

Q1.

2 (a) (i) Define displacement.

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.....

(ii) Use your definition to explain how it is possible for a car to travel a certain distance and yet have zero displacement.

.....  
.....

[3]

(b) A car starts from rest and travels upwards along a straight road inclined at an angle of  $5.0^\circ$  to the horizontal, as illustrated in Fig. 2.1.

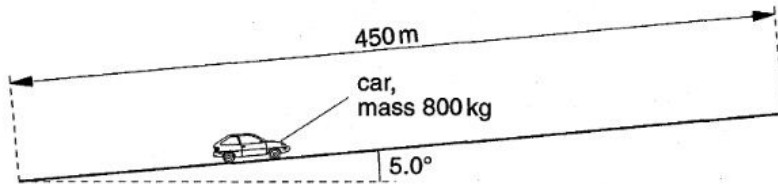


Fig. 2.1

The length of the road is 450 m and the car has mass 800 kg. The speed of the car increases at a constant rate and is  $28 \text{ m s}^{-1}$  at the top of the slope.

(i) Determine, for this car travelling up the slope,

1. its acceleration,

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

2. the time taken to travel the length of the slope,

time taken = ..... s [2]

3. the gain in kinetic energy,

gain in kinetic energy = ..... J [2]

4. the gain in gravitational potential energy.

gain in potential energy = ..... J [3]

Us

(ii) Use your answers in (i) to determine the useful output power of the car.

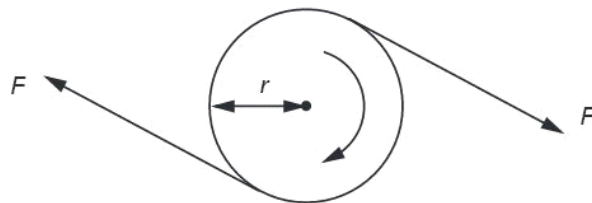
power = ..... W [3]

(iii) Suggest one reason why the actual power output of the car engine is greater than that calculated in (ii).

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..... [2]

**Q2.**

5 Two forces, each of magnitude  $F$ , form a couple acting on the edge of a disc of radius  $r$ , as shown in Fig. 5.1.



**Fig. 5.1**

(a) The disc is made to complete  $n$  revolutions about an axis through its centre, normal to the plane of the disc. Write down an expression for

(i) the distance moved by a point on the circumference of the disc,

distance = .....

(ii) the work done by one of the two forces.

work done = .....

[2]

- (b) Using your answer to (a), show that the work  $W$  done by a couple producing a torque  $T$  when it turns through  $n$  revolutions is given by

$$W = 2\pi nT. \quad [2]$$

- (c) A car engine produces a torque of 470N m at 2400 revolutions per minute. Calculate the output power of the engine.

Use

$$\text{power} = \dots\dots\dots \text{ W } [2]$$

**Q3.**

- 3 A bullet of mass 2.0 g is fired horizontally into a block of wood of mass 600 g. The block is suspended from strings so that it is free to move in a vertical plane. The bullet buries itself in the block. The block and bullet rise together through a vertical distance of 8.6 cm, as shown in Fig. 3.1.

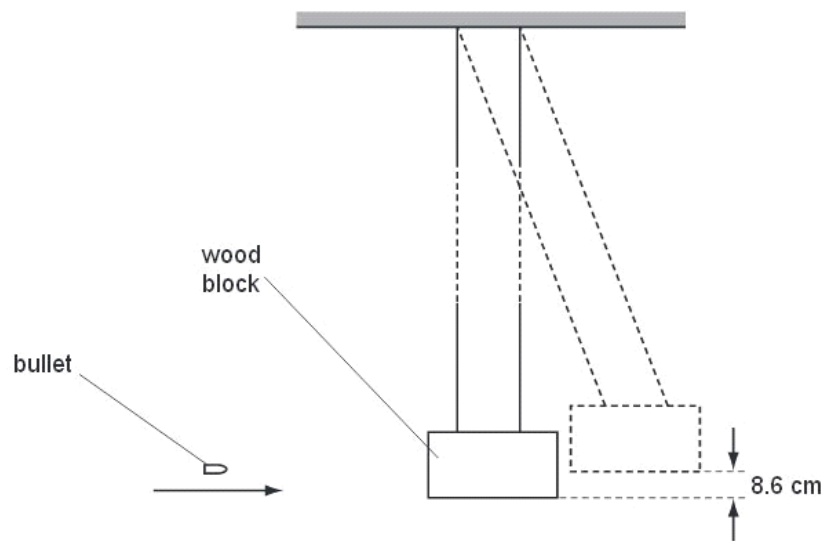


Fig. 3.1

- (a) (i) Calculate the change in gravitational potential energy of the block and bullet.

change = ..... J [2]

- (ii) Show that the initial speed of the block and the bullet, after they began to move off together, was  $1.3 \text{ m s}^{-1}$ .

[1]

- (b) Using the information in (a)(ii) and the principle of conservation of momentum, determine the speed of the bullet before the impact with the block.

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speed = ..... m s<sup>-1</sup> [2]

- (c) (i) Calculate the kinetic energy of the bullet just before impact.

kinetic energy = ..... J [2]

- (ii) State and explain what can be deduced from your answers to (c)(i) and (a)(i) about the type of collision between the bullet and the block.

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.....  
.....[2]

Q4.

- 4 (a) A stone of mass 56 g is thrown horizontally from the top of a cliff with a speed of  $18 \text{ m s}^{-1}$ , as illustrated in Fig. 4.1.

Use

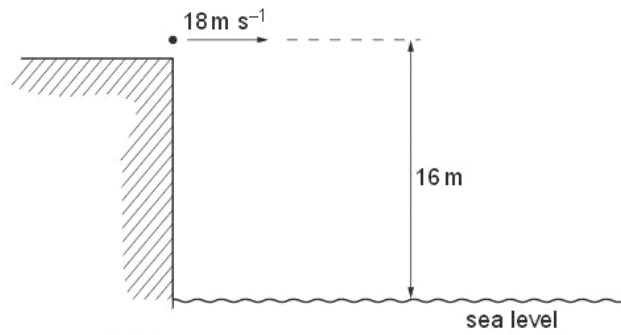


Fig. 4.1

The initial height of the stone above the level of the sea is 16 m. Air resistance may be neglected.

- (i) Calculate the change in gravitational potential energy of the stone as a result of falling through 16 m.

change = ..... J [2]

- (ii) Calculate the total kinetic energy of the stone as it reaches the sea.

kinetic energy = ..... J [3]

(b) Use your answer in (a)(ii) to show that the speed of the stone as it hits the water is approximately  $25 \text{ m s}^{-1}$ .

[1]

(c) State the horizontal velocity of the stone as it hits the water.

horizontal velocity = .....  $\text{m s}^{-1}$  [1]

(d) (i) On the grid of Fig. 4.2, draw a vector diagram to represent the horizontal velocity and the resultant velocity of the stone as it hits the water. [1]

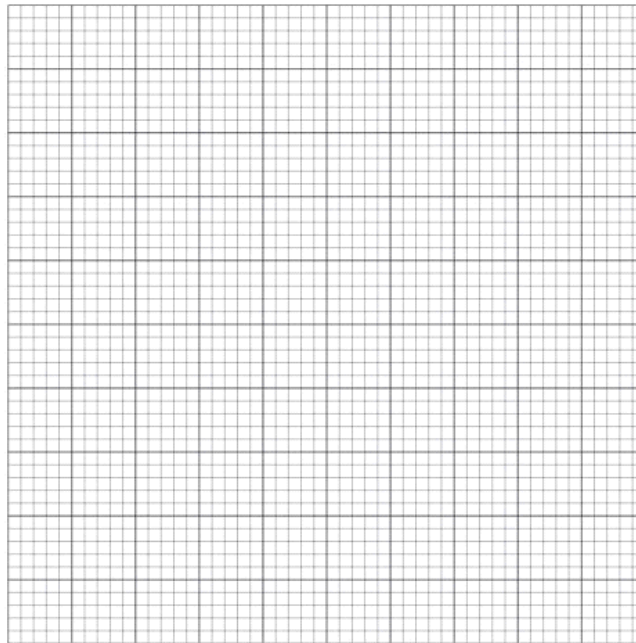


Fig. 4.2



- (ii) Use your vector diagram to determine the angle with the horizontal at which the stone hits the water.

angle = ..... ° [2]

Q5.

- 3 (a) The variation with extension  $x$  of the tension  $F$  in a spring is shown in Fig. 3.1.

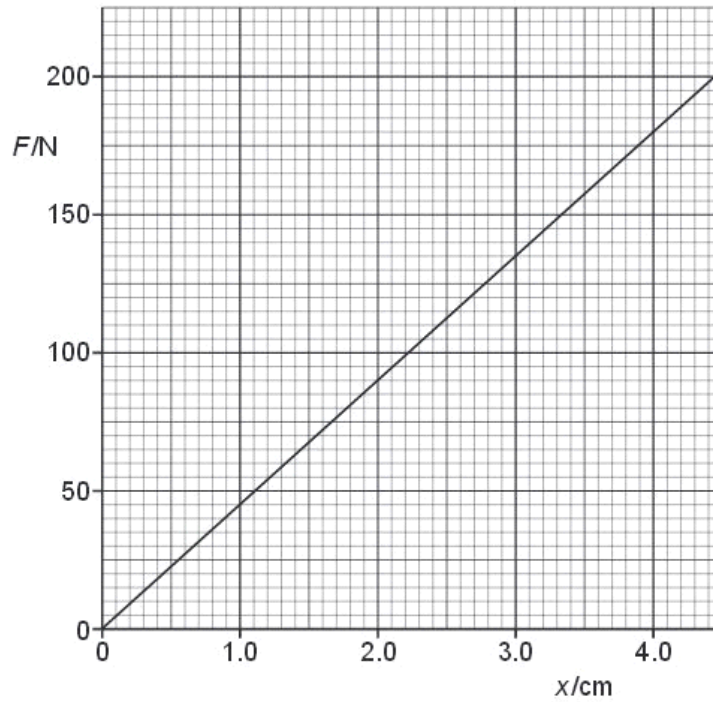


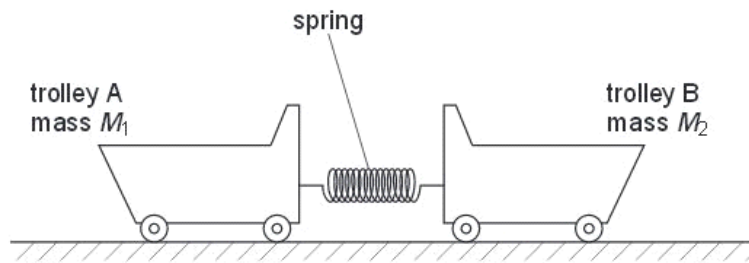
Fig. 3.1

Use Fig. 3.1 to calculate the energy stored in the spring for an extension of 4.0 cm.  
Explain your working.

energy = ..... J [3]

(b) The spring in (a) is used to join together two frictionless trolleys A and B of mass  $M_1$  and  $M_2$  respectively, as shown in Fig. 3.2.

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t



**Fig. 3.2**

The trolleys rest on a horizontal surface and are held apart so that the spring is extended.

The trolleys are then released.

- (i) Explain why, as the extension of the spring is reduced, the momentum of trolley A is equal in magnitude but opposite in direction to the momentum of trolley B.

.....  
.....  
.....  
.....[2]

- (ii) At the instant when the extension of the spring is zero, trolley A has speed  $V_1$  and trolley B has speed  $V_2$ .  
Write down

1. an equation, based on momentum, to relate  $V_1$  and  $V_2$ ,

.....  
.....[1]

2. an equation to relate the initial energy  $E$  stored in the spring to the final energies of the trolleys.

.....  
.....[1]

- (iii) 1. Show that the kinetic energy  $E_K$  of an object of mass  $m$  is related to its momentum  $p$  by the expression

$$E_K = \frac{p^2}{2m}.$$

[1]

2. Trolley A has a larger mass than trolley B.  
Use your answer in (ii) part 1 to deduce which trolley, A or B, has the larger kinetic energy at the instant when the extension of the spring is zero.

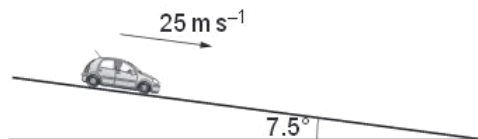
.....  
.....[1]

**Q6.**

- 2 (a) Explain what is meant by *work done*.

.....  
..... [1]

- (b) A car is travelling along a road that has a uniform downhill gradient, as shown in Fig. 2.1.



**Fig. 2.1**

The car has a total mass of 850 kg. The angle of the road to the horizontal is  $7.5^\circ$ .

Calculate the component of the weight of the car down the slope.

component of weight = ..... N [2]

(c) The car in (b) is travelling at a constant speed of  $25 \text{ m s}^{-1}$ . The driver then applies the brakes to stop the car. The constant force resisting the motion of the car is 4600 N.

(i) Show that the deceleration of the car with the brakes applied is  $4.1 \text{ m s}^{-2}$ .

[2]

(ii) Calculate the distance the car travels from when the brakes are applied until the car comes to rest.

distance = ..... m [2]

**(iii)** Calculate

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1. the loss of kinetic energy of the car,

loss of kinetic energy = ..... J [2]

2. the work done by the resisting force of 4600 N.

work done = ..... J [1]

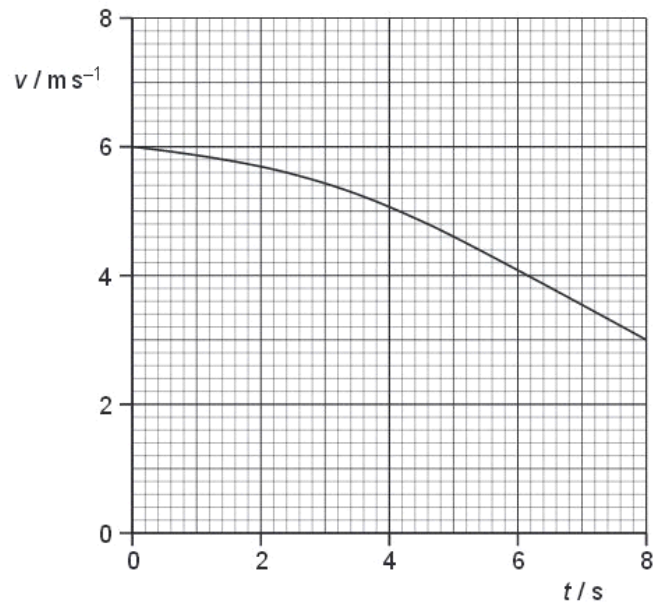
**(iv)** The quantities in **(iii) part 1** and in **(iii) part 2** are not equal. Explain why these two quantities are not equal.

.....  
..... [1]

**Q7.**

- 3 A cyclist is moving up a slope that has a constant gradient. The cyclist takes 8.0 s to climb the slope.  
 The variation with time  $t$  of the speed  $v$  of the cyclist is shown in Fig. 3.1.

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**Fig. 3.1**

- (a) Use Fig. 3.1 to determine the total distance moved up the slope.

distance = ..... m [3]

**(b)** The bicycle and cyclist have a combined mass of 92 kg.  
The vertical height through which the cyclist moves is 1.3 m.

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**(i)** For the movement of the bicycle and cyclist between  $t = 0$  and  $t = 8.0$  s,

1. use Fig. 3.1 to calculate the change in kinetic energy,

change = ..... J [2]

2. calculate the change in gravitational potential energy.

change = ..... J [2]

**(ii)** The cyclist pedals continuously so that the useful power delivered to the bicycle is 75W.

Calculate the useful work done by the cyclist climbing up the slope.

work done = ..... J [2]



(c) Some energy is used in overcoming frictional forces.

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(i) Use your answers in (b) to show that the total energy converted in overcoming frictional forces is approximately 670 J.

[1]

(ii) Determine the average magnitude of the frictional forces.

average force = .....N [1]

(d) Suggest why the magnitude of the total resistive force would not be constant.

.....  
.....  
.....[2]

Q8.

3 (a) (i) Explain what is meant by *work done*.

.....  
..... [1]

(ii) Define *power*.

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..... [1]

(b) Fig. 3.1 shows part of a fairground ride with a carriage on rails.

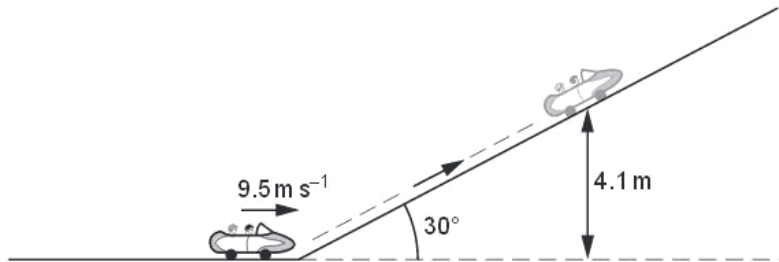


Fig. 3.1

The carriage and passengers have a total mass of 600 kg. The carriage is travelling at a speed of  $9.5 \text{ m s}^{-1}$  towards a slope inclined at  $30^\circ$  to the horizontal. The carriage comes to rest after travelling up the slope to a vertical height of 4.1 m.

(i) Calculate the kinetic energy, in kJ, of the carriage and passengers as they travel towards the slope.

kinetic energy = ..... kJ [3]

(ii) Show that the gain in potential energy of the carriage and passengers is 24 kJ.

[2]

- (iii) Calculate the work done against the resistive force as the carriage moves up the slope.

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work done = ..... kJ [1]

- (iv) Use your answer in (iii) to calculate the resistive force acting against the carriage as it moves up the slope.

resistive force = ..... N [2]

Q9.

- 2 (a) A ball is thrown vertically down towards the ground and rebounds as illustrated in Fig. 2.1.

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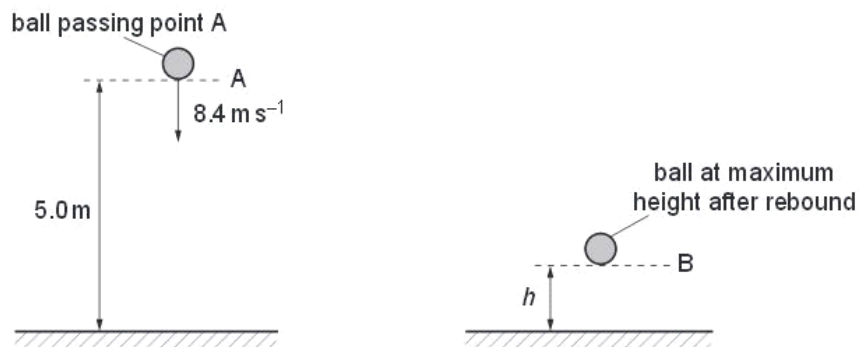


Fig. 2.1

As the ball passes A, it has a speed of  $8.4 \text{ m s}^{-1}$ . The height of A is  $5.0 \text{ m}$  above the ground. The ball hits the ground and rebounds to B. Assume that air resistance is negligible.

(i) Calculate the speed of the ball as it hits the ground.

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

(ii) Show that the time taken for the ball to reach the ground is 0.47 s.

[1]

(b) The ball rebounds vertically with a speed of  $4.2 \text{ m s}^{-1}$  as it leaves the ground. The time the ball is in contact with the ground is 20 ms. The ball rebounds to a maximum height  $h$ .

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The ball passes A at time  $t = 0$ . On Fig. 2.2, plot a graph to show the variation with time  $t$  of the velocity  $v$  of the ball. Continue the graph until the ball has rebounded from the ground and reaches B.



Fig. 2.2

[3]

(c) The ball has a mass of 0.050 kg. It moves from A and reaches B after rebounding.

(i) For this motion, calculate the change in

1. kinetic energy,

change in kinetic energy = ..... J [2]

2. gravitational potential energy.

change in potential energy = ..... J [3]

(ii) State and explain the total change in energy of the ball for this motion.

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.....  
.....  
..... [2]

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Q10.

3 (a) An object falls vertically from rest through air. State and explain the energy conversions that occur as the object falls.

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..... [3]

(b) A ball of mass 150 g is thrown vertically upwards with an initial speed of 25 m s<sup>-1</sup>.

(i) Calculate the initial kinetic energy of the ball.

kinetic energy = ..... J [3]

(b) A ball of mass 150 g is thrown vertically upwards with an initial speed of 25 m s<sup>-1</sup>.

(i) Calculate the initial kinetic energy of the ball.

kinetic energy = ..... J [3]

(ii) The ball reaches a height of 21 m above the point of release.

For the ball rising to this height, calculate

1. the loss of energy of the ball to air resistance,

energy loss = ..... J [3]

2. the average force due to the air resistance.

force = ..... N [2]

Q11.

4 (a) Explain what is meant by the concept of *work*.

.....  
.....  
.....[2]

(b) Using your answer to (a), derive an expression for the increase in gravitational potential energy  $\Delta E_p$  when an object of mass  $m$  is raised vertically through a distance  $\Delta h$  near the Earth's surface.

The acceleration of free fall near the Earth's surface is  $g$ . [2]

Q12.

8 (a) Explain the concept of *work*.

.....  
.....  
..... [2]

Ex6

- (b) A table tennis ball falls vertically through air. Fig. 8.1 shows the variation of the kinetic energy  $E_K$  of the ball with distance  $h$  fallen. The ball reaches the ground after falling through a distance  $h_0$ .

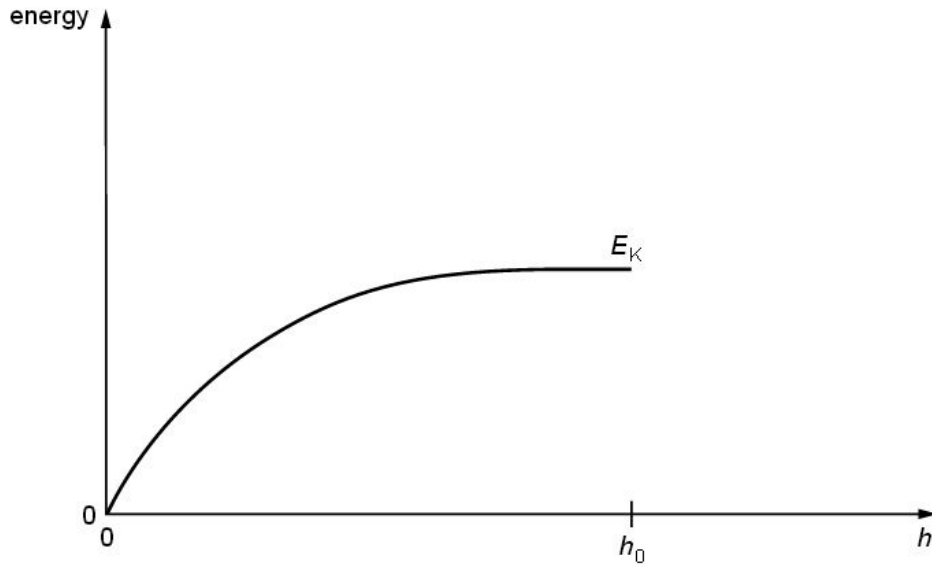


Fig. 8.1

- (i) Describe the motion of the ball.

.....

.....

.....

.....

..... [3]

- (ii) On Fig. 8.1, draw a line to show the variation with  $h$  of the gravitational potential energy  $E_P$  of the ball. At  $h = h_0$ , the potential energy is zero. [3]

Q13.



1 (a) Define what is meant by

(i) *work done*,

.....  
.....  
..... [2]

(ii) *power*.

.....  
..... [1]

(b) A force  $F$  is acting on a body that is moving with velocity  $v$  in the direction of the force.

Derive an expression relating the power  $P$  dissipated by the force to  $F$  and  $v$ .

[2]

(c) A car of mass 1900 kg accelerates from rest to a speed of  $27 \text{ m s}^{-1}$  in 8.1 s.

(i) Calculate the average rate at which kinetic energy is supplied to the car during the acceleration.

rate = ..... W [2]

- (ii) The car engine provides power at a constant rate. Suggest and explain why the acceleration of the car is **not** constant.

.....  
.....  
..... [2]

Q14.

- 3 (a) (i) Define potential energy.

.....  
..... [1]

- (ii) Distinguish between *gravitational* potential energy and *elastic* potential energy.

gravitational potential energy .....

.....

elastic potential energy .....

..... [2]

- (b) A small sphere of mass 51 g is suspended by a light inextensible string from a fixed point P.

The centre of the sphere is 61 cm vertically below point P, as shown in Fig. 3.1.

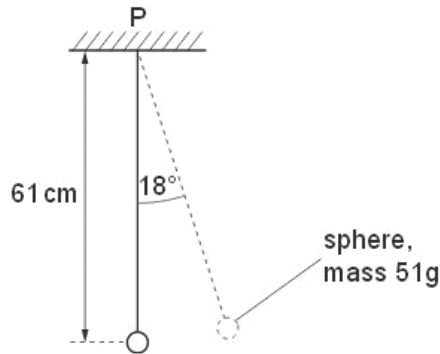


Fig. 3.1

The sphere is moved to one side, keeping the string taut, so that the string makes an angle of  $18^\circ$  with the vertical. Calculate

(i) the gain in gravitational potential energy of the sphere,

gain = ..... J [2]

(ii) the moment of the weight of the sphere about point P.

moment = ..... N m [2]

Q15.

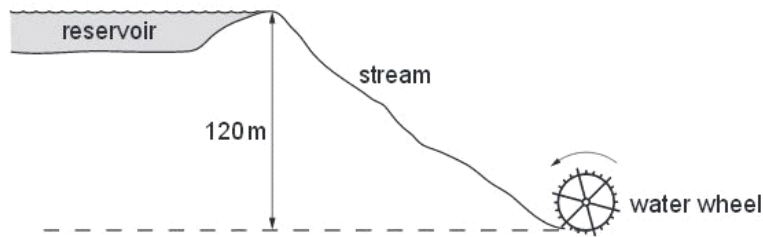
- 4 (a) Distinguish between *gravitational potential energy* and *electric potential energy*.

.....  
.....  
..... [2]

- (b) A body of mass  $m$  moves vertically through a distance  $h$  near the Earth's surface. Use the defining equation for work done to derive an expression for the gravitational potential energy change of the body.

[2]

- (c) Water flows down a stream from a reservoir and then causes a water wheel to rotate, as shown in Fig. 4.1.



**Fig. 4.1**

As the water falls through a vertical height of 120 m, gravitational potential energy is converted to different forms of energy, including kinetic energy of the water. At the water wheel, the kinetic energy of the water is only 10% of its gravitational potential energy at the reservoir.

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(i) Show that the speed of the water as it reaches the wheel is  $15 \text{ m s}^{-1}$ .

[2]

(ii) The rotating water wheel is used to produce  $110 \text{ kW}$  of electrical power. Calculate the mass of water flowing per second through the wheel, assuming that the production of electric energy from the kinetic energy of the water is 25% efficient.

mass of water per second = .....  $\text{kg s}^{-1}$  [3]

**Q16.**

3 (a) Define the terms

(i) *power*,

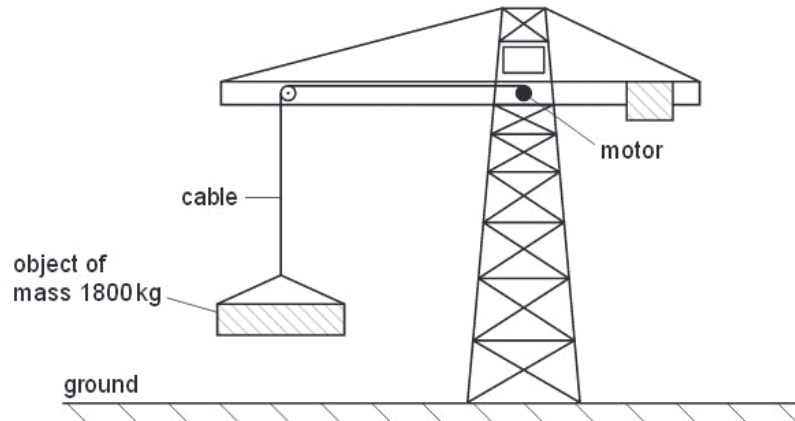
.....[1]

(ii) the *Young modulus*.

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.....  
.....[1]

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(b) A crane is used to lift heavy objects, as shown in Fig. 3.1.



**Fig. 3.1**

The motor in the crane lifts a total mass of 1800 kg from rest on the ground. The cable supporting the mass is made of steel of Young modulus  $2.4 \times 10^{11}$  Pa. The cross-sectional area of the cable is  $1.3 \times 10^{-4}$  m<sup>2</sup>. As the mass leaves the ground, the strain in the cable is 0.0010. Assume the weight of the cable to be negligible.

- (i) 1. Use the Young Modulus of the steel to show that the tension in the cable is  $3.1 \times 10^4$  N.

[2]

2. Calculate the acceleration of the mass as it is lifted from the ground.

acceleration = ..... m s<sup>-2</sup> [3]

**(ii)** The motor now lifts the mass through a height of 15 m at a constant speed.

Calculate

1. the tension in the lifting cable,

tension = ..... N [1]

2. the gain in potential energy of the mass.

gain in potential energy = ..... J [2]

**(iii)** The motor of the crane is 30% efficient. Calculate the input power to the motor required to lift the mass at a constant speed of  $0.55 \text{ m s}^{-1}$ .

input power = ..... W [3]

**Q17.**

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

.....  
 ..... [1]

- (b) A trolley of mass 400 g is moving at a constant velocity of  $2.5 \text{ m s}^{-1}$  to the right as shown in Fig. 3.1.

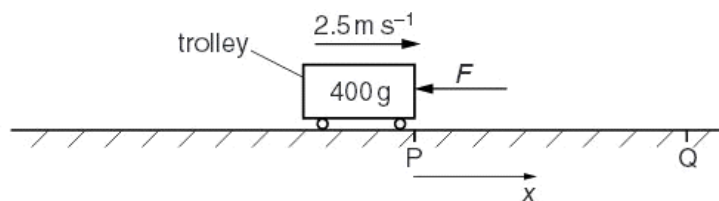


**Fig. 3.1**

Show that the kinetic energy of the trolley is 1.3 J.

[2]

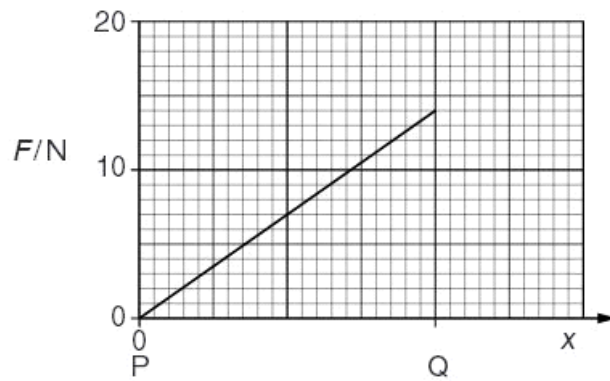
- (c) The trolley in (b) moves to point P as shown in Fig. 3.2.



**Fig. 3.2**

At point P the speed of the trolley is  $2.5 \text{ m s}^{-1}$ .  
 A variable force  $F$  acts to the left on the trolley as it moves between points P and Q.  
 The variation of  $F$  with displacement  $x$  from P is shown in Fig. 3.3.





**Fig. 3.3**

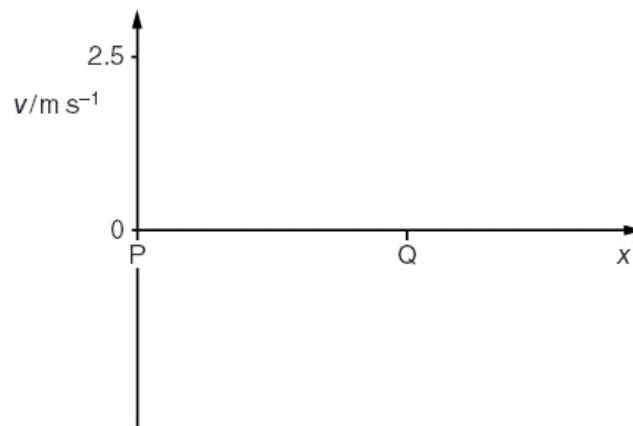
The trolley comes to rest at point Q.

(i) Calculate the distance PQ.

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distance PQ = ..... m [3]

(ii) On Fig. 3.4, sketch the variation with  $x$  of velocity  $v$  for the trolley moving between P and Q.



**Fig. 3.4**

[2]

**Q18.**

- 4 (a) Distinguish between gravitational potential energy and elastic potential energy.

Exa

.....  
.....  
.....[2]

- (b) A ball of mass 65 g is thrown vertically upwards from ground level with a speed of  $16 \text{ m s}^{-1}$ . Air resistance is negligible.

- (i) Calculate, for the ball,

1. the initial kinetic energy,

kinetic energy = ..... J [2]

2. the maximum height reached.

maximum height = ..... m [2]

- (ii) The ball takes time  $t$  to reach maximum height. For time  $\frac{t}{2}$  after the ball has been thrown, calculate the ratio

$$\frac{\text{potential energy of ball}}{\text{kinetic energy of ball}}$$

ratio = ..... [3]

**(iii)** State and explain the effect of air resistance on the time taken for the ball to reach maximum height.

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.....

..... [1]





