1. Motion, forces and energy

1.6 Momentum

Paper 4

Question Paper

Paper 4

Questions are applicable for extended candidates only

1 Fig. 2.1 shows a golfer about to hit a golf ball with a golf club. The initial momentum of the golf ball is zero.

Fig. 2.1

(a) Define momentum.

..... [1]

(b) The golf club is in contact with the ball for 5.0×10^{-4} s. The velocity of the golf ball as it leaves the golf club is 41 m/s. The golf ball has a mass of 0.046 kg.

(i) Calculate the impulse on the golf ball.

impulse = ... [2]

(ii) Calculate the force applied to the ball by the golf club.

force = ... [2]

[Total: 5]

2 **(b)** The girl releases the ball and it falls towards the path. The ball strikes the path and bounces vertically upwards.

Fig. 1.1 shows the ball falling towards the path.

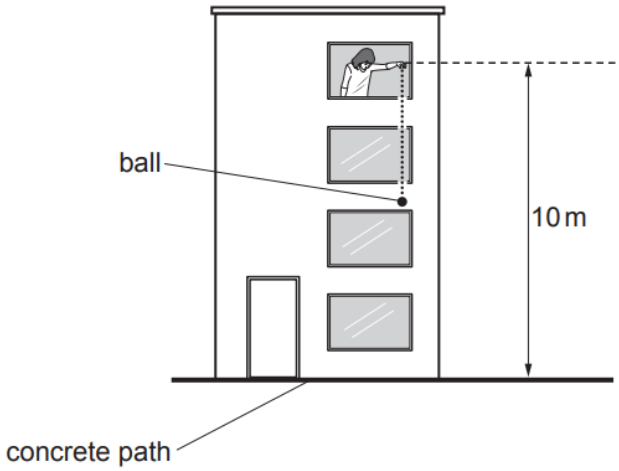

Fig. 1.1

The speed of the ball immediately **before** it strikes the path is 14 m/s.

The speed of the ball immediately **after** it strikes the path is 12 m/s.

(i) Calculate the kinetic energy of the ball immediately **after** it strikes the concrete path.

kinetic energy = ... [2]

(ii) Show that the change in momentum of the ball when it bounces off the path is 5.2 kg m/s.

[3]

(iii) The ball is in contact with the path for 0.25 s.

Calculate the average resultant force on the ball when it is in contact with the path.

force = ... [2]

[Total: 9]

3 **(a)** A balloon of mass 15 g is glued to a straw. The straw is threaded onto a horizontal string, as shown in Fig. 3.1.
The balloon is filled with air and then the air is released.

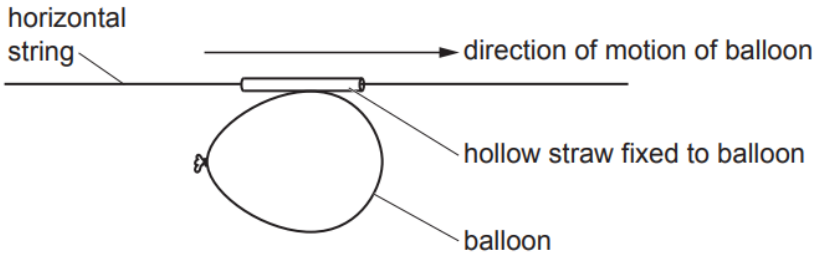

Fig. 3.1

As the air leaves the balloon, the balloon experiences a force.
The balloon accelerates from rest until it reaches a constant speed. It then travels 0.67 m in 0.18 s at this constant speed.

(i) Explain in words what is meant by the term impulse.

.....

..... [1]

(ii) Calculate the resultant impulse on the balloon while it is accelerating.

impulse = ... [3]

(iii) Explain how momentum is conserved as the balloon accelerates.

.....

.....

..... [2]

(b) Fig. 3.2 shows the directions of two forces acting on a different balloon as it moves.

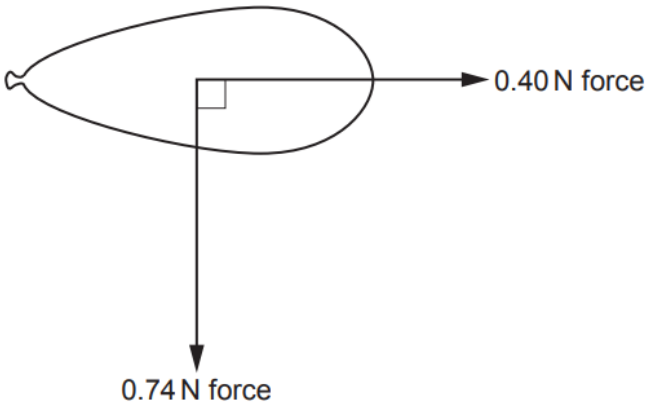

Fig. 3.2 (not to scale)

Determine the magnitude and direction of the resultant force on the balloon.

magnitude .....

direction relative to horizontal force .....
[4]

[Total: 10]

4 Two blocks, A and B, are joined by a thin thread that passes over a frictionless pulley. Block A is at rest on a rough horizontal surface and block B is held at rest, just below the pulley.

Fig. 1.1 shows the thread hanging loose.

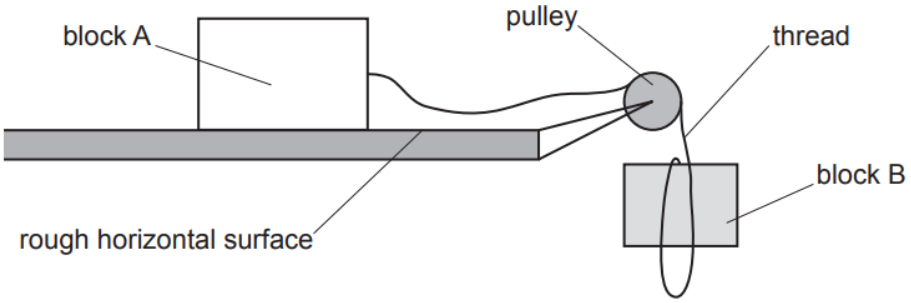

Fig. 1.1 (not to scale)

Block B is released and it falls vertically. The thread remains loose until block B has fallen a distance of 0.45 m.

The mass of block B is 0.50 kg.

(b) The mass of block A is 2.0 kg.

When the thread tightens, it pulls on block A which moves to the right at a speed of 0.60 m/s.

(i) Calculate the impulse exerted on block A as it accelerates from rest to 0.60 m/s.

impulse = ... [3]

(ii) Both of the blocks now move at a constant speed of 0.60 m/s until block B hits the ground and the thread becomes loose.

Explain the energy change that takes place in block A after block B stops moving.

.....

.....

.....

..... [3]

5 Fig. 3.1 shows a collision at very slow speed between two cars travelling along a straight road.

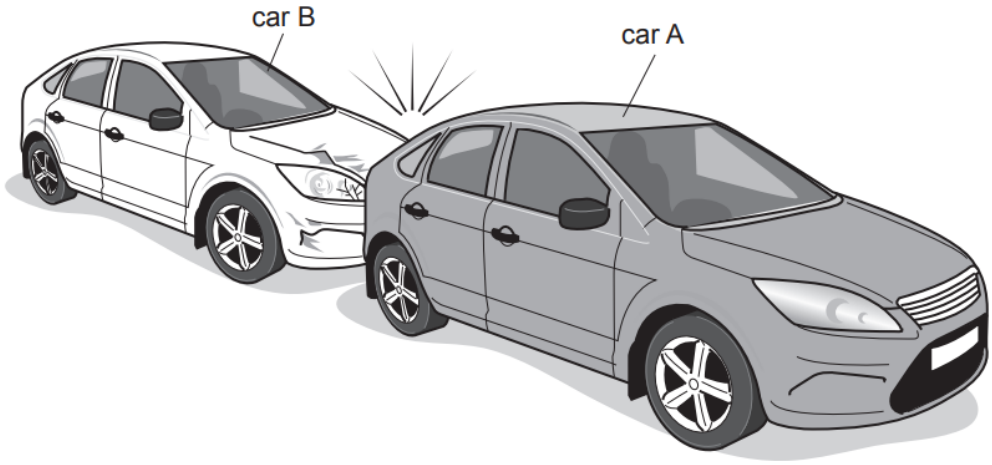

Fig. 3.1

Car B, of mass 800 kg, is moving at 2.0 m/s and collides with car A, of mass 1000 kg, which is stationary. After the collision, both cars travel in the same direction as the initial direction of car B.

(a) After the collision, car A moves at 1.3 m/s.

Show that the speed of car B after the collision is approximately 0.4 m/s.

[3]

(b) (i) Calculate the impulse exerted by car A on car B.

impulse = ... [2]

(ii) State the impulse exerted by car B on car A.

impulse = ... [1]

[Total: 6]

6 Fig. 2.1 shows a wooden trolley of mass 1.2 kg at rest on the rough surface of a bench.

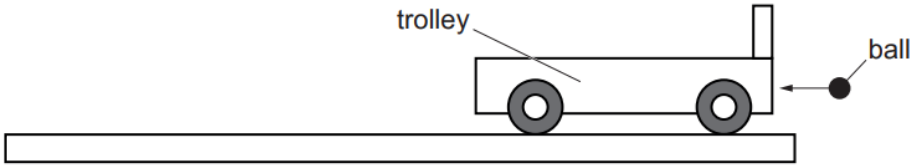

Fig. 2.1

A ball of mass 0.52 g travels horizontally towards the trolley. The ball embeds itself in the wood of the trolley. The trolley moves with an initial speed of 0.065 m/s.

(a) Calculate:

(i) the impulse exerted on the trolley

impulse = ... [2]

(ii) the speed of the ball as it hits the trolley.

speed = ... [2]

(b) As the trolley moves across the rough surface, it slows down and stops.

Explain, in terms of the work done, the energy change that takes place as the trolley slows down.

.....

.....

.....

..... [3]

[Total: 7]

7 Fig. 1.1 shows an ice-hockey player moving on ice. He is preparing to hit the solid disc called a puck.

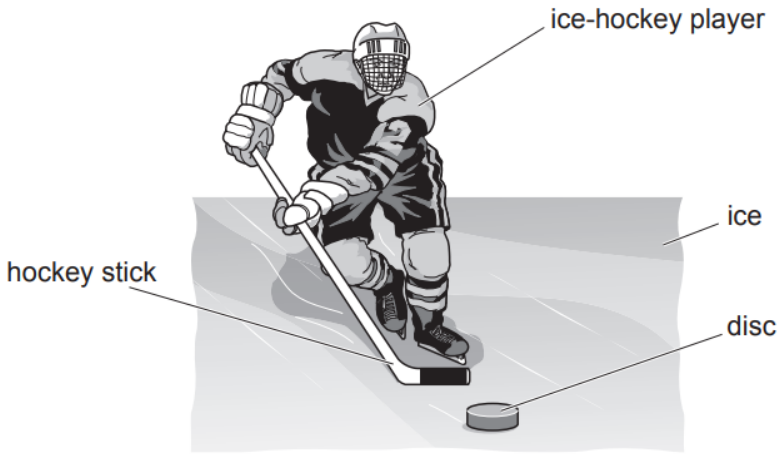

Fig. 1.1

The disc of mass 0.16 kg is moving horizontally across the surface of the ice at a speed of 15 m/s.

(a) Calculate the magnitude of the momentum of the disc.

magnitude of momentum = ... [2]

(b) The hockey player strikes the disc with his hockey stick and the momentum of the disc changes. The disc gains momentum of 3.0 kg m/s at 45° to the original direction of travel of the disc, as shown in Fig. 1.2.

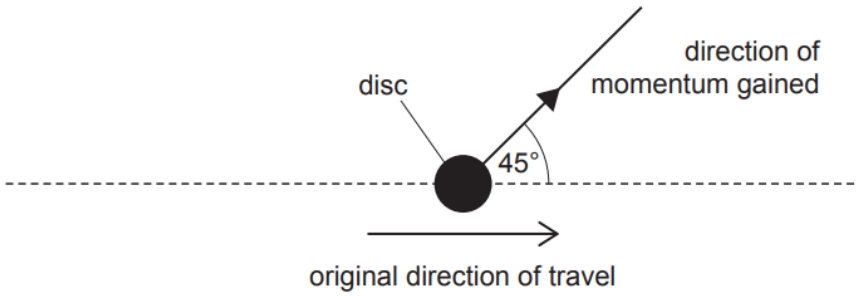

Fig. 1.2 (view from above)

(i) State the magnitude of the impulse exerted on the disc and the direction, in degrees, of the impulse relative to the original direction of travel.

magnitude of impulse = ...

direction of impulse: ..... ° to original direction

[1]

(ii) Determine the magnitude of the new momentum of the disc and its new direction relative to the original direction of travel by drawing a scale diagram.

magnitude of new momentum = ...

direction of new momentum: ..... ° to original direction

[4]

[Total: 7]

8 Fig. 2.1 shows a train.

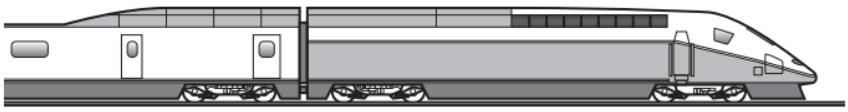

Fig. 2.1

The total mass of the train and its passengers is 750 000 kg. The train is travelling at a speed of 84 m/s. The driver applies the brakes and the train takes 80 s to slow down to a speed of 42 m/s.

(a) Calculate the impulse applied to the train as it slows down.

impulse = ... [3]

9 A rocket is stationary on the launchpad. At time $t = 0$, the rocket engines are switched on and exhaust gases are ejected from the nozzles of the engines. The rocket accelerates upwards.

(c) Some time later, the rocket is far from the Earth. The effect of the Earth's gravity on the motion of the rocket is insignificant. As the rocket accelerates, its momentum increases.

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

.....

.....

..... [2]

(ii) Explain how the principle of the conservation of momentum applies to the accelerating rocket and the exhaust gases.

.....

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..... [2]

10 Fig. 2.1 shows a model fire engine. Its brakes are applied.

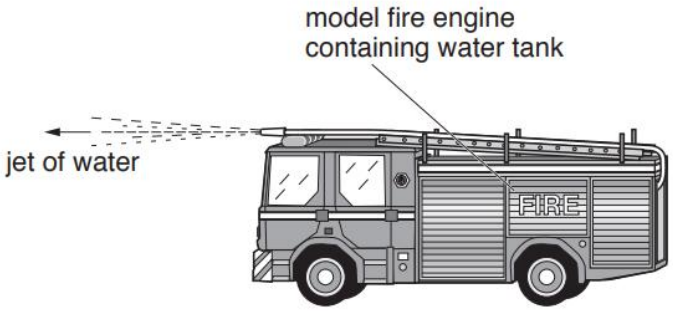

Fig. 2.1

0.80 kg of water is emitted in the jet every 6.0 s at a velocity of 0.72 m/s relative to the model.

(a) Calculate the change in momentum of the water that is ejected in 6.0 s.

momentum = ... [2]

(b) Calculate the magnitude of the force acting on the model because of the jet of water.

force = ... [2]

11 **(a)** State what is meant by *the principle of conservation of energy*.

.....

.....[1]

(b) Fig. 3.1 shows a girl throwing a heavy ball.

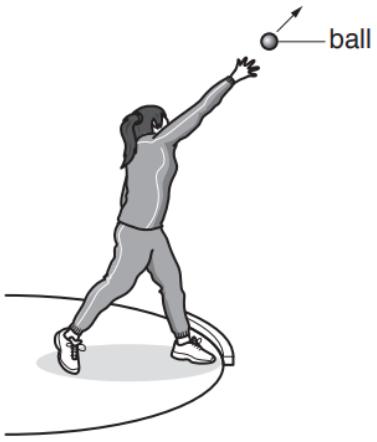

Fig. 3.1

(i) State the energy changes that take place from when the girl begins to exert a force on the ball until the ball hits the ground and stops moving.

.....

.....

.....

.....

.....[2]

(ii) The mass of the ball is 4.0 kg. The girl exerts a force on the ball for 0.60 s. The speed of the ball increases from 0 m/s to 12 m/s before it leaves the girl's hand.

Calculate:

1. the momentum of the ball on leaving the girl's hand

momentum = ...[2]

2. the average resultant force exerted on the ball.

average resultant force = ...[2]

[Total: 7]

12 **(a)** The velocity of an object of mass *m* increases from *u* to *v*.

State, in terms of *m*, *u* and *v*, the change of momentum of the object.

.....[1]

(b) In a game of tennis, a player hits a stationary ball with his racquet.

(i) The racquet is in contact with the ball for 6.0 ms. The average force on the ball during this time is 400 N.

Calculate the impulse on the tennis ball.

impulse = ...[2]

(ii) The mass of the ball is 0.056 kg.

Calculate the speed with which the ball leaves the racquet.

speed = ...[2]

(iii) State the energy transfer that takes place:

1. as the ball changes shape during the contact between the racquet and the ball

.....

.....

2. as the ball leaves the racquet.

.....

.....

[2]