7 **(a)** Describe the structure of an **atom** of uranium-238, $^{238}_{92}\text{U}$.

....

....

.... [2]

(b) The decay of uranium-238 is shown by the equation

$$^{238}_{92}\text{U} \rightarrow \, ^{234}_{90}\text{Th} + \text{X}.$$

For nucleus X, calculate the ratio, in C kg^{-1}, of

$$\frac{\text{charge}}{\text{mass}}.$$

ratio = ... C kg^{-1} [3]

(c) Two particles P and Q each consist of three quarks. These quarks are up (u) or down (d) quarks.

Particle P has no overall charge.

Particle Q has an overall charge of $+2e$, where e is the elementary charge.

State the quark composition of:

(i) particle P

.... [1]

(ii) particle Q.

.... [1]

[Total: 7]

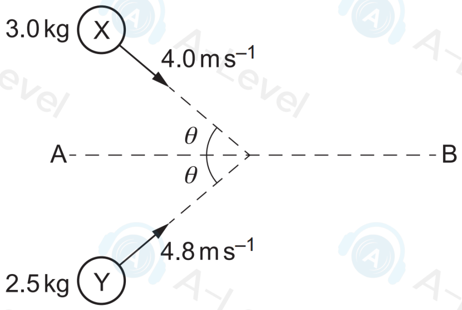
4 **(a)** State the principle of conservation of momentum.

....

....

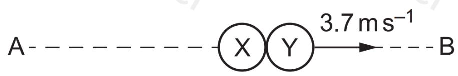
.... [2]

(b) Two balls, X and Y, move along a horizontal frictionless surface, as shown from above in Fig. 4.1.



before collision

Fig. 4.1 (not to scale)



after collision

Fig. 4.2 (not to scale)

Ball X has a mass of 3.0 kg and a velocity of $4.0\,\mathrm{m\,s^{-1}}$ in a direction at angle θ to a line AB. Ball Y has a mass of 2.5 kg and a velocity of $4.8\,\mathrm{m\,s^{-1}}$ in a direction at angle θ to the line AB.

The balls collide and stick together. After colliding, the balls have a velocity of $3.7\,\mathrm{m\,s^{-1}}$ along the line AB on the horizontal surface, as shown in Fig. 4.2.

(i) By considering the components of the momenta along the line AB, calculate θ.

θ = ... ° [3]

(ii) By calculation of kinetic energies, state and explain whether the collision of the balls is inelastic or perfectly elastic.

....

.... [2]

[Total: 7]

2 Water leaves the end of a hose pipe at point P with a horizontal velocity of $6.6\,\mathrm{m\,s^{-1}}$, as shown in Fig. 2.1.

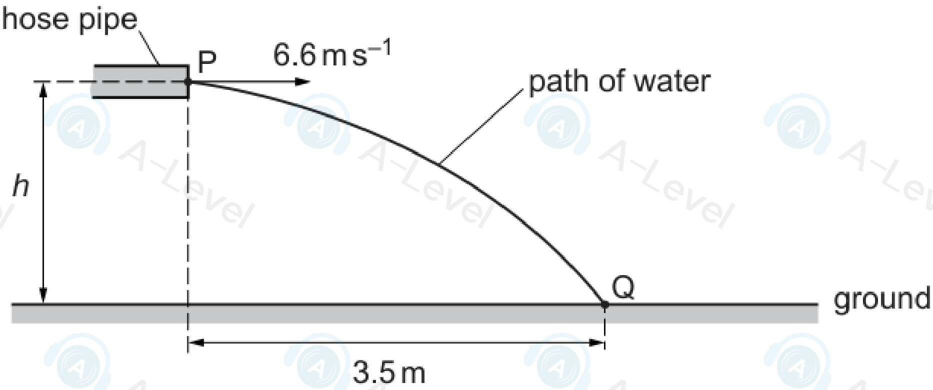


Fig. 2.1 (not to scale)

Point P is at height h above the ground. The water hits the ground at point Q. The horizontal distance from P to Q is 3.5 m.

Air resistance is negligible. Assume that the water between P and Q consists of non-interacting droplets of water and that the only force acting on each droplet is its weight.

(a) Explain, briefly, why the horizontal component of the velocity of a droplet of water remains constant as it moves from P to Q.

....

.... [1]

(b) Show that the time taken for a droplet of water to move from P to Q is 0.53 s.

[1]

(c) Calculate height h.

h = ... m [2]

(d) For the movement of a droplet of water from P to Q, state and explain whether the displacement of the droplet is less than, more than or the same as the distance along its path.

3 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.

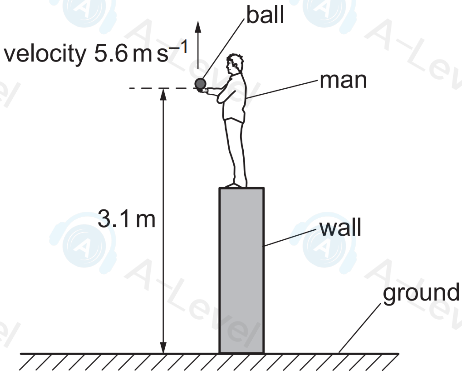


Fig. 3.1 (not to scale)

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.

time taken = ... s [2]

(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.

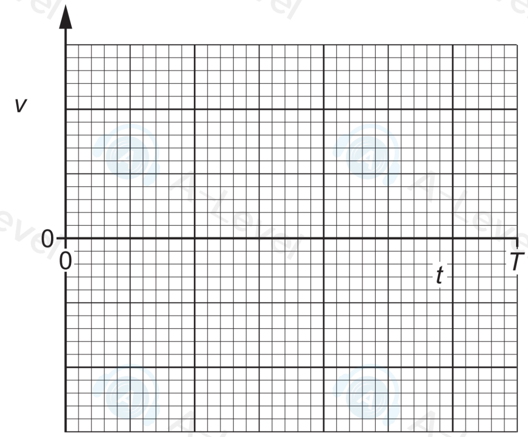


Fig. 3.2

[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]

[Total: 10]

6 **(a)** Define electric potential difference.

....

.... [1]

(b) A battery is connected to two resistors X and Y, as shown in Fig. 6.1.

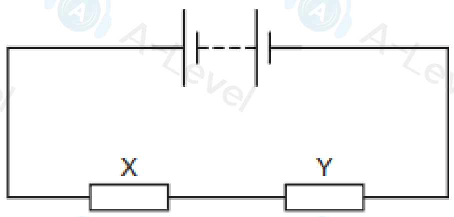


Fig. 6.1

The resistance of resistor X is greater than the resistance of resistor Y.

State and explain which resistor dissipates more power.

....

....

....

....

.... [3]

(c) A battery of electromotive force (e.m.f.) 9.0 V and internal resistance *r* is connected to two resistors P and Q, as shown in Fig. 6.2.

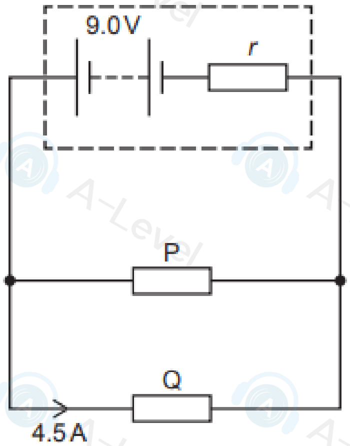


Fig. 6.2

A total charge of 650 C moves through resistor P in a time interval of 540 s. During this time resistor P dissipates 4800 J of energy. The current in resistor Q is 4.5 A. Assume that the e.m.f. of the battery remains constant.

Calculate:

(i) the current in resistor P

current = ... A [2]

(ii) the potential difference across resistor P

potential difference = ... V [2]

(iii) the internal resistance *r* of the battery.

r = ... Ω [2]

[Total: 10]

2 A spherical balloon is filled with a fixed mass of gas. A small block is connected by a string to the balloon, as shown in Fig. 2.1.

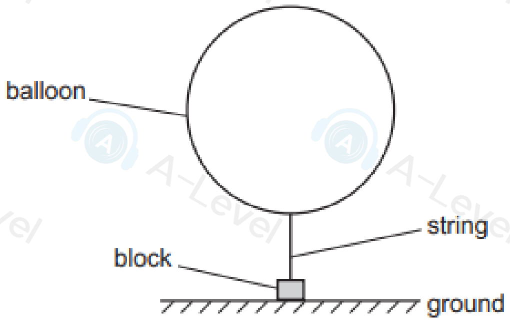


Fig. 2.1 (not to scale)

The block is held on the ground by an external force so that the string is vertical. The density of the air surrounding the balloon is $1.2\,kg\,m^{-3}$. The upthrust acting on the balloon is 0.071 N. The upthrust acting on the string and block is negligible.

(a) By using Archimedes' principle, calculate the radius *r* of the balloon.

r = ... m [2]

(b) The total weight of the balloon, string and block is 0.053 N.

The external force holding the block on the ground is removed so that the released block is lifted vertically upwards by the balloon.

Calculate the acceleration of the block immediately after it is released.

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

(c) The balloon continues to lift the block. The string breaks as the block is moving vertically upwards with a speed of $1.4\,m\,s^{-1}$. After the string breaks, the detached block briefly continues moving upwards before falling vertically downwards to the ground. The block hits the ground with a speed of $3.6\,m\,s^{-1}$.

Assume that the air resistance on the block is negligible.

(i) By considering the motion of the block after the string breaks, calculate the height of the block above the ground when the string breaks.

height = ... m [2]

(ii) The string breaks at time $t = 0$ and the block hits the ground at time $t = T$.

On Fig. 2.2, sketch a graph to show the variation of the velocity v of the block with time t from $t = 0$ to $t = T$.

Numerical values of t are not required. Assume that v is positive in the upward direction.

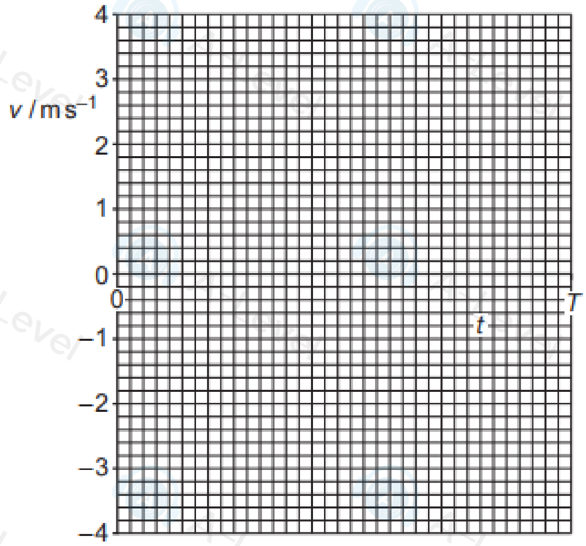


Fig. 2.2

[2]

[Total: 9]

4 A horizontal spring is fixed at one end. A block is pushed against the other end of the spring so that the spring is compressed, as shown in Fig. 4.1.

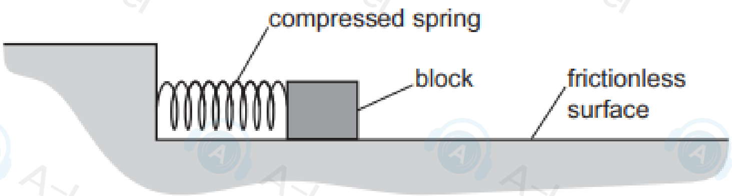


Fig. 4.1

The block is released and accelerates along a horizontal frictionless surface as the spring returns to its original length. The block leaves the end of the spring with a speed of $2.3\,m\,s^{-1}$, as shown in Fig. 4.2.

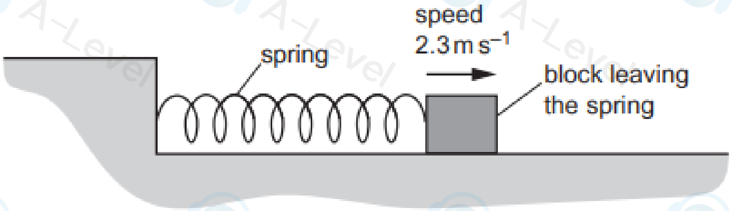


Fig. 4.2

The block has a mass of 250 g and the spring has a spring constant of $420\,N\,m^{-1}$.

Assume that the spring always obeys Hooke's law and that all the elastic potential energy of the spring is transferred to the kinetic energy of the block.

(a) Calculate the kinetic energy of the block as it leaves the spring.

kinetic energy = ... J [2]

(b) Calculate the compression of the spring immediately before the block is released.

compression = ... m [2]

(c) After leaving the spring, the block moves along the surface until it hits a barrier at a speed of $2.3\,\text{m}\,\text{s}^{-1}$. The block then rebounds at a speed of $1.5\,\text{m}\,\text{s}^{-1}$ and moves back along its original path. The block is in contact with the barrier for a time of 0.086 s.

Calculate:

(i) the change in momentum of the block during the collision

change in momentum = ... Ns [2]

(ii) the average resultant force exerted on the block during the collision.

average resultant force = ... N [1]

(d) The maximum compression x of the spring is now varied in order to vary the kinetic energy E_K of the block as it leaves the spring. Assume that all the elastic potential energy in the spring is always transferred to the kinetic energy of the block.

On Fig. 4.3, sketch a graph to show the variation with x of E_K.

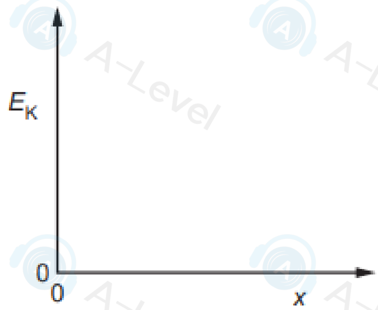


Fig. 4.3

[1]

[Total: 8]