Question	Answers	Extra information	Mark	AO / Specification reference
01.1	suitable method, e.g., • attach trolley to string with hanging mass over pulley or diagram • keep force constant • use motion sensor/light gates to measure velocities and times/acceleration • change mass measure acceleration • repeat several times and find mean	accept diagram illustrating answer	1 1 1 1 1	AO1 AO2 4.5.6.2.2
01.2	Newton's second law says that the acceleration of an object is proportional to the (net) force and inversely proportional to the mass		1	AO1 4.5.6.2.2
01.3	inertia is the tendency of objects to continue in their state of rest or in uniform motion/a measure of how difficult it is to change the velocity of an object		1	AO1 4.5.6.2.2
01.4	if the acceleration is inversely proportional to mass, then doubling the mass will halve the acceleration the acceleration for a mass of 0.1 kg is 40 and half of 40 is 20		1 1	AO3 4.5.6.2
01.5	yes friction would reduce the resultant force which would produce an acceleration smaller than predicted by Newton's second law		1 1 1	AO2/1 AO3 4.5.6.2.2
02.1	no there is no resultant force acting on the puck		1 1	AO1 AO2 4.5.6.2.1

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02.2	no the puck does not carry the force/you need to apply a resultant force in the opposite direction (for it to stop)		1 1	AO1 AO2 4.5.6.2.1
02.3	no the force on the puck or the stick is the same magnitude as the force of the stick on the puck		1 1	AO1 AO2 4.5.6.2.3
02.4	yes the speed does not change, but the direction does, so the velocity changes and it accelerates		1 1	AO3 4.5.6.2.2
03.1	resultant force = mass × acceleration 10 000 - 2000 = 8400 × acceleration acceleration = $\frac{8000}{8400}$ = 0.95 m/s^2 no, it does not exceed the expected value		1 1 1 1 1	AO2 AO3 4.5.6.2.2
03.2	mass with half a load = 8400 – 1600 = 6800 kg mass with no load = 8400 – 3200 = 5200 kg acceleration when half full = $\frac{8000}{6800}$ = 1.18 m/s^2 acceleration when empty = $\frac{8000}{5200}$ = 1.54 m/s^2 it would be safe to do so with the lorry half empty but not when the lorry is completely empty.		1 1 1 1 1 1	AO2 AO3 4.5.6.2

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04.1	(1.5 N, 0.4 m/s^2)		1	AO3
04.2	line of best fit drawn		1	
04.3	systematic		1	AO3
04.4	the graph does not go through (0,0) **or** there is an intercept on the x-axis 0.15 N		1 1	AO3
04.5	(net) force = mass × acceleration		1	AO1 4.5.6.2.2
04.6	using a point such as (2.0, 0.9) force = 2.0 - 0.15 = 1.85 N, you need to subtract the zero error acceleration = 0.9 m/s^2 1.85 = mass × 0.9 mass = $\frac{1.85}{0.9}$ mass = 2.05 (kg)	pair of values read from graph	1 1 1 1	AO2 4.5.6.2.2
05.1	work is done by friction/energy transferred mechanically		1	AO1 4.5.6.3.4
05.2	the brakes/the surroundings		1	AO1 4.5.6.3.4

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05.3	deceleration = $\frac{\text{change in velocity}}{\text{time taken}}$ = $\frac{20}{4.3}$ = 4.7 m/s^2 assuming the acceleration is constant the acceleration is probably not constant because the brakes do not exert a constant force		1 1 1 1 1	AO1 AO2 AO3 4.5.6.3.4
05.4	braking force = mass × deceleration = 1250 × 4.7 = 5875 (= 5900 N) this is similar to the forces exerted by car engines	allow F = ma	1 1 1	AO2 4.5.6.3.4
06.1	graph B in an emergency stop the driver presses the brake pedal harder/uses a bigger force producing a bigger deceleration at every speed the braking distance is shorter		1 1 1 1	AO2 AO3 4.5.6.3.3 4.5.6.3.4
06.2	appropriate suggestion, e.g., • internal organs can be damaged • the organs of your body continue to move	alternative: extra friction on/damage to the tyres	1	AO2 4.5.6.3.4

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06.3	no difference/it is the same at a particular speed thinking distance is related to reaction time, which is the same in both situations at the same speed		1 1	AO1 AO2 4.5.6.3.1 4.5.6.3.2
07.1	independent – type of surface dependent – distance it travels on the surface before stopping control – any **two** from: • height of ramp • position of release of trolley • type of trolley • mass of trolley	one mark for each correct answer up to a maximum of two mark	1 1 2	AO2
07.2	method, e.g., • raise one end of the ramp by a height h • cover the floor at the other end of the ramp with a type of surface • place a trolley at the top of a ramp and releases it • measure the distance the trolley travels from the bottom of the ramp to the place that it stops • repeat the experiment twice more with the same surface • replace the surface with a different material and repeat the experiment with ramp at same height h • identify outliers; do not include them in the calculation of mean		5	AO1

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07.3	appropriate example with improvement e.g., releasing the trolley from exactly the same place each time improvement: draw a line on the ramp and line up the back of the trolley with the line each time.	**or** leaving ramp, make transition as smooth as possible by making sure the surface is at the same height as the bottom of the ramp	1 1	AO3
07.4	this is a good model because different surfaces will affect the stopping distance difference surfaces produce different frictional forces on the trolley, so do different amounts of work on it		1 1 1	AO3
07.5	the investigation does not involve braking because the trolley does not have brakes **or** no thinking distance can be included as no 'brain' in the trolley		1 1 **or** 1 1	AO2 AO3 4.5.6.3.4
08.1	weight = mass × gravitational field strength = 110 × 9.8 = 1078 N		1 1 1	AO1 AO2 4.5.6.2.2

Question	Answers	Extra information	Mark	AO / Specification reference
08.2	force = mass × acceleration = 110 × 2.0 = 220 N		1 1 1	AO1 AO2 4.5.6.2.2
08.3	total force = 1078 + 220 = 1298 N		1 1	AO2 4.5.6.2.2
08.4	the object will not move the upwards force is equal to the weight there is no resultant force		1 1 1	AO3 4.5.6.2.2
09.1	the data is checked by other scientists peer review		1 1	AO1
09.2	force is measured in newtons/kilograms or tonnes are both a unit of mass, not force		1	AO1 4.5.1.3
09.3	weight = mass × gravitational field strength	allow W = mg	1	AO1 4.5.1.3
09.4	W = 1000 × 9.8 = 9800 N		1 1	AO2 4.5.1.3
09.5	people (without a science background) reading the article may be able to relate better to tonnes than to newtons.		1	AO3

Question	Answers	Extra information	Mark	AO / Specification reference
09.6	momentum = mass × velocity acceleration = $\frac{\text{change in velocity}}{\text{time taken}}$ velocity = acceleration × time = 9.8 × 2.5 = 24.5 m/s momentum = 2.5 × 24.5 = 61.3 kg m/s	Alternative method: Ft = mv – mu 2.5 x 9.8 x 2.5 = mv – 0 mv = 61.25 kg m/s	1 1 1 1	AO1 AO2
10.1	force = mass × acceleration		1	AO1 4.5.6.2.2
10.2	conversion of both masses to the same units leafhopper = 2×10^{-6} × 1000 = 2×10^{-3} N cheetah = 50 × 5.0 = 250 N the force produced by the cheetah is $\frac{250}{2\times10^{-3}}$ = 125 000 times bigger.	substitution and answer substitution and answer	1 1+1 1+1 1	AO1 AO2 4.5.6.2.2
10.3	if acceleration is proportional to top speed then $\frac{\text{acceleration}}{\text{top speed}}$ = constant. for the leafhopper, $\frac{\text{acceleration}}{\text{top speed}} = \frac{1000}{4}$ = 250 for the cheetah, $\frac{\text{acceleration}}{\text{top speed}} = \frac{5}{30}$ = 0.17 no, they are not directly proportional		1 1 1 1	AO3 4.5.6.2.2

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10.4	F = 70 × 1000 = 70 000 N car = 40 kN = 40 000 N the suit has a force nearly twice that of a car		1 1 1 1	AO2 AO3 4.5.6.2
11.1	force = mass × acceleration A = 1611 × 4.79 = 7717 N B = 1565 × 3.78 = 5916 N C = 1864 × 5.59 = 10 420 N no, the forces produced by the engines are not the same		1 1 1 1 1	AO2 AO3 4.5.6.2.2
11.2	3000 N/3 kN		1	AO2 4.5.6.2.1
11.3	net force = -3000 N F = ma -3000 = 1565 × acceleration acceleration = $-\frac{3000}{1565}$ = -1.92 m/s^2	resistive force is negative	1 1 1 1	AO1 AO2 4.5.6.2