IG.P3 Newton's Laws of Motion, Momentum and Stopping Distances

EDEXCEL 4PH1 · Calculator allowed · about 65 minutes

Total Marks

Name: ______________________________ Date: ____ / ____ / ______

Answer ALL questions. Show all your working.

1 State Newtons first law as it applies to the motion of a car travelling along a straight, level road.

(Total for Question 1 is 2 marks)

2 State Newtons third law and give a road-traffic example involving a car and the road surface.

(Total for Question 2 is 2 marks)

3 Calculate the resultant force required to accelerate a 1200 kg car from rest at 0 to 2.5 m/s in 5.0 s on a straight road. Use F = ma and show your substitution and final unit.

(Total for Question 3 is 3 marks)

4 A cyclist of mass 70 kg is moving at 6.0 m/s and applies the brakes, coming to rest in 4.0 s. Calculate the average resultant braking force on the cyclist plus bicycle, using F = ma. Include equation, substitution and unit.

(Total for Question 4 is 3 marks)

5 A 0.50 kg tennis ball travelling at 30 m/s is hit by a racket so that it reverses direction and travels at 20 m/s in the opposite direction. Use the idea of momentum to calculate the change in momentum of the ball. Show your working and unit.

(Total for Question 5 is 3 marks)

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6 Two trolleys on a low-friction track collide. Trolley A (mass 2.0 kg) moves right at 1.5 m/s, trolley B (mass 3.0 kg) moves left at 0.5 m/s. Use conservation of momentum to calculate the velocity of the combined trolleys immediately after a perfectly inelastic collision where they stick together. Show equation, substitution and unit.

(Total for Question 6 is 3 marks)

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7 A bullet of mass 0.020 kg travelling at 400 m/s embeds into a stationary block of mass 2.0 kg on a frictionless surface. Use conservation of momentum to calculate the speed of the block plus bullet immediately after impact. Show equation, substitution and unit.

(Total for Question 7 is 3 marks)

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8 State the formula for linear momentum in mechanics and state its SI unit, as used for a vehicle travelling on a road.

(Total for Question 8 is 2 marks)

9 A car of mass 1200 kg is travelling at 25 m/s and the driver applies the brakes to bring it to rest in 5.0 s. Calculate the average braking force required, showing equation, substitution and unit.

(Total for Question 9 is 3 marks)

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10 Two ice-skaters on a frictionless pond are moving in the same direction. Skater A mass 50 kg moves at 3.0 m/s, skater B mass 70 kg moves at 1.0 m/s. They grab each other and move together. Calculate their common speed after they join, showing equation, substitution and unit.

(Total for Question 10 is 3 marks)

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11 Explain briefly how alcohol consumption increases a driver's stopping distance, referring to thinking distance and braking distance where appropriate. Give three distinct points.

(Total for Question 11 is 3 marks)

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12 State two vehicle or road factors that increase braking distance and give one short reason for each, in the context of driving on a wet road.

(Total for Question 12 is 2 marks)

13 Explain, using the idea of momentum and Newtons laws where appropriate, how an increase in vehicle speed affects the total stopping distance of a car. Give at least four distinct points involving thinking distance, braking distance, forces and momentum.

(Total for Question 13 is 5 marks)

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14 A 1000 kg car is travelling east at 15 m/s and collides head-on with a 1200 kg car travelling west at 10 m/s. After a perfectly inelastic collision they stick together. Use conservation of momentum to calculate the velocity of the wreckage immediately after impact, giving magnitude, direction and unit. Show equation and substitution.

(Total for Question 14 is 3 marks)

Mark scheme · IG.P3 Newton's Laws of Motion, Momentum and Stopping Distances

Question 1

- **B1** an object remains at rest or continues with constant velocity unless acted on by a resultant force
- **B1** application to a car: the car will keep moving at the same speed and direction unless a resultant force (e.g. brakes, friction, engine thrust) acts on it
- **Answer: An object stays at rest or keeps moving with constant velocity unless a resultant force acts on it; for a car this means it keeps moving at the same speed and direction unless forces such as braking or friction act.**

Question 2

- **B1** for every action there is an equal and opposite reaction
- **B1** example: tyre pushes backwards on the road and the road pushes forwards on the tyre with equal magnitude
- **Answer: For every action there is an equal and opposite reaction; e.g. a tyre pushes backwards on the road and the road pushes forwards on the tyre with equal magnitude.**

Question 3

- **M1** quotes the equation F = ma and uses a = (v - u) / t
- **M1** substitutes: a = (2.5 - 0) / 5.0 = 0.50 m/s^2 and then F = 1200 x 0.50
- **A1** gives F = 600 N cao with unit
- **Answer: 600 N**

Question 4

- **M1** quotes F = ma and a = (v - u) / t
- **M1** substitutes: a = (0 - 6.0) / 4.0 = -1.5 m/s^2, then F = 70 x -1.5
- **A1** gives F = -105 N cao, or 105 N opposing the motion
- **Answer: -105 N (105 N opposite to motion)**

Question 5

- **M1** quotes momentum p = mv and recognises change in momentum = m(v_final - v_initial) taking into account direction
- **M1** substitutes with sign: v_initial = +30 m/s, v_final = -20 m/s so change = 0.50 x (-20 - 30) = 0.50 x -50 = -25 kg m/s
- **A1** gives magnitude and unit: change in momentum = -25 kg m/s (or 25 kg m/s opposite to initial direction) cao
- **Answer: -25 kg m/s (change in momentum; 25 kg m/s opposite to initial direction)**

Question 6

- **M1** states conservation of momentum: $m_A v_A + m_B v_B = (m_A + m_B)$ v_final
- **M1** substitutes: total momentum = 2.0 x (+1.5) + 3.0 x (-0.5) = 3.0 - 1.5 = 1.5 kg m/s; total mass = 5.0 kg
- **A1** gives v_final = 1.5 / 5.0 = 0.30 m/s to the right, cao with unit
- **Answer: 0.30 m/s to the right**

Question 7

- **M1** states m_bullet v_bullet + m_block v_block = (m_bullet + m_block) v_final and notes v_block initial = 0
- **M1** substitutes: total momentum = 0.020 x 400 + 2.0 x 0 = 8.0 kg m/s; total mass = 2.02 kg
- **A1** gives v_final = 8.0 / 2.02 = 3.96 m/s cao (to 3 s.f.) with unit
- **Answer: 3.96 m/s**

Question 8

- **B1** states the formula p = mv
- **B1** states the SI unit as kilogram metre per second, kg m/s
- **Answer: p = mv; unit: kg m/s**

Question 9

- **M1** uses F = ma and a = (v - u) / t
- **M1** substitutes: a = (0 - 25) / 5.0 = -5.0 m/s^2 then F = 1200 x -5.0
- **A1** gives F = -6000 N cao, or 6000 N opposing the motion, with unit
- **Answer: -6000 N (6000 N opposite to direction of motion)**

Question 10

- **M1** conservation of momentum: $m_A v_A + m_B v_B = (m_A + m_B)$ v_final
- **M1** substitutes: total momentum = 50 x 3.0 + 70 x 1.0 = 150 + 70 = 220 kg m/s; total mass = 120 kg
- **A1** gives v_final = 220 / 120 = 1.83 m/s cao with unit (to 3 s.f.)
- **Answer: 1.83 m/s**

Question 11

- **B1** alcohol impairs reaction time, so thinking distance increases
- **B1** alcohol can impair judgement and steering leading to delayed or inappropriate braking, contributing further to increased stopping distance
- **B1** at higher intoxication braking may be less effective due to poor control, indirectly increasing braking distance or reducing use of brakes correctly
- **Answer: Alcohol slows reaction time increasing thinking distance; it impairs judgement so braking is delayed or inappropriate; at higher intoxication braking effectiveness and control may be reduced, increasing overall stopping distance.**

Question 12

- **B1** worn tyres, with reason: reduced grip on wet surface so brakes take longer to slow the vehicle
- **B1** poor brake condition, with reason: brakes provide less deceleration so stopping distance is increased
- **Answer: Worn tyres, because they reduce grip on wet roads; poor brake condition, because brakes give less deceleration so braking distance increases.**

Question 13

- **B1** states that thinking distance increases with speed because the car covers more distance during the driver's reaction time
- **B1** uses momentum p = mv to state that momentum increases as speed increases for the same mass
- **B1** applies Newtons second law: to reduce momentum to zero a larger change in momentum per unit time requires a larger resultant force or a longer braking time/distance
- **B1** explains that braking distance increases more than thinking distance as speed rises because kinetic energy and change in momentum grow with speed, so brakes must do more work and provide more impulse
- **B1** concludes that total stopping distance increases significantly with speed, combining the increased thinking and the disproportionately larger braking distance

Question 14

- **M1** sets up m1 v1 + m2 v2 = (m1 + m2) v_final with consistent sign convention (east positive)
- **M1** substitutes: total momentum = 1000 x (+15) + 1200 x (-10) = 15000 - 12000 = 3000 kg m/s; total mass = 2200 kg
- **A1** gives v_final = 3000 / 2200 = 1.36 m/s east cao with unit
- **Answer: 1.36 m/s east**