CAMBRIDGE INTERNATIONAL AS & A LEVEL • PHYSICS 9702

Topical Questions

Unit 5: Work, Energy and Power

Past Papers 2021 – 2025

QUESTION PAPER 19 Questions

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Question 1

(a) State what is meant by *work done*.

....

.... [1]

(b) A beach ball is released from a balcony at the top of a tall building. The ball falls vertically from rest and reaches a constant (terminal) velocity. The gravitational potential energy of the ball decreases by 60 J as it falls from the balcony to the ground. The ball hits the ground with speed $16\,\mathrm{m\,s^{-1}}$ and kinetic energy 23 J.

(i) Show that the mass of the ball is 0.18 kg.

[2]

(ii) Calculate the height of the balcony above the ground.

height = ... m [2]

(iii) Determine the average resistive force acting on the ball as it falls from the balcony to the ground.

average resistive force = ... N [2]

(c) State and explain the variation, if any, in the magnitude of the acceleration of the ball in **(b)** during the time interval when the ball is moving downwards **before** it reaches constant (terminal) velocity.

....

....

....

....

....

.... [3]

[Total: 10]

Question 2

A person uses a trolley to move suitcases at an airport. The total mass of the trolley and suitcases is 72 kg.

(a) The person pushes the trolley and suitcases along a horizontal surface with a constant speed of $1.4\,\mathrm{m\,s^{-1}}$ and then releases the trolley. The released trolley moves in a straight line and comes to rest. Assume that a constant total resistive force of 18 N opposes the motion of the trolley and suitcases.

(i) Calculate the power required to overcome the total resistive force on the trolley and suitcases when they move with a constant speed of $1.4\,\mathrm{m\,s^{-1}}$.

power = ... W [2]

(ii) Calculate the time taken for the trolley to come to rest after it is released.

time = ... s [3]

(b) At another place in the airport, the trolley and suitcases are on a slope, as shown in Fig. 2.1.

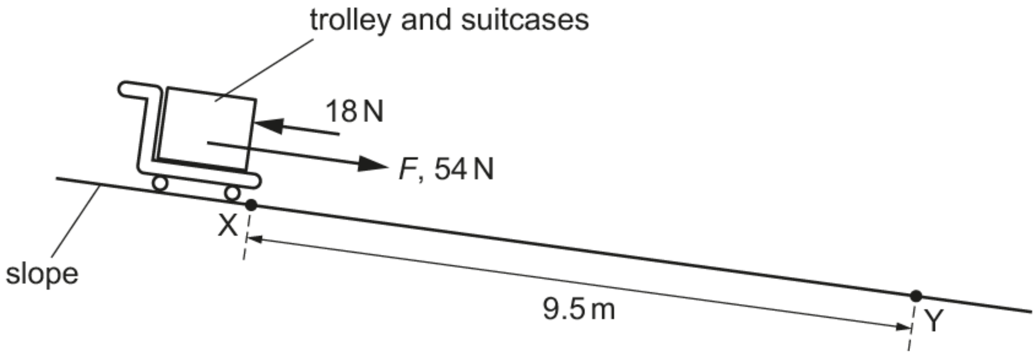

Fig. 2.1 (not to scale)

The person releases the trolley from rest at point X. The trolley moves down the slope in a straight line towards point Y. The distance along the slope between points X and Y is 9.5 m.

The component F of the weight of the trolley and suitcases that acts along the slope is 54 N. Assume that a constant total resistive force of 18 N opposes the motion of the trolley and suitcases.

(i) Calculate the speed of the trolley at point Y.

speed = ... m s^{-1} [3]

(ii) Calculate the work done by F for the movement of the trolley from X to Y.

work done = ... J [1]

(iii) The trolley is released at point X at time t = 0.

On Fig. 2.2, sketch a graph to show the variation with time t of the work done by F for the movement of the trolley from X to Y.
Numerical values of the work done and t are not required.

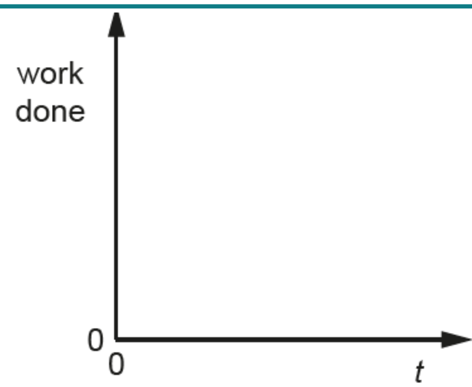

Fig. 2.2

[2]

(c) The angle of the slope in **(b)** is constant. The frictional forces acting on the wheels of the moving trolley are also constant.

Explain why, in practice, it is incorrect to assume that the total resistive force opposing the motion of the trolley and suitcases is constant as the trolley moves between X and Y.

....

.... [1]

[Total: 12]

Question 3

A pendulum consists of a solid sphere suspended by a string from a fixed point P, as shown in Fig. 3.1.

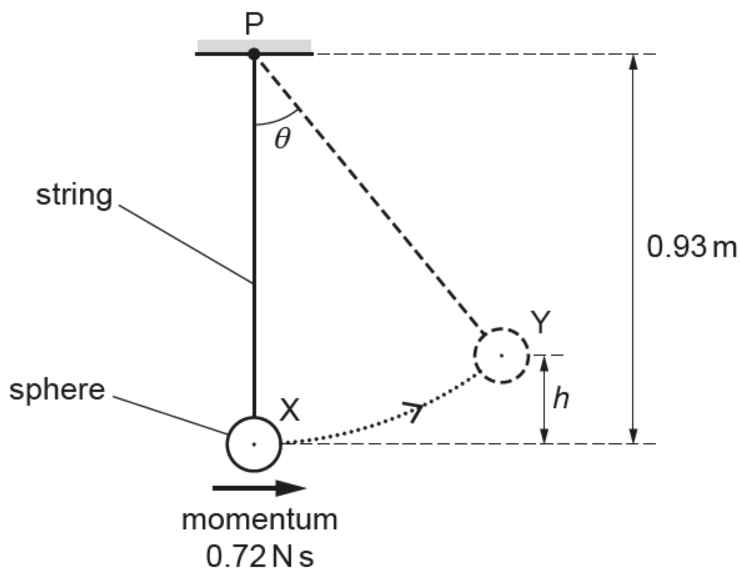

Fig. 3.1 (not to scale)

The sphere swings from side to side. At one instant the sphere is at its lowest position X, where it has kinetic energy 0.86 J and momentum 0.72 N s in a horizontal direction. A short time later the sphere is at position Y, where it is momentarily stationary at a maximum vertical height h above position X.

(b) Show that the mass of the sphere is 0.30 kg.

[3]

(c) Calculate height h.

h = ... m [2]

(d) The distance between point P and the centre of the sphere is 0.93 m. When the sphere is at position Y, the string is at an angle θ to the vertical.

Show that θ is 47°.

[1]

(e) For the sphere at position Y, calculate the moment of its weight about point P.

moment = ... N m [2]

(f) State and explain whether the sphere is in equilibrium when it is stationary at position Y.

....

.... [1]

[Total: 10]

Question 4

A child of weight 330 N is at point X at the top of a slide. The slide is at the edge of a swimming pool, as shown in Fig. 3.1.

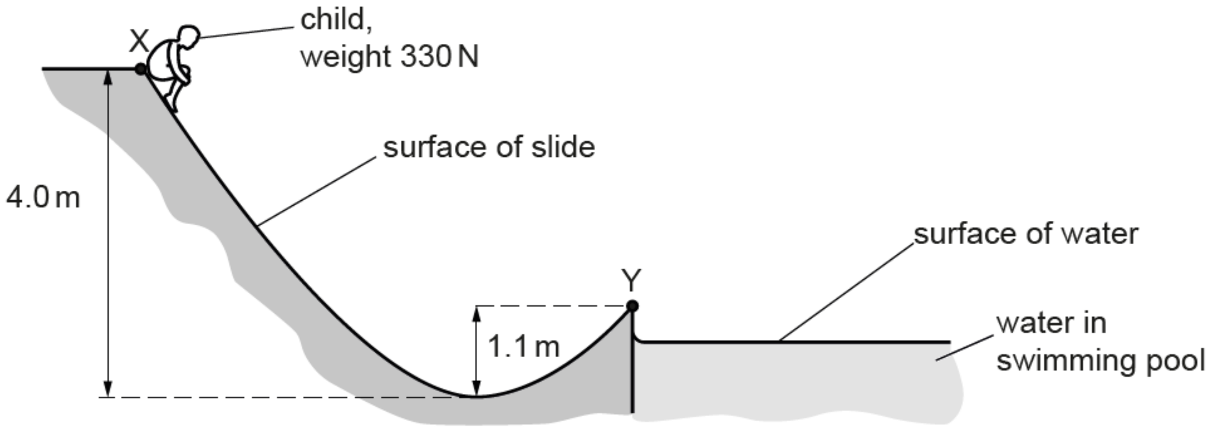

Fig. 3.1 (not to scale)

The child moves from rest to the lowest point of the slide that is a vertical distance of 4.0 m below X. The child continues moving towards point Y which is at the end of the slide and a vertical distance of 1.1 m above the lowest point. The kinetic energy of the child at Y is 540 J.

(a) Calculate the difference in the gravitational potential energy of the child at points X and Y.

difference in gravitational potential energy = ... J [2]

(b) An average frictional force of 52 N acts on the child when moving from X to Y.

By considering changes of energy, determine the distance moved by the child from X to Y.

distance moved = ... m [2]

(c) The child leaves the slide at point Y with a velocity that is at an angle of 41° to the horizontal. The path of the child through the air is shown in Fig. 3.2.

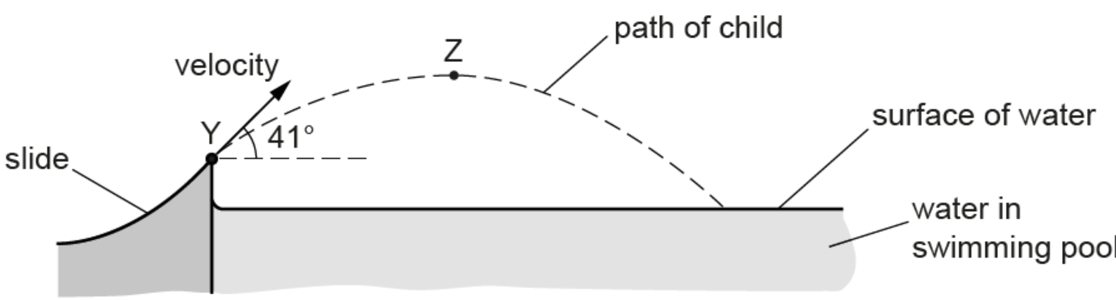

Fig. 3.2 (not to scale)

Point Z is the highest point on the path of the child through the air.
Assume that air resistance is negligible.

Calculate the speed of the child at:

(i) point Y

speed = ... $m s^{-1}$ [2]

(ii) point Z.

speed = ... $m\,s^{-1}$ [2]

[Total: 8]

Question 5

(a) Define *power*.

....

.... [1]

(b) A car of mass 1700 kg moves in a straight line along a slope that is at an angle θ to the horizontal, as shown in Fig. 3.1.

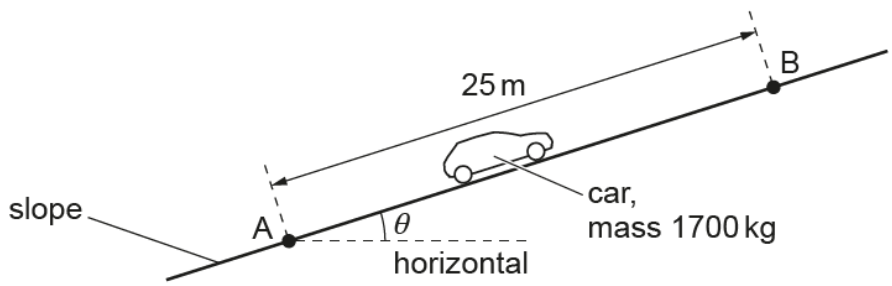

Fig. 3.1 (not to scale)

The car moves at constant velocity for a distance of 25 m from point A to point B.
Air resistance and friction provide a total resistive force of 440 N that opposes the motion of the car.

For the movement of the car from A to B:

(i) state the change in the kinetic energy

change in kinetic energy = ... J [1]

(ii) calculate the work done against the total resistive force.

work done = ... J [1]

(c) The movement of the car in **(b)** from A to B causes its gravitational potential energy to increase by 4.8×10^4 J.

Calculate:

(i) the increase in vertical height *h* of the car for its movement from A to B

h = ... m [2]

(ii) angle θ.

θ = ... ° [1]

(d) The engine of the car in **(b)** produces an output power of 1.7×10^4 W to move the car along the slope.

Calculate the time taken for the car to move from A to B.

time = ... s [2]

[Total: 8]

Question 6

(a) State what is meant by *work done*.

....

.... [1]

(b) Use your answer in **(a)** to show that the SI base units of energy are $\text{kg}\,\text{m}^2\,\text{s}^{-2}$.

[1]

(c) A metal rod is heated at one end so that thermal energy flows to the other end. The thermal energy E that flows through the rod in time t is given by

$$E = \frac{cA(T_1 - T_2)t}{L}$$

where A is the cross-sectional area of the rod,
T_1 and T_2 are the temperatures of the ends of the rod,
L is the length of the rod,
and c is a constant.

Determine the SI base units of c.

SI base units .... [3]

[Total: 5]

Question 7

A child moves down a long slide, as shown in Fig. 4.1.

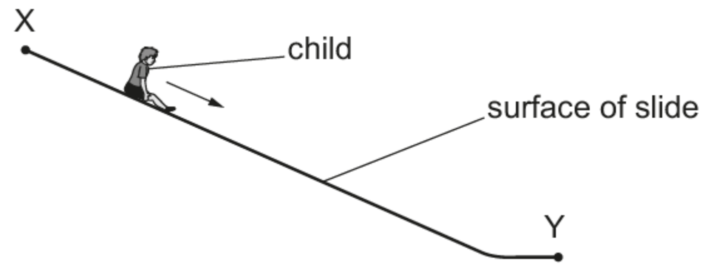

Fig. 4.1 (not to scale)

The child moves from rest at the top end X of the slide. An average resistive force of 76 N opposes the motion of the child as they move to the lower end Y of the slide. The kinetic energy of the child at Y is 300 J. The decrease in gravitational potential energy of the child as it moves from X to Y is 3200 J.

(a) Determine the ratio

$$\frac{\text{kinetic energy of the child at Y when the resistive force is 76 N}}{\text{kinetic energy of the child at Y if there is no resistive force}}.$$

ratio = ... [1]

(b) Use the answer in **(a)** to calculate the ratio

$$\frac{\text{speed of the child at Y when the resistive force is 76 N}}{\text{speed of the child at Y if there is no resistive force}}.$$

ratio = ... [2]

(c) Calculate the length of the slide from X to Y.

length = ... m [2]

(d) At end Y of the slide, the child is brought to rest by a board, as shown in Fig. 4.2.

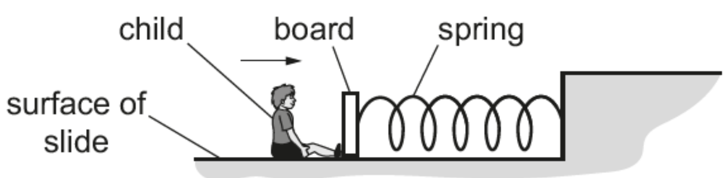

Fig. 4.2 (not to scale)

A spring connects the board to a fixed point. The spring obeys Hooke's law and has a spring constant of 63 N m^{-1}. The child hits the board so that it moves to the right and compresses the spring. The speed of the child becomes zero when the elastic potential energy of the spring has increased to its maximum value of 140 J.

(i) Calculate the maximum compression of the spring.

maximum compression = ... m [2]

(ii) Calculate the percentage efficiency of the transfer of the kinetic energy of the child to the elastic potential energy of the spring.

percentage efficiency = ... % [1]

(iii) The maximum compression of the spring is x_0. On Fig. 4.3, sketch a graph to show the variation of the elastic potential energy of the spring with its compression x from $x = 0$ to $x = x_0$. Numerical values are not required.

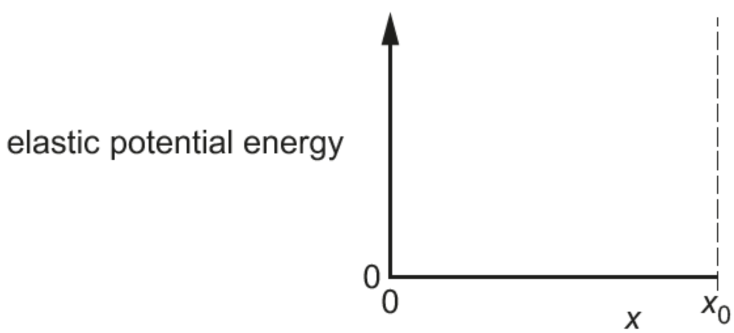

Fig. 4.3

[2]

[Total: 10]

Question 8

(a) (i) Define power.

....

.... [1]

(ii) A force F takes time t to move an object through a displacement x at constant velocity v in the direction of the force. The work done by the force is W.

Use the definition of power to show that the power P transferred by the force is given by

$$P = Fv.$$

[2]

(b) A block is pulled up a slope by a wire attached to a motor, as shown in Fig. 3.1.

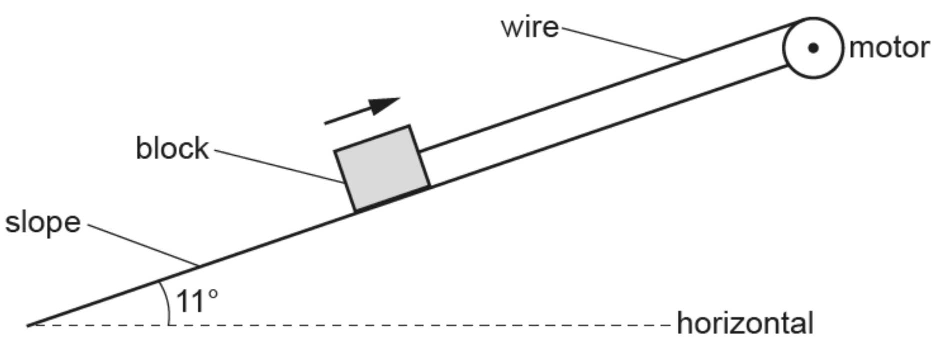

Fig. 3.1 (not to scale)

The useful power output of the motor is 56 W. The block has a weight of 430 N and travels with constant velocity along the slope at an angle of 11° to the horizontal.

Assume that there are no resistive forces opposing the motion of the block.

(i) Calculate the tension T in the wire.

T = ... N [2]

(ii) Calculate the speed of the block.

speed = ... $m\,s^{-1}$ [1]

(iii) The rate of increase of gravitational potential energy of the block is equal to the useful power output of the motor. One of the reasons for this is that there is no work done against resistive forces.

By considering the motion of the block, state another reason for this.

....

.... [1]

(iv) The motor has an efficiency of 80%.

Calculate the time taken for an input energy of 1.2 kJ to be supplied to the motor.

time taken = ... s [2]

[Total: 9]

Question 9

(a) A mass m moves a vertical distance Δh in a uniform gravitational field and gains gravitational potential energy ΔE_P. The acceleration of free fall is g.

Use the concept of work done to show that

$$\Delta E_P = mg\Delta h.$$

[2]

(b) A 0.60 kg mass is attached to a string which is wrapped around the wheel of a generator, as shown in Fig. 4.1.

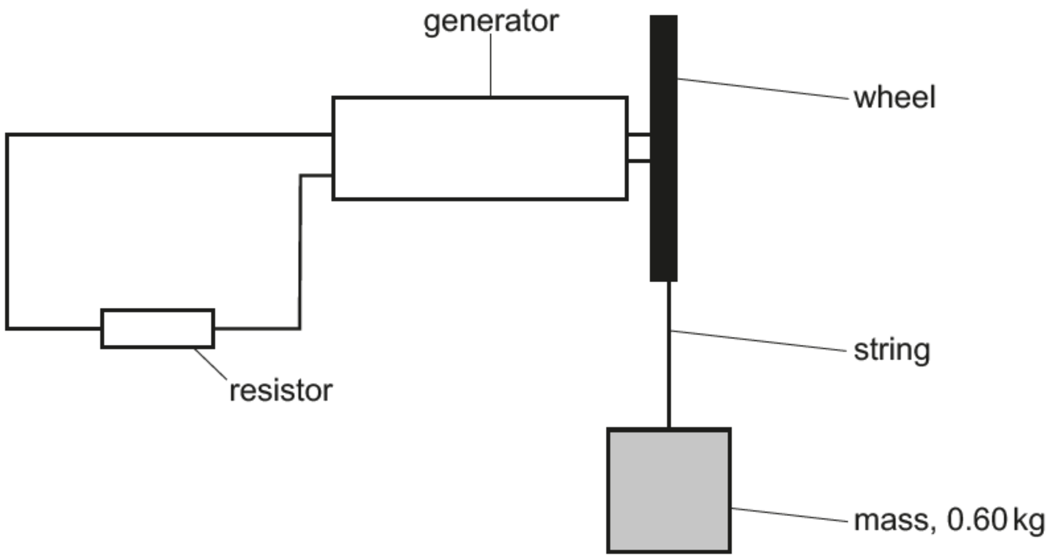

Fig. 4.1

The mass is held stationary above the floor. When released, the mass initially accelerates and then falls at a steady speed and spins the wheel. The generator causes a current in a resistor. Air resistance is negligible.

State the main energy change when the mass is falling at a steady speed.

.... energy to .... energy. [1]

(c) When falling at a steady speed, the mass in **(b)** falls through a vertical distance of 1.4 m in a time of 4.0 s. This causes a current of 90 mA in the resistor. The resistance of the resistor is 47 Ω.

Calculate:

(i) the rate of work done by the falling mass

rate of work done = ... W [2]

(ii) the power dissipated in the resistor

power = ... W [2]

(iii) the efficiency of the generator.

efficiency = ... [2]

[Total: 9]

Question 10

(a) **(i)** Define power.

....

.... [1]

(ii) Mechanical power P can be calculated using the formula $P = Fv$.

Use the concept of work and the definition of power to show how this formula is derived.

[2]

(b) The engine of a lorry provides 130 kW of power to the lorry's wheels when it is travelling at a constant speed of $25\,\mathrm{m\,s^{-1}}$ along a straight horizontal road.

Show that the resistive force opposing the forward motion of the lorry is 5200 N.

[1]

(c) The lorry in **(b)** travels up a straight section of road that is inclined at an angle θ to the horizontal, as shown in Fig. 3.1.

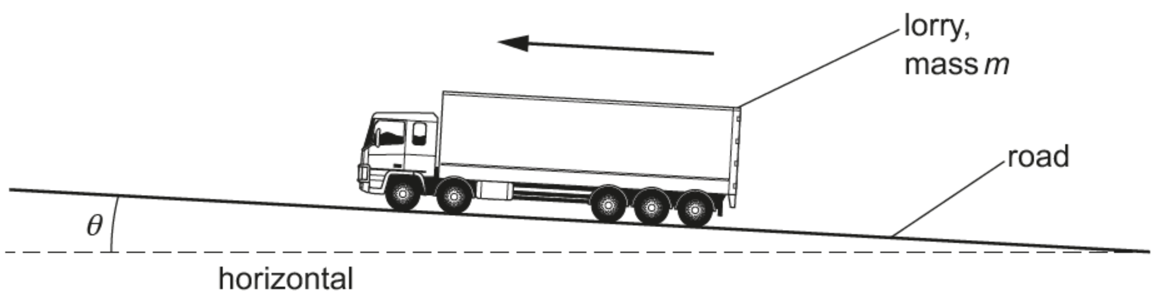

Fig. 3.1 (not to scale)

The lorry has mass m and the acceleration of free fall is g.

(i) Determine an expression, in terms of m, g and θ, for the component of the weight of the lorry that acts parallel to the surface of the road.

[1]

(ii) The total resistive force remains unchanged at 5200 N and the engine now provides greater power to maintain the speed of 25 m s^{-1}. The total mass m of the lorry is 36 000 kg. The angle θ is 1.4°.

Determine the power, in kW, now provided by the engine.

power = ... kW [3]

[Total: 8]

Question 11

(c) The string is cut so that the spring extends upwards. This causes the beam to rotate and launch the block into the air. The block reaches its maximum height and then falls back to the ground.

Fig. 2.2 shows part of the path of the block in the air shortly before it hits the horizontal ground.

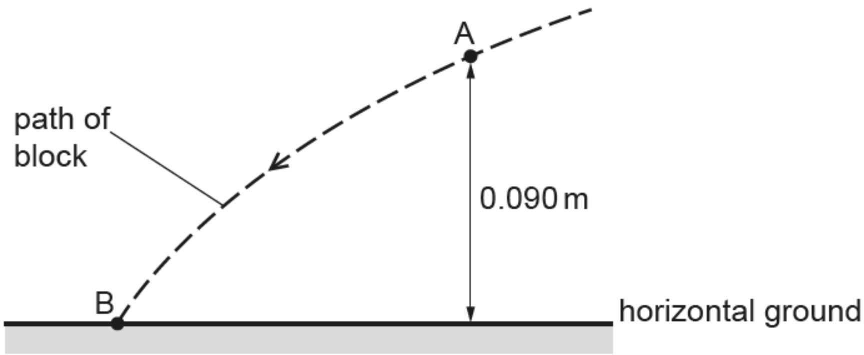

Fig. 2.2 (not to scale)

The block is at a height of 0.090 m above the ground when it passes through point A. The block has a kinetic energy of 0.044 J when it hits the ground at point B.
Air resistance is negligible.

(i) Calculate the decrease in the gravitational potential energy of the block for its movement from A to B.

decrease in gravitational potential energy = ... J [2]

(ii) Use your answer in **(c)(i)** and conservation of energy to determine the speed of the block at point A.

speed = ... $m s^{-1}$ [3]

(iii) By reference to the force on the block, explain why the horizontal component of the velocity of the block remains constant as it moves from A to B.

....

.... [1]

(iv) The block passes through point A at time t_A and arrives at point B at time t_B.

On Fig. 2.3, sketch a graph to show the variation of the magnitude of the vertical component v_Y of the velocity of the block with time t from $t = t_A$ to $t = t_B$.
Numerical values of v_Y are not required.

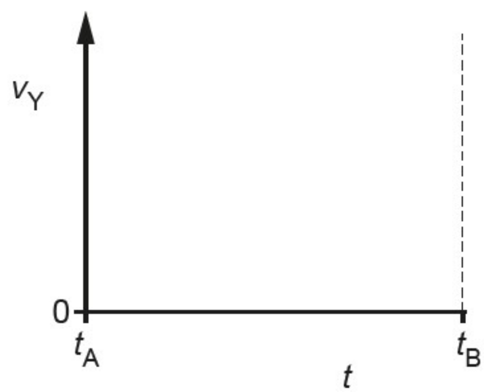

Fig. 2.3

[1]

Question 12

A beaker in air contains a liquid. The base of the beaker is in contact with the liquid and has area A, as shown in Fig. 4.1.

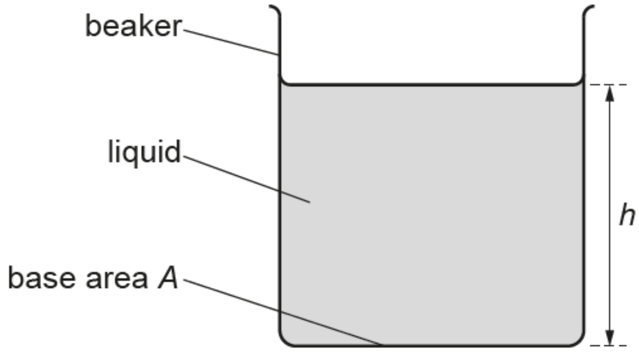

Fig. 4.1

The liquid has density ρ and fills the beaker to a depth h.

(a) By using the definitions of pressure and density, show that

$$p = \rho g h$$

where p is the pressure due to the liquid that is exerted on the base of the beaker and g is the acceleration of free fall.

[3]

(b) Suggest why the equation in **(a)** does not give the total pressure on the base of the beaker.

....

.... [1]

(c) Fig. 4.2 shows the variation of the total pressure inside the liquid with depth *x* below the surface.

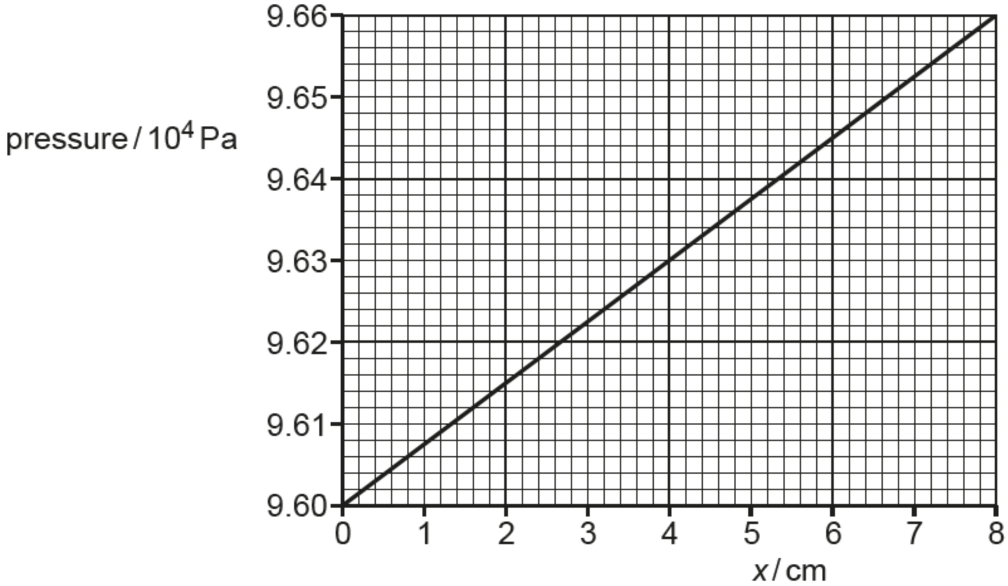

Fig. 4.2

Determine the density of the liquid.

density = ... kg m^{-3} [2]

Question 13

(c) The beam in **(b)** rotates when the string is cut and the small block of weight 2.4 N is projected through the air. Fig. 2.2 shows the last part of the path of the block before it hits the ground at point Y.

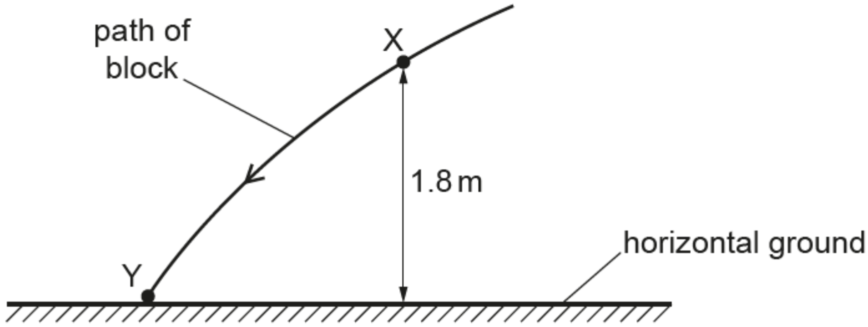

Fig. 2.2 (not to scale)

At point X on the path, the block has a speed of $3.4\,\text{m}\,\text{s}^{-1}$ and is at a height of 1.8 m above the horizontal ground. Air resistance is negligible.

(i) Calculate the decrease in the gravitational potential energy of the block for its movement from X to Y.

decrease in gravitational potential energy = ... J [2]

(ii) Use your answer to **(c)(i)** and conservation of energy to determine the kinetic energy of the block at Y.

kinetic energy = ... J [3]

(iii) State the variation, if any, in the direction of the acceleration of the block as it moves from X to Y.

.... [1]

(iv) The block passes point X at time t_X and arrives at point Y at time t_Y.

On Fig. 2.3, sketch a graph to show the variation of the magnitude of the horizontal component of the velocity of the block with time from t_X to t_Y.
Numerical values are not required.

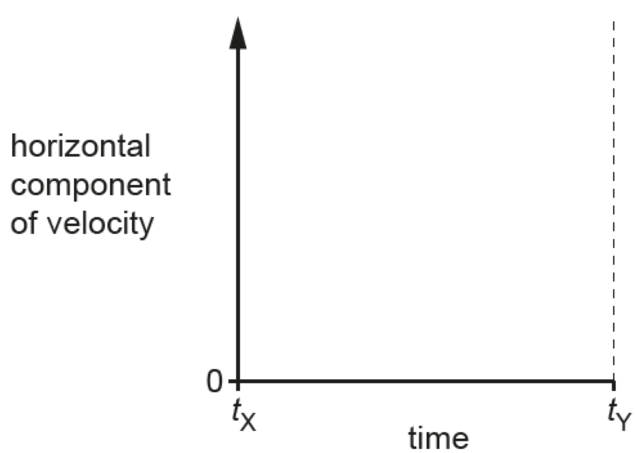

Fig. 2.3

[1]

Question 14

(a) State what is meant by the work done by a force.

....

.... [1]

(b) A block of mass *m* is raised vertically at constant speed. The vertical height gained by the block is Δh, as shown in Fig. 3.1.

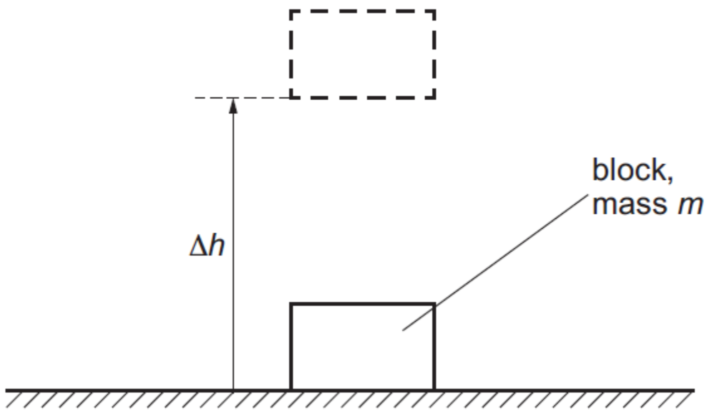

Fig. 3.1

Derive an expression, in terms of *m* and Δh, for the change in gravitational potential energy ΔE_P of the block. State the meaning of any other symbols you use.

[2]

(c) An electric motor has an input power of 900 W. The motor takes 1.0 minute to lift a load of weight 240 N at constant speed through a vertical height of 150 m. Resistive forces are negligible.

(i) Show that the work done by the motor on the load in 1.0 minute is 36 kJ.

[1]

(ii) Determine the useful output power of the motor.

power = ... W [2]

(iii) Use your answer in **(c)(ii)** to determine the efficiency of the motor.

efficiency = ... [2]

(iv) Some of the power wasted in the motor is dissipated by the resistance of its coil. This dissipated power is 280 W.

The coil of the motor is made from wire of total length 23 m. The wire has a cross-sectional area of $2.6 \times 10^{-8}\,m^2$ and is made from metal of resistivity $1.7 \times 10^{-8}\,\Omega\,m$.

Calculate the current in the coil.

current = ...A [3]

[Total: 11]

Question 15

(a) Define power.

....

.... [1]

(b) An electric car is powered by a motor. The car is travelling at a constant speed of $35\,m\,s^{-1}$ along a straight horizontal road, as shown in Fig. 3.1.

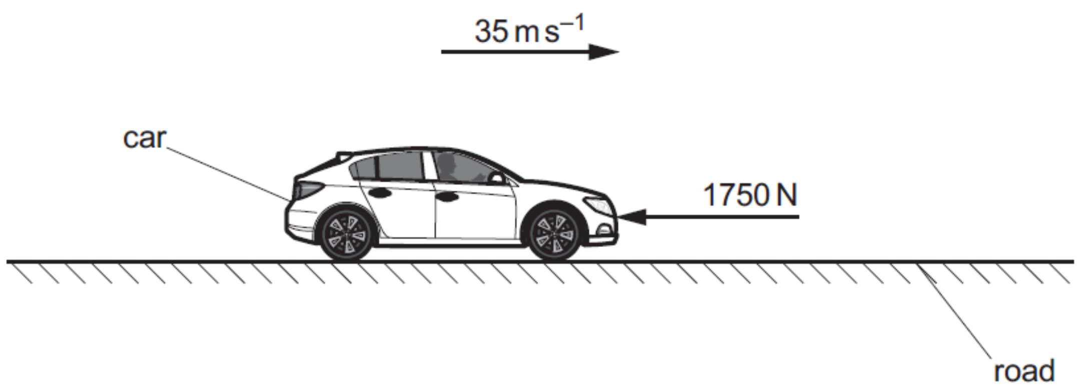

Fig. 3.1

There is a total resistive force of 1750 N acting on the car.

(i) Calculate the power transmitted to the wheels of the car by the motor.

power = ... W [2]

(ii) Calculate the useful work done by the motor when the car travels a distance of 17 km.

work done = ... J [2]

(iii) The potential difference (p.d.) across the motor has a constant value of 600 V and the motor has an efficiency of 85%.

Calculate the current in the motor.

current = ... A [3]

(c) The car in **(b)** now reaches a slope, as shown in Fig. 3.2.

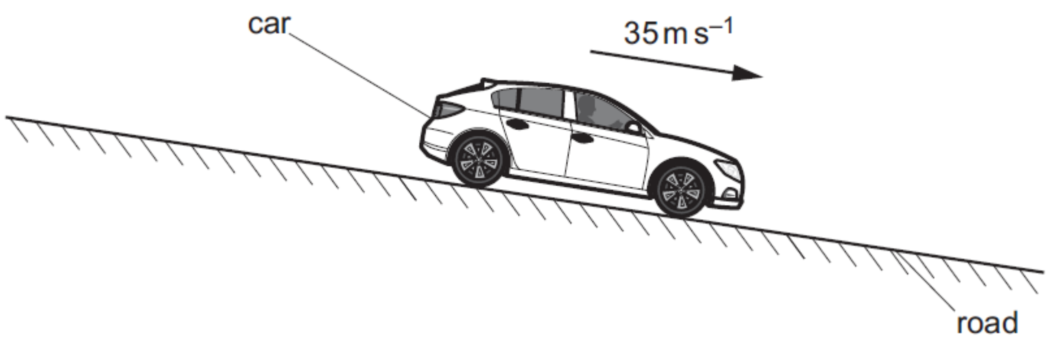

Fig. 3.2

The car continues down the slope at the same speed as in **(b)**.

State and explain the effect, if any, of the slope on:

(i) the air resistance acting on the car

....

.... [1]

(ii) the current in the motor.

....

.... [1]

[Total: 10]

Question 16

(b) A constant resultant force F acts on a car of mass m. The car moves from rest with constant acceleration a along horizontal ground. When the car has displacement s, the speed of the car is v.

(i) Using the concept of work done on the car, show that the kinetic energy E_K of the car is given by the equation

$$E_K = \frac{1}{2}mv^2.$$

[3]

(ii) The mass of the car is 920 kg. At time $t = 0$, the car is at rest. At time $t = 5.8$ s, its velocity is 17 m s^{-1}.

Calculate the kinetic energy of the car at time $t = 5.8$ s.

kinetic energy = ... J [1]

(iii) Between time t = 0 and time t = 5.8 s, the work done against resistive forces is 4.7×10^4 J.

Determine the average output power of the car during this time.

power = ... W [3]

(iv) At time t = 5.8 s, the speed of the car becomes constant.

State and explain whether the output power of the car is greater than, less than or the same as the output power just before t = 5.8 s.

....

.... [1]

Question 17

A car of mass 1500 kg is travelling along a straight horizontal road at constant velocity v. The car is subject to a total resistive force F, as shown in Fig. 3.1.

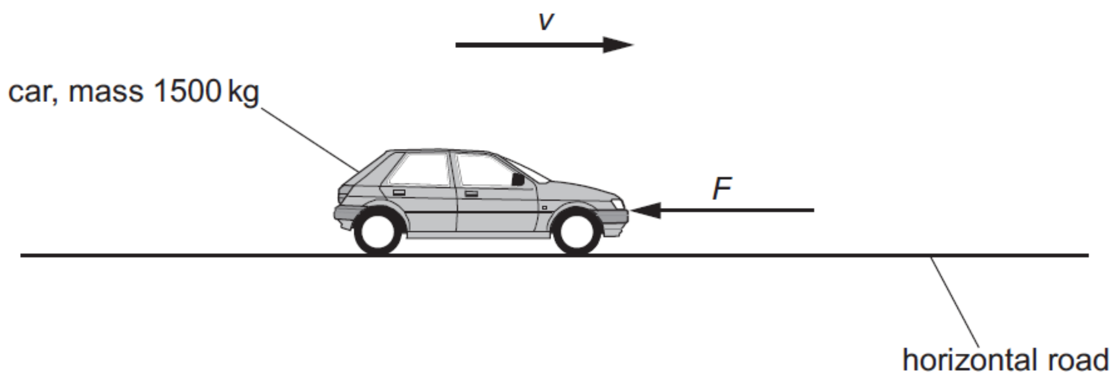

Fig. 3.1

(a) Show that the power P developed by the engine in overcoming the total resistive force is given by the equation

$$P = Fv \, .$$

[2]

(b) The car now moves up a slope at a constant speed of $30\,m\,s^{-1}$.
The slope is at an angle to the horizontal of 6.0°, as shown in Fig. 3.2.

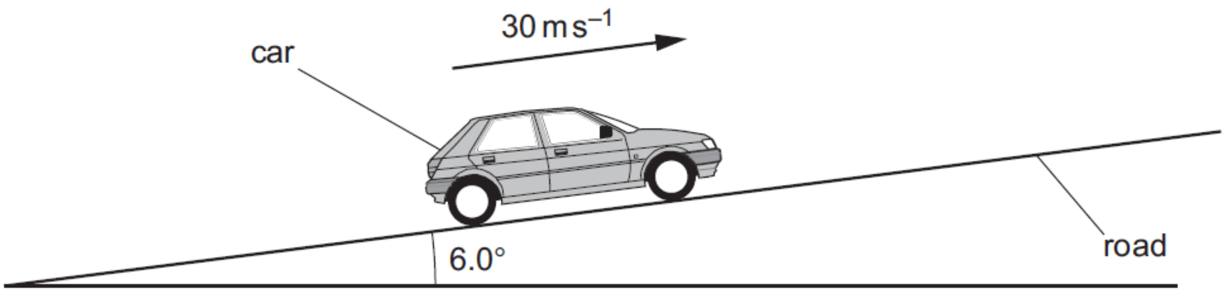

Fig. 3.2

The total resistive force acting on the car is 1600 N.

(i) Show that the increase in gravitational potential energy of the car in a time of 1.0 s is 46 000 J.

[2]

(ii) Use the information in **(b)(i)** to determine the power developed by the engine to move the car up the slope.

power = ... W [2]

(c) The car picks up a passenger and then continues up the slope at the same speed as in **(b)**.

State and explain the effect, if any, that the passenger has on:

(i) the air resistance acting on the car

....

.... [1]

(ii) the power developed by the engine.

....

.... [1]

[Total: 8]

Question 18

(a) State the principle of conservation of momentum.

....

....

.... [2]

(b) An object A of mass 4.0 kg travels at a velocity of $6.0\,m\,s^{-1}$ to the right on a horizontal frictionless surface. It moves towards a second object B of mass 2.0 kg that is moving at a velocity of $3.0\,m\,s^{-1}$ in the same direction as A, as shown in Fig. 4.1.

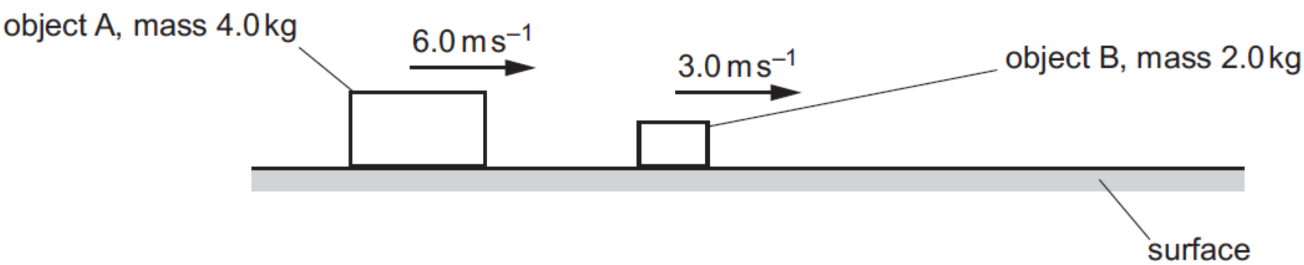

Fig. 4.1

Object A collides with object B. The two objects join and move off together with velocity *v*.

Calculate:

(i) velocity *v*

v = ... $m\,s^{-1}$ [2]

(ii) the percentage of the total initial kinetic energy of the two objects that is transferred to other forms of energy during the collision.

percentage = ... % [2]

[Total: 6]

Question 19

The lower end of a vertical spring is fixed to a horizontal surface, as shown in Fig. 3.1.

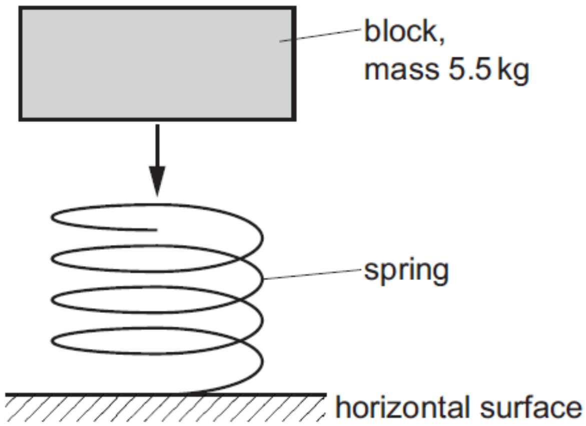

Fig. 3.1

The mass of the spring is negligible. A block of mass 5.5 kg drops vertically onto the spring and is brought to rest as the spring is compressed.

(a) The block has kinetic energy 110 J as it makes contact with the spring.

(a) The block has kinetic energy 110 J as it makes contact with the spring.

Calculate the speed of the block as it makes contact with the spring.

speed = ... ms^{-1} [2]

(b) The gravitational potential energy of the block decreases by 20 J as the spring is compressed to its maximum compression x_0.

Show that x_0 is 0.37 m.

[2]

(c) Assume that, as the spring compresses, all of the energy lost by the block is converted into the elastic potential energy of the spring.

Use the data from **(a)** and **(b)** to determine the maximum elastic potential energy of the spring.

Show your working.

maximum elastic potential energy = ... J [1]

(d) The variation of the force F acting on the spring with the compression x of the spring is shown in Fig. 3.2.

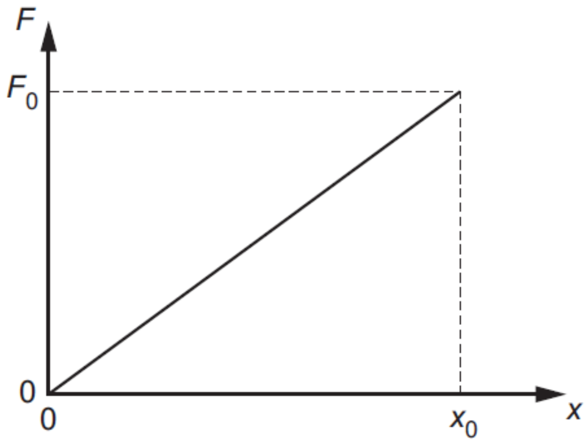

Fig. 3.2

Use the information in **(b)** and your answer in **(c)** to show that the maximum force F_0 exerted on the spring by the block is 700 N.

[2]

(e) Use the information in **(d)** to determine, for the instant that the block is first brought to rest by the spring, the magnitude of:

(i) the resultant force acting on the block

resultant force = ... N [2]

(ii) the acceleration of the block.

acceleration = ... $m\,s^{-2}$ [2]

[Total: 11]

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