Newton's Laws and Momentum Questions – OCR A Level Physics

Praneel Physics

1. State Newton's First Law of Motion. **(P)**

Working and Answer:

An object remains at rest or moves with constant velocity unless acted on by a resultant external force.
Answer: Law of inertia – motion unchanged without resultant force.

2. Define momentum and state its unit. **(P)**

Working and Answer:

Momentum is defined as mass multiplied by velocity:

$$p = mv$$

Unit: $\mathrm{kg} \cdot \mathrm{m/s}$

3. A 2 kg trolley moves at 3 m/s. Calculate its momentum. **(P)**

Working and Answer:

$$p = mv = 2 \times 3 = 6 \text{ kg} \cdot \text{m/s}$$

Answer: 6 kg · m/s

4. State Newton's Second Law in terms of momentum. **(P)**

Working and Answer:

The net force on an object is equal to the rate of change of momentum:

$$F = \frac{dp}{dt}$$

Answer: $F = \frac{\Delta p}{\Delta t}$

5. A 4 kg object has its momentum changed by 12 kg $\cdot$ m/s in 3 seconds. Calculate the force. **(P)**

Working and Answer:

$$F = \frac{\Delta p}{\Delta t} = \frac{12}{3} = 4 \text{ N}$$

Answer: 4 N

6. A 5 kg object accelerates from rest to 10 m/s in 2 s. Calculate the resultant force acting on it. **(PP)**

Working and Answer:

Acceleration:

$$a = \frac{\Delta v}{\Delta t} = \frac{10}{2} = 5 \text{ m/s}^2$$

Force:

$$F = ma = 5 \times 5 = 25 \text{ N}$$

Answer: 25 N

7. Explain the difference between elastic and inelastic collisions. **(PP)**

Working and Answer:

Elastic: total kinetic energy conserved.
Inelastic: some kinetic energy is transformed to other forms (e.g., heat, sound).
Answer: Elastic = KE conserved; Inelastic = KE not conserved.

8. Calculate the impulse of a 20 N force acting for 0.4 s. **(PP)**

Working and Answer:

Impulse = Force $\times$ Time = $20 \times 0.4 = 8$ Ns
Answer: 8 Ns

9. A 1500 kg car slows from 25 m/s to 0 in 5 s. Calculate the average braking force. **(PP)**

Working and Answer:

$$\Delta p = 1500 \times (0 - 25) = -37500 \text{ kg} \cdot \text{m/s}$$

$$F = \frac{\Delta p}{\Delta t} = \frac{-37500}{5} = -7500 \text{ N}$$

Answer: 7500 N

10. State the law of conservation of momentum. **(PP)**

Working and Answer:

In a closed system with no external forces, total momentum before and after an interaction remains constant.
Answer: Total momentum is conserved in isolated systems.

11. Two objects, 1.5 kg and 2.5 kg, move at 4 m/s and -3 m/s respectively. Calculate total momentum. **(PPP)**

Working and Answer:

$$p_{\text{total}} = (1.5 \times 4) + (2.5 \times -3) = 6 - 7.5 = -1.5 \text{ kg} \cdot \text{m/s}$$

Answer: -1.5 kg · m/s

12. A 3 kg object moving at 6 m/s collides elastically with a 2 kg stationary object. Find the velocity of the 2 kg object after collision. **(PPP)**

Working and Answer:

$$v_2 = \frac{2m_1}{m_1 + m_2} u_1 = \frac{2 \times 3}{5} \times 6 = \frac{6}{5} \times 6 = 7.2 \text{ m/s}$$

Answer: 7.2 m/s

13. Define impulse and explain its relationship to force and time. **(PPP)**

Working and Answer:

Impulse = Change in momentum = Force × Time:

$$\text{Impulse} = F\Delta t = \Delta p$$

Answer: Impulse is area under a force-time graph.

14. A 6 kg object moving at 3 m/s collides and sticks to a 4 kg object at rest. Find their combined velocity. **(PPP)**

Working and Answer:

Initial momentum: $p = 6 \times 3 = 18$ kg $\cdot$ m/s
Total mass $= 6 + 4 = 10$ kg

$$v = \frac{18}{10} = 1.8 \text{ m/s}$$

Answer: 1.8 m/s

15. Explain how crumple zones reduce injury in car crashes. **(PPP)**

Working and Answer:

Crumple zones increase impact time $\rightarrow$ reduces rate of momentum change $\rightarrow$ reduces force on passengers.
Answer: $F = \Delta p/\Delta t$: increase Δt, reduce F.

16. A 1000 kg car crashes into a wall at 15 m/s and comes to rest in 0.1 s. Calculate the average force. **(PPPP)**

Working and Answer:

$$\Delta p = 1000 \times (0 - 15) = -15000 \text{ kg} \cdot \text{m/s}$$

$$F = \frac{-15000}{0.1} = -150000 \text{ N}$$

Answer: 150000 N

17. Two carts (2 kg and 3 kg) collide inelastically. The 2 kg cart moves at 3 m/s, the other is at rest. Find final velocity. **(PPPP)**

Working and Answer:

$$p_{\text{initial}} = 2 \times 3 = 6 \text{ kg} \cdot \text{m/s}$$

Total mass = 5 kg

$$v = \frac{6}{5} = 1.2 \text{ m/s}$$

Answer: 1.2 m/s

18. A 0.5 kg ball hits a wall at 8 m/s and rebounds at -6 m/s. Collision lasts 0.05 s. Find average force. **(PPPP)**

Working and Answer:

$$\Delta v = -6 - 8 = -14 \text{ m/s}$$

$$\Delta p = 0.5 \times (-14) = -7 \text{ kg} \cdot \text{m/s}$$

$$F = \frac{-7}{0.05} = -140 \text{ N}$$

Answer: 140 N

19. A 1000 kg van travelling at 12 m/s collides with a 600 kg car at 4 m/s in the same direction. After collision, they move together. Calculate final velocity. **(PPPPP)**

Working and Answer:

$$p_{\text{initial}} = (1000 \times 12) + (600 \times 4) = 12000 + 2400 = 14400 \text{ kg} \cdot \text{m/s}$$

Total mass = 1600 kg

$$v = \frac{14400}{1600} = 9 \text{ m/s}$$

Answer: 9 m/s

20. A 2 kg puck travelling at 5 m/s collides elastically with a 1 kg puck at rest. Calculate both final velocities. **(PPPPP)**

Working and Answer:

Use elastic collision equations:

$$v_1 = \frac{m_1 - m_2}{m_1 + m_2} u_1 = \frac{2-1}{3} \times 5 = \frac{5}{3} \approx 1.67 \text{ m/s}$$

$$v_2 = \frac{2m_1}{m_1 + m_2} u_1 = \frac{4}{3} \times 5 = \frac{20}{3} \approx 6.67 \text{ m/s}$$

Answer: $v_1 = 1.67$ m/s, $v_2 = 6.67$ m/s