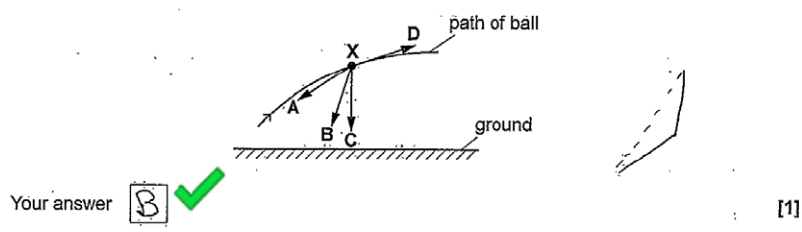
Mark scheme – Nature of Quantities

Question			Answer/Indicative content	Marks	Guidance
1			**A**	1	
			Total	**1**	
2			B	1	
			Total	**1**	
3	a		Arrow vertical down <u>and</u> an arrow opposite to the frictional force. Both arrows labelled correctly.	M1 A1	**Allow** weight / mg / W for the downward arrow <u>and</u> tension / T / 'force in rod' / 'force in tow bar' /'driving force' for the 'upward' arrow
	b		(W_s =) 1100 × 9.81 × sin 10° **or** 1100 × 9.81 × cos 80° (W_s = 1874 N or 1900 N)	C1 A0	**Allow** g instead of value
	c		force = 1900 + 300 force = 2200 (N)	A1	**Allow** 1870 + 300 = 2170 (N)
	d		(distance =) 120 / sin 10° **or** 691 (m) (work done =) 2200 × 691 work done = 1.5 × 10^6 (J)	C1 C1 A1	**Allow** ECF from **(c)** **Allow** ECF from an incorrect attempt at first mark.
	e		(A =) π × 0.006^2 **or** 1.1 × 10^{-4} (m^2) (stress =) $\frac{2200}{\pi \times 0.00}$ <u>an</u> <u>d</u> $2.0 \times 10^{11} = \frac{\text{stre}}{\text{stra}}$ x = 4.8 × 10^{-5} (m)	C1 C1 A1	**Allow** ECF from **(c)** **Allow** $x\,(=FL/EA) = \frac{2174 \times 0.5}{2.0 \times 10^{11} \times 1.1 \times 10^{-4}}$ **Allow** 2 marks for 1.2 × 10^{-5}; 1.2 × 10^{-2} m used as radius **Allow** answer between 4.7 and 5.1 × 10^{-5} (m)
			Total	**10**	
4			A quantity that has both direction and magnitude. Correct example given, e.g. velocity.	B1	**Note**: The B1 mark is for a correct statement and a correct example.

			Total	**1**	
5			**B**	1	<u>**Examiner's Comments**</u> The question requires knowledge and understanding of the forces acting on the ball in flight and resultant force. The path of the ball is shown. At **X**, the ball is travelling in the direction shown by the **D** arrow. The drag force will be in the opposite direction. Weight is other force acting on the ball – vertically downwards. Vectorially adding the weight and the small drag will produce a resultant in the direction shown by the **B** arrow. The answer (key) is therefore is **B**. The most popular distractors were **A** and **D**. **Exemplar 1**  The right–hand side of the exemplar has the jottings of a candidate and it does help to visualise the problem. This would certainly not qualify as an acceptable answer in Section B, but here, it demonstrates excellent technique; a vertical line for the *weight* and a slanting line for the *drag* and both being added to give the dotted line for the *resultant force*. This matches the arrow **B**.
			Total	**1**	
6			C	1	**Examiner's Comments** All of the questions showed a positive discrimination, and the less able candidates could access the easier questions. The questions in Section A do require careful reading and scrutiny. Candidates are advised to reflect carefully before recording their response in the box. Candidates must endeavour to use a variety of quick techniques when answering multiple choice questions. The correct key was **C** and the most popular distractor was **A**. The kinetic energy of the ball at the ground was K. At maximum height, the ball just has horizontal component of velocity. The kinetic energy of the ball is proportional to speed^2. At the maximum height the kinetic energy must therefore be $\cos^2 30° K = 0.75 K$.
			Total	**1**	
7			A	1	
			Total	**1**	
8			**A**	1	
			Total	**1**	
9			A	1	
			Total	**1**	

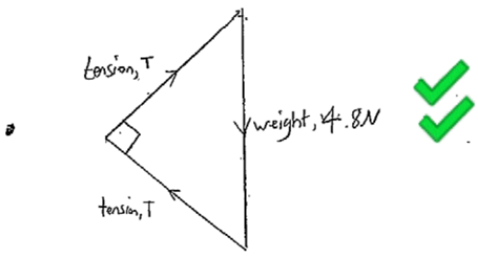
10			D	1	
			Total	**1**	
11			At t = 0 (and t = 15, 30) the (magnitude of the) centripetal force equals $R - W$ (as only vertical forces act on the tourist)	B1	**Allow** at t = 0 (**or** the bottom of the circle) the centripetal force is provided by the resultant/ upwards/vertical force
			Total	**1**	
12			**D**	**1**	
			Total	**1**	
13			A	1	
			Total	**1**	
14			**B**	**1**	
			Total	**1**	
15			**C**	**1**	
			Total	**1**	
16			**D**	1	**Examiner's Comments** This question showed that candidates had generally forgotten that the resultant force does not have to be in the direction of travel, hence all three statements could be correct, giving option D. This question provided opportunities for middle-grade candidates.
			Total	**1**	
17			C	1	
			Total	**1**	
18			B	1	
			Total	**1**	
19			**A**	1	
			Total	**1**	
20	a		$2 \times T^2 = 4.8^2$ **or** $2T\sin45° = 4.8$ **or** $T = 4.8 \sin45°$ **T** = 3.39(4)(N)	**B1** **B1**	**Note**: sin45° = cos45° **Note**: T must be given to at least 3 SF

Examiner's Comments

This question was good discriminator, where the top–end candidates could demonstrate their powers of analysis. The success in **(c)** was very much dependent on a well–annotated triangle of forces in **(b)**. Most triangle of forces were workable but lacked detail. Missing labels and incorrect direction of the force arrows were the main misdemeanours. As expected, candidates used a range of methods to show the force in the extended spring was 3.4 N. In order of popularity, the techniques were using Pythagoras' theorem, using trigonometry, resolving forces in the vertical direction and sine (or cosine) rule. It is sensible to show the final answer to more significant figures than required in a 'show' question.

Exemplar 6

(b) Sketch a **labelled** triangle of forces diagram for the three forces acting at point **X**. You do not need to draw this diagram to scale.



(c) Show that the tension *T* in each extended spring is 3.4 N.

$T^2 + T^2 = 4.8^2$

$2T^2 = 23.04$

$T^2 = 11.52$

$T = 3.39\ N$

~~3.4N~~

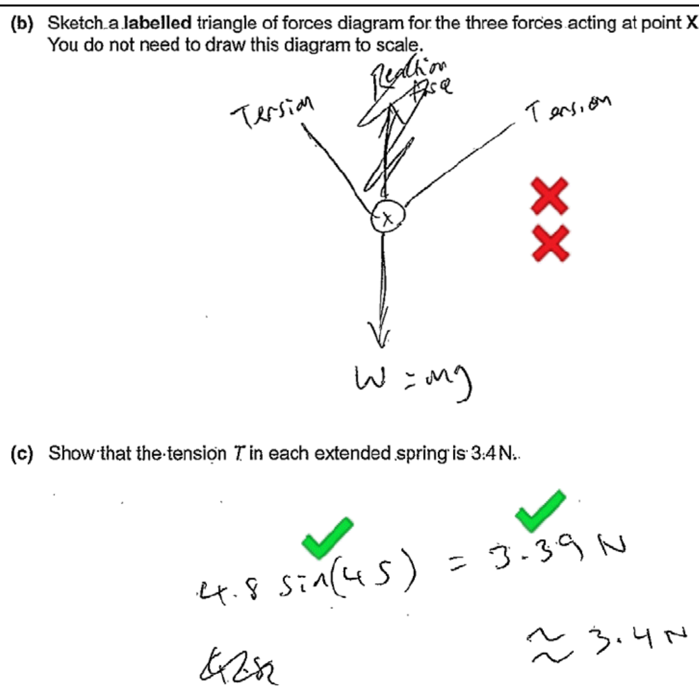
$\rightarrow 3.4N$

This exemplar illustrates a flawless answer from a top–end candidate.

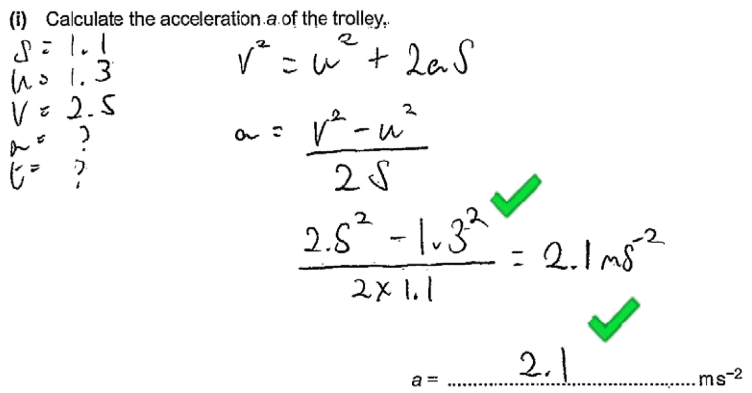
The triangle of forces of perfect – all labels clear and the pivotal angle 90° between the two tensions marked. The calculation in **(c)** makes an excellent use of this triangle to show that the force is 3.39 N and hence 3.4 N.

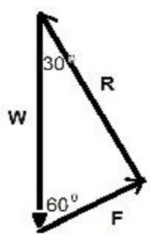
Contrast the above excellent solution with the exemplar shown below from a grade C candidate.

Exemplar 7

					 The triangle of forces in **(b)** is simply not right. However, in **(c)**, the analysis is correct and shows another plausible method for securing the 2 marks. Again, it is good to see the penultimate value for the force given to **more** than two significant figures.
	b		3.4 = 24x **or** $(x=)\ \frac{3.4}{24}$ **or** (x=) 0.14(17)(m) (E = ½ × 24 × 0.1417^2 **or** E = ½ × 3.4 × 0.1417) energy = 0.24 (J)	**C1** **A1**	**Allow** the C1 mark for $E = 3.4^2/(2 \times 24)$ **Allow** 3.39(4) N No ECF from **(c)**
			Total	**4**	
2 1	a	i	u = 17 cos 30 = 14.7 (m s^{-1})	C1	
		i	h = ut − ½gt^2; = 14.7 × 1.5 − ½ × 9.81 × 1.5^2	C1	**or** use $v^2 = u^2 - 2gs$ **or** $s = (u + v)t/2$
		i	h = 11 (m)	A1	**note**: if g = 10 is used, then maximum score is 2/3
		ii	s = 2 × 8.5 × 1.5	C1	**ecf 2a**
		ii	s = 26 (m)	A1	allow 25.5 m
	b		0 = 17 sin 30 t - ½ × 9.81 × t^2	C1	
			so t = 0 or 17/9.81 = 1.73	C1	
			s = 14.7 × 1.73 = 25.4 (m)	A1	allow s = 15 × 1.7 = 25.5 (accept 25 or 26 to 2 sf)

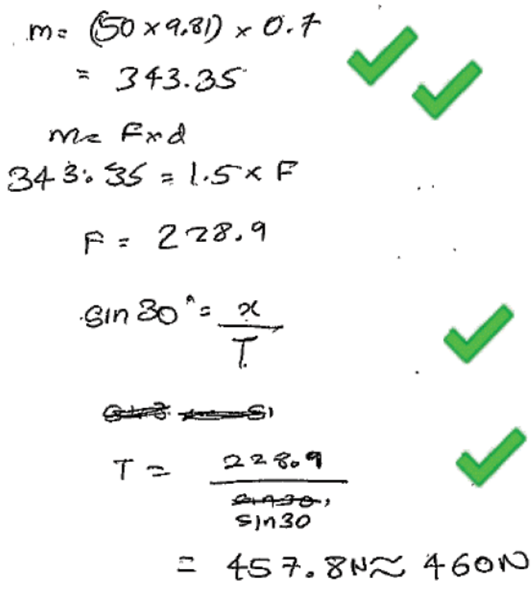
	c		the ball has the same speed (of 17 m s^{-1}) but is at different (either at 60° or 30°) angle to the horizontal.	B1	
			larger horizontal velocity (second trajectory) so travels further or higher bounce (first trajectory) so less drag from grass so travels further.	B1	accept any sensible answer, e.g. steeper bounce loses more energy in impact so slows more.
	d		horizontal component = 17 sin 30 or 17 cos 60 = 8.5 (m s^{-1})	B1	
			at highest point vertical component of velocity is zero.	B1	
			Total	**12**	
22			(The resultant of the tensions in the springs is) *W* / 4.8 (N) Direction: up(wards) / opposite to weight / opposite to *W* (because the total force in the vertical direction is zero)	**B1** **B1**	
			Total	**2**	
23			Mass is a scalar (quantity) and velocity is a vector (quantity).	B1	
			(Addition of) velocity depends on direction / sign / vector triangle / resolving (ORA)	B1	**Allow** 'Velocity can be cancelled out' **Examiner's Comments** Candidates answered this opening question extremely well, with the majority gaining two marks. A variety of answers were accepted. Most candidates knew that the direction of velocities had to be considered when adding vectors. Candidates who identified mass as a scalar and velocity as a vector and then defined these two quantities were awarded full marks.
			Total	**2**	
24		i	($v^2 = u^2 + 2as$) $2.5^2 = 1.3^2 + 2 \times 1.10 \times a$ (Any subject) a = 2.1 (m s^{-2})	**C1** **A1**	**Allow** other methods **Allow** this mark for t = 0.58 (s) **Note** answer to 3 SF is 2.07 (m s^{-2}) **Examiner's Comments** Most candidates demonstrated excellent understanding and application of equations of motion. The solutions were often well represented, calculations done correctly and the answer written to the correct number of significant figures (SF). A variety of routes were possible, but the most popular method was using the equation $v^2 = u^2 + 2as$.

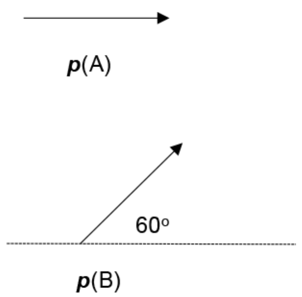
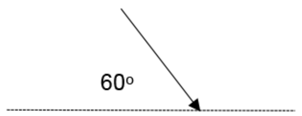
					Exemplar 5  This exemplar from a grade E candidate shows flawless technique. The known and unknown quantities are written on the left-hand side. The equation is clear, as is the substitution and the final answer for the acceleration.
		ii	$ma = mg$ sinθ **or** $a = g$ sinθ **or** 2.07 = 9.81 × sinθ	**C1**	**Allow** 2.1 (m s^{-1}) **Allow** $g = 9.8$ **Note** using tan^{-1}(2.07/9.81) is **wrong physics**.
			θ = 12°	**A1**	Possible ECF from **(b)(i)** **Allow** g = 10 here; it gives the same answer to 2 SF **Allow** 1 mark for 78°
			Total	**2**	
25			T = 60/sin 30 **or** 60/cos 60	C1	
			T = 120 (N)	A1	
			Total	**2**	
26	a	i	weight; (tractive) force up slope; drag; (normal) reaction		
		i		B1	
		i	All forces in correct direction and correctly labelled.		
		ii	14.4 + (85 × 9.81 × sin θ) = 41.7	C1	**ecf** from **(a)(ii)**
		ii	θ = 1.9 °	A1	
	b		any three from: • drag reduces velocity **or** increases time to cross **or** some kinetic energy of cyclist goes to heat. • longer crossing time results in cyclist at lower point on other side of gap. • moment on bicycle	B1 × 3	Allow argument based on: • very short crossing time (< 0.43s at speed of 6 ms^{-1} up slope). • energy changed to heat insignificant compared to KE • amount of rotation very small in short time.

			• rotation lowers height of front wheel.		
					conclusion based on argument(s). So no change in maximum gap width.
			Conclusion based on argument(s). The maximum gap width is smaller.	B1	
			Total	**7**	
27			resultant force = $(7.0^2 + 5.0^2 - 2 \times 7.0 \times 5.0 \times \cos40)^{1/2}$	C1	**Allow**: resultant force = $[(7.0 - 5.0 \times \cos40)^2 + (5.0 \times \sin40)^2]^{1/2}$
			resultant force = 4.51 (N)	C1	**Allow** full marks for a correct scale drawing to determine the resultant force; resultant force = 4.5 ± 0.1 N
			acceleration = 4.51 / 0.320 = 14 (m s^{-2})	A1	**Allow** full marks for resolving into horizontal and vertical components and combining correctly.
			Total	**3**	
28		i	Straight line drawn from the bottom of the 9.0 m s^{-1} vector to the end of the 4.2 m s^{-1} vector	B1	**Ignore** incorrect / omitted direction of resultant vector **Ignore** any other additional lines drawn
		ii	$v^2 = 9.0^2 + 4.2^2 - 2 \times 9.0 \times 4.2 \times \cos50°$ v = 7.1 (m s^{-1}) **OR** length of resultant vector line measured **and** some calculations v = 7.1 (m s^{-1})	C1 A1 C1 A1	**Allow** other correct variants of this method **Note** answer to 3 SF is 7.07 **Allow** length of resultant vector in the range 5.4 − 5.6 cm **Allow** ± 0.20 (m s^{-1})
			Total	**3**	
29			$W (= mg)$ = 8.0 x 9.81 F = (W sin30 = 78.5 x 0.5 =) 39 (N) R = (W cos30 = 78.5 x 0.87) = 68 (N)	C1 A1 x 2	= 78(.5) (**N**) **not** 80 (**N**) **Allow** 8g **Allow** 1/2 for F and R the wrong way round  Credit full marks for use of a scale drawing which gives answers correct to ±2N **Special case:** Allow 2/3 for use of W = 80 (N) giving F = 40 (N) and R = 69 (N)

					Examiner's Comments Most candidates were able to answer this question easily, although a few got their answers for F and R the wrong way around.
			Total	**3**	
30		i	speed = $\frac{2 \times \pi \times 0.60}{20}$	C1	
		i	speed = 0.19 (m s^{-1})	A1	
		ii	Displacement is the direct distance of the locomotive from **A**, so the graph is symmetrical about t = 10 s.	B1	
		ii	At t = 20 s it returns back to **A or** at t = 10 s it is 1.2 m from **A or** at t = 10 s, it is at **C**.	B1	
			Total	**4**	
31		i	Any <u>two</u> from: • Direction of g for Earth and Mars are in opposite directions • For small values of r / r < about 4.4 (× 10^{10} m) g for Earth is greater or resultant g is towards the Earth • At r about 4.4 (× 10^{10} m) the g values are the same/AW • Inverse square law for g for either planet causes curve near to either planet's surface/AW • Zero point for (resultant) g is further from the Earth (than the midpoint) since Earth has a larger mass than Mars • g at Earth's surface is larger than g at surface of Mars because Earth has a larger mass than Mars	**B1x2**	**Allow** field / (gravitational) force for g **Allow** for r values larger than 4.4 (× 10^{10} m) g for Mars is greater or resultant g is towards Mars **Examiner's Comments** Most candidates mis–read the question and tried to describe the shape of the curve, rather than explain why the curve has that shape. Many candidates also mis–used the term 'exponential' to describe a curve that is related to 1/r^2. Others thought that the graph showed the effect of Mars and the Earth on each other, rather than on a small mass between them. They went on to describe what happened when Mars and Earth were separated by an increasingly large distance. It is good practice to be specific about which section of the graph you are talking about. 'When r is below 2.0 × 10^{10} m' is much clearer than 'At the start'. *Potential, potential difference, potential energy, field strength and force* These terms are all very similar yet subtly different and with differing formula. Be careful you know which is which.
		ii	Any valid equation relating g_{Earth} and g_{Mars} e.g. $GM_{Earth}/r_E^2 = GM_{Mars}/r_M^2$ ratio <u>consistent</u> with values above	**C1** **A1**	

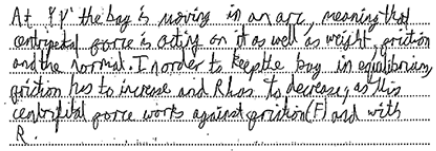
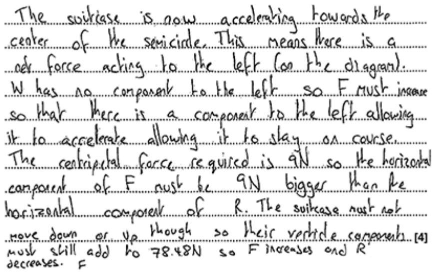
					Note: the correct ratio is in the range 8.2 to 12 allowing for values of r of 4.4 ± 0.1 (× 10^{10} m) when g = 0 **Examiner's Comments** To correctly answer this question, the candidate should equate the gravitational field strength from Earth (GM_{Earth}/x^2 where x is the distance to the point where g=0 from the centre of Earth) and the gravitational field strength from Mars (GM_{Mars}/y^2 where y is the distance to the point where g=0 from the centre of Mars). Many candidates did not get this far, yet some that did substituted and re-arranged correctly get a value in the correct range. Errors occurred when candidates were unsure of which distances to use in the equation. The commonest error was to use 0.9 × 10^{10} m for the distance of the zero-point since the graph stops at 5.3 × 10^{10} m, rather than using the data provided that the distance between the centres of the two planets was 5.8 × 10^{10} m and so the correct value for r was 1.4 × 10^{10} m.
			Total	**4**	
3 2			(weight of plank =) 50 × 9.81 or 490.5 OR uses a distance of 0.7m to calculate clockwise moment (anticlockwise moment =) *T*sin30° × 1.5 OR 0.75T (clockwise moment =) 490.5 × 0.7 = 343 (N m) *T*sin30° × 1.5 = 343 OR *T*sin30° = 229 *T* = 457.8 (N)	C1 C1 C1 C1 A0	**Allow** *T*cos60° × 1.5 **Allow** 344, **Allow 458.6**, **Examiner's Comments** This question was a "show" type question where candidates needed to show that the tension in the cable was about 460 N. Ideally in these type of questions, candidates should have shown their working logically and gained answer of 457.8 (N). Most candidates scored a mark for determining the weight of the beam. Good candidates clearly showed their working. Good candidates stated the principle of moments, indicated how the clockwise moment would be determined, indicated how the anticlockwise moment would be determined and gave an answer of 457.8 (N). To determine the anticlockwise moment candidates needed to resolve the

					tension T into its vertical component − both Tsin30° and Tcos60° were acceptable. **Exemplar 3**  In this exemplar the candidate has clearly shown the working to answer the question. Initially the candidate has calculated the clockwise moment by multiplying the force (mass of 50 (kg) by 9.81) by 0.7 (m). This gains two marks. The candidate's answer could have better if the candidate had written on the left-hand side "clockwise moment" rather than "m", however, it is implicit from the candidate's working the meaning of "m". The candidate has then clearly shown that the anticlockwise moment is equal to the clockwise moment and determined correctly the perpendicular force or vertical force. The candidate then correctly relates the force T to sin 30° and the vertical force and evaluates the answer as 457.8 N before indicating that this is approximately 460 N. Including the 457.8 is appropriate in these type of show questions.
			Total	**4**	
3 3		i	$(t =)\frac{6.3}{9.8(1)}$	M1	**Allow** other correct methods, e.g:
					$(t) = \sqrt{\frac{2 \times 2.0}{9.8(1)}}$ or $(t) = \frac{2 \times 2.0}{6.3}$
		i	(t =) 0.6(42....s)	A0	**Not** a = 10 m s^{-2} **Note** t must be the unknown **Examiner's Comments** There were some convoluted answers. A number of candidates gained

					credit but wasted time by solving a quadratic equation. Some candidates assumed that the vertical velocity was an average and determined the time and then just multiplied by two without explanation – this did not gain credit. Clear explanations of the method are used to answer these types of “show” questions.
		ii	(v_H =) $\frac{18}{0.64}$ or $\frac{18}{0.6}$	M1	**Note** v must be the unknown
		ii	(v_H =) 28 (m s^{-1}) or 30 (m s^{-1})	A0	**Examiner's Comments** This part was answered better although some candidates tried using an equation with acceleration.
		iii	$v = \sqrt{6.3^2 + 30^2}$	C1	$v = \sqrt{6.3^2 + 28^2}$ **Allow** trigonometry methods
		iii	v = 31 (m s^{-1})	A1	v = 29 (m s^{-1}) **Note** 940 scores one mark **Examiner's Comments** A pleasing number of candidates determined the magnitude of the velocity correctly, Some correctly used trigonometry methods.
			Total	**4**	
34		i	Example (not to scale): 	B1 B1	horizontal arrow (judge by eye), in the direction shown arrow drawn at an angle of 60° to the horizontal (angle must be shown), in the direction shown
		ii	Example (not to scale):  (Can apply principle of) conservation of momentum (since no external forces are acting)	B1 B1	arrow drawn at an angle of 60° to the horizontal (angle must be shown), in the direction shown **<u>Examiner’s Comments</u>** This was not an easy question but, even so, a good number of candidates did well. The marks were given for the direction (rather than for the magnitude) of the momentum vectors. Some of the common errors were: • forgetting to label relevant angles • not using arrows to show direction • drawing a vector triangle without any indication of which arrow was meant to be the final momentum.
			Total	**4**	

35		i	4.4 – 4.6 (N)	B1	
		ii	Weight of cylinder 3.5 cm vertically (judge by eye) Correct closed triangle drawn including T_A Correct directions indicated for weight and T_A and T_A = 6.4 ± 0.2 (N)	M1 M1 A1	
		iii	39 ± 1°	A1	**Allow ECF** from **(b)(ii)** for trigonometry methods
			Total	**5**	
36	a		Correct pattern Correct direction of the field	**B1** **B1**	**Note:** At least five field lines must be drawn and of these, two must be perpendicular (by eye) to the surface of the sphere and plate **Note:** This may be shown on just one line **Examiner's Comment** Most candidates drew decent field patterns and showed the correct direction of the electric field. It is difficult to draw curved field lines, but those who were careful and had the field lines perpendicular at both the surface of the sphere and the metal plate were rewarded.
	b		(Electric potential) is the <u>work</u> done per (unit) charge in bringing a <u>positive</u> charge from infinity (to the point).	**B1**	**Allow:** <u>work</u> done / <u>energy</u> required to bring a unit <u>positive</u> charge from infinity (to the point) **Examiner's Comment** This was not well-answered; the modal mark was zero. Definition for electric potential lacked precision and often made no reference to a 'unit **positive** charge' or 'per unit **positive** charge'. At times, other quantities such as electric field strength and gravitational field strength were being defined. This was a missed opportunity -definitions just need to be learnt.
	c	i	$V = Q/4\pi\varepsilon_0 r$ (Allow any subject) $Q = 4\pi \times 8.85 \times 10^{-12} \times 0.015 \times 5000$ $Q = 8.3(4) \times 10^{-9}$ (C)	**C1** **C1** **A0**	**Note** using E **=** V/d with $E = \Omega/4\pi\varepsilon_0 r^2$ is wrong physics and hence scores zero **Note** if the value of ε_0 is not given here, it could be implied in the correct 3sf answer **Allow** any subject here if the answer is given to more than 2sf **Allow** the use of $1/4\pi\varepsilon_0 = 9 \times 10^9$ **Examiner's Comment** By contrast to the last question, the answers here were perfect. Correct values were substituted into the equation for electric potential to show that the charge was that stated in the question. In a 'show' question, always give the final answer to more significant figures than the required answer. It was good to see many scripts with the final answer written as 8.3**4** × 10^{-9} C.

		ii	1 (electric force =) $1.7 \times 10^{-2} \times \tan 4.0$ (Allow any subject) (electric force = 1.19×10^{-3} N) 2 $E = 1.2 \times 10^{-3}/8.3(4) \times 10^{-9}$ $E = 1.4 \times 10^{5}$ (N C^{-1})	**M1** **(A0)** **C1** **A1**	**Not** 1.7×10^{-2} sin4 or 1.7×10^{-2} cos86 **Allow** $1.7 \times 10^{-2} \times$ sin4/cos4 **Allow** 2 marks for 1.45×10^{5} (N C^{-1}), 8.3×10^{-9} used **Allow** 2 marks for 1.43×10^{5} (N C^{-1}), 1.19×10^{-3} (N) used **Examiner's Comment** This was a good discriminator with high-scoring candidates either using triangle of forces, or resolution of forces, to determine the electric force on the sphere. The value of the force was given so that it could be used to answer the next question. More than half of the candidates correctly calculated the electric field strength using the information provided in **(c)(i)** and **(c)(ii)1.** Some candidates used the elementary charge rather than the value from **(c)(i)** to calculate the field strength; this gave an incorrect answer of 7.5×10^{15} N C^{-1}.
			Total	**8**	
37		i	The direction of the electric field due to the negative charge is to the left and right for the positive charge.	B1	
		i	The magnitude of the electric field strength due to the positive charge is smaller than that for the negative charge (because of greater distance). (Hence the resultant electric field strength is to the left.)	B1	
		ii	energy = $\dfrac{Qq}{4\pi\varepsilon_0 r} = \dfrac{(1.60\times10^{-19})^2}{4\pi\varepsilon_0 \times 3.0\times10^{-10}}$	C1	
		ii	energy = $7.67(2) \times 10^{-19}$ (J)	C1	
		ii	energy = 4.8 (eV)	A1	
			Total	**5**	
38		i	$F = (mv^2/r =)\ 8.0 \times 1.5^2/2.0$ $F = 9.0$ (N)	C1 A1	**Allow** answer to 1s.f. **Examiner's Comments** Question 4(b)(ii) proved very difficult and highlighted poor understanding of circular motion. Almost all candidates described the centripetal force as an additional force that had appeared out of nowhere. This centripetal force 'pulled the suitcase inwards' (or, in some cases, outwards) or 'balanced the frictional force' or 'added to the frictional force' and so on.

					Exemplar 5  At 'Y' the bag is moving in an arc, meaning that centripetal force is acting on it as well as weight, friction and the normal. In order to keep the bag in equilibrium friction has to increase and R has to decrease, as this centrifugal force works against friction (F) and with R. The candidate who gave the response in Exemplar 5 clearly thinks that an additional force, called the centripetal force, now acts on the suitcase. The forces F and R have to adjust in order to keep the suitcase in equilibrium. They have not realised that the suitcase is no longer in equilibrium horizontally but is accelerating. This means that the available forces have to adjust in order to provide a resultant force towards the centre of the circle, while still balancing vertically. **Exemplar 6**  The suitcase is now accelerating towards the center of the semicircle. This means there is a net force acting to the left (on the diagram). W has no component to the left so F must increase so that there is a component to the left allowing it to accelerate allowing it to stay on course. The centripetal force required is 9N so the horizontal component of F must be 9N bigger than the horizontal component of R. The suitcase must not move down or up though so their vertical components [4] must still add to 78.48N so F increases and R decreases. F In contrast, the candidate who wrote the response in Exemplar 6 has a much better grasp of the situation. **AfL** Rather than using the phrase 'centripetal force', candidates could be encouraged to think of motion in a circle as a special case of $F = ma$ where the resultant force F points towards the centre of the circle and the acceleration a is given by v^2/r. This should hopefully encourage them to think about which of the forces available in the situation could provide the resultant force for this motion to occur.
		ii	• Suitcase accelerates / changes its velocity / (constantly) changes direction / has a resultant force acting on it / is no longer in equilibrium • The resultant force must act (horizontally) towards centre of circle / to the left • The centripetal force can only be provided by (an increase in) F	B1 x 4 A0	Any answer that mentions **centrifugal** force scores 0/4 **Ignore** any statement that treats the centripetal force as an extra force **Allow** net or unbalanced or total for resultant throughout **or** $F\cos30^{\circ} - R\sin30^{\circ}$ increases (from 0 to 9.0 (N)) / the (magnitude of the) horizontal component of F must exceed the (magnitude of the) horizontal component of R **not** a resultant force acts towards **Y** e.g. Friction is the only force able to provide the centripetal force / only F has a component to the left **Allow** F provides the centripetal force **Not** the horizontal force must increase / increases

			• Increased vertical component of F means the vertical component of R must decrease (in order to balance W) So R must decrease		**or** $F\sin30^\circ + R\cos30^\circ = W$ / W is the vector sum of F and R / $W = (F^2 + R^2)^{½}$ (and F increases while W remains constant) Total
			Total	**6**	

3
9
			Level 3 (5–6 marks)
			Clear description and analysis.
			
			There is a well–developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.
			
			Level 2 (3–4 marks)
			Some description and some analysis.
			
			There is a line of reasoning presented with some structure. The information presented is in the most–part relevant and supported by some evidence.
			
			Level 1 (1–2 marks)
			Limited description and limited analysis
			or limited description
			or limited analysis
			
			There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.
			
			0 marks
			No response (NR) or no response worthy of credit (0).
				B1 x 6	**Indicative scientific points may include:**
					Description
					
					• Ruler used to determine x
					• Average readings to determine x
					• x recorded for various v
					• Suitable method for consistent v or varying v e.g.
					    • Released from same point on a track
					    • Ejected from a spring device with different compressions
					• Suitable method of determining point of impact e.g.
					    • trial run to get eye in approximate correct position
					    • carbon paper so that ball makes a mark on paper
					    • scale in frame of video recording
					    • tray of sand to catch ball
					• Suitable instrument used to determine v (light–gate / motion sensor / video techniques) or suitable description of inference of v from other measurements such as energy released from spring of known k and x
					• Ensuring the initial velocity of ball is horizontal
					
					Analysis
					
					• Horizontal velocity is constant
					• Time of fall is independent of v/horizontal velocity
					• Suggested relationship: e.g. $x \propto v$,x d.p. to V^2, etc
					• Plot a graph of x against v or graph consistent with candidate's suggested relationship
					• If relationship is correct, then a **straight line** through the **origin**.
					• Suggested relationship supported by correct physics or algebra.
					• Correct relationship supported by physics.
					
					Note:
					L1 is used to show 2 marks awarded and L1^ is used to show 1 mark

awarded.

Examiner's Comments

Many candidates had plenty to say that was sensible. There was plenty of evidence that candidates had seen this experiment or had performed a similar one themselves. A few confused the question, instead describing how to find the time of flight or that the ball was falling vertically. Others described what they thought would happen to the vertical component of velocity when they changed the vertical distance that the ball dropped.

Exemplar 2

Use your knowledge of projectile motion to suggest the relationship between *v* and *x*. De… how an experiment can be safely conducted to test this relationship and how the data… analysed.

make sure no one in way

As in a projectile the horizontal compo… of velocity is constant given air r… is negligible then a equation of $x = \frac{1}{2}$(… would become $x = vt$ where x is distanc… travelled v is velocity of ball and t … time of flight therefor for a constant … of flight it can be said $x \propto v$.

~~To test this it is very hard to kee… time of flight constant as this is d… to its time of freefall~~

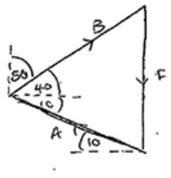
To test this a ball would be roll… of a table at varying speeds. T… calculate this speed a light gate can be used passing through the center of the metal ball. As distanc… travelled is equal to the diameter of th… ball, measured by a ruler, speed … be calculated using distance / time from…

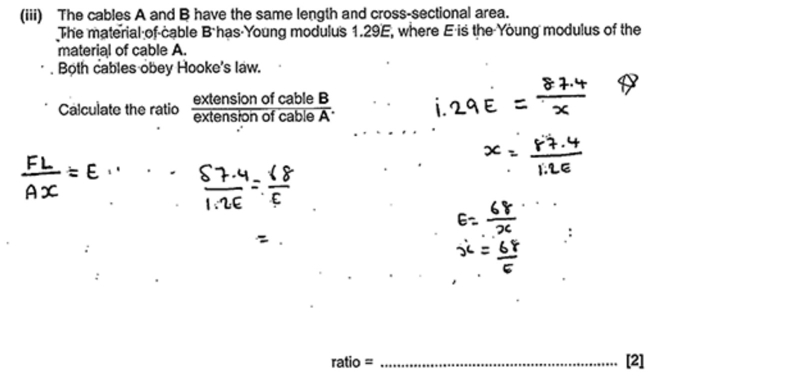
					light gate. For Safety the ball sho land in Sand as not to shatter o land on someones foot. This also makes measuring x much easier as x is equal to the horizontal distance from th edge of the table to the crater in Sand measured using a ruler. If the t taken to fall is kept constant mea by using a stop watch and control by raising or lowering the launch point when v is plotted agains x on a graph it can be exp to be linear and pass through origin. In the first paragraph, the candidate has made clear that the time of flight is constant and goes on to explain why towards the end of the response. This supports the prediction that $v \propto \chi$ In addition, the candidate takes time to explain how to obtain data for both the horizontal velocity and horizontal distance. It was pleasing to see light gates and motion sensors being employed, with the best answers explaining how to use the data provided by the sensors to calculate the velocity of projection. The exemplar response also includes the correct analysis. There is a graph of v against x and the resulting best fit straight line through the origin supports the idea that these two variables are directly proportional. Too many candidates did not mention the crucial statement about the line going through the origin, limiting their response to a high L1 or low L2.
			Total	**6**	

4
0
			Level 3 (5–6 marks)
			Clear explanation of terms **and** explanation of results correctly comparing momentum and kinetic energy.
			
			There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.
			
			Level 2 (3–4 marks)
			Clear explanation of terms **and** limited explanation of results comparing momentum
			
			or limited explanation of terms and some explanation of results
				B1 × 6	***Indicative scientific points may include:***
					Explanation of terms
					
					• $p = mv$
					• $E_k = \frac{1}{2}mv^2$
					• Total momentum conserved in all collisions
					• Total energy conserved in all collisions
					• E_k conserved in elastic collision
					• E_k NOT conserved in inelastic collision
					• Speed of approach = speed of separation in elastic collision
					
					Explanation of results
					
					• Initial p_A= 15 kg cm s^{-1} or 0.15 kg m s^{-1}
					• Initial E_{kA} = 0.015 J
					• Expt 1:
					  ○ Speed of separation = 0.150 + 0.050 = 0.200 m s^{-1}
					  ○ p_A after collision = (-) 0.375 kg m s^{-1}
					  ○ p_B after collision = 0.1875 kg m s^{-1}

			or correct comparison of momentum and kinetic energy. *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Has limited explanation of terms **or** limited comparison of momentum / kinetic energy. *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* **0 marks** No response or no response worthy of credit.		○ Total p after collision = 0.15 kg m s^{-1} ○ E_{kA} after collision = 0.0009375 J ○ E_{kB} after collision = 0.0140625 J ○ Total E_k after collision = 0.015 J ○ Collision is elastic since E_k conserved • Expt 2: ○ p after collision = 0.15 kg m s^{-1} ○ E_k after collision = 0.005625 J ○ Collison is inelastic since E_k not conserved • Momentum conserved in both collisions
			Total	**6**	
41		i	vertical component =30.0 sin(70°) or 30.0 cos(20°) vertical component = 28.2 (m s^{-1})	**A1**	**Allow** 2 SF answer of 28
		ii	Evidence of $v^2 = u^2 + 2as$ and v = 0 or $gh = {}^1/_2\, u^2$ $h = \frac{28.2^2}{2 \times 9.81}$ (Any subject) h = 40.5 (m)	**C1** **M1** **A0**	**Allow** v and u interchanged; a and g interchanged **Allow** use of candidate's answer for (a)(i) at this point **Ignore** sign **Allow** $h = \frac{28^2}{2 \times 9.81}$ or (30 sin(70))^2/(2 × 9.81) **No ECF from (a)(i) for the second mark**
		iii	The ball has horizontal motion / velocity (AW)	**B1**	**Allow** idea of horizontal e.g. sideways, forwards **Not**: 'moving' unqualified

		iv	(horizontal velocity =) 30.0 cos 70° or 10.2.… (m s^{-1}) or 30.0 sin 20°. $E_k = \frac{1}{2} \times 0.057 \times 10.26^2$ E_k = 3.0(J)	**C1** **A1**	**Allow** 1 SF answer **Not** 22 (J), *v* = 28 used **Not** 23 (J), *v* = 28.2 used **Not** 140 (J), *v* = 70 used **<u>Examiner's Comments</u>** Part (i) was particularly well answered by 95% of all candidates. Nine out of ten candidates scored full marks in part (a)(ii), as they remembered that the question asks to *show* that the maximum height is around 40m. Working for this type of question is essential. In part (a)(iii), three quarters of all candidates correctly talked about the ball still having a horizontal velocity (which wasn't zero) and therefore still possessing some KE. The key to this part (a)(iv), remembered by most candidates, was to use the horizontal component of velocity to find the KE at the maximum height. Some used the initial speed and others used the initial vertical velocity component found in part (a)(i).
			Total	**6**	
42		i	87.4cos50° **or** 68.0sin10° *F* = 68.0 (N)	C1 A1	**Allow** 87.4sin40° or 68.0cos80° **Allow** cosine and sine rules being used, e.g. $F^2 = 68.0^2 + 87.4^2 - 2 \times 68.0 \times 87.4 \times \cos 50°$ **or** $F = 87.4 \times \sin 50°/\sin 80°$ **or** F = 68.0 × sin50°/sin50° **Allow** 2 SF answer here **<u>Examiner's Comments</u>** The question has a clue for making a start on this question. Most candidates did resolve the two tensions in the cables vertically. The majority of the responses were well-structured and demonstrated excellent understanding of vectors. Although not straightforward, many candidates used the correct angle when determining the vertical components of the forces. The correct answer of 68.0 N appeared on most scripts. A small number of candidates got 1 mark for just getting one of the components correct. A very small number of candidates got the correct answer by using trigonometry and triangle of forces. This is not what was expected, but full credit was given for this alternative approach. Correct responses will always score marks, even when the candidates choose not to go along the path designed by the examiners. This different approach is illustrated in the exemplar 6 below. **Exemplar 6**

					Calculate the **total** vertical force F supplied by cables **A** and **B** by resolving the tensions in cables **A** and **B**.  $F^2 = A^2 + B^2 - 2AB\cos\theta$ $F = \sqrt{68^2 + 87.4^2 - 2 \times 68 \times 87.4 \times \cos 50}$ $= \sqrt{4622.329...}$ $= 67.98...$ N ≈ 68.0 N (3sf) F = ... 68.0 N **[2]** The candidate has used a triangle of forces and the cosine rule to determine the net downward. As it happens, the F in this calculation is the weight of the dolphin. However, it is numerically equal to the total upward vertical force. This concise and perfect alternative technique picked up the maximum marks.
		ii	68 = m × 9.81 m = 6.9 (kg)	C1 A1	Possible ECF from **(c)(i)** **Allow** 68 = mg **Note** answer to 3 SF is 6.93 (kg) **Allow** g = 9.8; this gives 6.94 (kg) **Not** g = 10; this gives 6.8 (kg). Only the first C1 mark can be scored **<u>Examiner's Comments</u>** Almost all candidates correctly used $W = mg$ to determine the mass of the dolphin. Full marks were frequently picked up because of error carried forward (ECF) from **(c)(i)**. There were very few cases of g = 10 m s^{-2} being used; this was penalised because g = 9.81 m s^{-2} is given in the Data, Formulae and Relationship Booklet.
		iii	$E = \frac{\text{stress}}{\text{strain}}$ (Any subject) (Tension and E increase by the same factor of 1.29) ratio = 1.0	C1 A1	**Allow** $E = \frac{\sigma}{\varepsilon}$ **or** $E = \frac{FL}{Ax}$ (Any subject) **Allow** 1 SF answer **Allow** 1:1 **<u>Examiner's Comments</u>** This question on the equation for Young modulus E was well-answered with most candidates picking up one or more marks. The extension x of a wire is given by the expression $x = \frac{FL}{EA}$, where F is the tension in the wire, L its length and A its cross-sectional area. In this question, the extension $x \propto \frac{F}{E}$. Since both F and E increase by the same factor of 1.29, this meant that the ratio is 1.00. The most frequent incorrect answers were 1.29 and 1.29^{-1} or 0.78. The majority of the candidates in the upper quartile picked up 2 marks. Exemplar 7

					 (iii) The cables **A** and **B** have the same length and cross-sectional area. The material of cable **B** has Young modulus 1.29*E*, where *E* is the Young modulus of the material of cable **A**. Both cables obey Hooke's law. Calculate the ratio $\frac{\text{extension of cable B}}{\text{extension of cable A}}$. ratio = ... [2] This exemplar shows a response from a top-grade candidate. The solution is much more elaborate and the response of 0.996 is given to 3 significant figures. A perfect solution that earned this candidate 2 marks.
			Total	**6**	
43		i	(For circular motion) there must (always) be a resultant force towards the centre The resultant force is not always vertical/sometimes has a horizontal component This can only be provided by friction/cannot be provided by *R* and W / *R* and W are always vertical/only *F* is horizontal	B1 x 2	any 2 from 3 marking points **Allow** *F* provides the horizontal (component of the) centripetal force
		ii	Sine wave with period 30 min and amplitude 0.050 (N) Correct phase, i.e. <u>negative</u> sine wave	B1 B1	Must start at the origin
		iii	F = 0.050 cos 40° F = 0.038 (N)	C1 A1	**Allow** alternative methods e.g. triangle of forces **Allow ECF** from graph if used
			Total	**6**	
44		i	(force =) $\frac{(1.6\times10^{-19})^2}{4\pi\epsilon_0\times(1.0\times10^{-15})^2}$ (*F* =) 230 (N) $F^2 = 230^2 + 230^2 - 2 \times 230 \times 230 \times \cos 120°$ **or** *F* = 2 × 230cos30° *F* = 400 (N)	C1 C1 C1	**Special case:** $F = \frac{Qq}{4\pi\epsilon_0 r^2} = \frac{2\times1.6\times10^{-19}}{4\pi\epsilon_0\times(1.0\times10^{-15})^2}$ loses this C1 mark, then ECF for the rest of the marks **Not** the first two C1 marks for incorrect charge, then allow ECF for the final C1A1 marks **Note** force to 4 SF is 230.2 N **Allow** sine rule / scale drawing **Allow** this mark for 230cos30° **or** 200 (N) **Allow** ± 10 (N) if scale drawing used

		ii	*F* / arrow vertical up the page	B1	**Allow** correct arrow direction anywhere on the figure
		iii	Strong (nuclear) force (acts on the protons) The strong (nuclear) force is attractive	B1 B1	**Ignore** gravitational force **Allow** pulls / holds (the protons) / binds (the protons) for ‘attractive’
			Total	**7**	