2.4 Momentum & Impulse

Question Paper

Course	DP IB Physics
Section	2. Mechanics
Topic	2.4 Momentum & Impulse
Difficulty	Hard

Time allowed: 80

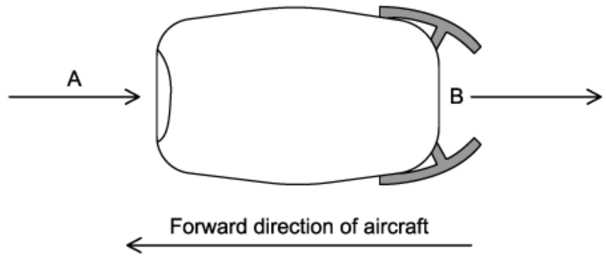
Score: /63

Percentage: /100

Question 1a

Air enters a cargo plane's engine at A and is heated before leaving at B, at a much higher speed.

The rotating blades draw air in and while in the engine, the air is compressed and mixed with fuel, combusted and shot out the back of the engine.



In one second a mass of 3.75×10^5 g of air enters A and the speed of this mass of air increases by 587 m s^{-1} as it passes through the engine.

(a)
Calculate the force exerted by the air on the engine.

[1]

[1 mark]

Question 1b

Hot air flows out of the exhaust engine at B through a cross-sectional area of 5.9×10^6 mm^2. The density of the hot air is 457.9 g m^{-3}.

(b)
Calculate the volume of air leaving the engine every second.

[2]

[2 marks]

Question 1c

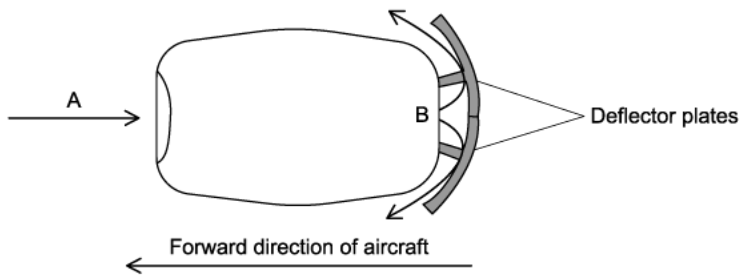
(c)
Explain, referring to the momentum of the air as it passes through the engine and using appropriate laws of motion, why it exerts a force on the engine in a forward direction.

[3]

[3 marks]

Question 1d

When a cargo plane lands its engines exert a decelerating force on the aircraft by making use of deflector plates. These cause the air leaving the engines to be deflected at an angle to the direction the aircraft is travelling.



The speed of the deflected air is the same as the speed of the air leaving B.

(d)
(i)
Explain why the momentum of the air changes.

[2]

(ii)
Suggest why the decelerating force provided by the deflector plates may not remain constant.

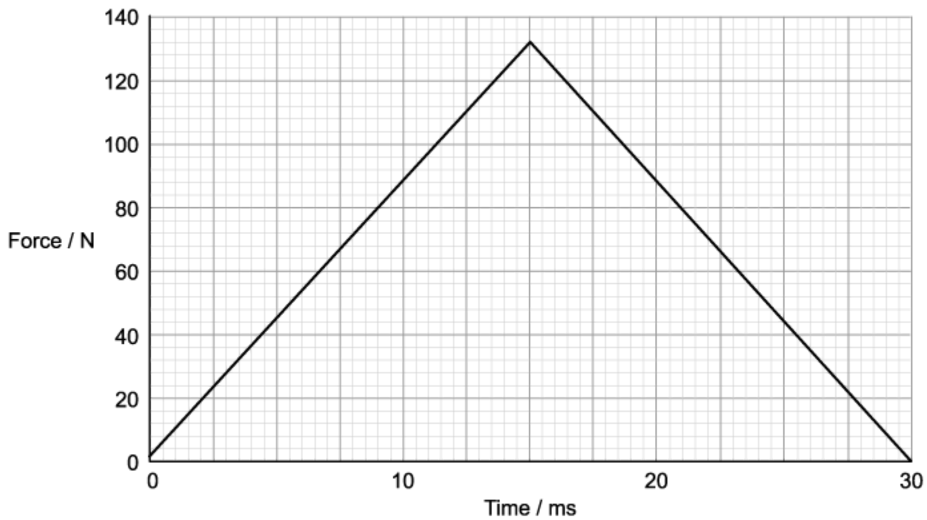
[2]

[4 marks]

Question 2a

A squash ball is raised from the ground and dropped onto a hard plate to test its properties. A sensor measured the force exerted by the plate on the ball during its collision with the plate.

The variation of force exerted on the squash ball with time is shown on the graph.



The ball strikes the plate with a speed of 19.16 m s^{-1} and has a mass of 60 g. It leaves the plate with a speed of 13.83 m s^{-1}.

(a)
Show that this is consistent with the impulse obtained from the graph.

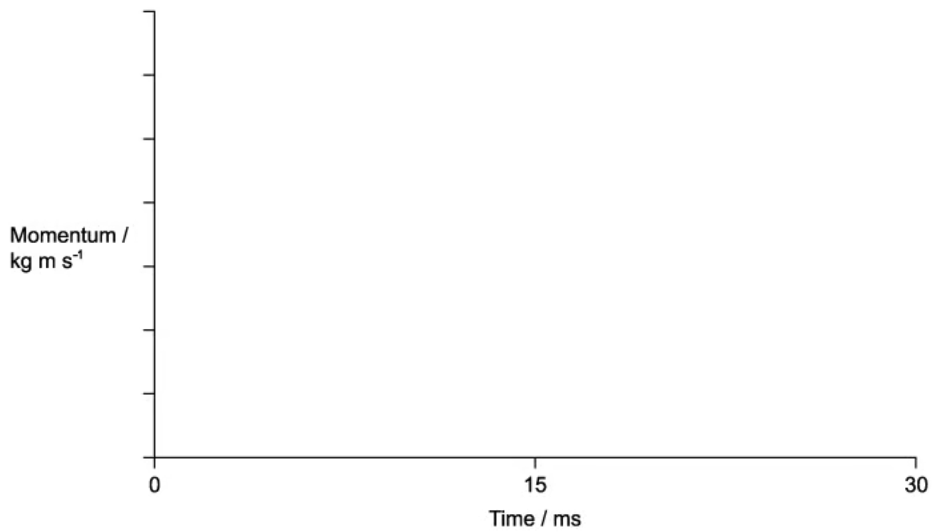
[3]

[3 marks]

Question 2b

(b)
Considering the first 30 ms of the ball's motion:

(i)
Sketch a graph to show how the momentum of the ball varies.



[1]

(ii)
Explain how the variation.

[5]

[6 marks]

Question 2c

The ball continues to bounce, each time losing the same fraction of its energy when it strikes the plate. Air resistance is negligible.

(c)
Determine the percentage of the original gravitational potential energy of the ball that remains when it reaches its maximum height after bouncing five times.

[3]

[3 marks]

Question 2d

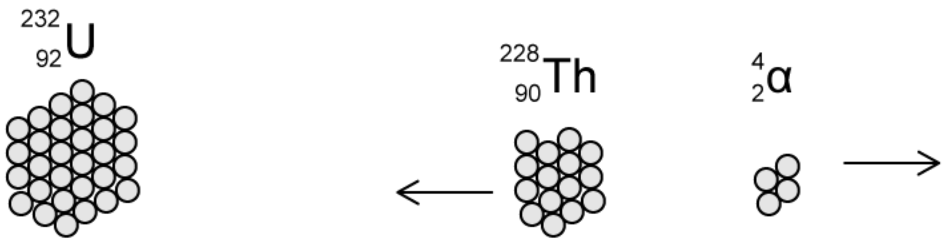
(d)
Explain, with reference to the conservation of momentum, the effect that the motion of the squash ball has on the motion of the Earth from the instant it is released until it bounces off the plate.

[3]

[3 marks]

Question 3a

A stationary uranium nucleus decays by emitting an α particle and thorium nucleus.



(a)
Discuss how the principle of conservation of momentum applies in this explosion.

[3]

[3 marks]

Question 3b

Assume that all of the energy released in the emission process is transferred as kinetic energy to the α particle and the recoiling nucleus and is equal to 6.46 MeV.

(b)
Calculate the kinetic energy of the Thorium nucleus and α particle in MeV.

[4]

[4 marks]

Question 3c

(c)
Show that momentum is conserved in this decay.

[3]

[3 marks]

Question 3d

Collisions can occur between neutrons and stationary Uranium nuclei, for example, during nuclear fission.

(d)
Discuss how this collision would be if this was inelastic as opposed to elastic.

[4]

[4 marks]

Question 4a

Hemp ropes were the first to be used for ships' rigging to adjust the position of the sails and support the masts. Hemp is one of the strongest natural fibres available, has a very high tensile strength and is extremely rigid.

Today rock climbers use nylon ropes which are attached to their harness to break their fall. Nylon stretches considerably under tension.

(a)
Discuss in terms of impulse and momentum, why nylon ropes are favoured by rock climbers compared to hemp ropes.

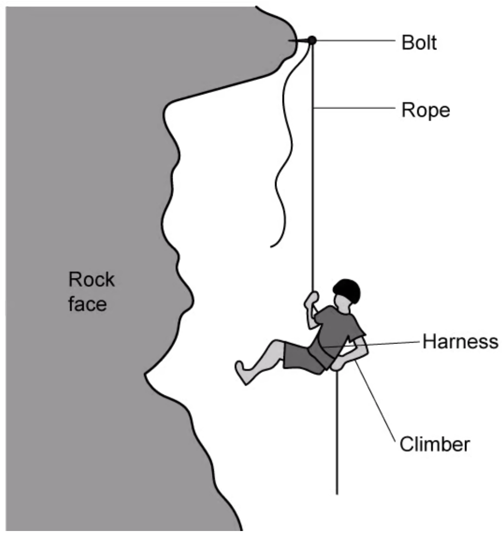
[4]

[4 marks]

Question 4b

A rock climber of mass *m* slips just after they attach a bolt to a piece of rock as they are climbing.

The length of the rope between their harness and the bolt on the rock face is *h*. Once the rope is fully extended their speed just before they come to a stop is *v*.



(b)
Show that the magnitude of the average decelerating force *F* on the climber when they are brought to rest is equal to their weight.

[3]

[3 marks]

Question 4c

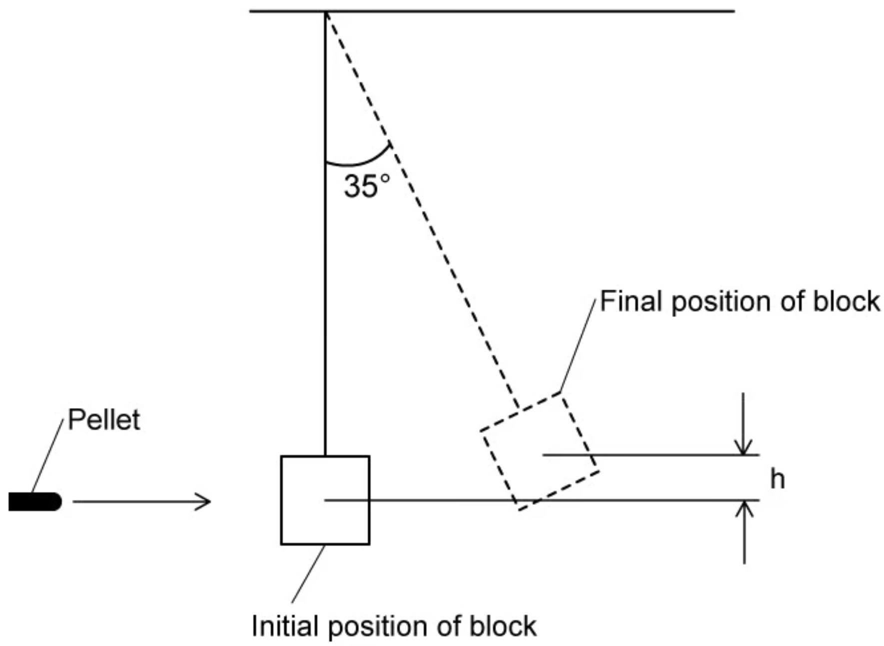
(c)
Deduce, without calculation, whether the average decelerating force *F* would still be equal to the climber's weight if they fell from higher up.

[2]

[2 marks]

Question 5a

The speed of a dart pellet of mass 2.73 g is measured by firing it into a polystyrene block of mass 543 g suspended from a rigid support. The pellet becomes completely embedded in the polystyrene block. The block can swing freely at the end of a light inextensible string of length 1.5 m measured from the pivot to the centre of the block.



The centre of mass of the block rises by *h* at an angle of 35° to the vertical.

(a)
Determine the speed of the pellet when it strikes the polystyrene block.

[5]

[5 marks]

Question 5b

The polystyrene block is replaced by a wooden block of the same mass. The experiment is repeated with the wooden block and an identical pellet. The pellet rebounds after striking the block.

A student makes an assumption that the angle that the wooden block makes with the vertical will be greater than 35° because the block doesn't have the additional mass of the pellet embedded within it.

(b)
Discuss the validity of the student's assumptions.

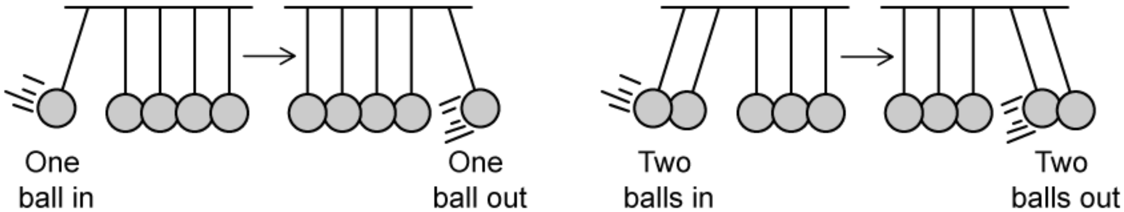
[5]

[5 marks]

Question 5c

A popular demonstration of the conservation of momentum and conservation of energy is Newton's cradle. It features several identical polished steel balls hung in a straight line in contact with each other.

If one ball is pulled back and allowed to strike the line, one ball is released from the other end whilst the rest are stationary. If two are pulled out, two are released on the other end and so forth.



(c)
Assuming that Newton's Cradle is in a vacuum and considering energy and momentum conservation, explain why swinging one ball from the left will not release two balls on the right.

[5]

[5 marks]