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N e w S o l u t i o n s . N e w M i n d s

About AS LEVEL

PHYSICS
Paper 2
(TOPICAL)

About Learning Corner

This section reveals the extra/relevant information that are not required as part of the model answers but to expand the student's knowledge in the respective fields. At the same time, it induces eagerness and interest into their learning process.

period	2010 to 2025
contents	June & November, P2, Worked Solutions
form	Topic By Topic
compiled for	AS Levels
special features	Learning Corner

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CONTENTS

AS LEVEL

Topic 2

Kinematics

2.1 Equations of motion

Candidates should be able to:

1 define and use distance, displacement, speed, velocity and acceleration

2 use graphical methods to represent distance, displacement, speed, velocity and acceleration

3 determine displacement from the area under a velocity–time graph

4 determine velocity using the gradient of a displacement–time graph

5 determine acceleration using the gradient of a velocity–time graph

6 derive, from the definitions of velocity and acceleration, equations that represent uniformly accelerated motion in a straight line

7 solve problems using equations that represent uniformly accelerated motion in a straight line, including the motion of bodies falling in a uniform gravitational field without air resistance

8 describe an experiment to determine the acceleration of free fall using a falling object

9 describe and explain motion due to a uniform velocity in one direction and a uniform acceleration in a perpendicular direction

learning CORNER

TOPIC 2 *opening ....*

Question 1

(a) The distance *s* moved by an object in time *t* may be given by the expression

$$S = \frac{1}{2}at^2$$

where *a* is the acceleration of the object.
State two conditions for this expression to apply to the motion of the object. [2]

(b) A student takes a photograph of a steel ball of radius 5.0 cm as it falls from rest. The image of the ball is blurred, as illustrated in Fig. 2.1.

The image is blurred because the ball is moving while the photograph is being taken.

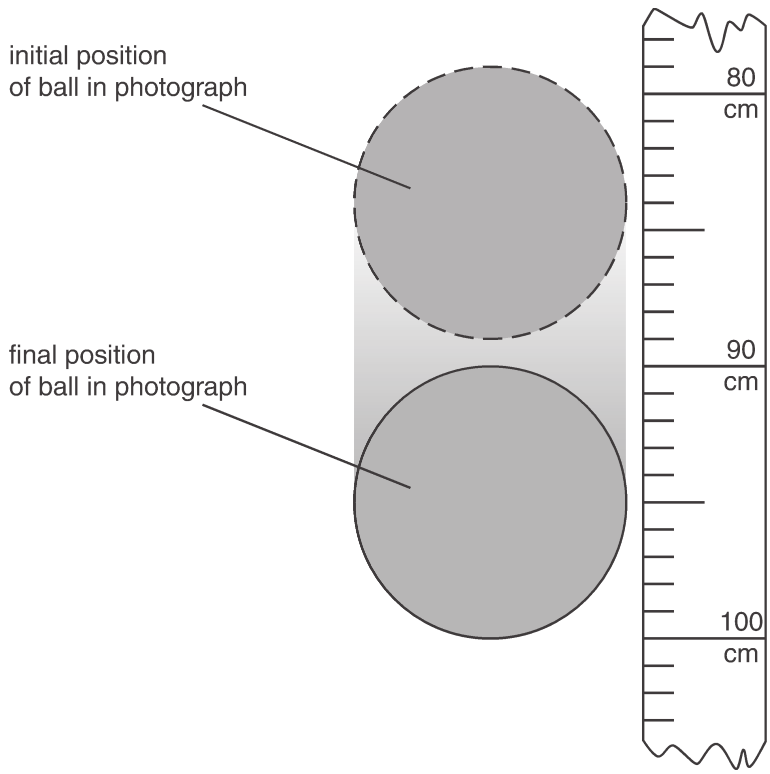

Fig. 2.1

The scale shows the distance fallen from rest by the ball. At time $t = 0$, the top of the ball is level with the zero mark on the scale. Air resistance is negligible.

Calculate, to an appropriate number of significant figures,

(i) the time the ball falls before the photograph is taken, [3]

(ii) the time interval during which the photograph is taken. [3]

(c) The student in **(b)** takes a second photograph starting at the same position on the scale.

The ball has the same radius but is less dense, so that air resistance is not negligible.

State and explain the changes that will occur in the photograph. [2]

[J10/P2/Q2]

Suggested Solution:

(a) **1.** The object started from rest i.e. it's initial velocity is zero.

2. Equation is valid for uniformly accelerated motion.

(b) **(i)**

$$S = ut + \frac{1}{2}at^2$$

$$79 \times 10^{-2} = (0)t + \frac{1}{2}(9.81)t^2 \quad \Rightarrow \quad t = 0.401 \text{ s}$$

(ii) Time taken by ball to travel 90 cm

$$S = ut + \frac{1}{2}at^2$$

$$90 \times 10^{-2} = (0)t + \frac{1}{2}(9.81)t^2 \quad \Rightarrow \quad t = 0.428$$

$\therefore$ time travel $= 0.428 - 0.401 = 0.027$ s

(c) Air resistance would cause the acceleration or the velocity to be less than before. This also reduces the distance/length of the image.

Question 2

A ball is thrown from a point P, which is at ground level, as illustrated in Fig. 2.1.

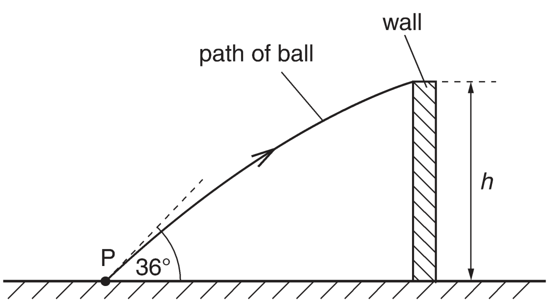

Fig. 2.1

The initial velocity of the ball is 12.4 ms^{-1} at an angle of 36° to the horizontal.

The ball just passes over a wall of height *h*. The ball reaches the wall 0.17 s after it has been thrown.

(a) Assuming air resistance to be negligible, calculate

(i) the horizontal distance of point P from the wall, [2]

(ii) the height *h* of the wall. [3]

(b) A second ball is thrown from point P with the same velocity as the ball in **(a)**. For this ball, air resistance is not negligible.

This ball hits the wall and rebounds.

On Fig. 2.1, sketch the path of this ball between point P and the point where it first hits the ground. [2]

[N10/P2/Q2]

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Suggested Solution:

(a) (i) Consider horizontal motion

distance, $S_H = V_H t$

$= (12.4 \cos 36°)(0.17)$

$= 1.705 \approx 1.71$ m

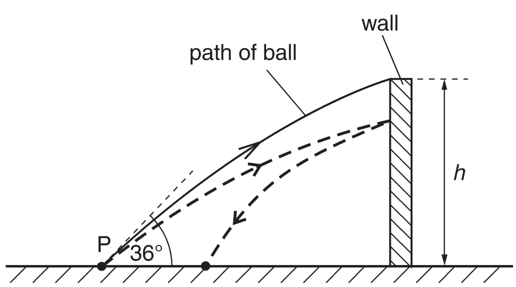
(ii) Consider vertical motion

using $S_V = u_V t + \frac{1}{2} a_V t^2$

$h = (12.4 \sin 36°)(0.17) + \frac{1}{2}(-9.81)(0.17)^2$

$= 1.097 \approx 1.10$ m

(b)



(a) (i) The ball travel the horizontal distance with uniform velocity as no force acts horizontally.

(ii) The ball may not be at the highest point when crossing over the wall so it's final vertical velocity is not zero.

(b) Both the horizontal and vertical distance travelled by the projectile decreases in air resistance.

Question 3

(a) Distinguish between *scalar* quantities and *vector* quantities. [2]

(b) In the following list, underline **all** the scalar quantities.

acceleration force kinetic energy mass power weight [1]

(c) A stone is thrown with a horizontal velocity of 20 ms^{-1} from the top of a cliff 15 m high. The path of the stone is shown in Fig. 1.1.

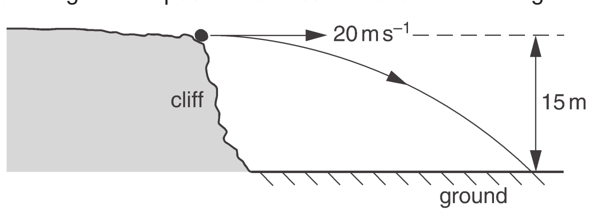


Fig. 1.1

Air resistance is negligible.

For this stone,

(i) calculate the time to fall 15 m, [2]

(ii) calculate the magnitude of the resultant velocity after falling 15 m,[3]

(iii) describe the difference between the displacement of the stone and the distance that it travels. [2]

[J11/P2/Q1]

Suggested Solution:

(a) Physical quantities which need magnitude only for specification are called scalars while vectors are specified by magnitude as well as direction.

(b) <u>kinetic energy</u> <u>mass</u> <u>power</u>

(c) (i) Consider vertical motion only,

$$S_v = u_v t + \frac{1}{2} a_v t^2$$

$$15 = (0)(t) + \frac{1}{2}(9.81)t^2$$

$$15 = 4.9t^2$$

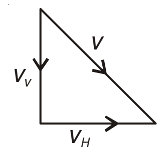
$$t = \sqrt{\frac{15}{4.9}} = 1.75\ \text{s}$$

(ii) Final vertical velocity, $v_v = u_v + a_v t$

$$= 0 + (9.81)(1.75) = 17.2\ \text{ms}^{-1}$$

Resultant velocity, $v = \sqrt{v_v^2 + v_H^2}$

$$= \sqrt{(17.2)^2 + (20)^2} = 26.4\ \text{ms}^{-1}$$



(iii) Displacement is the straight directed distance from the starting point to the ending point while distance is the actual path travelled by the stone.

Learning CORNER

(c) (ii) Initial $(E_P + E_K)$ = Final E_K

$$mgh + \frac{1}{2}mu^2 = \frac{1}{2}mv^2$$

$$\frac{2gh + u^2}{2} = \frac{v^2}{2}$$

$$v = \sqrt{2gh + u^2}$$

$$v = \sqrt{2(9.81)(15) + (20)^2}$$

$$v = 26.3\ \text{ms}^{-1}$$

Question 4

The variation with time t of the displacement s for a car is shown in Fig. 1.1.

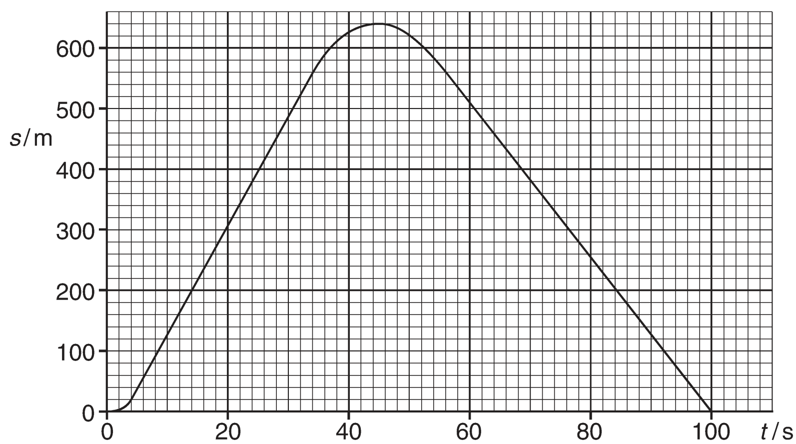


Fig. 1.1

(a) Determine the magnitude of the average velocity between the times 5.0 s and 35.0 s. [2]

(b) On Fig. 1.2, sketch the variation with time t of the velocity v for the car.

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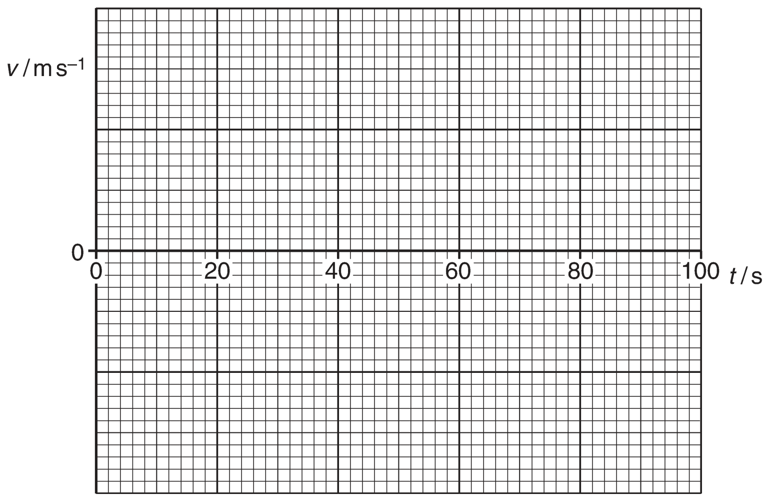


Fig. 1.2

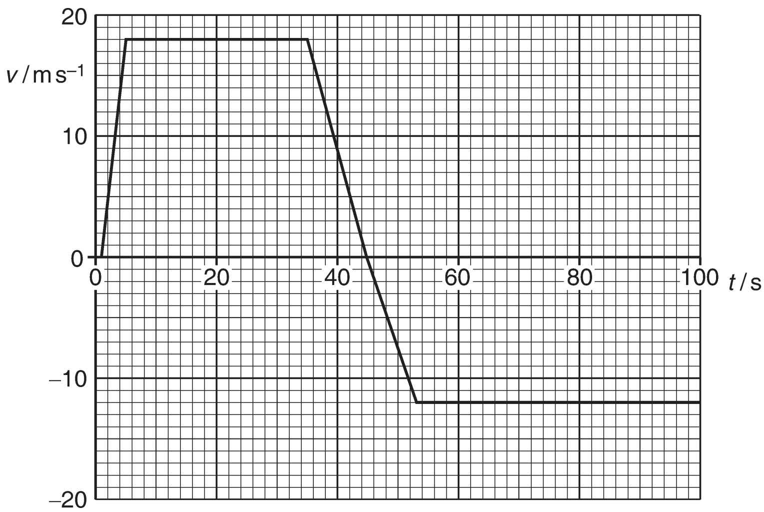
[N11/P2/Q1]

Suggested Solution:

(a) Velocity = Gradient of s/m against t/s graph

$$v = \frac{580 - 40}{35.0 - 5.0} = 18.0 \text{ ms}^{-1}$$

(b)



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Question 12

A golfer strikes a ball so that it leaves horizontal ground with a velocity of 6.0 m s^{-1} at an angle θ to the horizontal, as illustrated in Fig. 1.1.

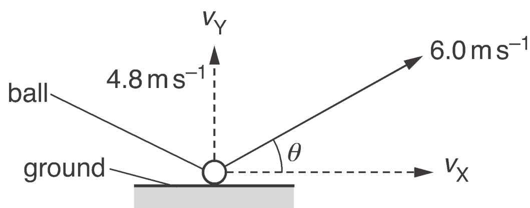


Fig. 1.1 (not to scale)

The magnitude of the initial vertical component v_Y of the velocity is 4.8 m s^{-1}.
Assume that air resistance is negligible.

(a) Show that the magnitude of the initial horizontal component v_X of the velocity is 3.6 m s^{-1}. [1]

(b) The ball leaves the ground at time $t = 0$ and reaches its maximum height at $t = 0.49$ s.

On Fig. 1.2, sketch separate lines to show the variation with time t, until the ball returns to the ground, of

(i) the vertical component v_Y of the velocity (label this line Y), [2]

(ii) the horizontal component v_X of the velocity (label this line X). [2]

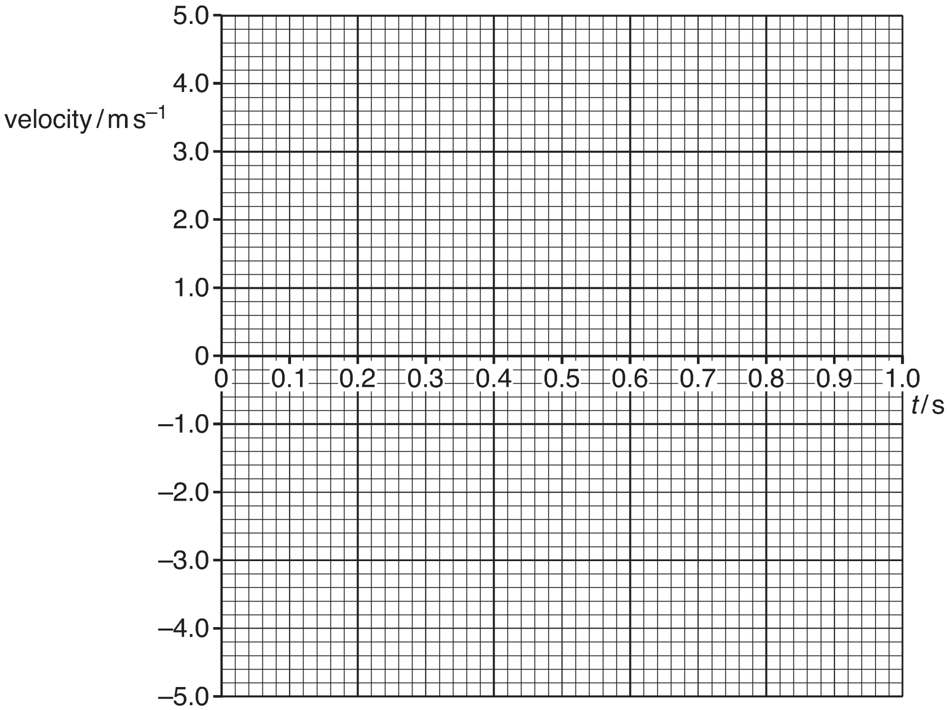


Fig. 1.2

(c) Calculate the maximum height reached by the ball. [2]

(d) For the movement of the ball from the ground to its maximum height, determine the ratio

$$\frac{\text{kinetic energy at maximum height}}{\text{change in gravitational potential energy}}.$$

[4]

(e) In practice, significant air resistance acts on the ball. Explain why the actual time taken for the ball to reach maximum height is less than the time calculated when air resistance is assumed to be negligible. [1]

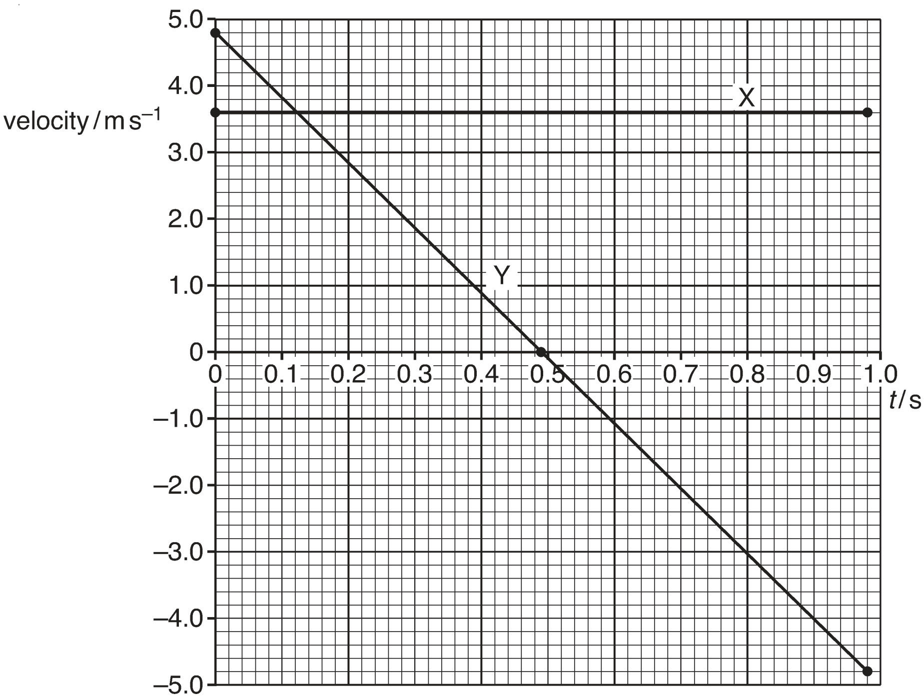
[N18/P2/Q1]

Suggested Solution:

(a) Using pythagoras theorem

$$v^2 = v_X^2 + v_Y^2$$
$$(6.0)^2 = v_X^2 + (4.8)^2$$
$$v_X^2 = 36 - 23$$
$$v_X = \sqrt{13} \quad \Rightarrow \quad v_X = 3.6 \text{ m s}^{-1}$$

(b) (i) & (ii)



(c) Consider vertical motion

Using $s_v = u_v t + \frac{1}{2}at^2$

$$s_v = (4.8)(0.49) + \frac{1}{2}(-9.81)(0.49)^2$$
$$= 2.352 - 1.178 = 1.17 \text{ m}$$

Learning CORNER

(a) Initially find an angle θ

$$\sin\theta = \frac{4.8}{6.0}$$
$$\Rightarrow \quad \theta = \sin^{-1}\left(\frac{4.8}{6.0}\right)$$
$$\Rightarrow \quad \theta = 53.1°$$
$$v_X = v\cos\theta$$
$$\Rightarrow \quad v_X = 6.0\cos 53.1°$$
$$= 3.6 \text{ m s}^{-1}$$

(b) – Vertical component, v_Y of velocity decreases uniformly due to gravitational pull of earth.

– Horizontal component of velocity, v_X remains constant as no force acts horizontally.

(c) Loss of E_K = Gain in E_P

$$\frac{1}{2}mu_v^2 = mgh$$
$$h = \frac{u_v^2}{2g}$$
$$h = \frac{(4.8)^2}{2(9.81)}$$
$$h = 1.17 \text{ m}$$

(d) $$\frac{\text{kinetic energy at maximum height}}{\text{change in gravitational potential energy}} = \frac{\frac{1}{2}m v_X^2}{m g h} = \frac{v_X^2}{2gh} = \frac{(3.6)^2}{2(9.81)(1.17)} = 0.56$$

(e) Air resistance always acts in opposite direction to velocity. This increases the resultant opposing force and ball gain lesser maximum height and at lesser time.

Learning CORNER

(d) At maximum height, vertical velocity (v_V) becomes zero and horizontal velocity is 3.6 m s^{-1}.

Question 13

(a) Define *acceleration*. [1]

(b) A steel ball of diameter 0.080 m is released from rest and falls vertically in air, as illustrated in Fig. 2.1.

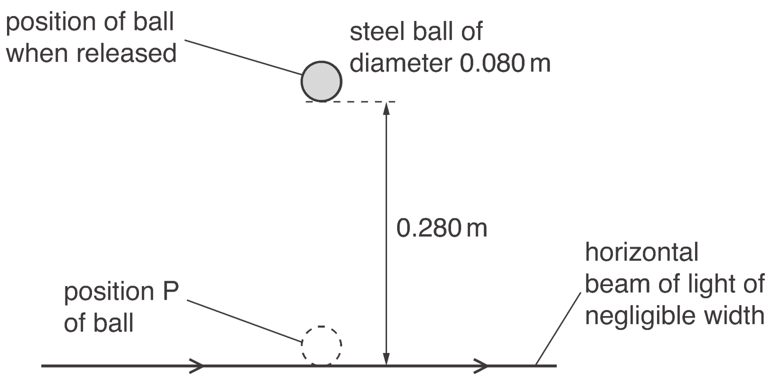


Fig. 2.1 (not to scale)

A horizontal beam of light of negligible width is a vertical distance of 0.280 m below the bottom of the ball when it is released. The ball falls through and breaks the beam of light.

(i) Explain why the force due to air resistance acting on the ball may be neglected when calculating the time taken for the ball to reach the beam of light. [1]

(ii) Calculate the time taken for the ball to fall from rest to position P where the bottom of the ball touches the beam of light. [2]

(iii) Determine the time interval during which the beam of light is broken by the ball. [2]

(c) A different ball is released from the same position as the steel ball in **(b)**. This ball has the same diameter but a much lower density. For this ball, the force due to air resistance cannot be neglected as the ball falls.

State and explain the change, if any, to the time interval during which the beam of light is broken by the ball. [2]

[N19/P2/Q2]

Suggested Solution:

Learning CORNER

(a) Change of velocity per unit time.

(b) (i) Force due to air resistance is negligible in comparison to weight.

(ii) $s = ut + \frac{1}{2}at^2$

$0.280 = (0)(t) + \frac{1}{2}(9.81)(t^2)$

$0.280 = 4.905t^2$

$t = \sqrt{\frac{0.280}{4.905}} = 0.239 \text{ s}$

(iii) Total distance moved $= 0.280 + 0.080 = 0.360$

Using, $s = ut + \frac{1}{2}at^2$

$0.360 = (0)(t) + \frac{1}{2}(9.81)t^2$

$t = \sqrt{\frac{3(0.360)}{9.81}} = 0.271 \text{ s}$

$\therefore$ Time interval $= 0.271 - 0.239 = 0.032 \text{ s}$

(c) Resultant force and thus acceleration of low-density ball is less. Hence time interval is longer.

Question 14

(a) Fig. 2.1 shows the velocity–time graph for an object moving in a straight line.

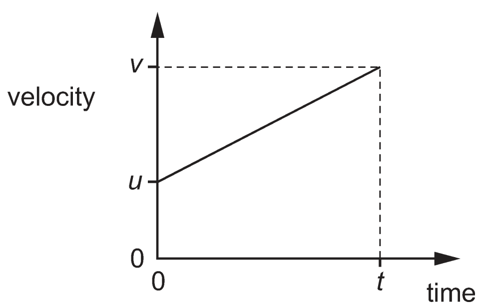


Fig. 2.1

(i) Determine an expression, in terms of u, v and t, for the area under the graph. [1]

(ii) State the name of the quantity represented by the area under the graph. [1]

(b) A ball is kicked with a velocity of 15 m s^{-1} at an angle of 60° to horizontal ground. The ball then strikes a vertical wall at the instant when the path of the ball becomes horizontal, as shown in Fig. 2.2.

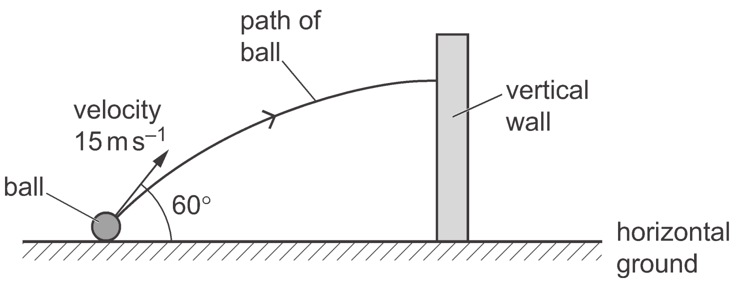


Fig. 2.2 (not to scale)

Assume that air resistance is negligible.

(i) By considering the vertical motion of the ball, calculate the time it takes to reach the wall. [3]

(ii) Explain why the horizontal component of the velocity of the ball remains constant as it moves to the wall. [1]

(iii) Show that the ball strikes the wall with a horizontal velocity of 7.5 m s^{-1}. [1]

(c) The mass of the ball in **(b)** is 0.40 kg. It is in contact with the wall for a time of 0.12 s and rebounds horizontally with a speed of 4.3 m s^{-1}.

(i) Use the information from **(b)(iii)** to calculate the change in momentum of the ball due to the collision. [2]

(ii) Calculate the magnitude of the average force exerted on the ball by the wall. [1]

[J20/P2/Q2]

Learning CORNER

(a) (i) Area $= ut + \frac{1}{2}(v-u)t$

Suggested Solution:

(a) (i) Area under graph = Area of trapezium

$$= \frac{1}{2}(u+v)(t)$$

(ii) Displacement

(b) (i) $v_v = u_v + a_v t$

$$0 = 15\sin 60° + (-9.81)t$$

$$t = \frac{15\sin 60°}{9.81} = 1.32 \text{ s}$$

(ii) No force is acting along horizontal direction.

(iii) $v_H = u_H$

$$= 15\cos 60° = 7.5 \text{ m s}^{-1}$$

(c) (i) Momentum before collision $= (m)(u) = (0.40)(7.5) = 3.0$

Momentum after collision $= (m)(-v) = (0.40)(-4.3) = -1.72$

Change in momentum, $\Delta p = -1.72 - 3.0$

$$= -4.72 \text{ kg m s}^{-1}$$

Learning CORNER

(ii) Average force, $F = \dfrac{\Delta p}{\Delta t}$

$$= \frac{-4.72}{0.12} = -39.3 \text{ N}$$

Question 15

(a) Complete Table 1.1 by putting a tick (✓) in the appropriate column to indicate whether the listed quantities are scalars or vectors.

Table 1.1

quantity	scalar	vector
acceleration		
density		
temperature		
momentum		

[2]

(b) A toy train moves along a straight section of track. Fig. 1.1 shows the variation with time t of the distance d moved by the train.

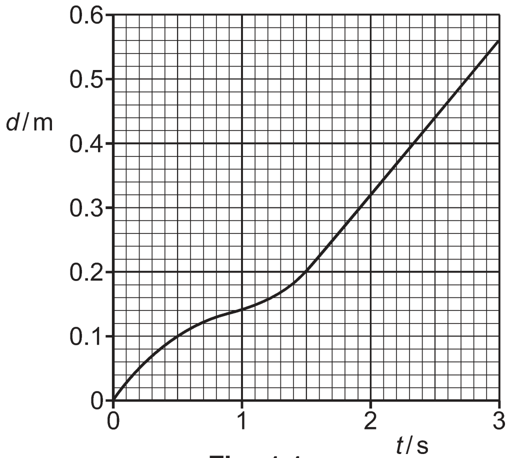


Fig. 1.1

(i) Describe qualitatively the motion of the train between time $t = 0$ and time $t = 1.0$ s. [1]

(ii) Determine the speed of the train at time $t = 2.0$ s. [2]

(c) The straight section of track in **(b)** is part of the loop of track shown in Fig. 1.2.

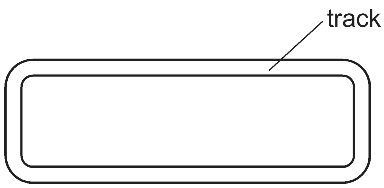


Fig. 1.2

The train completes exactly one lap of the loop.

State and explain the average velocity of the train over the one complete lap. [1]

[N20/P2/Q1]

Suggested Solution:

Learning CORNER

(a)

quantity	scalar	vector
acceleration		✓
density	✓	
temperature	✓	
momentum		✓

(b) (i) As gradient of d/m against t/s graph at different times decreases, so speed decreases.

(ii) Speed = Gradient of graph

$$= \frac{\Delta d}{\Delta t}$$

$$= \frac{0.56 - 0.20}{3.0 - 1.5} = 0.24 \text{ m s}^{-1}$$

(c) Average velocity $= \dfrac{\text{Total displacement}}{\text{Total time}}$

Average velocity is zero due to zero displacement because train returns to its starting position in a loop.

(b) (i) Since final speed/ velocity is lesser than initial velocity, so train decelerates in first 1.0 s.

(ii) Graph of d / m against t / s is a straight line, so it has constant gradient or speed at all times. So instantaneous speed at t = 2.0 is 0.24 m s^{-1}.

Question 16

A man standing on a wall throws a small ball vertically upwards with a velocity of 5.6 m s^{-1}. The ball leaves his hand when it is at a height of 3.1 m above the ground, as shown in Fig. 3.1.

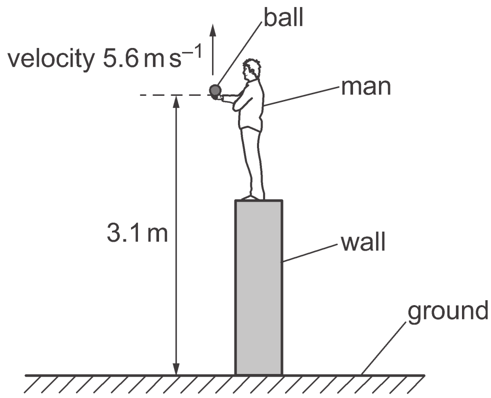


Fig. 3.1 (not to scale)

Assume that air resistance is negligible.

(a) Show that the ball reaches a maximum height above the ground of 4.7 m. [2]

(b) The man does not catch the ball as it falls.

Calculate the time taken for the ball to fall from its maximum height to the ground. [2]

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(c) The ball leaves the man's hand at time $t = 0$ and hits the ground at time $t = T$.

On Fig. 3.2, sketch a graph to show the variation of the velocity v of the ball with time t from $t = 0$ to $t = T$. Numerical values of v and t are not required. Assume that v is positive in the upward direction.

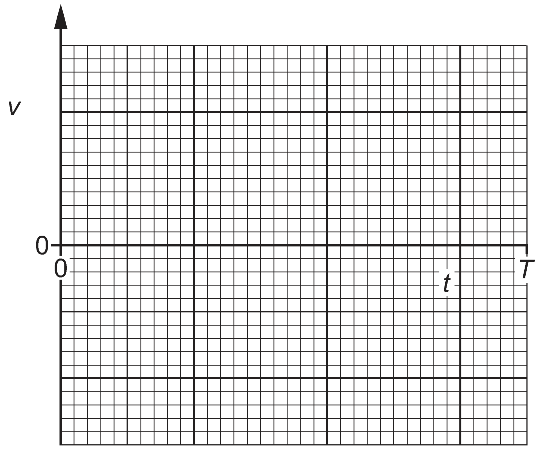


Fig. 3.2

[3]

(d) State what is represented by the gradient of the graph in **(c)**. [1]

(e) The man now throws a second ball with the same velocity and from the same height as the first ball. The mass of the second ball is greater than that of the first ball. Assume that air resistance is still negligible.

For the first and second balls, compare:

(i) the magnitudes of their accelerations [1]

(ii) the speeds with which they hit the ground. [1]

[J22/P2/Q3]

Suggested Solution:

(a)

$$2as = v^2 - u^2$$

$$2(-9.81)h = (0)^2 - (5.6)^2$$

$$h = 1.6 \text{ m}$$

OR

Initial K.E. = Final P.E.

$$\frac{1}{2}mv^2 = mgh$$

$$h = \frac{v^2}{2g}$$

$$h = \frac{(5.6)^2}{2(9.81)} = 1.6 \text{ m}$$

Maximum height above ground, $h = 1.6 + 3.1 = 4.7$ m

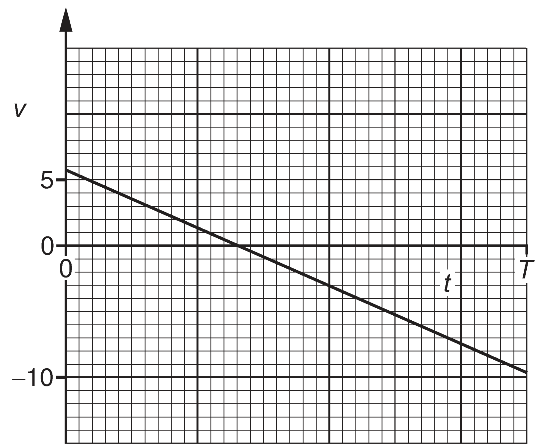
(b)

$$s = ut + \frac{1}{2}at^2$$

$$4.7 = (0)(t) + \frac{1}{2}(9.81)t^2$$

$$t = \sqrt{\frac{2(4.7)}{9.81}} \quad \Rightarrow \quad t = 0.979 \approx 0.98 \text{ s}$$

(c)



(d) Acceleration of free fall (g).

(e) **(i)** Constant (same) as acceleration of free fall is independent of mass.

(ii) Same speed as they fall from same height.

Learning CORNER

(c) Final velocity on hitting ground:

$v^2 = 2gh$

$v = \sqrt{2(9.81)(4.7)}$

$v = 9.6\ \text{m s}^{-1}$

Numerical values are not needed as stated in question.

Upward motion:
+ve lesser velocity

Highest point: 0

Downward motion:
–ve greater velocity.

Straight line due to constant value of acceleration due to gravity.

Question 17

(a) In the following list, underline **all** quantities that are SI base quantities.

charge electric current force time [1]

(b) Under certain conditions, the distance s moved in a straight line by an object in time t is given by

$$s = \frac{1}{2}at^2$$

where a is the acceleration of the object.

State **two** conditions under which the above expression applies to the motion of the object. [2]

(c) The variation with time t of the velocity v of a car that is moving in a straight line is shown in Fig. 1.1.

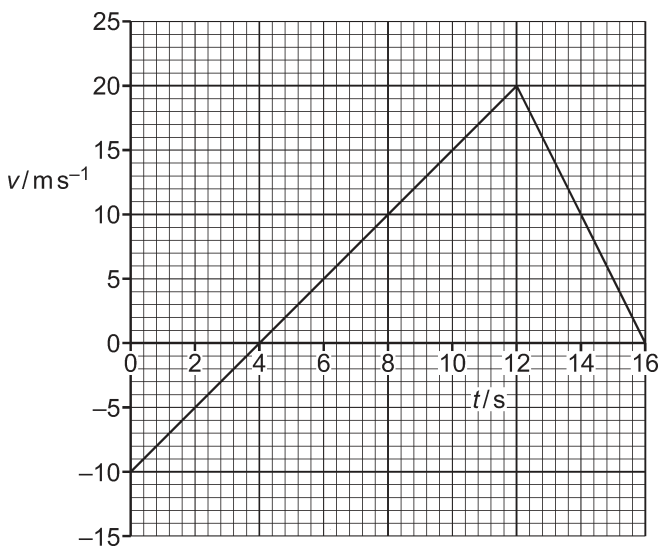


Fig. 1.1

(i) Compare, qualitatively, the acceleration of the car at time $t = 8.0$ s and at time $t = 14.0$ s in terms of:

- magnitude
- direction.

[2]

(ii) Determine the magnitude of the acceleration of the car at time $t = 4.0$ s. [2]

(iii) The car is at point X at time $t = 0$.

Determine the magnitude of the displacement of the car from X at time $t = 12.0$ s. [2]

[N23/P2/Q1]

Learning CORNER

Suggested Solution:

(a) charge <u>electric current</u> force <u>time</u>

(b) 1. Object starts from rest ($u = 0$).

2. Acceleration (a) of object remains constant.

(c) (i) Magnitude: Magnitude of acceleration at $t = 8.0$ s is less than at $t = 14.0$ s.

Direction: Direction of acceleration at $t = 8.0$ s is opposite to acceleration at 14.0 s.

(ii) Acceleration, $a =$ gradient of $v\,/\,\mathrm{m\,s^{-1}}$ against $t\,/\,\mathrm{s}$ graph

$$a = \frac{0-(-10)}{4.0-0} = 2.5\ \mathrm{m\,s^{-2}}$$

(iii) Distance from $t = 0$ to $t = 4.0$ s

$= \text{area above graph with time axis} = \frac{1}{2}(4)(-10) = -20$ m

Distance from $t = 4.0$ to $t = 12.0$ s

$= \text{area under graph with time axis} = \frac{1}{2}(12-4)(20) = 80$ m

$\therefore$ Displacement $= 80 + (-20) = 60$ m

(b) $s = ut + \frac{1}{2}at^2$

If $u = 0$, then,

$s = \frac{1}{2}at^2$

Topic 5

Work, Energy and Power

An understanding of the forms of energy and energy transfers from Cambridge IGCSE/O Level Physics or equivalent is assumed.

5.1 Energy conservation

Candidates should be able to:

1. understand the concept of work, and recall and use *work done* = *force* × *displacement* in the direction of the force
2. recall and apply the principle of conservation of energy
3. recall and understand that the efficiency of a system is the ratio of useful energy output from the system to the total energy input
4. use the concept of efficiency to solve problems
5. define power as work done per unit time
6. solve problems using $P = \frac{W}{t}$
7. derive $P = Fv$ and use it to solve problems

5.2 Gravitational potential energy and kinetic energy

Candidates should be able to:

1. derive, using $W = Fs$, the formula $\Delta E_p = mg\Delta h$ for gravitational potential energy changes in a uniform gravitational field
2. recall and use the formula $\Delta E_p = mg\Delta h$ for gravitational potential energy changes in a uniform gravitational field
3. derive, using the equations of motion, the formula for kinetic energy $E_k = \frac{1}{2}mv^2$
4. recall and use $E_k = \frac{1}{2}mv^2$

Learning CORNER

TOPIC 5 *opening ....*

Question 1

(a) (i) Explain what is meant by *work done*. [1]

(ii) Define *power*. [1]

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

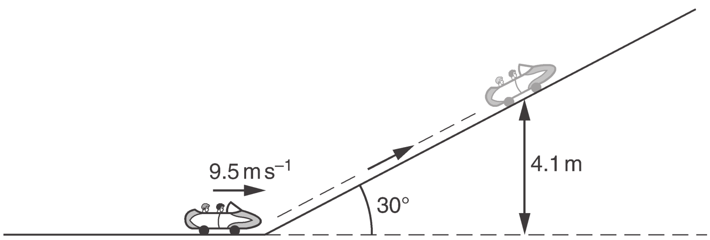


Fig. 3.1

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° 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. [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. [1]

(iv) Use your answer in **(iii)** to calculate the resistive force acting against the carriage as it moves up the slope. [2]

[J11/P2/Q3]

Suggested Solution:

(a) (i) Product of force and displacement travelled in the direction of force.

(ii) Work done per unit time is called power.

(b) (i) $E_k = \frac{1}{2}mv^2$

$= \frac{1}{2}(600)(9.5)^2 = 27.1\times10^3 = 27.1\text{ kJ}$

(ii) $E_p = mgh$

$= (600)(9.81)(4.1)$

$= 24.1\times10^3 = 24.1\text{ kJ}$

(iii) Initial E_k = Gain in E_p + Work done against friction

$27.1 = 24.1 + W \quad \Rightarrow \quad W = 3.0\text{ kJ}$

(iv) $W = (F)(S)$

$$3.0\times10^3 = (F)\left(\frac{4.1}{\sin 30}\right) \quad \Rightarrow \quad F = 366\text{ N}$$

Learning CORNER

Question 2

(a) Define

(i) *force*, [1]

(ii) *work done*. [1]

(b) A force F acts on a mass m along a straight line for a distance s. The acceleration of the mass is a and the speed changes from an initial speed u to a final speed v.

(i) State the work W done by F. [1]

(ii) Use your answer in **(i)** and an equation of motion to show that kinetic energy of a mass can be given by the expression

kinetic energy = ½ × mass × (speed)^2. [3]

(c) A resultant force of 3800 N causes a car of mass of 1500 kg to accelerate from an initial speed of 15 m s^{-1} to a final speed of 30 m s^{-1}.

(i) Calculate the distance moved by the car during this acceleration. [2]

(ii) The same force is used to change the speed of the car from 30 m s^{-1} to 45 m s^{-1}.
Explain why the distance moved is not the same as that calculated in **(i)**. [1]

[N11/P2/Q2]

Suggested Solution:

(a) (i) *force:* Rate of change of momentum is called force.

(ii) *work done:* Product of force and displacement travelled in the direction of force.

(b) (i) $W = (F)(s)$

(ii) Since $W = (F)(s)$ ··········(1)

By Newton's second law, $F = ma$
and displacement from third equation of motion is,

$$2as = v^2 - u^2 \quad \Rightarrow \quad s = \frac{v^2 - u^2}{2a}$$

Now, eq. (1) is modified as

$$W = (ma)\left(\frac{v^2 - u^2}{2a}\right) = \frac{m}{2}(v^2 - u^2)$$

As the object started from rest i.e. $u = 0$ and this work done becomes the kinetic energy of the mass, $E_k = \frac{1}{2}mv^2$.

(c) (i)

$$2as = v^2 - u^2$$
$$2(\frac{F}{m})s = v^2 - u^2$$
$$2(\frac{3800}{1500})s = (30)^2 - (15)^2$$
$$s = 133 \text{ m}$$

(ii) The change in kinetic energy is greater because the same force has done greater work done.

(a) (i) $F = \frac{\Delta p}{\Delta t}$

(ii) $W = (F)(s)$

(b) (i) Other correct answers would be

- $W = (ma)(s)$
- $W = m\left(\frac{v^2 - u^2}{2a}\right)$

(c) (ii)

$$2as = v^2 - u^2$$
$$2\left(\frac{F}{m}\right)s = v^2 - u^2$$
$$2\left(\frac{3800}{1500}\right)(s) = (45)^2 - (30)^2$$
$$s = 222 \text{ m}$$

Question 7

A ball of mass 0.030 kg moves along a curved track, as shown in Fig. 2.1.

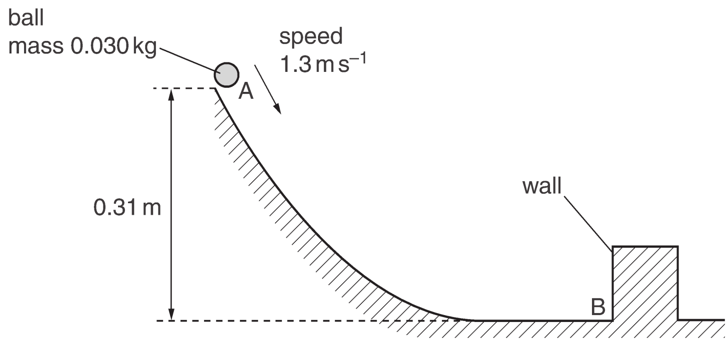


Fig. 2.1

The speed of the ball is 1.3 m s^{-1} when it is at point A at a height of 0.31 m. The ball moves down the track and collides with a vertical wall at point B. The ball then rebounds back up the track. It may be assumed that frictional forces are negligible.

(a) Calculate the change in gravitational potential energy of the ball in moving from point A to point B. [2]

(b) Show that the ball hits the wall at B with a speed of 2.8 m s^{-1}. [3]

(c) The change in momentum of the ball due to the collision with the wall is 0.096 kg m s^{-1}. The ball is in contact with the wall for a time of 20 ms.

Determine, for the ball colliding with the wall,

(i) the speed immediately after the collision, [2]

(ii) the magnitude of the average force on the ball. [2]

(d) State and explain whether the collision is elastic or inelastic. [1]

(e) In practice, frictional effects are significant so that the actual increase in kinetic energy of the ball in moving from A to B is 76 mJ. The length of the track between A and B is 0.60 m.

Use your answer in **(a)** to determine the average frictional force acting on the ball as it moves from A to B. [2]

[N16/P2/Q2]

Learning CORNER

Suggested Solution:

(a) Change in G.P.E, $\Delta E_p = mg\Delta h$

$$= (0.030)(9.81)(0-0.31) = -0.091 \text{ J}$$

(a) Negative sign shows that gravitational potential energy decreases when ball moves from A to B.

(b) Total energy at A = kinetic energy at B

$$(E_P)_A + (E_K)_A = (E_K)_B$$

$$mgh + \frac{1}{2}mu^2 = \frac{1}{2}mv^2$$

$$2gh + u^2 = v^2$$

$$v = \sqrt{2gh + u^2}$$

$$= \sqrt{2(9.81)(0.31) + (1.3)^2}$$

$$= \sqrt{6.08 + 1.69} = 2.79 \text{ ms}^{-1}$$

Learning CORNER

(c) (i)

$$\Delta p = m\Delta v$$
$$\Delta p = m(v-u)$$
$$0.096 = 0.030[v-(-2.8)]$$
$$3.2 = v + 2.8 \quad \Rightarrow \quad v = 0.40$$

$\therefore$ speed immediately after collision $= 0.40\ \text{ms}^{-1}$

(ii) Force, $F = \dfrac{\Delta p}{\Delta t} = \dfrac{0.096}{20\times10^{-3}}$

$$= 4.8\ \text{N}$$

(d) Collision is inelastic because kinetic energy of the system (ball and wall) is not conserved.

(d) Inelastic as relative speed of approach of ball and wall is greater than relative speed of their separation.

(e) P.E. at A = K.E. at B + work done against friction

$$0.091 = 76\times10^{-3} + (F\times s)$$
$$0.60F = 0.091 - 76\times10^{-3}$$
$$F = 0.025\ \text{N}$$

Question 8

(a) Explain what is meant by *work done*. [1]

(b) A ball of mass 0.42 kg is dropped from the top of a building. The ball falls from rest through a vertical distance of 78 m to the ground. Air resistance is significant so that the ball reaches constant (terminal) velocity before hitting the ground. The ball hits the ground with a speed of 23 m s^{-1}.

(i) Calculate, for the ball falling from the top of the building to the ground:

1. the decrease in gravitational potential energy [2]

2. the increase in kinetic energy. [2]

(ii) Use your answers in **(b)(i)** to determine the average resistive force acting on the ball as it falls from the top of the building to the ground. [2]

(c) The ball in **(b)** is dropped at time $t = 0$ and hits the ground at time $t = T$. The acceleration of free fall is g.

On Fig. 3.1, sketch a line to show the variation of the acceleration a of the ball with time t from time $t = 0$ to $t = T$.

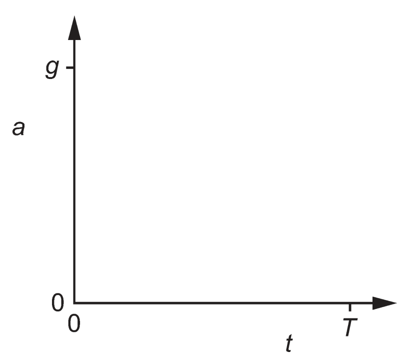


Fig. 3.1 [2]

[J20/P2/Q3]

Suggested Solution:

Learning CORNER

(a) Work done is the product of force and displacement travelled in the direction of force.

(b) (i) 1. $\Delta E_p = mg\Delta h$

$= (0.42)(9.81)(78) = 321\text{ J}$

2. Increase in K.E, $\Delta E_k = \frac{1}{2}m(v^2 - u^2)$

$= \frac{1}{2}(0.42)(23^2 - 0^2) = 111\text{ J}$

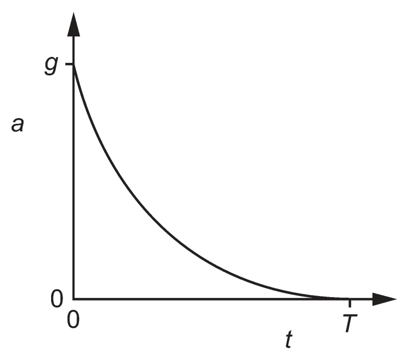
(ii) Loss of E_p = Gain in E_k + work done against air resistance

$321 = 111 + (F)(78)$

$F = 2.69$

$\therefore$ average resistive force = 2.69 N

(c)



Question 9

(a) A spring is fixed at one end and is compressed by applying a force to the other end. The variation of the force F acting on the spring with its compression x is shown in Fig. 3.1.

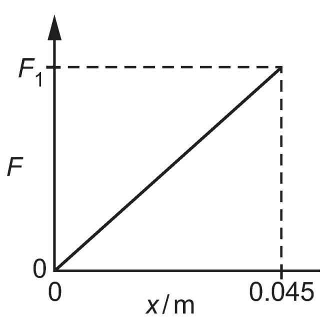


Fig. 3.1

A compression of 0.045 m is produced when a force F_1 acts on the spring. The spring has a spring constant of 800 N m^{-1}.

(i) Determine F_1. [2]

(ii) Use Fig. 3.1 to show that, for a compression of 0.045 m, the elastic potential energy of the spring is 0.81 J. [2]

Learning CORNER

(b) A child's toy uses the spring in **(a)** to launch a ball of mass 0.020 kg vertically into the air. The ball is initially held against one end of the spring which has a compression of 0.045 m. The spring is then released to launch the ball. The kinetic energy of the ball as it leaves the toy is 0.72 J.

(i) The toy converts the elastic potential energy of the spring into the kinetic energy of the ball. Use the information in **(a)(ii)** to calculate the percentage efficiency of this conversion. [1]

(ii) Determine the initial momentum of the ball as it leaves the toy. [3]

(c) The ball in **(b)** leaves the toy at point A and moves vertically upwards through the air. Point B is the position of the ball when it is at maximum height h above point A, as illustrated in Fig. 3.2.

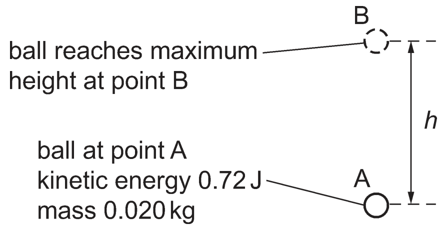


Fig. 3.2 (not to scale)

The gravitational potential energy of the ball increases by 0.60 J as it moves from A to B.

(i) Calculate h. [2]

(ii) Determine the average force due to air resistance acting on the ball for its movement from A to B. [2]

(iii) When there is air resistance, the ball takes time T to move from A to B.

State and explain whether the time taken for the ball to move from A to its maximum height will be more than, less than or equal to time T if there is **no** air resistance. [1]

[N20/P2/Q3]

Suggested Solution:

(a) (i) By Hooke's law

$F = kx$

$F_1 = (800)(0.045) = 36\text{ N}$

(ii) Elastic potential energy, E_P = Area under graph

$$= \frac{1}{2}(F)(x)$$

$$= \frac{1}{2}(36)(0.045) = 0.81\text{ J}$$

(b) (i) $\text{Efficiency} = \dfrac{\text{Useful kinetic energy}}{\text{Total elastic potential energy}} \times 100$

$$\eta = \left(\frac{0.72}{0.81}\right) \times 100 = 88.9\%$$

Learning CORNER

(ii) Since momentum is, $p = mv \Rightarrow v = \dfrac{p}{m}$ ....(1)

Kinetic energy : $E_K = \dfrac{1}{2}mv^2$ ....(2)

Substitute equation (1) into (2)

$$E_K = \frac{1}{2}m\left(\frac{p}{m}\right)^2$$

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

$$\Rightarrow p = \sqrt{2mE_K}$$

$$\Rightarrow p = \sqrt{2(0.020)(0.72)} = 0.1697 = 0.17\ \text{Ns}$$

(c) (i) $\Delta E_P = mg(\Delta h)$

$0.60 = (0.020)(9.81)(\Delta h) \Rightarrow h = 3.06$ m

(ii) By principle of conservation of energy

Loss of K.E = Gain in GPE + Work done against air resistance

$\Rightarrow 0.72 = 0.60 + (F)(s)$

$\Rightarrow (F)(3.06) = 0.72 - 0.60 \Rightarrow F = \dfrac{0.72 - 0.60}{3.06} = 0.0392$ N

(iii) The resultant force is less on ball without air resistance and so there is less deceleration. Hence ball takes more time to move to its maximum height.

(c) (i) Increase in gravitational potential energy ∝ Gain of height

$\Delta E_P \propto \Delta h$

Question 10

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.

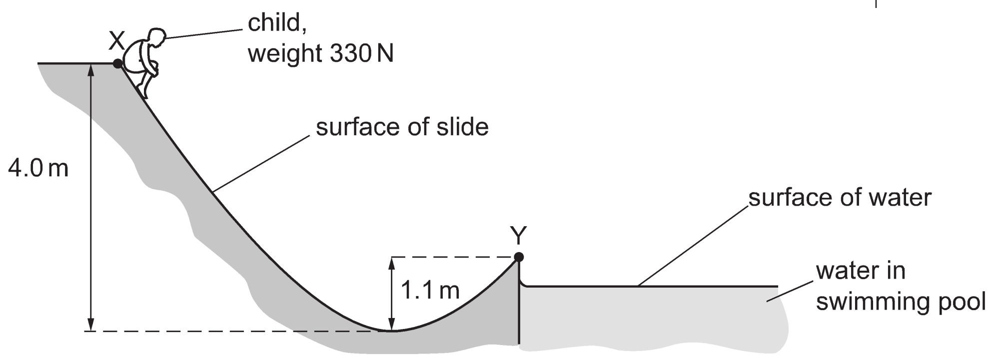


Fig. 3.1 (not to scale)

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. [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. [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.

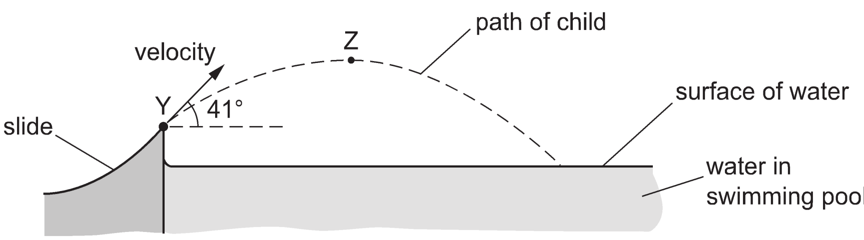


Fig. 3.2 (not to scale)

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 [2]

(ii) point Z. [2]

[J21/P2/Q3]

Learning CORNER

Suggested Solution:

(a) $\Delta E_p = mgh_Y - mgh_X$

$= (330)(1.1) - (330)(4.0)$

$= -957$

–ve sign shows the loss of G.E_p

$\therefore$ Difference in gravitational potential energy = 957 J

(b) By principle of conservation of energy

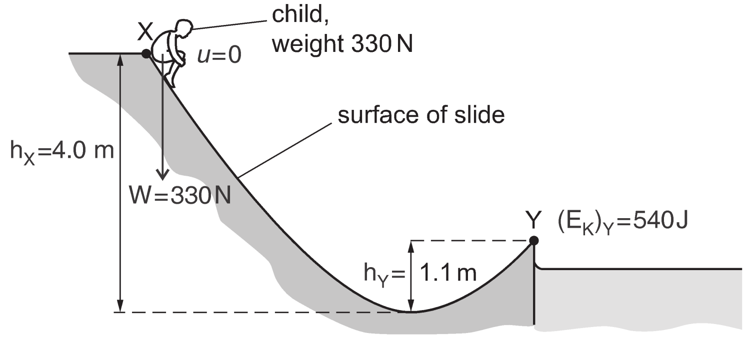
PE at X = KE at Y + PE at Y + Work done against friction

$\Rightarrow$ $(330)(4.0) = 540 + (330)(1.1) + 52 \times d$

$\Rightarrow$ $52d = 957 - 540$

$\Rightarrow$ $52d = 417$ N $\Rightarrow$ $d = \dfrac{417}{52} = 8.02$

$\therefore$ distance moved = 8.02 m



(c) (i) Speed, $E_k = \frac{1}{2}mv^2$

$$E_k = \frac{1}{2}\left(\frac{W}{g}\right)v^2$$

$$540 = \frac{1}{2}\left(\frac{330}{9.81}\right)v^2$$

$$v = \sqrt{32.1}$$

$$v = 5.67\ \text{m s}^{-1}$$

(ii) speed, v_Z = Horizontal component of velocity at Y

$$v_Z = v\cos 41$$

$$v_Z = 5.67\cos 41 = 4.28\ \text{m s}^{-1}$$

Learning CORNER

(c) (ii) At the highest point, vertical velocity is zero and possess only horizontal component which remain constant at all positions as no force acts horizontally.

Question 11

(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.

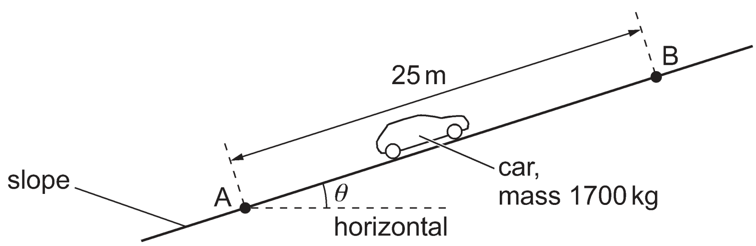


Fig. 3.1 (not to scale)

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 [1]

(ii) calculate the work done against the total resistive force. [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 [2]

(ii) angle 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. [2]

[N21/P2/Q3]

Suggested Solution:

(a) Work done per unit time is power.

(b) (i) Change in kinetic energy = 0 J

(ii) Work done, $W = (f)(s_{AB})$

$= (440)(25) = 1.1\times10^4$ J

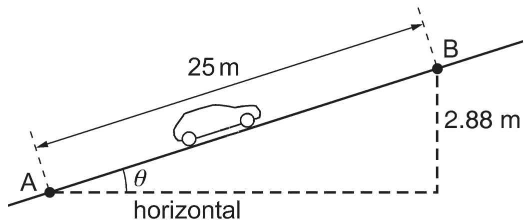
(c) (i)

$$\Delta E_P = mg(\Delta h)$$
$$4.8\times10^4 = (1700)(9.81)(\Delta h)$$
$$\Delta h = 2.88 \text{ m}$$

(ii) $\sin\theta = \dfrac{2.88}{25}$

$\theta = \sin^{-1}(0.115)$

$\theta = 6.62°$



(d) Total work done

= work done against resistive forces + Gain in G.E_P

$= (1.1\times10^4) + (4.8\times10^4) = 5.9\times10^4$ J

$P = \dfrac{W}{t}$

$\Rightarrow \quad 1.7\times10^4 = \dfrac{5.9\times10^4}{t} \quad \Rightarrow \quad t = 3.47$ s

Learning CORNER

(a) $P = \dfrac{W}{t}$

(b) (i) Since both mass and velocity of car are constants, so kinetic energy is constant.

Question 12

(a) State what is meant by the centre of gravity of an object. [1]

(b) Two blocks are on a horizontal beam that is pivoted at its centre of gravity, as shown in Fig. 2.1.

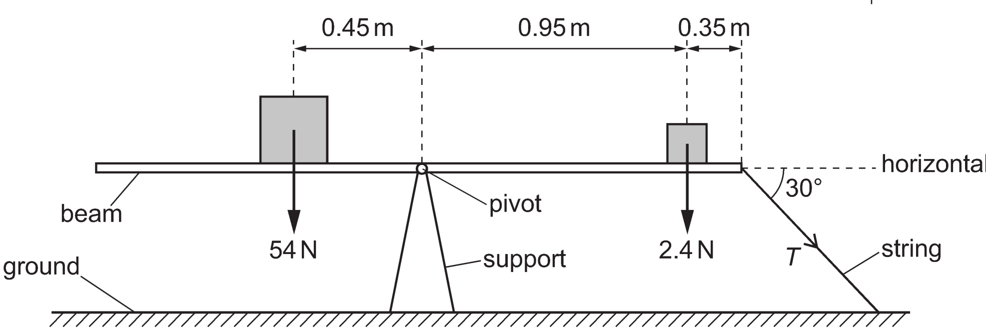


Fig. 2.1 (not to scale)

A large block of weight 54 N is a distance of 0.45 m from the pivot. A small block of weight 2.4 N is a distance of 0.95 m from the pivot and a distance of 0.35 m from the right-hand end of the beam.

The right-hand end of the beam is connected to the ground by a string that is at an angle of 30° to the horizontal. The beam is in equilibrium.

Learning CORNER

(i) By taking moments about the pivot, calculate the tension T in the string. [3]

(ii) The string is cut so that the beam is no longer in equilibrium. Calculate the magnitude of the resultant moment about the pivot acting on the beam immediately after the string is cut. [1]

(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.

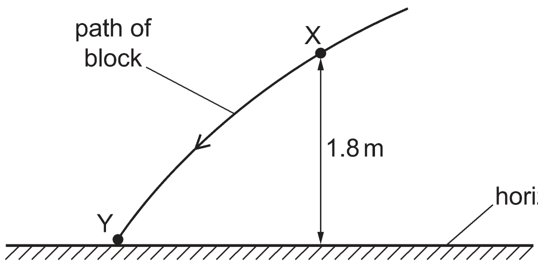


Fig. 2.2 (not to scale)

At point X on the path, the block has a speed of $3.4\ \text{m s}^{-1}$ 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. [2]

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

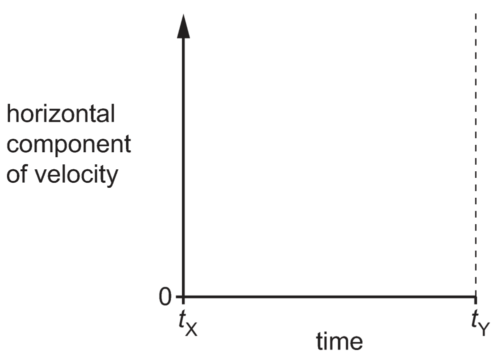


Fig. 2.3

[1]

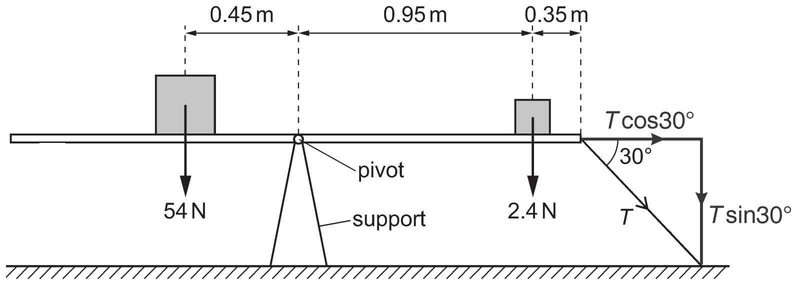
[J23/P2/Q2]

Suggested Solution:

(a) The point where whole weight of an object appears to act.

Learning CORNER

(b) (i)



Resolve tension T into its components and apply principle of moment i.e.,

$$\text{Sum of clockwise moments} = \text{sum of anticlockwise moments}$$

$$(2.4)(0.95) + (T\sin30°)(0.95 + 0.35) = (54)(0.45)$$

$$(2.28) + (T\sin30°)(1.3) = 24.3$$

$$0.65T = 22.02$$

$$T = 34 \text{ N}$$

(ii) Clockwise moment $= (2.4)(0.95) = 2.28$ Nm

Anticlockwise moment $= (54)(0.45) = 24.3$ Nm

Resultant moment in anticlockwise direction

$= 24.3 - 2.28 \approx 22.0$ Nm

(c) (i) Gravitational potential energy, $\Delta E_p = mgh_Y - mgh_X$

$$= (2.4)(0) - (2.4)(1.8)$$

$$= -4.32 \text{ J}$$

–ve sign shows that gravitational potential energy decreases.

(ii) Total energy at X = Kinetic energy at Y

$$E_k + E_p = E_k \text{ at Y}$$

$$\frac{1}{2}mv^2 + E_p = E_k$$

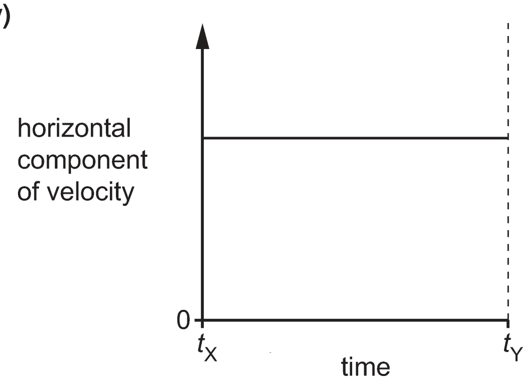
$$\frac{1}{2}\left(\frac{2.4}{9.81}\right)(3.4)^2 + 4.32 = E_k$$

$$E_k = 5.74$$

$\therefore$ Kinetic energy at Y = 5.74 J

(iii) No change, as only force acting is the gravitational pull of Earth.

(iv)



(c) (iv) Horizontal component of velocity remain constant as no force acts horizontally.

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Question 13

A vertical rod is fixed to the horizontal surface of a table, as shown in Fig. 3.1.

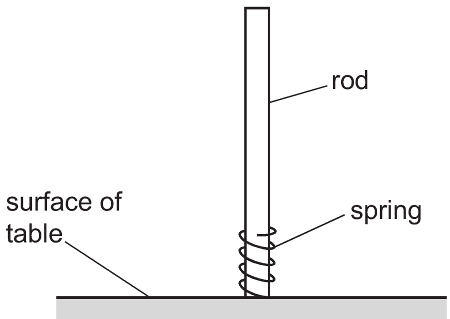

Fig. 3.1 (not to scale)

A spring of mass 7.5 g is able to slide along the full length of the rod.

The spring is first pushed against the surface of the table so that it has an initial compression of 2.1 cm. The spring is then suddenly released so that it leaves the surface of the table with a kinetic energy of 0.048 J and then moves up the rod.

Assume that the spring obeys Hooke's law and that the initial elastic potential energy of the compressed spring is equal to the kinetic energy of the spring as it leaves the surface of the table. Air resistance is negligible.

(a) By using the initial elastic potential energy of the compressed spring, calculate its spring constant. [2]

(b) Calculate the speed of the spring as it leaves the surface of the table. [2]

(c) The spring rises to its maximum height up the rod from the surface of the table. This causes the gravitational potential energy of the spring to increase by 0.039 J.

(i) Calculate, for this movement of the spring, the increase in height of the spring after leaving the surface of the table. [2]

(ii) Calculate the average frictional force exerted by the rod on the spring as it rises. [2]

(d) The rod is replaced by another rod that exerts negligible frictional force on the moving spring. The initial compression x of the spring is now varied in order to vary the maximum increase in height Δh of the spring after leaving the surface of the table. Assume that the spring obeys Hooke's law for all compressions.

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On Fig. 3.2, sketch a graph to show the variation with x of Δh. Numerical values are not required.

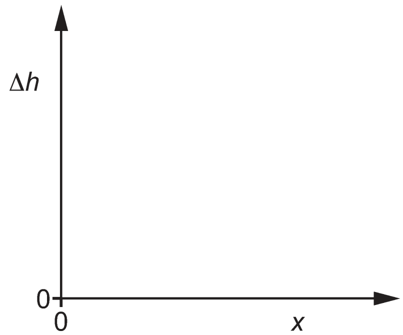


Fig. 3.2

[2]

[N23/P2/Q3]

Suggested Solution:

(a) Initial Elastic potential energy of spring,

$$E_K = 0.048 \text{ J}$$

$$\Rightarrow \frac{1}{2}ke^2 = 0.048$$

$$\Rightarrow k = \frac{2(0.048)}{e^2}$$

$$= \frac{2(0.048)}{(2.1\times10^{-2})^2} = 217.7 \approx 218 \text{ N m}^{-1}$$

$\therefore$ spring constant $= 218 \text{ N m}^{-1}$

(b) $E_K = \frac{1}{2}mv^2$

$$\Rightarrow 0.048 = \frac{1}{2}(7.5\times10^{-3})v^2$$

$$\Rightarrow v = \sqrt{\frac{2(0.048)}{7.5\times10^{-3}}} = 3.58 \approx 3.6 \text{ m s}^{-1}$$

(c) (i) $\Delta E_P = mg(\Delta h)$

$$0.039 = (7.5\times10^{-3})(9.81)\Delta h$$

$$\Delta h = \frac{0.039}{(7.5\times10^{-3})(9.81)} = 0.530 \text{ m}$$

(ii) Initial K.E = work against friction + gain in G.P.E

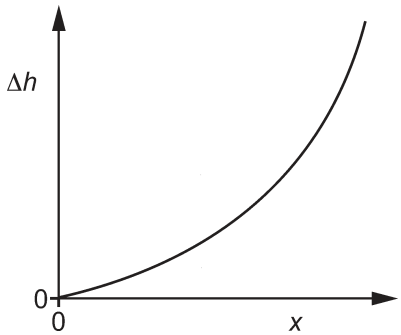
$$0.048 = (F)(0.530) + 0.039$$

$$F = \frac{0.048 - 0.039}{0.530} = 0.0170 \text{ N}$$

$\therefore$ average frictional force $= 0.0170$ N

(c) (ii) Use principle of conservation of energy.

(d)



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(d) By principle of conservation of energy.

$$mg\Delta h = \frac{1}{2}kx^2$$

$$\Rightarrow \Delta h = \left(\frac{k}{2mg}\right)x^2$$

$$\Rightarrow \Delta h \propto x^2$$

So, trend should be increasing gradient in graph.

Question 14

A pinball machine uses a spring to launch a small metal ball of mass 4.5×10^{-2} kg up a ramp. The spring is compressed by 8.0×10^{-2} m and held in equilibrium, as shown in Fig. 4.1.

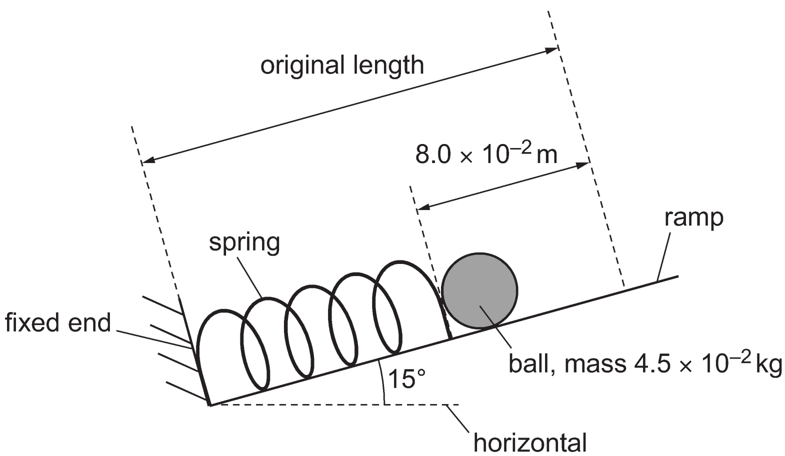


Fig. 4.1

The ramp is at an angle of 15° to the horizontal.

(a) The spring obeys Hooke's law and has a spring constant of 29 N m^{-1}.

Calculate the elastic potential energy in the compressed spring. [2]

(b) The spring is released and expands quickly back to its original length.

(i) Calculate the increase in gravitational potential energy of the ball when the spring returns to its original length. [3]

(ii) The ball leaves the spring when the spring reaches its original length. Assume that all the elastic potential energy of the spring is transferred to the ball.

Calculate the speed of the ball as it leaves the spring. [3]

(c) The ball comes to rest on a horizontal trapdoor of negligible mass at a distance *d* from its pivot.

A force *F* acts vertically downwards at a distance of 2.0 cm from the pivot, as shown in Fig. 4.2.

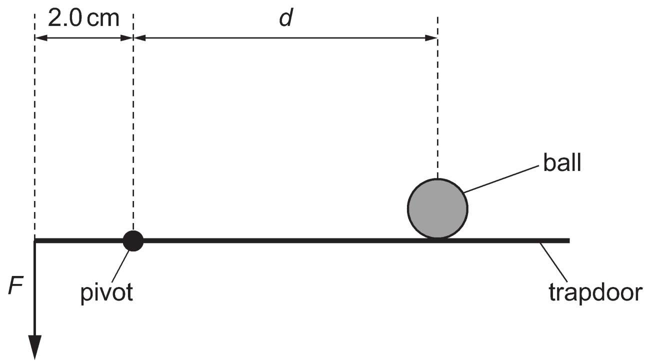


Fig. 4.2

(i) The trapdoor is in equilibrium when F is 1.7 N.
Calculate d. [2]

(ii) Force F is decreased from 1.7 N.
State the direction of the resultant moment about the pivot on the trapdoor. [1]

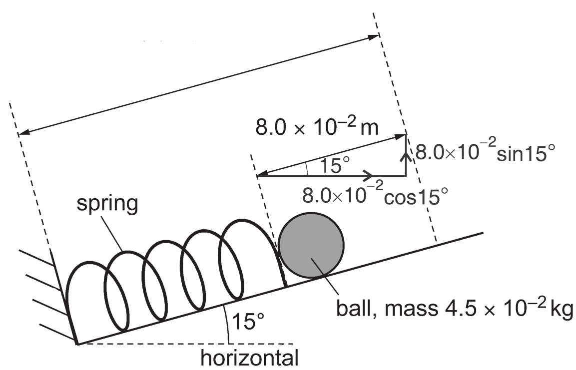
[J24/P2/Q4]

Suggested Solution:

(a) $E_p = \frac{1}{2}ke^2$

$= \frac{1}{2}(29)(8.0\times10^{-2})^2$

$= 0.0928\text{ J} = 9.28\times10^{-2}\text{ J}$



(b) (i) Increase in gravitational potential energy,

$\Delta E_p = mg(\Delta h)$

$= (4.5\times10^{-2})(9.81)(8.0\times10^{-2}\sin15°)$

$= 9.14\times10^{-3}\text{ J}$

(ii) Loss of elastic P.E. = gain in G.P.E. + gain in K.E.

$\Rightarrow\ 9.28\times10^{-2} = 9.14\times10^{-3} + \frac{1}{2}(4.5\times10^{-2})v^2$

$\Rightarrow\ \frac{1}{2}(4.5\times10^{-2})v^2 = 9.28\times10^{-2} - 9.14\times10^{-3}$

$\Rightarrow\ v = \sqrt{\dfrac{2(9.28\times10^{-2} - 9.14\times10^{-3})}{4.5\times10^{-2}}} \quad \Rightarrow \quad v = 1.93\text{ m s}^{-1}$

(c) (i) Clockwise moment = anticlockwise moment

$(F)(2.0\times10^{-2}) = (mg)(d)$

$(1.7)(2.0\times10^{-2}) = (4.5\times10^{-2})(9.81)(d)$

$d = \dfrac{(1.7)(2.0\times10^{-2})}{(4.5\times10^{-2})(9.81)}$

$d = 7.70\times10^{-2}\text{ m}$

(ii) Clockwise moment