Question	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 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	walking – 1.5 m/s cycling – 6 m/s		1 1	AO1 4.5.6.1.2

Question	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		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	two points for points plotted correctly	2	AO2 4.5.6.1.4
03.2	evidence of tangent drawn at 4 seconds calculation of change in distance/change in time = $\frac{8 - 2}{6 - 2}$ = 1.5 m/s	accept values from one or two 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

Question	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 line is horizontal between four and seven minutes		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 a slope after seven minutes		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 = $\frac{7500}{240}$ = 31 (31.25 m/s)	reading values off graph and converting	1 1 1 1	AO2 4.5.6.1.4
05.1	it is possible to find the velocity at a range of different times/lots of times, compared to light gates which measure two velocities		1	AO3 4.5.6.1.5

Question	Answers	Extra information	Mark	AO / Specification reference
05.2	AB shows decreasing acceleration BC shows constant acceleration CD shows zero acceleration/constant speed/constant velocity		1 1 1	AO3 4.5.6.1.5
05.3	initial (greatest acceleration) = $\frac{\text{change in velocity}}{\text{time taken}}$ = $\frac{0.5 - 0}{0.2}$ = 2.5 m/s^2.	accept 2.5 with no working for the two calculation marks	1 1 1	AO2 4.5.6.1.5
05.4	distance travelled = area under the graph by counting squares one square = 0.5 × 0.5 = 0.25 m number of squares = 38 total distance = 38 × 0.25 = 9.5 m	allow answers between nine and ten m	1 1 1 1	AO2 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 4.5.61.2
	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	

Question	Answers	Extra information	Mark	AO / Specification reference
	Indicative content: ➢ suitable value for typical speeds: ➢ car – 50 mph ➢ distance = speed × time ➢ 20 miles = 50 mph × time ➢ time = $\frac{20}{50} = \frac{2}{5}$ hour = 2 × $\frac{60}{5}$ = 24 minutes ➢ bicycle – 15 mph ➢ method as above: 80 minutes ➢ you arrive 80 - 24 = 56 minutes earlier ➢ train – 80 mph ➢ method as above: 15 minutes ➢ 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 distance = speed × time 40 400 000 = 300 000 000 × time time = $\frac{40400000}{300000000}$ = 0.13 s		1 1 1 1	AO1 AO2 4.5.6.1.2

Question	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 × 0.13 = 3.20 m (if 25 m/s and 0.1 s used, then 3.3 m)		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 × gravitational field strength = $10 \times 10^3 \times 9.8$ = 9.8×10^4 (N) **or** 98000 (N)		 1 1	AO1 AO2 4.5.1.3

Question	Answers	Extra information	Mark	AO / Specification reference
08.3	work done = force × distance $= 9.8 \times 10^4 \times 2$ $= 1.96\times10^5$ (J)	accept 2.0×10^5	1 1	AO1 AO2 4.5.2
08.4	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 × 4 = 208 000 J	resultant	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 size 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

Question	Answers	Extra information	Mark	AO / Specification reference
09.3	use of initial linear section of the graph/line of best fit (ignoring outlier) 1.0 N = spring constant × 0.011 spring constant = $\frac{1.0}{0.011}$ = 90 N/m (or 0.8 N/cm)		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

Question	Answers	Extra information	Mark	AO / Specification reference
10.4	one mark for two straight lines 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 **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	one mark for two straight lines 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	3	AO2 AO3 4.5.6.1.5