2.4 Momentum & Impulse

Question Paper

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

Time allowed: 80

Score: /62

Percentage: /100

Question 1a

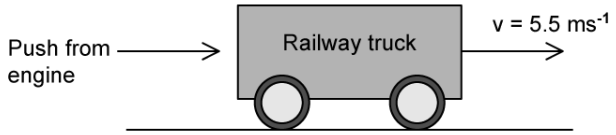
(a)

Show, using the equation $F = ma$, how the impulse of a force F is related to the change in momentum Δp that it produces for a mass m with acceleration a.

[2 marks]

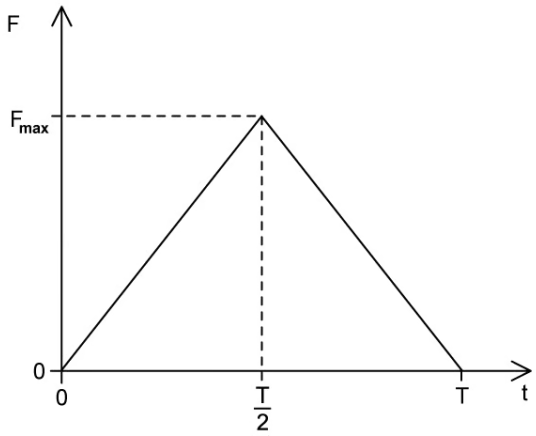
Question 1b

A railway truck on a level, straight track is initially at rest. The truck is given a quick, horizontal push by an engine so that it now rolls along the track.



The engine is in contact with the truck for a time $T = 0.60$ s and the initial speed of the truck after the push is 5.5 m s^{-1}. The mass of the truck is 3.1×10^3 kg.

Due to the push, a force of magnitude F is exerted by the engine on the truck. The sketch shows how F varies with contact time t.



(b)

Determine the magnitude of the maximum force exerted by the engine on the truck.

[4 marks]

Question 1c

When the speed of the truck is 2.3 m s^{-1}, it collides with a stationary truck of mass 4.7×10^3 kg. The two trucks move off together with a speed *V*.

(c)
Show that the speed $V = 0.9$ m s^{-1}

[4 marks]

Question 1d

(d)
State and explain whether the collision of the two trucks is elastic or inelastic.

[2 marks]

Question 2a

Two identical blocks A and B of mass 200 g are travelling towards each other along a straight line through their centre. Assume that the surface is frictionless.

Both blocks are moving at a speed of 0.21 m s^{-1} relative to the surface.

As a result of the collision, the blocks reverse their direction of motion and travel at the same speed as each other. During the collision, 30% of the kinetic energy of the blocks is given off as thermal energy to the surroundings.

(a)
Deduce whether the collision is elastic or inelastic and state your reasoning.

[2 marks]

Question 2b

(b)
Calculate the final speed of the blocks relative to the surface.

[4 marks]

Question 2c

The duration of the collision between the blocks is 650 ms.

(c)
Determine the average force one block exerted on the other.

[3 marks]

Question 2d

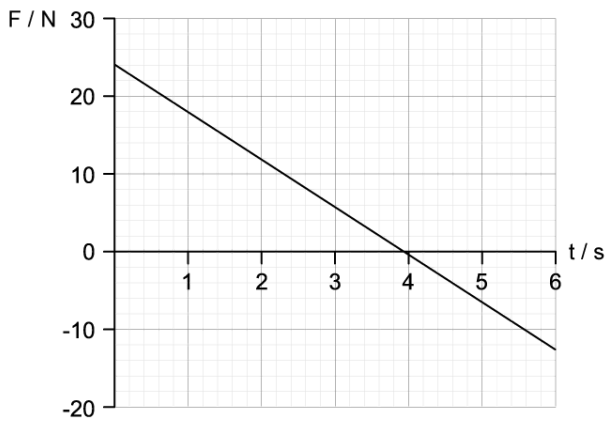
In a different experiment that is 100% efficient, the boxes stick together and move together after the collision.

(d)
Show that the speed of the combined boxes after the collision is the same as before the collision.

[4 marks]

Question 3a

The force acts on a mass of 5.0 kg initially at rest.



(a)
Show that the speed of the mass at $t = 3$ s is 9.0 m s^{-1}.

[4 marks]

Question 3b

(b)
Calculate the deceleration of the mass up to time $t = 4$ s.

[3 marks]

Question 3c

(c)
Calculate the total impulse experienced by the mass.

[3 marks]

Question 3d

(d)
Outline the motion of the mass as indicated by the graph.

[2 marks]

Question 4a

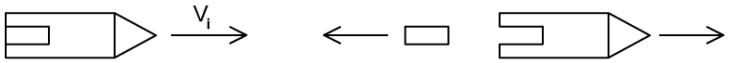
A space rocket is moving with constant velocity. The engines of the space rocket are turned on and it accelerates by burning fuel and ejecting gases.

(a)
Discuss how the law of conservation of momentum allows the space rocket to accelerate forward, although it ejects gases in the opposite direction.

[3 marks]

Question 4b

A rocket is travelling at constant velocity in space after exiting the Earth's atmosphere. The engines are turned off, and a module separates from the rocket.



The module has a mass of 6 000 kg and is ejected at 10 km s^{-1}. The combined mass of the rocket and the module is 81 000 kg and the remaining part of the rocket after the explosion travels at 4500 m s^{-1} after the module has been ejected.

(b)
Calculate the initial speed of the rocket.

[4 marks]

Question 4c

(c)
Calculate the force exerted on the module in 0.2 s during the explosion.

[3 marks]

Question 4d

Inside the rocket, some walls are padded to reduce damage to its interior when it is accelerated into space.

(d)
Explain, with reference to change in momentum, why padded walls are less likely to cause damage to the interior of the rocket compared to a rigid wall.

[2 marks]

Question 5a

Joanna and Lindsay are two roller skaters initially at rest on a horizontal surface. They are facing each other and Joanna is holding a ball. Joanna throws the ball to Lindsay who catches it. The speed at which the ball leaves Joanna, measured relative to the ground, is 6.2 m s^{-1}.

The following data are available.

Mass of Joanna = 59 kg

Mass of Lindsay = 64 kg

Mass of ball = 3.3 kg

(a)
(i)
Calculate the velocity *v* of Joanna relative to the ground immediately after she throws the ball

[3]

(ii) State the direction that Joanna travels in after she throws the ball

[1]

[4 marks]

Question 5b

(b)
Calculate the speed *V* of Lindsay relative to the ground immediately after she catches the ball. Assume the speed of the ball stays constant throughout its motion.

[4 marks]

Question 5c

(c)
Determine whether Lindsay catching the ball is an elastic or inelastic collision.

[3 marks]

Question 5d

Lindsay has a previous injury to her hand, so decides to wear padded gloves whilst playing this game with Joanna. This is similar to what players would wear in cricket if they need to catch a ball at high speed.

(d)
Explain why the padded gloves would protect Lindsay's hands when she catches the ball.

[2 marks]