AQA A-LEVEL PHYSICS · 7408

PHYSICS



EXAM QUESTION PACK

3.4.1 FORCE, ENERGY AND MOMENTUM · PACK 4

SCORE	PERCENTAGE
/428	%

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

_____

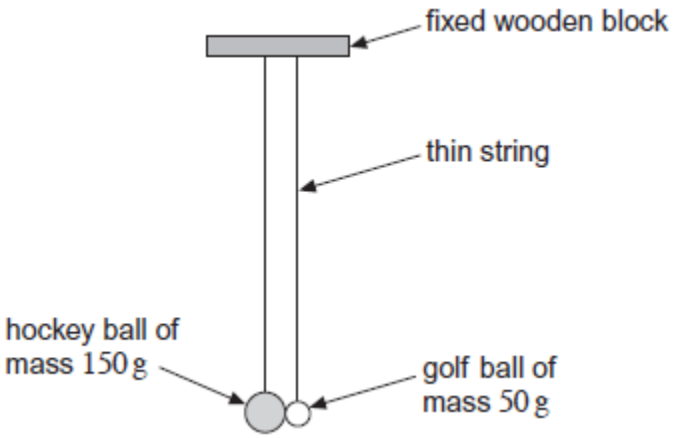
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(2)

(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)

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(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.

_____

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(2)

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

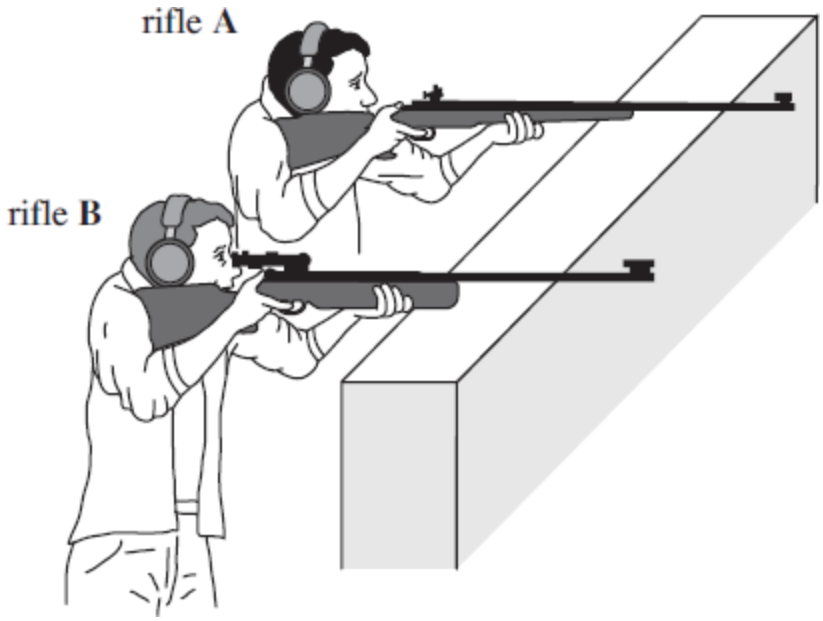
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(1)

(Total 13 marks)

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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)

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(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**.

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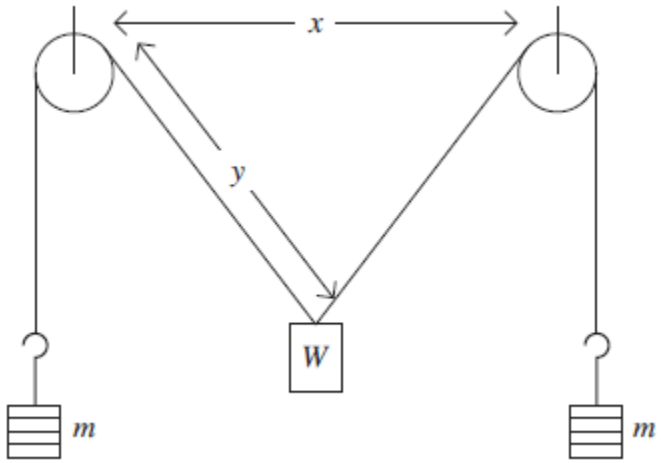
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(3)

(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



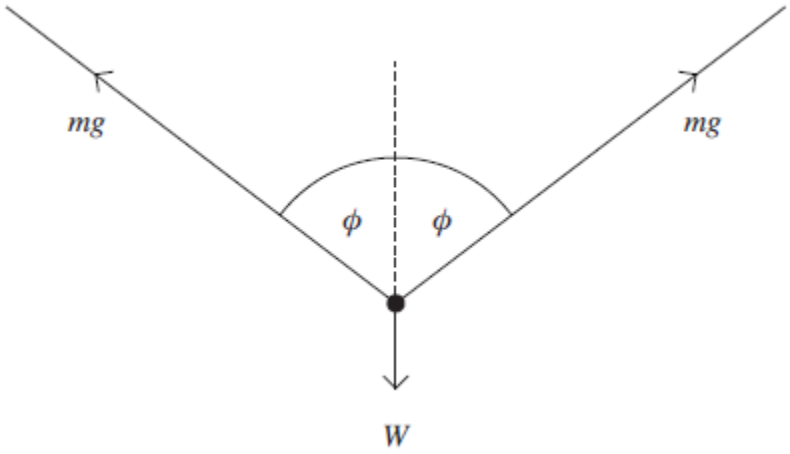
The distance x was kept constant throughout the experiment. The length y was measured for different values of m.

The distance between the strings at the pulleys, x = 0.500m

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(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.

_____

_____

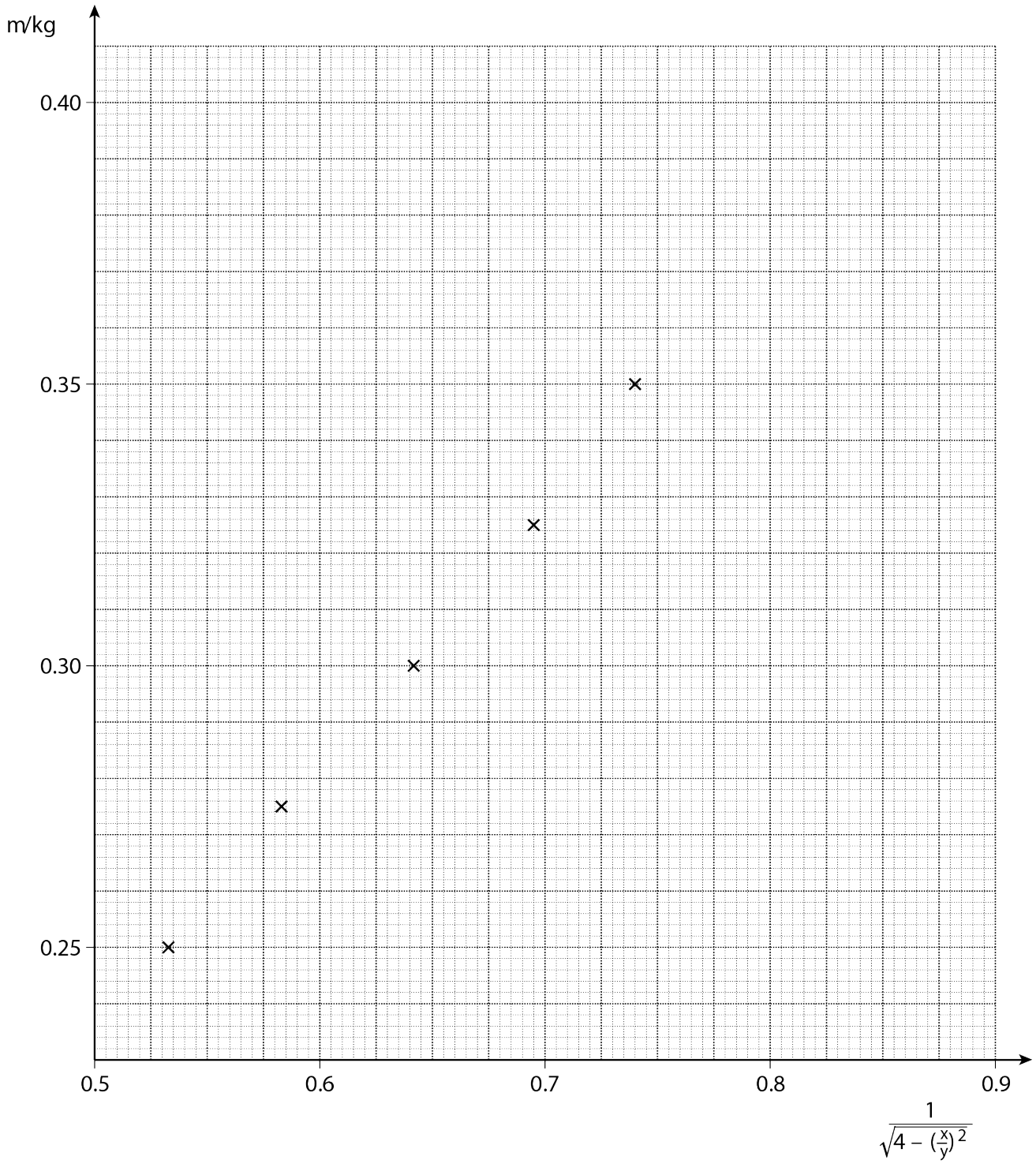
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_____

(1)

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



(1)

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(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 = 9.81Nkg^{-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 kg.

(3)

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(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.

_____

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_____

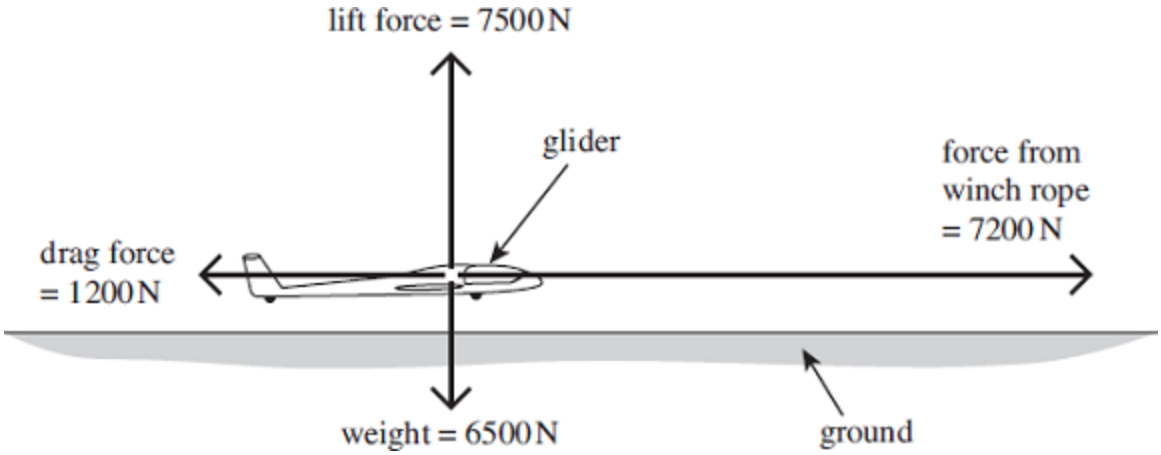
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(2)

(Total 13 marks)

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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)

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(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.

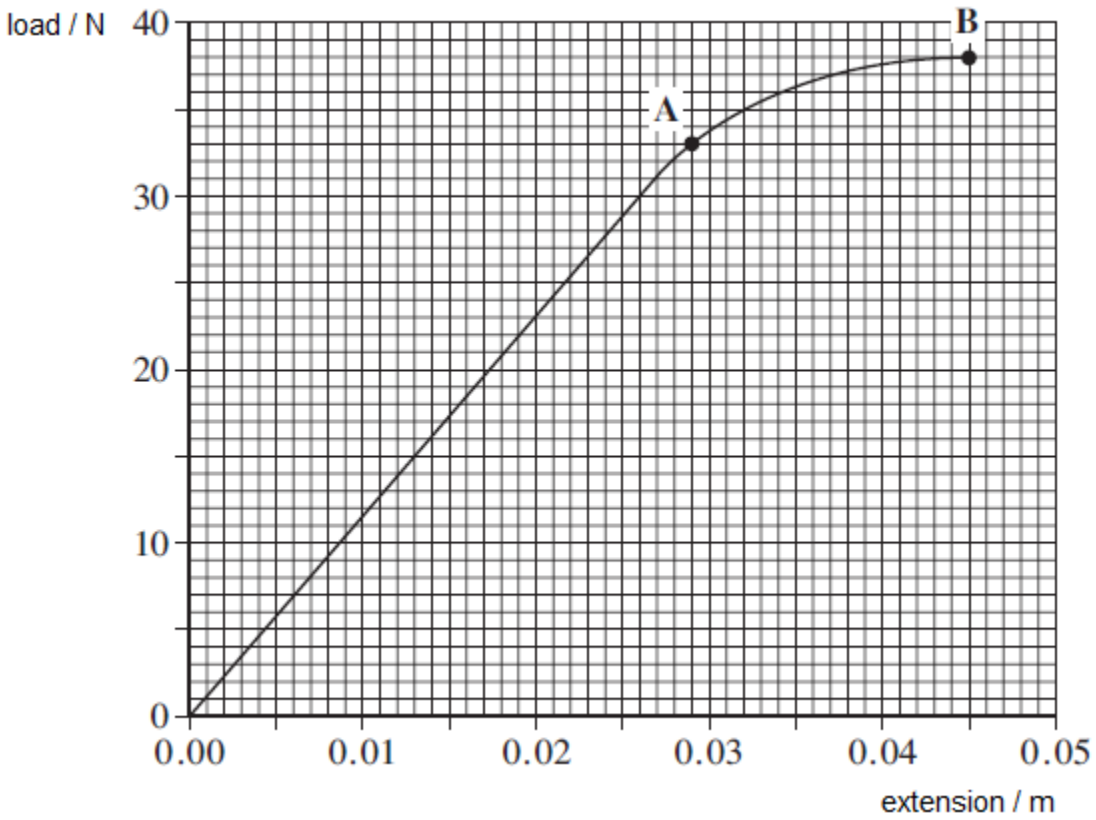
efficiency _____ %

(3)

(Total 11 marks)

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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)

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(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.

_____

_____

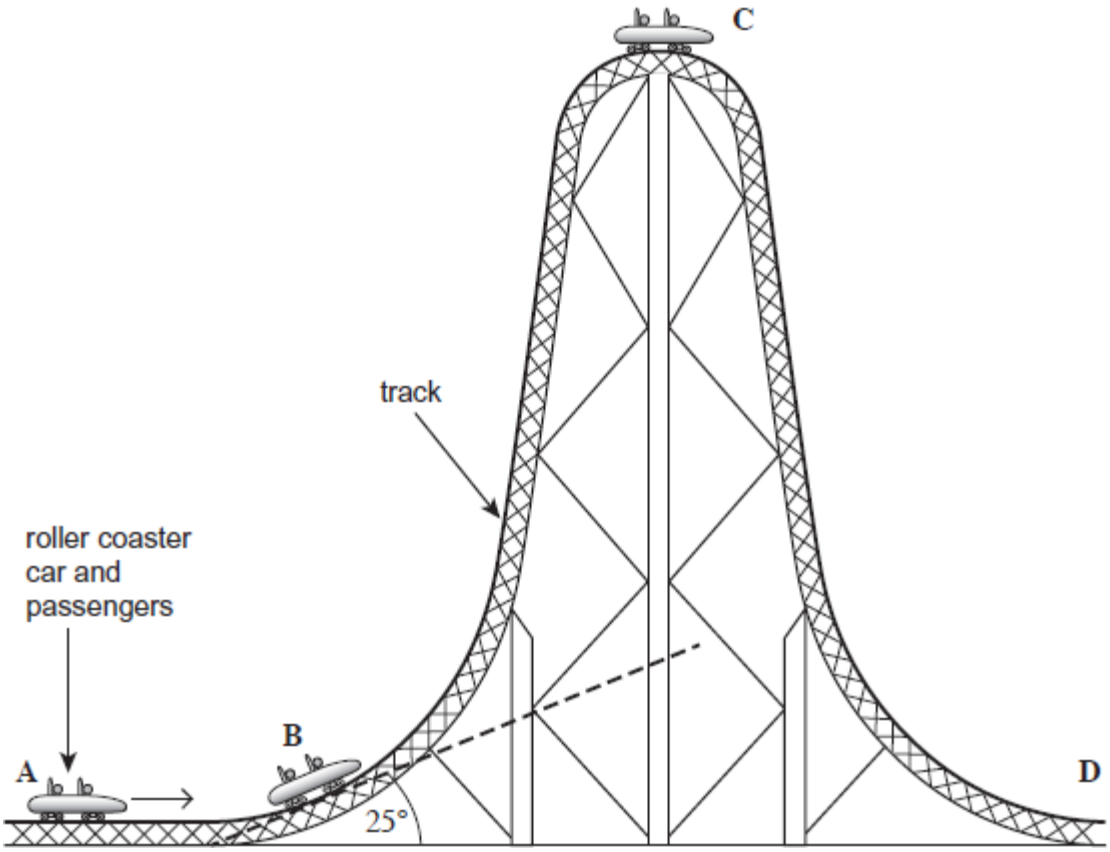
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(1)

(Total 12 marks)

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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)

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(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.

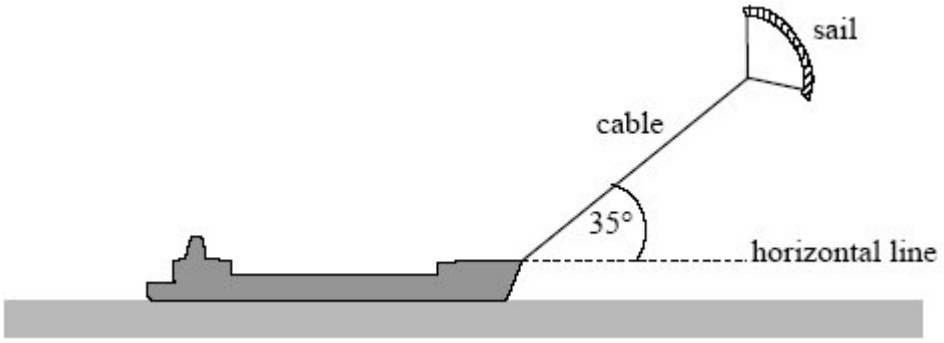
scalar quantities _____

vector quantities _____

(3)

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(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 propellors.



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)

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(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)

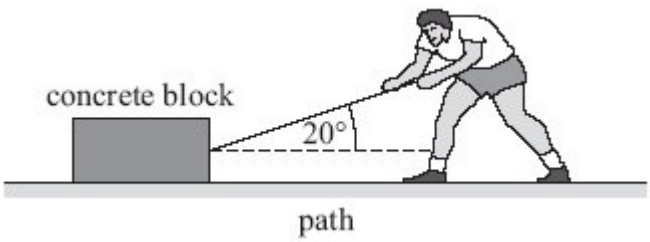
(Total 14 marks)

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.



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(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)

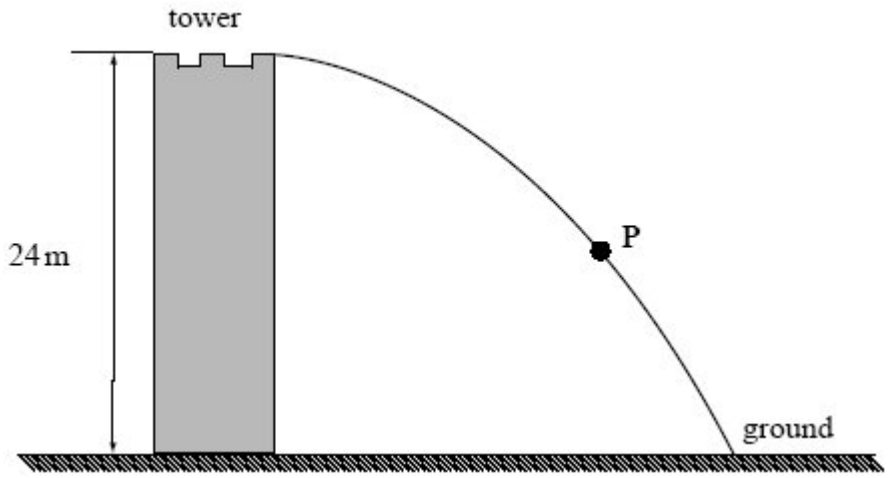
(b) Calculate the minimum work that the man has to do to complete the event.

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)

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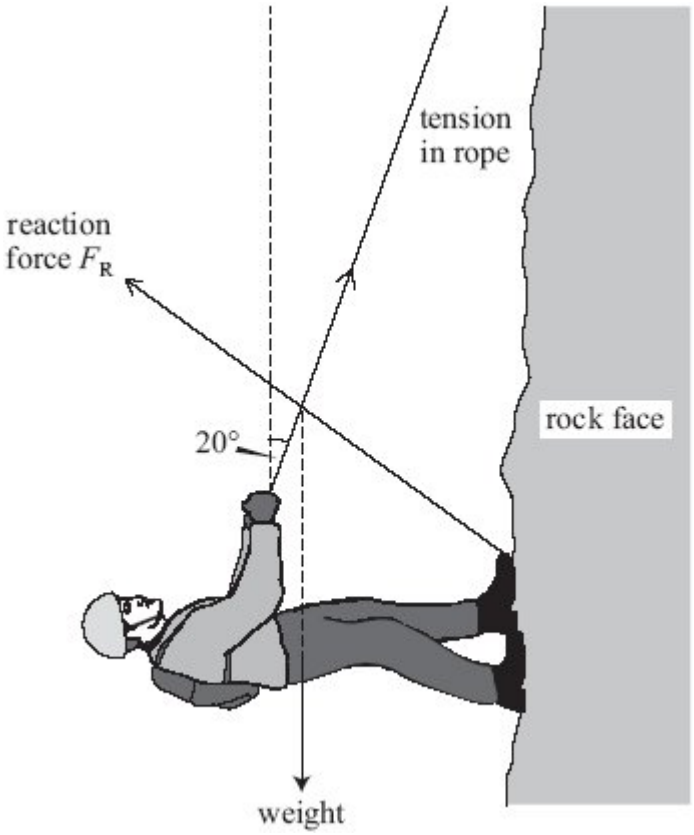
(ii) The ball hits the ground 27 m from the base of the tower. Calculate the speed at which the ball is thrown.

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.

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

vertical component _____ N

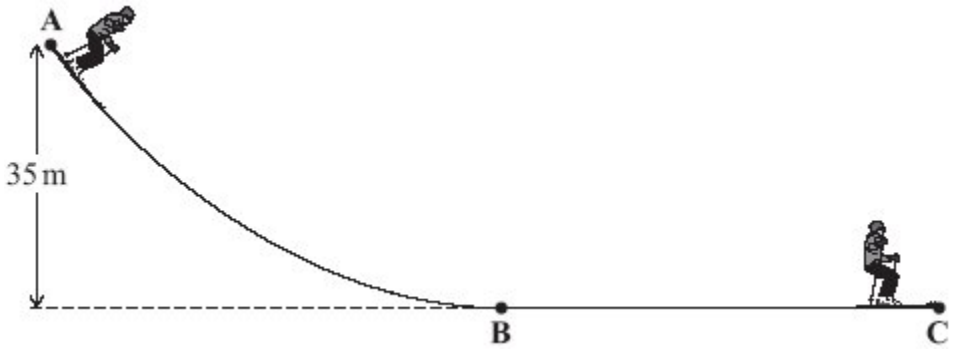
(Total 3 marks)

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**.

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(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)

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(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)

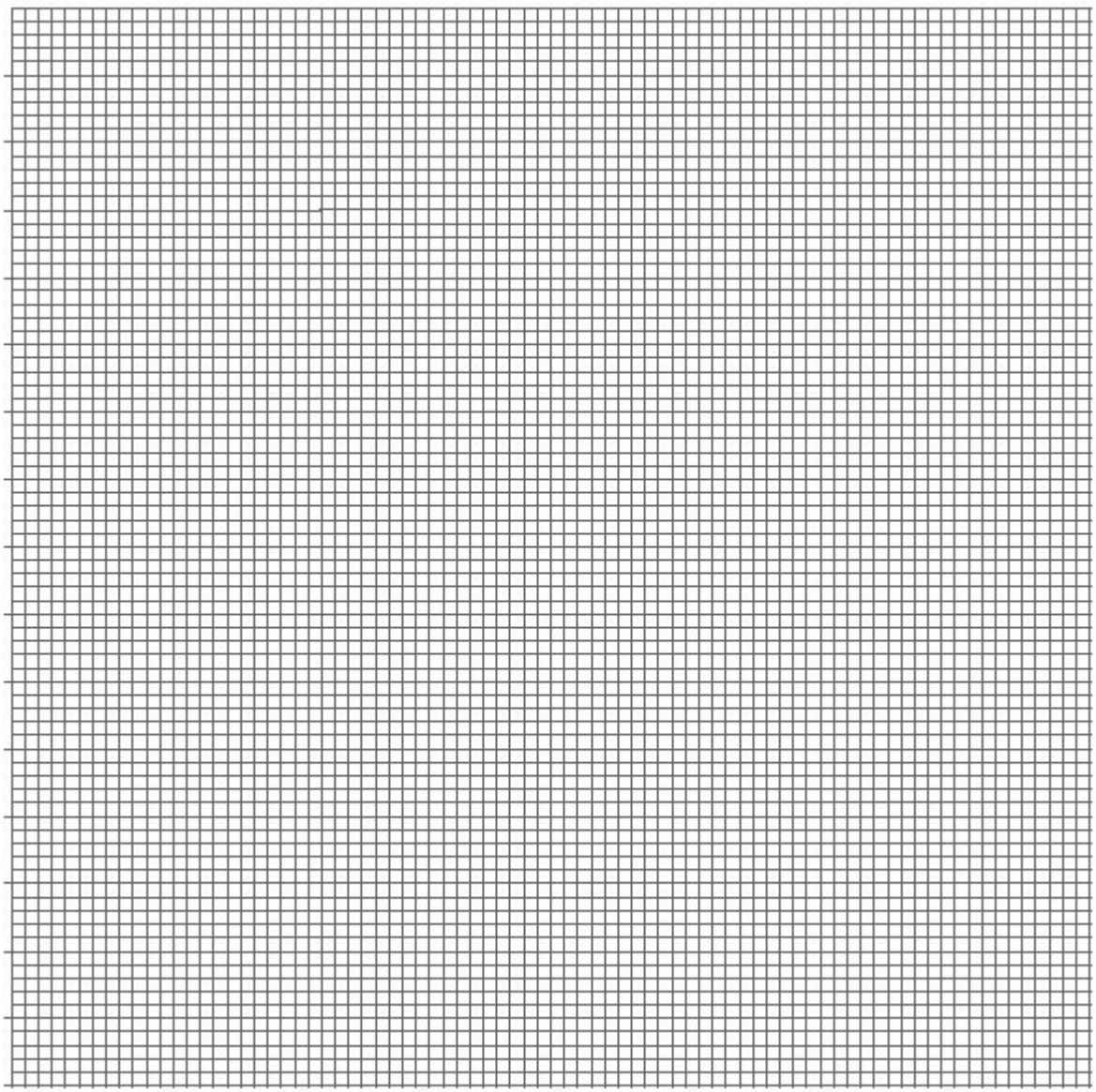
(Total 12 marks)

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

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(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)

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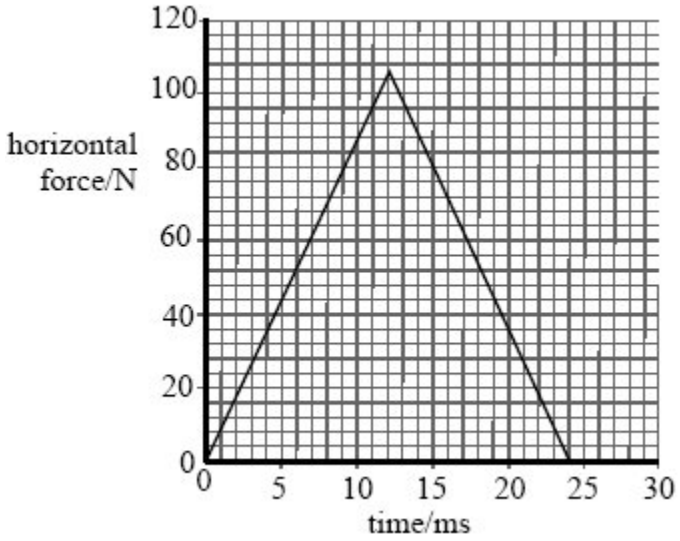
(ii) Use your graph to calculate the distance the car travelled after the lights turned red to when it stopped.

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)

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(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)

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(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 7.2×10^{-4} m^2 at a rate of 2.0×10^{-4} m^3 per second. How much momentum is carried by the water leaving the hose per second?

A 5.6×10^{-5} N s

B 5.6×10^{-2} N s

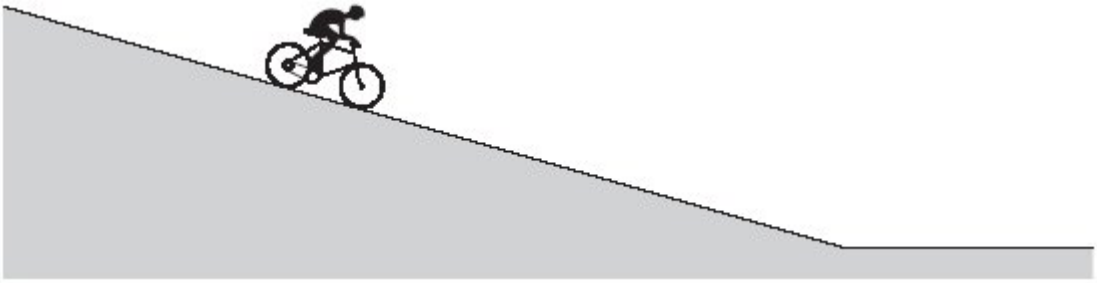
C 0.20 N s

D 0.72 N s

(Total 1 mark)

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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)

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(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.

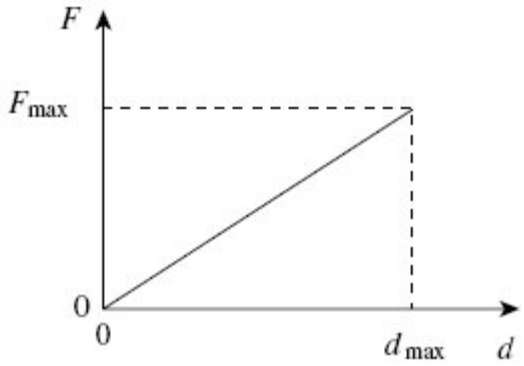
answer _____ N

(3)

(Total 13 marks)

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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

$$v = \sqrt{\frac{F_{max} d_{max}^2}{m}}$$

where m is the mass of the arrow.

_____

_____

_____

_____

_____

(2)

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(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)

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(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)

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(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.

_____

_____

_____

_____

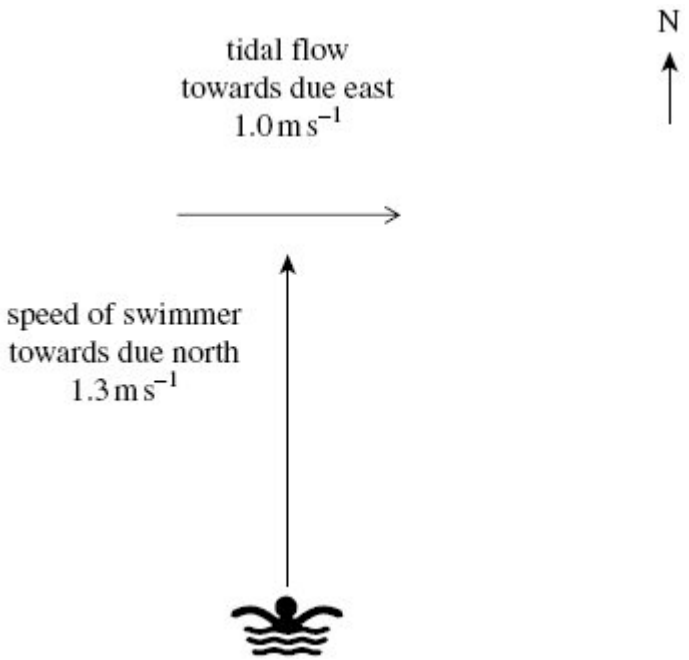
spring stiffness _____

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)

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

_____

_____

_____

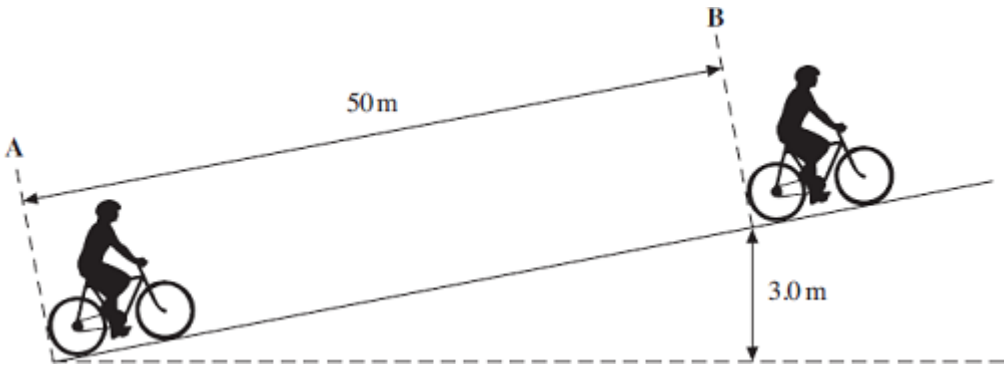
_____

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)

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(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)

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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 3.5×10^5 m^3.

(i) Show that the mass of air that would pass through the blades each second is about 4×10^5 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)

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(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 _____

_____

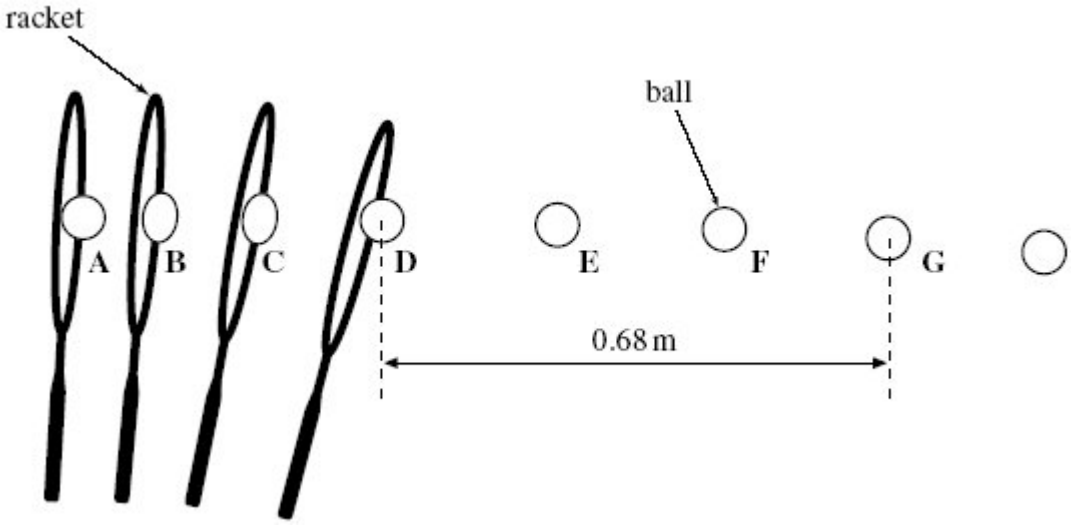
Disadvantage _____

_____

(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.



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(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)

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

_____

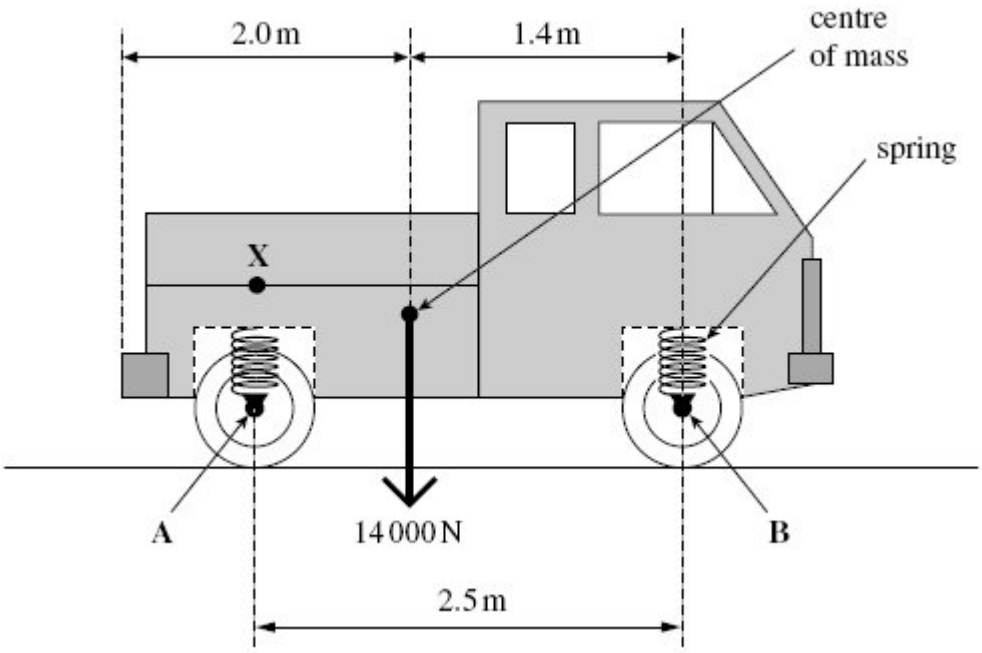
_____

_____

(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)

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(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 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)

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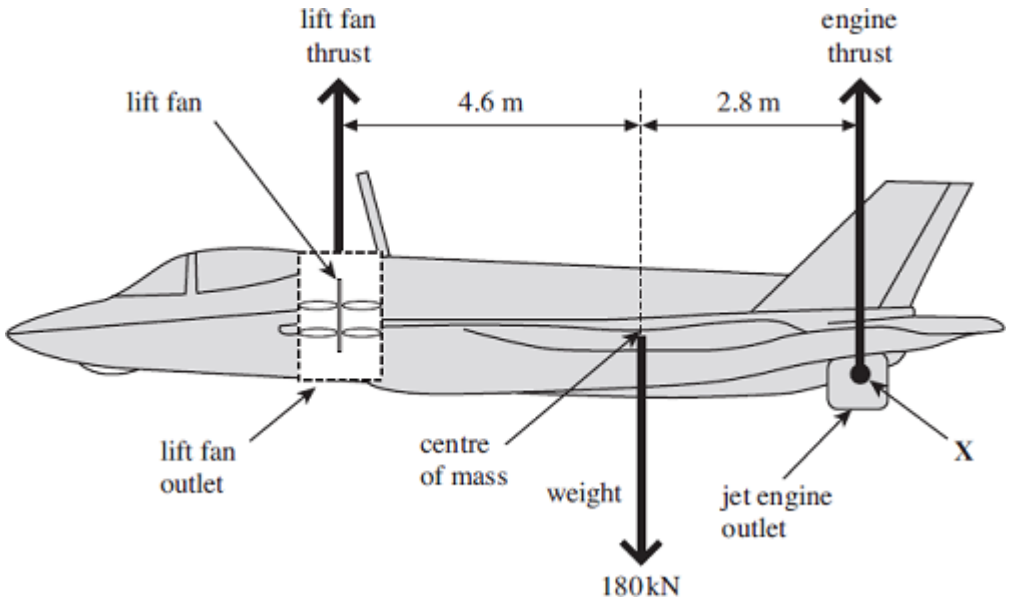
(c) The springs must not be compressed by more than an additional 0.065 m. Calculate the maximum load that could be placed at point **X**, which is directly above the centre of the rear axle **A**, as shown in the diagram above.

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)

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(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)

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(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.

_____

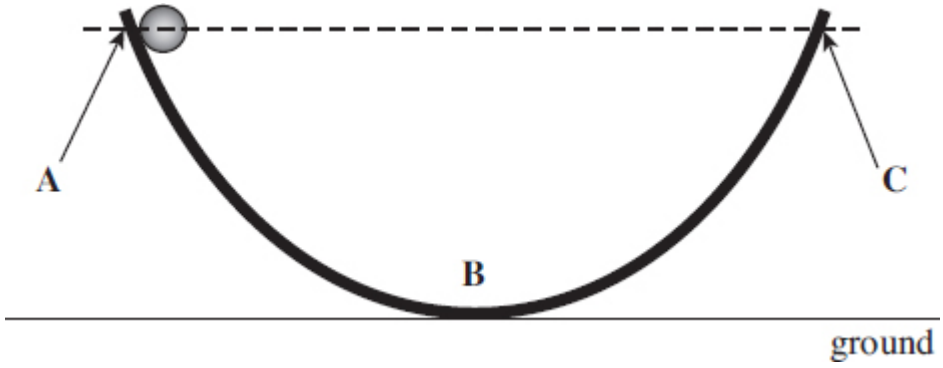
(1)

(Total 13 marks)

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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.

_____

_____

_____

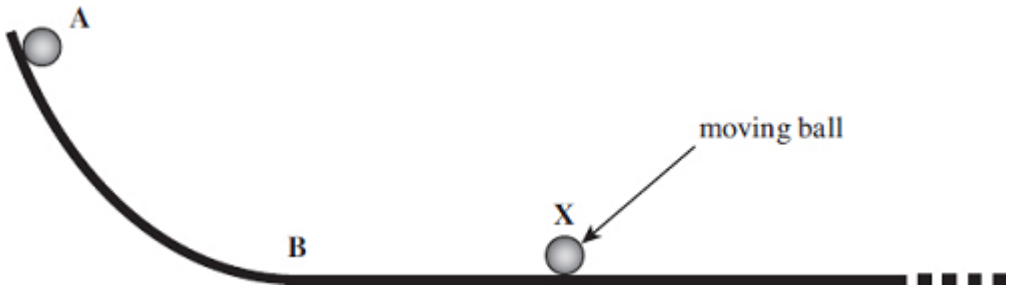
_____

_____

(3)

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

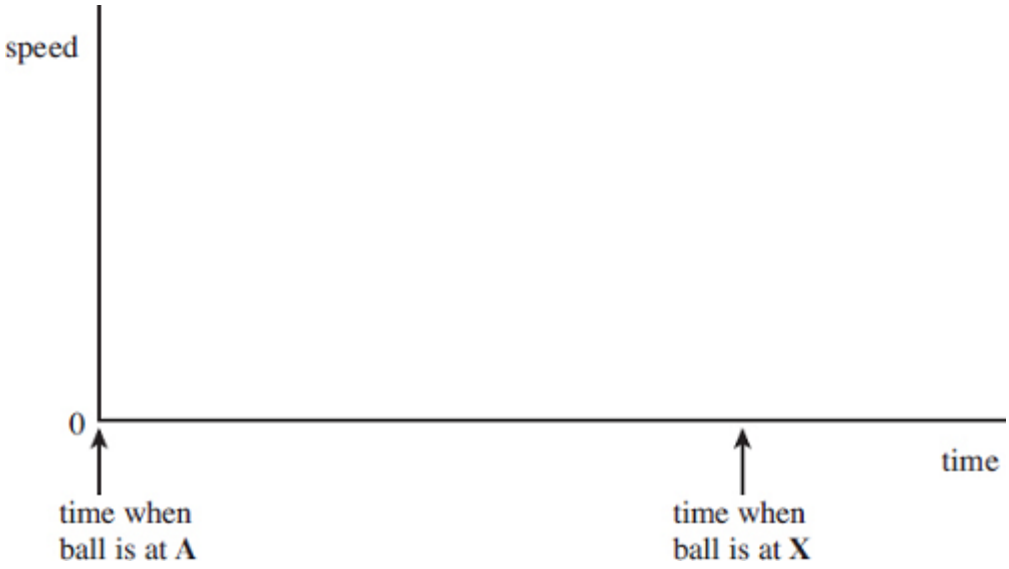
Figure 2



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

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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**.

_____

_____

_____

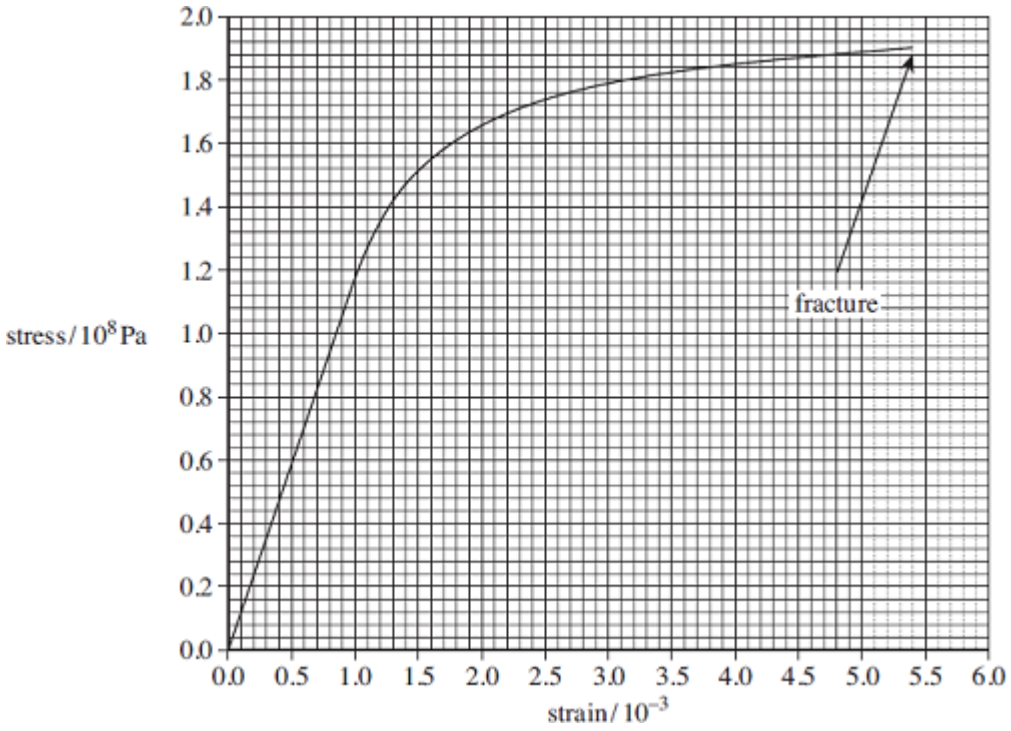
_____

(2)

(Total 8 marks)

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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)

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(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)

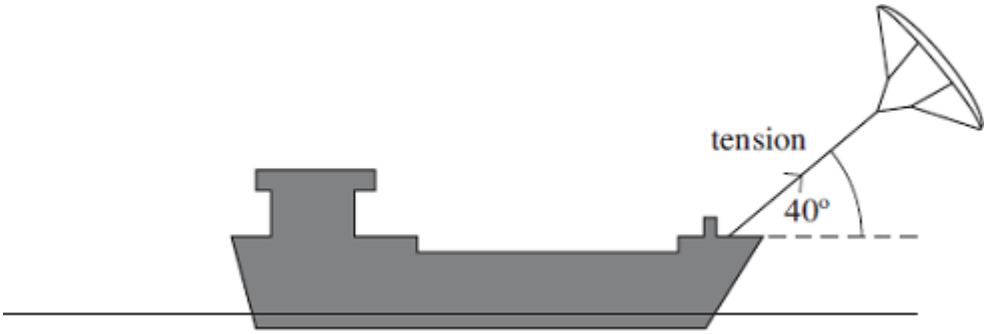
(f) A certain material has a Young modulus greater than copper and undergoes brittle fracture at a stress of 176 MPa.

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 1.3×10^{8} J.

(2)

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(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)

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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

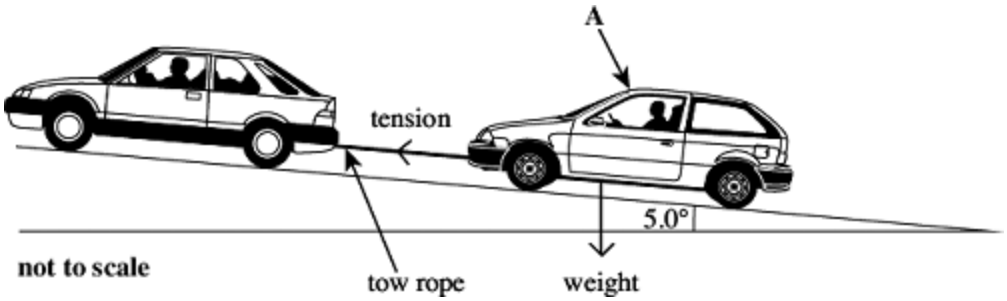
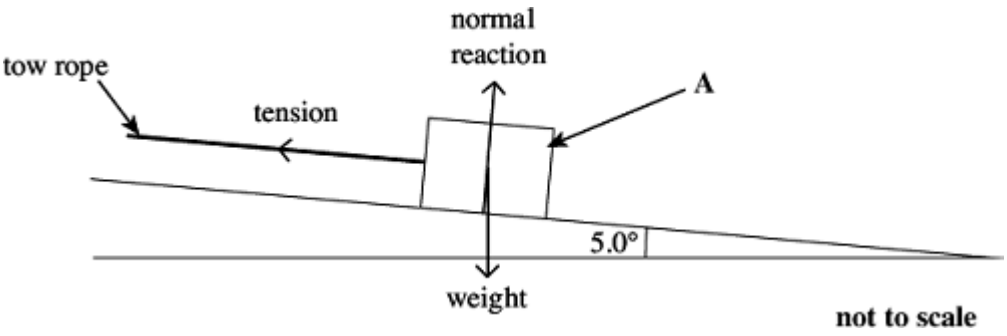


Figure 2 represents a simplified version of the forces acting on car **A** at the instant shown in **Figure 1**.

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)

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(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 2.5×10^{4} 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 2.5×10^{4} Nm^{-1}.

_____

_____

_____

_____

_____

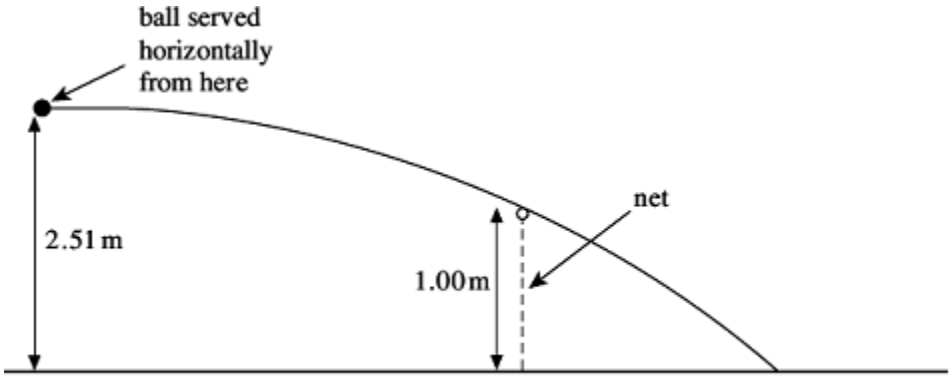
(3)

(Total 9 marks)

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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.



not to scale

(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)

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(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)

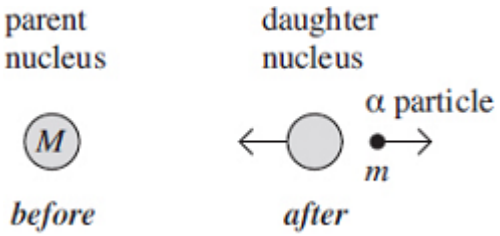
33. Two ice skaters, initially at rest and in contact, push apart from each other.
Which line, **A** to **D**, in the table states correctly the change in the total momentum and the total kinetic energy of the two skaters?

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

(Total 1 mark)

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

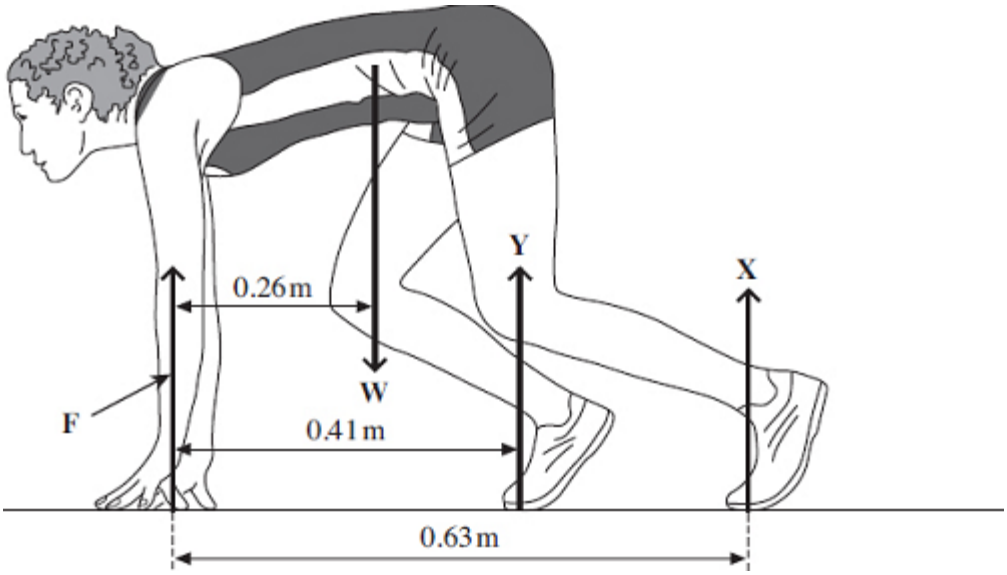
C $\frac{(M-m)}{\sqrt{2mE}}$

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

(Total 1 mark)

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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 **F**.

answer = _____N

(1)

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(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)

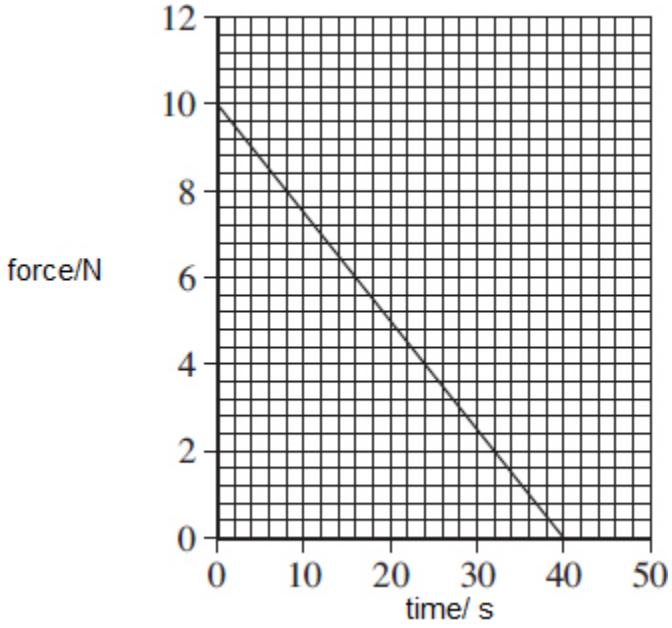
36. Which line, **A** to **D**, in the table correctly describes the trajectory of charged particles which enter separately, at right angles, a uniform electric field, and a uniform magnetic field?

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

(Total 1 mark)

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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}

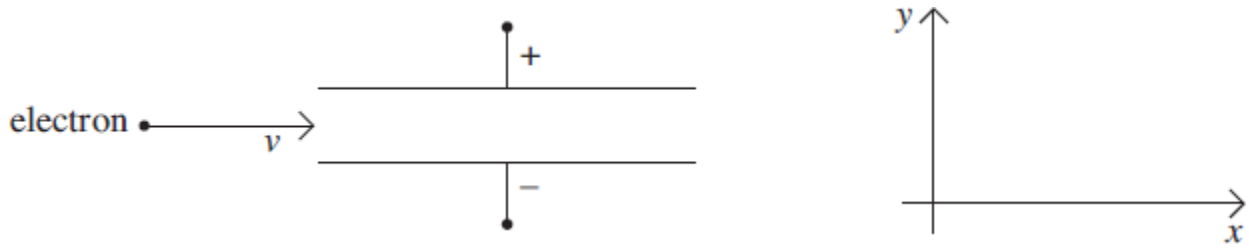
C 800 ms^{-1}

D 1600 ms^{-1}

(Total 1 mark)

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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.

_____

_____

_____

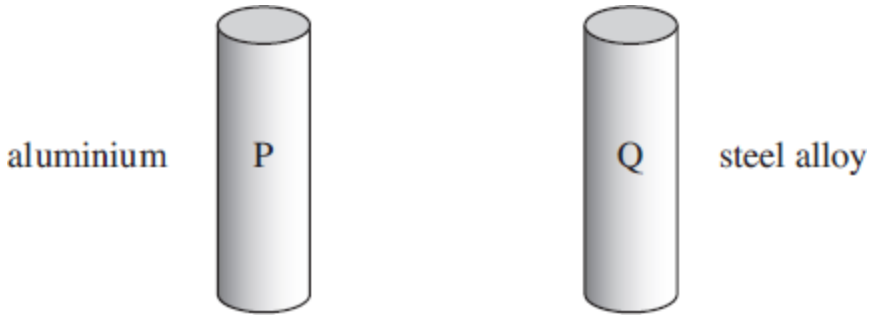
_____

(2)

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

Figure 1



(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.

_____

_____

_____

_____

_____

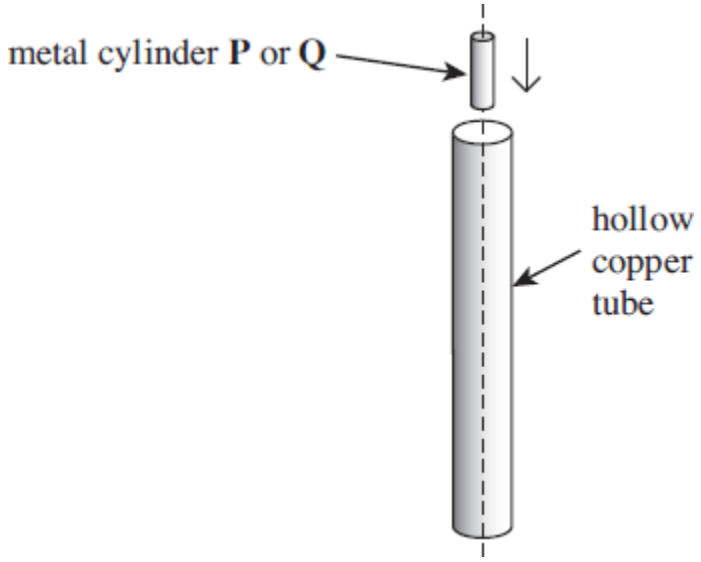
_____

(2)

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(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**.

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)

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(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)

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(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)

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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

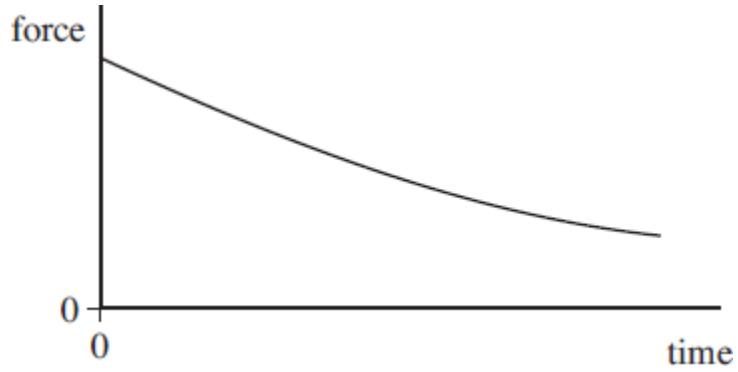
C 15 N

D 200 N

(Total 1 mark)

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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

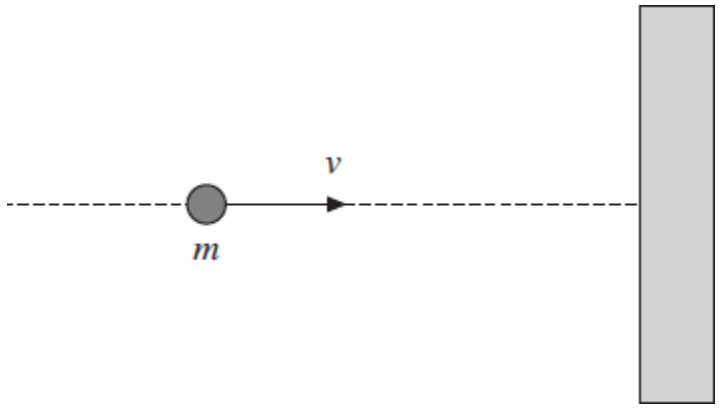
C acceleration

D impulse

(Total 1 mark)

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



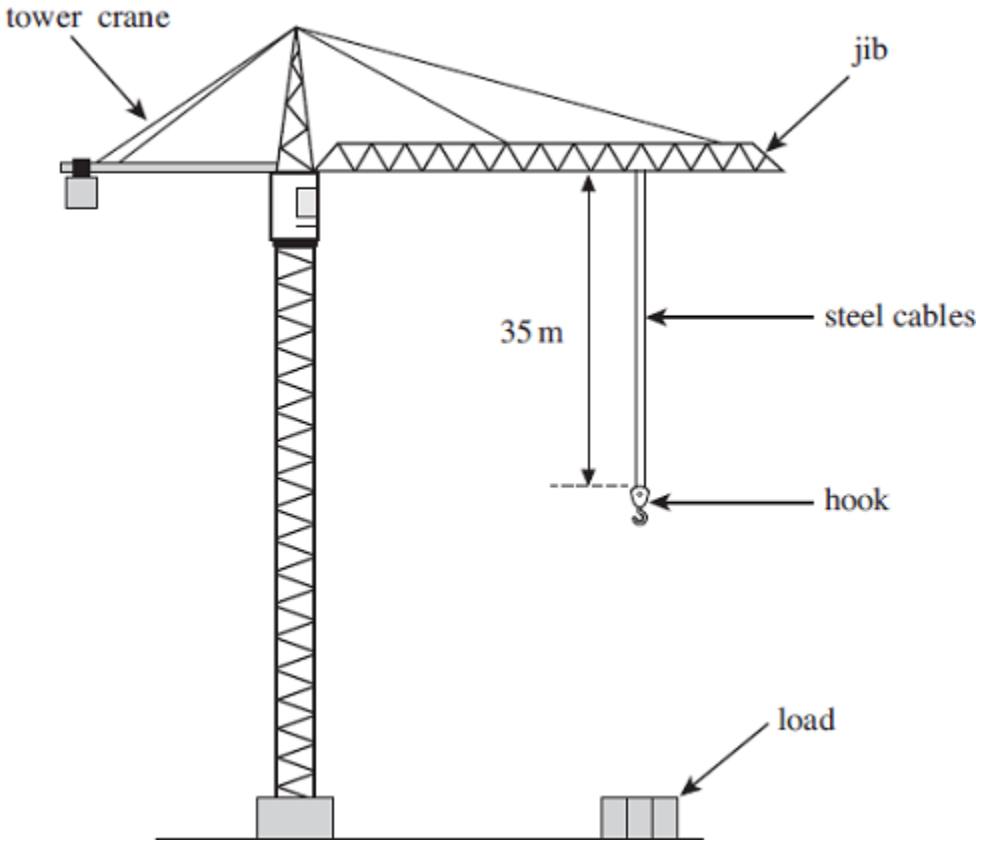
Which line, **A** to **D**, in the table, gives the correct expressions for the magnitude of the change of momentum, and the change of kinetic energy, of the ball?

	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)

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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 = 6.2×10^{-4} m^2

breaking stress = _____ Pa

(2)

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(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.

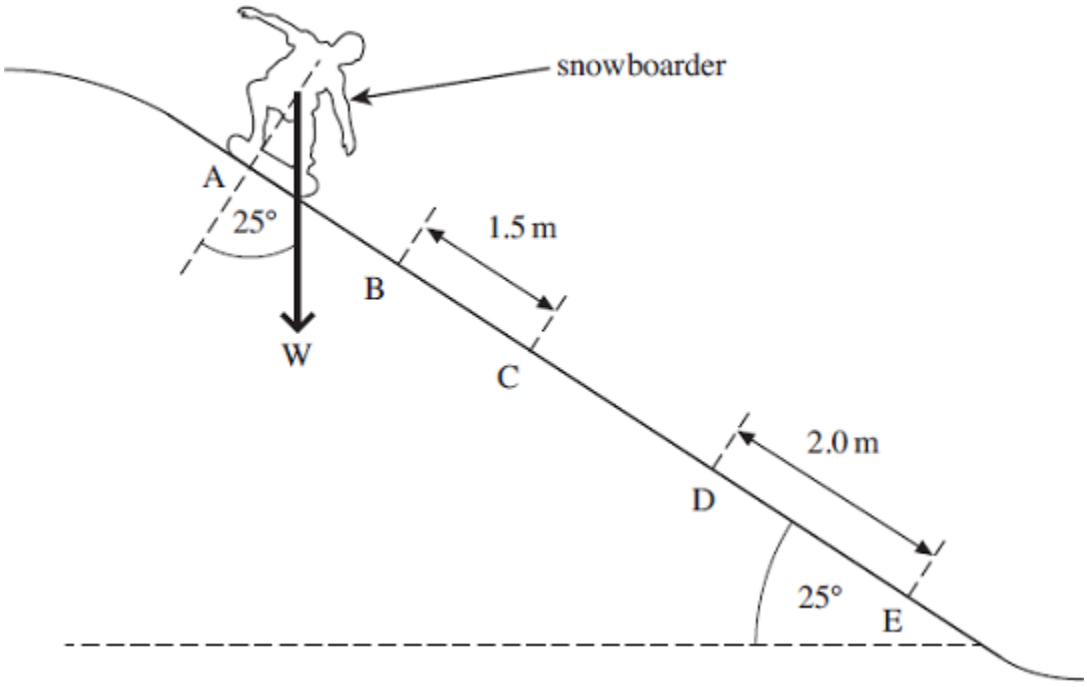
energy stored = _____ J

(2)

(Total 13 marks)

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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)

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(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.

_____

_____

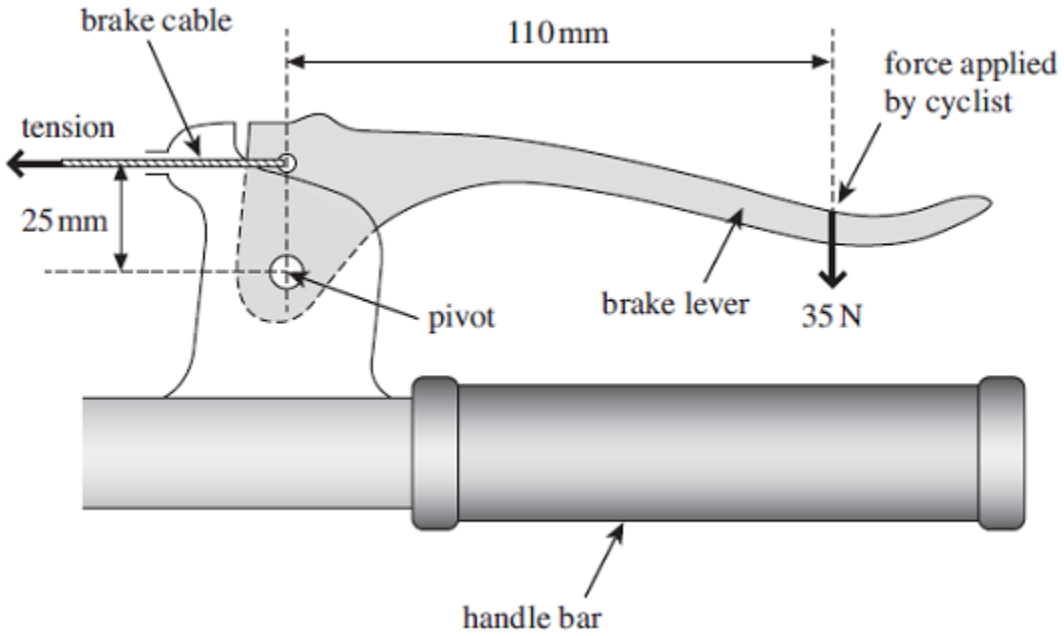
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(3)

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(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)

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(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 1.39×10^7 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)

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(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.

_____

_____

_____

_____

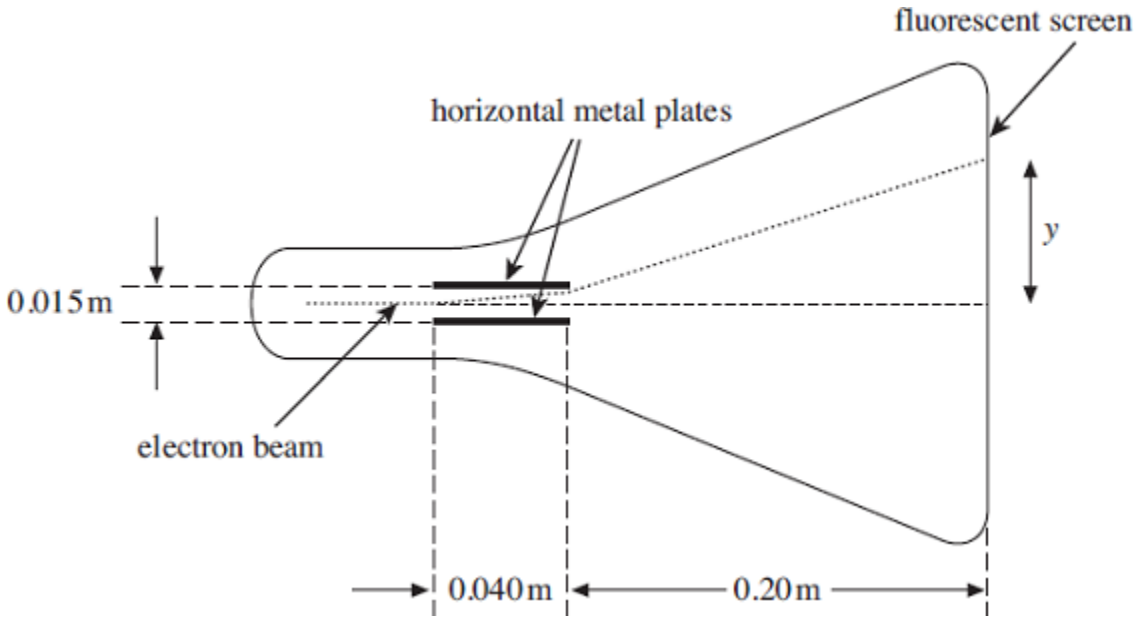
_____

_____

(3)

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(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 3.2×10^{15} ms^{-2}.

(3)

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(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 4.7×10^6 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)

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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

$$d = kv^{\circ}$$

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.

_____

_____

_____

_____

_____

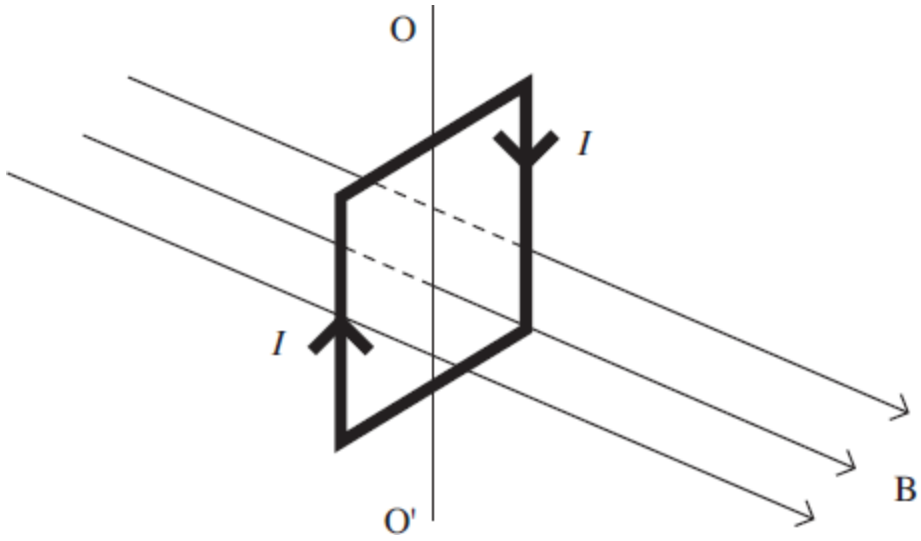
_____

(3)

(Total 9 marks)

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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.

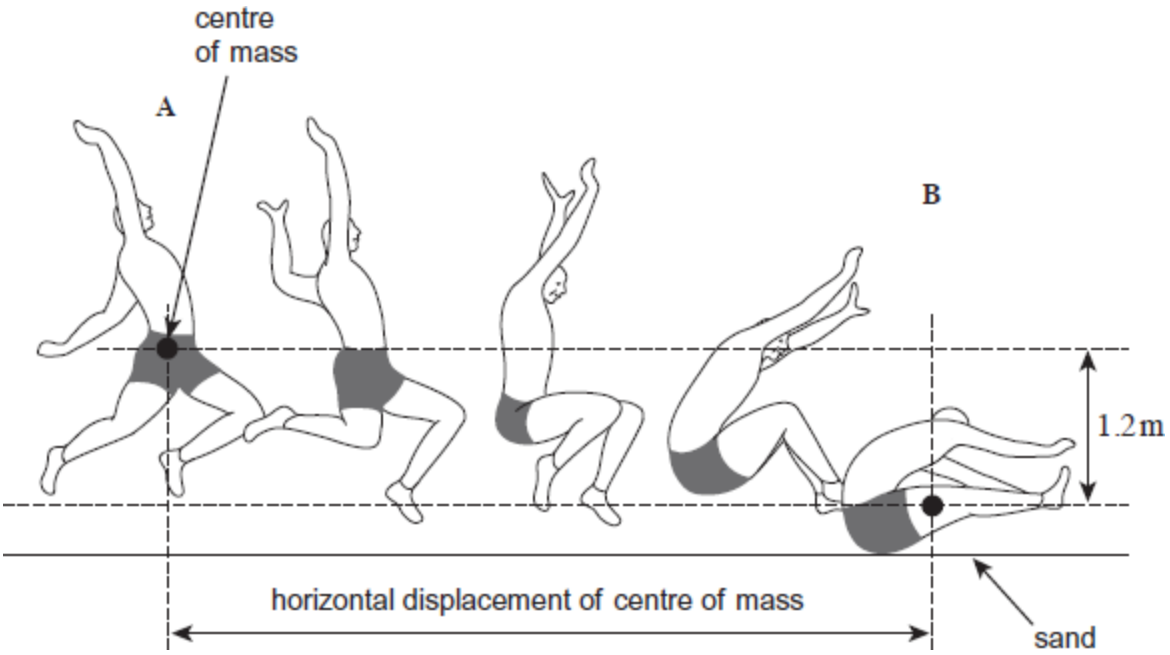
C No forces act on the horizontal sides of the coil.

D If the coil is turned through a small angle about OO' and released, it will remain in position.

(Total 1 mark)

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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 noair resistance. Calculate the horizontal displacement of the centre of mass from **A** to **B**.

horizontal displacement _____ m

(2)

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(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.

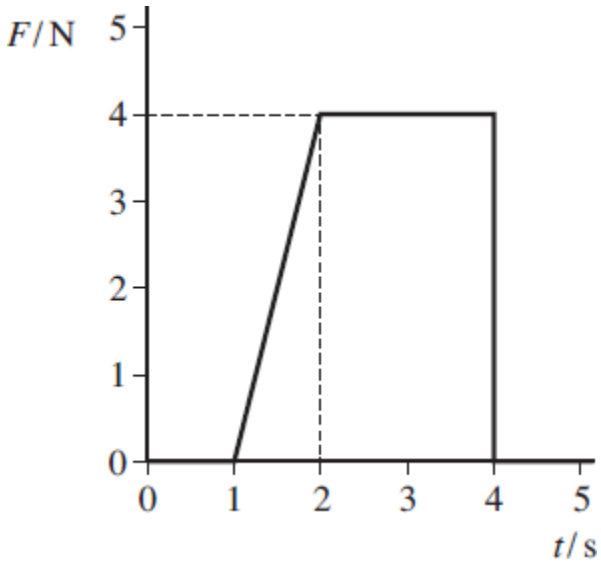
horizontal component of resistive force _____ N

(3)

(Total 10 marks)

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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)

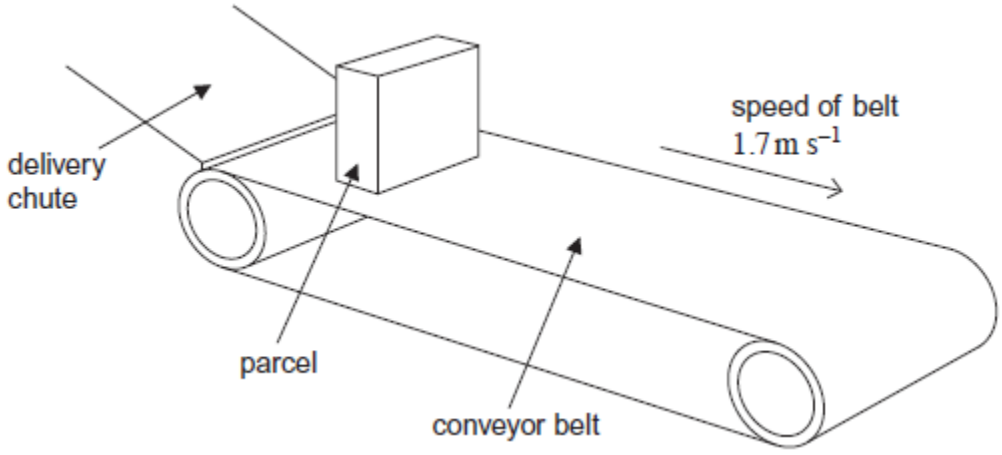
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55. (a) A parcel of mass 15 kg drops from a delivery chute onto a conveyor belt as shown in **Figure 1**.

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)

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(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.

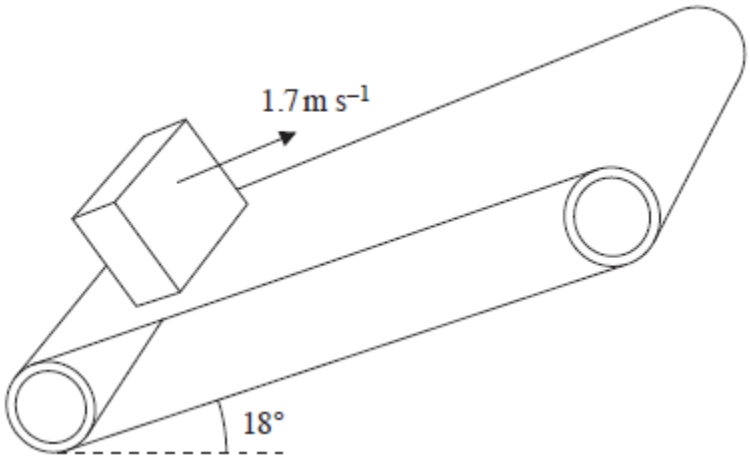
horizontal distance _____ m

(2)

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(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

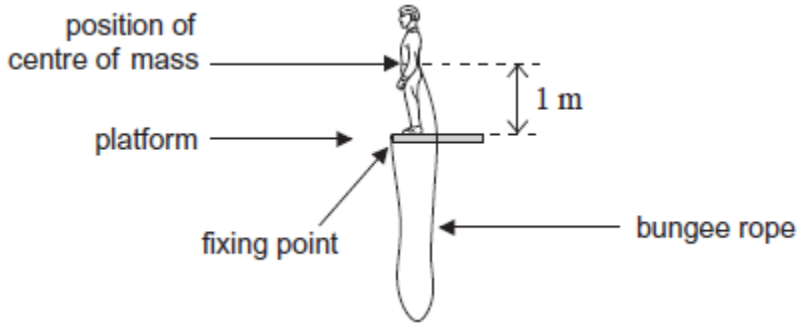
(3)

(Total 7 marks)

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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)

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(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)

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(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.

_____

_____

_____

_____

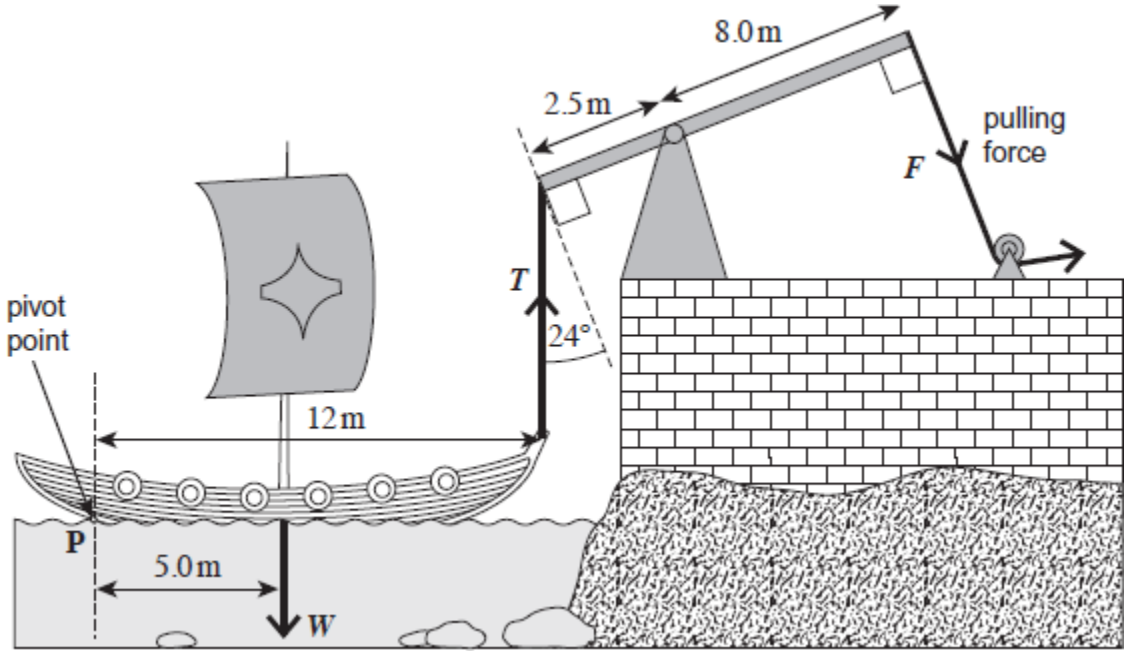
_____

_____

(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)

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(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 2*mu*.

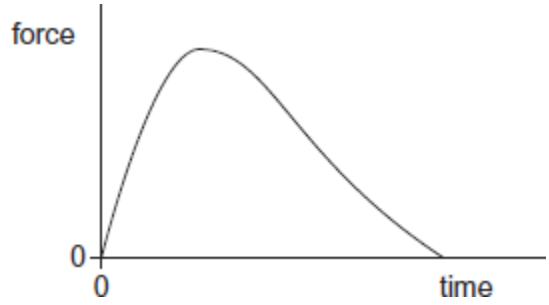
C The force exerted by the molecule on the side of the container is equal to the force exerted by the container on the molecule.

D The change in kinetic energy of the molecule is zero.

(Total 1 mark)

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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

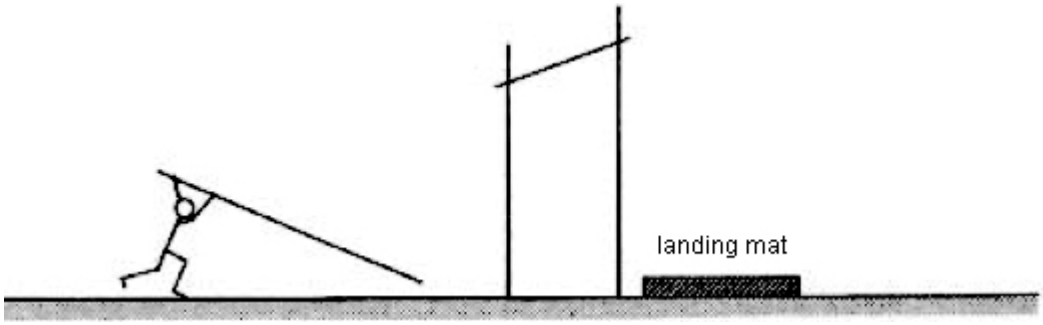
B gain in kinetic energy

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)

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(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)

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