	Answers	Extra information	Mark	AO / Specification reference
01.1	hold the ruler as close to the centre of the light gates as possible, with the ruler vertical make the measurement by looking directly at/at 90° to the ruler.		1 1	AO1 AO2
01.2	suitable suggestion e.g., the card was dropped from different heights above light gate 1		1	AO3 4.5.6.1.4
01.3	the light gates use a light beam so produces a measurement of time, and the computer calculates velocity, so velocity measurements are more precise/more significant figures the data logger can measure to $\frac{1}{1000}$ second/1 ms when you use a ruler you can measure to the nearest mm.		1 1 1	AO3
01.4	(final velocity)^2 – (initial velocity)^2 = 2 × acceleration × distance $(2.987)^2 - (1.376)^2 = 2 \times$ acceleration $\times 0.30$ acceleration = $\frac{2.987^2 - 1.376^2}{2 \times 0.3}$ = 11.715 = 11.7 (m/s^2)	allow symbols answer given to two significant figures accept 11.7 with no working for the two calculation marks	1 1 1	AO2
01.5	measured value is more than calculated value because card may not have fallen completely vertically and so distance travelled is actually greater than 30 cm		1	AO3 4.5.6.1.5
02.1	typical speeds: walking – 1.5 m/s cycling – 6 m/s		1 1	AO1 4.5.6.1.2

	Answers	Extra information	Mark	AO / Specification reference
02.2	distance = speed × time		1	AO1 4.5.6.1.2
02.3	1500 = 1.5 × time time A = $\frac{1500}{1.5}$ = 1000 s time B = $\frac{1500}{6}$ = 250 s difference = 1000 – 250 = 750 s = 12.5 minutes		1 1 1 1 1 1	AO1 AO2 4.5.6.1.2
02.4	average speed = $\frac{\text{total distance}}{\text{total time}}$ you do not need to travel at the fastest speed for the whole time	or words to that effect	1 1	AO1 AO2 4.5.6.1.2
03.1	plots are: (0,0), (2,2), (4,5), (6,8), (8,14), (10,20), (12,22) curved line of best fit		2	AO2 4.5.6.1.4
03.2	calculation of $\frac{\text{change in time}}{\text{change in distance}}$ = $\frac{8 - 2}{6 - 2}$ = 1.5 m/s		1 1 1	AO2 4.5.6.1.4
03.3	the student moves with a steady speed higher than 1.5 m/s for about 4 seconds then slows down		1 1	AO3 4.5.6.1.4

	Answers	Extra information	Mark	AO / Specification reference
04.1	car A the gradient of the line is greatest/steepest line		1 1	AO2 AO3 4.5.6.1.4
04.2	car C the car is horizontal between 4 and 7 mins		1 1	AO2 AO3 4.5.6.1.4
04.3	car C the line is curved/not a straight line/not a constant gradient or slope after 7 mins		1 1	AO2 AO3 4.5.6.1.4
04.4	car A it travelled the same distance in the shortest time		1 1	AO2 AO3 4.5.6.1.4
04.5	correct time = 4 minutes = 240 seconds, correct distance = 7.5 km = 7500 m distance = speed × time 7500 = speed × 240 speed = $\frac{7500}{240}$ s = 31.25 m/s	accept 31.255 with no working for the two calculation marks	1 1 1 1	AO2 4.5.6.1.4
05.1	0.6 m/s		1	AO2 4.5.6.1.5

	Answers	Extra information	Mark	AO / Specification reference
05.2	area of each rectangle = 0.2 × 0.1 = 0.02 m 36 rectangles under straight line section 18 under curve (counting whole and partial rectangles) total of 36 + 18 = 54 rectangles distance = 54 × 0.02 = 1.08 m	allow 0.9 to 1.15 m	1 1 1	AO2 4.5.6.1.5
05.3	one mark for line with higher gradient one mark for having that line take longer to reach a horizontal line one line for that line stopping sooner the weight is bigger, so the initial acceleration is bigger the helicopter takes longer to reach terminal velocity the area under each graph is the same.		1 1 1 1 1 1	AO3 4.5.6.1.5
05.4	there is a drag force that is proportional to the velocity/as velocity increases, air resistance increases **or** the helicopter is spinning	accept any sensible suggestion	1	AO3 4.5.6.1.5
06	**Level 3**: Well organized answer with descriptions of reasons for calculations. Appropriate units given in all calculations. At least one assumption with effect on calculation given		5-6	AO1 AO2 AO3 4.5.6.1.2
	Level 2: Some relevant calculations, and difference in time calculated, but unit conversions missing or unhelpful. Some comment about speeds not being constant.		3-4	
	Level 1: Some relevant calculations completed, but unit conversions may be missing, and no explanation of method. No comment about assumptions.		1-2	
	No relevant comment.		0	

	Answers	Extra information	Mark	AO / Specification reference
	Indicative content: • suitable value for typical speeds: ○ car – 50 mph ➢ distance = speed × time ➢ 20 = 50 × time ➢ time = $\frac{20}{50} = \frac{2}{5}$ hour = $2 \times \frac{60}{5}$ = 24 minutes ○ bicycle – 15 mph ➢ method as above: 80 minutes ➢ you arrive 80 – 24 = 56 minutes earlier by car ○ train – 80 mph ➢ method as above: 15 minutes so fastest by train • assuming he travels at that speed for the entirety of the journey • he will not do this, if faster than assumed speed he will arrive quicker and if slower journey times would be longer • for most journeys there are multiple parts travelling at different speeds • train has ignored the time taken to get to and from the station, this should be added on	allow suitable values for typical speeds in m/s and times calculated with distance of 20 miles converted to metres		
07.1	distance travelled = 2 × 20 200 000 = 40 400 000 m distance = speed × time 40 400 000 m = 300 000 000 × time time = $\frac{40400000}{300000000}$ = 0.135 s	distance double that given in question	1 1 1	AO1 AO2 4.5.6.1.2

	Answers	Extra information	Mark	AO / Specification reference
07.2	convert 55 mph to m/s: 55 mph = 55 × $\frac{1609}{3600}$ = 24.6 m/s (25 m/s) distance = speed × time = 24.6 m/s × 0.135 s = 3.3 m	allow 3.2 to 3.3 m for use of 0.1 s	1 1 1	AO2 4.5.6.1.2
07.3	systematic the same time difference is introduced each time (though the distance will depend on the speed that distance is predictable)		1 1	AO3
07.4	work out two positions work out the time (between the two positions) finds the distance between the two positions and the time to work out the speed		1 1 1	AO3 4.5.6.1.3
07.5	(the satellite is moving at a constant speed but) its direction is constantly changing its velocity is constantly changing, (so it is accelerating)		1 1	AO3 4.5.6.1.3
08.1	gravity		1	AO1 4.5.1.3
08.2	weight = mass x gravitational field strength = 10×10^3 x 9.8 = 9.8×10^4 N **or** 98 000 N		1 1 1	AO1 AO2 4.5.1.3
08.3	work done = force x distance = 9.8×10^4 x 2 = 1.96×10^5 (2.0×10^5) J		1 1 1	AO1 AO2 4.5.2

	Answers	Extra information	Mark	AO / Specification reference
08.4	draw a scale diagram draw two arrows at 90 degrees, one along the slope and one perpendicular to the slope use the scale to work out the length alternative answer based on my question: draw two arrows at 90 degrees one arrow along the slope and one perpendicular to the slope use the parallelogram rule to work out the length		1 1 1	AO1 AO2 4.5.1.4
08.5	force needed to pull block up slope= 3000 + 49 000 = 52 000N distance = 4 m work = force x distance = 52 000 x 4 m = 208 000 J		1 1 1	AO1 AO2 4.5.2
08.6	the force needed along the slope is smaller than lifting it vertically against gravity	do not accept 'easier' without some reference to the sie of the force	1	AO2 4.5.2
09.1	the point at 4.2 cm/4.4 N		1	AO3 4.5.3
09.2	force = spring constant × extension		1	AO1 4.5.3

	Answers	Extra information	Mark	AO / Specification reference
09.3	use of initial linear section of the graph/line of best fit (ignoring outlier) 4.5 N = spring constant x 0.052 m spring constant = $\frac{4.5}{0.0052}$ = 87 N/m (or 0.87 N/cm)	allow tolerance of +/- 10 (N/m)	1 1 1 1	AO2 4.5.3
09.4	That is where the line starts to curve/bend/is no longer a straight line/as F is no longer proportional to e		1	AO1 4.5.3
10.1	acceleration = $\frac{\text{final velocity-initial velocity}}{\text{time}}$	allow a = $\frac{v-u}{t}$ or acceleration = $\frac{\text{change in velocity}}{\text{time}}$	1	AO1 4.5.6.1.5
10.2	acceleration = $\frac{7.12-1.12}{1.25}$ = 4.8 m/s^2	accept 4.8 with no working for two calculation marks	1 1 1	AO1 AO2 4.5.6.1.5
10.3	the acceleration due to gravity 9.8 m/s^2 ratio = 4.8:9.8 = 1:2 (2.04)	accept 2:1 with reverse working shown	1 1	AO1 AO2 4.5.6.1.5

	Answers	Extra information	Mark	AO / Specification reference
10.4	one mark for two straight line sections with correct overall shape not starting at origin one mark for a longer time decelerating than accelerating one mark for steeper line accelerating than decelerating and any two from: • the acceleration of the trolley down the ramp is bigger than the deceleration (because the change in velocity takes a longer time) • the gradient when accelerating is larger than decelerating • the acceleration part shows a positive gradient, and the deceleration shows a negative gradient.		1 1 1 2	AO2 AO3 4.5.6.1.5
11.1	pressure increases as you increase the depth (total weight of the air plus) the total weight of the water over a given surface area	allow P = h x ρ x g, larger depth (h) = larger P	1 1	AO1 4.5.5.2
11.2	change in pressure = 1 318 250 - 101 325 = 1 216 925 Pa change in pressure = density x gravitational field strength x change in height 1 216 925 = 1000 x 9.8 x change in height change in height = $\frac{1216925}{9800}$ = 124 m.		1 1 1 1	AO2 4.5.5.2 4.5.5.1.2
12.1	the first fuel cell (the acceleration is bigger so) the kinetic energy store is filling at a faster rate		1 1	AO2 AO3 4.5.6.1.5 4.1.1.1

	Answers	Extra information	Mark	AO / Specification reference
12.2	acceleration = $\frac{\text{change in velocity}}{\text{time taken}}$ = $\frac{50-30}{4}$ = 5 m/s^2		1 1	AO2 4.5.6.1.5
12.3	10 s area under graph = distance travelled, maximum area is at 10 s **or** when it is a maximum distance from the ground its velocity is zero/it has stopped momentarily		1 1	AO2 AO3 4.5.6.1.5
12.4	when it hits ground, the distance travelled upwards = distance travelled downwards distance = area under graph, the area before 10 seconds is greater than the area after 10 seconds		1 1	AO3 4.5.6.1.5
13.1	light gates at top surface and the height where she wishes to measure		1	AO2
13.2	(final velocity)^2 - (initial velocity)^2 = 2 × acceleration × distance (0.013)^2 - (0.035)^2 = 2 × acceleration × 0.30 acceleration = $\frac{0.013^2 - 0.035^2}{2 \times 0.30}$ = – 0.00 176 m/s^2 the sign of the acceleration is negative because the object is slowing down.	accept -0.00 176 with no working for two calculation marks negative sign justification	1 1 1 1	AO2 AO3 4.5.6.1.5
13.3	use several light gates placed equal distances apart to measure the velocity of the modelling clay at different points if the velocity does not change then it has reached terminal velocity		1 1	AO1 AO3 4.5.6.1.5

	Answers	Extra information	Mark	AO / Specification reference
13.4	as the density of the liquid increases the distance decreases bigger density means bigger drag force bigger negative acceleration/The speed changes over a smaller distance		1 1 1	AO3 4.5.6.1.5
14.1	distance and speed are scalars		1	AO1 4.5.1.1 4.5.6.1.1 4.5.6.1.3
14.2	20 km - 10 km = 10 km south	accept 10 with no working for one calculation mark	1 1	AO2 4.5.6.1.1
14.3	displacement is the position relative to a particular point/takes direction into account distance is the total distance that you move, which may not be the same as displacement if you change direction/does not take direction into account		1 1	AO1 AO2 4.5.6.1.1
14.4	velocity the cyclist is giving both a magnitude and a direction		1 1	AO1 AO2