7 Laws of motion and momentum
Answers to practice questions

Question	Answer	Marks
1 (a)	momentum = mass × velocity base unit of momentum = base unit of mass (kg) × base unit of velocity ($m\ s^{-1}$) Therefore, the base unit of momentum is $kg\ m\ s^{-1}$.	1 1 1
1 (b) (i)	The area under the graph is the impulse; impulse = 3.2 N s impulse = change in momentum $3.2 = 0.060\,v - 0$ (initial momentum of ball = 0) $v \approx 53\ m\ s^{-1}$	1 1 1
1 (b) (ii)	impulse = average force × time $3.2 = F_{av} \times 6 \times 10^{-3}$ $F_{av} = 533.3$ N Therefore maximum force ≈ 2 × 533.3 ≈ 1.1×10^3 N	 1 1 1
1 (b) (iii)	The ball gains momentum after being hit. According to the principle of conservation of momentum, the racquet loses its forward momentum. Hence the velocity of the racquet decreases.	1 1 1
2 (a)	impulse = force acting on object × time for which the force acts	1
2 (b) (i)	$F = m\,a$, therefore the acceleration of the car is maximum at $t = 0$. The acceleration decreases **linearly** and is equal to zero at $t = 3.0$ s.	1 1
2 (b) (ii)	Curve starting at origin. The graph has the correct shape.	1 1
2 (b) (iii)	The area under the graph is the impulse impulse = $\frac{1}{2} \times 15 \times 10^3 \times 3.0 = 2.25 \times 10^4$ N s impulse = change in momentum $2.25 \times 10^4 = 1200\,v - 0$ (initial momentum of ball = 0) $v = 18.8\ m\ s^{-1}$ $E_k = \frac{1}{2} m v^2 = \frac{1}{2} \times 1200 \times 18.8^2$ $E_k = 2.1 \times 10^5$ J	1 1 1 1 1
3 (a)	The net force acting on an object is directly proportional to the rate of change of momentum.	1
3 (b)	force = change in momentum/time $F = \frac{mv - mu}{t}$, where v = final velocity, u = initial velocity and t = time taken $F = \frac{m(v-u)}{t}$; acceleration = $a = \frac{v-u}{t}$	1 1 1
3 (c) (i)	$v^2 = u^2 + 2\,a\,s$; $u = 0$ $s = \frac{v^2}{2a} = \frac{5.4^2}{2 \times 9.81}$ $s = 1.5$ Assumption – there is no drag or acceleration is constant (at $9.81\ m\ s^{-2}$)	1 1 1 1
3 (c) (ii)	The graph is a 'mirror image'. The force exerted by the ball on the ground is equal and opposite to the force exerted by the ground on the ball (Newton's third law).	1 1
3 (c) (iii)	change in momentum = (0.080 × –3.0) – (0.080 × 5,4) change in momentum = (–)0.67 $kg\ m\ s^{-1}$	1 1
4 (a)	momentum = $m\,v$ = 500 × 0.60 = 300 Unit: $kg\ m\ s^{-1}$ (or N s)	1 1

Question	Answer	Marks
4 (b) (i)	The momentum of the steel bar increases. According to Newton's second law of motion, there must be a force on the bar because force = rate of change of momentum. *Or* The bar is accelerating. The bar must be experiencing a force because: force = mass × acceleration.	1 1 1 1
4 (b) (ii)	The force acts to the right.	1
4 (b) (iii)	Time = $\frac{\text{distance}}{\text{speed}} = \frac{3.0}{0.60}$ = 5.0 s	1
4 (b) (iv)	$F = \frac{\Delta p}{\Delta t} = \frac{mv - mu}{t}$ $F = \frac{(500 \times 1.8) - (500 \times 0.6)}{5.0}$ Force = 120 N	1 1 1
5 (i)	(3 × 5) – (7 × 2) = 10v $v = \frac{15 - 14}{10}$ v = 0.10 m s^{-1} to the right	1 1 1
5 (ii)	impulse = 3 × (0.1 – 5) impulse = - 14.7 N s ≈ (–)15 N s to the left	 1 1
5 (iii)	(Newton's 3rd law says) The force on B (due to A) is equal and opposite to the force on A (due to B) time of contact (t) is the same for both **and** impulse = Ft impulse on A is equal and opposite to impulse on B	1 1
6 (a)	In order: Elastic AND Inelastic Elastic Elastic AND Inelastic Elastic AND Inelastic	 1 1 1 1
6 (b) (i)	(Velocity) <u>increases</u> at a <u>constant</u> / <u>uniform</u> rate	1
6 (b) (ii)	impulse = area under curve Area = $\left(\frac{1}{2} \times 0.6 \times 10^{-3} \times 2.2 \times 10^{3}\right) + \left(0.3 \times 10^{-3} \times 2.2 \times 10^{3}\right)$ $+ \left(\frac{1}{2} \times 0.6 \times 10^{-3} \times 2.2 \times 10^{3}\right)$ = 0.66 + 0.66 +0.66 = 1.98 (N s)	 1 1
6 (b) (iii)	Impulse = Δ(m v) $v = \frac{1.98}{140 \times 10^{-3}}$ = 14 (m s^{-1})	 1
7 (a)	In both collisions, momentum and total energy are conserved. In an elastic collision, kinetic energy is also conserved. In an inelastic collision, kinetic energy is not conserved. Some energy is transferred to other forms, such as heat.	1 1 1
7 (b) (i)	According to Newton's third law, the force experienced by A and B is the same and in <u>opposite</u> directions. Hence they fly off in opposite directions. The momentum of each is the same.	1 1
7 (b) (ii)	momentum of A = momentum of B 0.25 $M \times v_A$ = 0.75 $M \times v_B$ (M = total mass of object) v_A = 3.0 v_B ratio = $\frac{\frac{1}{2} \times 0.25M \times (3.0v_B)^2}{\frac{1}{2} \times 0.75M \times v_B^2}$	1 1 1 1
8 (a)	A collision in which momentum is conserved but kinetic energy is not.	1

Question	Answer	Marks
8 (b) (i)	change in momentum of A = (–) change in momentum of B change in momentum of B = 2.0 – 5.0 = (–) 3.0 kg m s^{-1}	1 1
8 (b) (ii)	force = rate of change of momentum and according to Newton's third law the force experienced by A and B have the same magnitude. force = $\frac{2.0 - 5.0}{0.05}$ force = (–) 60 N	1 1 1
8 (c)	total initial momentum = total final momentum (1.2 × 2.0) – (0.80 × 2.0) = (1.2 × 0.3) + 0.80 v v = 0.55 m s^{-1} (to the right)	1 1 1
8 (d) (i)	The component of the momentum at right angles to the initial direction of travel of X is zero; hence the total momentum in this direction remains zero.	1
8 (d) (ii)	The momentum in the original direction remains the same. (m × 5.2) cos 30 + (m × 3.0) cos θ = (m × 6.0) (m = mass of each ball) θ = 60° (Alternatively: 3.0 sin θ = 5.2 sin 30 and hence θ = 60°)	1 1 1