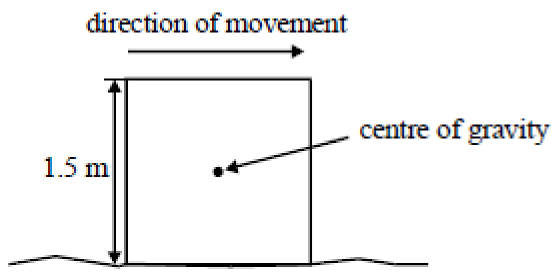
1 A uniform square block is sliding with uniform speed along a rough surface as shown in the diagram.



The force used to move the block is 200 N. The moment of the frictional force acting on the block about the centre of gravity of the block is

A 150 N m, clockwise

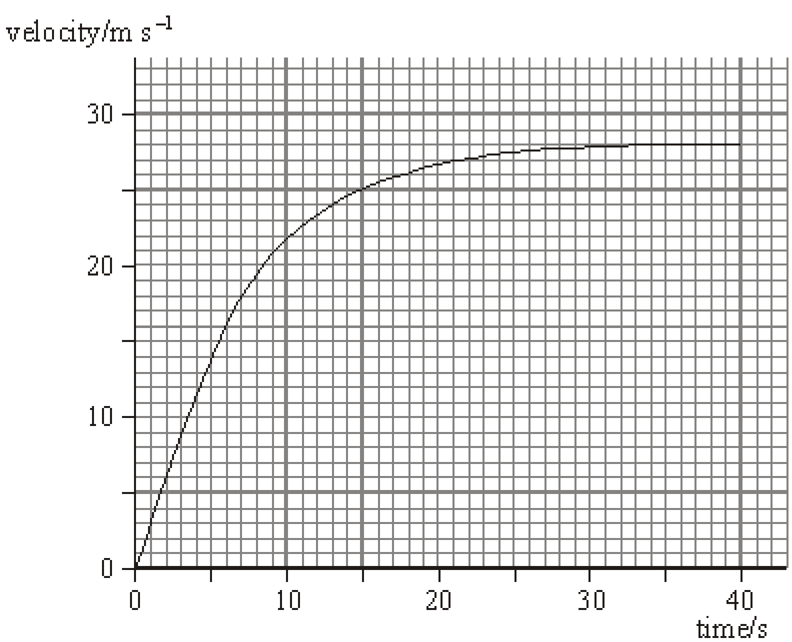
B 150 N m, anticlockwise

C 300 N m, clockwise

D 300 N m, anticlockwise

(Total 1 mark)

2 The figure below shows how the velocity of a motor car increases with time as it accelerates from rest along a straight horizontal road.



(a) The acceleration is approximately constant for the first five seconds of the motion. Show that, over the first five seconds of the motion, the acceleration is approximately 2.7 m s^{-2}.

(3)

(b) Throughout the motion shown in the figure above there is a constant driving force of 2.0 kN acting on the car.

(i) Calculate the mass of the car and its contents

mass ....

(ii) What is the magnitude of the resistive force acting on the car after 40 s?

resistive force ....

(3)

(c) Find the distance travelled by the car during the first 40 s of the motion.

distance ....

(3)
(Total 9 marks)

3 A solid iron ball of mass 890 kg is used on a demolition site. It hangs from the jib of a crane suspended by a steel rope. The distance from the point of suspension to the centre of mass of the ball is 15 m.

(a) Calculate the tension in the rope when the mass hangs vertically and stationary.

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(2)

(b) The iron ball is pulled back by a horizontal chain so that the suspension rope makes an angle of 30° with the vertical. Calculate the new tension in the suspension rope.

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(2)

(c) The ball is now released from rest and hits a brick wall just as it passes through the vertical position. It can be assumed that the ball is brought to rest by the impact with the wall in 0.2 s.

Calculate

(i) the vertical height through which the ball falls,

....

....

(ii) the speed of the ball just before impact,

....

....

....

(iii) the average force exerted by the ball on the wall.

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....

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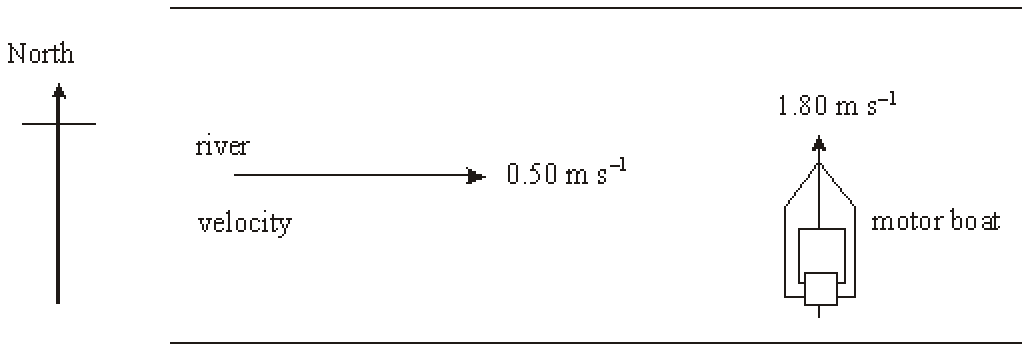
(5)
(Total 9 marks)

4 The figure below shows a river which flows from West to East at a constant velocity of 0.50 m s^{-1}. A small motor boat leaves the south bank heading due North at 1.80 m s^{-1}. Find, by scale drawing or otherwise, the resultant velocity of the boat.

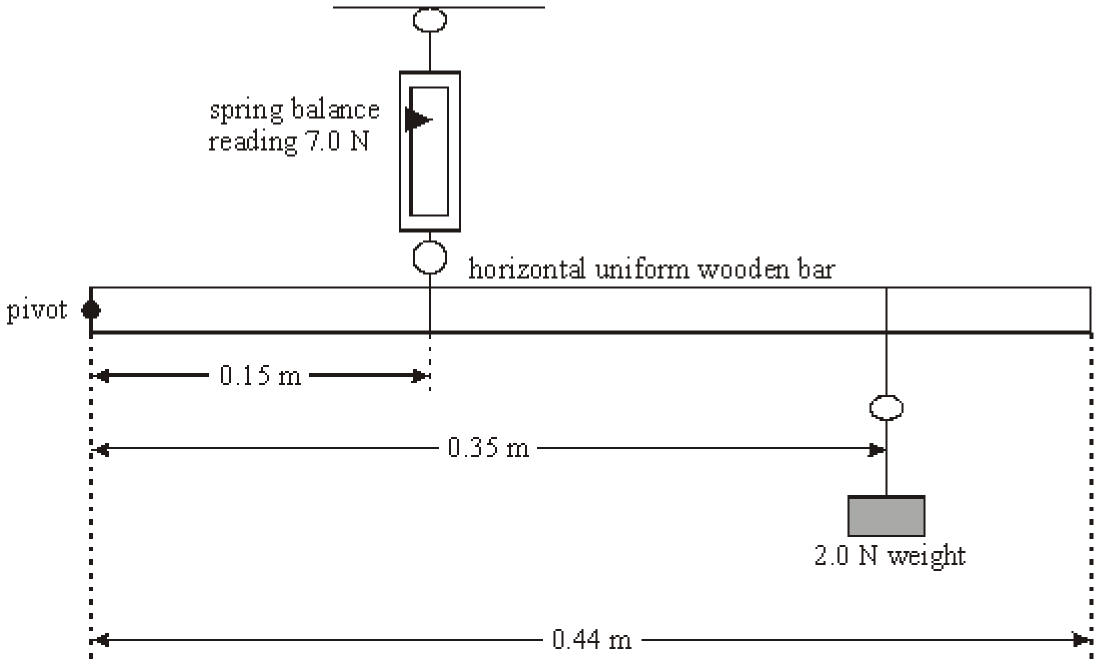


speed ....

direction ....

(Total 5 marks)

5 A student set up the apparatus shown in the figure below to demonstrate the principle of moments.



(a) Using the values on the figure calculate:

(i) the magnitude of the moment about the pivot due to the tension of the spring in the spring balance;

moment due to spring tension ....

(1)

(ii) the magnitude of the moment about the pivot produced by the 2.0 N weight;

moment due to 2.0 N weight ....

(1)

(iii) the weight of the wooden bar.

weight ....

(1)

(b) (i) Calculate the magnitude of the force exerted on the bar by the pivot.

magnitude of force ....

(1)

(ii) State the direction of the force on the pivot.

....

(1)
(Total 5 marks)

6 (a) Explain what is meant by the *principle of conservation of momentum*.

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(2)

(b) A hose pipe is used to water a garden. The supply delivers water at a rate of 0.31 kg s^{-1} to the nozzle which has a cross-sectional area of 7.3×10^{-5} m^2.

(i) Show that water leaves the nozzle at a speed of about 4 m s^{-1}.
density of water = 1000 kg m^{-3}

(2)

(ii) Before it leaves the hose, the water has a speed of 0.68 m s^{-1}. Calculate the force on the hose.

(3)

(iii) The water from the hose is sprayed onto a brick wall the base of which is firmly embedded in the ground. Explain why there is no overall effect on the rotation of the Earth.

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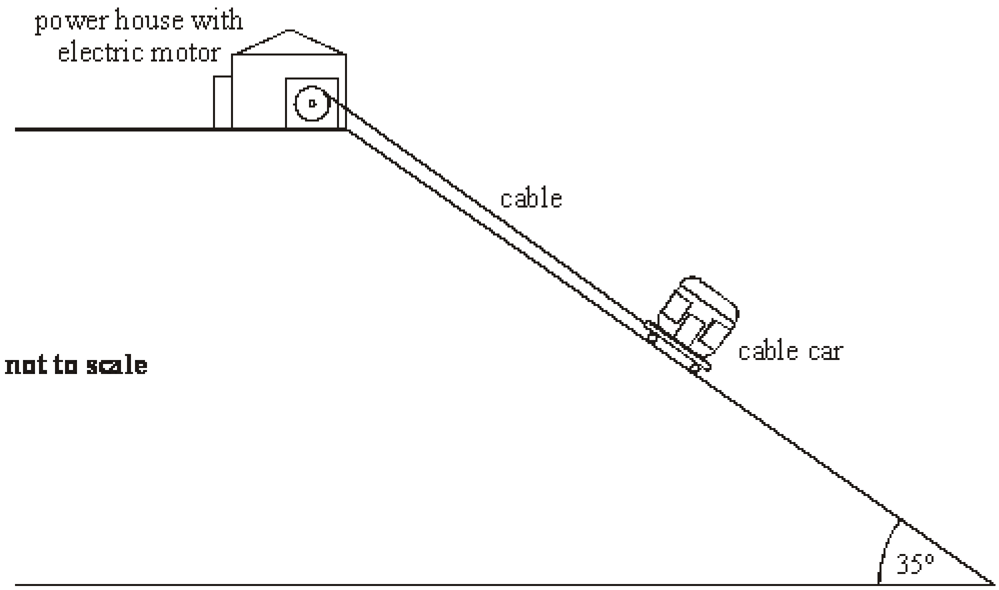
(2)
(Total 9 marks)

7 The figure below shows a cable car being pulled up a 35° slope of length 120 m.



The cable car has a weight of 1.5×10^4 N. The total frictional force resisting motion is 3.0×10^3 N.

the gravitational field strength, $g = 9.8$ N kg^{-1}

(a) (i) Show that the component of the weight of the cable car parallel to the slope is 8600 N.

(1)

(ii) Calculate the tension in the cable when the cable car is moving at a constant speed up the slope.

tension ....

(1)

(b) The cable snaps when the cable car is at rest at the top of the slope. The frictional force remains constant at 3.0×10^3 N.

Calculate:

(i) the acceleration of the cable car down the slope;

acceleration ....

(3)

(ii) the speed of the cable car when it reaches the bottom of the slope;

speed ....

(2)

(iii) the time taken for the cable car to reach the bottom of the slope.

time taken ....

(2)
(Total 9 marks)

8 A car accelerates uniformly from rest to a speed of 100 km h^{-1} in 5.8 s.

(a) Calculate the magnitude of the acceleration of the car in m s^{-2}.

Acceleration = ...m s^{-2}

(3)

(b) Calculate the distance travelled by the car while accelerating.

Distance travelled = ...

(2)
(Total 5 marks)

9 A girl sits at rest on a garden swing. The swing consists of a wooden seat of mass 1.2 kg supported by two ropes. The mass of the girl is 16.8 kg. The mass of the ropes should be ignored throughout this question.

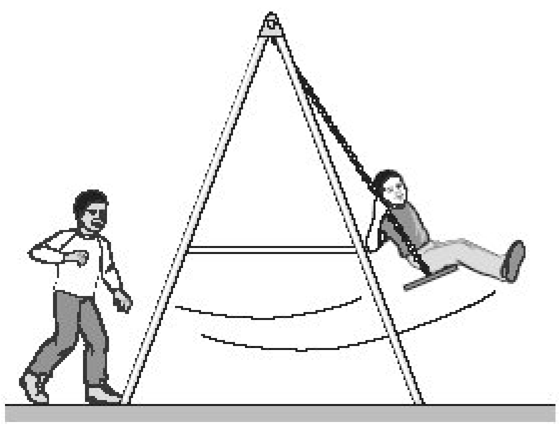


Figure 1

(a) A boy grips the seat and gives a firm push with both hands so that the girl swings upwards as shown in **Figure 1**. The swing just reaches a vertical height of 0.50 m above its rest position.

(i) Show that the maximum gain in gravitational potential energy of the girl and the swing is about 88 J.

acceleration due to gravity = 9.8 m s^{-2}

(3)

(ii) The work done against resistive forces as the swing moves upwards is 20 J. Calculate the work done on the swing by the boy during the push.

(1)

(iii) As he pushed, the boy's hands were in contact with the seat of the swing for a distance of 0.40 m. Calculate the average force applied to the swing.

(2)

(b) Calculate the speed of the girl as she passes back through the lowest point of her ride for the first time. Assume that the work done against resistive forces is the same in both directions.

(4)

(c) The girl is not pushed again. On the axes in **Figure 2**, sketch a graph to show how the kinetic energy of the girl varies with time over two complete cycles of the motion. Start your graph from the time when she is 0.50 m above the rest position. You are not required to mark a scale on either axis.

Figure 2

(3)
(Total 13 marks)

10 **Figure 1** shows a skier being pulled by rope up a hill of incline 12° at a steady speed. The total mass of the skier is 85 kg. Two of the forces acting on the skier are already shown.

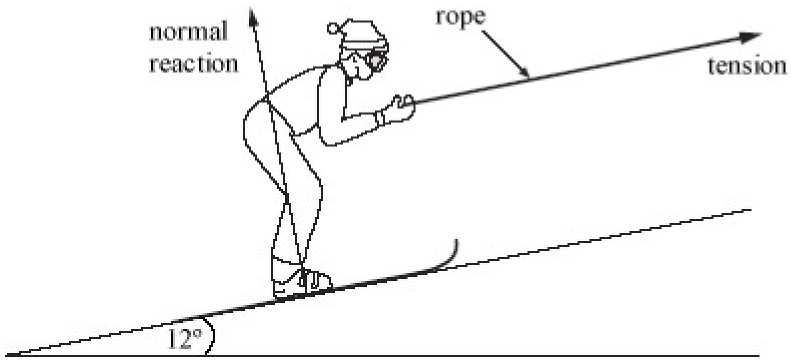


Figure 1

(a) Mark with arrows and label on **Figure 1** a further two forces that are acting on the skier.

(2)

(b) Calculate the magnitude of the normal reaction on the skier.
gravitational field strength, g = 9.8 N kg^{-1}

Normal reaction = ...

(3)

(c) Explain why the resultant force on the skier must be zero.

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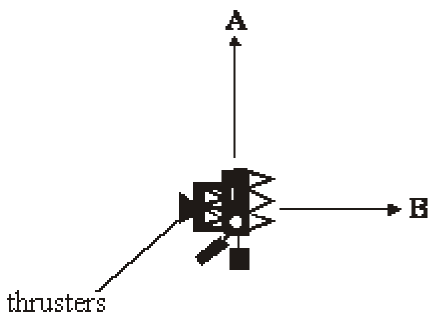
(1)
(Total 6 marks)

11 The diagram below shows a spacecraft that initially moves at a constant velocity of 890 m s^{-1} towards **A**.



To change course, a sideways force is produced by firing thrusters. This increases the velocity towards **B** from 0 to 60 m s^{-1} in 25 s.

(a) The spacecraft has a mass of 5.5×10^4 kg. Calculate:

(i) the acceleration of the spacecraft towards **B**;

Acceleration ....

(1)

(ii) the force on the spacecraft produced by the thrusters.

Force on spacecraft ....

(2)

(b) Calculate the magnitude of the resultant velocity after 25 s.

Magnitude of resultant velocity ....

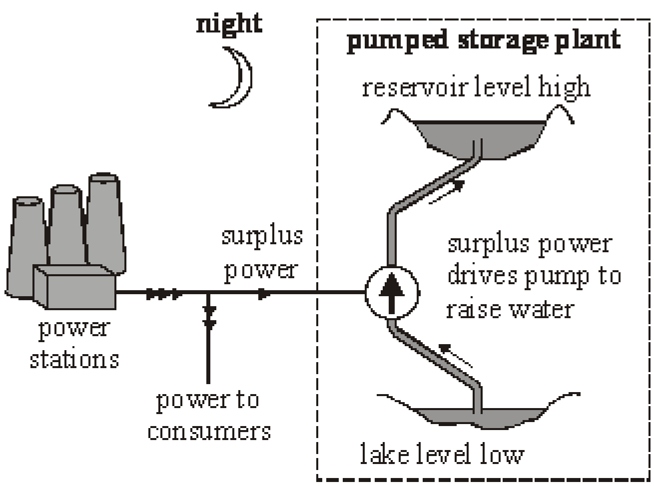
(2)

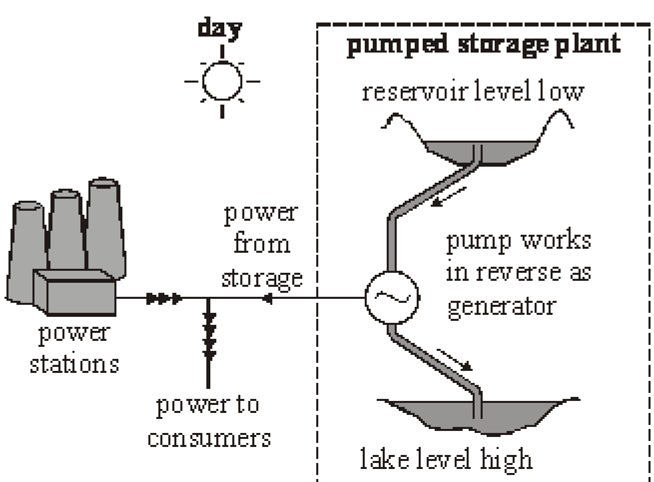
(c) Calculate the angle between the initial and final directions of travel.

Angle ....

(1)
(Total 6 marks)

12 The diagram below shows the principle of a hydroelectric pumped storage plant. During times when there is a low demand for electricity, the spare capacity of other power stations is used to pump water from the lake into the reservoir. The potential energy of the water is then converted into electricity when needed to satisfy peak demands.





For this plant the water falls a mean distance of 370 m between the reservoir and the generator. The mass of water stored in the reservoir when it is full is 1.0×10^{10} kg.

gravitational field strength g = 9.8 N kg^{-1}

(a) (i) Show that the useful gravitational potential energy stored when the reservoir is full is about 4×10^{13} J.

(2)

(ii) Calculate the speed of the water as it reaches the generator assuming that no energy is lost as the water falls.

Speed of water ....

(2)

(iii) The pumped storage plant has four 100 MW generators. Calculate the longest time, in hours, for which the stored energy alone could provide power at maximum output. Assume that all the stored gravitational potential energy can be converted into electrical energy.

Time ....

(3)

(b) In practice not all the stored energy that is put into the system during the night can be retrieved as electrical energy during the day. State and explain how energy is lost in the system.

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(3)
(Total 10 marks)

13 Complete the following table.

Quantity	**Vector or Scalar**	**S.I. Unit**
Displacement	Vector	m
Velocity		
Weight		
Energy		

(Total 3 marks)

14 (a) Starting with the relationship between impulse and the change in momentum, show clearly that the unit, N, is equivalent to kg m s^{-2}.

(2)

(b) A rocket uses a liquid propellant in order to move.
Explain how the ejection of the waste gases in one direction makes the rocket move in the opposite direction.

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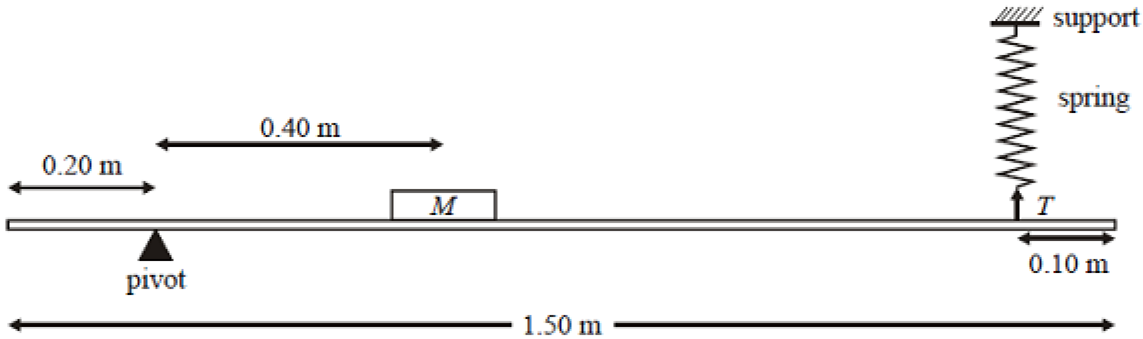
(3)

(c) A rocket ejects 1.5×10^4 kg of waste gas per second. The gas is ejected with a speed of 2.4 km s^{-1} relative to the rocket. Show that the average thrust on the rocket is about 40 MN.

(2)
(Total 7 marks)

15 The diagram below shows a laboratory experiment to test the loading of a uniform horizontal beam of weight W. The length of the beam is 1.50 m. The load, M, has a weight of 100 N and its centre of mass is 0.40 m from the pivot. The beam is held in a horizontal position by the tension, T, in the stretched spring.



(a) Add clearly labelled arrows to the diagram above so that it shows all of the forces acting on the beam.

(2)

(b) The tension, T = 36 N. Calculate the moment of T about the pivot.

Moment ....

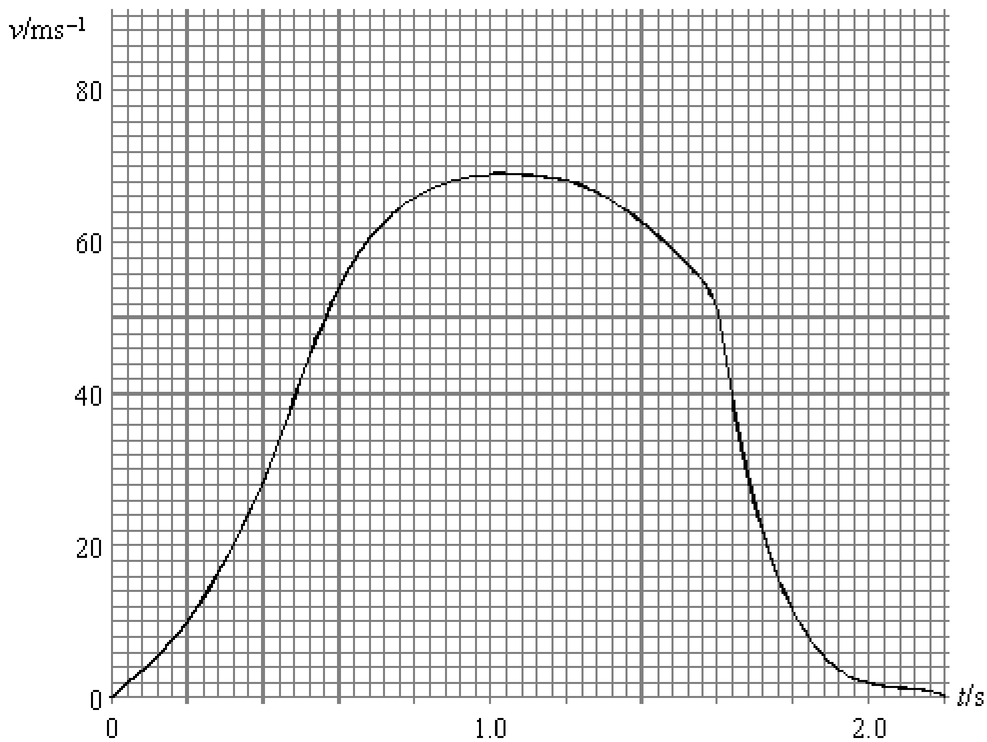
(2)

(c) Calculate the weight, W, of the beam.

Weight W ....

(3)
(Total 7 marks)

16 The graph below shows how the vertical component, v, of the velocity of a rocket varies with time, t, from its take-off on level ground to the **highest point of its trajectory**.



(a) Take readings from the graph to calculate the average vertical acceleration of the rocket from time t = 0 to time t = 0.60 s.

Average acceleration ....

(3)

(b) Use the graph to estimate the maximum height reached by the rocket.

Maximum height ....

(3)

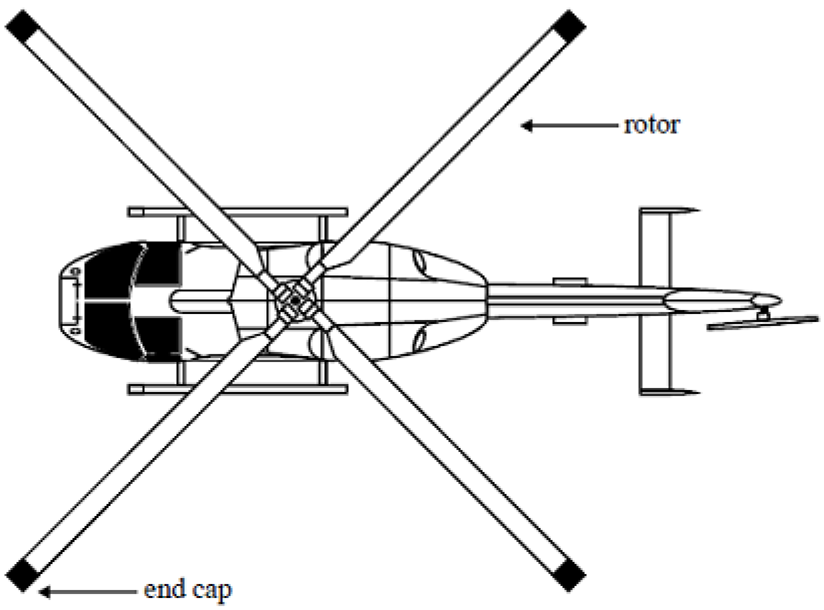
(c) Assume that air resistance is negligible. Calculate the time taken for the rocket to fall from its maximum height back to the ground.

acceleration of free fall g = 9.8 m s^{-2}

Time to fall to the ground ....

(2)
(Total 8 marks)

17 The diagram below shows the rotor-blade arrangement used in a model helicopter. Each of the blades is 0.55 m long with a uniform cross-sectional area of 3.5×10^{-4} m^2 and negligible mass. An end-cap of mass 1.5 kg is attached to the end of each blade.



(a) (i) Show that there is a force of about 7 kN acting on each end-cap when the blades rotate at 15 revolutions per second.

(3)

(ii) State the direction in which the force acts on the end-cap.

....

(1)

(iii) Show that this force leads to a longitudinal stress in the blade of about 20 MPa.

(2)

(iv) Calculate the change in length of the blade as a result of its rotation.

Young modulus of the blade material = 6.0×10^{10} Pa

(2)

(v) Calculate the total strain energy stored in one of the blades due to its extension.

(2)

(b) The model helicopter can be made to hover above a point on the ground by directing the air from the rotors vertically downwards at speed v.

(i) Show that the change in momentum of the air each second is $A\rho v^2$, where A is the area swept out by the blades in one revolution and ρ is the density of air.

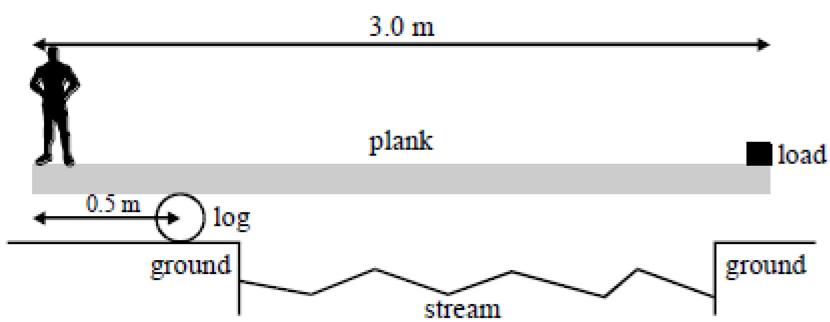
(2)

(ii) The model helicopter has a weight of 900 N. Calculate the speed of the air downwards when the helicopter has no vertical motion.

Density of air = 1.3 kg m^{-3}

(3)
(Total 15 marks)

18 The diagram below shows a student standing on a plank that pivots on a log. The student intends to cross the stream.



(a) The plank has a mass of 25 kg and is 3.0 m long with a uniform cross-section. The log pivot is 0.50 m from the end of the plank. The student has a mass of 65 kg and stands at the end of the plank. A load is placed on the far end in order to balance the plank horizontally.

Draw on the diagram the forces that act on the plank.

(3)

(b) By taking moments about the log pivot, calculate the load, in N, needed on the right-hand end of the plank in order to balance the plank horizontally.

Gravitational field strength, g = 9.8 N kg^{-1}

Load ....

(3)

(c) Explain why the load will eventually touch the ground as the student walks towards the log.

....

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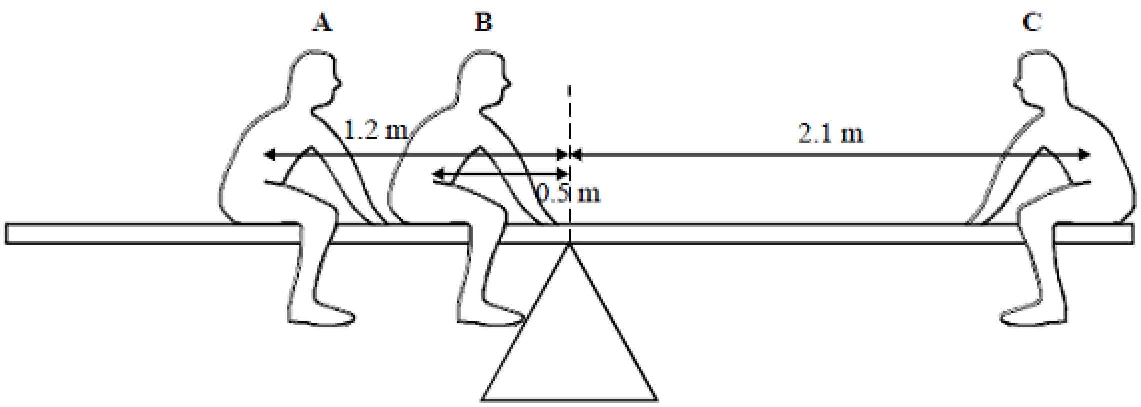
....

(2)
(Total 8 marks)

19 The diagram below shows three children **A**, **B** and **C** sitting on a balanced, horizontal see-saw of mass 35 kg. The centre of mass of the see-saw is vertically above the pivot.

A has a weight of 650 N and **B** has a weight of 550 N. **A** sits 1.2 m from the pivot and **B** sits 0.5 m from the pivot of the see-saw.



(a) **C** sits 2.1 m from the pivot.

By taking moments about a suitable point, calculate the weight of **C**.

Weight of **C** ....

(3)

(b) Calculate the force on the pivot of the see-saw.

gravitational field strength of Earth, $g = 9.8\ \text{N kg}^{-1}$

Force on pivot ....

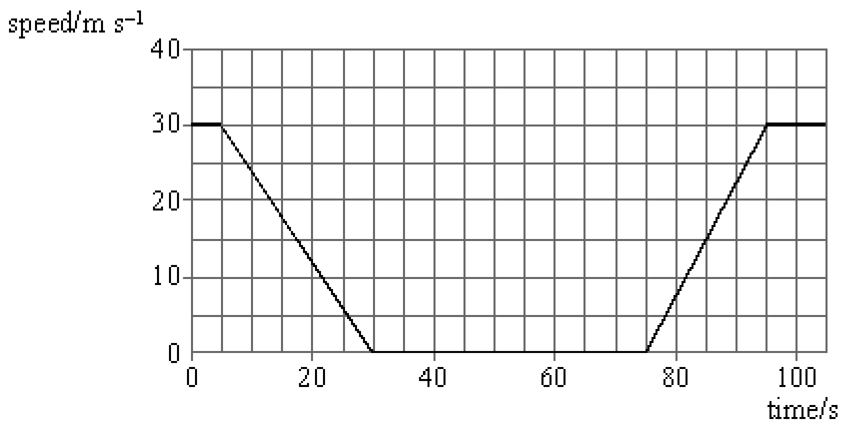
(2)
(Total 5 marks)

20 For which of the following relationships is the quantity y related to the quantity x by the relationship $x \propto \frac{1}{y}$?

	x	y
A	energy stored in a spring	extension of the spring
B	gravitational field strength	distance from a point mass
C	de Broglie wavelength of an electron	momentum of the electron
D	period of a mass-spring system	spring constant (stiffness) of the spring

(Total 1 mark)

21 The diagram below shows a speed-time graph for a car that halts at traffic lights and then moves away.



(a) Use the graph to show that the car travels about 380 m whilst decelerating.

(2)

(b) Use the graph to calculate the acceleration of the car for the time interval from 75 s to 95 s.

Acceleration ....

(2)

(c) Calculate the total distance travelled by the car in the time interval 5 s to 95 s.

Distance travelled ....

(1)

(d) A second car travels the same route without being halted at the traffic lights. The speed of this car is a constant 30 m s^{-1}.

Calculate the difference in journey time between the first and second cars.

Journey time difference ....

(3)
(Total 8 marks)

22 (a) A raindrop falls at a constant vertical speed of 1.6 m s^{-1} in still air. The wind now blows horizontally at 1.4 m s^{-1}.

(i) Draw a scale diagram and use it to find the angle the path of the raindrop now makes with the vertical.

(2)

(ii) Use your scale diagram or a calculation to determine the resultant speed of the raindrop when the wind is blowing.

Speed of raindrop ....

(1)

(b) The mass of the raindrop is 4.5×10^{-8} kg. Calculate its kinetic energy.

Kinetic energy ....

(3)

(c) Calculate the work done by the raindrop as it falls through a vertical distance of 5.0 m in still air.

Gravitational field strength, $g = 9.8\ \mathrm{N\ kg^{-1}}$

Work done ....

(3)

(d) Explain why a raindrop falling vertically through still air eventually reaches a constant speed.

Two of the 6 marks in this question are available for the quality of your written communication.

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(6)
(Total 15 marks)

23 (a) State the difference between vector and scalar quantities.

....

(1)

(b) State **one** example of a vector quantity (other than force) and **one** example of a scalar quantity.

Vector quantity ....

(1)

Scalar quantity ....

(1)

(c) A 6.0 N force and a 4.0 N force act on a body of mass 7.0 kg at the same time. Calculate the maximum and minimum accelerations that can be experienced by the body.

Maximum acceleration....................... Minimum acceleration.....................

(3)
(Total 6 marks)

24 (a) State the principle of conservation of momentum.

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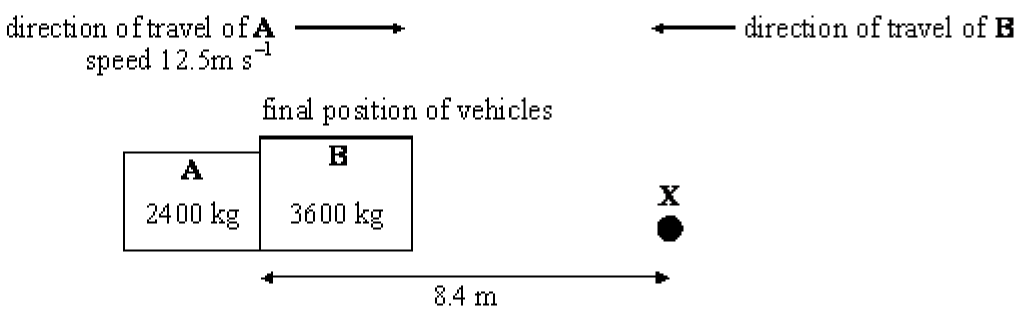
(2)

(b) The diagram below shows a sketch drawn by an accident investigator following a head-on collision between two vehicles.



From the skid marks and debris on the road the investigator knows that the collision took place at the point marked **X.** The vehicles locked together on impact and vehicle **A** was pushed backwards a distance of 8.4 m.

For the road conditions and vehicle masses the average frictional force between the road and the vehicles immediately after the collision was known to be 7500 N.

(i) Calculate the work done against friction in bringing the vehicles to rest.

(2)

(ii) Determine the speed of the interlocked vehicles immediately after impact.

(2)

(iii) Vehicle **A** was known to be moving at 12.5 m s^{-1} just before the impact. Calculate the speed of vehicle **B** just before impact.

(3)

(iv) The drivers of both vehicles have the same mass. State and explain which driver is likely to experience the higher force during the impact.

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(4)
(Total 13 marks)

25 A horizontal force of 1.5 kN acts on a motor car of mass 850 kg that is initially at rest.

(a) Calculate:

(i) the acceleration of the motor car;

(1)

(ii) the speed of the motor car after 15 s;

(2)

(iii) the distance travelled by the motor car in the first 7.5 s of the motion;

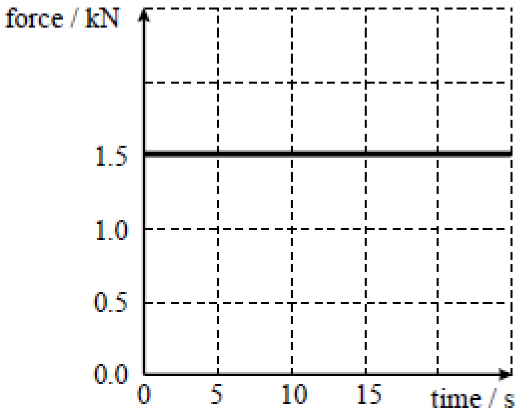
(2)

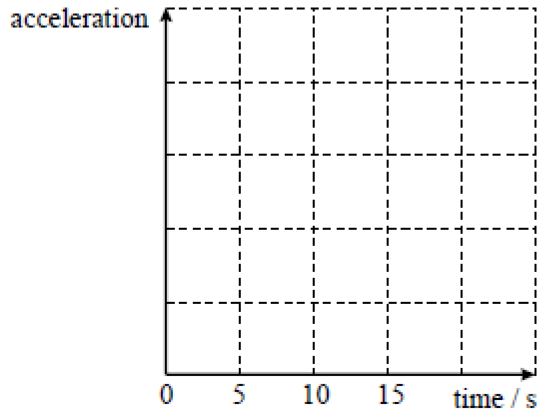
(iv) the distance travelled by the motor car in the first 15 s of the motion.

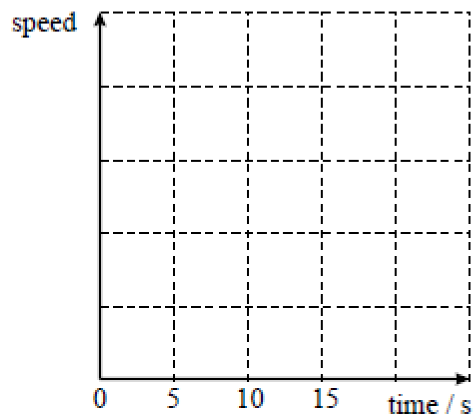
(1)

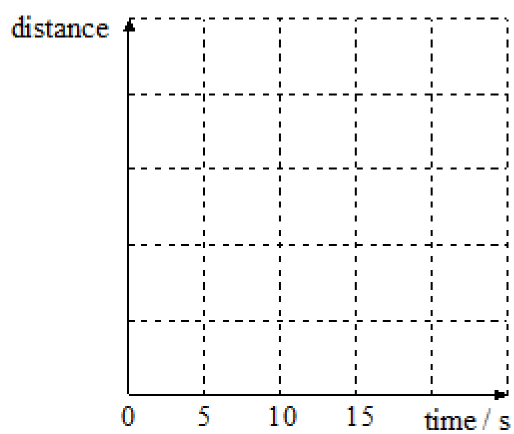
(b) The diagrams below show the graph of force against time together with three incomplete sets of axes. Sketch on these axes the corresponding graphs for acceleration, speed and distance travelled for the first 15 seconds of the car's motion.

You should include labels for the axes and any known numerical values.









(4)

(c) In practice the resultant force exerted on the motor car will not be constant with time as suggested by the force-time graph. Air resistance is one factor that affects the resultant force acting on the vehicle.

(i) Suggest how the force-time graph will change when air resistance is taken into account. Explain your answer. You may wish to sketch a graph to illustrate your answer.

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(3)

(ii) Explain why the vehicle will eventually reach a maximum speed even though the motorist keeps the accelerator pedal fully depressed.

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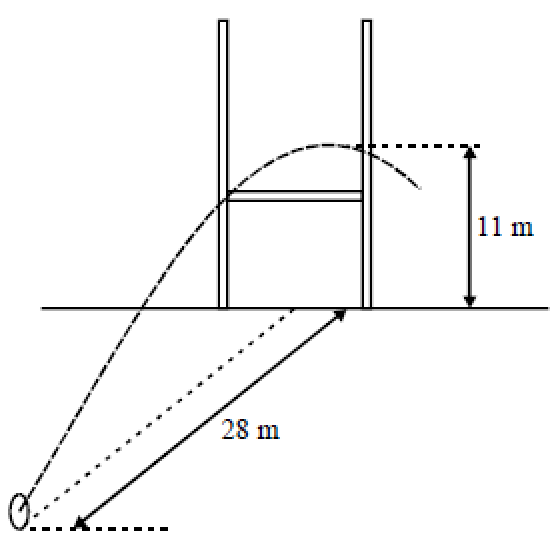
(2)
(Total 15 marks)

26 A rugby ball is kicked towards the goal posts shown in the diagram below from a position directly in front of the posts. The ball passes over the cross-bar and between the posts.



(a) The ball takes 1.5 s to reach a point vertically above the cross-bar of the posts.

(i) Calculate the ball's horizontal component of velocity, v_h. Ignore air resistance.

v_h ....

(2)

(ii) The ball reaches its maximum height at the same time as it passes over the crossbar. State the vertical component of velocity when the ball is at its maximum height.

....

(1)

(iii) The ball's maximum height is 11 m. Calculate, v_v, the vertical component of velocity of the ball immediately after it has been kicked. Ignore the effects of air resistance.

acceleration due to gravity, g = 9.8 m s^{-2}

v_v ....

(3)

(b) (i) Determine the magnitude of the initial velocity, v, of the ball immediately after it is kicked.

v ....

(3)

(ii) Determine the angle above the horizontal at which the ball was kicked.

Angle ....

(1)

(c) State and explain at what instant the ball will have its maximum kinetic energy.

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(2)
(Total 12 marks)

27 (a) State the principle of moments.

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(2)

(b) **Figure 1** shows a student of weight 550 N doing a "press up". In the position shown the body is horizontal and the forearms are vertical.

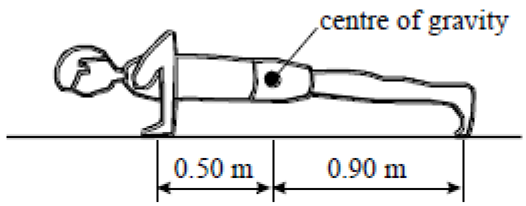


Figure 1

Assuming that each arm experiences the same force and that the forces acting on each foot are equal, calculate the compression force acting:

(i) in each of the student's forearms;

(2)

(ii) on each of the student's feet.

(1)

(c) Another student attempts the same exercise but with the forearms at an angle of 30° to the ground, as shown in **Figure 2**.

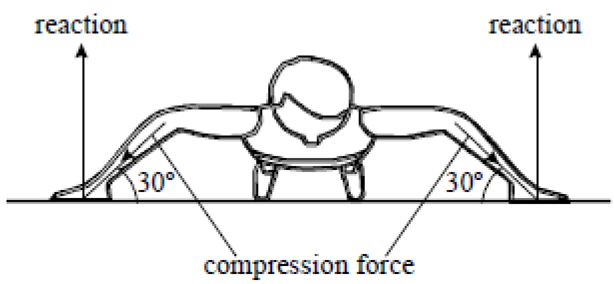


Figure 2

(i) The directions of some of the forces acting on the hands have been indicated. Indicate, on **Figure 2**, any other forces acting on the hands

(1)

(ii) State the cause of these additional forces.

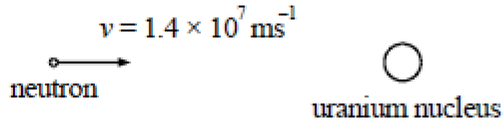
....

(1)

(iii) The reaction force at each hand is 210 N. Calculate the magnitude of the compression force in each forearm in this position.

(1)
(Total 8 marks)

28 The figure below shows a neutron of mass 1.7×10^{-27} kg about to collide inelastically with a stationary uranium nucleus of mass 4.0×10^{-25} kg. During the collision, the neutron will be absorbed by the uranium nucleus.



(a) Calculate the velocity of the uranium nucleus immediately after the neutron has been absorbed.

(3)

(b) Collisions between neutrons and uranium nuclei can also be elastic. State, and explain briefly, how the speed of the uranium nucleus after impact would be different in the case of an elastic collision.
Do not perform any further calculations.

....

....

....

....

....

....

(3)

(c) Using the data at the beginning of the question, calculate the kinetic energy of the neutron before it collides with the uranium nucleus.

(3)
(Total 9 marks)

29 A gymnast does a hand-stand on a horizontal bar. The gymnast then rotates in a vertical circle with the bar as a pivot. The gymnast and bar remain rigid during the rotation and when friction and air resistance are negligible the gymnast returns to the original stationary position.

Figure 1 shows the gymnast's position at the start and **Figure 2** shows the position after completing half the circle.

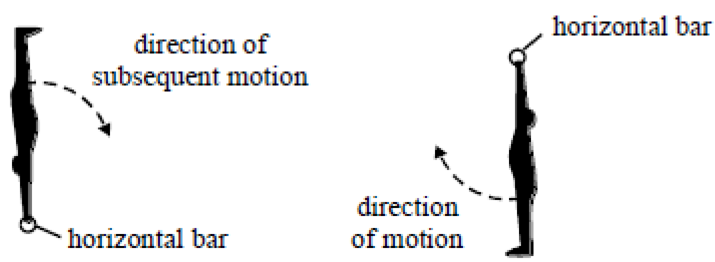


Figure 1 **Figure 2**

(a) The gymnast has a mass of 70 kg and the centre of mass of the gymnast is 1.20 m from the axis of rotation.

acceleration of free fall, $g = 9.8 \text{ m s}^{-2}$

(i) Show clearly how the principle of conservation of energy predicts a speed of 6.9 m s^{-1} for the centre of mass when in the position shown in **Figure 2**.

(3)

(ii) The maximum force on the arms of the gymnast occurs when in the position shown in **Figure 2**.

Calculate the centripetal force required to produce circular motion of the gymnast when the centre of mass is moving at 6.9 m s^{-1}.

(2)

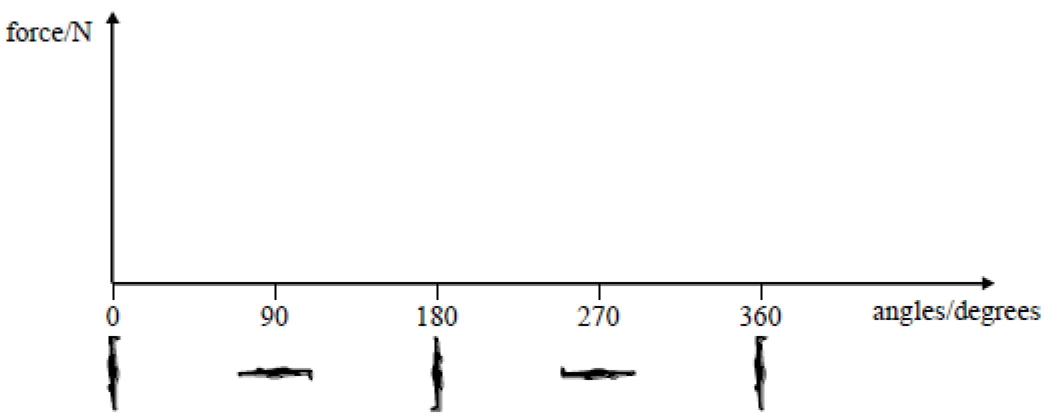
(iii) Determine the maximum tension in the arms of the gymnast when in the position shown in **Figure 2**.

(1)

(iv) Sketch a graph to show how the **vertical** component of the force **on the bar** varies with the angle rotated through by the gymnast during the manoeuvre. Assume that a downward force is positive.

Include the values for the initial force and the maximum force on the bar.

Only show the general shape between these values.



(2)

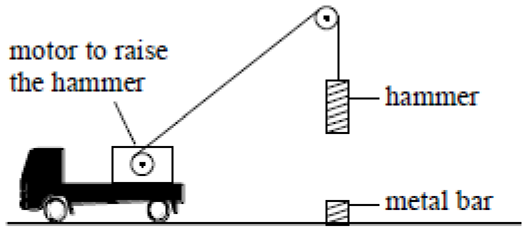
(b) The bones in each forearm have a length of 0.25 m. The total cross-sectional area of the bones in both forearms is $1.2 \times 10^{-3} \text{ m}^2$. The Young modulus of bone in compression is 1.6×10^{10} Pa.

Assuming that the bones carry all the weight of the gymnast, calculate the reduction in length of the forearm bones when the gymnast is in the start position shown in **Figure 1**.

(3)

(Total 11 marks)

30 The figure below shows a pile driver being used to drive a metal bar into the ground.



The heavy metal hammer of mass 500 kg is raised so that its bottom end is 4.00 m above the top of the metal bar. The bar has negligible mass compared with that of the hammer. When the hammer is released it falls freely. On striking the metal bar the hammer remains in contact with it and the hammer moves down a further 0.50 m.

acceleration of free fall, $g = 9.8 \text{ m s}^{-2}$

(a) Calculate:

(i) the speed of the hammer at the instant it comes into contact with the bar;

(2)

(ii) the time for which the hammer is falling freely.

(2)

(b) (i) Determine the **total** change in potential energy of the hammer during one drop.

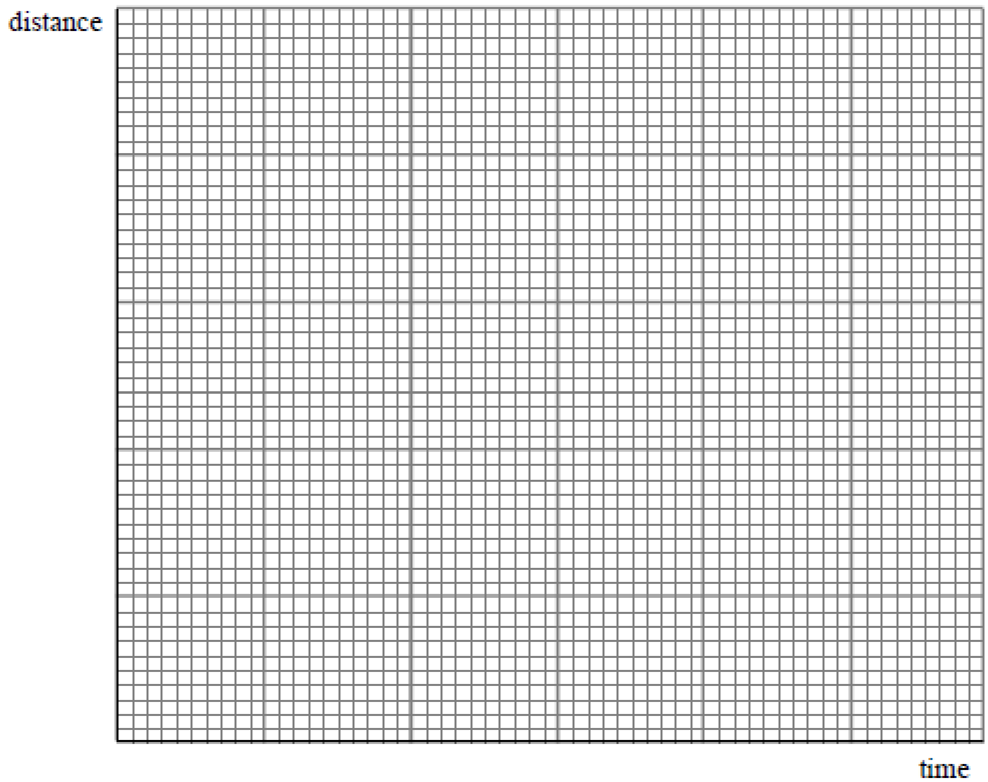
(2)

(ii) Assuming that the force resisting movement of the bar is constant and that all the potential energy of the hammer is used to drive in the bar, determine the value of this resistive force.

(2)

(c) The time for which the bar moves when being driven in is 0.10 s. Sketch a graph to show how the distance fallen by the hammer varies with time from the instant of release until it comes to rest.

Include scales on the distance and time axes. Indicate with a letter **T** the point on your graph at which the hammer and bar make contact.



(3)
(Total 11 marks)

31 To determine the force and power involved when a football is kicked, a student suspended a ball from the roof of a gymnasium by a long string as shown in **Figure 1**.

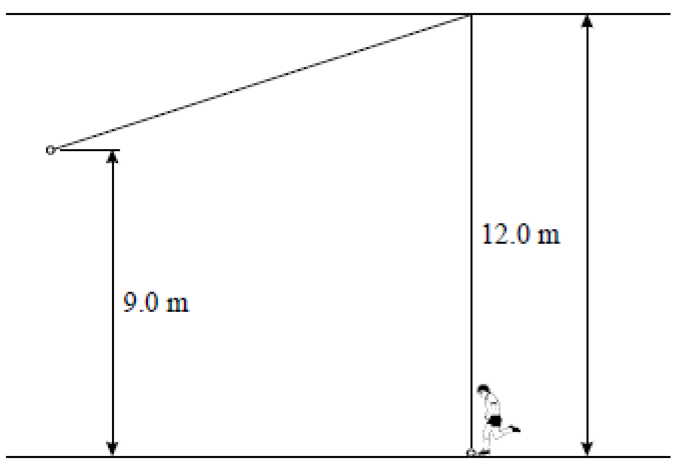


Figure 1

When the ball of mass 0.45 kg was kicked it rose to a maximum height of 9.0 m. The student measured the contact time between the ball and the boot as 0.12 s.

the acceleration of free fall, $g = 9.8\ \text{m s}^{-2}$

(a) Assume that air resistance was negligible so that all the initial kinetic energy given to the ball was converted into gravitational potential energy.

Calculate:

(i) the velocity of the ball immediately after being kicked;

(2)

(ii) the average force exerted on the ball when in contact with the boot;

(2)

(iii) the average useful power developed by the student when the ball was kicked.

(2)

(b) (i) The ball is kicked so that its initial motion is horizontal. Explain why the tension in the supporting string increases when the ball is kicked.

....

....

....

(2)

(ii) Calculate the tension in the string immediately after the ball is kicked.

(3)

(c) When it reached half its maximum height the ball was moving at 51° to the horizontal as shown in **Figure 2**.

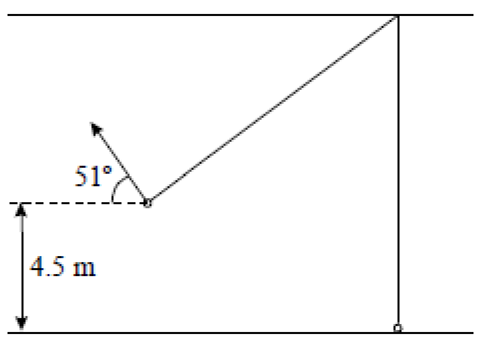


Figure 2

(i) Calculate the velocity of the ball in this position.

(2)

(ii) In one test the string broke when the ball was in the position shown in **Figure 2**. Explain why the ball reached a lower maximum height on this occasion than it did when the string did not break.

(2)
(Total 15 marks)

Mark schemes

1 A

[1]

2 (a) clear statement that gradient = acceleration *accept* $\Delta v/\Delta t$

or statement of v = u + at

B1

suitable values taken from graph

M1

3

i.e. (5.0, 13.5 – 0.5) (4.0, 11 – 0.5) (3.0, 8 – 0.5)

acceleration = 2.7 – 0.1 (m s^{-2})

A1

(b) (i) *use of* m = F/a

C1

mass = 740 kg

accept 741 kg
or answer consistent with part (a)

A1

3

(ii) resistive force = 2.0 kN

c.a.o.

B1

(c) clear attempt to count squares/estimate area *(37 – 2 cm²)*

C1

scale factor 1 cm^2:25 m

C1

3

distance = 925 – 50 m

rA1

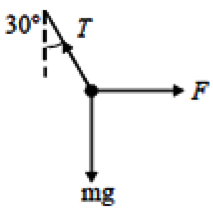
[9]

3

(a) $T = mg$ = 890 × 10 = 8900 **(1)** N **(1)**
(accept alternative correct value using g = 9.81 N kg^{-1})

(2)

(b)



resolve vertically $T \cos 30° = mg$ **(1)**

$T = \dfrac{mg}{\cos 30°}$ = 10280 (1.03 × 10^4) N **(1)**

(2)

(c) (i) vertical height fallen = $l(1 - \cos\theta)$ = 15(1 – 0.866) = 2.0(1) m **(1)**
(allow e.c.f. if h calculated wrongly)

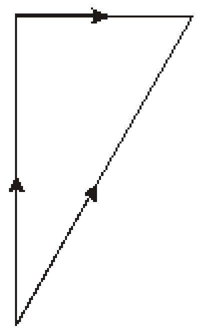
(ii) $\frac{1}{2}mv^2 = mgh$ or reference energy **(1)** $v = \sqrt{2\times10\times2.01}$ = 6.34 m s^{-1} **(1)**
(max 1 / 3 if equations of motion used)

(iii) $F = \left(= \dfrac{\Delta(mv)}{\Delta t}\right) = \dfrac{890 \times 6.34}{0.2} = 2.8 \times 10^4$ N **(1)(1)**
(allow e.c.f of v and m as before)

(5)

[9]

4



scale clearly stated

B1

correct triangle drawn

B1

all arrows shown

B1

1.8 m s^{-1} < speed $\leq$ 2.0 m s^{-1}

B1

direction = N (16 +– 2)° E

B1

or unambiguous alternative

or *use of* $c^2 = a^2 + b^2$ or *use of* $\tan\theta = a/b$

C1

$v^2 = 1.80^2 + 0.50^2$

C1

$\theta = \tan^{-1}(0.50/1.80)$ *or other valid angle*

C1

speed = 1.87 ms^{-1}

A1

direction N 15.5° E
or unambiguous alternative

A1

[5]

5 (a) (i) 1.05 (1.1) N m (up for J)

B1

1

(ii) 0.70 N m (condone 1 sf)

B1

1

(iii) weight of bar = 1.59 N (1.8 if (a) (i) = 1.1)

B1

1

(b) (i) 3.4 N (3.2 N if weight = 1.8 N) {ecf 5 – (a) (iii)}

B1

1

(ii) upwards (not clockwise)
(allow ecf for answer consistent with weight
i.e. down if (weight +2)>7)

B1

1

[5]

6 (a) **total** momentum of system constant/**total** momentum before =

B1

total momentum after
isolated system/no external force

B1

2

(b) (i) clear explanation of method

B1

correct numerical working leading to 4.25 m s^{-1}

B1

2

(ii) F = 0.31 × a speed

C1

use of speed difference [4.25 – 0.68]

C1

= 1.11 N [ecf]

A1

3

(iii) states that two momenta/forces related to hose and wall are equal in size/appreciates reaction force

B1

transmitted by hose to Earth and in opposite direction

B1

2

[9]

7 (a) (i) 1.5×10^4 sin 35 or 1.5×10^4 cos 55 seen = 8603.65 (to 4 sf minimum-no up)

B1

1

(ii) 11 600 N or 12 000 N

B1

1

(b) (i) any 2 from the following for C marks

accelerating force = 5600 N

C1

mass of cable car = 1530 kg (or 15 000/9.8 seen)

C1

F = ma

3.7 m s^{-2} (cnao)

A1

3

(ii) $v^2 = u^2 + 2as$

C1

30 (29.6) m s^{-1} (ecf for acceleration $\sqrt{240 \times acc}$)

A1

2

(iii) any equation of uniformly accelerated motion that includes *t*

C1

8.1 s (ecf for *v* or *a)*
(correct substitution leading to answer = their *v/a* or 240/their *v)*

A1

2

[9]

8 (a) km $h^{-1} \rightarrow ms^{-1}$ (27.8 m s^{-1}) or 100000/(5.8 × 3600)

C1

acceleration equation or correctly substituted values

C1

4.79 cao

A1

3

(b) equation of motion or correctly substituted values

($s = ut + \frac{1}{2}at^2$; $s = (v + u)t/2$; $v^2 = u^2 + 2as$)

C1

80.6 m e.c.f. from (a)

A1

2

[5]

9 (a) (i) $\Delta E = mg\Delta h$

B1

= (16.8+1.2)9.8 × 0.5 *or a mass × 9.8 × 0.5*

B1

= **88.2** (J)

B1

3

(ii) 108 J *or answer to (a) (i) + 20 J*

B1

1

(iii) 108/0.40 *allow ecf from (ii) (i.e. their (ii)/0.40)*

C1

270 N {*68/.4 = 170*}

A1

2

(b) gain in KE = loss in PE - work done

C1

= 88-20 = 68

C1

KE = ½ mv^2

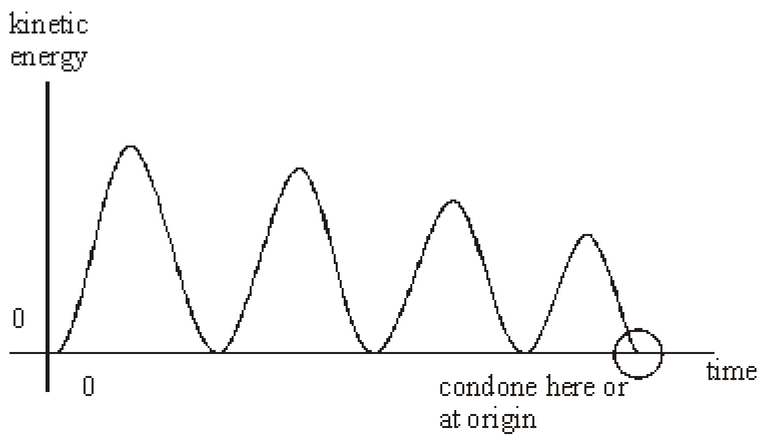
C1

v = 2.7(5) m s^{-1} *no ecf*

A1

4

(c)



graph starts at origin and forms a full rounded peak

B1

exactly two cycles (4 peaks) shown but not arches

B1

height of peaks decreases **and** peaks approximately equally spaced

B1

3

[13]

10 (a) air resistance (drag) /friction with correct arrow
from or towards body

B1

weight (force of gravity/ 838 N) not *gravity* with correct arrow
from somewhere on skier or ski -vertically downwards

B1

(b) clear attempt to resolve weight (not mass) or equate
normal reaction with component of weight (condone sin θ)

C1

$Mg\cos\theta$ or substituted values

C1

815 (or 810 or 820) N

A1

3

(c) constant speed/velocity or zero acceleration

B1

1

[6]

11 (a) (i) 2.4 m s^{-2}

B1

1

(ii) $F = ma$

C1

132 000 N (ecf from (i))

A1

2

(b) final speed = $(890^2 + 60^2)^{1/2}$

C1

892 m s^{-1} (cao) (allow 890 m s^{-1} as final answer but 892 must be seen in working)

A1

2

(c) $\tan^{-1}$ 60/890 or $\sin^{-1}$ 60/892 = 3.9° (3.86)°
or $\cos^{-1}$(890/892) = 3.8 (4)°
or $\sin^{-1}$ 60/890 =3.9° (3.86)° if ecf from (b)

B1

1

[6]

12 (a) (i) PE = $mg\Delta h$ or mgh or correct numerical substitution (condone g = 10 m s^{-2})

B1

3.6(3) × 10^{13} J (accept 3.6 or 3.7)(NB not only 4.0 × 10^{13}J)

B1

2
no up

(ii) $mg\Delta h = ½\, mv^2$ or $E = ½\, mv^2$ or numerical substitution
n.b. not $v^2 = u^2 + 2\,as$

M1

85 (84.9) m s^{-1} or use of 4 × 10^{13}J giving 89 m s^{-1}

A1

2

(iii) $E = Pt$ or $t = ½ mv^2/P$ or numerical substitution

i.e. time = their (i)/400 × 10^6 or 4 × 10^{13}/400 × 10^6

or time = their (i)/100 × 10^6 or 4 × 10^{13}/100 × 10^6

(allow attempt using incorrect v from (ii) for this mark only)

(note no further ecf for incorrect *v*)

C1

90 000 s or 1 × 10^5 s

or 3.6 × 10^5 s or 4 × 10^5 s 100 – 112 hours

(i.e. forgetting to include factor of 4)

C1

25 hours or 27.8 (28 h) (using 4 × 10^{13})

A1

3

(b) inefficiency of the pump or generator/turbines with no further detail

(This is a compensation mark and is not awarded if any of the next three marks are given)

B1

work done/power/energy/heat lost due to friction in pumps or generators/turbines

B1

energy/power/heat lost in transmission/generator/pump due to current/resistance in wires

I^2R heating

collisions of electrons with lattice etc

not just energy lost in the wires

B1

KE of water not reduced to zero in the generator/not all KE converted to electrical energy

B1

energy lost
due to friction between water and ground/pipes
or moving stones as water falls
or due to turbulence in water or viscosity of water

B1

distance from reservoir to generator < lake to reservoir
not water evaporation/sound/resistance in pipes

B1

max 3

[10]

13 1 mark each correct row

B3

[3]

14 (a) $F = \frac{\Delta(mv)}{t}$ or $Ft = mv - mu$ etc.

M1

substitute units

A1

2

(b) conservation of momentum mentioned

B1

ejected gas has momentum or velocity in one direction

B1

rocket must have equal momentum in the opposite direction

B1

3

or force = rate of change of momentum

(B1)

ejected gas has momentum or velocity in one direction

(B1)

rocket must have equal and opposite force

(B1)

(c) equation seen ($F = m/t \times v$ but not $F = ma$)

B1

substitution into any sensible equation leading to
3.6×10^7 (N)

B1

2

[7]

15 (a) two correct weight arrows *with labels* (100N, W)
*arrows must **act on beam** (horiz. scope: M, 50 m respectively)*

B1

normal reaction arrow at pivot point (with label)

B1

(2)

(b) Use of 36 × a distance

C1

moment = 43.2 Nm *(36 × 1.3 = 46.8)*

A1

(2)

(c) clockwise moment = anti-clockwise moment

C1

$43.2 = 0.40 \times 100 + 0.55w$

M1

$w = 5.8$ N

A1

allow ecf from (b) (46.8 gives 12.4 N)

(2)

[7]

16 (a) a velocity divided by a time

C1

single reading from graph of v in range 54..56

C1

acceleration in range 90..93.4 ms^{-2}

A1

3

(b) clear attempt to estimate area under the curve

C1

use of correct scale factor: 1 cm^2 represents 10 × 0.2 m

C1

max height in range 80..90 m

A1

3

(c) t^2 = (2 × answer to (b))/9.8

C1

expected answer in range 4.0..4.3 s
allow ecf for height

A1

2

[8]

17 (a) (i) 15 rev / s = 30π rad / s **or** v = 51 / 52 m s^{-1} [could appear in subst]

Bl

$F = mw^2r$ [or mv^2 / r & $v = \omega r$]

Bl

appropriate sub leading to 7.33 kN [2+sf evaluation mandatory]

Bl

(ii) to centre of rotor OWTTE

Bl

(iii) *stress* = F / A **Bl**

correct substitution from ai **Bl**

(iv) $0.55 \times 2.09 \times 10^{7} / 6 \times 10^{10}$ [or $\varepsilon = 3.3 \times 10^{-4}$] **Cl**

= 0.192 mm **Al**

(v) $\frac{1}{2} \times 7.32 \times 10^{3} \times 1.92 \times 10^{-4}$ [ecf] **Cl**

= 0.702 J **Al**

(b) (i) volume pushed down [per second] = Av [mass = ρ × volume] **Bl**

Change of momentum [per second] = mass pushed down per second × v **Bl**

(ii) Upward force = 900 N OWTTE [penalise use of 900g]
OR area swept out by blades = $\pi \times 0.55^{2}$ **Cl**

$900 = (0.55)^{2}\, \pi 1.3 v^{2}$ **Cl**

= 27 m s^{-1} **Al**

[15]

18 (a) wt of person + load marked vertically downwards **B1**

wt of plank marked in centre downwards **B1**

upward force at pivot marked
inappropriate reaction forces loses one mark **B1**

(b) clear attempt to equate moments in both senses **C1**

$65g \times 0.5 = 25g \times 1.0 + L \times 2.5$ **C1**

L = 29.4 [N] **A1**

(c) anticlockwise / student moment becomes smaller **B1**

clockwise moment now larger or plank rotates clockwise **B1**

[8]

19 (a) Use of moment formula

C1

$0.5 \times 550 + 1.2 \times 650 = \text{Weight C} \times 2.1$

C1

Weight C = 502 N

A1

(b) Weight of see-saw = 9.8 × 35 = 343 N **or** total people *wt* = 1200 + C ecf

B1

Total weight = 2.05 kN

B1

[5]

20 C

[1]

21 (a) *states* area under graph = distance **or** clear evidence of graph use

B1

½ × 30 × 25 *seen*

B1

2

(b) accel = grad of graph **or** uses a = $\Delta v/\Delta t$

M1

30/20 = 1.5 m s^{-2}

A1

2

(c) 300 + 375 = 675 m

B1

1

(d) 675/680 m (ecf) at 30m/s takes 22.5/22.7 s

C1

but actually took 90 s

C1

so loss of time = 67.5/67.3 s

A1

3

[8]

22 (a) (i) construction correct, accurate and uses space sensibly

B1

41° [correct calculation scores 2]

B1

2

(ii) work leading to 2.1 ms^{-1}

B1

1

(b) ½ mv^2

C1

$\times 4.5 \times 10^{-8} \times (2.13)^2$

C1

1.02×10^{-7} J

A1

3

(c) *work done =force x distance*

B1

= $(4.5 \times 10^{-8} \times 9.8) \times 5$

C1

= 2.21×10^{-6} J

A1

3

(d) air resistance increases with speed

B1

eventually drag = weight

B1

so overall force is zero

B1

hence acceleration is zero

B1

4

the use of physics terms is accurate, the answer is fluent/well argued with few errors in spelling, punctuation and grammar **and** scores **3+**

B2

the use of physics terms is accurate, but the answer lacks coherence or the spelling, punctuation and grammar are poor **and** scores **1+**

B1

the use of physics terms is inaccurate, the answer is disjointed with significant errors in spelling, punctuation and grammar

B0

2

[15]

23 (a) vector has direction, scalar has no direction / only vector has direction

B1

(b) vector: any vector except force (accept weight)

B1

scalar: any scalar

B1

(c) $F = ma$ in any form

C1

maximum: 1.4 m s^{-2}

minimum: 0.29 m s^{-2}

A1

[6]

24 (a) **total** momentum before a collision = **total** momentum after a collision or total momentum of a system is constant or $\Sigma mv = 0$, where mv is the momentum

B1

no external forces acting on the system/ isolated system

B1

2

(b) (i) work done = $F s$

C1

63 000 J

A1

2

(ii) KE = ½ mv^2 or $F = ma$ and $v^2 = u^2 + 2as$

C1

combined speed v = 4.6 (4.58) m s^{-1}

A1

2

(iii) reasonable attempt at a momentum conservation equation (2 terms before and one term after any signs)

C1

(+ or -) 3600 v + (2400 × 12.5) = (6000 × 4.58) (e.c.f)

C1

16 m s^{-1} (cao ignoring sign)

A1

3

(iv) driver A is likely to experience the greater force

B1

force = rate of change of momentum ($\Delta mv/t$) or $F = ma$

B1

time for deceleration on impact is (approximately) the same

B1

change in velocity of driver B = 11.4 m s^{-1} (ecf from (ii) and (iii))
and
change in velocity of driver A = 17.1 m s^{-1} (ecf from (ii) and (iii))
or
Δmv or Δv of A > Δmv or Δv of B

B1

4

[13]

25 (a) (i) (acceleration = F / m =) 1.76 m s^{-2}

B1

(1)

(ii) ($v = u + at$) = 0 + 1.76 × 15

C1

= 26.4 m s^{-1}
allow e.c.f. from (i)

A1

(2)

(iii) ($s = ut + 0.5\ at^2$) = $0.5 \times 1.76 \times 7.5^2$ **C1**

= 49.5 m
allow e.c.f. from (i) **A1** **(2)**

(iv) t doubles so s quadruples = 4 × 49.5 ~ 200 m
[or equivalent] **B1** **(1)**

(b) acceleration graph correct: same shape as F-t;
1.8 (1.76) identifiable on axis **B1**

speed graph correct: straight line through origin to
identifiable 26 m s^{-1}
at 15 s **B1**

distance graph correct: shape parabolic; both calculated points
identifiably marked **B1**

all axes labelled with unit **B1** **(4)**

(c) (i) total force decreases as time increases [or appropriate graph] **B1**

(because) speed increase leads to drag force increase **B1**

total thrust is sum of engine force – drag (frictional force) **B1** **(3)**

(ii) forward thrust = friction force **B1**

so (total thrust = 0) and acceleration = 0 **B1** **(2)**

[15]

26 (a) (i) $v = s / t$ **C1**

19 (18.7) m s^{-1} **A1**

(ii) zero tolerate missing unit **B1**

(iii) $v^2 = (u^2) + 2as$ $v = u + at^2$ $s = ut + 1 / 2at^2$ **C1**

$v = \sqrt{(2 \times 9.8 \times 11)}$ **C1**

15 m s^{-1} / 14.7 m s^{-1} **A1**

(b) (i) use of Phytagoras **C1**

$18.7^2 + 14.7^2 = v^2$ **OR** $v^2 = \sqrt{(\text{their (a)(i)}^2 + \text{their (a)(iii)}^2)}$ **C1**

24 (23..7 or 23.8) ms^{-1} **ecf** **A1**

OR velocities drawn correctly to scale **C1**

suitable scale used and quoted **M1**

23 – 25 m s^{-2} **A1**

(ii) 38° to 39° 37° to 40° for scale drawing

ecf $\tan^{-1} \frac{\text{their (a)(iii)}}{\text{their (a)(i)}}$ **B1**

(c) when kicked / when landing has max KE **B1**

has no PE at this point / has max speed and KE = $½mv^2$ **B1**

or loses energy because of (work done against) air resistance **B1**

total energy greatest just after it's been kicked **B1**

[12]

27 (a) vague statement:
e.g. clockwise moments = anticlockwise moments
or recognition of the equilibrium condition
precise statement: must have 'sum of' and equilibrium condition
i.e. when in equilibrium sum of clockwise moments =
sum of anticlockwise moments (about any point)

C1

or Σclockwise moments = Σanticlockwise moments
or vector sum of moments = 0
or no resultant moment (or torque)

A1
(2)

(b) (i) correct moments equation (354 N seen)

C1

175 N to 180 N (177 N)

A1
(2)

(ii) 95 N to 100 N (98 N)

or 275 – (i)

or 550 – 354 = 196 N

(i.e. e.c.f. for those who forget about two hands and feet;

also allow reverse answers as e.c.f.)

A1
(1)

(c) (i) two friction forces correctly shown at ground level

(at least one on the line)

B1
(1)

(ii) friction between the hands and the floor
or resistance to relative motion of hands and floor

B1
(1)

(iii) 420 N

B1
(1)
[8]

28 (a) conservation of momentum equation or statement quoted or used even with incorrect data **C1**

$1.4 \times 10^7 \times 1.7 \times 10^{-27} = 401.7 \times 10^{-27} \times v$ **C1**

$5.9(3) \times 10^4$ m s^{-1} **A1**

(3)

(b) neutron will rebound / have velocity / momentum to the left **B1**

momentum transferred to the uranium will be greater **B1**

velocity of uranium will be greater

(no loss of kinetic energy argument gets the final mark only) **B1**

(3)

(c) KE = $\frac{1}{2}mv^2$ seen or used **C1**

$0.5 \times 1.7 \times 10^{-27} \times (1.4 \times 10^7)^2$ **C1**

1.7×10^{-13} J ($1.67 - 10^{-13}$ J) **A1**

(3)

[9]

29 (a) (i) loss of PE = gain of KE or $mgh = \frac{1}{2}mv^2$

allow for statement of conservation of energy

(energy can not be destroyed but can be converted from one form to another) **B1**

correct height used (2.4 m or 2 × 1.2 seen in an equation) **B1**

correct substitution including values for h and g (no u.p.) **B1**

(3)

(ii) $F = mv^2 / r$

(allow $mr\omega^2$ **C1**

2800 N (2780 N) or

2700 N (2740 N) if using $v = 6.86$ m s^{-1} **A1**

(2)

(iii) (ii) + 690 (3500 N or 3460 N)

(3400 N or 3430 N if using v = 6.86 m s^{-1})

B1

(1)

(iv) graph shape down up down up (condone linear); minima at 90° and 270°

M1

graph starts at 690 (N); this point labelled;

maximum labelled consistent with answer to (iii),

zero at 90 and 270 (allow any shape between these points)

A1

(2)

(b) stress = F / A and strain = extension /original length **and** E = stress / strain

or

$E = Fl / Ae$

C1

correct substitution using 690 N (condone 700 N)

or substitution with e.c.f. from graph

C1

allow e.c.f. for use of g without substitution if penalised in (i)

$8.9 \times 10^{-6} - 9.1 \times 10^{-6}$ m

A1

allow only 1 mark if candidate divides by 2 at any stage

(3)

[11]

30 (a) (i) $v^2 = u^2 + 2as$

or $mgh = ½ mv^2$

or numerical equation or other correct sequence of equations

C1

8.9 m s^{-1}

A1

(2)

(ii) $v = u + at$

C1

0.90 s or 0.91 s

A1

(e.c.f. forgetting the square root in (i) gives 78.4 m s^{-10} for (i) and 8.0 s for (ii))

(2)

(b) (i) Δ(PE) = mgh

C1

22 kJ

A1

(2)

(ii) force = change in energy / distance moved

or F = ma and $v^2 = u^2 + 2as$

or $Ft = \Delta(mv)$ using t from next part

C1

(i)/ 0.5 = 44 kN

19.6 kJ leads to 39.2 kN; 20 kJ leads to 40 kN

$Ft = \Delta(mv)$ and v = 8.9 m s^{-1} leads to 45 kN

C1

(2)

(c) correct initial curvature

C1

correct shape overall with inflexion at (0.90 ± 0.05) s

C1

correct shape, inflexion at 0.90 s and 4.0 m, maximum at 1.0 s and 4.5 m and **T** indicated correctly

A1

accurate plotting is not essential
omission of unit on an axis loses final mark

(3)

[11]

31 (a) (i) $mgh = \frac{1}{2} mv^2$ **or** correct numerical substitution

M1

13.3 m s^{-1}

no marks for use of equation of motion for constant acceleration

allow $gh = mv^2 / 2$ or $v^2 = 2gh$) but not $v^2 = 2as$

A1

(2)

(ii) mv = Ft (or F = ma and a = v / t)

(or numerical equivalent)

C1

48.8 to 50.0 N e.c.f. from (i) {3.75 × (i)}

A1

(2)

(iii) power = energy transformed / time

C1

or power = average force × average velocity

or $P = Fv$ leading to (i) × (ii) (664 W if (i) and (ii) are correct)

330 to 332 W e.c.f. from (i) and / or (ii) {(i) × (ii) / 2}

A1

(2)

(b) (i) the ball accelerates toward centre (of circular path) /
the point of suspension / upwards

or the ball is changing direction upwards

B1

centripetal force / resultant force upwards /
force towards centre of circular path

or string initially stretches producing an elastic force

B1

(2)

(ii) $T - mg = mv^2 / r$ **or** $F = mv^2 / r$ (or numerical equivalent)

or $F = ma$ **and** $a = v^2 / r$

C1

centripetal / resultant accelerating force = 6.6 N

e.c.f. from (i) (0.0375 × (a)(i)^2)

C1

tension = their centripetal force + 4.4 N (11 N)

A1

(3)

(c) (i) $\frac{1}{2} m(13.3)^2 = \frac{1}{2} mv^2 + mg \times 4.5$

or velocity is same as when falling 4.5 m so $\frac{1}{2} mv^2 = mg \times 4.5$
or KE at bottom = KE at half way + PE

allow $\frac{1}{2} mv^2 = mg \times 4.5$

B1

9.4 m s^{-1} (no marks if 9.4 m s^{-1} arrived at using equation of motion)

B1

(2)

(ii) horizontal velocity is constant after string breaks

or continued movement in the horizontal direction

oridea of KE due to horizontal motion

B1

at max height the ball still has KE so acquires less PE

ornot all KE becomes (gravitational) PE

B1

(2)

orupward velocity = 9.4 sin 51

B1

use of equation of motion leading to 2.72 m after the break

B1

orafter string breaks downward force increases /
the upward force ceases to exist

B1

there is greater vertical deceleration

B1

[15]

Examiner reports

2 A significant majority of candidates gained over half marks on this question and a high number of fully correct answers were seen.

(a) A straightforward question, but a number of candidates did not clearly state the principle or formula they were using. Since this was a ‘show that’ question, this omission was penalised.

(b) (i) Most candidates correctly calculated the mass; although there was the usual confusion between mass and weight in the minds of some.

(ii) Less than half of the candidates realised that the horizontal forces were in equilibrium so some very odd answers were seen.

(c) Counting squares is a well rehearsed technique and as expected, many correct answers were seen.

4 This question was answered well by the majority of candidates; most chose to calculate the resultant velocity rather than to use a scale drawing but then often had difficulty in clearly defining the direction for the final mark.

5 (a) (i&ii) The structuring allowed most candidates to calculate the magnitudes of the moments correctly but many incurred a unit penalty here.

(iii) Many candidates had no appreciation of how to apply the principle of moments to this situation. A common mistake was to assume the mass to be concentrated at the end of the wooden bar.

(b) (i) The simple idea of equating the sums of the upward and downward forces to determine the force necessary to maintain the equilibrium of the bar was appreciated by relatively few candidates.

(ii) Candidates were expected to appreciate that the pivot must exert a downward force on the bar to maintain equilibrium so that there would be an upward force on the pivot.

6 (a) For full credit, candidates needed to state that the total momentum is constant (in some appropriate way) and also to mention the absence of external forces. It was common to see answers that featured one but not the other.

(b) (i) Although many candidates carried out computations which ended in a numerical solution that was plausible, the general level of explanation (whether algebraic or descriptive) was very poor. Many solutions consisted of a jumble of numbers from which examiners could make little sense. This was a ‘show that’ question and candidates needed to be much more careful about the level of their description in order to obtain full credit.

(ii) There were many poor attempts in this part also. The ostensibly correct solutions often needed considerable work by examiners to determine the line of argument. Those who write down equations at random (the dubious $F = ma$ was a case in point) need to be exceptionally clear in their solutions if their work is to be credible.

(iii) The explanation of why water sprayed onto a wall does not alter the Earths rotation eluded many. Common misconceptions included the idea that nothing happened because the Earth is massive and the water flow is not. Also many candidates wrote wisely about the action and reaction forces at the wall but failed to gain credit because they did not consider the whole system.

7

(a) (i) More were able to handle the resolution of the force correctly in this part than were able to do so in question 1.

(ii) Subtraction of the frictional force from the answer to part (i) was the most common error.

(b) (i) Most appreciated that they had to use $F = ma$, but there were two pitfalls which led to many incorrect answers. Firstly, an incorrect determination of the force acting down the slope and secondly, the use of 1.5×10^4 (N) as the mass.

(ii) & (iii) Allowing the error carried forward these parts were generally done well.

8

(a) Most candidates were able to use an appropriate form of the equation $v = u + at$. Weaker candidates were penalised for suggesting that acceleration is velocity divided by time. A sizable number failed to convert kilometres per hour into metres per second.

(b) With error carried forward from (a) many candidates gained full marks for this part. Common errors were to use the kilometre per hour velocity a second time in the equation $s = (v + u)t/2$ or to quote the final distance to four (or more) significant figures.

9 This question discriminated well, with nearly every candidate being able to achieve some marks and the more able scoring well. A few candidates achieved full marks.

(a) (i) This part was generally done well, but some candidates lost a mark by not clearly stating the formula they were using.

(ii) This part was less well answered. Common errors included 20 J being subtracted rather than added, and the answer being quoted to 4 significant figures. Also a surprising number of candidates were unable to add 88 to 20 successfully.

(iii) Most candidates gained both marks for this part, albeit, in some cases, with an error carried forward from part (ii).

(b) Only those candidates who read the question carefully accounted for the work done against friction on the downward swing.

(c) Most curves were sufficiently well drawn to gain at least two of the three marks. A common error was to draw arches rather than sine curves or to show only two peaks instead of four. The decreasing height of the peaks was well known.

10 (a) Most candidates appeared to know the forces acting but many were penalised for showing the weight arrow with no point of application, showing it acting at a clearly non-vertical angle or labelling weight as “gravity” or “mass”. Nearly all candidates correctly identified an appropriate frictional force.

(b) There was considerable variety relating to the resolving of the weight. In many cases, candidates appeared to take pot luck as to whether they should be writing the sine or the cosine. Other candidates seemed very unsure as to what needed to be resolved, with attempts to resolve the normal reaction being quite common.

(c) Most candidates recognise the constant velocity as being the key to the skier being in equilibrium.

11 (a) (i) This part was usually correct but the unit caused more problems than it should have done at this level.

(ii) Few candidates had problems with this part.

(b) Most were successful in this part. Those who failed usually gave $(890^2 + 2.4^2)^{1/2}$

(c) Again the majority of the candidates did this correctly. Those who failed usually determined the wrong angle and gave 86.1° as the final answer.

12 (a) (i) Most candidates completed this successfully.

(ii) The majority did this correctly using $mgh = \frac{1}{2} mv^2$. The situation was not one of free fall with constant acceleration so the use of $v^2 = u^2 + 2as$, although giving the same answer, was inappropriate.

(iii) There was a good proportion of correct responses but many did not know the relationship between energy and power. Others failed to get the correct answer because they ignored the fact that there were four generators or because they could not convert correctly from MW to W.

(b) It was disappointing that many candidates failed to identify losses due to physical factors in the pumping, generating and transmission systems. When friction was mentioned, answers lacked depth and commonly included phrases such as ‘energy is lost to friction’. Relatively few stated clearly where the frictional force existed. Inefficiency in the pump or generator was often mentioned without any detail of the causes. Weak responses included evaporation of water, leakage though soil or animals drinking some of the water.

13 Not the easy “starter for three” one might have expected. The most common error: weight given as a scalar quantity and/or measured in kilograms. Also a disappointing number of candidates did not know the unit for energy.

14 (a) Candidates’ attempts to show the relationship between impulse and momentum and their units were variable. There was considerable confusion regarding the unit of impulse ($\mathrm{Ns^{-1}}$ being fairly commonplace). Too frequently candidates simply started with $F = ma$ without attempting to show how this related to the impulse/change of momentum equation. It was relative common to see candidates stating that impulse is equal to the *rate of* change of momentum.

(b) Arguments for how the ejection of waste gas propels a rocket were variable. Most candidates had an idea that conservation of momentum was involved, but tended to be rather loose in their application of this concept. Many simply said that forces are equal and opposite, or that if there was momentum in one direction there must be momentum in *the other* direction.

(c) It was not apparent from most candidates’ answers whether or not they understood that in this example it is mass changing with time rather than velocity. Although credit was allowed;for equation $F = \frac{mv}{t}$, $F = ma$; $F = m\frac{\Delta v}{\Delta t}$ or $F = \frac{mu - mv}{t}$ were not allowed.

A significant minority of candidates failed to convert $\mathrm{km\ s^{-1}}$ into $\mathrm{m\ s^{-1}}$ yet still quoted their final answer in MN.

15 Generally the force arrows were poorly drawn and / or not labelled, or left out altogether. Parts (b) and (c) were often well answered although unit errors were quite common.

16 This proved to be a difficult question for many candidates.

An accurate calculation of average acceleration was achieved by only about half of the candidates, while rather less than that were able to calculate the correct area under the graph to find the maximum height.

Many of the candidates who gained credit for part (a) did so on the basis of error carried forward from part (b). Other candidates had the rocket falling back to Earth with an initial velocity of 69 m s^{-1}. However, there were a significant number of candidates who did achieve full marks on the question.

17 (a) (i) Candidates here (and elsewhere in the paper) must recognise that questions beginning with the words '*Show that*...' demand a clear and well-explained exposition of the calculation or proof. Examiners are not satisfied with muddled and incomplete answers or answers that simply re-state the question. Explicitly, in this part, candidates were expected to quote their answer to *more than* the one significant figure in the question. They were also expected to show how they converted 15 revolutions per second into a value that could be used in their equation. Failures to convince often lead to loss of marks.

(ii) Although examiners were generous here, the common answer 'to the centre' is not adequate for a candidate at A2 level in a physics examination; the centre of what? Strong candidates often illustrated the answer on a labelled diagram of the helicopter itself *and drew the examiner's attention to this amendment* . Candidates should take every opportunity to make their answers clear.

(iii) Again, a 'show that' which often did not. Those who quote the equation $p = F / A$ for 'stress' without defining their symbols must not be surprised if the examiner assumes that p stands for 'pressure'. The safest route is to supply a word equation in cases like this.

(iv) There were many good answers here, but solutions were frequently marred by arithmetic errors and by negligent candidates who calculated the strain and then omitted to go on to evaluate the required change in length.

(v) Again, this was well done by many, but there was a significant number of candidates who attempted to go via the route
strain energy per unit volume = ½ stress × strain.
This is indeed a possible method, but these candidates too often failed to multiply in the volume of the helicopter blade.

(b) (i) Only a few candidates were able to prove this simple relationship. Those who did stated clearly the volume of air being forced downwards every second, could use this to evaluate the mass of air being forced down, and could go on to show the change in momentum of this air. Otherwise candidates simply floundered around trying unsuccessfully to 'spot' a relationship that would yield the result they needed.

(ii) To the examiners' surprise very many found the evaluation of the air speed beyond them. Although many recognised that the change in momentum per unit time has to equal the weight of the helicopter, candidates still turned the weight of the aircraft back to mass, and failed to spot the squared velocity term. This was a disappointing failure by many candidates.

18 It was rare to see a reaction force drawn at the point where the log met the plank. The weights of the load and the plank itself were often present, however. Drafting skills were poor, and the substantial number of non-vertical forces were penalized.

As ever, moment calculations proved difficult. Many could give some balanced equation of anticlockwise and clockwise moments. Fewer could incorporate g correctly or correctly state all three terms. Weak candidates attempted the calculation in small individual parts and usually came to grief over signs. Even candidates who negotiated all these hurdles often quoted the answer as a mass (load was required and the unit was given in the question as an additional hint).

Too often examiners found themselves marking a question in which the candidate crossed the log.

Candidates must take time to read the questions carefully. However, those who understood what was required gave correct explanations.

19 (a) Answers to the first part were mostly good with only significant figure errors marring the answer. Candidates appear to have improving standards in respect to these moment calculations.

(b) There were only a few complete answers. Many were able to suggest that the weight of the see-saw was 343 N or that the total weight (excluding the see-saw) was 1700 N. Few could combine the two.

21 The question told candidates to 'use the graph…'. Many failed to make it clear in any way how they did this and lost marks. Otherwise, this question was done well.

The calculation of acceleration was done well by most, but there was a smattering of incorrect units for the acceleration.

There were no major problems here apart from the few who used the distance travelled for the whole of the graph (and who had therefore failed to read the question).

Again, errors centred on the use of incorrect time periods for one or more parts of the calculation.

22 (a) (i) Here again the question was often read poorly, leading some candidates to the determine the angle with the horizontal rather than the vertical. The drawings themselves were often crude and careless. A large area was available for the construction, but many used only a small fraction of this space, obtained an approximate answer, and penalised themselves. Candidates who opted for a calculation were not penalised in the mark scheme, but the expression of the answer to 0.01° lead to a significant figure penalty error.

(ii) Most candidates calculated the speed and were completely successful. Unit errors crept in here however, as did the occasional power-of-ten error. Almost every candidate quoted the formula correctly but a significant number forgot to square the speed when it came to the calculation itself. Significant figure errors were also common. It was quite common to see candidates omit parts of the argument here. Too often there was a bald statement of ‘g.p.e. = mgh’ with no clear statement that this was identical to the work done by the raindrop. The calculation was usually carried through well but both significant figure and unit errors were rife here and many only scored 2/3 as a result.

Good candidates gave complete, well-sequenced, logical answers. Weaker candidates could not construct the extended explanation with any ease. It was common to see statements such as ‘the air resistance force equals the speed…’. Some candidates tried to describe the forces acting on the drop in terms of thrust and lift, clearly confusing the situation with the movement of an aircraft.

23

(a) The majority of candidates could distinguish correctly between vectors and scalars.

(b) Candidates could also give examples of each although a few did not read the question carefully enough and gave force as their example of a vector.

(c) These calculations were usually well done but some candidates could not identify the resultant forces that would yield the maximum and minimum accelerations. Significant figure penalties were quite common in this question.

24

(a) Most candidates were able to gain one mark for the definition. The most common errors were either not giving the condition of no external force or failing to refer to the total momentum in the definition. It was therefore unclear whether the definition referred to the momentum of a body or the system of bodies. There was a minority who stated the principle as ‘the momentum of a body remains constant unless a force acts on it’.

(b) (i) This was usually correct.

(ii) A significant proportion of the candidates tried using the principle of conservation of momentum in this part. Those who appreciated that they had to use $KE = \frac{1}{2} mv^2$ usually completed this successfully but some used an incorrect mass or failed to take the square root.

(iii) There were many correct answers and many structured their responses sensibly. Most were able to make a realistic attempt equating two momenta before the collision to one momentum after. Many however failed to take account of the fact that the final momentum would be to the left whilst the original momentum of A is to the right and so the signs for these terms needed to be different, regardless of the convention they used.

(iv) There were some excellent logical arguments presented in response to this question and many gained full marks. Even weak candidates usually suggested that driver A would feel the greater force but explaining why proved more difficult. Some realised that use of $F = ma$ or $F = \Delta(mv)/t$ was useful but many went on to discuss the vehicles rather that the drivers. The most common omission was failure to state that in the comparison the time for each driver to come to rest would be (approximately) the same.

25 (a) (i) There were many good and complete solutions, part (iii) giving the most problems.

(ii) There were many good and complete solutions, part (iii) giving the most problems.

(iii) There were many good and complete solutions, part (iii) giving the most problems.

(iv) There were many good and complete solutions, part (iii) giving the most problems.

(b) Although sketches of the acceleration / speed / distance–time graphs were poor. There was a general failure to recognise the distance–time graph as being quadratic in form and the force–time graph was often shown as increasing with time. Despite a clear indication in the question, some candidates still failed to add values and unit labels to the graph axes.

(c) (i) Many realised that drag due to air resistance rises with vehicle speed and that therefore the force decreases with time. Many fewer stated that the resultant force exerted on the motor car is the difference between the drag force and the engine thrust.

(ii) A good number recognised that equality of the thrust and the drag forces means that the resultant force is zero and that in consequence the acceleration is also zero. Failures here centred around the use of the term ‘constant speed’ rather than ‘zero acceleration’ as an attempted answer.

26 (a) (i) Most candidates managed the first calculation correctly by simply using $s = vt$ but quite a few complicated issues by selecting other equations of motion that involved acceleration.

(ii) The majority of candidates realised that the vertical component of velocity at the highest point would be zero. Some, however, embarked on lengthy calculations.

(iii) Many candidates were successful with this calculation. This, and other calculations in this question caused many candidates to incur significant figure penalties.

(b) (i) Fewer candidates were successful by the time they reached this stage in the question. There principal problem was realising that they should find the resultant to their answers to parts (a) (i) and (a) (iii). However, many of the better candidates managed straightforward, well set out solutions to all parts of the question.

(ii) This was well done by many but a significant number used the horizontal and vertical distances given in the diagram to calculate the angle, instead of using the velocities they had calculated earlier.

(c) Most candidates could indicate the correct points at which the ball's kinetic energy would be a maximum. Clear and complete explanations about why this was the case were rarer. Candidate's explanations tended to be loose and lacking in detail or clarity. Rather than simply mentioning air resistance, for example, candidates should have commented on the work done by the ball against air resistance.

28 (a) This calculation was well done by most candidates. Nearly everyone recognised it as a situation in which the principle of conservation of momentum was important. Some of the weaker candidates made statements to this effect but then proceeded in attempts to use the conservation of energy. Another mistake made by significant numbers of candidates was to use the mass of the uranium nucleus in determining the momentum after the impact, rather than the increased mass of the nucleus, incorporating an additional neutron. Significant figure errors were common in this part.

(b) Few candidates attempted to analyse this situation in terms of conservation of momentum. Very few identified the recoil of the neutron or the reversal of the direction of its momentum. Partial credit was gained by many candidates who used arguments based on kinetic energy conservation in an elastic collision. These candidates failed to appreciate that their arguments were not sufficient to explain the behaviour of the particles.

(c) This part was well done by nearly all of the candidates. There were a few who used incorrect data for the mass or the speed of the neutron and some others who forgot to square the velocity when doing the calculation. Significant figure penalties were not uncommon. Some candidates expressed their answer in a notation similar to that shown on their calculators (i.e. 1.7^{13}). This is clearly incorrect and candidates should be advised that the use of this notation will be penalised.

29 (a) (i) The majority of the candidates appreciated and tried to use the fact that the change in PE would be equal to the gain in KE. The most common error was to use 1.2 m as the change in height of the centre of mass. Even though this gave an incorrect answer few seemed to go back to check why their answer was incorrect.

(ii) Most candidates knew the correct equation and used correct data. Some however tried to use $F = mr\omega^2$, substituting 6.9 m s^{-1} for ω. A significant proportion of the candidates incurred a significant figure penalty in this part.

(iii) This part was not well done. Many candidates gave the answer as the weight of the gymnast mg (690 N) not appreciating that this had to be added to the force determined in (a)(ii). Some subtracted the weight.

(iv) The graph was partly a test in graphing data that had previously been determined and appreciating that in the initial position the force downwards is the weight of the gymnast and realising that the vertical force on the bar would be zero when the gymnast is in the horizontal position. Those who determined the weight in (a)(iii) could gain full marks here as error carried forward. Candidates were not expected to realise that the force acts upwards before this position is reached.

(b) Most candidates were able to quote a correct equation or series of equations. Candidates could gain full credit for using the weight or the value they had plotted on the graph for 0°. Many, however, used the value from part (a)(ii) or an incorrect value from (a)(iii). The ‘record’ for arm-stretching during this manoeuvre was 10^{13} m, arrived at without comment!