	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	5	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	accept F = ma	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 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
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

	Answers	Extra information	Mark	AO / Specification reference
02.3	no the force of the puck on 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
04.1	075N, 0.4m/s^2		1	AO3
04.2	line of best fit drawn		1	
04.3	systematic		1	AO3

	Answers	Extra information	Mark	AO / Specification reference
04.4	the graph does not go through (0,0)/there is an intercept on the x-axis 0.15 N		1	AO3
04.5	(net) force = mass × acceleration	accept F = ma	1	AO1 4.5.6.2.2
04.6	using a point such as (1.0, 0.89) force = 1.0 - 0.15 = 0.85 N, you need to subtract the zero error acceleration = 0.89 m/s^2 0.85 = mass × 0.89 mass = 0.96 (kg)	accept 0.85 – 1.05 with no working for two calculation marks	1 1 1 1	AO2 4.5.6.2.2
05.1	40 miles = 40 x 1609 = 64 360 m speed = $\frac{\text{distance}}{\text{time}}$ = $\frac{64360}{3600}$ = 17.9 m/s		1 1 1	AO1 AO2 4.5.6.1.2
05.2	the direction		1	AO1 4.5.6.1.3
05.3	cyclist speed – 6m/s it is about three times faster than a cyclist		1	AO1 AO2 4.5.6.1.2

	Answers	Extra information	Mark	AO / Specification reference
05.4	$(\text{final velocity})^2 - (\text{initial velocity})^2 = 2 \times \text{acceleration} \times \text{distance}$ $(17.9)^2 - (0)^2 = 2 \times \text{acceleration} \times 30$ $\text{acceleration} = \frac{17.9^2}{2 \times 30}$ $= \frac{320}{60}$ = 5.34 = 5.3 m/s^2	answer given to two significant figures	1 1 1 1 1	AO2 4.5.6.1.5
05.5	one mark for initial section with constant slope one mark for having this followed by horizontal section maximum velocity = 17.9 m/s labelled		1 1	AO2 4.5.6.1.5
06.1	B		1	AO2 4.5.6.2.1
06.2	C		1	AO2 4.5.6.2.1
06.3	force = mass × acceleration = 3500 × (-4) = -14 000 N	two marks only if no minus sign	1 1 1	AO2 4.5.6.2.2
06.4	the track is not straight/the track is a curved/it's rough so more friction		1	AO3 4.5.6.2.1
07.1	15 N		1	AO2 4.5.1.3

	Answers	Extra information	Mark	AO / Specification reference
07.2	weight = mass × gravitational field strength		1	AO1 4.5.1.3
07.3	1.4 = mass × 9.8 mass = $\frac{1.4}{9.8}$ mass = 0.143 kg		1 1 1	AO2 4.5.1.3
07.4	frictional force on block = 3.5 N (from graph) applied force = 5 N, so net force = 5 - 3.5 = 1.5 N force = mass × acceleration 1.5 = 0.143 × acceleration acceleration = $\frac{1.5}{0.143}$ = 10.5 m/s^2		1 1 1 1 1 1	AO1 AO2 AO3 4.5.1.3
07.5	the frictional force is less than that shown on the graph when the object is moving		1	AO3 4.5.1.3
08.1	acceleration = $\frac{\text{change in velocity}}{\text{time taken}}$	accept a = $\frac{v-u}{t}$	1	AO1 4.5.6.1.5
08.2	a = $\frac{10000}{5 \times 60}$ = 33.3 m/s^2		1 1 1	AO1 AO2 4.5.6.1.5

	Answers	Extra information	Mark	AO / Specification reference
08.3	(final velocity)^2 – (initial velocity)^2 = 2 × acceleration × distance $(10\,000)^2 - (0)^2 = 2 \times 33.3 \times$ distance distance = $\frac{10000^2}{2 \times 33.3}$ = 1 501 502 m = 1.5×10^6 m	answer is given in standard form	1 1 1 1	AO2 4.5.6.1.5
08.4	distance = speed × time $3.8 \times 10^5 \times 10^3 = 10\,000 \times$ time time = 38 000 s = 10.5 hours	accept d = s × t	1 1 1 1	AO1 AO2 4.5.6.1.2
08.5	sensible suggestion for less time e.g., as you get close to the Moon, its gravity will accelerate you, increasing the speed and decreasing the time sensible suggestion for more time e.g., as you move away from the Earth, the Earth's gravity still acts on you, decreasing the speed, increasing the time		1 1	AO3 4.5.1.3
09.1	weight = mass x gravitational field strength of object = 110 × 9.8 = 1078 N		1 1 1	AO1 AO2 4.5.6.2.2
09.2	force = mass x acceleration = 110 x 2.0. = 220 N		1 1 1	AO1 AO2 4.5.6.2.2
09.3	total force = 1078 + 220 N = 1298 N		1 1	AO2 4.5.6.2.2

	Answers	Extra information	Mark	AO / Specification reference
09.4	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
10.1	place one light gate at the top of the ramp place the other light gate at the bottom place the trolley at the top of the ramp, immediately before the first light gate and release the trolley	accept any sensible description	1 1 1	AO1 4.5.6.2.2
10.2	the force acting on the trolley is the component of the weight acting down the slope the magnitude of the component depends on the angle of the slope, which depends on the height as the height increases the force increases	must include 'component' must include 'angle'	1 1 1	AO2 4.5.6.2.2
10.3	no there could be uncertainty in the positioning/height of the top of the ramp	do not accept changes in acceleration	1 1	AO2 4.5.6.2.2
10.4	Points plotted at: (0, 0.00), (15, 2.59), (20, 3.42), (25, 4.22), (30, 5.00), (35, 5.73), (40, 6.43)	one mark for up to four points plotted correctly one mark for rest of points correctly one mark for line of best fit	3	AO2 AO3 4.5.6.2.2
10.5	eventually the ramp will be vertical/the trolley will just fall it will be a value equal to the acceleration due to gravity	accept values 9.81/10 m/s^2	1 1	AO3 4.5.6.2.2
11.1	force = mass × acceleration		1	AO1 4.5.6.2.2

	Answers	Extra information	Mark	AO / Specification reference
11.2	conversion of both masses to the same units leafhopper = $2\times10^{-6} \times 1000 = 2\times10^{-3}$ N cheetah = 50 × 5.0 = 250 N the force produced by the cheetah is $\frac{250}{2\times10^{-3}}$ = 125 000 times bigger		1 1+1 1+1 1	AO1 AO2 4.5.6.2.2
11.3	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
11.4	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
12.1	force = mass × acceleration F_{tesla} = 1611 × 4.79 = 7717 N F_{audi}= 1565 × 3.78 = 5916 N F_{BMW}= 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
12.2	3000 N/3 kN		1	AO2 4.5.6.2.1

	Answers	Extra information	Mark	AO / Specification reference
12.3	net force = - 3000 N –3000 = 1565 × acceleration acceleration = $-\frac{3000}{1565}$ = –1.92 m/s^2		1 1 1 1	AO1 AO2 4.5.6.2
13.1	when two objects interact, the forces they exert on each other are equal and opposite		1	AO1 4.5.6.2.3
13.2	the exhaust gases pushing downwards produces force of equal magnitude acting in the opposite direction	one mark for equal magnitude one mark for opposite direction	2	AO2 4.5.6.2.3
13.3	no Newton's Third Law applies to two different objects interacting, and the student is talking about one object.		1 1	AO2 4.5.6.2.3
14	**Level 3:** Describes effect of the forces in each case, and that the ball on track B ends up with the higher average speed due to the additional acceleration at the start.		5-6	AO1 AO2 AO3 4.5.6.2.2
	Level 2: Describes effect of the forces in each case in accelerating and decelerating the ball, acknowledging that the ball on track B travels faster.		3-4	
	Level 1: Describes how the force of gravity produces an acceleration of each ball and deduces that the balls reach the end of the track at the same time.		1-2	
	No relevant comment		0	

	Answers	Extra information	Mark	AO / Specification reference
	Indicative content: • on track A the ball experiences an accelerating force while it is on the curved part of the track • then it will travel at a steady speed • on track B the ball will accelerate to the same velocity as the ball in A before it goes into the dip • as it goes into the dip it will accelerate again • it will spend the time at the bottom of the dip travelling at a faster speed than the ball on track A • so the ball on track B will have the highest average speed • so will reach the end of the track first			