9702/21/M/J/16/Q2

1 A ball is thrown from a point P with an initial velocity u of $12\,\mathrm{m\,s^{-1}}$ at 50° to the horizontal, as illustrated in Fig. 2.1.

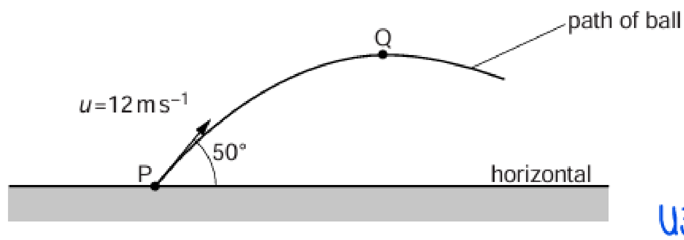
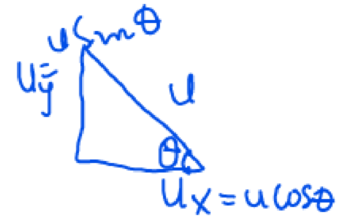


Fig. 2.1



The ball reaches maximum height at Q.

Air resistance is negligible.

(a) Calculate

(i) the horizontal component of u,

$U = 12\,\mathrm{ms^{-1}}$ $\quad U_x = u\cos\theta = 12\cos 50 = 7.7\,\mathrm{ms^{-1}}$

$\theta = 50°$

horizontal component = ...7.7.... $\mathrm{m\,s^{-1}}$ [1]

(ii) the vertical component of u.

$U_y = U\sin\theta$

$12\sin 50 = 9.2\,\mathrm{ms^{-1}}$

vertical component = ...$9.2\,\mathrm{ms^{-1}}$.... $\mathrm{m\,s^{-1}}$ [1]

(b) Show that the maximum height reached by the ball is 4.3 m.

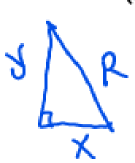
At max Height $V_y = 0$, $U_y = 9.2\,\mathrm{ms^{-1}}$

$a = -g$ (ball is thrown vertically upward)

$V_y^2 = U_y^2 + 2gH$, $0^2 = 9.2^2 - 2 \times 9.8 \times H$

$9.2^2 = 19.6\,H$, $H = 9.2^2/19.6 = 4.31\,\mathrm{m}$ [2]

(c) Determine the magnitude of the displacement PQ.



First find time $\quad 4.3 = 0 \times t + \frac{1}{2} \times 9.8 \times t^2$

$H = ut + \frac{1}{2}gt^2$, $\quad 8.6 = 9.8\,t^2$

$t^2 = \frac{8.6}{9.8}$, $\quad t = \sqrt{\frac{8.6}{9.8}} = 0.94$ seconds.

$S_x = ut = 7.7 \times 0.94 = 7.24\,\mathrm{m}$. $\quad R = \sqrt{4.3^2 + 7.24^2}$

displacement = ...8.41.... m [4]

[Total: 8]

9702/21/M/J/16/Q3

2 A ball of mass 150 g is at rest on a horizontal floor, as shown in Fig. 3.1.

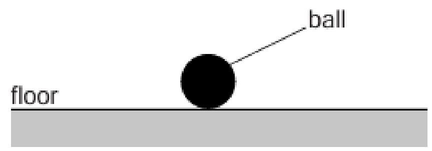


Fig. 3.1

(a) **(i)** Calculate the magnitude of the normal contact force from the floor acting on the ball.

$R = mg = \frac{150}{1000} kg \times 9.8$

force = 1.47 N [1]

(ii) Explain your working in **(i)**.

Weight = Normal reaction = mg
The forces are equal but
opposite in direction. [1]

(b) The ball is now lifted above the floor and dropped so that it falls vertically, as illustrated in Fig. 3.2.

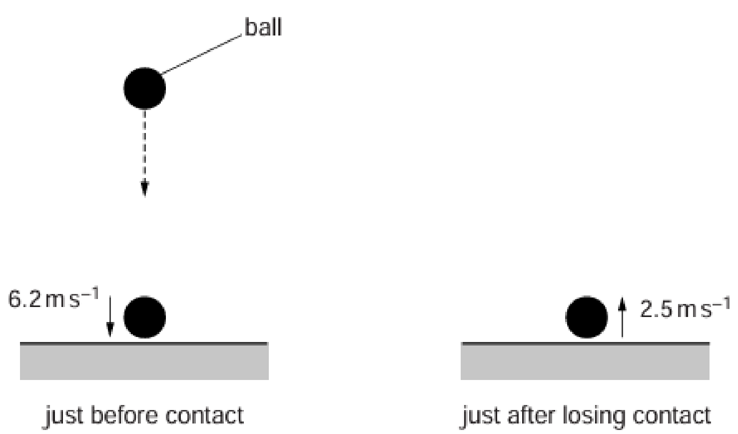


Fig. 3.2

Just before contact with the floor, the ball has velocity 6.2 m s^{-1} downwards. The ball bounces from the floor and its velocity just after losing contact with the floor is 2.5 m s^{-1} upwards. The ball is in contact with the floor for 0.12 s.

(i) State Newton's second law of motion.

Force is proportional to the rate of change of momentum [1]

(ii) Calculate the average resultant force on the ball when it is in contact with the floor.

$f \propto \frac{\delta p}{\delta t}$

$f = \frac{m(v-u)}{t}$

$f = \frac{0.15(-2.5 - (-6.2))}{0.12}$

$F = 0.15 \frac{(6.2 + 2.5)}{0.12} = 10.9$

magnitude of force = 10.9 N

direction of force upward

[3]

(iii) State and explain whether linear momentum is conserved during the collision of the ball with the floor.

Linear momentum is conserved because total momentum of ball before hitting the ground is equal to total [2]

momentum after hitting the ground.

[Total: 8]

3 **(a)** Explain what is meant by *gravitational potential energy* and by *kinetic energy*.

gravitational potential energy: This is the energy stored by a body due to it position or heigh

kinetic energy: This is the energy possessed by a body by virtue of it motion

[2]

(b) A motion sensor is used to measure the velocity of a ball falling vertically towards the ground, as illustrated in Fig. 3.1.

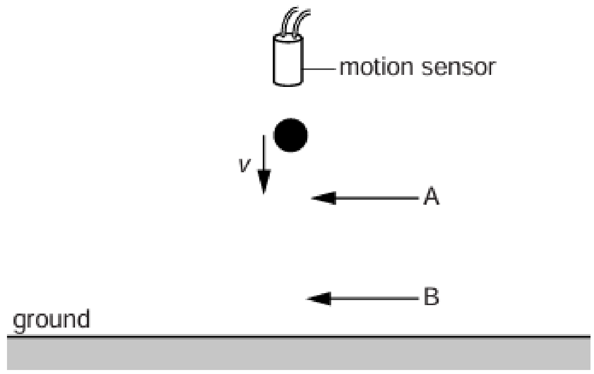


Fig. 3.1

The ball passes through points A and B as it falls. The ball has a mass of 1.5 kg.

The variation with time t of the velocity v of the ball as it falls from A to B is shown in Fig. 3.2.

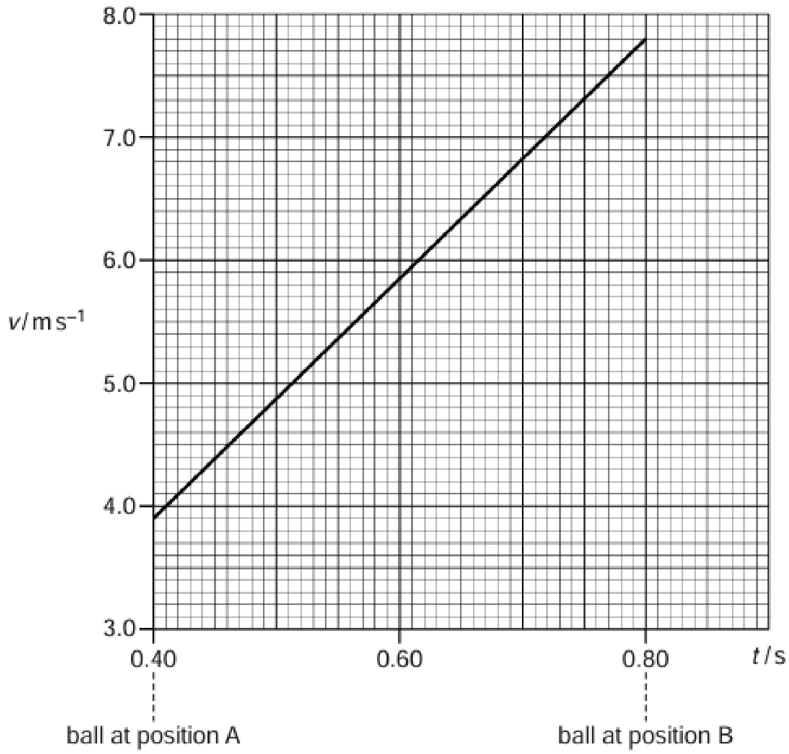


Fig. 3.2

Use Fig. 3.2 to calculate, for the ball falling from A to B,

(i) the displacement, the area under a velocity time graph is the displacement

the area under the the graph is the area of a triangle

$$A = \frac{1}{2} \times b \times h = \left(\frac{u+v}{2}\right) \times t = \frac{3.9 + 7.8}{2} \times 0.4$$

displacement = 2.34 m [3]

(ii) the acceleration, acceleration is the gradient of a velocity time graph

$$a = \frac{\Delta v}{\Delta t} = \frac{v - u}{t_2 - t_1} = \frac{7.8 - 3.9}{0.8 - 0.4} = \frac{3.9}{0.4} = 9.75$$

acceleration = 9.75 m s^{-2} [2]

The variation with time t of the velocity v of the ball as it falls from A to B is shown in Fig. 3.2.

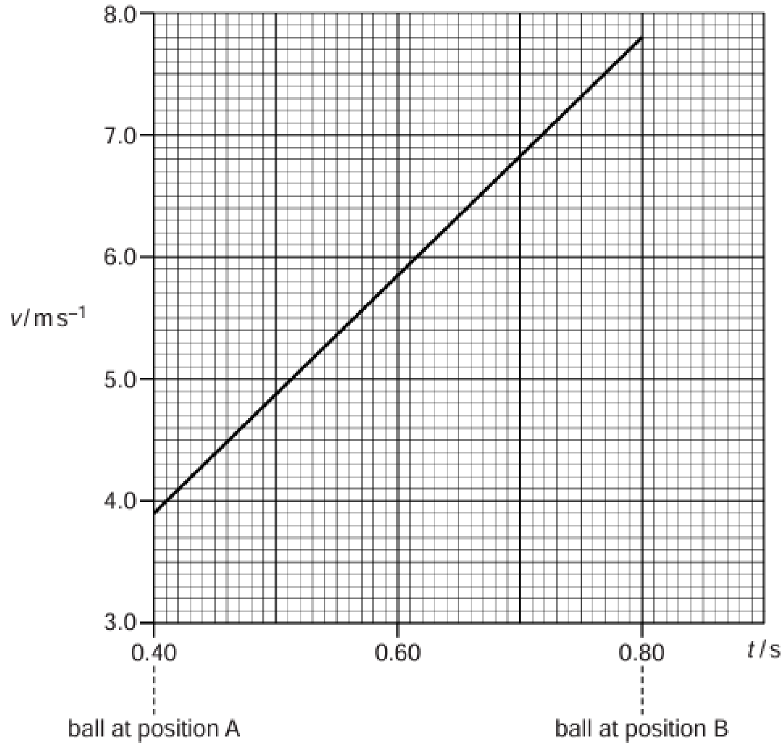


Fig. 3.2

Use Fig. 3.2 to calculate, for the ball falling from A to B,

(i) the displacement, the area under a velocity time graph is the displacement

the area under the the graph is the area of a triangle

$$A = \frac{1}{2} \times b \times h = \left(\frac{u+v}{2}\right) \times t = \frac{3.9 + 7.8}{2} \times 0.4$$

displacement = 2.34 m [3]

(ii) the acceleration, acceleration is the gradient of a velocity time graph

$$a = \frac{\Delta v}{\Delta t} = \frac{v-u}{t_2 - t_1} = \frac{7.8 - 3.9}{0.8 - 0.4} = \frac{3.9}{0.4} = 9.75$$

acceleration = 9.75 m s^{-2} [2]

4 **(a)** State the law of conservation of momentum.

it states that, in a closed system the rate of change of momentum is constant, i.e momentum before collision is equal to momentum after collision

.... [2]

(b) Two particles A and B collide elastically, as illustrated in Fig. 5.1.

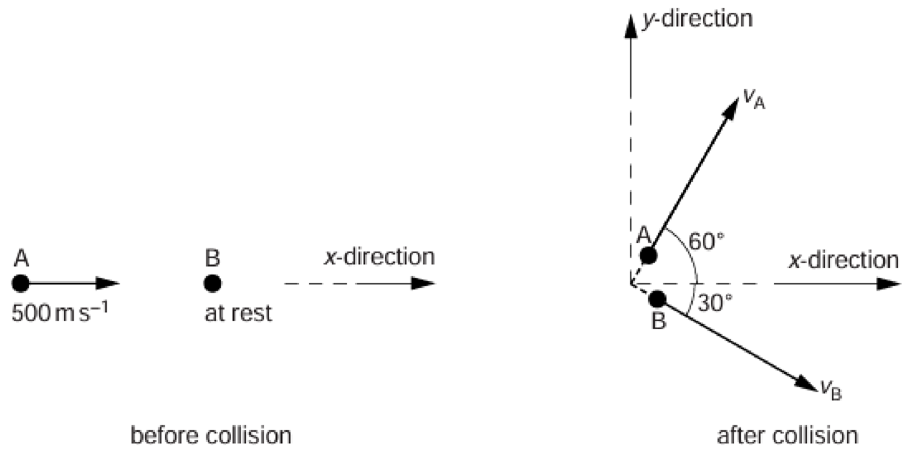


Fig. 5.1

The initial velocity of A is $500\,\mathrm{m\,s^{-1}}$ in the *x*-direction and B is at rest.

The velocity of A after the collision is v_A at 60° to the *x*-direction. The velocity of B after the collision is v_B at 30° to the *x*-direction.

The mass *m* of each particle is 1.67×10^{-27} kg.

(i) Explain what is meant by the particles colliding *elastically*.

It means that kinetic energy is not lost [1]

(ii) Calculate the total initial momentum of A and B.

$M_A U_A + M_b U_b$, $U_A = 500\,ms^{-1}$ $U_B = 0$ (at rest)

$m = 1.67 \times 10^{-27}$

$(1.67 \times 10^{-27} \times 500) + (1.67 \times 10^{-27} \times 0) = 8.35 \times 10^{-25} + 0$

momentum = 8.35×10^{-25} N s [1]

(iii) State an expression in terms of m, v_A and v_B for the total momentum of A and B after the collision

1. in the x-direction,

$m_A v_A \cos 60 + m_B v_B \cos 30$ They move in same direction

2. in the y-direction.

$m_A v_A \sin 60 - m_B v_B \sin 30$ They move in opposite direction

[2]

(iv) Calculate the magnitudes of the velocities v_A and v_B after the collision.

$m_A u_A + m_B u_B = m_A v_A + m_B v_B$

$1.67 \times 10^{-27} \times 500 + 1.67 \times 10^{-27} \times 0 = m v_A \cos 60 + m v_B \cos 30$

$8.35 \times 10^{-25} = m(v_A \cos 60 + v_B \cos 30)$ -- (1)

$0 = m v_A \sin 60 - m v_B \sin 30$

$0 = m(v_A \sin 60 - v_B \sin 30)$ --- (ii)

solve i and ii to get v_A and v_B.

v_A = ... m s^{-1}

v_B = ... m s^{-1}

[3]

[Total: 9]

9702/21/M/J/17/Q2

5 **(a)** State the two conditions for a system to be in equilibrium.

1. Sum of upward force must be equal to sum of downward force

2. The sum of clockwise turning moment about a point must be equal to sum of anticlockwise moment about same point. [2]

(b) A paraglider P of mass 95 kg is pulled by a wire attached to a boat, as shown in Fig. 2.1.

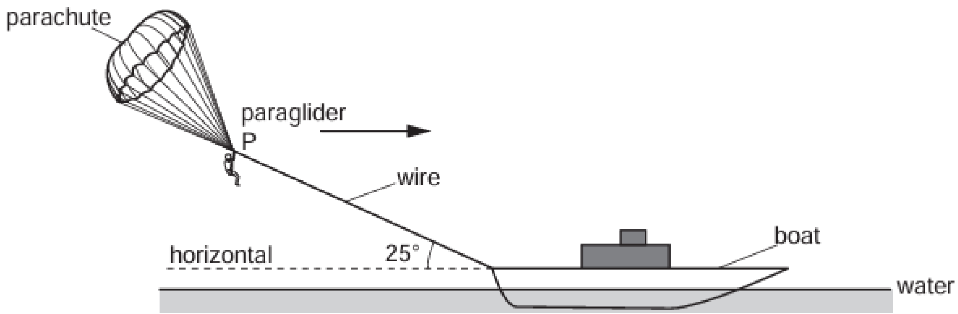


Fig. 2.1

The wire makes an angle of 25° with the horizontal water surface. P moves in a straight line parallel to the surface of the water.

The variation with time t of the velocity v of P is shown in Fig. 2.2.

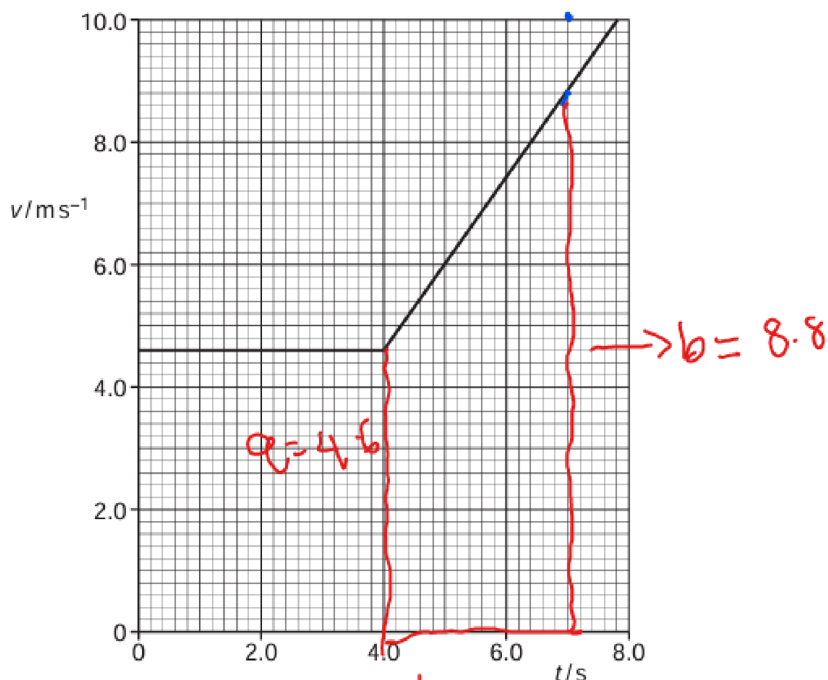


Fig. 2.2

h = 3

(i) Show that the acceleration of P is $1.4\,\mathrm{m\,s^{-2}}$ at time $t = 5.0\,\mathrm{s}$.

$a = v - u/t = \dfrac{8.8 - 4.6}{7.0 - 4.0} = \dfrac{4.2}{3.0} =$

$1.4\ \mathrm{ms^{-2}}$

[2]

(ii) Calculate the total distance moved by P from time $t = 0$ to $t = 7.0\,\mathrm{s}$.

distance = area under graph $= (L \times B) + \frac{1}{2}(a+b) \times h$

$(4.0 \times 4.6) + \left(\dfrac{8.8 + 4.6}{2}\right) \times 3$

distance = ...38.5 m....m [2]

(iii) Calculate the change in kinetic energy of P from time $t = 0$ to $t = 7.0\,\mathrm{s}$.

change in K.E $= \frac{1}{2} \times m\,(V^2 - U^2) = \frac{1}{2} \times 95 \times (8.8^2 - 4.6^2)$

$=$ $3678 - 1005 = 2673\ \mathrm{J}$

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

(iv) The tension in the wire at time $t = 5.0\,\mathrm{s}$ is 280 N.

Calculate, for the horizontal motion,

$W = m \times g = 95 \times 9.8 = 932$

1. the vertical lift force F supporting P,

Vertical tension force $= 280 \sin 25^\circ = 118.3\ \mathrm{N}$

$F = 118.3 + 932 = 1050.3\ \mathrm{N}$

F = ...1050N.... N [3]

2. the force R due to air resistance acting on P in the horizontal direction.

Resultant force $= m \times a$

$F_R = 95 \times 1.4 = 133\ \mathrm{N}$

horizontal tension force $= 280 \cos 25 = 253.8\ \mathrm{N}$

$133 = 258.3 - R,\quad R = 258.3 - 133 = 120.8\ \mathrm{N}$

R = ...120.8.... N [3]

[Total: 14]

6 **(a)** Define *velocity*.

Velocity is the rate of change of displacement.

[1]

(b) A ball of mass 0.45 kg leaves the edge of a table with a horizontal velocity *v*, as shown in Fig. 2.1.

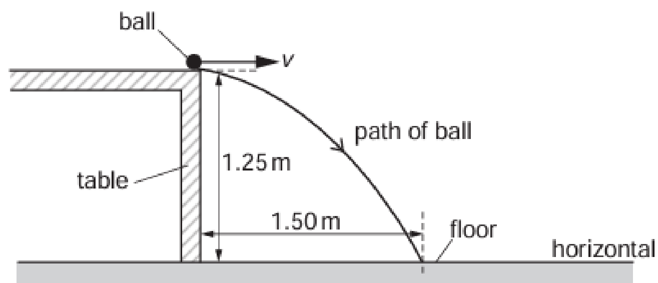


Fig. 2.1

The height of the table is 1.25 m. The ball travels a distance of 1.50 m horizontally before hitting the floor.

Air resistance is negligible.

Calculate, for the ball,

(i) the horizontal velocity *v* as it leaves the table,

$h = 1.25\ m$

$h = u_y t + \frac{1}{2} g t^2$

$1.25 = 0 \times t + \frac{1}{2} \times 9.8\ t^2$

$1.25 = 4.9 t^2$

$t^2 = \frac{1.25}{4.9}$

$t = \sqrt{0.255}$

$t = 0.5\ sec$

horizontal distance = 1.50m

$t = 0.5$

$S = vt$

$1.50 = V \times 0.5$

$v = 1.50/0.5 = 3\ ms^{-1}$

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

(ii) the velocity just as it hits the floor,

This has to do with vertical motion

$V_y^2 = u_y^2 + 2gh$

$V_y^2 = 0 + 2 \times 9.8 \times 1.25$

$V_y^2 = 24.5$

$V_y = \sqrt{24.5} = 4.94 m/s$

$\tan\theta = \frac{V_y}{V_x}$

$\theta = \tan^{-1}(3/5)$

$\theta = 59°$

magnitude of velocity = 4.94 m s^{-1}

angle to the horizontal = 59° °
[4]

(iii) the kinetic energy just as it hits the floor,

$\frac{1}{2} \times 0.45 \times 4.9^2$

$0.5 \times 0.45 \times 4.9^2$

kinetic energy = 5.40 J J [2]

(iv) the loss in gravitational potential energy as it falls from the table to the floor.

$= m \times g \times h = 0.45 \times 9.81 \times 1.25$

loss in potential energy = 5.5 J [2]

(c) Explain why the kinetic energy of the ball in **(b)(iii)** does not equal the loss of gravitational potential energy in **(b)(iv)**.

The ball has an initial velocity before leaving [1]

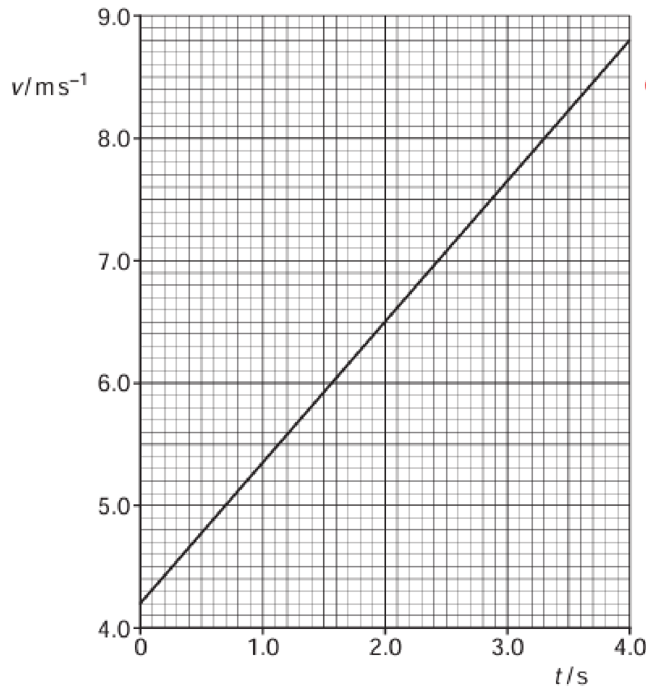
[Total: 13]

9702/23/M/J/17/Q2

8 (a) State Newton's second law of motion.

Force is proportional to the rate of change of momentum. [1]

(b) A constant resultant force F acts on an object A. The variation with time t of the velocity v for the motion of A is shown in Fig. 2.1.



at $t=0$

$u = 4.2$

at $t=4$ $v = 8.8$

Fig. 2.1

The mass of A is 840 g. = 0.84 Kg

Calculate, for the time $t = 0$ to $t = 4.0$ s,

(i) the change in momentum of A,

$f = \frac{m(v-u)}{t}$, $ft = m(v-u) = 0.84(8.8-4.2)$

$= 3.86 \simeq 3.9$

change in momentum = 3.9 kg m s^{-1} [2]

(ii) the force F.

$F = \frac{\Delta p}{t} = 3.9/4 = 0.965\,N$

$F =$ 0.97 N [1]

7 **(a)** State Newton's first law of motion.

Force is proportional to the rate of change of momentum ....[1]

(b) An object A of mass 100 g is moving in a straight line with a velocity of 0.60 m s^{-1} to the right. An object B of mass 200 g is moving in the same straight line as object A with a velocity of 0.80 m s^{-1} to the left, as shown in Fig. 4.1.

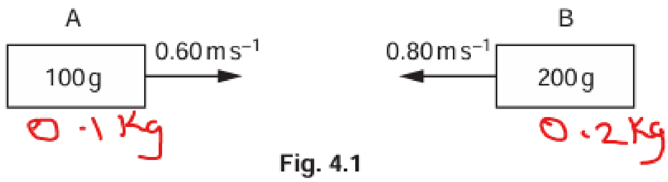


Fig. 4.1

Objects A and B collide. Object A then moves with a velocity of 0.40 m s^{-1} to the left.

(i) Calculate the magnitude of the velocity of B after the collision.

$m_A u_A + (-m_B u_B) = m_A v_A + m_B v_B$

$0.1 \times 0.6 - 0.2 \times 0.8 = 0.1 \times 0.4 + 0.2 v_B$

$0.06 - 0.16 = -0.04 + 0.2 v_B$

$-0.1 = -0.04 + 0.2 v_B$

$-0.1 + 0.04 = 0.2 v_B$

magnitude of velocity = ... -0.3 .... m s^{-1} [2]

(ii) The collision between A and B is inelastic.

Explain how the collision is inelastic and still obeys the law of conservation of energy.

Their Kinetic energy is not conserved but total energy is conserved.

....[1]

[Total: 4]

5 **(a)** Define the *frequency* of a sound wave.

The frequency of sound wave is the number of cycle per seconds ....[1]

(b) A sound wave travels through air. Describe the motion of the air particles relative to the direction of travel of the sound wave.

The motion of particle in air is parallel or the same to the ....[1] direction of travel of sound wave.

(c) The force F is removed at t = 4.0 s. Object A continues at constant velocity before colliding with an object B, as illustrated in Fig. 2.2.

Fig. 2.2

Object B is initially at rest. The mass of B is 730 g.
The objects A and B join together and have a velocity of 4.7 m s^{-1}.

(i) By calculation, show that the changes in momentum of A and of B during the collision are equal and opposite.

Change in momentum of A
$0.84(4.7 - 8.8) = -3.43$
Change in momentum of B
$0.73(4.7 - 0) = 3.44$
$-3.43 = 3.44$ (different in sign = opposite)

[2]

(ii) Explain how the answers obtained in **(i)** support Newton's third law.

The signs are different but the values are the same, this support Newton's third of law motion wh

which states that action and reaction are equal in magnitude but opposite in direction

....

....[2]

(iii) By reference to the speeds of A and B, explain whether the collision is elastic.

inelastic as relative speed of approach not equal to relative speed of separation

....[1]

[Total: 9]

9702/21/M/J/18/Q2

9 **(a)** State Newton's first law of motion.

a body continues at (rest or) constant velocity unless acted upon by a

resultant force ....[1]

(b) A block of weight 15 N hangs by a wire from a remotely controlled aircraft, as shown in Fig. 2.1.

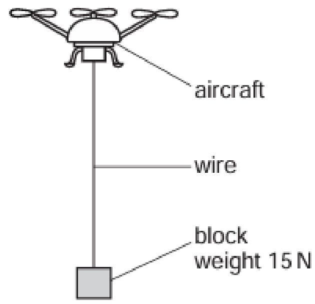


Fig. 2.1

The aircraft is used to move the block only in a vertical direction. The force on the block due to air resistance is negligible.

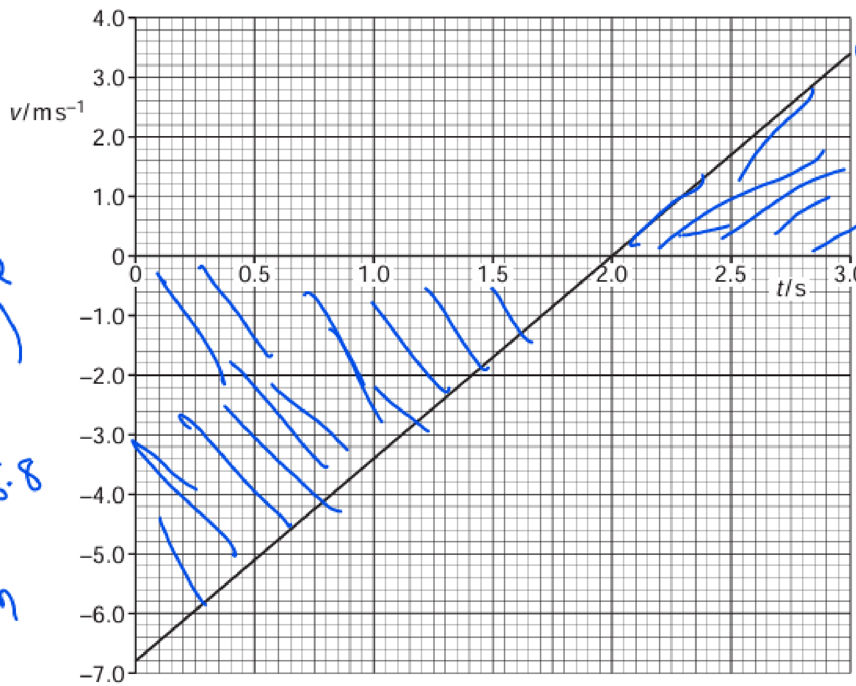
The variation with time t of the vertical velocity v of the block is shown in Fig. 2.2.
The velocity is taken to be positive in the upward direction.

for time 0 – 2 (sec)

$\frac{1}{2} \times b \times h$

$= \frac{1}{2} \times 2 \times 6.8$

$= 6.8$ m



displacement is the area under the graph $= \frac{1}{2} \times b \times h$

for time 2 – 3 seconds

$\frac{1}{2} \times 1 \times 3.4$

$= 1.7$ m

displacement $= 6.8 - 1.7 = 5.1$ m

Fig. 2.2

(i) Determine, for the block,

1. the displacement from time $t = 0$ to $t = 3.0$ s,

for time 2-3 sec $= \frac{1}{2} \times 1 \times 3.4 = 1.7$ m

for time 0-2 sec $= \frac{1}{2} \times 2 \times 6.8 = 6.8$ m

displacement $= 6.8 - 1.7 = 5.1$ m

magnitude of displacement = 5.1 m

direction of displacement downward

[3]

2. the change in gravitational potential energy from time $t = 0$ to $t = 3.0$ s.

$\Delta E = mg\Delta h = W \times h = 15 \times 5.1$

change in gravitational potential energy = 77 J [2]

(ii) Calculate the magnitude of the acceleration of the block at time $t = 2.0$ s.

The gradient of velocity-time graph is the acceleration.

$a = \frac{v-u}{t}$ or $dv/dt = \frac{3.4-0}{3-2} = 3.4\,ms^{-2}$

acceleration = 3.4 m s^{-2} [2]

(iii) Use your answer in **(b)(ii)** to show that the tension T in the wire at time $t = 2.0$ s is 20 N.

$T - W = ma$

$T = ma + 15$

$\frac{15}{9.81} \times 3.4 + 15 = 20.1986 \simeq 20$ N

[2]

(iv) The wire has a cross-sectional area of $2.8 \times 10^{-5}\,m^2$ and is made from metal of Young modulus 1.7×10^{11} Pa. The wire obeys Hooke's law.

Calculate the strain of the wire at time $t = 2.0$ s.

$E = \frac{F}{A} \div \frac{e}{l}$ - strain

$8tran = F/A \times E = \frac{20}{2.8 \times 10^{-5}} \times 1.7 \times 10^{11} =$

4.2×10^{-6}

strain = 4.2×10^{-6} [3]

(v) At some time after $t = 3.0$ s the tension in the wire has a constant value of 15 N.

State and explain whether it is possible to deduce that the block is moving vertically after $t = 3.0$ s.

The block is no longer moving
it is now in equilibrium
and there is no resultant
force. [2]

[Total: 15]

9702/21/M/J/18/Q3

10 **(a)** State what is meant by the *mass* of a body.

mass is the amount of matter in a body. [1]

(b) Two blocks travel directly towards each other along a horizontal, frictionless surface. The blocks collide, as illustrated in Fig. 3.1.

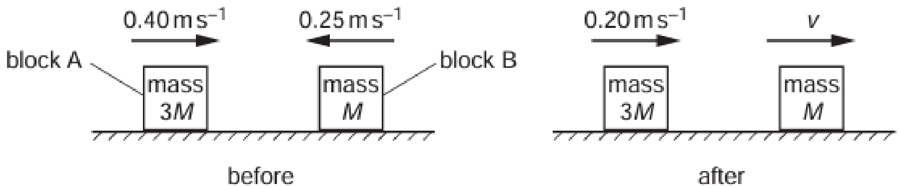


Fig. 3.1

Block A has mass $3M$ and block B has mass M.
Before the collision, block A moves to the right with speed $0.40\,\mathrm{m\,s^{-1}}$ and block B moves to the left with speed $0.25\,\mathrm{m\,s^{-1}}$.
After the collision, block A moves to the right with speed $0.20\,\mathrm{m\,s^{-1}}$ and block B moves to the right with speed v.

(i) Use Newton's third law to explain why, during the collision, the change in momentum of block A is equal and opposite to the change in momentum of block B.

Both A and B exerts equal and opposite force on each other [2]

(ii) Determine speed v.

$m_A u_A + m_B u_B = (m_A v + m_b v)$

$0.4 \times 3m - 0.25 \times m = (3m \times 0.2 + m v)$

$1.2m - 0.25m = 0.6m + mv$

$0.95m - 0.6m = mv$

$0.35m = mv$

$v = 0.35\,\mathrm{ms^{-1}}$

$v =$ 0.35 $\mathrm{m\,s^{-1}}$ [3]

(iii) Calculate, for the blocks,

1. the relative speed of approach,

relative speed of approach = $0.4 + 0.25 = 0.65$ m s^{-1}

2. the relative speed of separation.

relative speed of separation = $0.35 - 0.20 = 0.15$ m s^{-1}

[2]

(iv) Use your answers in **(b)(iii)** to state and explain whether the collision is elastic or inelastic.

(relative) speed of separation not equal to/less than (relative) speed of approach

[1]

[Total: 9]