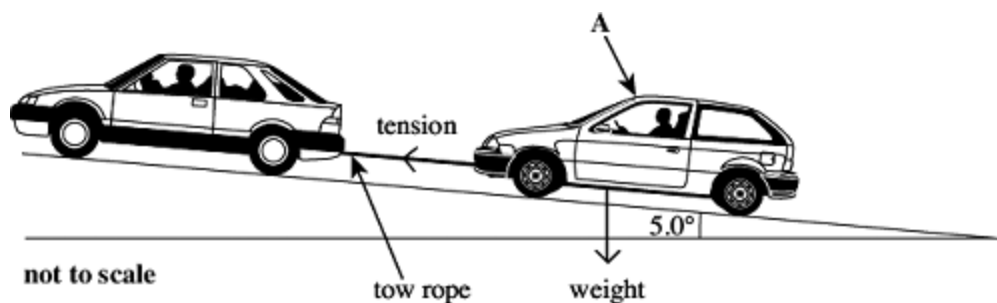
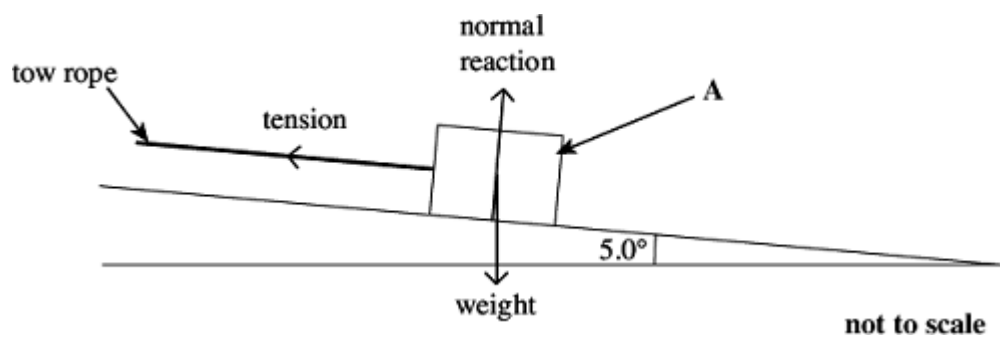


Figure 2 represents a simplified version of the forces acting on car **A** at the instant shown in **Figure 1**.

Figure 2



- (a) (i) Car **A** has a mass of 970 kg. Show that the component of its weight that acts parallel to the slope is approximately 830 N.

(2)

- (ii) Calculate the energy stored in the tow rope as car **A** is towed up the slope at a steady speed. The tow rope obeys Hooke's law and has a stiffness of $2.5 \times 10^4 \text{ Nm}^{-1}$.

energy stored _____ J

(4)

- (b) The tow rope is attached to a fixing point on car **A** using a metal hook. During the ascent of the slope the fixing point snaps and the metal hook becomes detached from car **A**. The metal hook gains speed due to the energy stored in the rope. State and explain how the speed gained by the hook would have changed if the rope used had a stiffness greater than $2.5 \times 10^4 \text{ Nm}^{-1}$.

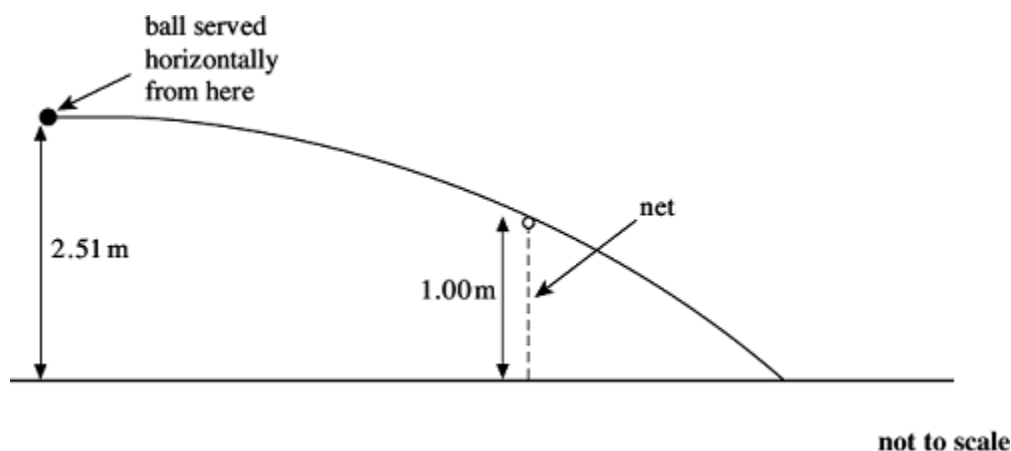
(3)

(Total 9 marks)

32.

A tennis player serves a ball from a height of 2.51 m at 18.0 ms^{-1} in a horizontal direction. The ball just clears the net which is 1.00 m high. In this question assume that air resistance is negligible.

The figure below shows the ball and its resulting trajectory across the court.



- (a) Show that the ball takes approximately 0.6 s to reach the net after being served.

(3)

- (b) (i) Calculate the vertical component of the velocity of the ball as it passes over the net.

vertical component of velocity _____ ms^{-1}

(2)

- (ii) Calculate the overall velocity of the ball as it passes over the net.

magnitude of velocity _____ ms^{-1}

angle to horizontal _____ degree

(3)

(Total 8 marks)

33.

Two ice skaters, initially at rest and in contact, push apart from each other.

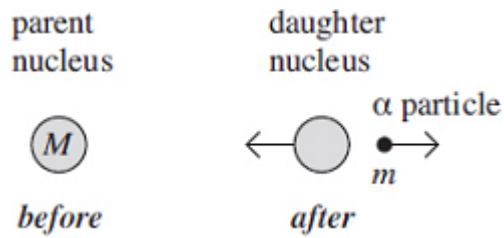
Which line, **A** to **D**, in the table states correctly the change in the total momentum and the total kinetic energy of the two skaters?

	total momentum	total kinetic energy
A	unchanged	increases
B	unchanged	unchanged
C	increases	increases
D	increases	unchanged

(Total 1 mark)

34.

A stationary unstable nucleus of mass M emits an α particle of mass m with kinetic energy E



What is the speed of recoil of the daughter nucleus?

A $\frac{\sqrt{2mE}}{(M - m)}$

B $\frac{\sqrt{2mE}}{M}$

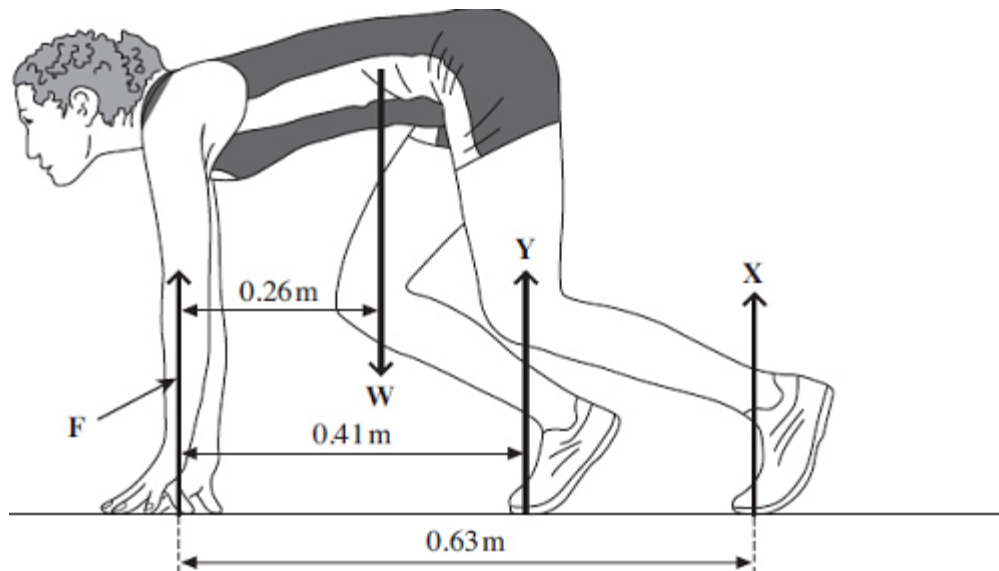
C $\frac{(M - m)}{\sqrt{2mE}}$

D $\frac{2mE}{(M - m)^2}$

(Total 1 mark)

35.

A sprinter is shown before a race, stationary in the 'set' position, as shown in the figure below. Force **F** is the resultant force on the sprinter's finger tips. The reaction force, **Y**, on her forward foot is 180 N and her weight, **W**, is 520 N. **X** is the vertical reaction force on her back foot.



- (a) (i) Calculate the moment of the sprinter's weight, **W**, about her finger tips.
Give an appropriate unit.

answer = _____ unit _____

(2)

- (ii) By taking moments about her finger tips, calculate the force on her back foot, marked **X**.

answer = _____ N

(3)

- (iii) Calculate the force $\mathbf{F}$.

answer = _____ N

(1)

- (b) The sprinter starts running and reaches a horizontal velocity of 9.3 ms^{-1} in a distance of 35 m.

- (i) Calculate her average acceleration over this distance.

answer = _____ m s^{-2}

(2)

- (ii) Calculate the resultant force necessary to produce this acceleration.

answer = _____ N

(2)

(Total 10 marks)

36.

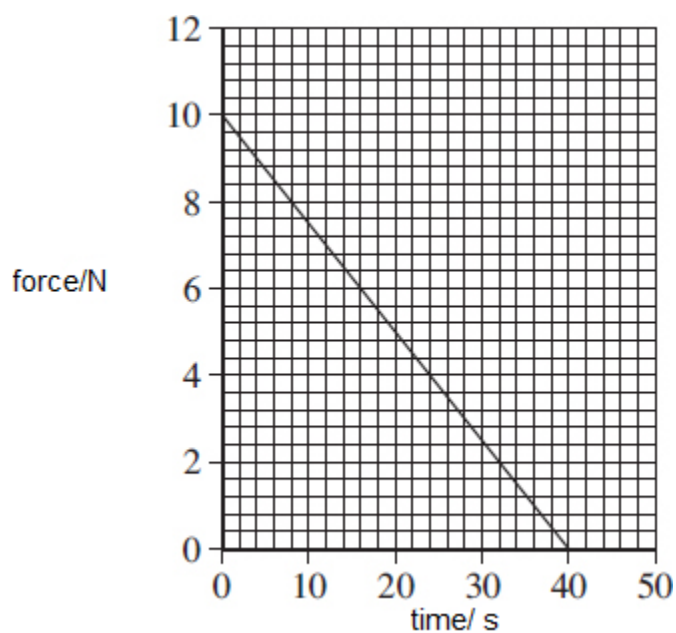
Which line, **A** to **D**, in the table correctly describes the trajectory of charged particles which enter separately, at right angles, a uniform electric field, and a uniform magnetic field?

	uniform electric field	uniform magnetic field
A	parabolic	circular
B	circular	parabolic
C	circular	circular
D	parabolic	parabolic

(Total 1 mark)

37.

The graph shows how the force acting on a body changes with time.



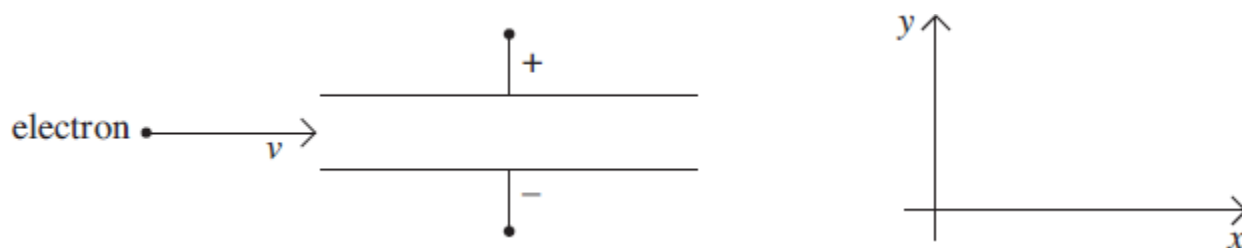
The body has a mass of 0.25 kg and is initially at rest. What is the speed of the body after 40 s assuming no other forces are acting?

- A** 200 ms⁻¹
- B** 400 ms⁻¹
- C** 800 ms⁻¹
- D** 1600 ms⁻¹

(Total 1 mark)

38.

A beam of electrons, moving with a constant velocity v in a vacuum, enters a uniform electric field between two metal plates.



Which line, **A** to **D**, in the table describes the components of the acceleration of the electrons in the x and y directions as they move through the field?

	acceleration in x direction	acceleration in y direction
A	zero	zero
B	zero	constant
C	constant	zero
D	constant	constant

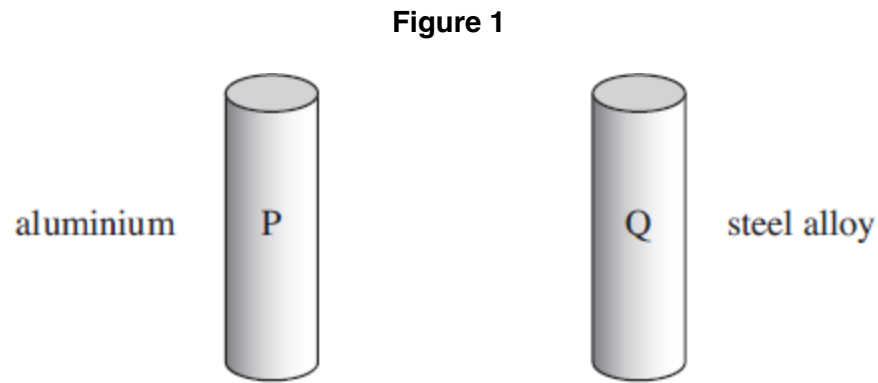
(Total 1 mark)

39.

(a) State Lenz's law.

(2)

- (b) **Figure 1** shows two small, solid metal cylinders, **P** and **Q**. **P** is made from aluminium. **Q** is made from a steel alloy.



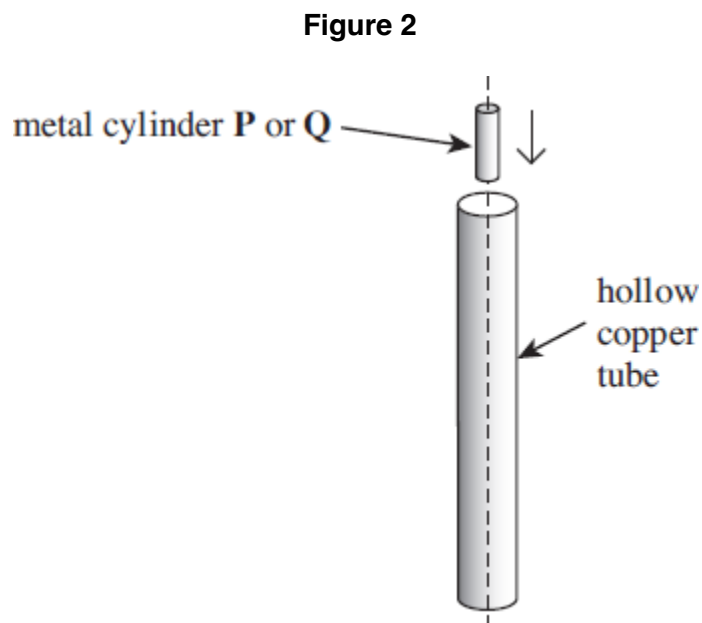
- (i) The dimensions of **P** and **Q** are identical but **Q** has a greater mass than **P**. Explain what material property is responsible for this difference.

(1)

- (ii) When **P** and **Q** are released from rest and allowed to fall freely through a vertical distance of 1.0 m, they each take 0.45 s to do so. Justify this time value and explain why the times are the same.

(2)

- (c) The steel cylinder **Q** is a strong permanent magnet. **P** and **Q** are released separately from the top of a long, vertical copper tube so that they pass down the centre of the tube, as shown in **Figure 2**.



The time taken for **Q** to pass through the tube is much longer than that taken by **P**.

- (i) Explain why you would expect an emf to be induced in the tube as **Q** passes through it.

(2)

- (ii) State the consequences of this induced emf, and hence explain why **Q** takes longer than **P** to pass through the tube.

(3)

- (d) The copper tube is replaced by a tube of the same dimensions made from brass. The resistivity of brass is much greater than that of copper. Describe and explain how, if at all, the times taken by **P** and **Q** to pass through the tube would be affected.

P: _____

Q: _____

(3)

(Total 13 marks)

40.

The world record for a high dive into deep water is 54 m.

- (a) Calculate the loss in gravitational potential energy (gpe) of a diver of mass 65 kg falling through 54 m.

loss in gpe = _____ J

(2)

- (b) Calculate the vertical velocity of the diver the instant before he enters the water. Ignore the effects of air resistance.

velocity = _____ ms^{-1}

(2)

- (c) Calculate the time taken for the diver to fall 54 m. Ignore the effects of air resistance.

time = _____ s

(2)

- (d) Explain, with reference to energy, why the velocity of the diver is independent of his mass if air resistance is insignificant.

(3)

(Total 9 marks)

41.

A canoeist can paddle at a speed of 3.8 ms^{-1} in still water.

She encounters a current which opposes her motion. The current has a velocity of 1.5 ms^{-1} at 30° to her original direction of travel as shown in the figure below.



By drawing a scale diagram determine the magnitude of the canoeist's resultant velocity.

magnitude of velocity _____ ms^{-1}

(Total 3 marks)

42.

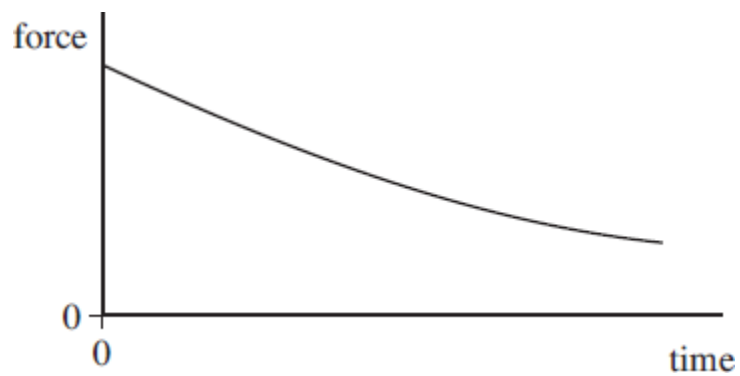
A cricket ball of mass 0.16 kg travelling at a speed of 35 ms^{-1} is hit by a bat and, as a result of the impact, leaves the bat in the opposite direction at 30 ms^{-1} . If the duration of the impact is 52 ms , what is the magnitude of the average force on the ball?

- A** 0.015 N
- B** 0.20 N
- C** 15 N
- D** 200 N

(Total 1 mark)

43.

A ball is released so that it falls vertically. The graph shows how the resultant force acting on the ball changes with time.



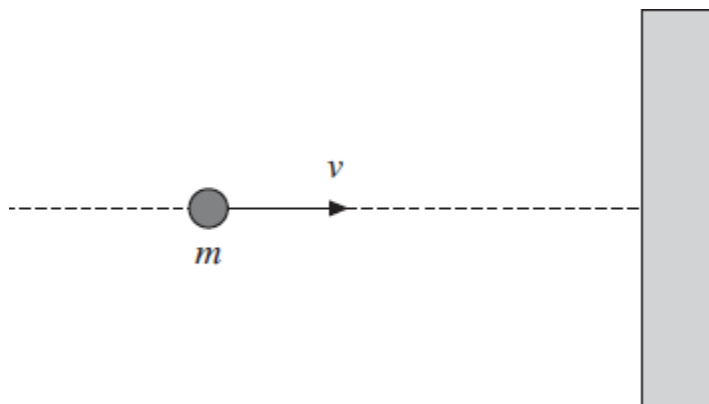
Which one of the following is represented by the area under the graph?

- A** distance travelled
- B** gain in kinetic energy
- C** acceleration
- D** impulse

(Total 1 mark)

44.

A ball of mass m travelling at velocity v collides normally with a smooth wall, as shown in the diagram, and rebounds elastically.



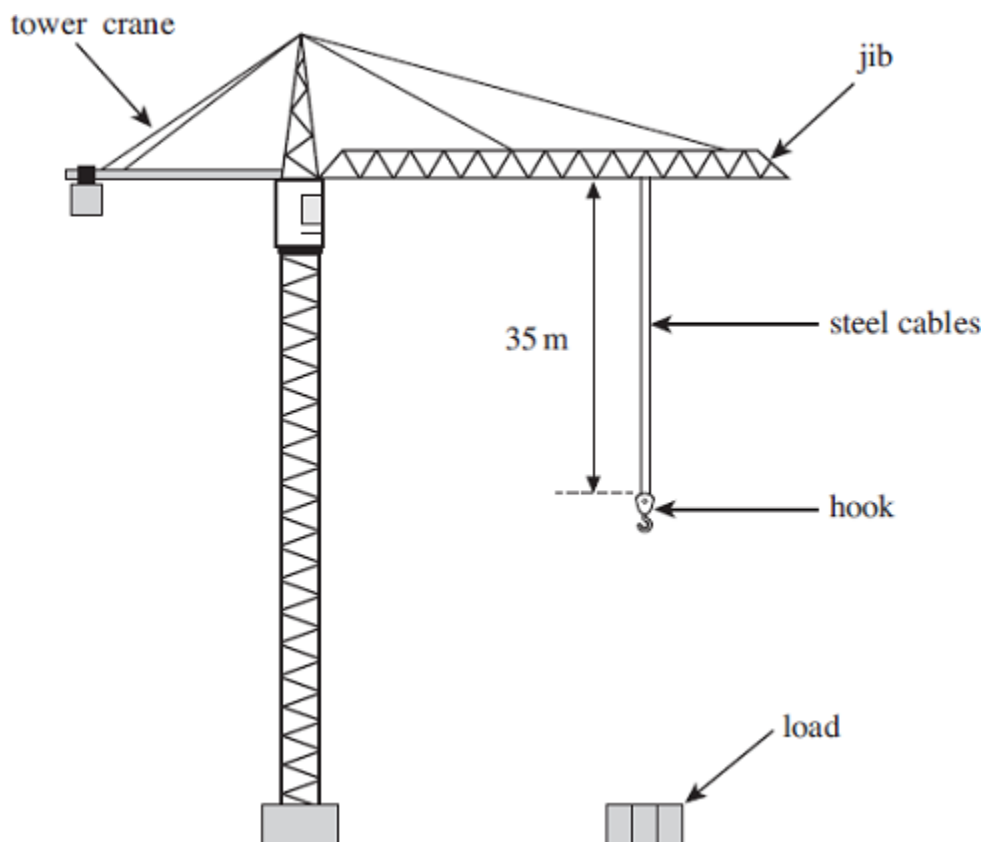
Which line, **A** to **D**, in the table, gives the correct expressions for the magnitude of the change of momentum, and the change of kinetic energy, of the ball?

	magnitude of change of momentum	change of kinetic energy
A	$2mv$	0
B	$2mv$	mv^2
C	0	0
D	0	mv^2

(Total 1 mark)

45.

The diagram below shows a tower crane that has two identical steel cables. The length of each steel cable is 35 m from the jib to the hook.



- (a) Each cable has a mass of 4.8 kg per metre. Calculate the weight of a 35 m length of one cable.

weight = _____ N

(2)

- (b) The cables would break if the crane attempted to lift a load of 1.5×10^6 N or more. Calculate the breaking stress of **one** cable.

cross-sectional area of each cable = $6.2 \times 10^{-4} \text{ m}^2$

breaking stress = _____ Pa

(2)

- (c) When the crane supports a load **each** cable experiences a stress of 400 MPa. Each cable obeys Hooke's law. Ignore the weight of the cables.

Young modulus of steel = 2.1×10^{11} Pa

- (i) Calculate the weight of the load.

weight = _____ N

(2)

- (ii) The unstretched length of each cable is 35 m.

Calculate the extension of each cable when supporting the load.

extension = _____ m

(3)

- (iii) Calculate the combined stiffness constant, k , for the **two** cables.

stiffness constant = _____ Nm^{-1}

(2)

- (iv) Calculate the total energy stored in both stretched cables.

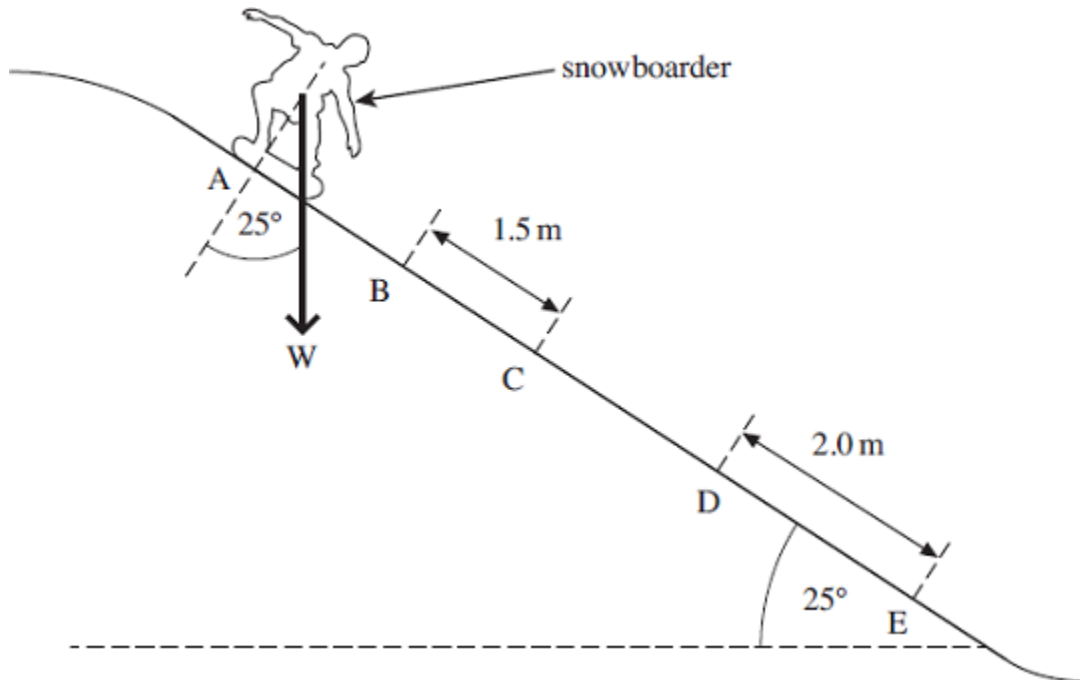
energy stored = _____ J

(2)

(Total 13 marks)

46.

A snowboarder slides down a slope, as shown in the diagram below. Between **B** and **C** her acceleration is uniform.



- (a) The snowboarder travels 1.5 m from B to C in a time of 0.43 s and her velocity down the slope at C is 5.0 ms^{-1} .

Calculate her velocity down the slope at B.

velocity = _____ ms^{-1}

(3)

- (b) The combined mass of the snowboarder and snowboard is 75 kg and the angle of the slope is 25°

- (i) Calculate the component of the weight of the snowboarder and snowboard acting down the slope.

weight component = _____ N

(2)

- (ii) At D the snowboarder has reached a constant velocity. She moves a distance of 2.0 m at constant velocity between D and E.

Calculate the work done against resistive forces as she moves from D to E.

work done = _____ J

(1)

- (c) State and explain what happens to the gravitational potential energy lost between D and E.

(3)

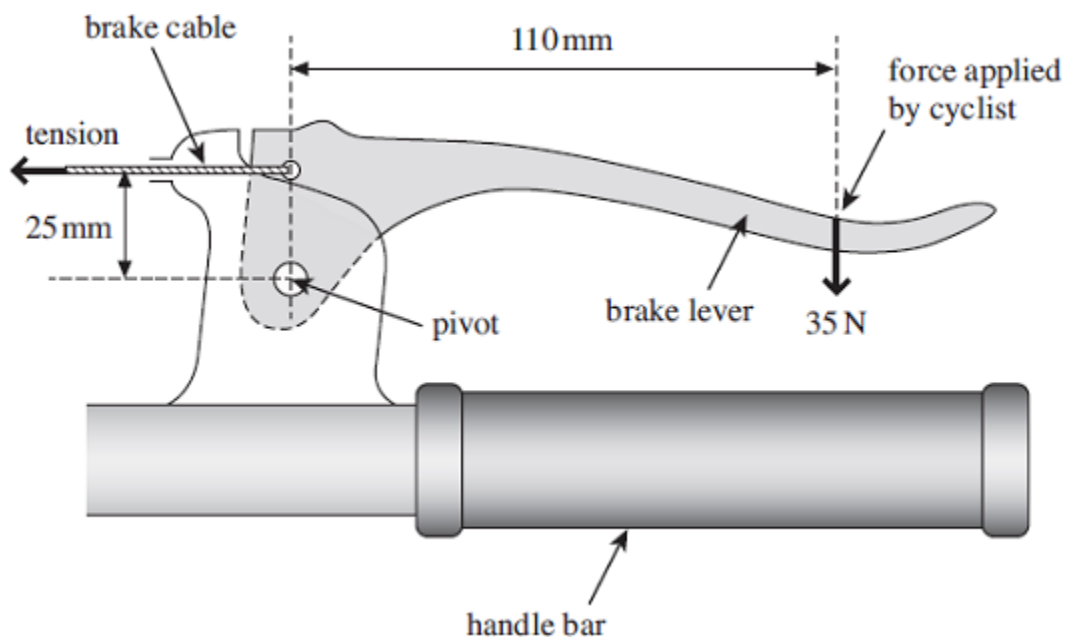
(Total 9 marks)

47.

- (a) State the principle of moments.

(3)

- (b) The diagram below shows a bicycle brake lever that has been pulled with a 35 N force to apply the brake.



- (i) Calculate the moment of the force applied by the cyclist about the pivot. State an appropriate unit.

moment = _____ unit _____

(3)

- (ii) Calculate the tension in the brake cable. Assume the weight of the lever is negligible.

tension = _____ N

(3)

- (c) In order to maintain a constant velocity of 15 ms^{-1} downhill, the cyclist applies the brake. The power developed by the braking force is 2.8 kW .

Calculate the total average frictional force between the brake blocks and the wheel rim.

frictional force = _____ N

(2)

(Total 11 marks)

48.

- (a) (i) Define gravitational field strength and state whether it is a scalar or vector quantity.

(2)

- (ii) A mass m is at a height h above the surface of a planet of mass M and radius R . The gravitational field strength at height h is g . By considering the gravitational force acting on mass m , derive an equation from Newton's law of gravitation to express g in terms of M , R , h and the gravitational constant G .

(2)

- (b) (i) A satellite of mass 2520 kg is at a height of $1.39 \times 10^7 \text{ m}$ above the surface of the Earth. Calculate the gravitational force of the Earth attracting the satellite. Give your answer to an appropriate number of significant figures.

force attracting satellite _____ N

(3)

- (ii) The satellite in part (i) is in a circular polar orbit. Show that the satellite would travel around the Earth three times every 24 hours.

(5)

- (c) State and explain **one** possible use for the satellite travelling in the orbit in part (ii).

(2)

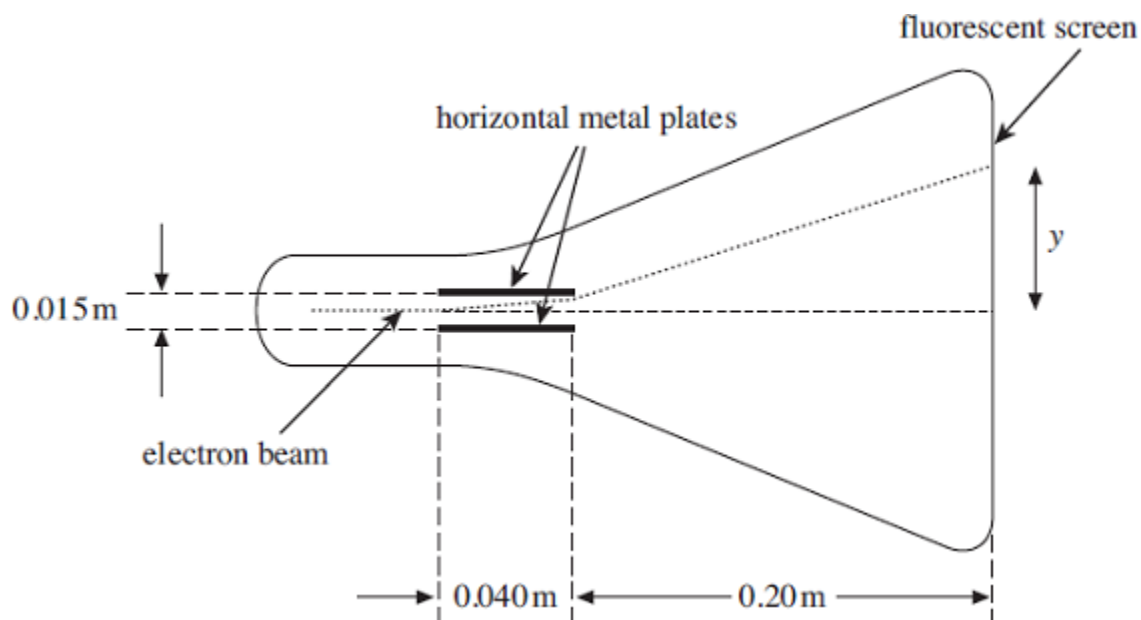
(Total 14 marks)

49.

- (a) Describe how a beam of fast moving electrons is produced in the cathode ray tube of an oscilloscope.

(3)

- (b) The figure below shows the cathode ray tube of an oscilloscope. The details of how the beam of electrons is produced are not shown.



The electron beam passes between two horizontal metal plates and goes on to strike a fluorescent screen at the end of the tube. The plates are 0.040 m long and are separated by a gap of 0.015 m. A potential difference of 270 V is maintained between the plates. An individual electron takes 1.5×10^{-9} s to pass between the plates. The distance between the right-hand edge of the plates and the fluorescent screen is 0.20 m.

- (i) Show that the vertical acceleration of an electron as it passes between the horizontal metal plates is approximately $3.2 \times 10^{15} \text{ ms}^{-2}$.

(3)

- (ii) Show that the vertical distance travelled by an electron as it passes between the horizontal metal plates is approximately 3.6 mm.

(2)

- (iii) Show that the vertical component of velocity achieved by an electron in the beam by the time it reaches the end of the plates is approximately $4.7 \times 10^6 \text{ m s}^{-1}$.

(2)

- (iv) Calculate the vertical displacement, y , of the electron beam from the centre of the screen. Give your answer in m.

vertical displacement _____ m

(3)

(Total 13 marks)

50.

The driver of a car travelling with a velocity, v , along a level road, applies the brakes. The brakes lock and the car skids to a stop. The skidding distance, d , is given by

$$d = kv^2$$

where k is a constant.

- (a) For a car travelling at a speed of 30 ms^{-1} , d is 45 m. Calculate the value of d when the car is travelling at 15 ms^{-1} .

d _____ m

(2)

- (b) The mass of the car and its passengers is 700 kg. Calculate the average skidding force that would bring the car to a stop from an initial speed of 30 ms^{-1} in a skidding distance of 45 m.

average skidding force _____ N

(4)

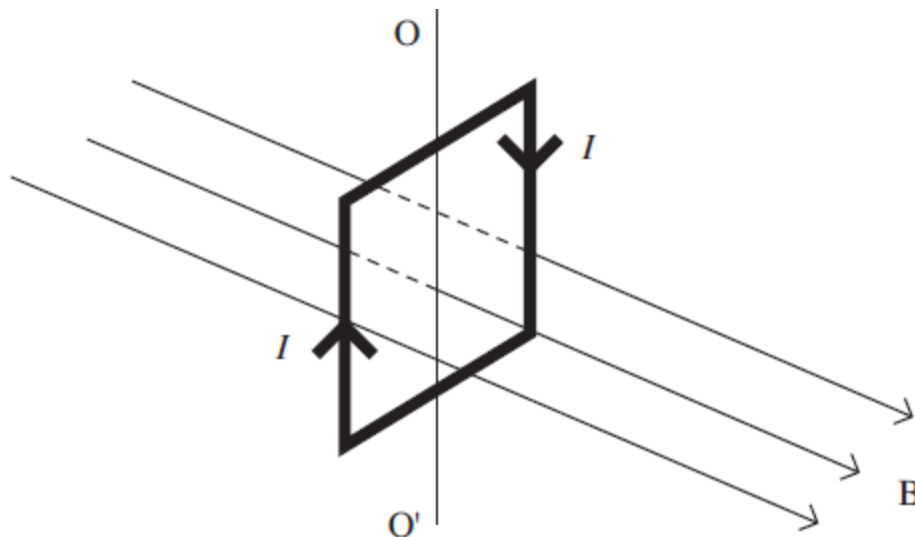
- (c) By considering the equations for kinetic energy and the skidding distance, discuss how the heat generated when the car skids is related to d .

(3)

(Total 9 marks)

51.

The diagram shows a vertical square coil whose plane is at right angles to a horizontal uniform magnetic field B . A current, I , is passed through the coil, which is free to rotate about a vertical axis OO' .



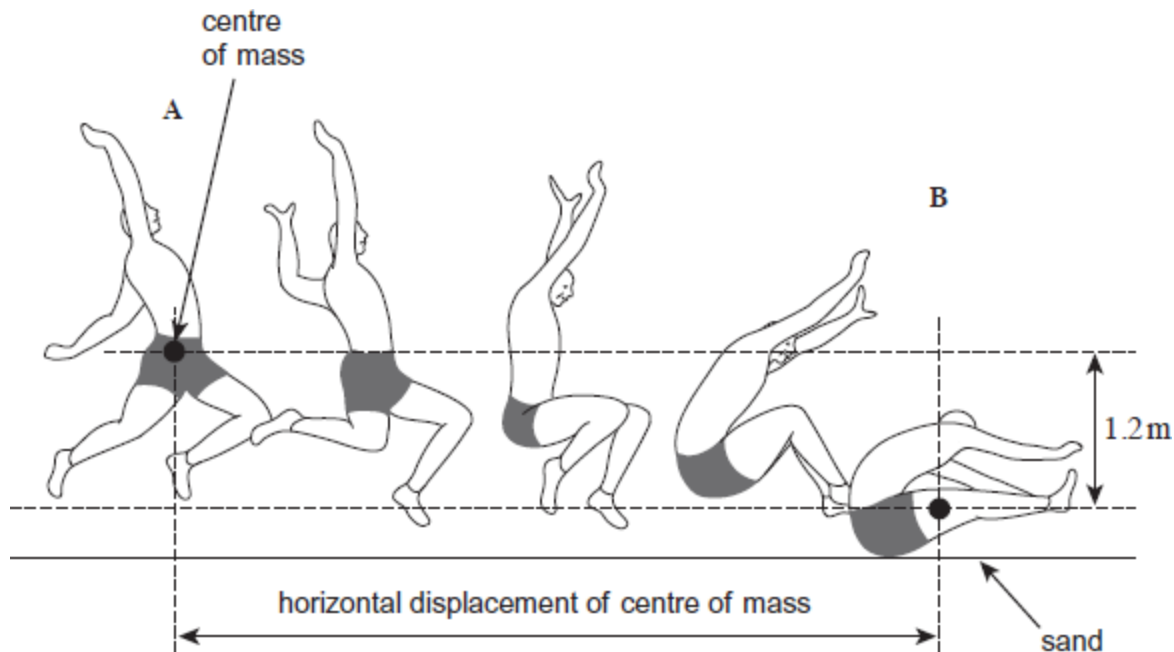
Which one of the following statements is correct?

- A** The forces on the two vertical sides of the coil are equal and opposite.
- B** A couple acts on the coil.
- C** No forces act on the horizontal sides of the coil.
- D** If the coil is turned through a small angle about OO' and released, it will remain in position.

(Total 1 mark)

52.

The motion of a long jumper during a jump is similar to that of a projectile moving under gravity. The figure below shows the path of an athlete above the ground during a long jump from half-way through the jump at position **A**, to position **B** at which contact is made with sand on the ground. The athlete is travelling horizontally at **A**.



(a) During this part of the jump, the centre of mass of the athlete falls 1.2 m.

(i) Calculate the time between positions **A** and **B**.

time _____ s

(3)

(ii) The athlete is moving horizontally at **A** with a velocity of 8.5 m s^{-1} . Assume there is no air resistance. Calculate the horizontal displacement of the centre of mass from **A** to **B**.

horizontal displacement _____ m

(2)

- (b) (i) The athlete in the image above slides horizontally through the sand a distance of 0.35 m before stopping.

Calculate the time taken for the athlete to stop. Assume the horizontal component of the resistive force from the sand is constant.

time _____ s

(2)

- (ii) The athlete has a mass of 75 kg. Calculate the horizontal component of the resistive force from the sand.

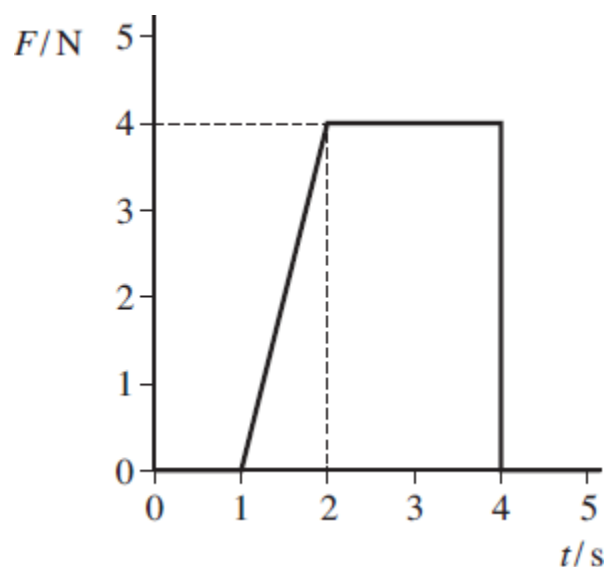
horizontal component of resistive force _____ N

(3)

(Total 10 marks)

53.

The graph shows how the resultant force, F , acting on a body varies with time, t .



What is the change in momentum of the body over the 5 s period?

- A** 2N s
- B** 8N s
- C** 10N s
- D** 12N s

(Total 1 mark)

54.

A golf club strikes a stationary golf ball of mass 4.8×10^{-2} kg and the ball leaves the club with a speed of 95 m s^{-1} . If the average force exerted on the ball is 7800 N, how long are the ball and club in contact?

- A** 5.8×10^{-4} s
- B** 1.2×10^{-2} s
- C** 0.51 s
- D** 0.58 s

(Total 1 mark)

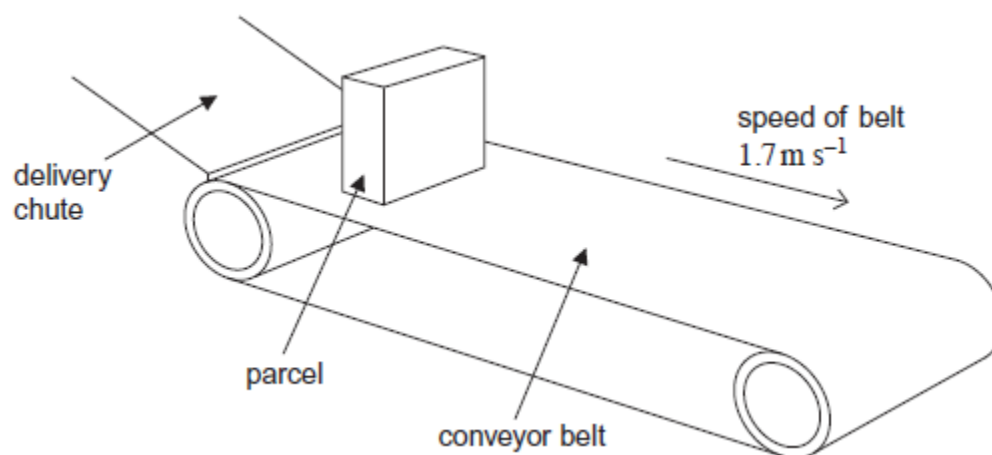
55.

- (a) A parcel of mass 15 kg drops from a delivery chute onto a conveyor belt as shown in **Figure 1**.

The belt is moving at a steady speed of 1.7 m s^{-1} .

The parcel lands on the moving belt with negligible speed and initially starts to slip. It takes 0.82 s for the parcel to gain enough speed to stop slipping and move at the same speed as the conveyor belt.

Figure 1



- (i) Calculate the change in kinetic energy of the parcel during the first 0.82 s.

change in kinetic energy _____ J

(2)

- (ii) The average horizontal force acting on the parcel during the first 0.82 s is 31 N.

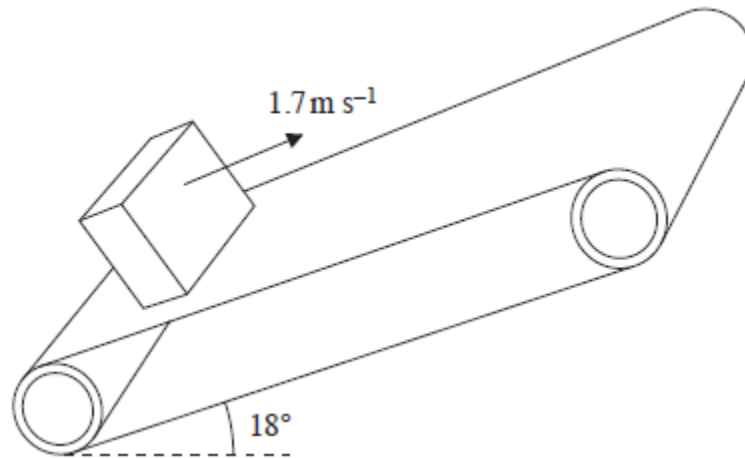
Calculate the horizontal distance between the parcel and the end of the delivery chute 0.82 s after the parcel lands on the conveyor belt. Assume that the parcel does not reach the end of the conveyor belt.

horizontal distance _____ m

(2)

- (b) At a later stage the parcel is being raised by another conveyor belt as shown in **Figure 2**.

Figure 2



This conveyor belt is angled at 18° to the horizontal and the parcel moves at a steady speed of 1.7 m s^{-1} without slipping.

Calculate the rate at which work is done on the parcel.

rate at which work is done _____ W

(3)

(Total 7 marks)

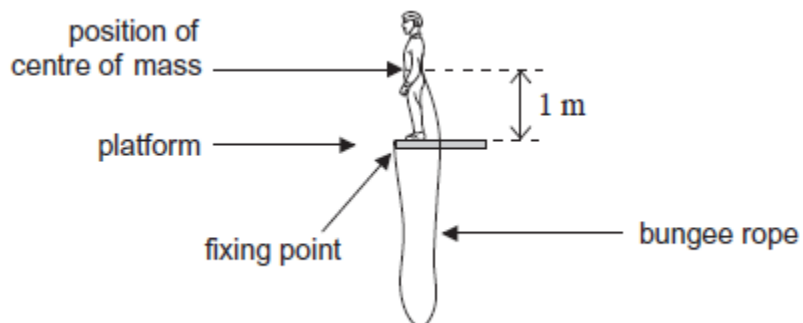
56.

The diagram below shows a bungee jumper of mass 75 kg about to step off a raised platform. The jumper comes to a halt for the first time when his centre of mass has fallen through a distance of 31 m.

The bungee rope has an unextended length of 19 m and a stiffness of 380 N m^{-1} .

Ignore the effects of air resistance and the mass of the rope in this question.

Treat the jumper as a point mass located at the centre of mass.



- (a) (i) Calculate the extension of the bungee rope when the centre of mass of the jumper has fallen through 31 m.

extension _____ m

(1)

- (ii) Calculate the resultant force acting on the jumper when he reaches the lowest point in the jump.

resultant force _____ N

(2)

- (b) Calculate the extension of the rope when the jumper's acceleration is zero.

extension _____ m

(2)

- (c) The extension of the bungee rope is 5.0 m when the jumper's centre of mass has fallen through a distance of 25 m.

Use the principle of conservation of energy to calculate the speed of the jumper in this position.

speed _____ m s^{-1}

(4)

- (d) The bungee jump operator intends to use a bungee rope of the same unextended length but with a much greater stiffness. The rope is to be attached in the same way as before.

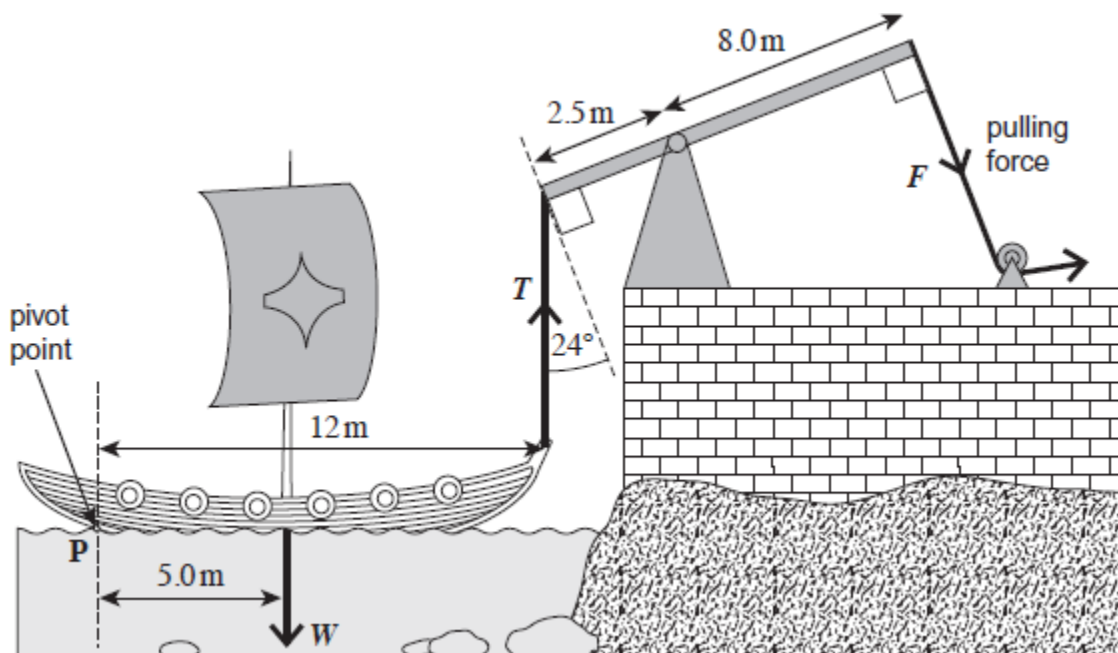
Explain, with reference to the kinetic energy of the jumper, any safety concerns that may arise as the jumper is slowed down by the new rope.

(3)

(Total 12 marks)

57.

It is said that Archimedes used huge levers to sink Roman ships invading the city of Syracuse. A possible system is shown in the following figure where a rope is hooked on to the front of the ship and the lever is pulled by several men.



- (a) Calculate the mass of the ship if its weight was 3.4×10^4 N.

mass _____ kg

(1)

- (b) Calculate the moment of the ship's weight about point **P**. State an appropriate unit for your answer.

moment _____ unit _____

(2)

- (c) Calculate the minimum vertical force, T , required to start to raise the front of the ship. Assume the ship pivots about point **P**.

minimum vertical force _____ N

(2)

- (d) Calculate the minimum force, F , that must be exerted to start to raise the front of the ship.

force _____ N

(3)

(Total 8 marks)

58.

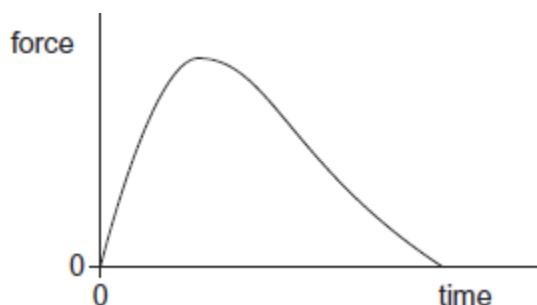
A gas molecule of mass m moving at velocity u collides at right angles with the side of a container and rebounds elastically. Which one of the following statements concerning the motion of the molecule is **incorrect**?

- A The magnitude of the change in momentum of the molecule is zero.
- B The magnitude of the change in momentum of the molecule is $2mu$.
- C The force exerted by the molecule on the side of the container is equal to the force exerted by the container on the molecule.
- D The change in kinetic energy of the molecule is zero.

(Total 1 mark)

59.

The graph shows how the force acting on a rocket varies with time.



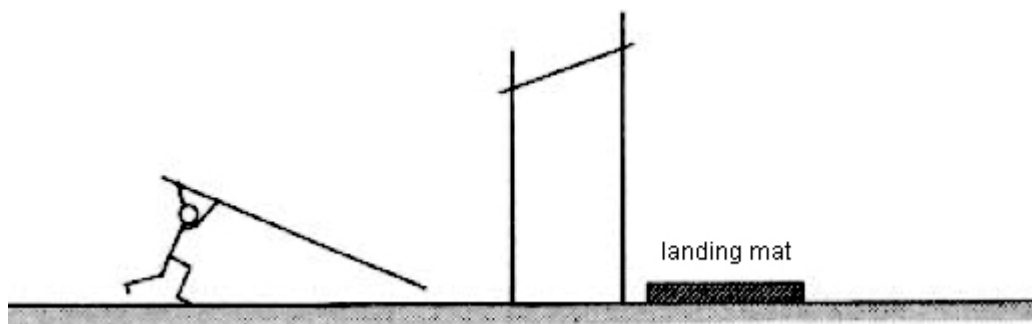
Which one of the following is represented by the area under the graph?

- A distance travelled
- B gain in kinetic energy
- C change in velocity
- D change in momentum

(Total 1 mark)

60.

The following figure shows an athlete of mass 65 kg about to perform a pole vault.



The centre of mass of the athlete rises 4.2 m during the vault.

- (a) Calculate the change in potential energy of the athlete between take off and reaching the highest point.

change in potential energy _____ J

(2)

- (b) Assuming that the centre of mass falls the same distance when falling. Calculate the vertical speed, in m s^{-1} , of the athlete when he lands.

vertical speed _____ m s^{-1}

(2)

- (c) Explain how the landing mat reduces the force experienced by the athlete to an acceptable level when landing.

(2)

(Total 6 marks)

Mark schemes

1.

(a) ANY 2 from

- Slow moving neutrons or low (kinetic) energy neutrons

B1

- (They are in) thermal equilibrium with the moderator /
Are in thermal equilibrium with other material (at a
temperature of about 300 K)

B1

- Have energies of order of 0.025 eV
- Have (range of) KE similar to that of a gas at 300 K or
room temperature

2

(b) (i) Use of $mgh = \frac{1}{2}mv^2$ by substitution or rearranges to make
h the subject

PE for use of equation of motion (constant acceleration)

C1

0.086(1) (m) or 0.086(2) (m)

A1

2

- (ii) Correct equation for conservation of momentum
 $m_1 u_1 (+ m_2 u_2) = m_1 v_1 + m_2 v_2$
or states momentum before = momentum after **or** $p_{\text{before}} = p_{\text{after}}$

B1

(Correct clear Manipulation =) $0.065 (+ 0) = - 0.0325 + 0.0975$

or $-0.065 (+ 0) = 0.0325 - 0.0975$ must see signs

Condone non-SI here:

$$65 (+0) = - 32.5 + 97.5$$

B1

States initial kinetic energy = final kinetic energy **or**

States kinetic energy is conserved

Allow equivalent on RHS where masses are summed in one KE term

B1

(Correct clear Manipulation=) $0.04225 = 0.0105625 + 0.0316875$

Or equivalent workings with numbers seen

and $0.04225 = 0.04225$ / KE before = KE after

B1

4

- (iii) (Percentage / fraction remaining after 1 collision =) $\frac{1}{4} = 25\%$
seen

C1

OR

% remaining = $100 \times \frac{1}{2} m(1.3^2 - 0.65^2) / \frac{1}{2} m1.3^2$

or hockey ball = 0.0317 **and** initial ke = 0.04225

or their $KE_{\text{hb}} / 0.04225$ or their $KE_{\text{hb}} / \text{their } KE_{\text{T}}$

75(%)

range 75 to 76

A1

2

(iv) **Demonstrates:**

Slowing down / loss of KE of golf ball is like neutrons slowed down / Neutrons can lose KE by elastic collisions also

B1

Differs:

Collisions in a reactor are not always / rarely head-on

or

KE loss is variable

or

Collisions are not always elastic

or

Ratio of mass of neutron to mass of nucleus is usually much smaller in a reactor

B1

2

(v) Water

B1

1

[13]

2.

(a) (i)

$$(s = \frac{1}{2}gt^2)$$

Allow $g=10$ (0.5477)

$$1.5 = \frac{1}{2}9.81t^2 \quad \text{OR} \quad t = \sqrt{\frac{2s}{g}} \quad \text{OR} \quad t = \sqrt{\frac{2 \times 1.5}{9.81}} \quad \checkmark$$

$$(= 0.553) = 0.55 \text{ (s) } \checkmark$$

0.6 gets 2 marks only if working shown. 0.6 on its own gets 1 mark.

2

(ii) $(s = vt = 430 \times 0.553 = 237.8 =) 240 \text{ (m) } \checkmark$
ecf a(i)

1

(b) their vertical motion is independent of their horizontal motion

OR downward / vertical acceleration is the same for both

OR acceleration due to gravity is the same for both

OR vertical speed / velocity is the same for both $\checkmark$

Allow 'time is constant'

Don't allow 'similar'

(bullets A and B will be in the air) for the same time $\checkmark$

(Horizontal acceleration is zero and thus horizontal) distance is proportional to horizontal speed **OR** $s = ut$ where u is the horizontal velocity $\checkmark$

'velocity smaller so distance smaller' is not sufficient

3

[6]

3.

(a) (i) $W = 2mg \cos\phi \quad \therefore m = W/(2g \cos\phi)$ ✓

The question says show that, so the candidates must write down both steps.

1

(ii) Well drawn straight line of best fit. ✓

The line should follow the trend of the points with an even scatter of points on either side of the line.

1

(b) (i) Triangle drawn with smallest side at least 8 cm in length. ✓

Correct readings taken from the line for the triangle ✓

Gradient in the range 0.45 to 0.49 (0.445 to 0.494) quoted to 2 or 3 significant figures ✓

The size of the triangle can be identified from readings taken from the line.

The third mark is independent of the other two: error carried forward for incorrect readings (or for a poor line of best fit) which give a gradient out of range is not allowed.

3

(ii) Candidate's answer for gradient in (b)(i) correctly multiplied by g (expected answer 4.6) ✓

N ✓

No s.f. penalty.

The second mark is for the unit and can be awarded if the numerical answer is incorrect.

2

(c) $\delta x\% = 0.2$ and $\delta y\% = 0.5$ ✓

$$\delta(x/y)\% = \delta x\% + \delta y\% = 0.2 + 0.5 = 0.7 \quad \checkmark$$

$$\text{Use of } \delta(x/y)^2\% = 2 \times \delta(x/y)(\%) \quad \checkmark$$

Final answer is ($\pm$) 1.4 (%) which automatically gains all three marks

Otherwise

Accept only 1 s.f. for 1st and/or 2nd marks.

The third mark is for the method, not the final answer

3

(d) (i) Systematic errors in measurements are errors which show a pattern or a bias or a trend ✓

Some acceptable alternatives

- **A systematic error** is one which deviates by a fixed amount from the true value of a measurement
- An error which has the same value in all readings
- A difference between the true value of a quantity and the indicated value caused by a fault in the measuring device
- Accept a good example of systematic error.

1

- (ii) y would be larger ✓
 because angle θ would be smaller
or
 because friction would be opposing the increasing weight of m ✓

2

[13]

4.

- (a) (i) 1000(N) AND 6000(N) seen

Independent marks

OR

$$F = \sqrt{(1000)^2 + (6000)^2} \quad \checkmark \text{ allow incorrect values seen}$$

$$= 6083 \text{ (N)} (= 6100) \quad \checkmark \text{ More than 2 sf seen}$$

Allow full credit for appropriate scale drawing

Ignore rounding errors in 3rd sig fig.

2

- (ii) $\tan \theta = 1000 / 6000$ or correct use of sin or cos ✓

$$\theta = 9.5 \text{ (} 9.46^\circ \text{)} \quad \checkmark$$

Allow range 9.4 – 10.4

Use of cos yields 10.4

Allow use of 6100

Some working required for 2 marks.

Max 1 mark for correct calculation of vertical angle (range 79.6 – 80.6) some working must be seen

2

- (iii) ($m = W/g =$) $6500 / 9.81 (= 662.6 \text{ kg})$ ✓

$$(a = F / m = 6083 / 662.6)$$

$$= 9.2 \text{ (ms}^{-2}\text{)} \quad \checkmark \text{ (} 9.180 \text{)}$$

Use of weight rather than mass gets zero

Correct answer on its own gets 2 marks

Penalise use of $g=10$ in this question part only (max 1)

2

- (b) (i) $= 6500 \times 600$ ✓ ($662.6 \times 9.81 \times 600$)

$$= 3\,900\,000 \quad \checkmark \text{ (J)}$$

Look out for $W \times g \times h$ which gives 39000000 (gets zero)

Correct answer on its own gets 2 marks

Do not allow use of $1/2 mv^2 (= 39\,000)$

2

- (ii) $(E = Pt =) 320\,000 \times; 55 (= 17\,600 \text{ kJ})$
OR $P = 1(b)(i) / 55 (7.09 \times 10^4)$ ✓
 $3.9 / 17.6$ OR $70.9 / 320$ OR $= 0.22(16)$ ✓ ecf from first line
Some valid working required for 3 marks

conversion to a percentage $(= 22 \%)$ ✓

Look out for physics error: Power / time $(320/55)$ then use of inverted efficiency equation yielding correct answer
Do not allow percentages $\geq 100\%$ for third mark

3

[11]

5.

- (a) Force proportional to extension ✓

up to the limit of proportionality (accept elastic limit) ✓ dependent upon award of first mark

Symbols must be defined

Accept word equation

allow ' $F = k\Delta L$ (or $F \propto \Delta L$) up to the limit of proportionality' for the second mark only

allow stress $\propto$ strain up to the limit of proportionality' for the second mark only

2

- (b) Gradient clearly attempted / use of $k = F / \Delta L$ ✓

$$k = 30 / 0.026 = 1154$$

$$\text{or } 31 / 0.027 = 1148$$

correct values used to calculate gradient with appropriate 2sf answer given (1100 or 1200)

1100 or 1200 with no other working gets 1 out of 2

OR 1154 ± 6 seen

Do not allow $32/0.0280$ or $33/0.0290$ (point A) for second mark.

AND load used ≥ 15 ✓ $(= 1100 \text{ or } 1200 \text{ (2sf)})$

$32 / 0.028$ is outside tolerance. $32/0.0277$ is just inside.

Nm⁻¹ / N / m (newtons per metre) ✓ (not n / m, n / M, N / M)

3

- (c) any area calculated or link energy with area / use of $1 / 2F\Delta L$ ✓

(or 0.001 Nm for little squares)

35 whole squares, 16 part gives 43 ± 1.0

OR equivalent correct method to find whole area ✓

0.025 Nm per (1cm) square $\times$ candidates number of squares and correctly evaluated

OR $(= 1.075) = 1.1 \text{ (J)}$ (1.05 to 1.10 if not rounded) ✓

3

- (d) permanent deformation / permanent extension ✓

*Allow: 'doesn't return to original length'; correct reference to 'yield'
e.g. allow '**extension beyond the yield point**'
do not accept: 'does not obey Hooke's law' or 'ceases to obey Hooke's law',*

1

- (e) any line from B to a point on the x axis from 0.005 to 0.020 ✓

straight line from B to x axis (and no further) that reaches x axis for $0.010 \leq \Delta L \leq 0.014$ ✓

2

- (f) work done by spring < work done by the load

Accept 'less work' or 'it is less' (we assume they are referring to the work done by spring)

1

[12]

6.

- (a) 8300×9.81 OR $= 81423$ ✓
($8300 \times 9.81 \sin 25$)

$= 3.4 \times 10^4$ (N) ✓ (34 411 N) ecf from first line unless g not used

$m \sin 25$ gets zero

*Penalize use of $g = 10$ here only
(35 077 N)*

Allow 9.8 in any question

Correct answer only, gets both marks for all two mark questions

2

- (b) (i) ($E_k = \frac{1}{2}mv^2$)

$$= \frac{1}{2} \times 8300 \times 56^2 \checkmark$$

$$= 1.3 \times 10^7 \text{ (J)} \checkmark (13\,014\,400) \text{ allow use of } 8300 \text{ only}$$

In general: Penalise transcription errors and rounding errors in answers

2

- (ii) $mgh = KE$ (13 014 400) for mgh allow GPE or E_p

$$\text{OR } 13\,014\,400 / 81\,423 \checkmark$$

$$h = 160 \text{ (m)} \checkmark (159.8) \text{ ecf 1bi}$$

Allow use of suvat approach

2

- (c) (i) (work done) by friction \ drag \ air resistance \ resistive forces ✓
(energy converted) to internal \ thermal energy ✓

Allow 'heat'

2

(ii) $0.87 \times (8300 \times 9.81 \times 140 = 9\,917\,000)$ OR $v = \sqrt{\frac{2 \times (9\,917\,000)}{8300}} \checkmark$
 $= 49 \text{ (} = 48.88 \text{ ms}^{-1} \text{)} \checkmark$

87% of energy for 140m or 160m only for first mark.

Use of 160 (52.26) and / or incorrect or no % (52.4) gets max 1 provided working is shown

Do not credit suvat approaches here

2

[10]

7.

(a) (i) vector has direction **and** a scalar does not **(1)**

(ii) scalar examples; any two e.g. speed, mass, energy, time, power

vector examples; any two e.g. displacement, velocity, acceleration, force or weight

(1)(1)(1) for 4 correct, **(1)(1)** for 3 correct, **(1)** for 2 correct

4

(b) (i) horizontal component ($= 2.8 \cos 35$) $= 2.3 \text{ (kN)}$ (2293.6) **(1)**

vertical component ($= 2.8 \sin 35$) $= 1.6 \text{ (kN)}$ (1606.0) **(1)**

(ii) power = force $\times$ velocity **or** $2.3 \text{ kN} \times 8.3 \text{ m s}^{-1}$ **(1)** (ecf from (b) (i))

$= 1.9 \times 10^4$ (19037 or 19100) **(1)** ecf

W (or J s^{-1}) **(1)** (or 19 W (or kJ s^{-1}))

5

(c) (area of cross-section of cable $= \pi \times (\frac{1}{2} 0.014)^2$) (1)

$$= 1.5(4) \times 10^{-4} \text{ (m}^2\text{)} (1)$$

$$\text{stress } (=F/A) = \frac{2800 \text{ N}}{1.54 \times 10^{-4} \text{ m}^2}$$

(allow ecf here if attempt to calculate area) (1)

$$= 1.8(2) \times 10^7 \text{ (1) ecf}$$

Pa (or N m^{-2}) (1)

QWC	descriptor	mark range
good-excellent	The candidate provides a comprehensive and coherent description which includes all the necessary measurements in a logical order. The description should show awareness of the need to use a range of standard masses. In addition, the use of the measurements is explained clearly, including an outline of a graphical method to find the mass of the rock sample, or calculation using two or more standard masses and averaging. For 6 marks there must be a description of how to make accurate measurements.	5-6
modest-adequate	The candidate's description includes the necessary measurements using one standard mass as well as the rock sample. The description may not be presented in a logical order and they show little consideration in relation to making the measurements accurately. A clear explanation is provided of how to find the mass of the rock sample from their measurements, including correct use of Hooke's law through calculations or inadequate graphical method.	3-4
poor-limited	The candidate knows the necessary measurements to be made using a standard mass and the rock sample. The explanation of how to find the mass of the rock sample may be sketchy.	1-2

5

[14]

8.	correct boxes ticked gravitational potential energy (1)	B1	1	[3]
	potential energy and kinetic energy (1)			
	elastic potential energy (in 'rope') (1) (condone gravitational PE in addition)	B1		
		B1		
9.	(a) 2800/cos 20 = 3000 (2980)N (1)	B1	1	[2]
	(b) 42000J (1)			
		B1	1	
10.	(a) velocity vector tangential to path and drawn from the ball, arrow in correct direction (1)			
	acceleration vector vertically downwards, arrow drawn and in line with ball (1)		2	
	(b) (i) $s = \frac{1}{2}gt^2$ gives $t = \sqrt{\frac{2s}{g}} = \sqrt{\frac{2 \times 24}{9.8(1)}} (1) = 2.2(1) \text{ s } (1)$			
	(ii) $v (= s/t) = 27/2.2(1) (1) = 12(.2 \text{ m s}^{-1})$ or $12(.3) (1)$ (ecf from (b)(i)) (answer only gets both marks)		4	[6]

11.

vertical component of rope = $610 \times \cos(20)$ or 573(N)

C1

610 cos 20 seen in an equation

(vertical component of resultant) = $590 - 573$ or their F_v

C1

16.8 or 17(N) cao

A1

[3]

12.

work done = 1500×0.35 (525J)

or power = work done/time taken (1)

C1

615-620W (1) 2 or 3 sf only

A1

[2]

13.

(a) (i) $65 \times 9.8 \times 35$ seen and evaluated to 22295 or 2231 or 22300J

B1

(ii) correct substitution of 65 kg and either 11000J or 18 m s^{-1} in ke formula seen

B1

18.4 (18.397) (m s^{-1}) to at least 3 sf

B1

(iii) distance = energy loss/force or work done/force or numerical equivalent

C1

64-64.3 using $E_p = 20\text{kJ}$ or 79 – 81(m) using 22.3 kJ

A1

(iv) friction

B1

air resistance

B1

further detail eg friction at ski-ice surface

or caused by need to move air when passing through it

B1

8

(b) (i) time = $\Delta v/a$ or numerical equivalent

C1

6.4(3) – 6.6(6.57) (s)

A1

(ii) use of appropriate kinematic equation

C1

(57.8 – 60.4) 58 m or 60 (m) to 2 sf

A1

4

[12]

14.

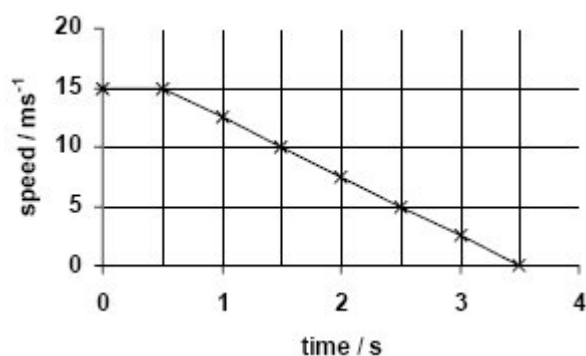
(a) axes labelled correctly with correct units shown (1)

suitable scales (1)

6 points plotted correctly (1)

all points plotted correctly (1)

both sections of line drawn correctly (1)



5

- (b) (i) the gradient (of the slope section) represents the deceleration/
calculates 5 m s^{-2} **(1)**
- (deceleration is uniform because) the gradient is constant/
line is straight **(1)**
- (ii) distance travelled = area under line (0 to 3.5 s or 0.5 to 3.5 s) **(1)**
- (= 15.0×0.5) = 7.5 m in first 0.5 s **(1)**
- (= $0.5 \times 15.0 \times 3.0$) or $s = \frac{1}{2}(u + v)t$, etc) = 22.5 m
(from 0.5s to 3.5s) **(1)**
- (= $\frac{1}{2}(0.5 + 3.5) \times 15$ gets all three method marks)
(total distance travelled = $7.5 + 22.5$) = 30m **(1)**

6

[11]

15.

- (a) (i) clear working:
attempts to evaluate area under line
(12 – 13 squares $\times 0.1 \text{ N s}$)
or $\frac{1}{2} \times 106(105) \times 24 \times 10^{-3}$ seen

B1

1.260 – 1.272 (N s) 1.2 – 1.3 for square counting

B1

- (ii) area under graph/impulse = Δmv

B1

22.3 (22.8) (m s^{-1})

B1

4

- (b) use of Pythagoras $\sqrt{22.3^2 + 6.1^2}$ or $\tan^{-1}(6.1/22.3)$

B1

or $\sqrt{20^2 + 6.1^2}$ or $\tan^{-1}(6.1/20)$

22.8 – 23.8 (m s^{-1}) 20.9 or 21 (m s^{-1})

B1

14.9 – 15.5 ($^\circ$) (15 – 16 ($^\circ$)) 17/18($^\circ$)

B1

3

[7]

16.

- (a) a force/1300 (condone power of ten error)

C1

$$6200 \div 1300$$

C1

$$4.77 \text{ (m s}^{-2}\text{)}$$

A1

3

- (b) use of suitable kinematic equation

C1

$$\text{eg distance} = 27^2 / (2 \times 4.8) \text{ correct sub}$$

C1

$$76/76.4 \text{ m} / 72.9 \text{ from } a = 5 / 75.9 \text{ from } a = 4.8$$

A1

3

[6]**17.**

B

[1]**18.**

- (a) (i) ($E_K = \frac{1}{2} mv^2$) $0.5 \times 68 \times 16^2$ **(1)** = **8700** or 8704(J) **(1)**
 (ii) ($\Delta E_P = mg\Delta h$) $68 \times 9.8(1) \times 12$ **(1)** = **8000** or 8005 (J) **(1)**
 (iii) any **three** from

gain of kinetic energy > loss of potential energy **(1)**

(because) cyclist does work **(1)**

energy is wasted (on the cyclist and cycle) due to air resistance
or friction or transferred to thermal/heat **(1)**

KE = GPE + W – energy 'loss' **(1)** (owtte)

$$\text{energy wasted} (= 8000 + 2400 - 8700) = 1700(\text{J}) \text{ **(1)**}$$

7

- (b) (i) ($u = 16 \text{ m s}^{-1}$, $s = 160 \text{ m}$, $v = 0$, rearranging $s = \frac{1}{2} (u + v) t$ gives)

$$160 = \frac{1}{2} \times 16 \times t \text{ or } t = \frac{2s}{(u + v)} \text{ or correct alternative}$$

$$\frac{2 \times 160}{16} \text{ (gets 2 marks) } \mathbf{(1)} = 20\text{s } \mathbf{(1)}$$

- (ii) acceleration $a = \left(\frac{v - u}{t} \right) = \frac{0 - 16}{20}$ ecf (b) (i) $\mathbf{(1)} = (-) \mathbf{0.80} \text{ (m s}^{-2}\text{)}$
 resultant force $F = ma = 68 \times (-) 0.80 \mathbf{(1)} = (-) 54 \text{ (N) } \mathbf{(1)}$ or 54.4
 or (work done by horizontal force = loss of kinetic energy
 work done = force $\times$ distance gives)

$$\text{force} = \frac{(\text{loss of kinetic})\text{energy}}{\text{distance}} \mathbf{(1)} = \frac{8700 \text{ J}}{160 \text{ m}}$$

$$\text{ecf (a) (i) } \mathbf{(1)} = 54 \text{ (N) } \mathbf{(1)}$$

6

[13]

19.

- (a) (i) area under graph = energy stored

B1

$$\text{area} = \frac{1}{2} \text{ base} \times \text{height}$$

B1

or quotes $\frac{1}{2} F\Delta l$ and identifies F as F_{max} and Δl as d_{max}

B1

2

- (ii) equates $\frac{1}{2} F\Delta l$ and $\frac{1}{2} mv^2$ clearly

M1

$$v^2 = F_{\text{max}} d_{\text{max}} / m \text{ shown}$$

A1

2

- (b) (i) $\sqrt{650 \times 0.60 / 0.060}$

M1

$$81(80.6) \text{ (m s}^{-1}\text{)}$$

A1

2

(ii) **max 1 from**

friction between arrow and bow during release

B1

bow moves during release so absorbs some energy in kinetic form flight feathers provide drag

B1

uneven stretch/distortion in bow during draw

B1

1

(c) (i) $65\cos(35^\circ) = 53.2 \text{ (m s}^{-1}\text{)}$

B1

1

(ii) $0 = 53.2 - 9.8 \times t$ seen condone sign errors

B1

$t = 5.4 \text{ s}$ to top of motion

B1

in air for 10.8/10.9 s

B1

or $0 = 53t - \frac{1}{2} \times 9.8 \times t^2$ seen
condone sign errors

B1

$53t = \frac{1}{2} \times 9.8 \times t^2$
sign working must be correct

B1

in air for 10.8 s
must be from correct working

B1

3

(iii) $s = 65 \times \cos(55^\circ) \times 10.8$

C1

400 (m) 2 sf/405 (m) sf/410 m from 11 s

A1

2

[13]

20.

D

[1]

21.

- (a) conversion to seconds seen (60×40)
or velocity = $300/40$ seen
or energy gain in 40 mins = $750 \times 300 = 2.25 \times 10^5$ (J)

C1

use of $p = Fv$
power = $750 \times (300)/(2400)$
or $750 \times$ their velocity (eg seen $750 \times 300/40$)

C1

94 (93.8) (W) cnao

A1

3

- (b) $k = \frac{750}{15 \times 10^{-3}}$ (allow use of m or mm) use of $k = F/\Delta L$

C1

5.0×10^4

A1

N m^{-1} (allow if calculation not attempted or incomplete)

A1

3

[6]

22.

- (a) $\sqrt{1.3^2 + 1.0^2}$

C1

1.6/1.64 (m s^{-1})

A1

2

(b) $\text{angle} = \tan^{-1} (1.0/1.3)$

C1

N38°E/N37.6°E

A1

2

[4]

23.

- (a) (i) $(s = \frac{1}{2}(u + v) t) t = 2s/v$ ✓ (correct rearrangement, either symbols or values)
 $(= 100/6.7) = 15$ ✓ (s) (14.925)
 or alternative correct approach

2

(ii) $(KE = \frac{1}{2}mv^2 = \frac{1}{2} \times 83 \times 6.7^2) = 1900$ ✓ (1862.9 J)

2 sf ✓

2

(iii) $GPE = 83 \times 9.81 \times 3.0$ ✓ penalise use of 10, allow 9.8
 $= 2400$ (2443 J) ✓ do not allow 2500 (2490) for use of $g = 10$

2

- (b) (i) $5300 + 3700$ (or 9000 seen)
or $- 2443 - 1863$ (or $(-)$ 4306 seen) ✓
 $= 4700$ (J) ✓ (4694) ecf from parts aii & aiii

2

- (ii) mention of friction and appropriate location given ✓
 mention of **air** resistance (or drag) ✓

do not allow energy losses or friction within the motor

do not allow energy losses from the cyclist

must give a **cause** not just eg 'heat loss in tyres'

2

[10]

24.

- (a) (i) $(m = \rho V) = 1.2 \times 3.5 \times 10^5$ must be seen **(1)**
 4.2×10^5 (kg) seen **(1)**

2

(ii) $(E_k = \frac{1}{2}mv^2) = \frac{1}{2} \times 4.2 \times 10^5 \times 11^2$ **(1)**

2.5 or 2.4×10^7 (J) **(1)** (25.4 or 24.2 MJ)

2

(iii) $\frac{10 \times 10^6}{2.54 \times 10^7}$ (1) allow ecf from (a) (ii)

39 to 41.6 (%) (1) allow ecf from (a) (ii) unless percentage is greater than 100

2

(b) **advantages**, any one:

wind has: no fuel cost/causes no air pollution/no CO₂/is renewable (1)

disadvantages, any one from:

wind: varies/is intermittent/unreliable/causes visual pollution/noise/danger to birds/has a high capital cost/high 'start up' cost/requires changes to National Grid need (1) allow 'unpredictable'

2

[8]

25.

(a) (i) $v = \frac{s}{t}$ (1)

$t = 0.015$ (s) or 15 (ms) (1)

$0.68/0.015$ (1) (= 45)

3

(ii) $\left(a = \frac{\Delta v}{\Delta t} = \frac{45.3}{0.015} \right) = 3000 \text{ (m s}^{-2}\text{) (3022) (1)}$

1

(b) (i) $s = (ut) = \frac{1}{2}gt^2$ or $t = \sqrt{\frac{2s}{g}}$ (1)

correct substitution seen = $\sqrt{\frac{2 \times 2.3}{9.81}}$ (1)

0.68 to 0.69 correct answer to more than one dp seen (1)

3

(ii) $(s = vt) = 45(.3) \times 0.685$ or 0.7 (1)

= 30.6 to 32 (1) (m)

2

(iii) mention of air resistance or drag (1)

causing **horizontal** deceleration or 'slowing down' (1)

2

[11]

26.

- (a) (i) force
- $\times$
- perpendicular distance
- (1)**

between line of action of force and the point **(1)**

2

- (ii) rear
- (1)**

at rear + idea that centre of mass is closer to the rear wheel
(than to the front wheel) **(1)**

2

- (iii)
- $14000 \times 1.4 = F \times 2.5$
- (1)**

$$F = 7840 \text{ (N)} \text{ **(1)**}$$

divides their final answer by 2 **(1)**

$$= 3900 \text{ (N)} \text{ **(1)** (3922)}$$

4

- (b)
- $(F = k\Delta l) \frac{F}{k} \text{ or } (\Delta l =) \frac{(a)(iii)}{1000000}$
- (1)**

$$= 0.039 \text{ (m)} \text{ **(1)** ecf}$$

2

- (c)
- $F = (100000 \times 0.065 =) 6500 \text{ (N)} \text{ **(1)**}$

$$F = (2 \times 6500) = 13000 \text{ (N)} \text{ **(1)**}$$

2

[12]**27.**

- (a) (i)
- 180000×2.8
- ✓

$$= 500000 \text{ ✓ (504000 Nm)} \quad \text{ecf from first line for incorrect power of 10}$$

2

- (ii)
- $7.4 \times \text{lift fan thrust}$
- ✓

$$= 180000 \times 2.8 \text{ (504000 Nm)} \text{ ✓} \quad \text{ecf from part ai}$$

$$F = 68000 \text{ or } 68 \text{ k (N)} \text{ ✓ (68108 N)} \quad \text{ecf}$$

3

- (iii)
- $180\text{k} - 68.1\text{k} = (111.9 =) 112 \text{ k (N)} \text{ ✓} \quad \text{ecf from part aii}$

or by taking moments

1

- (b) (i)
- $(m = W/g) = 180\,000/9.81$
- ✓
- $(= 18349 \text{ kg})$

$$a = F/m = 155\,000/18349 = 8.4 \text{ ✓ (8.4475 ms}^{-2}\text{)}$$

ecf for use of 180 in 1st mark

use of weight rather than mass gets zero

2

- (ii) **cross-sectional or surface** area / shape / streamlining / aerodynamics / nature of surface / drag coefficient ✓

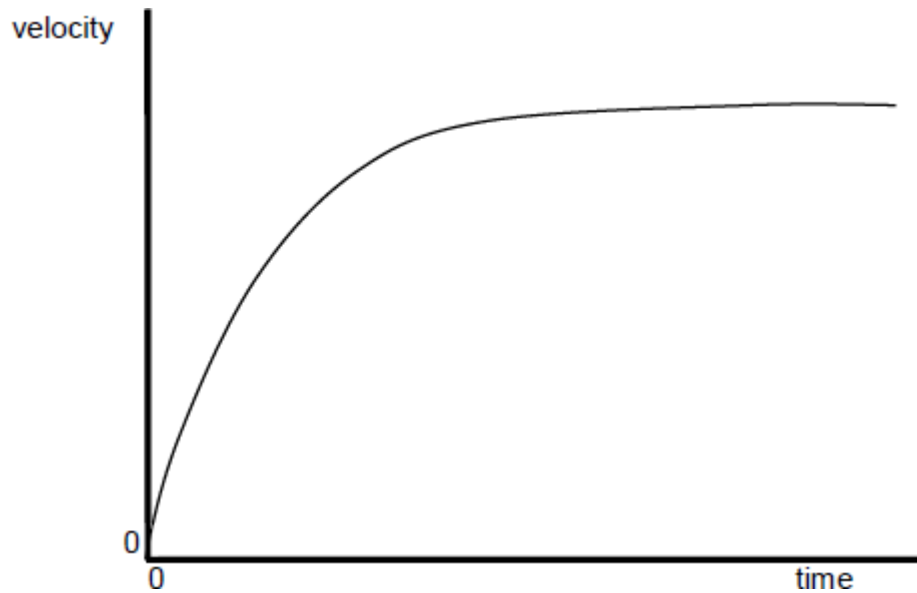
correctly linked to its effect on air resistance/drag ✓

or maximum thrust/force power of engine ✓

counterforce increases with speed

or when drag equals thrust (forces are balanced) ✓

2



line starting at zero and **curving with decreasing gradient** ✓

reaching a constant velocity ✓

2

- (c) steepest/maximum gradient ✓

1

[13]

- 28.** (a) *GPE* to *KE* to *GPE* ✓

no energy lost (from system) / no work done against resistive forces ✓

initial *GPE* = final (*GPE*) / initial (*GPE*) = final *GPE*

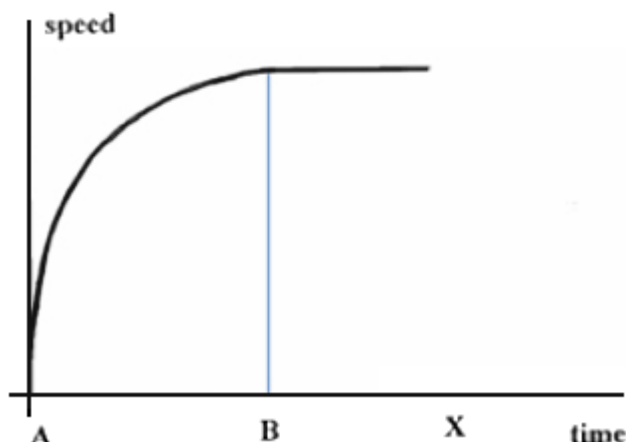
OR $h = GPE / mg$ and these are all constant so h is the same ✓

3

- (b) Initial curve with decreasing gradient and reaching constant maximum speed before X and maintaining constant speed up to X ✓

B labelled in correct place ✓

B labelled in correct place **AND** constant speed maintained for remainder of candidates graph and line is straight ✓



3

- (c) (first law) ball travels in a straight line at a constant speed / constant velocity / (maintains) uniform / no change in motion / zero acceleration ✓

there is no (external) **unbalanced / resultant** force acting on it ✓

2

[8]

29.

- (a) extension divided by its **original** length ✓

do not allow symbols unless defined ✓

1

- (b) 1.9×10^8 (Pa) ✓

1

- (c) point on line **marked 'A'** between a strain of 1.0×10^{-3} and 3.5×10^{-3} ✓

1

- (d) clear evidence of gradient calculation for **straight section**

eg $1.18 (1.2) \times 10^8 / 1.0 \times 10^{-3}$ ✓

= 120 GPa **and stress used $\geq 0.6 \times 10^8$ Pa** ✓ allow range 116 – 120 GPa

Pa or Nm^{-2} or N/m^2 ✓

3

- (e) (i) clear attempt to calculate correct area (evidence on graph is sufficient) ✓

(32 whole squares + 12 part/2 = 38 squares)

(38 $\times$ 10000 =) 380000 (J m^{-3}) ✓ allow range 375000 to 400000

2

(ii) $V = m/\rho$ or 0.015/8960 or $1.674 \times 10^{-6} \text{ (m}^3\text{)}$ ✓

$380\,000 \times 1.674 \times 10^{-6} = 0.64 \text{ (0.6362 J)}$ ✓ ecf from ei

2

- (f) straight line passing through origin (small curvature to the right only above 160 MPa is acceptable) end at 176 MPa ✓ (allow 174 to 178)

straight section to the left of the line for copper (steeper gradient) ✓

2

[12]

30.

(a) $170 \times 10^3 \times \cos 40$ (or 1.3×10^5) ✓

$\times 1000$ ✓ (= $1.302 \times 10^8 \text{ J}$)

2

(b) (i) $(P = Fv) = 1.3 \times 10^5 \times 7.0$ ✓

$= 9.1 \times 10^5$ ✓ (911.6 kW) ecf wrong force from part a

or correct alternative approach using $t = s/v$ and $P = E/t$

2

(ii) (total power =) $9.1 (\times 10^5) + 21 (\times 10^5)$ ✓ ecf from bi

powers of 10 must be consistent for this mark (eg not $9.1 + 2.1$)

(percentage = $(9.1/9.1 + 21) \times 100$)

$= 30 \text{ (\%)}$ ✓

ecf for power of 10 error in first mark

ecf from bi, but must have attempted to calculate **total power**

eg 9.1/21 gains zero

2

- (c) **any two from**

(surface) **area** (of the sail) ✓

wind speed/strength/power/KE/force (not air resistance) ✓

acceleration or speed of the ship ✓

2

[8]

31.	(a) (i) uses trigonometry (<i>mg sin5 or mg cos85</i> seen)	B1	2	[9]
	829.3 / 828.5 (N) at least 3 sf	B1		
	(ii) tension = 830 (N)	C1		
	$E = \frac{1}{2} F \Delta L$ and $F = k \Delta L$ identified / or combined to $E = \frac{1}{2} (F^2 / k)$	C1		
	correct sub condone power 10 error	C1		
	13.8 (J) range 13.9 to 13.7	A1	4	
	(b) lower speed	B1		
	less extension	B1		
	less energy stored (in rope)	B1	3	
32.	(a) $\Delta h = 2.51 - 1.00 = 1.51$ (m) / (s =) 1.51 m seen	M1		
	use of appropriate kinematics formula correctly makes t subject	M1		
	time = 0.555 (s) / 0.56 (s) (allow 0.55 (s))	A1	3	

- (b) (i) use of appropriate kinematics equation to find vertical v

C1

$$v = 5.4 \text{ (ms}^{-1}\text{)} \text{ (accept 5.4 to 5.9)}$$

A1

2

- (ii) any use of Pythagoras where $v_h = 18$ or use of appropriate trig ratio where $v_h = 18$ and angle is to horizontal

C1

$$\text{velocity} = 18.8 / 18.9 / 19 \text{ (ms}^{-1}\text{)}$$

A1

$$\text{angle} = 16.8 \text{ to } 18.1 \text{ (}^\circ\text{)}$$

A1

3

[8]

33.

A

[1]

34.

A

[1]

35.

- (a) (i) (moment = 520×0.26) = 140 (135.2) ✓

Nm ✓

2

- (ii) **180 x 0.41** and **0.63 X** seen ✓

$$135.2 = 180 \times 0.41 + 0.63 X \text{ ✓ ecf from (a)(i)}$$

$$(X = (135.2 - 73.8) / 0.63)$$

$$= 97 \text{ ✓ (N) (97.46) allow 105 from use of 140Nm ecf from (a)(i)}$$

3

- (iii) (520 – (180 + 97.46))

$$= 240 \text{ ✓ (242.5 N) ecf (or from correct moments calculation)}$$

1

(b) (i) $(v^2 = u^2 + 2as)$

$9.3^2 = 2 \times a \times 35$ OR $9.3^2 = 70a$ OR $a = v^2/2s$
OR $9.3^2/70$ ✓

OR correct alternative approach

$1.2 (1.2356)$ ✓ (m s^{-2})

2

(ii) $(m = W/g) = 520/9.81 (= 53.0)$ ✓ (kg)

$F = ma = 53 \times 3bi (1.2356) = 65$ (N) (65.49) ✓

accept use of 1.2 giving 64(63.6) , allow $53 \times 124 = 65.7$

2

[10]

36.

A

[1]

37.

C

[1]

38.

B

[1]

39.

- (a) direction of induced emf (or current) ✓
opposes change (of magnetic flux) that produces it ✓

2

- (b) (i) (volumes are equal and mass of Q is greater than that of P) density of steel > density of aluminium ✓

Allow density of Q greater (than density of P).

1

- (ii) use of $s = \frac{1}{2} g t^2$ gives $t^2 = \frac{2 \times 1.0}{9.81}$ (from which $t = 0.45$ s) ✓

Backwards working is acceptable for 1st mark

(vertical) acceleration [or acceleration due to gravity] is independent of mass of falling object

[or correct reference to $F = mg = ma$ with m cancelling] ✓

2nd mark must refer to mass.

Do not allow "both in free fall" for 2nd mark.

2

- (c) (i) moving magnet [or magnetic field] passes through tube ✓ there is a change of flux (linkage)(in the tube)

[or flux lines are cut or appropriate reference to $\varepsilon = N (\Delta\phi / \Delta t)$] ✓

In this part marks can be awarded for answers which mix and match these schemes.

[Alternative:

(conduction) electrons in copper (or tube) acted on by (moving) magnetic field of Q ✓

induced emf (or current) is produced by redistributed electrons ✓]

2

- (ii) emf produces current (in copper) ✓
 this current [allow emf] produces a magnetic field ✓
 this field opposes magnetic field (or motion) of Q
 [or acts to reduce relative motion or produces upward force] ✓
 no emf is induced by P because it is not magnetised (or not magnet)
 [or movement of P is not opposed by an induced emf or current] ✓

Alternative to 3rd mark:

current gives heating effect in copper and energy for this comes from ke of Q ✓

max 3

- (d) time for P is unaffected because there is still no (induced) emf
 [or because P is not magnetised
 or because there is no repulsive force on P] ✓
 time for Q is shorter (than in (c)) ✓
 current induced by Q would be smaller ✓
 because resistance of brass $\propto$ resistivity and is therefore higher
 [or resistance of brass is higher because resistivity is greater] ✓
 giving weaker (opposing) magnetic field
 [or less opposition to Q's movement] ✓

Condone "will pass through faster" for 2nd mark.

If emf is stated to be smaller for Q, mark (d) to max 2.

max 3

[13]

40.

- (a) ($E_p = mg\Delta h$)
 $= 65 \times 9.81 \times 54$ ✓
 $= 3.44 \times 10^4 = 3.4 \times 10^4$ (J) ✓ (34433)
max 1 if $g = 10$ used (35100 J)
Correct answer gains both marks

2

(b) $v = \sqrt{\frac{2Ep}{m}}$ OR $v = \sqrt{\frac{2 \times 34433}{65}}$ ✓ = 33 (32.55 ms⁻¹) ✓ ecf 1(a)

allow 32 (32.3) for the use of 34000

allow 32.6

OR correct use of $v^2 = 2gs$

don't penalise $g = 10$ (32.863)

2

(c) ($s = \frac{1}{2}gt^2$ or other kinematics equation)

$t = \sqrt{\frac{2s}{g}}$ OR $t = \sqrt{\frac{2 \times 54}{9.81}}$ ✓ = 3.318 = 3.3 (s) ✓

With use of $g = 9.8$ or 9.81 or 10 and / or various suvat equations, expect range 3.2 to 3.4 s.

No penalty for using $g = 10$ here.

ecf from 1(b) if speed used

2

(d) (all G)PE (lost) is transferred to KE

no (GP)E transferred to 'heat' / 'thermal' / internal energy

OR ✓

Must imply that all GPE is transferred to KE. E.g. accept 'loss of GPE is gain in KE' but not: 'loses GPE and gains KE'.

(therefore) $mg\Delta h = \frac{1}{2}mv^2$ ✓
mass cancels. ✓

Accept 'm's crossed out

3

[9]

41.

scale <1cm to 1 m s⁻¹ stated or obvious from calculation (allow × 3, 7 etc. here)

B1

allow 2 max for correct calculation

correct resultant direction by eye (needs arrow if not clear from parallelogram or triangle)

B1

allow 1 max for

2.6±0.2 (m s⁻¹)

B1

correct method of calculation but with error(s)

3

[3]

42.

D

[1]

43.

D

[1]

44.

A

[1]

45.(a) ($W = mg$)

$$= 4.8 \times 35 \times 9.81 \checkmark$$

$$= 1600 \text{ (1648 N)} \checkmark$$

Allow $g=10$: 1680 (1700 N)

$g = 9.8 \rightarrow 1646 \text{ N}$

max 1 for doubling or halving.

Max 1 for use of grammes

2

(b) (stress = tension / area)

For first mark, forgive absence of or incorrect doubling / halving.

$$= (0.5 \times) 1.5 \times 10^6 / 6.2 \times 10^{-4} \text{ OR } = 1.5 \times 10^6 / (2 \times) 6.2 \times 10^{-4} \checkmark$$

$$= 1.2 \times 10^9 \text{ (1.21 GPa)} \checkmark$$

Forgive incorrect prefix if correct answer seen.

2

(c) (i) (weight = stress $\times$ area)

max 1 mark for incorrect power of ten in first marking point

$$= 400 \times (10^6) \times 6.2 \times 10^{-4} (= 248\,000 \text{ N}) \checkmark$$

max 1 mark for doubling or halving both stress and area

$$(\times 2 =) 5.0 \times 10^5 \text{ (496\,000 N)} \checkmark$$

Forgive incorrect prefix if correct answer seen. Look out for $YM \div 400 \text{ kPa}$ which gives correct answer but scores zero.

2

- (ii) $\Delta L = \frac{F L}{A E}$ OR correct substitution into a correct equation (forgive incorrect doubling or halving for this mark only) ✓

OR alternative method:

strain = stress / E

then $\Delta L = L \times \text{strain}$

$$= \frac{(\text{Ans 4ci}/2) \times 35}{6.2 \times 10^{-4} \times 2.1 \times 10^{11}} \quad \text{OR} \quad \frac{\text{Ans 4ci} \times 35}{2 \times 6.2 \times 10^{-4} \times 2.1 \times 10^{11}} \quad \checkmark \quad \text{ecf from 4ci}$$

If answer to 4ci is used, it must be halved, unless area is doubled, for this mark

$$(= \frac{(4.96 \times 10^5 / 2) \times 35}{6.2 \times 10^{-4} \times 2.1 \times 10^{11}} =) \quad 6.7 \times 10^{-2} \quad (6.667 \times 10^{-2} \text{ m}) \quad \checkmark \quad \text{ecf from 4ci}$$

Any incorrect doubling or halving is max 1 mark.

Allow 0.07

3

- (iii)

$$(\quad k = \frac{F}{\Delta L} \quad)$$

$$= \frac{2 \times 248\,000}{6.667 \times 10^{-2}} \quad \text{OR correct substitution into } F = k\Delta L \quad \checkmark \quad \text{ecf ci and cii (answer 4c(i) } \div \text{ answer 4c(ii))}$$

Allow halving extension for force on one cable

$$= 7.4(4) \times 10^6 \quad \checkmark (\text{Nm}^{-1})$$

Correct answer gains both marks

2

- (iv) $(\quad E = \frac{1}{2} F \Delta L \quad \text{or} \quad E = \frac{1}{2} k \Delta L^2 \quad)$

Correct answer gains both marks

$$= \frac{1}{2} \times 496\,000 \times 6.667 \times 10^{-2} \quad \text{OR} \quad \frac{1}{2} \times 7.4(4) \times 10^6 \times (6.667 \times 10^{-2})^2 \quad \checkmark \quad \text{ecf ci, cii, ciii}$$

$$= 1.6(5) \times 10^4 \text{ (J)} \quad \checkmark$$

Forgive incorrect prefix if correct answer seen.

Doubling the force gets zero.

2

[13]

46.

(a) $(s = \frac{1}{2}(u + v)t)$

Correct answer with no working gets 2 out of three.

$$u = \frac{2s}{t} - v \text{ OR substitution in above equation OR } u = \frac{2 \times 1.5}{0.43} - 5.0 \checkmark$$

$$= 6.9767 - 5.0 \checkmark = 2.0 \checkmark (1.98 \text{ m s}^{-1})$$

Full credit for use of $g \sin 25 = \text{acceleration down slope}$. This yields answer 3.22 m s^{-1}

Allow 1sf answer (2).

3

(b) (i) $(F = 75 \times 9.81 \times \sin 25^\circ) \checkmark$
 $= 310 \text{ (311, 310.94) (N)} \checkmark$

use of $g = 10$ not penalised here

'sin25' on its own

Use of $g = 10$ yields 317

Allow cos65

2

(ii) $W = Fs$
 $= 311 \times 2.0 = 620 \text{ (622 J)} \checkmark \text{ ecf (2bi) } \times 2.0$

1

- (c) Idea that GPE is ultimately transferred to: internal (energy) / 'heat' / 'thermal' (energy in the surroundings) $\checkmark$

Allow transfer of GPE to KE and then to 'thermal' etc

Do not allow reference to 'sound' on its own

Correct reference to a named resistive force: friction / drag / air resistance $\checkmark$

Don't accept implication that a resistive force is a form of energy

All GPE becomes 'heat', etc **OR** no (overall) increase in KE **OR** reference to work done against or by a resistive force $\checkmark$

Do not allow references to loss of body heat.

Allow: '(GPE) not converted to KE'

3

[9]**47.**

- (a) (sum of) clockwise moment(s) = (sum of) anticlockwise moment(s) $\checkmark$
sum of clockwise moment s = sum of anticlockwise moment s (about any given point) $\checkmark$
 (for a system in) equilibrium $\checkmark$ allow 'balanced'

third mark depends upon the first

Don't allow references to 'forces' being balanced.

Don't allow 'stationary'.

Allow 'total', etc instead of sum

Ignore definitions of moment

3

- (b) (i) $35 \times 110 (\times 10^{-3})$ ✓
 $(= 3.85) = 3.9$ (or 3.8) ✓
allow 4 or 3.90 but not 4.0
- (3.9) **Nm** / allow (3850, 3900) **Nmm** ✓ don't allow nm, NM
unit must match answer

3

- (ii) $3.85 = T \times 25 (\times 10^{-3})$ ✓ ecf from (bi)
Correct answer with no working gets 2 out of three.

$$T = 3.85 / 25 (\times 10^{-3}) = 0.150 (\times 10^3)$$
 ✓ ecf
Allow 156 (160) N from rounding error

$$= 150 (154 \text{ N})$$
 ✓

3

- (c) $(P = Fv, F = P / v)$
 $= 2.8 (\times 10^3) / 15$ ✓
 $= 190 (186.7 \text{ N})$ ✓

2

[11]

48.

- (a) (i) force per unit mass ✓
a vector quantity ✓
Accept force on 1 kg (or a unit mass).

2

- (ii) force on body of mass m is given by $F = \frac{GMm}{(R+h)^2}$ ✓

$$\text{gravitational field strength } g \left(= \frac{F}{m} \right) = \frac{GM}{(R+h)^2}$$
 ✓

For both marks to be awarded, correct symbols must be used for M and m .

2

- (b) (i) $F \left(= \frac{GMm}{(R+h)^2} \right) = \frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24} \times 2520}{((6.37 \times 10^6) + (1.39 \times 10^7))^2}$ ✓

$$= 2.45 \times 10^3 (\text{N})$$
 ✓ to **3SF** ✓

1st mark: all substituted numbers must be to at least 3SF.

If 1.39×10^7 is used as the complete denominator, treat as AE with ECF available.

*3rd mark: **SF mark is independent.***

3

$$(ii) \quad F = m\omega^2 (R + h) \text{ gives } \omega^2 = \frac{2450}{2520 \times 2.03 \times 10^7} \checkmark$$

$$\text{from which } \omega = 2.19 \times 10^{-4} \text{ (rad s}^{-1}\text{)} \checkmark$$

$$\text{time period } T \left(= \frac{2\pi}{\omega} \right) = \frac{2\pi}{2.19 \times 10^{-4}} \quad \text{or} = 2.87 \times 10^4 \text{ s } \checkmark$$

$$[\text{or } F = \frac{mv^2}{R+h} \text{ gives } v^2 = \frac{2.45 \times 10^3 \times ((6.37 \times 10^6) + (13.9 \times 10^6))}{2520} \checkmark$$

$$\text{from which } v = 4.40 \times 10^3 \text{ (m s}^{-1}\text{)} \checkmark$$

$$\text{time period } T \left(= \frac{2\pi(R+h)}{v} \right) = \frac{2\pi \times 2.03 \times 10^7}{4.40 \times 10^3} \quad \text{or} = 2.87 \times 10^4 \text{ s } \checkmark]$$

$$[\text{or } T^2 = \frac{4\pi^2(R+h)^3}{GM} \checkmark$$

$$= \frac{4\pi^2((6.37 \times 10^6) + (13.9 \times 10^6))^3}{6.67 \times 10^{-11} \times 5.98 \times 10^{24}} \checkmark$$

$$\text{gives time period } T = 2.87 \times 10^4 \text{ s } \checkmark]$$

$$= \frac{2.87 \times 10^4}{3600} = 7.97 \text{ (hours)} \checkmark$$

$$\text{number of transits in 1 day} = \frac{24}{7.97} = 3.01 \text{ (} \approx 3 \text{)} \checkmark$$

Allow ECF from wrong F value in (i) but mark to max 4 (because final answer won't agree with value to be shown).

First 3 marks are for determining time period (or frequency). Last 2 marks are for relating this to the number of transits.

Determination of $f = 3.46 \times 10^{-5} \text{ (s}^{-1}\text{)}$ is equivalent to finding T by any of the methods.

5

(c) acceptable use $\checkmark$

satisfactory explanation $\checkmark$

e.g. monitoring weather **or** surveillance:

whole Earth may be scanned **or** Earth rotates under orbit

or information can be updated regularly

or communications: limited by intermittent contact

or gps: several satellites needed to fix position on Earth

Any reference to equatorial satellite should be awarded 0 marks.

2

[14]

49.

- (a) thermionic emission / by heating

B1

cathode heated / heating done by electric current / overcoming work function

B1*Must mention anode for third mark*

anode which is positive wrt cathode / accelerated by electric field between anode and cathode

B1

3

- (b) (i) one relevant equation seen:
- $E = V/d$
- /
- $F = Ee$
- /
- $a = F/m$

B1*Equation should be in symbols*

$$a = \frac{1.6 \times 10^{-19} \times 270}{9.1 \times 10^{-31} \times 0.015} \quad / \quad F = 2.88 \times 10^{-15}$$

B1*Substitution may be done in several stages*

$$3.16 \times 10^{15} \text{ (m s}^{-2}\text{)}$$

B1*Must be more than 2 sf*

3

- (ii)
- $s = (ut) + \frac{1}{2} at^2$
- or
- $v = u + at$
- and
- $s = v_{av}t$
- OR
- $s = vt$
- used

B1*Appropriate symbol equation seen and used for 1st mark*

$$3.56 \times 10^{-3} \text{m}$$

B1*Expect at least 3 sf but condone 3.6 for candidates who use $a = 3.2 \times 10^{15}$*

2

(iii) $v = u + at$ / $v = at$ $v^2 = u^2 + 2as$ used

B1

May also use $eV = \frac{1}{2}mv^2$

$4.74 \times 10^6 \text{ m s}^{-1}$ to at least 3 sf

B1

Allow 4.8 (2 or more sf) – consistent with use of $a = 3.2 \times 10^{15}$

2

(iv) $t = 7.5 \times 10^{-9} \text{ s}$ seen or used

C1

May use ratios for 1st 2 marks: $s_v/s_h = v_v/v_h$ C1

$3.53 \times 10^{-2} \text{ (m)}$ A1

$3.53 \times 10^{-2} \text{ (m)}$ **ecf** for wrong t

A1

adds $3.56 \times 10^{-3} \text{ (m)}$ to their 3.53×10^{-2}

B1

clipped with b(i) and b(ii)

Allow reasonable rounding

3

[13]

50.

(a) $K = \frac{45}{30^2} (= \frac{45}{900} = 0.05)$ or $\frac{d}{45} = \frac{15^2}{30^2} (= \frac{1}{4})$
 $d = 11.25 \text{ (m)}$

C1

A1

2

- (b) rearrangement or substitution into $v^2 = u^2 + 2as$ or $s = \frac{v+u}{2}t$

C1

$$a = (-)10 \text{ or } t = 3.0$$

A1

allow use of more than one equation of motion provided it gives a deceleration or time

use of $F = ma$ or $Ft = mv - mu$ (-)7000 (N)

C1

A1

4

- (c) mention of $E_k = \frac{1}{2}mv^2$

B1

allow a mark for kinetic

all used to heat brakes / surroundings

B1

energy to 'heat'

since both ke and d are proportional to V^2

B1

d must be proportional to heat generated or to the kinetic energy

B1

$$E = md / 2k \text{ gains two marks}$$

3 max

[9]

51.

A

[1]

52.

- (a) (i) use of $(s = \frac{1}{2}gt^2)$ OR $t^2 = 2s/g$ ✓

$$t = \sqrt{\frac{2 \times 1.2}{9.81}} \checkmark$$

$$= 0.49 \text{ (0.4946 s)} \checkmark \text{ allow 0.5 do not allow 0.50}$$

Some working required for full marks. Correct answer only gets 2

3

(ii) $(s = vt)$
 $= 8.5 \times 0.4946 \checkmark$ ecf ai
 $= 4.2 \text{ m} \checkmark (4.20)$ ecf from ai

2

(b) (i) $\left(s = \frac{1}{2} (u + v) t \right)$

$t = \frac{2s}{u(+v)}$ or correct sub into equation above $\checkmark$

$= \frac{2 \times 0.35}{8.5} = 8.2 \times 10^{-2} \text{ (s)} \checkmark (0.0824)$ allow 0.08 but not 0.080 or 0.1

Allow alternative correct approaches

2

(ii) $a = (v - u) / t$ OR correct substitution OR $a = 103 \checkmark$
 $(= -8.5) / 8.24 \times 10^{-2} = 103.2$

$(F = ma =) 75 \times (103.2) \checkmark$ ecf from bi for incorrect acceleration due to arithmetic error only, not a physics error (e.g. do not allow $a = 8.5$. Use of g gets zero for the question.

$= 7700 \text{ N} \checkmark (7741)$ ecf (see above)

Or from loss of KE

Some working required for full marks. Correct answer only gets 2

3

[10]

53. C

[1]

54. A

[1]

55. (a) (i) Use of $KE = \frac{1}{2} m v^2$

C1

21.7 (J)

A1

2

- (ii) Use of $W = Fs$
Allow 1 mark for use of suvat or $F=ma$

C1

0.70 (m)

A1

2

- (b) Use of $\Delta E_p = mg\Delta h$

C1

Correct sub for h ($1.7 \sin 18^\circ$)

C1

77.3 (W)

OR

Use of $P = Fv$

Correct sub for F ($mg \sin 18^\circ$) or v ($1.7 \sin 18^\circ$)

77.3 (W)

A1

3

[7]

56.

- (a) (i) 11 (m)

B1

1

- (ii) Use of $F = k\Delta L$ or $W = mg$
Allow use of $\Delta L = 12$ m

C1

3400 (N)

A1

2

- (b) Sets $mg = k\Delta L$

C1

1.9 (m)

A1

2

- (c) Correct use of $W = \frac{1}{2}k\Delta L^2$ or $\frac{1}{2}F\Delta L$
 $\Delta L = 5 \text{ m}$

C1

Correct use of $\Delta GPE = mg\Delta h$
 $\Delta h = 25 \text{ m}$

C1

States or uses $(mg\Delta h) - (\frac{1}{2} k\Delta L^2) = \frac{1}{2}mv^2$

C1

19 (m s⁻¹) cnao

A1

4

- (d) Same kinetic energy when rope begins to stretch

B1

More work done per unit extension / stops in shorter distance
"Shorter time" gets no credit

B1

Increases force on jumper (increasing the risk of injury)

B1

3

[12]

57.

- (a) $m = W / g$
 $(3.4 \times 10^4 / 9.81 =) 3500 \text{ (3466 kg) } \checkmark$
Allow use of $g = 10$

1

- (b) (moment = $34\,000 \times 5.0$) = $1.7 \times 10^5 \checkmark$ (Nm)
Nm $\checkmark$ do not allow NM \ nM etc
allow in words

2

- (c) $170\,000 = T \times 12$ OR $T = 170\,000 / 12 \checkmark$ ecf aii
 $= 1.4(167) \times 10^4 \checkmark$ (N)

2

- (d) (component of T perpendicular to lever) = $T \cos 24$
OR $14\,167 \times 0.9135$ **OR** 12942 (N) ✓ ecf aiii allow $2.5 \cos 24 \times T$

$$(12942) \times 2.5 = F \times 8.0$$

OR $F = ((12942) \times 2.5) / 8.0$ ✓ ecf for incorrect component of T or T on its own

$F = 4000$ (N) ✓ (4044) ecf for incorrect component of T or T on its own

allow 4100 for use of 14 200 (4054)

Some working required for full marks. Correct answer only gets 2

Failure to find component of T is max 2 (4400 N)

3

[8]

58.

A

[1]

59.

D

[1]

60.

- (a) use of $E = mgh$ (1)

2680 J (1)

2

- (b) use of $v^2 = 2$ as (1)

9.1 m s⁻¹ (1)

2

- (c) increases the time taken for the athlete to come to rest/reduced deceleration

force = mass × acceleration/mass × change in velocity/time (1)

or momentum argument

or energy argument (1)

2

[6]

Examiner reports

1.

(a) The majority of candidates were able to score at least 1 mark in this explanation. Only the best candidates were producing quality answers that gained full credit. Many candidates were unfamiliar with the term and offered answers suggesting that these were neutrons that were produced due to heat.

(b) (i) Surprisingly, only 50% of candidates gained full marks here. A significant proportion of candidates attempted to use the equations of motion and consequently were awarded no marks. Candidates must be aware that these equations only apply to situations where acceleration is constant. Some candidates lost marks by rounding the final answer to 1 significant figure. Many lower achieving candidates failed to

correctly rearrange $\frac{1}{2} m v^2 = m g h$, dropping the factor of $\frac{1}{2}$ was a common mistake.

(ii) This was another “Show that...” style question and again it posed problems for many candidates with just over 20% of candidates gaining 3 or 4 marks. A very large proportion of candidates did not attempt the elastic collision part of the question and limited themselves to 2 marks. Many of these candidates had difficulty with the vector nature of momentum and their signs were often inconsistent or incorrect. Grade A candidates typically presented well laid out workings that were easy-to-follow, convincing.

(iii) Most candidates achieved both marks here. However, some had casual use of powers of 10 errors on their KE calculations due to keeping the mass in grams. This of course cancelled due to the ratio aspect of the question. A number of candidates thought that 25% was the answer; this was due to not reading the question carefully enough.

(iv) Most candidates gained 1 mark for stating how the demonstration related to the moderation process. Only a small number of candidates were able to develop their answer by providing information that was more than the converse of the information provided, thus demonstrating a sound knowledge of the moderation process.

(v) Just under 80% of candidates knew that water was the moderator in a PWR. A few candidates incorrectly thought that the moderator was heavy water.

2.

- (a) (i) A very large number of candidates took 430ms^{-1} as the final vertical velocity and obtained a time of 44 seconds for the bullet to fall 1.5m. Many used $t = s / v$ with $v = 430\text{m}^{-1}$. This gave a time of 3.5 ms to fall 1.5m. Students need to be encouraged to look at their answers and consider whether they are sensible.
- (ii) Here we saw the usual erroneous use of 'suvat': e.g. $s = 1/2 (u + v)t$ with either u or v being set to zero. Given that this type of question is not uncommon, it is surprising how many students do not understand that the horizontal velocity is constant and that the suvat equations are not necessary.
- (b) Some candidates thought that the slower bullet reaches the ground first and some did not distinguishing between *velocity and horizontal velocity*. It is important to be very specific when describing motion.

This is a very good question for addressing misconceptions. One could perhaps use the following examples in class and ask students to mark them and analyse the physics:

'Because the horizontal velocity of B is less than A, the bullet is slowed down more by drag. Also the pull of gravity will allow it to travel less horizontal distance than A because the bullet has less resistance to the gravitational force causing it to be pulled down to earth quicker.'

'It has less forward force to use. This means that gravity will have an affect on this bullet sooner. The lower the horizontal force, the quicker the vertical force overpowers it, thus making it hit the ground sooner and a shorter distance travelled.'

3.

- (a) (i) Answered well by most candidates. The explanation had to demonstrate that candidates understood the resolving process.
- (ii) Correctly answered by most candidates, with only a small proportion of inappropriate lines of best fit.
- (b) (i) This question features on all ISA's but many candidates still fail to achieve the full 3 marks. The most common error was again misreading of one of the data points, and this then usually gives a gradient value out of tolerance, hence losing another mark. Triangles were generally large enough to meet the 8 cm criteria, with fewer lost marks on this point than in previous years.
- (ii) Answered reasonably well by most candidates – by multiplying their gradient by 'g'.
A significant proportion of candidates lost the mark awarded for the unit. (Some candidates using 'n' instead of 'N'!).
- (c) This question discriminated well, with only the most able candidates scoring all three marks. Significant figure errors and failing to double the combined uncertainty in x and y were the most common mistakes.
- (d) (i) A surprising number of candidates failed to give an adequate description of a systematic error.
- (ii) A large proportion of candidates scored the first mark, explaining that y would be larger. Only the most able candidates were able to give an adequate explanation, usually relating to friction opposing the increasing weight of m .

4.

- (a) (i) Nearly all showed a 3 or 4 significant figure answer before rounding to 6100 and very few dropped marks here.
- (ii) Some selected the wrong angle (angle to vertical rather than horizontal) but apart from that the question was very well done.
- (iii) Generally well answered but the wrong force was sometimes used, e.g. 6000N rather than 6083N and sometimes weight was used rather than mass.
- (b) (i) Most were successful here, but some thought 6500N was the mass and multiplied this by 9.81.
- (ii) Some confusion over the calculation of useful power, with many candidates wrongly trying to calculate kinetic energy or calculating power from $P = Fv$. Some divided an *energy* by a *power*. The evidence suggests that many centres need to practice more of these questions.

5.

- (a) This question was well answered. Some left out 'up to limit of *proportionality*' and some put '*elastic limit*' - though this was forgiven. Some gave the equation only in symbols, and this was not sufficient.

Again, with recall questions, not enough students are learning definitions and laws, producing instead vague descriptions rather than precisely memorised statements. E.g. '*Hooke's law is the extension of a spring when a force is applied.*'

- (b) There were quite a few mistakes with units here; 'Nm', 'Nm⁻²' and 'Pa' were all common incorrect units. In calculating the gradient, the point labelled '**A**' was often used. However, at this point, the line had clearly ceased to be straight and thus the answer fell outside the range of tolerance.
- (c) For calculating the work done up to point **B**, there was much use of $\frac{1}{2} FL = \frac{1}{2} \times 38 \times 0.045$, and sometimes simply 38×0.045 , rather than an attempt to sum up the area under the line. Many estimates of the area were wildly inaccurate due to the approach being too approximate, counting some areas twice or missing bits out.

Summing the area under a curve is a technique that students must practise.

- (d) Most candidates got this correct. A few said words to the effect of '*no longer obeys Hooke's law*', which was not sufficient.
- (e) There were many careless graphs drawn here, with the line not drawn exactly parallel, and this lost a mark. This means that some very straightforward marks are needlessly dropped by many candidates. In order to ensure that a line is parallel, students should be encouraged to make a quick measurement of the distance between the lines at a couple of points.

It would also appear that many students elect to sketch with a pen and are then reluctant to scribble out their line and replace it with a more accurate one. For diagrams only, please encourage students to use an HB pencil; this will show up perfectly well on the scans that are seen by the examiners.

- (f) The majority of candidates understood that the area underneath the unloading line was less than for the loading. However, a significant number of candidates thought that the work done would be the same since '*energy is conserved*'.

6.

- (a) The number of mistakes on this question was surprising. Most candidates knew it was something to do with 'cos' or 'sin' but they resolved incorrectly. Common errors included resolving the mass rather than the weight ($8300\sin 25$), finding the wrong component ($mg \cos 25$), incorrect trigonometry ($mg / \sin 25$) or simply calculating the weight without resolving (8300×9.81). Plenty of practice and assessment on resolution of forces on inclined planes is needed for many students.
- (b) (i) These presented few problems apart from an occasional power of ten error or use of weight instead of mass.
- (ii) As above.
- (c) (i) There were lots of really good answers on this question with correct descriptions of energy transformations and mention of friction and 'thermal energy'.

However, some mentioned the appropriate force (friction, drag, etc.) but not the form of energy (internal, 'thermal', 'heat') and vice versa. Some candidates do not know the difference between a form of energy and the process that causes the transformation: 'kinetic energy is converted to friction' being a typical comment.

- (ii) This was generally well done, but some used 160 m instead of 140 m.

Some candidates used a 'suvat' equation but this is incorrect physics due to the fact that the acceleration is not constant. Students must first identify if a situation involves constant velocity, uniform acceleration or changing acceleration. If the acceleration is changing, the kinematics equations used at AS will not be applicable.

7.

Part (a) was answered very successfully. A common error was to state .length. or 'height' rather than distance, although 'length' was tolerated.

On part (b) (ii), candidates knew what to do but most did not gain full marks due to confusion over powers of ten or units for power.

Half of candidates achieved four or five marks out of five on part (c). Again there was confusion with prefixes/powers of ten and units. It is important that candidates stated 'Pa' not 'pa'.

8.

Those who gained one mark usually had the first line correct. Those who gained two marks usually forgot the gravitational PE in the second line.

9.

The common error in part (a) was to multiply the frictional force by $\cos 20$ instead of dividing. Had candidates written the equation in the form $F \cos 20 = 2800$ first, many more could have been successful.

In part (b), the majority multiplied the value from (a) by the distance moved forgetting that the distance moved is the force $\times$ distance moved **in the direction of the force**.

10.

In part (a), a large number of candidates thought that the horizontal component of velocity was to be shown rather than the instantaneous velocity at a tangent to the path. Many candidates who had the right idea still did not gain marks due to a badly drawn tangential arrow. The mark for the acceleration was gained by many candidates. Of those candidates who gained no marks in part (b) (i), many simply could not rearrange $s = 1/2gt^2$. Those who successfully did this picked up both marks. A majority of candidates gained two marks but some believed they had to use a 'suvat. equation and gained no marks.

11. Solution to this question required candidates to find the vertical component of the tension from $610 \cos 20$ and realisation that the sum of the upward forces produced by the rope and reaction force is equal to the weight. There was a good proportion of completely correct answers but some who could do the resolution correctly did not realise what the next step should be. Some candidates overcomplicated the problem by trying to calculate the reaction force shown on the diagram.

12. The majority of candidates correctly used the data to obtain a correct value but many quoted the answer to too many significant figures. Some candidates appeared to think they needed to find a new force (perhaps confusing force and power). These candidates made no use of the distance

moved and used 1500 N as ΔW in the formula $t F = \frac{\Delta W}{\Delta t}$.

13. Most candidates successfully completed part (a) (i).

Part (ii) was also successfully completed by a majority of the candidates.

The use of the equation for uniform decelerated motion was inappropriate in part (iii). Only a minority of the candidates appreciated that the work done had to be equated to the gravitational potential energy that had been transferred to forms other than to kinetic energy.

Only a small minority did not gain some credit in part (iv) and most stated friction and air resistance. A significant proportion of these did not identify where the friction was occurring. Vague answers such as between the skier and the ground were not accepted.

Most candidates completed part (b) (i) successfully.

Part (ii) was also done well by the majority of the candidates.

14. Part (a) proved to be a very easy question, with the majority of candidates correctly plotting all the points and gaining all five marks.

A large number of candidates only got one mark out of two for part (b) (i), because they did not point out that the gradient is the deceleration - though it is possible that the majority knew this. Most recognised the significance of the straight line.

For half the candidates, part (b) (ii) was a straightforward calculation of the area. However, many candidates did not recognise its simplicity. A common incorrect approach was to select a kinematics equation and substitute in 15 m/s and 3.5 s. Candidates would gain higher marks on this type of question if they routinely state the principle they are using, e.g. in this case .distance travelled = area under line..

15. Only a minority of the candidates made progress with part (a) (i). The working in many responses did not convey a correct physics approach to the problem. Multiplying the peak force by half the time did not show that the aim was to determine the area, but rather that the aim was to find a number that fitted that given in the question. It would help demonstration of a correct approach to a problem, and in particular to 'show that' questions, if candidates were to include a subject for the formula and/or numerical substitution.

Candidates were generally more successful in part (a) (ii), almost half the candidates gaining both marks.

In part (b), candidates either coped very well or not at all with the straightforward task of finding the resultant magnitude and direction of the vector addition of horizontal and vertical velocities, both of which were given in the question. Many were unsuccessful because they could not successfully use Pythagoras' rule or identify the appropriate relationship to find the angle.

16. The very straight forward part (a) was well answered with generally clear solutions being provided.

Part (b) was answered more unevenly. About 60% of candidates arrived at a complete answer with the remainder making more or less progress with what was a straightforward question. Inconsistencies of sign in the treatment of deceleration and the velocities were very common and were penalised. It is not acceptable simply to ignore the fact that an equation yields a squared quantity with a negative sign.

17. This question required candidates to determine the momentum of the water flowing out of a garden hose in one second. This called for mathematical application as well as knowledge and it was therefore much more demanding. 41% of the candidates selected the correct answer, and the question was not a strong discriminator. The most popular incorrect distractor, chosen by 28%, was C (0.20). This numerical value could be found by multiplying the density of water by the flow rate, ignoring the cross-sectional area value given in the question.

18. Part (a) (i) was straightforward and was answered very well.

Again, part (a) (ii) proved to be a particularly accessible question and candidates performed well.

In part (a) (iii), most grasped the concept that energy was wasted but less able candidates did not realise that the cyclist did work, believing it to be a simple transfer of potential energy to kinetic energy. Many candidates perhaps did not realise that marks could be gained by performing the relevant calculation.

In part (b) (i), a surprising number of candidates used $\text{time} = \text{distance}/\text{speed} = 160/16 = 10 \text{ s}$. They did not appreciate that the situation involved uniform deceleration and therefore a kinematics equation should be used.

Part (b) (ii) was generally done well, with most calculating the acceleration and then using $F = ma$. It was possible to gain full marks even with the use of an incorrect answer from the previous question.

19. In part (a) (i), only partial credit was available to those who failed to relate the area under the graph to the stored energy.

Many were able to successfully begin part (a) (ii) by equating the stored energy with kinetic energy. But, from this point on, explanations became poor with the full detail of the algebraic manipulations either not being shown or being fudged.

The straightforward substitution and evaluation from the equation in (a) (ii) was done well in part (b) (i).

Full credit was rare to part (b) (ii). Candidates are too fond of stating air resistance as their full answer without suggesting the seat of the energy loss. There are a number of air resistance possibilities in this situation and many candidates left it to the examiners to decide which one was operating here. There were frequent answers that suggested air resistance when the arrow had left the bow despite the question's focus on the initial acceleration of the arrow whilst in the bow. Examiners are looking for more awareness of the context in this type of question.

Those who attempted the three parts to part (c), all of which examined the use of kinematic equations and vector components, did well, often achieving full credit. However, many (about one-fifth) did not attempt (c) (iii).

20. This was a straightforward test of candidates' knowledge. It required candidates to decide whether or not mass, momentum, kinetic energy and total energy would be conserved in an inelastic collision. 85% of the candidates appreciated that everything except kinetic energy would be conserved. Incorrect responses were fairly evenly spread around the other three distractors.

21. More than half of the candidates answered part (a) correctly and most gained some credit for making some progress with the question. Incorrectly converting 40 minutes to seconds was common. A significant proportion did not appreciate the difference between mass and weight. The weight was given in N but many multiplied this by g in their working.

The unit prefix again presented problems for many when attempting to convert 15 mm to mm in part (b) and 106 was not uncommon. The vast majority divided 750 by 15 or 15×10.3 but then gave an inconsistent unit.

22. Part (a) was done well by the overwhelming majority.

About half the candidates completed part (b) successfully. Errors here usually centred around non-clarity in the direction of the velocity. It was often unclear whether the angle was to the east or west of north.

23.

A common error in part (a) (i) was to use $t = s/v = 50/6.7$. Students are not always aware that, for uniform acceleration, the 'suvat' equations must be used. Another common error was to use $t = \sqrt{(2s/a)}$ with the speed used as the acceleration.

Nearly all students were successful with the calculation in part (a) (ii). However, a large number stated an answer to more than two significant figures and lost a mark.

Part (a) (iii) was very straightforward and most students got this right.

A pleasingly large number of students were successful in part (b) (i). It was necessary to fully understand the situation to get both marks. There were errors such as subtracting the KE from the GPE rather than adding them, or only taking one of them from the input energy of 9 kJ.

Energy losses within the motor are not a cause of the energy loss calculated in part (b) (i). This is because the work done by the motor is the energy output from the motor. The energy losses from the rider also are not relevant here. The energy losses are therefore due to drag and friction. However, the candidate must make it clear that the frictional losses are between tyre and road or between other moving parts of the bike other than within the motor. Many students did not state where the friction was acting and many mentioned the losses within the motor. Many gained a mark for mentioning air resistance or drag.

24.

Part (a) (i) was a fairly easy two marks for the majority of candidates. Most gave 420000 but about 10% omitted this and lost one mark.

Part (a) (ii) was straight forward for most but a common error was the use of the volume instead of the velocity.

For part (a) (iii), perhaps 10-20% didn't know 'M' was 10^{-6} . Quite a few divided by 10×10^{-6} . About 14% left this question out, either indicating that they had run out of time or they had forgotten how to calculate efficiency. About 43% gained full marks.

Perhaps candidates pressed for time had spotted part (b) and sensibly decided to skip part (a) (iii) and pick up this little gift instead; still a little surprising that only 56% managed to get both marks even though 95% attempted the question.

25.

In part (a) (i), most candidates quoted the equation and correctly calculated the time. The most frequent misconception was the belief that a 'suvat' equation should be used even though the velocity is constant.

The correct answer of 3000, or 3022, was accepted in part (a) (ii) and the majority successfully produced this value.

In part (b) (i) most select and quoted the correct equation and showed the correct substitution. Some lost the mark as they did not show the answer to more than one significant figure.

Part (b) (ii) was a very easy question for over 40% of candidates who understood that the horizontal acceleration was zero. For these students, $45.3 \times 0.685 = 31$ gained two marks. However, 13% did not attempt the question and another 40% misapplied a kinematics equation to the situation often using 9.81 as the acceleration.

The vast majority of candidates identified air resistance as the key factor to part (b) (iii). However, only 7% mention that **horizontal** deceleration is caused by air resistance.

In part (a) (i), the majority of candidates stated 'force $\times$ perpendicular' distance but only 16% stated the full definition. Many did not recall the definition accurately or did not say the distance was between the line of action of the force and the point. Many said 'force $\times$ perpendicular distance from the line of action' or 'force $\times$ perpendicular distance to the point'. These candidates were only awarded one mark. A significant number of candidates stated the Law of moments rather than the definition of a moment and some produced a vague description of a turning effect rather than a definition. Students should be encouraged to learn the full definition off by heart.

In part (a) (ii) 57% scored two marks very easily. However, a surprising number selected the front springs rather than the rear due to 'a larger distance from the pivot causing a greater moment on the front'; confusing the *centre of mass* with the 'pivot'. Some candidates assumed the *centre of mass* is always closer to the front of a truck. However, the question shows a rear-engined pick-up. Some candidates thought that the rear springs were 2.0 m from the *centre of mass* having incorrectly interpreting the dimensions on the diagram. Some felt that since the truck was in equilibrium, both sets of springs would be equally compressed.

For such a simple moments question, part (a) (iii) was done poorly by the majority. Perhaps the context made it seem more difficult than it really was, but many chose the wrong distances and equated a moment with a force rather than another moment. Common incorrect answers were $14000 \times 1.4 = 19600$ and $14000 \times 1.4 = 14000 \times 1.1$. Many common answers given were greater than the weight of the truck. Most of those who couldn't pick up any marks for the moments calculation did realise that it would be necessary to divide by two at the end and so most scored at least one mark.

In part (b) most gained two marks with the error carried forward from their previous answer.

The poor response to part (c) was very surprising. Only 5% gained two marks with 47% getting zero and 18% not attempting the question. Perhaps those who had struggled on previous parts of this question made the assumption that this would be difficult as it was the final part of the question. However, it was perhaps the easiest part of the question and was independent of the previous parts.

Part (a) (i) was very straightforward and most students scored two marks. Some scored zero by attempting a moments calculation. There were a few mixn-ups with powers of ten; some thought that kN was 10^6 N and some did not spot k.

Many students used 4.6m rather than $4.6 + 2.8 = 7.4$ m to calculate the moment of the lift-fan force in part (a) (ii). There is still a lot of confusion with moments questions for students in the January paper, and the evidence may suggest that many schools have not practised enough of these.

The maths of this question could not be made much simpler apart from perhaps giving the 7.4m dimension on the diagram. It was again apparent that a large number of students believed a complicated solution must be required; perhaps the context persuaded them that this must be so. However, once the candidate has simplified the diagram, the question is straightforward and simply dividing their previous answer by 7.4 yields all three marks. Given the frequency of this style of question on PHYA2 papers, it is really worth going over as many of these as possible with students.

The weight of the aircraft minus the engine thrust previously calculated yielded the mark for most students in part (a) (iii). However, a significant number did not know this or used the law of moments again.

In part (b) (i) a very large number of students used $a = F/m$ with the weight of the aircraft used for mass. This approach did not gain any marks. Many rounded their mass before using it to calculate the acceleration, this was forgiven in this question, as was the use of $g = 10 \text{ ms}^{-2}$. These errors are condoned here because we do not penalise the same mistake several times in a paper.

In response to part (b) (ii), many students did not realise they had to state a characteristic of the aircraft. This meant referring to the shape or aerodynamics in some way or the maximum thrust. Marks could not be scored unless one of these was mentioned. There seemed to be a common misconception that 'its air resistance' was a characteristic of the plane. The question was interpreted by many as 'explain why the plane reaches a terminal velocity'. Many believed that the mass of the aircraft would be a factor. However, the mass would limit the acceleration rather than the top speed.

In part (b) (iii), examiners were looking for an understanding that the acceleration would be falling towards zero as the terminal velocity was approached. Many students recognised that the velocity would increase and then remain constant. However, a very large proportion of students drew a straight diagonal line with an abrupt change to constant velocity. There were also many 's' shaped curves and curves that showed the acceleration continually increasing. Many also drew straight diagonal lines that did not 'level off'.

Part (c) was an easy question but students did not read it well and many lost the mark because they simply stated that the maximum acceleration is the gradient rather than the **maximum** gradient. A large number also believed that the area represents the acceleration or that the gradient at maximum velocity would be the maximum acceleration. Note that the response; 'the part of the graph where the gradient is steepest' does not make it clear that the gradient = the acceleration.

Many students lost the mark because they said the maximum acceleration was the initial gradient. This would apply to the graph in part (b) (iii) but it was not enough for the mark. Some students responded that 'the gradient of the flat part of the graph' should be found.

28.

The answers to part (a) were generally very detailed with many students continuing to write to the bottom of the page. Answers could have been more succinct perhaps. eg *No energy lost, so all GPE at A is converted to KE at B which is converted to back to an equal amount of GPE at C.* Some students explained that GPE transfers to KE but then failed to mention the conversion back to GPE. eg 'all the GPE is converted to KE at B, so it gets to the same height at C'. Often the law of energy conservation was quoted but they did not explicitly state that there were no energy 'losses' due to no friction or drag.

In part (b) there was some carelessness in the positioning of the label for B. Many students had a significant straight section at the start and showed the ball decelerating after point X.

In part (c) students often stated that the speed was constant but did not point out that the ball would move in a straight line. They often explained the motion in terms of there being 'no forces' acting on the ball rather than 'balanced forces'.

29.

In part (a), many students confused strain with stress and there were many vague descriptions rather than definitions, for example 'amount of extension due to a force applied'. The definition has to describe how a correct strain would be calculated. Therefore, it is essential that the 'original' length is specified and the phrase 'divided by' rather than 'compared to' needs to be used. Some students used the word 'from' to convey 'divided by' for example, 'the extension from the original length'. This was not accepted. 'The ratio of the extension from the original length' was acceptable.

Only 1.9×10^8 was accepted as an answer to part (b). Few students strayed from 1.9. However, many lost the mark by missing out the power of ten.

Most students did very well on part (c). Nearly all put the point in a sensible place just beyond the linear section but a few did not include a suitable label and therefore they did not get the mark.

Most students were very successful in part (d). Most chose the straight section for the gradient calculation and most chose a large enough section of it. Some went to a stress of 1.3 or more where the line was clearly curving. The unit was usually correct but a few had capital M or m^{-1} . Surprisingly, a significant number missed the unit out altogether.

Part (e)(i) should have been a straightforward question. Most students identified the correct area to evaluate but either did not use an accurate method or did not recognise the value of each square they counted. A very common answer was 38 rather than 38×10^5 . Many divided the area into two triangles and a rectangle, leaving out a significant area from their calculation. With a number of similar examples of area approximation on past papers, it was surprising that very few were able to score both marks here. Many students do not know how to find the area under a curve to a sufficient accuracy.

Many students obtained the volume in answer to part (e) (i) but did not realise that they then needed the value they calculated from part (e) (i).

In part (f), many students did not recognise that a higher Young Modulus would give a steeper line and many who did realise this did not stop their line at 176 MPa. Many showed excessive curvature not characteristic of a brittle material.

30. Most students were successful on part (a) (i). A few used 170 N rather than 170 kN or did not multiply by the distance of 1000 m.

Many used 170 kN rather than the resolved horizontal component in answer to part (b) (i). Some students used the value of the power from part (a) and lost both marks.

In part (b) (ii) many students did not calculate the total power or inverted the calculation.

Many students mentioned the drag force in part (c) but by itself, this was too obvious. Examiners needed to see what factors changed the drag on the sail such as the area and the wind speed. Many students referred to the drag force on the ship, the 'tension in the sail' and the weight of the ship.

31. Most students performed well in part (a) with many examples of well laid out calculations in part (a) (ii).

Part (b) again provided a good discriminator which challenged students' understanding of the situation and looked for detailed analysis of the situation.

Many students correctly identified that the hook would have a lower speed but often the supporting explanation was superficial and lacked the rigour expected at this level.

Best examples used a knowledge of physics to support explanations through thorough use of equations and coherent multi-staged arguments.

32. This question posed the greatest problems for students with less than half presenting work in a convincing manner. Many students failed to deal with the perpendicular nature of the horizontal and vertical velocities.

In part (a) a significant number of students were unsure how to tackle this problem. Many assumed that the initial vertical velocity was 18 ms^{-1} . These students also failed to realise that the ball had undergone a vertical displacement of 1.51 m on reaching the net.

Part (b) proved to be an excellent discriminator with under half of the students showing an understanding of the situation and demonstrating the knowledge and mathematical skills required. Again in part (b) (i) students failed to realise that the initial vertical velocity was zero. In part (b) (ii) many students attempted to use equations of motion showing little awareness of how to solve this type of problem.

Correct calculations were well organised with equations and processing being arranged in a logical manner.

33. This question tested basic facts concerning the quantities that are conserved when two bodies – two skaters in this question – separate from each other with a release of kinetic energy. Almost 70% of the students gave the correct response. The most common incorrect response was distractor B, the students involved not realising that kinetic energy must increase when two stationary bodies start to move.

34. Students often find that questions in which the result of a calculation is shown algebraically are harder than ones in which the calculation is purely numerical. In this question, where the recoil speed after an explosion was to be found in terms of kinetic energy. Just under half of the students arrived at the correct expression, and the question did not discriminate very well. 27% of the students selected distractor B, because they regarded the mass of the daughter nucleus still to be M (instead of $M - m$) after it had emitted the α particle.

35. For part (a)(i) most students successfully gained the unit mark here, but a few put Nm^{-1} , N/m , NM or Nm^{-2} . In part (a)(ii) students fared better on this moments problem than we have seen on previous papers. However, there were still plenty of problems. In particular, some students are unable to identify clockwise and anticlockwise moments. It is perhaps surprising how many AS physics students do not understand the concept of a moment and are unable to identify the direction of rotation that it would cause about a given point if no other forces acted. One possible strategy is get students to identify the clockwise and anticlockwise moments in many situations before teaching them how to use the law of moments. There were also a lot of mathematical errors by those who had equated the moments correctly and then could not rearrange correctly. Many rounded 97.46 to 97.5 and then rounded again to 98. For part (a)(iii) most were successful. Very few resorted to an unnecessary moments calculation for this one and many picked up the mark for an error carried forward if their previous answer had been wrong.

In part (b)(i) nearly all students were successful here though some used s rather than $2s$. In part (b)(ii) a significant number of students used 520 N as the mass, not realising it was necessary to divide the weight by 9.81 to get the mass. Some multiplied by 9.81 instead of dividing. However, this was an easy two marks for most.

36. This question had appeared in an examination previously; it tested the fairly familiar knowledge of the trajectory of charged particles in electric and magnetic fields and this time had a facility of 71%.

37. This question was an easy starter that required the application of “change of momentum = area under force/time graph”. This question discriminated well, and just over two-thirds of the students gave the correct answer. The most popular incorrect response was distractor D, no doubt because the students who chose it overlooked the factor of $\frac{1}{2}$ when calculating a triangular area.

38. This question required an understanding of whether the accelerations in two perpendicular directions are constant or zero when a beam of electrons travels through a uniform electric field. This was well known, giving over 70% of correct responses.

39. Acceptable statements really needed to refer to both the direction of the induced emf (or current) and to the change (in magnetic flux) that produces the effect. In part (b)(i) an explanation of the greater mass of Q was required, so a simple statement that density was involved was inadequate; candidates had to state that steel (or Q) has a greater density than aluminium (or P). In part (b)(ii) the time of 0.45s was usually justified through the application of $s = ut + \frac{1}{2} at^2$, although some candidates made no attempt to justify this value. Backwards working, such as showing that the distance fallen is approximately 1.0m when the time of fall is 0.45s, was accepted. Explanations of why the two times are equal were expected to refer to acceleration due to gravity being independent of the mass of a falling body.

There was widespread misunderstanding in candidates' attempts to answer part (c). In part (i), clearly Q is a moving magnet passing through a conducting tube and so the magnet's flux lines are cut by the tube – hence an emf is induced. A significant number of responses stated that Q would be cutting through the flux lines of the tube. The tube was regularly referred to as a magnet. A very common misapprehension was that when a current is induced in the tube, it is the current that causes the emf. In part (c)(ii) many answers were too trivial, such as ones which referred to the repulsion of poles, or were simply wrong, such as attributing the effect to induced *charges*. Some responses even suggested that the induced electromotive force acts as a mechanical force to oppose the falling magnet. Examiners were pleased to encounter logical answers stating that the induced emf caused a current to flow in the copper, which then produced a magnetic field to oppose the movement of the falling magnet Q by opposing the magnet's own field. Relatively few answers made any reference as to why cylinder P would fall without opposition.

Full marks were regularly awarded in part (d), where it was usually seen that the time for P would be unaffected (an explanation was needed for the mark) but that for Q would be shorter. Some candidates thought that the increased resistance of the tube would cause a reduced emf; these answers were subjected to a two mark maximum.

- 40.**
- (a) Candidates were generally very successful on these questions.
 - (b) Candidates were generally very successful on these questions.
 - (c) Most candidates were successful. However, a few used $t = s / v = 54 / 33$ instead of a kinematics equation.
 - (d) As with previous papers, candidates lacked the depth of knowledge necessary to describe energy transfers. Perhaps some teachers assume candidates already know this from GCSE. More practice on this type of question is necessary. Too few candidates are able to make the link between potential and kinetic energy.

41. Most candidates were able to draw a reasonable vector diagram. Scales could often have been larger and a minority of candidates failed to state the scale factor. Few showed the direction of the resultant – for which they were penalised unless it was clear from the directions of the two velocities being added. Those correctly calculating the resultant were penalised by a mark, however most attempted calculations were incorrect.

42. More than one third of the candidates incorrectly chose distractor C in this Question, where an average force has to be calculated by applying $F = \Delta mv / \Delta t$. Just over half of them correctly chose alternative D. Undoubtedly the error of so many candidates was to fail to appreciate the vector nature of velocity and momentum. Distractor C would have been the correct answer had the change in velocity been $35 - 30 = 5 \text{ m s}^{-1}$.

43. This question concerned the significance of the area under a force-time graph. When this question was pre-tested just over half of the students gave the correct answer. The responses in the examination shows that candidates prepare much more seriously for real examinations than for pre-testing sessions, because it proved to be the easiest question in the paper.

44. This question tested the vector nature of momentum, the scalar nature of kinetic energy and the meaning of an elastic collision. Just over two thirds of the candidates realised that the exact reversal of momentum meant a change of $2mv$ and that an elastic collision meant no change in kinetic energy. Almost 20% of them chose distractor C, thinking there is no change in momentum.

- 45.**
- (a) Most were successful but a significant number did not multiply by g , perhaps not understanding the difference between weight and mass.
 - (b) A common error was to not half the force (or double the area). However, a high percentage did realise that you had to do more than simply substitute the numbers given.
 - (c)
 - (i) Most correctly calculated the load on one of the cables but many did not realise they needed to double their result to get the complete load.
 - (ii) A lot of rounding errors were evident. 0.06 recurring was often rounded to 0.06 rather than 0.067. Many used their value for weight but did not halve it. Some candidates therefore lost a mark because even though they got the correct answer, they had not halved that weight and this was a physics error.
 - (iii) Many did not understand that they should use the weight and the extension previously calculated. Many thought that the total load divided by the extension of one cable would give only half of the total stiffness constant. This is not the case because the extension of each cable is the same.

- 46.**
- (a) This was quite well done. A few used $v = s / t = 1.5 / 0.43$ and there was some use of $a = 9.81$. Those who had practiced less of these questions got confused because u was not zero. Incorrect rearranging of the equation was also quite common.
 - (b) A common error was to use $\cos 25$ rather than $\sin 25$ for resolving along the slope.
 - (c) This was very poorly answered. It was expected that candidates would realise that kinetic energy was not changing, and therefore, the transfer could be easily summed up as gravitational potential energy transferred to internal / thermal energy. Most did not pick up the more subtle points that the GPE ultimately all ends up as internal / thermal energy and the KE stays constant.

It was not enough to say that some of the GPE transfers to KE and some to heat. That doesn't answer the question and could apply to many situations. Candidates should always name the forces. 'Resistive forces' did not score the mark, 'friction' or 'drag' was needed.

Many candidates have learnt that 'loss of GPE is equal to the gain in KE' and they believe this applies to all situations.

47.

- (b) (i) Most candidates got this correct. Only a few dropped a mark for the unit, e.g. with N / m rather than Nm.
- (ii) A very large number of candidates thought that $W = F \cos \theta$ had to be used and needlessly multiplied by $\cos 25$.
- (iii) This tended to be 3 marks or zero. Some lost marks due to errors in the powers of ten. Other than that, a large number didn't know how to do a simple moments calculation.
- (c) The majority were very successful on this question.

48.

The definition in part (a)(i) was well known. Because the quantity concerned is called gravitational field *strength*, there was frequent confusion as to whether it is a vector or a scalar, with many answers being crossed out and changed. Part (a)(ii) was also generally very rewarding. The main problem was a failure to show how the terms from the data booklet equations (m_1 , m^2 and r) translated into the terms in the question (m , M , R and h). In the derivation, some students cancelled M instead of m . However, others had so little confidence in their use of algebra that they could make little progress even in a simple derivation such as this.

Part (b)(i) caused few problems and marks were generally high. Sometimes incorrect values had been extracted from the data booklet for the mass and radius of the Earth. Three significant figures were expected in the answer; therefore a minimum of three significant figures should also have been used in the substitution and working. When $h = 1.39 \times 10^7$ was used as the radius of the orbit one mark was lost and the value of the force thus obtained was carried forward to make most marks available in part (b)(ii). Part (b)(ii) offered a very wide range of approaches to enable students to show that the satellite would make three transits of Earth in every 24 hours. Apart from the three alternatives given in the mark scheme (all of which were frequently seen) a very concise calculation showed that a satellite with an angular speed of $2.19 \times 10^{-4} \text{ rad s}^{-1}$ would move through an angle of 18.9 rad in one day, equating to $(18.9 / 2\pi \Rightarrow) 3.01$ transits.

Use of polar orbiting satellites for monitoring the Earth (weather forecasting, spying, surveying, etc.) were well known in part (c), although some students confused the application with an equatorial geosynchronous satellite. Explanations of the application were often less satisfactory: reference to the rotation of Earth beneath the orbit, allowing the whole surface to be scanned, was the key here. The ability to provide regular updates of the information obtained was also an acceptable explanation. Students who mentioned the use of the polar satellite for communications gained the first mark but were usually unable to point out its limitations, caused by intermittent contact.

49.

Most of the candidates made significant progress in part (a) and there were some very good explanations of thermionic emission. The most common omission was in not describing the role of the electric field between the anode and cathode in accelerating the electrons in the beam.

Many candidates calculated the acceleration correctly and a significant number set out their work clearly and well. Some attempted to use the work done by the electric field between and others tried to use just the equations of motion.

Parts (b) (ii) and (b) (iii) were well done by many candidates.

In part (b) (iv), a significant number of candidates did not know how to proceed but the majority made some progress either by using ratios or equations of motion. For those that made significant headway, the most frequent mistake was to omit to add on the vertical distance that had already been travelled by the time the beam reached the end of the plates.

50.

Most candidates correctly took ratios to obtain the value for d in (a). Many then went on to calculate the acceleration, time or kinetic energy before substituting to find the force (from $F = ma$, $Ft = \Delta(mv)$ or $W = Fs$ respectively).

An unexpectedly large number of candidates failed to refer to the kinetic energy and skidding distance equation in (c) and consequently were unable to take their answers forward. The best answers showed the proportional relationship between skidding distance and kinetic energy and stated that the kinetic energy was entirely transferred into the internal energy of the tyres / road ('heat' was condoned for 'internal energy' here).

51.

This question has been used to test candidates in earlier years. The former one showed an improvement in facility and the latter one a deterioration. This question was about the magnetic forces that act on a coil which is free to rotate in a uniform magnetic field. 58% of the responses were correct. The most popular incorrect answer was distractor B. Candidates who chose this response had not spotted the fact that when the coil lies with its plane perpendicular to the field, the two forces on its sides act in opposite directions along the same straight line. Therefore they do not constitute a couple.

52.

- (a) (i) This was generally well done but a few used $t = s / v$. Some rounded 0.4946 to 0.495 and then rounded again to 0.50. This was penalised.
- (ii) A large majority of candidates used a 'suvat' equation for this. Unusually, quite a few did so correctly with $a = 0$ and $u = v = 8.5$.

Many teachers encourage the 'suvat' equations to be applied for constant velocity situations and this is fine if the candidates know what to do. Nevertheless, the most common error was the use of 'suvat' with either $a = 9.81$ or $u = 0$.

For constant velocity situations, it is simply necessary to use, $s = vt$.

Those who did choose $v = s / t$, sometimes rearranged as $s = v / t$.

- (b) (i) Uniform deceleration was implied in this question so a 'suvat' approach was appropriate with $s = 0.35$ m, $u = 8.5 \text{ ms}^{-1}$ and $v = 0$. Most errors were due to use of $t = s / v$ or using 9.81 for the acceleration.

A very large number of candidates rounded to 2 dp (0.08). This was forgiven here but it is not good practice. 2sf would be appropriate here (0.082). Many students clearly do not understand the difference between decimal places and significant figures.

- (ii) Extensive use of $a = 9.81$ to calculate a horizontal force was seen. Very many candidates clearly did not fully understand the context. They identified a suitable equation but substituted the wrong values. There were many errors such as confusing distance with time, speed with acceleration. Not many used KE / displacement and most of those that tried tended to make errors. Quite a few candidates didn't attempt to answer this question.

53.

This question required candidates to realise that change of momentum is equal to the impulse of a force, and that the answer is therefore represented by the area enclosed between the force-time graph and the time axis. 80% of them were able to do this correctly. Possibly it was inability to calculate the area of a triangle that caused 12% to choose distractor D.

54.

This question was a numerical test of "force $\times$ time = change in momentum". This topic was not examined in Section B. Outwardly this question is more demanding than the previous one, but an even higher percentage of the answers were correct. Consequently this was the easiest question in the test. The ability of a question to distinguish the ablest students usually suffers when the facility is high (97% in this case); hence this was also the least discriminating question in the test.

55.

Most candidates dealt with the simple calculation in part (a)(i) but many lost a mark by simply forgetting to square the velocity.

Part (a)(ii) gave the average horizontal force with no indication that the force, and therefore acceleration, was constant. Therefore, candidates who used suvat equations, apart from $s = \frac{1}{2}(u+v)t$, were awarded only 1 mark. Just under 20% of candidates got the answer using a valid method, with most opting to equate the work done to the change in kinetic energy.

Part (b) proved to be the most challenging question in the paper with barely one-sixth of candidates gaining any marks at all. The majority of candidates failed to see that a sin component of either displacement or velocity was required and instead used $W = F.s(\cos\theta)$ when dealing with the angle.

56.

Overall this question proved difficult to many candidates, with many failing to grasp the underlying physics in each part. Candidates would have aided their comprehension of this question by sketching diagrams to highlight the relevance of the information.

In part (a)(i) barely one-quarter of candidates could interpret the data given to work out the extension of the rope, and in part (a)(ii) most candidates only went so far as to calculate one of the forces acting on the jumper. A free-body diagram would have helped candidates elucidate both forces and then more likely identify the resultant force. This would have also helped candidates answer part (b), which was clearly poorly understood, with many candidates multiplying the mass by zero, rather than setting the resultant force as zero.

Part (c) was very poorly answered with very few answers showing an appreciation that there were 3 energies (kinetic, elastic potential and gravitational potential) involved in the calculation. Most candidates ignored the potential energy in the rope and treated the question as a simple conversion of gravitational potential energy to kinetic energy. The introduction of new data confused many candidates.

Despite part (d) directing candidates to consider the kinetic energy of the jumper, very few did. It was extremely rare to see answers that appreciated the kinetic energy remained unchanged and most candidates gave answers in terms of impulse and momentum. Candidates needed to consider the fact that the work done to reduce the kinetic energy to zero would occur over a shorter distance and so the force on the jumper would increase.

57.

- (a) Most candidates were successful on this one but a few divided by 9.81 rather than multiply.
- (b) There was significant use of mass rather than weight for this moment calculation and 12 m was occasionally used rather than 5 m.

Incorrect units were often seen. Nm^{-1} and NM being the most common errors.

- (c) Most candidates got this one right but a few attempted to use trigonometry to resolve the weight of the ship. A few used a distance of $12 - 5 = 7$ m, perhaps thinking the pivot was at the centre of mass.
- (d) Quite a few candidates did not attempt to resolve T and did $2.5 \times T = 8.0 \times F$, but nearly all had a correct moments equation, which was credited.

58.

This question was the first of two questions in this test that required candidates to select an incorrect statement, a type of question which often challenges their logical reasoning. In the perfectly elastic collision at right angles between a molecule and the side of a container, the velocity of the molecule is exactly reversed. The change in momentum is therefore $mu - (-mu) = 2mu$. 70% of the candidates were aware of this, but almost a quarter of them thought the change in momentum would be zero (and therefore chose distractor A). Very few candidates chose the other two distractors.

59.

This question was answered correctly by almost 95% of the students, who clearly recognised that the area under the graph was “force $\times$ time = impulse = change in momentum”. The surprising feature of this question is that when it was pre-tested in 2008 fewer than 60% of the students gave the correct response.