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1 A sphere has volume V and is made of metal of density ρ.

(a) Write down an expression for the mass m of the sphere in terms of V and ρ.

....[1]

(b) The sphere is immersed in a liquid. Explain the apparent loss in the weight of the sphere.

....

....

....

....[3]

(c) The sphere in **(b)** has mass 2.0×10^{-3} kg. When the sphere is released, it eventually falls in the liquid with a constant speed of 6.0 cm s^{-1}.

(i) For this sphere travelling at constant speed, calculate

1. its kinetic energy,

kinetic energy = ... J

2. its rate of loss of gravitational potential energy.

rate = ... J s^{-1} [5]

(ii) Suggest why it is possible for the sphere to have constant kinetic energy whilst losing potential energy at a steady rate.

....

....

....[2]

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2 A steel ball of mass 73 g is held 1.6 m above a horizontal steel plate, as illustrated in Fig. 4.1.

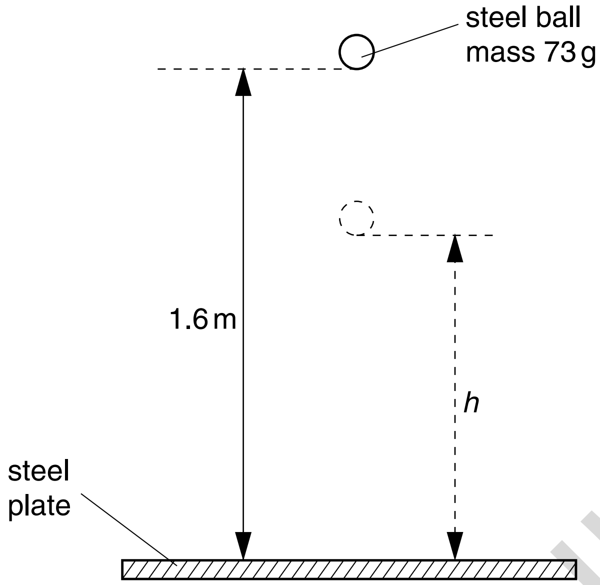

Fig. 4.1

The ball is dropped from rest and it bounces on the plate, reaching a height *h*.

(a) Calculate the speed of the ball as it reaches the plate.

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

(b) As the ball loses contact with the plate after bouncing, the kinetic energy of the ball is 90% of that just before bouncing. Calculate

(i) the height *h* to which the ball bounces,

h = ... m

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(ii) the speed of the ball as it leaves the plate after bouncing.

speed = ... $m\,s^{-1}$
[4]

(c) Using your answers to **(a)** and **(b)**, determine the change in momentum of the ball during the bounce.

change = ... N s [3]

(d) With reference to the law of conservation of momentum, comment on your answer to **(c)**.

....

....

....[3]

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3 Some gas is contained in a cylinder by means of a moveable piston, as illustrated in Fig. 5.1.

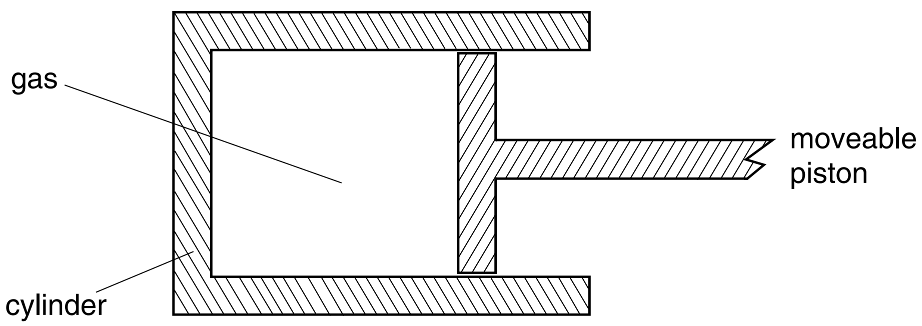

Fig. 5.1

State how, for this mass of gas, the following changes may be achieved.

(a) increase its gravitational potential energy

....[1]

(b) decrease its internal energy

....

....[1]

(c) increase its elastic potential energy

....

....[1]

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4 A ball falls from rest onto a flat horizontal surface. Fig. 3.1 shows the variation with time *t* of the velocity *v* of the ball as it approaches and rebounds from the surface.

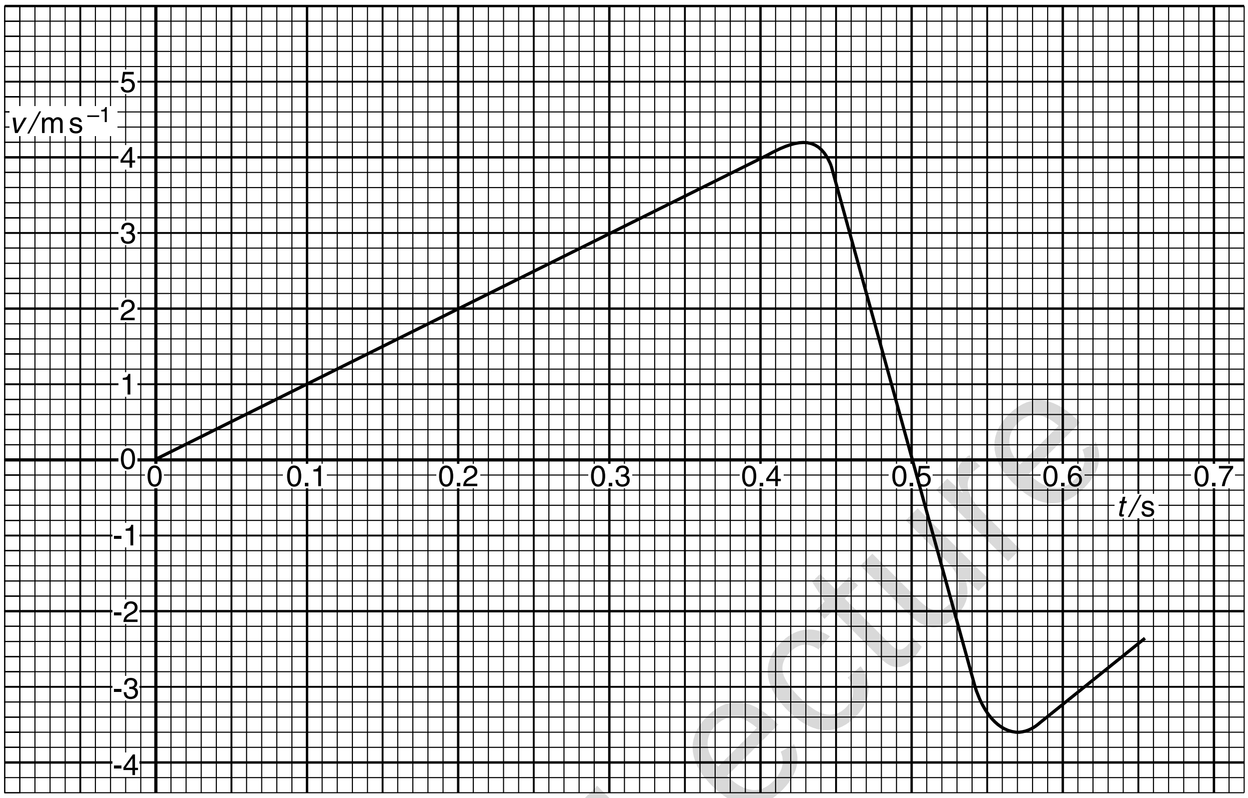

Fig. 3.1

Use data from Fig. 3.1 to determine

(a) the distance travelled by the ball during the first 0.40 s,

distance = ... m [2]

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(b) the change in momentum of the ball, of mass 45 g, during contact of the ball with the surface,

change = ... N s [4]

(c) the average force acting on the ball during contact with the surface.

force = ... N [2]

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5 A student has been asked to determine the linear acceleration of a toy car as it moves down a slope. He sets up the apparatus as shown in Fig. 3.1.

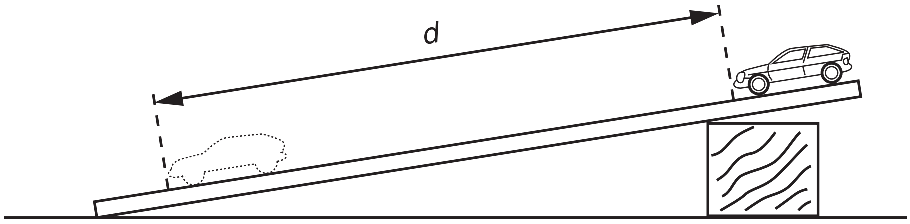

Fig. 3.1

The time *t* to move from rest through a distance *d* is found for different values of *d*. A graph of *d* (*y*-axis) is plotted against t^2 (*x*-axis) as shown in Fig. 3.2.

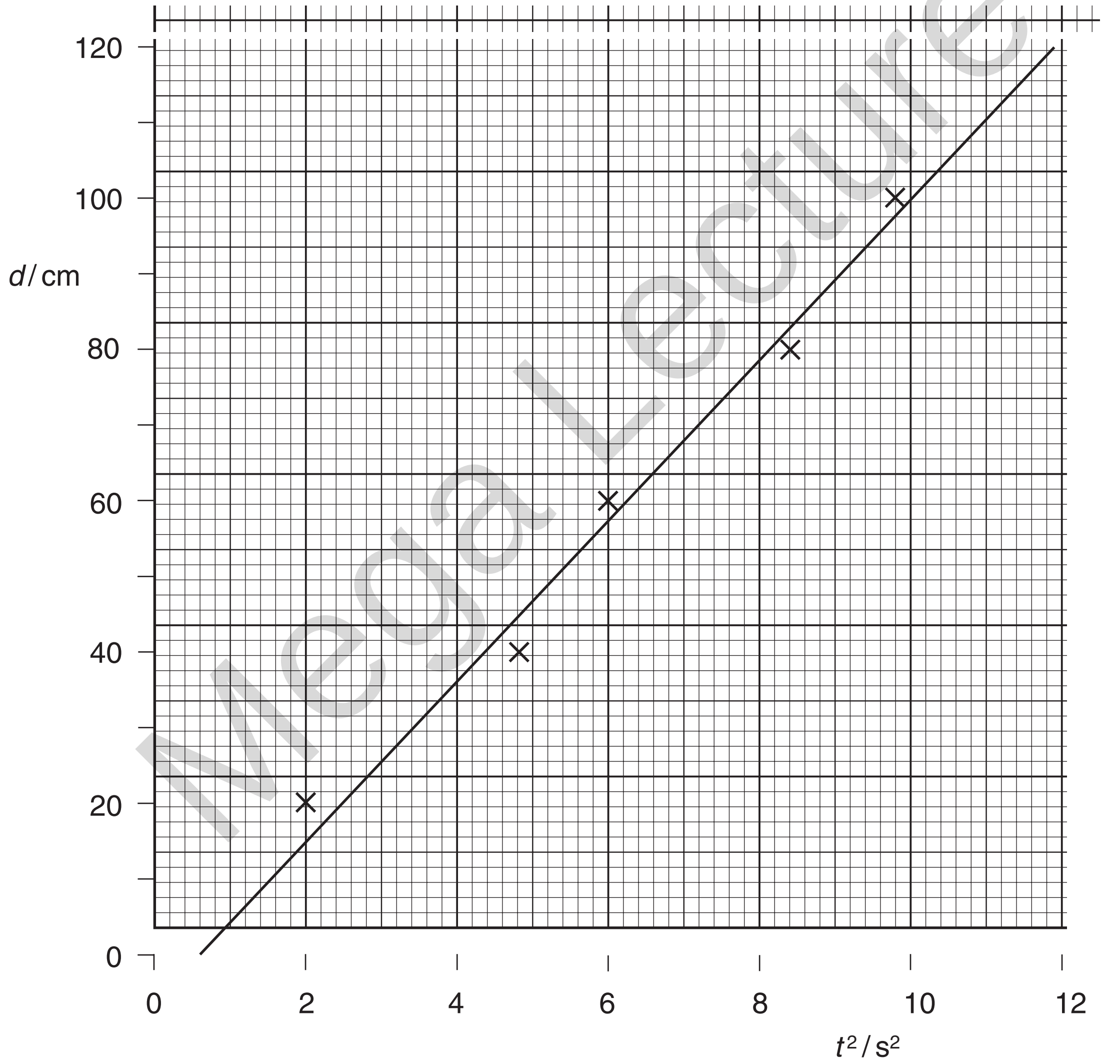

Fig. 3.2

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(a) Theory suggests that the graph is a straight line through the origin.
Name the feature on Fig. 3.2 that indicates the presence of

(i) random error,

....

(ii) systematic error.

....
[2]

(b) **(i)** Determine the gradient of the line of the graph in Fig. 3.2.

gradient = ... [2]

(ii) Use your answer to **(i)** to calculate the acceleration of the toy down the slope.
Explain your working.

acceleration = ... $m\,s^{-2}$ [3]

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6 A ball has mass m. It is dropped onto a horizontal plate as shown in Fig. 4.1.

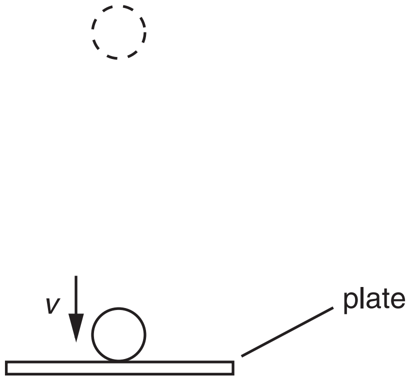

Fig. 4.1

Just as the ball makes contact with the plate, it has velocity v, momentum p and kinetic energy E_k.

(a) **(i)** Write down an expression for momentum p in terms of m and v.

....

(ii) Hence show that the kinetic energy is given by the expression

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

[3]

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(b) Just before impact with the plate, the ball of mass 35 g has speed 4.5 m s^{-1}. It bounces from the plate so that its speed immediately after losing contact with the plate is 3.5 m s^{-1}. The ball is in contact with the plate for 0.14 s.

Calculate, for the time that the ball is in contact with the plate,

(i) the average force, in addition to the weight of the ball, that the plate exerts on the ball,

magnitude of force = ... N

direction of force = ... [4]

(ii) the loss in kinetic energy of the ball.

loss = ... J [2]

(c) State and explain whether linear momentum is conserved during the bounce.

....

....

....

.... [3]

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7 A girl stands at the top of a cliff and throws a ball vertically upwards with a speed of $12\,m\,s^{-1}$, as illustrated in Fig. 3.1.

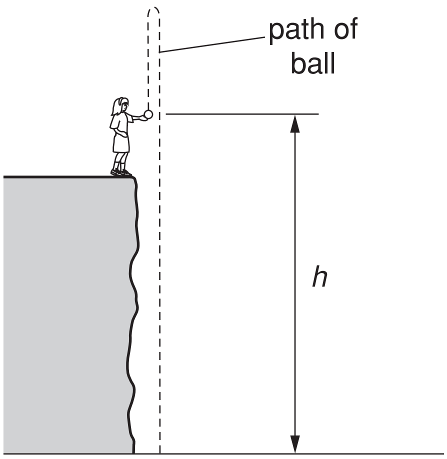

Fig. 3.1

At the time that the girl throws the ball, her hand is a height *h* above the horizontal ground at the base of the cliff.
The variation with time *t* of the speed *v* of the ball is shown in Fig. 3.2.

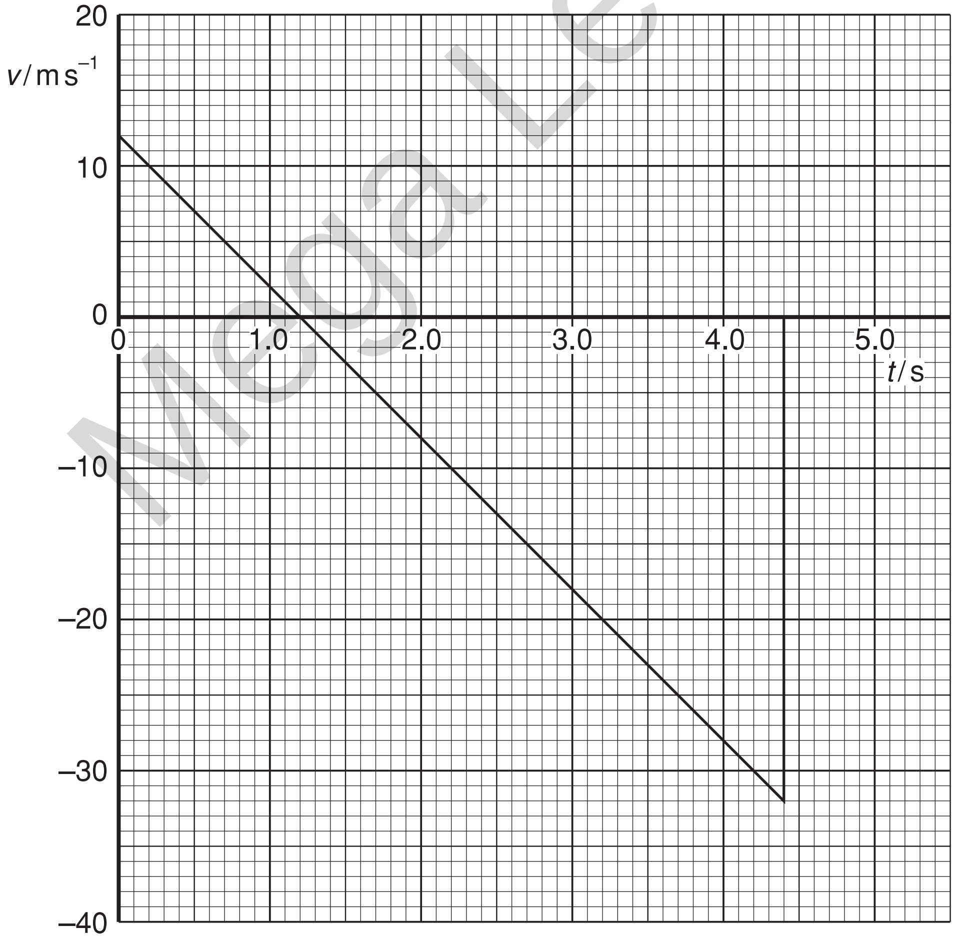

Fig. 3.2

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Speeds in the upward direction are shown as being positive. Speeds in the downward direction are negative.

(a) State the feature of Fig. 3.2 that shows that the acceleration is constant.

.... [1]

(b) Use Fig. 3.2 to determine the time at which the ball

(i) reaches maximum height,

time = ... s

(ii) hits the ground at the base of the cliff.

time = ... s [2]

(c) Determine the maximum height above the base of the cliff to which the ball rises.

height = ... m [3]

(d) The ball has mass 250 g. Calculate the magnitude of the change in momentum of the ball between the time that it leaves the girl's hand to time $t = 4.0$ s.

change = ... N s [3]

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(e) (i) State the principle of conservation of momentum.

....

....

.... [2]

(ii) Comment on your answer to **(d)** by reference to this principle.

....

....

....

.... [3]

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8 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.

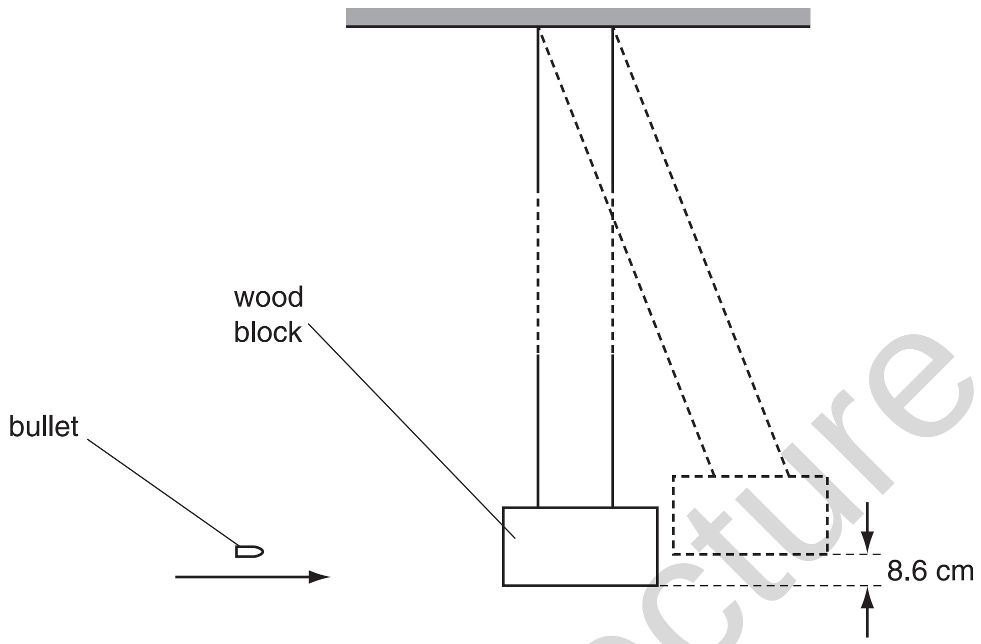

Fig. 3.1

(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 m s^{-1}.

[1]

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(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.

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

....

....

....[2]

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9 A trolley of mass 930 g is held on a horizontal surface by means of two springs, as shown in Fig. 4.1.

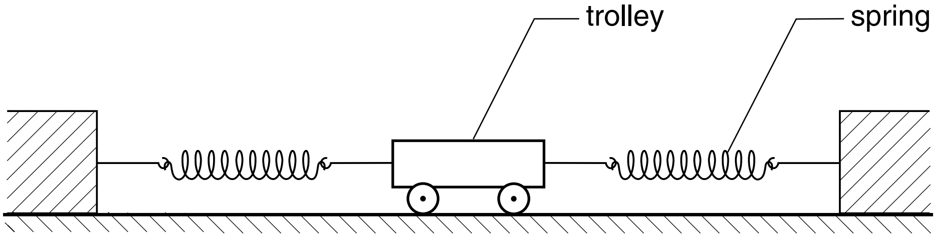

Fig. 4.1

The variation with time *t* of the speed *v* of the trolley for the first 0.60 s of its motion is shown in Fig. 4.2.

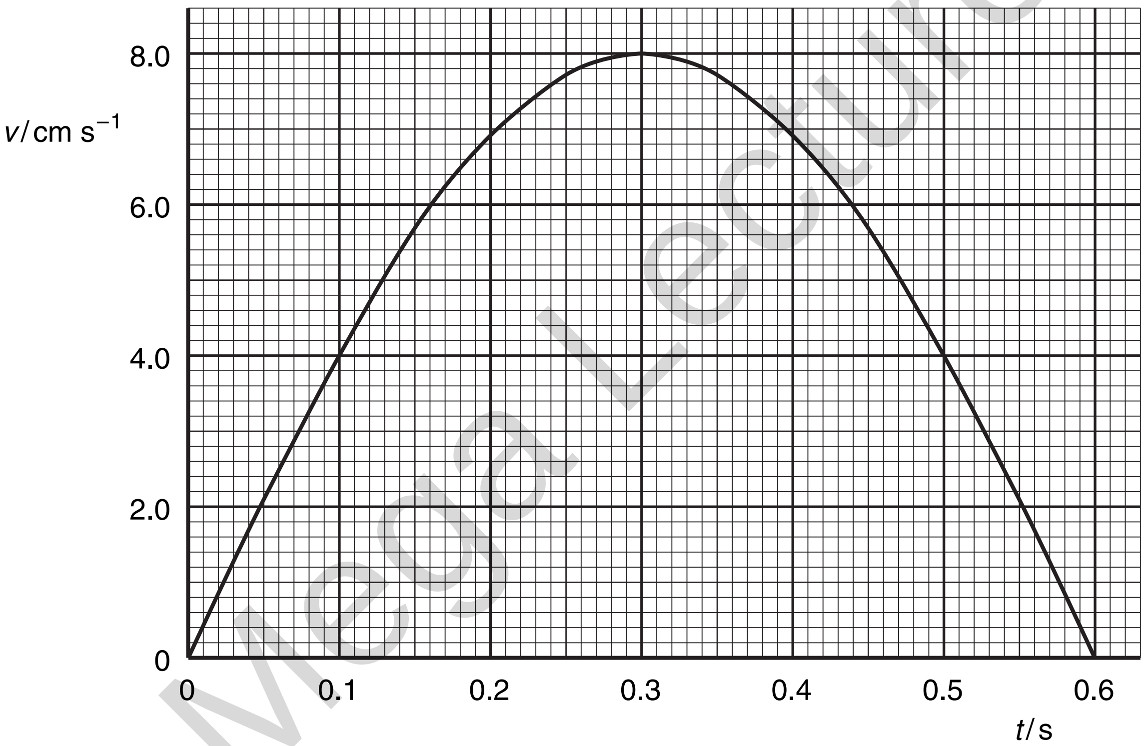

Fig. 4.2

(a) Use Fig. 4.2 to determine

(i) the initial acceleration of the trolley,

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

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(ii) the distance moved during the first 0.60 s of its motion.

distance = ... m [3]

(b) (i) Use your answer to **(a)(i)** to determine the resultant force acting on the trolley at time $t = 0$.

force = ... N [2]

(ii) Describe qualitatively the variation with time of the resultant force acting on the trolley during the first 0.60 s of its motion.

....

....

....

.... [3]

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

....

....

.... [2]

(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.

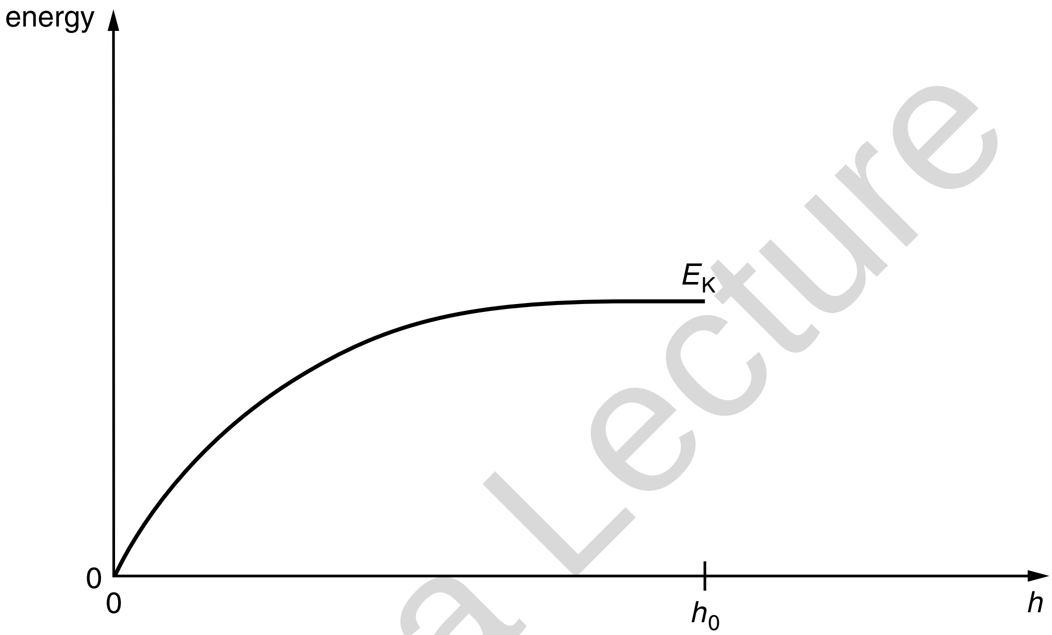

Fig. 8.1

(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]

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11 **(a)** Explain what is meant by the *internal energy* of a substance.

....

....

.... [2]

(b) State and explain, in molecular terms, whether the internal energy of the following increases, decreases or does not change.

(i) a lump of iron as it is cooled

....

....

....

.... [3]

(ii) some water as it evaporates at constant temperature

....

....

....

.... [3]

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12 (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 $27\,\text{m}\,\text{s}^{-1}$ in 8.1 s.

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

rate = ... W [2]

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

....

....

.... [2]

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13 A student investigates the speed of a trolley as it rolls down a slope, as illustrated in Fig. 2.1.

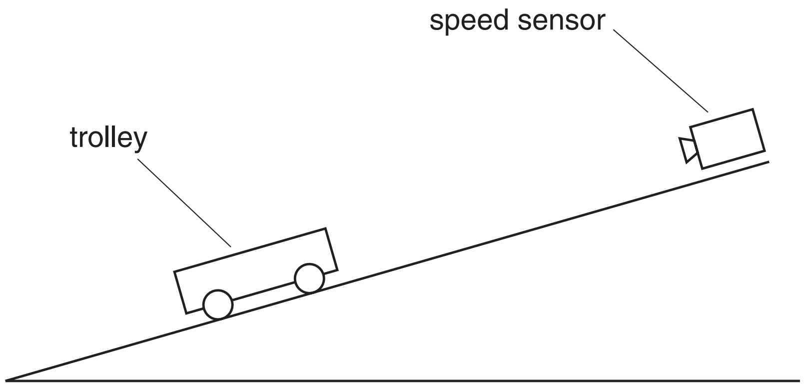

Fig. 2.1

The speed v of the trolley is measured using a speed sensor for different values of the time t that the trolley has moved from rest down the slope.

Fig. 2.2 shows the variation with t of v.

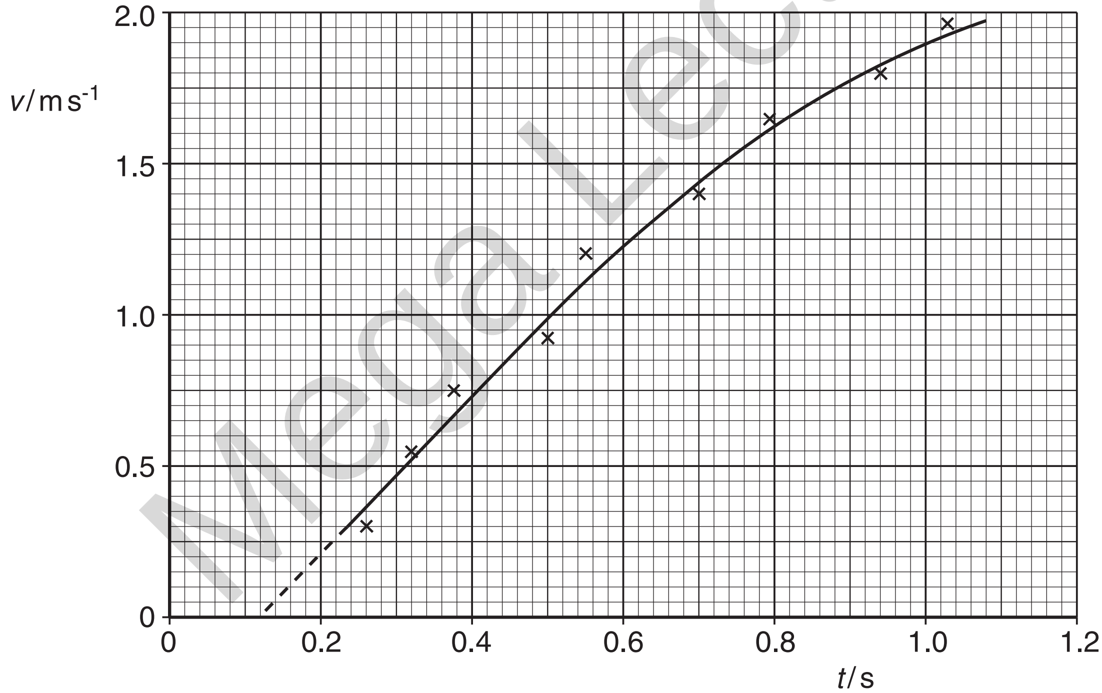

Fig. 2.2

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(a) Use Fig. 2.2 to determine the acceleration of the trolley at the point on the graph where t = 0.80 s.

acceleration = ... m s^{-2} [4]

(b) (i) State whether the acceleration is increasing or decreasing for values of t greater than 0.6 s. Justify your answer by reference to Fig. 2.2.

....

....

.... [2]

(ii) Suggest an explanation for this change in acceleration.

....

.... [1]

(c) Name the feature of Fig. 2.2 that indicates the presence of

(i) random error,

....

.... [1]

(ii) systematic error.

....

.... [1]

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

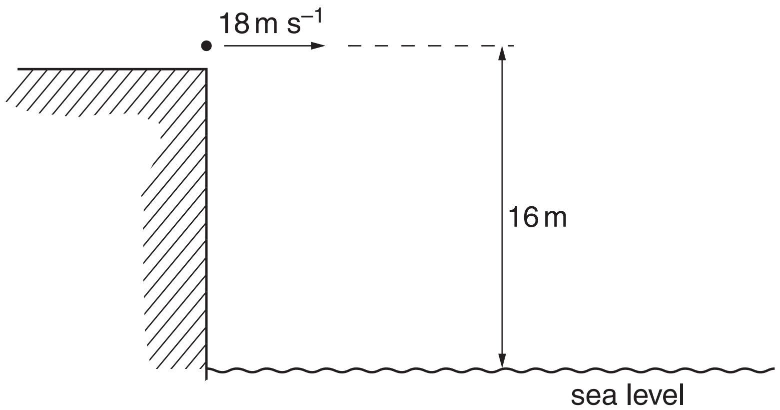

Fig. 4.1

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]

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

[1]

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

horizontal velocity = ... 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]

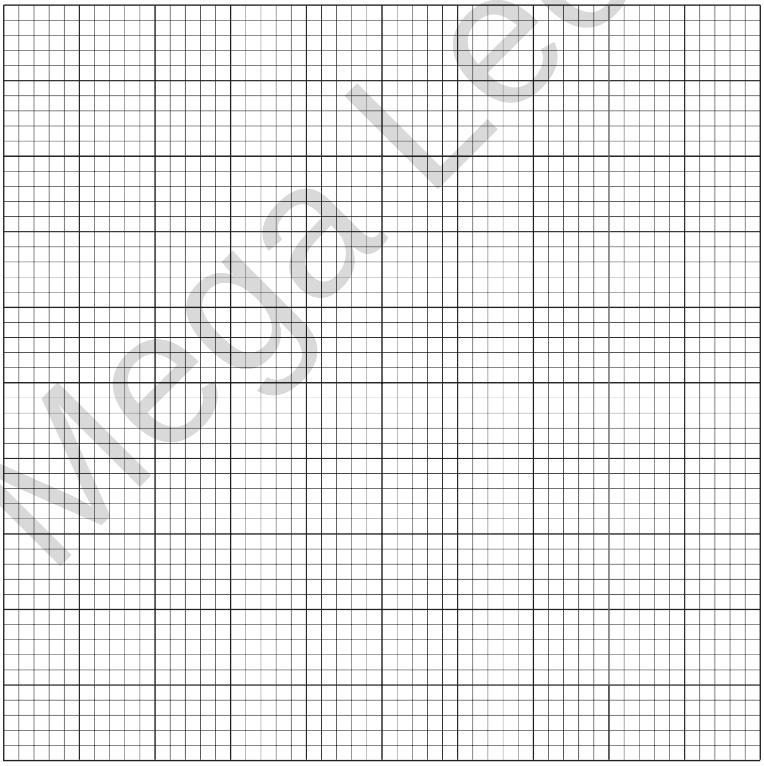

Fig. 4.2

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

angle = ... ° [2]

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15 A girl G is riding a bicycle at a constant velocity of 3.5 m s^{-1}. At time $t = 0$, she passes a boy B sitting on a bicycle that is stationary, as illustrated in Fig. 2.1.

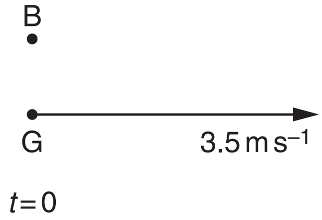

Fig. 2.1

At time $t = 0$, the boy sets off to catch up with the girl. He accelerates uniformly from time $t = 0$ until he reaches a speed of 5.6 m s^{-1} in a time of 5.0 s. He then continues at a constant speed of 5.6 m s^{-1}. At time $t = T$, the boy catches up with the girl.
T is measured in seconds.

(a) State, in terms of T, the distance moved by the girl before the boy catches up with her.

distance = ... m [1]

(b) For the boy, determine

(i) the distance moved during his acceleration,

distance = ... m [2]

(ii) the distance moved during the time that he is moving at constant speed.
Give your answer in terms of T.

distance = ... m [1]

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(c) Use your answers in **(a)** and **(b)** to determine the time T taken for the boy to catch up with the girl.

T = ... s [2]

(d) The boy and the bicycle have a combined mass of 67 kg.

(i) Calculate the force required to cause the acceleration of the boy.

force = ... N [3]

(ii) At a speed of $4.5\,m\,s^{-1}$, the total resistive force acting on the boy and bicycle is 23 N.
Determine the output power of the boy's legs at this speed.

power = ... W [2]

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16 **(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.

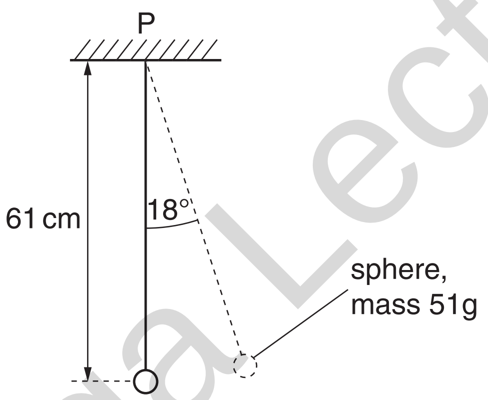

Fig. 3.1

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

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

gain = ... J [2]

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

moment = ... N m [2]

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17 A shopping trolley and its contents have a total mass of 42 kg. The trolley is being pushed along a horizontal surface at a speed of 1.2 $m s^{-1}$. When the trolley is released, it travels a distance of 1.9 m before coming to rest.

(a) Assuming that the total force opposing the motion of the trolley is constant,

(i) calculate the deceleration of the trolley,

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

(ii) show that the total force opposing the motion of the trolley is 16 N.

[1]

(b) Using the answer in **(a)(ii)**, calculate the power required to overcome the total force opposing the motion of the trolley at a speed of 1.2 $m s^{-1}$.

power = ... W [2]

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(c) The trolley now moves down a straight slope that is inclined at an angle of 2.8° to the horizontal, as shown in Fig. 3.1.

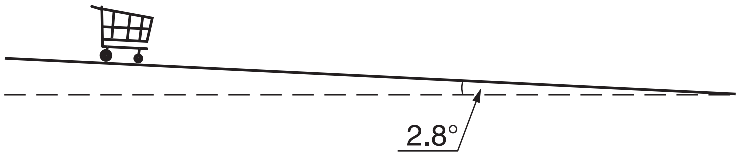

Fig. 3.1

The constant force that opposes the motion of the trolley is 16 N.

Calculate, for the trolley moving down the slope,

(i) the component down the slope of the trolley's weight,

component of weight = ... N [2]

(ii) the time for the trolley to travel from rest a distance of 3.5 m along the length of the slope.

time = ... s [4]

(d) Use your answer to **(c)(ii)** to explain why, for safety reasons, the slope is not made any steeper.

....

....[1]

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18 A car is travelling along a straight road at speed *v*. A hazard suddenly appears in front of the car. In the time interval between the hazard appearing and the brakes on the car coming into operation, the car moves forward a distance of 29.3 m. With the brakes applied, the front wheels of the car leave skid marks on the road that are 12.8 m long, as illustrated in Fig. 2.1.

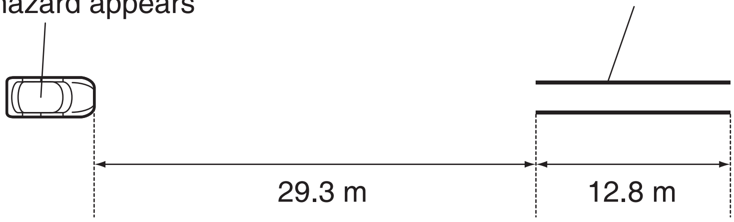

Fig. 2.1

It is estimated that, during the skid, the magnitude of the deceleration of the car is 0.85 *g*, where *g* is the acceleration of free fall.

(a) Determine

(i) the speed *v* of the car before the brakes are applied,

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

(ii) the time interval between the hazard appearing and the brakes being applied.

time = ... s [2]

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(b) The legal speed limit on the road is 60 km per hour.
Use both of your answers in **(a)** to comment on the standard of the driving of the car.

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