A Level Mechanics
Practice Test 1: Momentum and Impulse

Instructions:
Answer all questions. Show your working clearly.
Calculators may be used unless stated otherwise.
Draw diagrams where appropriate to illustrate your solutions.
Time allowed: 2 hours 15 minutes

Section A: Momentum Fundamentals [20 marks]

Question 1 [8 marks]

(a) Define momentum and state its SI unit. **[2 marks]**

(b) Explain why momentum is a vector quantity. **[2 marks]**

(c) State the condition under which momentum is conserved. **[2 marks]**

(d) Explain how momentum differs from kinetic energy. **[2 marks]**

Question 2 [12 marks] Calculate the momentum in the following situations:

(a) A car of mass 1200 kg traveling at 18 m/s east. **[2 marks]**

(b) A truck of mass 8000 kg and a car of mass 1500 kg, both traveling at 25 m/s in the same direction. Find their total momentum. **[3 marks]**

(c) Two particles: one with momentum 30 kgm/s east and another with momentum 40 kgm/s north. Find the magnitude and direction of the resultant momentum. **[4 marks]**

(d) A bullet of mass 0.015 kg is fired from a gun of mass 2.5 kg. If the bullet's speed is 350 m/s, find the recoil speed of the gun. **[3 marks]**

Section B: Conservation of Momentum [25 marks]

Question 3 [10 marks]

(a) State the law of conservation of momentum. **[2 marks]**

(b) Explain what is meant by an "isolated system." **[2 marks]**

(c) Derive the conservation of momentum from Newton's laws. **[4 marks]**

(d) Give two practical examples where momentum conservation is important. **[2 marks]**

Question 4 [15 marks] Two ice skaters are initially at rest on frictionless ice. Skater A has mass 65 kg and skater B has mass 75 kg. They push against each other and separate.

(a) If skater A moves away at 2.5 m/s, find the velocity of skater B. **[3 marks]**

(b) Calculate the total kinetic energy after separation. **[4 marks]**

(c) Explain where this kinetic energy came from. **[2 marks]**

(d) After separation, skater A throws a 1.5 kg bag to skater B at 4 m/s relative to herself. Find the final velocities of both skaters when B catches the bag. **[6 marks]**

Section C: Impulse and Impulse-Momentum Theorem [25 marks]

Question 5 [10 marks]

(a) Define impulse and state its SI unit. **[2 marks]**

(b) State the impulse-momentum theorem. **[2 marks]**

(c) Derive the impulse-momentum theorem from Newton's second law. **[4 marks]**

(d) Explain how impulse can be calculated when force varies with time. **[2 marks]**

Question 6 [15 marks] A tennis ball of mass 0.058 kg is hit by a racket. The ball's velocity changes from 20 m/s toward the racket to 28 m/s away from the racket. The contact time is 0.005 seconds.

(a) Calculate the change in momentum of the ball. **[3 marks]**

(b) Find the impulse delivered by the racket. **[2 marks]**

(c) Calculate the average force exerted by the racket on the ball. **[3 marks]**

(d) If the racket has mass 0.35 kg and was initially moving at 12 m/s toward the ball, find the racket's velocity immediately after impact. **[4 marks]**

(e) Verify that momentum is conserved in this collision. **[3 marks]**

Section D: Elastic Collisions [20 marks]

Question 7 [8 marks]

(a) Define an elastic collision. **[2 marks]**

(b) State what quantities are conserved in elastic collisions. **[2 marks]**

(c) Explain why perfectly elastic collisions are rare in everyday life. **[2 marks]**

(d) Define the coefficient of restitution. **[2 marks]**

Question 8 [12 marks] Two balls undergo an elastic collision. Ball A (mass 1.5 kg) moves at 8 m/s and collides head-on with ball B (mass 2.5 kg) moving at 3 m/s in the opposite direction.

(a) Calculate the velocities of both balls after collision. **[6 marks]**

(b) Verify that momentum is conserved. **[3 marks]**

(c) Verify that kinetic energy is conserved. **[3 marks]**

Section E: Inelastic Collisions [25 marks]

Question 9 [**8 marks**]

(a) Define an inelastic collision. [**2 marks**]

(b) What is a perfectly inelastic collision? [**2 marks**]

(c) Explain why kinetic energy is not conserved in inelastic collisions. [**2 marks**]

(d) Explain what happens to the "lost" kinetic energy. [**2 marks**]

Question 10 [**17 marks**] A car of mass 1200 kg traveling at 25 m/s collides with a stationary car of mass 1800 kg. After collision, both cars move together.

(a) Calculate the velocity of both cars immediately after collision. [**4 marks**]

(b) Find the kinetic energy before collision. [**3 marks**]

(c) Calculate the kinetic energy after collision. [**3 marks**]

(d) Determine the energy lost in the collision. [**2 marks**]

(e) If the collision lasted 0.12 seconds, find the average force between the cars. [**5 marks**]

Section F: Variable Force and Applications [20 marks]

Question 11 [**12 marks**] A ball is dropped from height 1.8 m onto the ground. The coefficient of restitution between ball and ground is 0.75.

(a) Find the speed just before impact. [**3 marks**]

(b) Calculate the speed just after impact. [**2 marks**]

(c) If the contact time is 0.008 seconds, find the average force during impact for a 0.4 kg ball. [**4 marks**]

(d) To what height will the ball bounce? [**3 marks**]

Question 12 [**8 marks**] A safety feature in cars is the airbag, which increases collision time to reduce injury.

(a) A 75 kg person moving at 12 m/s is stopped by an airbag in 0.15 seconds. Calculate the average force. [**3 marks**]

(b) Compare this with stopping in 0.008 seconds without an airbag. [**3 marks**]

(c) Explain why increasing collision time reduces the force. [**2 marks**]

Section G: Two-Dimensional Collisions [15 marks]

Question 13 [**15 marks**] Two pucks collide on a frictionless horizontal surface. Puck A (mass 0.25 kg) moves at 5 m/s east and collides with puck B (mass 0.35 kg) moving at 4 m/s north.

(a) Calculate the total momentum before collision (magnitude and direction). [**4 marks**]

(b) If the collision is perfectly inelastic, find the velocity of the combined pucks after collision. [**4 marks**]

(c) Calculate the kinetic energy before and after collision. [**4 marks**]

(d) Determine the energy lost in the collision. [**3 marks**]

Section H: Real-World Applications [15 marks]

Question 14 [8 marks] A bullet of mass 0.008 kg is fired horizontally at 280 m/s into a wooden block of mass 1.5 kg suspended by strings as a ballistic pendulum.

(a) Find the velocity of the block (with bullet) immediately after impact. **[3 marks]**

(b) Calculate the height to which the block swings. **[3 marks]**

(c) Determine the energy lost in the collision. **[2 marks]**

Question 15 [7 marks] A railway truck of mass 18,000 kg moving at 2.5 m/s collides and couples with another truck of mass 12,000 kg moving at 1.8 m/s in the opposite direction.

(a) Find the velocity of the coupled trucks after collision. **[4 marks]**

(b) Calculate the kinetic energy lost in the collision. **[3 marks]**

Physics Data and Formulae

Momentum and Impulse:

Momentum: $\vec{p} = m\vec{v}$

Impulse: $\vec{J} = \vec{F}\Delta t = \Delta\vec{p}$

Conservation of momentum: $\sum \vec{p}_{\text{before}} = \sum \vec{p}_{\text{after}}$

Elastic Collision (1D):

$$v_1' = \frac{(m_1 - m_2)v_1 + 2m_2v_2}{m_1 + m_2}$$

$$v_2' = \frac{(m_2 - m_1)v_2 + 2m_1v_1}{m_1 + m_2}$$

Perfectly Inelastic Collision:

$$v' = \frac{m_1v_1 + m_2v_2}{m_1 + m_2}$$

Coefficient of Restitution:

$$e = \frac{\text{speed of separation}}{\text{speed of approach}}$$

$e = \frac{v_2' - v_1'}{v_1 - v_2}$ (for direct collision)

Kinetic Energy:

$$E_k = \frac{1}{2}mv^2$$

Motion Equations:

$v^2 = u^2 + 2as$ (for free fall problems)

Constants:

Acceleration due to gravity: $g = 9.8$ m/s²

END OF TEST

Total marks: 165

Grade boundaries: A* 149, A 132, B 115, C 99, D 83, E 66

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