DYNAMICS

Challenging **MCQ** questions by The Physics Cafe

Compiled and selected by The Physics Cafe

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

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.... [1]

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(b) A squash ball of mass **24 g** hits the wall when it reaches its maximum height of **3.2 m**. It leaves a racket which is **1.7 m** above the ground as seen in Fig. 1.1. The ball is incident on the wall with a horizontal velocity of **15 m s^{-1}** and rebounds in a horizontal direction with a velocity of **12 m s^{-1}**. The ball is in contact with the wall for **0.15 s**.

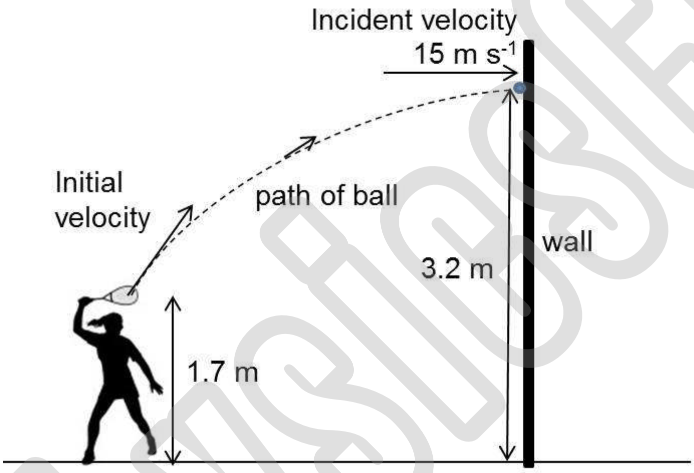

Fig. 1.1

(i) Calculate the initial vertical component of the ball's velocity.

vertical velocity = ……………. m s^{-1} [2]

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(ii) Determine the average force exerted on the wall during the ball's collision with the wall.

magnitude of the force = ……………………….. N

direction of force on the wall = ……………………........

[4]

(iii) State and explain whether the collision of the ball with the wall is elastic.

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.... [1]

(iv) Explain why the ball does not rebound to the point from where it was hit by the racket.

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.... [2]

Ans **(a)** It states that the **rate of change of momentum** of a body is **proportional** to the **resultant force** acting on it, and the **direction of momentum change** takes place in the direction of the resultant force.

(b) (i) Taking upwards as positive,

Using $v_y^2 = u_y^2 + 2as$

$0 = u_y^2 + 2(-9.81)(3.2 - 1.7)$

$u_y = 5.4 \text{ m s}^{-1}$

(ii) Applying Newton's 2nd law of motion, and taking rightwards as positive

$F_{avg} = \dfrac{\Delta p}{\Delta t}$,

$F_{avg} = \dfrac{m(v - u)}{t} = \dfrac{0.024(-12 - 15)}{0.15}$

= - 4.32 N (Force on ball by wall which acts to the left)

[1 for magnitude of F]

By Newton's 3rd law of motion, Force on wall by ball = - Force on ball by wall

= 4.32 N

Force on wall acts to the right.

(iii) It is **not elastic** as the speed of the ball has decreased from 15 m s^{-1} to 12 m s^{-1} which means that the **KE of the ball-wall system**, which is ½ mv^2, has **decreased.**

(iv) As the **horizontal velocity** is **reduced** after collision, with the **same time of flight** before collision with the wall, the **horizontal displacement** during rebound **will be reduced**. (The ball will land closer to the wall.)

Students must mention the reduction in both horizontal velocity and displacement.

2 **(a)** A simple two-stage rocket system consists of two components A and B as shown in Fig. 2.1. They are stacked one on top of another and fired in stages.

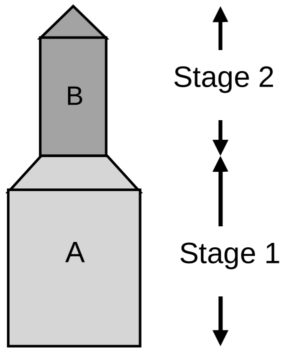

Fig. 2.1

When the two components separate in space, the variation of the force that component A exerts on component B is shown in Fig. 2.2 below.

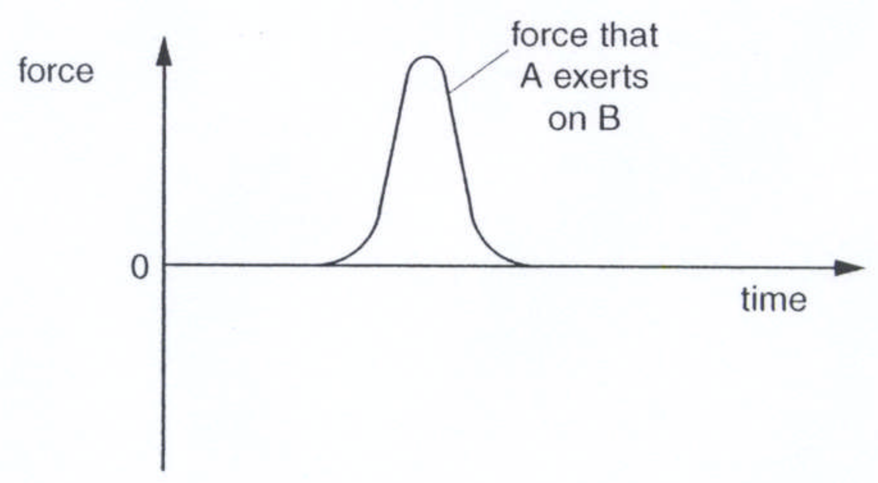

Fig. 2.2

(i) On Fig. 2.2, sketch the graph of the force that component B exerts on component A.

[1]

(ii) Suggest how the answer to **(i)** is consistent with the Principle of Conservation of Linear Momentum.

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.... [2]

(iii) The two-stage rocket consists of component A of mass *3m* and component B of mass 2*m*. The rocket is travelling in space at a constant speed V_o when an internal explosion causes component A to move backwards with a speed of $\frac{1}{3}V_o$.

Determine, in terms of V_o the speed of component B after the internal explosion.

speed of component B = ………………………… V_o [2]

(iv) Explain briefly why this two-stage rocket launching is advantageous compared to a single-stage launching from Earth.

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(b) Fig. 2.3 shows speed-time graphs for three spherical objects made of the same material but different radii, a_1, a_2, a_3, falling through a column of liquid after they are released from rest.

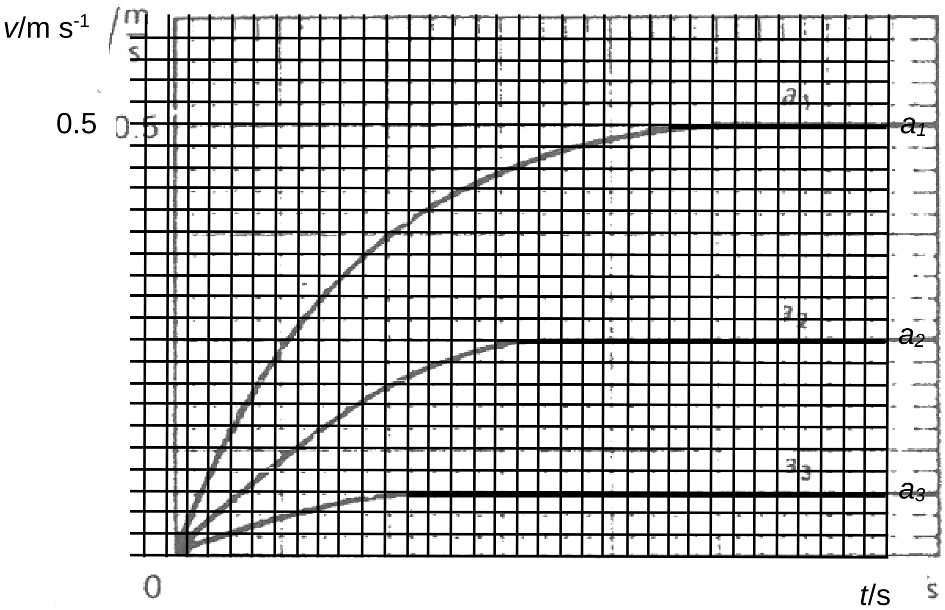

Fig. 2.3

(i) Explain qualitatively why the speeds tend to a constant value.

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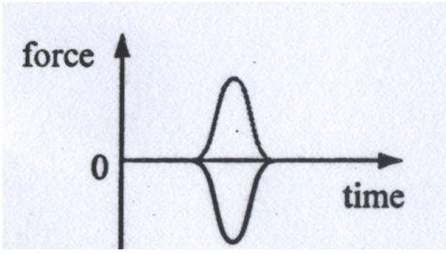
.... [3]

(ii) If the constant speed of a falling sphere is proportional to the square of its radius, calculate a_2 given that a_1 = 2.0 mm.

radius a_2 = ... mm [2]

Ans (a)(i)



[1] flip about $F = 0$

(a)(ii) When a variable force acts on an object, the change in momentum of the object is given by the area under the force-time graph.

The answer to (i) implies that the change in momentum of A and B are equal in magnitude and opposite in directions. [1]

Consider A and B as one system, their changes in momentum cancel out vectorially thus the total momentum of the system remains unchanged. [1]

(a)(iii) By Conservation of Linear Momentum,

$(2m + 3m)V_0 = (3m)(-\frac{1}{3}V_o) + 2mV_B$ [1] sub

$V_B = 3V_0$ [1] ans

(a)(iv) The internal explosion in the two-stage rocket gives additional forward force to component B, and hence its velocity increases. [1]

Furthermore, with a decrease in mass after discarding component A which is used as a fuel module, a greater acceleration can be experienced with the same thrust. [1]

b(i) The object experiences three forces acting on it namely weight *W*, upthrust *U* and a viscous force *R* when it moves in the liquid which opposes its motion. [1] statement
Net force on object,
$W - U - R = ma$
As the speed of object increases, viscous force increases,
acceleration of the object decreases until zero which implies that the object is moving at constant velocity. [1]
Hence the speed increases to a constant terminal value. [1]

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b(ii) Given $v \propto a^2$

$0.5 = k(2.0)^2$ ----- (1)

$0.25 = k(a_2)^2$ -------(2) [1] sub

$$\frac{(1)}{(2)} \quad \frac{0.5}{0.25} = \frac{2.0^2}{r_2^2}$$

r_2 = 1.4 mm [1] ans

3 A large metal ball is hung from a static crane by a cable of length **5.8 m** as shown in Fig. 1.1. In order to knock down a wall, a metal ball of mass **380 kg** is pulled away from the wall and then released. The ball moves through an arc and makes contact with the wall when the cable is vertical. The graph below in Fig. 1.2 shows the variation of the speed of the ball v with time t.

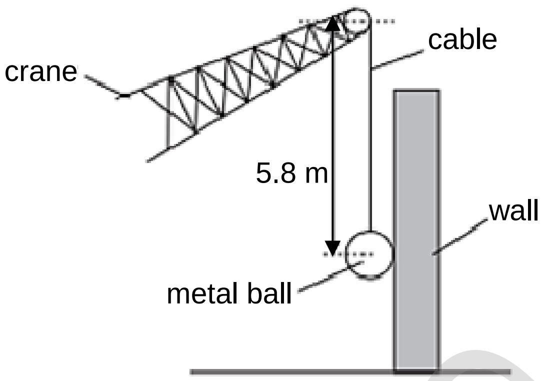

Fig. 1.1

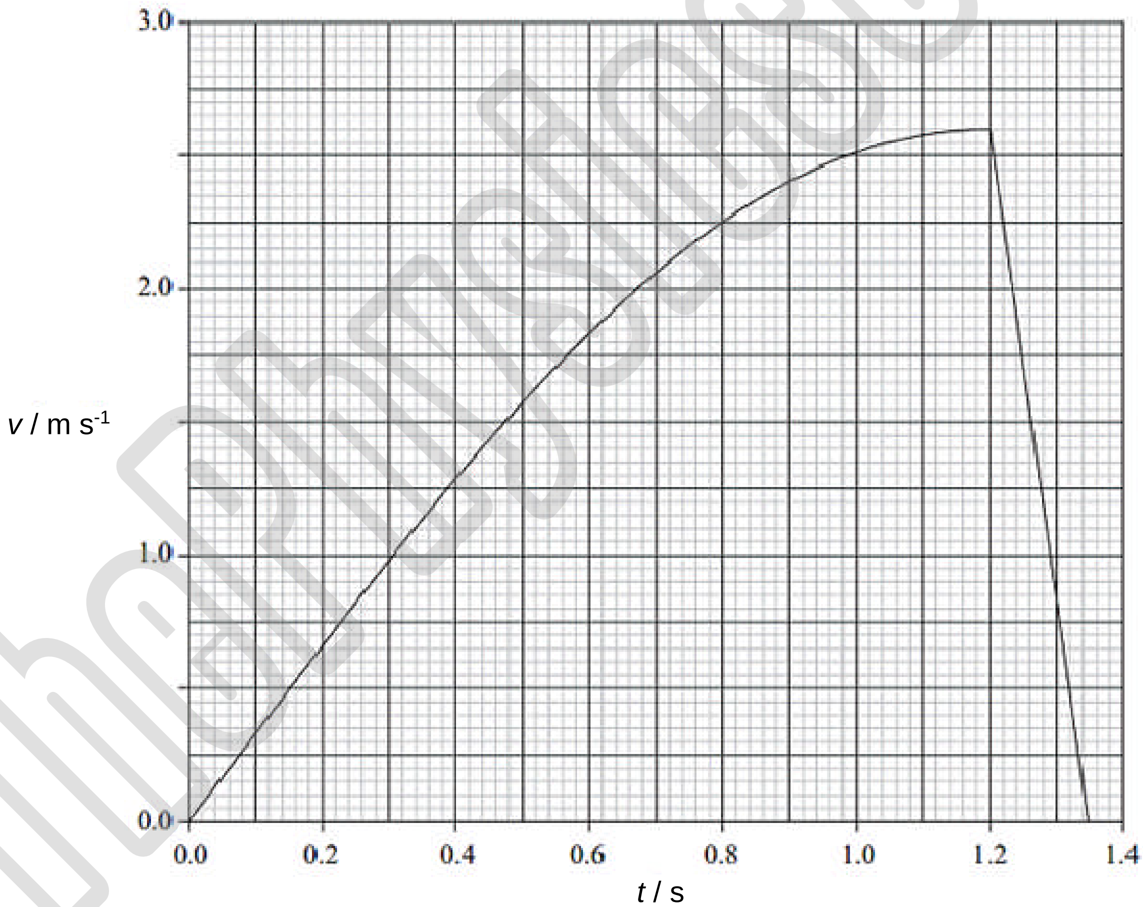

Fig. 1.2

(a) Just before the ball hits the wall,

(i) Explain why the tension is not equal to the weight of the ball.

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.... [2]

(ii) With reference to Fig. 1.2, estimate the tension in the cable.

tension = ………………………….. N [3]

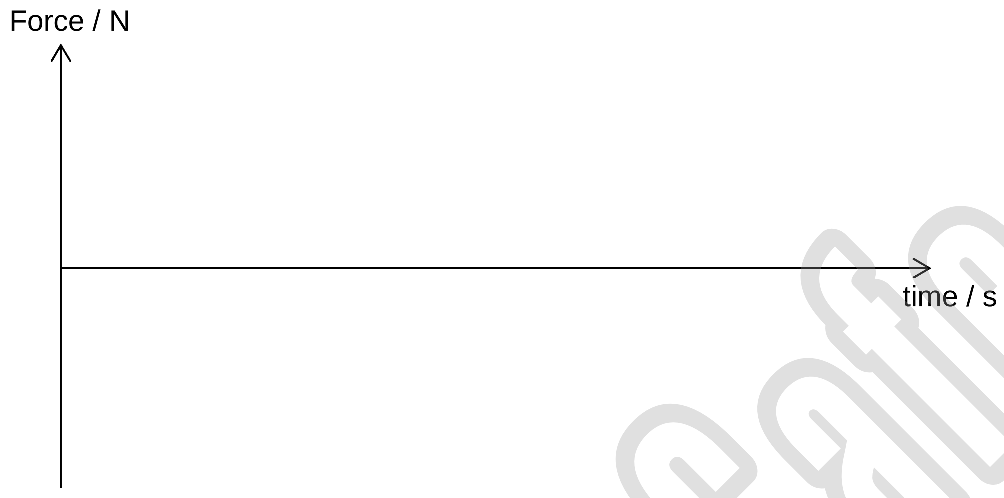
(b) Taking rightwards as positive, when the ball collides with the wall,

(i) determine the change in momentum of the ball.

magnitude of change in momentum = ………………………….. N s

direction of change in momentum = ……………………………… [2]

(ii) sketch a clearly labelled graph to show the variation with time of the force on the ball during the collision. [2]



(c) **(i)** State the *principle of conservation of momentum*.

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.... [1]

(ii) The ball has lost momentum in its collision with the wall. Explain whether the principle of conservation of momentum is violated in this situation.

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.... [2]

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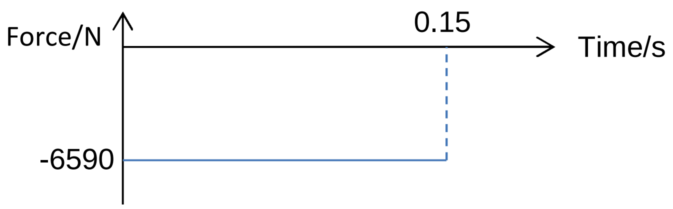
Ans **(a)** **(i)** Since the ball moves along the arc of a circle, M1
there will be a resultant force providing for the centripetal force. A1
Hence the tension is larger than the weight.

(ii) From the graph M1
$v = 2.6$ m s^{-1} at 1.2 s
Using N2L,
$F_{net} = ma$
Just before the ball hits the wall, it is almost vertical, hence
$T - mg = mv^2/r$
$T - (380 \times 9.81) = 380 \times 2.6^2 / 5.8$ M1
$T = 4170$ N A1

(b) **(i)** Change in momentum
$= p_f - p_i$
$= m(v_f - v_i)$
$= 380 (0 - 2.6)$
$= -988$ N s M1
The change in momentum of the ball is directed to the left, hence must have –ve A1
.

(ii) By N2L,
$$F = \frac{dp}{dt}$$
F = 988/0.15 (time interval read off from graph) A1
= 6590 N



Correct shape and labels for force and time
-1m for positive force. M1

(c) **(i)** From notes:
The **principle of conservation of momentum** states that the **total momentum** of a system of objects remains **constant** provided **no resultant external force** acts on the system. B2

(ii) Momentum is conserved:
The system is the ball, the wall and the Earth. M1

Loss in momentum of the ball equals to the gain in momentum of the wall and Earth. A1

OR

Momentum is not conserved: M1

There is an external force acting on the ball (system), so the ball's momentum is not conserved. A1

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