8 Newton's laws of motion
Answers to practice questions

Question	Answer	Marks	Guidance
1 (a) (i)	To find acceleration a, given values for u, v and s, rearrange $v^2 - u^2 = 2as$ to give $a = \frac{v^2 - u^2}{2s} = \frac{0 - 20^2}{2 \times 40}$ $= -5.0\ \text{m s}^{-2}$	1 1	Tests your ability to use the given data to calculate the deceleration of a child in a car that decelerates to a standstill and to calculate the force on the child due to his or her seat belt.
1 (a) (ii)	To find the force F on the child, use $F = ma = 15 \times 5.0 = 75$ N	1	
1 (b)	She would have continued to move forward as the car slowed down and she would have collided with the back of a front seat or with the front windscreen of the car. The impact time would have been much less so the impact force would have been much greater.	1 1	Requires knowledge and understanding of physics to be used in the context of UK safety legislation to explain why child car seats make improve safety.
1 (c)	The stopping distance would be much less at 20 mph than at 30 mph. This is because the braking distance depends on the square of the speed so it would be reduced by more than half i.e. $(20/30)^2$. Fewer accidents would occur because cars travelling at 20 mph would stop in a much shorter distance than cars at 30 mph.	1 1 1	How Science Works also features in **(c)** which asks students to discuss why a 20 mph speed limit near a school is better than a 30 mph speed limit. Any general statements in the answer (e.g. the braking distance is less) needs to be backed up with a physics explanation.
2 (a)	Relevant points include: • when at constant speed, resultant force is zero (or forces are balanced) • weight and tension must have equal magnitudes • but act in opposite directions • a correct application of either Newton's first or second law of motion	3	First law: a body travelling at constant velocity is equivalent to one that is at rest, requiring no resultant force to act on it. Second law: from $F = m\,a$, a body travelling at constant velocity is not accelerating and so $F = 0$, i.e. there is no resultant force.
2 (b) (i)	maximum acceleration is produced when resultant force is a maximum; $F_{max} = 12.0 + 8.0 = 20$ N use of $F = ma$ gives $a = \frac{F}{m} = \frac{20}{6.5} = 3.1\ \text{m s}^{-2}$	1 1	The maximum force that can be applied to the body is achieved by adding the forces in the same direction along a straight line. The minimum force is achieved by adding these vectors in opposite directions along a straight line. In this instance, any magnitude of force between 4 N and 20 N could be achieved by adding the 12 N and 8 N forces at an angle to each other, using vector addition.

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2 (b) (ii)	minimum acceleration is produced when resultant force is a minimum; F_{min} = 12.0 − 8.0 = 4.0 N use of $F = ma$ gives acceleration $a = \frac{F}{m} = \frac{4.0}{6.5}$ = 0.62 m s^{-2}	1 1	
3 (a)	acceleration = gradient of graph $= \frac{13.5}{5.0}$ = 2.7 (± 0.1) m s^{-2}	1 1 1	Alternatively, it would be acceptable to calculate the acceleration by using $v = u + a\,t$, taking values for v and t from a point on the graph.
3 (b) (i)	use of $F = ma$ gives mass of car $m = \frac{F}{a} = \frac{2.0 \times 10^3}{2.7}$ = 740 kg	1 1	Credit would be given in **(b)** for the correct application of $F = ma$, no matter how wrong your answer to **(a)** had been.
3 (b) (ii)	resistive force = 2.0×10^3 (because resultant force on car is zero)	1	After 40 s the car is travelling at constant velocity (28 m s^{-1}). The forces acting on it are balanced.
4 (a) (i)	use of F = ma gives acceleration $a = \frac{F}{m} = \frac{1.8 \times 10^3}{900}$ = 2.0 m s^{-1}	1 1	Another simple exercise in substituting the given values in $F = ma$ and working out the result.
4 (a) (ii)	use of $v = u + a\,t$ gives v = 0 + (2.0 × 8.0) = 16 m s^{-1}	1	Questions involving $F = ma$ are often combined with further practice on the uniform acceleration equations. But be aware of the fact that they only apply when the acceleration is constant.
4 (a) (iii)	use of $s = u\,t + \frac{1}{2}\,a\,t^2$ gives distance $s = 0 + (\frac{1}{2} \times 2.0 \times 8.0^2)$ = 64 m	1 1	
4 (b) (i)	resultant force decreases because air resistance increases as the car's speed increases	1 1	The propulsive force provided by the engine is opposed by increasing resistive forces as the car speeds up.
4 (b) (ii)	Relevant points include: • eventually the propulsive force and the resistive force are equal in magnitude • resultant force is zero • F = 0 means there is no acceleration (or speed remains constant) • a correct application of either Newton's first or second law of motion	3	First law: a body travelling at constant velocity is equivalent to one that is at rest, requiring no resultant force to act on it. Second law: from $F = m\,a$, a body travelling at constant velocity is not accelerating and so F = 0, i.e. there is no resultant force.
5 (a) (i)	270 × 4 = 1080 kN	1	There are four identical engines. When substituting in $F = ma$, note once more that the force must be in N and not in kN.

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5 (a) (ii)	use of $F = ma$ gives acceleration $a = \frac{F}{m} = \frac{1.08 \times 10^6}{3.2 \times 10^5}$ $= 3.38$ m s^{-2}	1 1	
5 (b) (i)	use of $v = u + a\,t$ gives $90 = 0 + 3.38\,t$ ∴ time to reach take-off speed = 27 s	1 1	A take-off speed of 90 m s^{-1} is 324 km h^{-1} (about 200 miles per hour).
5 (b) (ii)	resultant force on aircraft $F_{res} = ma = 3.2 \times 10^5 \times 2.0 = 6.4 \times 10^5$ N F_{res} = (force of engines) − (frictional force) ∴ frictional force = 1080 − 640 = 440 kN	1 1	The frictional force greatly reduces the overall propulsive effect on the aircraft, decreasing the acceleration considerably.
5 (c)	use of $v^2 = u^2 + 2\,a\,s$ gives $90^2 = 0 + (2 \times 2.0 \times s)$ ∴ minimum length of runway = 2025 m = 2.03 km	1 1	For safety reasons, the runway needs to be longer than this. A typical modern intercontinental airport has a main runway about 3 km long.
5 (d)	using $v = u + a\,t$ gives 260 = 90 + 2.0 t time to cruising speed t = 85 s	1 1	The time required is from the point of **take-off** (at 90 m s^{-1}) and not from when the aircraft was at rest.
5 (e)	Relevant points include: • (vertically) lift = weight, so flight is level • (horizontally) thrust = drag, so no acceleration • no resultant force either vertically or horizontally	2	When cruising, this aircraft moves at a constant horizontal velocity. It is obvious that the vertical forces must be balanced. The horizontal forces are demonstrating Newton's laws of motion: no acceleration means no resultant force is acting.
6 (a)	component of weight parallel to ramp $= W \sin\theta = 7.2 \times 103 \sin 30°$ $= 3.6 \times 103$ N	1	It usually helps to indicate the forces on a quick sketch. The angle between the vertical and a normal to the surface of the ramp is equal to the angle of the ramp.
6 (b)	mass of car and passengers $M = \frac{W}{g} = \frac{7.2 \times 10^3}{9.81} = 734$ kg use of $F = ma$ gives deceleration $a = \frac{F}{m} = \frac{3.6 \times 10^3}{734} = 4.90$ m s^{-2}	1 1	Unusually, you are provided with a value for the weight when $F = ma$ requires use to use the **mass**. The component of the weight acts **down** the ramp as the car moves **up** the ramp. This component therefore provides a decelerating force.
6 (c)	use of $v^2 = u^2 + 2\,a\,s$ gives $0 = 18^2 + (-2 \times 4.90 \times s)$ ∴ length of ramp s = 33 m	1 1	The decelerating force remains constant as the car travels up the ramp, so you can use the uniform acceleration equations.

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6 (d)	Relevant points include: • frictional forces act on car and passengers • these increase the resultant force acting down the ramp • therefore the deceleration is greater • energy is lost as heat	2	The frictional forces acting include air resistance and friction in the bearings of the fairground car's wheels. These forces contribute to a greater force down the ramp, producing a greater deceleration. Hence the car stops more quickly and covers a smaller stopping distance.