Mark scheme

Question			Answer/Indicative content	Marks	Guidance
1	a		3 out of the following 4: • Extension (or length) measured using a ruler • Extension = stretched length – original length • Force (weight of load) determined using a forcemeter **or** W = mg • (k is) gradient of graph of force against extension	B1 × 3	**Ignore** any incorrect statements unless contradictory **Allow** tape measure Could be shown on a labelled diagram **Allow** 4cm or 0.04m for original length **Allow** extension is change in length from original This mark may be scored by saying a graph of mass against extension would give gradient = k/g **Allow** k = gradient of graph of force against length **Allow** k/g = gradient of graph of mass against extension **Allow** *k* = load divided by extension, calculated for a single load **<u>Examiner's Comments</u>** In general, when asked to describe an experiment, it is good practice to describe which variables are being measured and what instruments are being used to measure them. In this case, we are measuring force (using a newton meter, or a top pan balance for mass plus F = mg) and extension (using a rule or tape measure). It is important to define extension, since it involves two measurements (extended length – initial length). It is also good practice to describe a graphical method for measuring *k* rather than just carrying out a simple calculation. Candidates who said, 'I would plot a graph of F against x' or 'I would divide F by *x*' (without stating what F and x represented in terms of this experiment) gained no credit.

	b	i	**Method 1** *d = 8.5 – 3.2* (= 5.3(cm)) (*F* = *kd* so) *F* = 0.62 × 5.30 (= 3.3 (N)) $a = \frac{F}{m}$ so $a = \frac{3.3}{0.20}$ *a* = 17(m s^{-2}) **Method 2** (*F* = *kd* so) *F* = 0.62 × 8.50 (= 5.27(N)) F_R = (0.62 × 8.50) – (0.20 × 9.81) (= 3.3 (N)) $a = \frac{F}{m}$ so $a = \frac{3.3}{0.20}$ **Method 3** (*F* = *kd* so) *F* = 0.62 × 8.5 (= 5.27(N)) $\left(a = \frac{F}{m} \text{ so}\right) a = \frac{5.27}{0.20}$ = 26 (m s^{-2}) $a_{initial}$ = 26.35 – 9.81 = 17 (m s^{-2})	C1 C1 A1 (C1) (C1) (A1) (C1) (C1) (A1)	**Mark whichever method leads to the most marks** *d* = 5.3cm does not need to be calculated explicitly but seeing 5.3 implies first C1 mark *F* = 3.3N does not need to be calculated explicitly but seeing 3.3 implies both C1 marks **Allow** *k* = 0.61 (N cm^{-1}) leading to *F* = 3.2 (N)... ... and *a* = 16 (m s^{-2}) *F* = 5.27(N) does not need to be calculated explicitly but seeing 5.27 or 5.3 implies first C1 mark **Allow** *k* = 0.61 (N cm^{-1}) leading to *F* = 5.19 (N) *F* = 3.3(N) does not need to be calculated explicitly but seeing 3.3 implies both C1 marks **Allow** *k* = 0.61 (N cm^{-1}) leading to *F* = 3.2 (N)... ... and *a* = 16 (m s^{-2}) *F* = 5.27(N) does not need to be calculated explicitly but seeing 5.27 or 5.3 implies first C1 mark **Allow** *k* = 0.61 (N cm^{-1}) leading to *F* = 5.19 (N) Note: *a*= 26 (ms^{-2}) is an intermediate calculation for $a_{initial}$ in this method only and is **not** the A1 mark **Allow** *k* = 0.61 leading to *F* = 5.19 and *a* = 16 **Examiner's Comments** There are two measurements for extension given here: an extension of 3.2cm under a load of (0.2 × 9.81) N and an extension of 8.5cm under a force of F + (0.2 × 9.81) The easiest way to approach the question is to recognise that the extension due to *F* alone must be (8.5 – 3.2) = 5.3cm. *F* = *kx* then becomes *F* = 0.62 × 5.3 (since *k* is given in N cm^{-1}) and so we can use *F* = *ma* with

					m = 0.2kg to find the acceleration a. However, other valid methods were also given credit.
		ii	Use of $a = (-)\omega^2 x$ Use of $f = \frac{\omega}{2\pi}$ f = 2.8 (Hz) **<u>Alternative method:</u>** ($a = F / m = kx/ m$ and a = (-) $(-)\omega^2 x$ gives) $\omega^2 = \frac{k}{m}$ $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$ $= \frac{1}{2\pi}\sqrt{\frac{0.62 \times 100}{0.2}}$ f = 2.8 (Hz)	C1 C1 A1 (C1) (C1) (A1)	The two C1 marks are independent and XP in one does not imply XP in the other **Not** just formula alone Expect a = 17 but **allow** ECF of a from **(b)(i)** **Allow** any value for x **Not** just formula alone Use of $a = (-)(2\pi f)^2 x$ scores both C1 marks **Allow** f = 2.9 (Hz) **Allow** $T = 2\pi\sqrt{\frac{m}{k}}$ $f = \frac{1}{T}$ **Allow** f = 2.9 (Hz) **<u>Examiner's Comments</u>** The answer to this question is frequency = 2.8Hz, since ω depends only on k and m ($\omega^2 = k/m$). However, most candidates used the formula $a = (-)\omega^2 x$ together with appropriate values for a and x.
	c	i	(motion of magnet M causes) a change of flux (linkage) in coil Y (inducing an e.m.f.) there is an (induced) <u>current</u> in (or through) coil X alternating current / field / flux in coil X interacts with the field of magnet L (causing an alternating force)	B1 B1 B1	**Allow** field (lines of M) cuts (turns of) coil Y **Allow** the coil or Y or solenoid for coil Y **Allow** the coils or the wire(s) or X for coil X **Ignore** (induced) e.m.f. **Not** changing or varying or oscillating for alternating **Allow** current / field / flux in coil X interacts with field of magnet L **to** cause an alternating force **Allow** changing direction for alternating **Allow** combines for interacts **Allow** cuts across for interacts with

					Examiner's Comments Clarity in explanation was important here, as there are two magnets, M and L, plus two coils, X and Y. It is a change in flux linkage in coil *Y* which leads to an induced alternating current in coil *X*. This current creates an alternating magnetic field in coil *X* which interacts with the field of magnet *L* to create an alternating force on L. **Assessment for learning** Many explanations were too generalised: 'Faraday's Law states that there must be an induced emf which is proportional to the rate of change of flux linkage' or 'Fleming's left hand rule states there must be a force on the magnet' were often seen. Candidates should be encouraged to write in less general terms and to focus their answer on the specific question.
		ii	frequency of magnet L (always) equals (forcing/driving) frequency of vibration generator / magnet M resonance occurs at / close to 2.5 Hz amplitude is maximum at resonance	B1 B1 B1	**Allow** frequency of magnet increases with frequency of vibration generator May be seen from a **labelled** graph of amplitude against frequency **Allow** resonance occurs when forcing / driving frequency = natural frequency May be seen from a labelled graph of amplitude against frequency **Examiner's Comments** Many candidates did not realise that this was a question about resonance, presumably because of the unfamiliar context of the question. **Common problems in 4(c)(ii)** • not answering every part of the question: most candidates forgot to describe how the

					frequency varied as well as the amplitude • not realising that the vibration generator is driving the oscillation of L, and that this is a question about resonance • not labelling the scales on the graph of amplitude against frequency (or just using letters such as *A* and *f*) • failing to mark the resonance frequency as 2.5Hz (instead calling it f_o)
•			**Total**	**15**	
2	a	i	0.99	A1	Award mark for all candidates as some centres may not have seen the erratum for this question. **<u>Examiner's Comments</u>** As stated in the Mark Scheme, it was unclear whether all candidates had seen the erratum. As a result, all candidates were awarded this mark.
		ii	Data plotted at 6.0, 0.99 within half a small square Two trendlines drawn Clear indication that upper curve's data is during loading and that lower curve's data is during unloading	B1 B1 B1	ecf from (a)(i) treat use of 0.81 from table as ecf if candidate has left 18 (a)(i) blank NOT straight lines connecting data points NOT straight line(s) of best fit e.g Correct arrow direction or label 'loading' on upper curve and correct direction arrow or label 'unloading' on lower curve. **<u>Examiner's Comments</u>** Almost all candidates scored the first mark here, correctly converting the data point they'd calculated in the previous part into graphical form. Candidates drew very good curves,

					although many lost the final mark for not indicating which curve was which.
		iii	Any TWO from: Not a straight line / AW (hence) not directly proportional Correct reference to plastic deformation when unloaded	B1 B1 B1	allow 'k / spring constant not constant' allow Hooke's Law should be (directly) proportional e.g. Mention of line not passing through origin when unloaded **<u>Examiner's Comments</u>** The best way of answering this sort of question is to link what evidence there is in the question - in this case the graph - to what the candidate knows about Hooke's Law. Here, the lines are clearly not straight, so cannot support an idea that the extension and loading force are directly proportional. **Examination Tip** When answering questions of this nature, a good start is to describe the trend line (or the relevant graphical feature) and then move on to how this either supports or rejects a particular theory or relationship.
		iv	joule	B1	Not J; since **name** is required. Allow joules NB if more than one answer given, mark first answer as per rubric on page 3 **<u>Examiner's Comments</u>** Some candidates stated the quantity (energy) or the base units (kg m^2 s^{-2}) or did both. The rubric in the mark scheme is clear: only the first answer is acceptable for this sort of question. **Assessment for learning** Teachers and candidates should be aware of not only the marking points in a mark scheme but also the large

					amount of guidance given to markers in the preceding pages of that mark scheme.
		v	(the area is) increase in thermal or in internal energy of the rubber reference to reduction in the energy of the object or in the force applied to the object or the force applied to the floor	B1 B1	ignore unqualified ‘energy’ or ‘work done’ allow change in work done on rubber between loading and unloading e.g. the energy absorbed by the rubber / not returned to the object e.g. energy dissipated as heat or energy not transferred back to KE e.g. The object will not bounce as high e.g. object less likely to be damaged because the force on object is smaller e.g. floor is less likely to be damaged because the force on the floor is smaller e.g. the larger the area between the curves the lower the damage caused **<u>Examiner’s Comments</u>** The scientific language is subtle here. The area between the two curves is not the work done (which is the area underneath any particular F-x graph) but it is the increase in the object’s internal energy typically as thermal energy, Similarly, the language needed to be suitably scientific for the second marking point, using A Level terminology.
	b		Any TWO from pulley adds friction / the load values would no longer equal the weights Greater lengths being used will reduce (%) uncertainty Reference to pulley’s suspension rope reduces h because it is not inextensible Larger range of h may make eye level	B1 B1 B1 B1 B1	ignore plastic deformation **<u>Examiner’s Comments</u>** The Mark Scheme lays out what was acceptable here. Just as in the previous item, credit would be given for suitably sufficient A Level Physics language. **Examination Tip**

			more difficult Larger h makes effect of non-vertical ruler more prominent		Practise using scientific terms and quantities learnt over the course to explain as many different phenomena as possible. This is equally applicable for theoretical or for experimental ideas.
			Total	**11**	
3			**C**	1	**<u>Examiner's Comments</u>** Overall, candidates performed well on this question with many correctly calculating the change in elastic potential energy as 610 J. The most common distractor was answer A, with candidates relating compression to a decrease in the change of elastic potential energy rather than an increase in the store of elastic potential energy. **Misconception** This question highlighted a possible common misconception that when a spring or object is compressed, there is a decrease in the change of elastic potential energy. This is probably as a result that a compression results in a decrease in the length of an object which candidates then relate to a decrease in the change in elastic potential energy. Even though an object is compressed the change in potential energy will always be positive as work is done by a force in the same direction as the displacement.
			Total	**1**	
4			**A**	1	**<u>Examiner's Comments</u>** Candidates performed well on this question with most candidates correctly identifying graph A as most indicative of the stress-strain characteristics for a brittle material, as brittle materials exhibit minimal plastic deformation and the relationship between stress and strain is linear.

			Total	1	
5	a	i	callipers	B1	**Examiner's Comments** Many candidates stated a ruler or metre rule without realising that these measuring instruments had a resolution of 1 mm not 0.1 mm. Other candidates incorrectly stated micrometer – a micrometer is not usually used for distances greater than two or three centimetres and normally a micrometer has a resolution of 0.01 mm or better. **Assessment for learning** Candidates should experience a wide range of measuring instruments in a science laboratory.
		ii	32.7 ± 0.2 (mm)	B1	**Examiner's Comments** Most candidates correctly determined *x* but a significant minority of candidates did not realise that the uncertainty in the measurements needed to be added. **Assessment for learning** Candidates should understand that when quantities are added or subtracted the absolute uncertainties are added. **OCR support** In the Practical Skills Handbook there is a section on uncertainties.
		iii	18 ×0.0327 ($\frac{18\times0.0327}{9.81}$ =) 0.060 (2sf)	C1 A1	**ALLOW ECF** from **(a)(ii)** **ALLOW** 36 ×0.01635 (alternative method; 1 spring)

					Note Answer must be 2 sf **ALLOW** one mark for 0.06 (1sf) **ALLOW** one mark for 60 (power of ten error) **<u>Examiner's Comments</u>** The common error was to use 36 N m^{-1} as the force constant and 0.0327 m as the extension. Other errors included either rounding the answer to one significant figure (0.06) or not changing the millimetre to metre. Clear working was needed to allow error carried forward marks into the next section. **Misconception** A number of candidates did not understand significant figures. Candidates should understand the implication of trailing zeros both before and after the decimal place. For example, 0.06 is one significant figure, 0.060 is two significant figures, etc.
		iv	$W = \frac{1}{2} \times 18 \times 0.0327^2$ 9.6×10^{-3} (J)	C1 A1	**ALLOW ECF** from **(a)(ii)** and **(iii)** for POT and/or *k* E.g. For x = 32.7: 9.6×10^3 (J) For k = 36 Nm^{-1}: 19.2×10^{-3} (J) For x = 32.7 and k = 36 N m^{-1}: 19.2×10^3(J) **<u>Examiner's Comments</u>** Most candidates gained credit in this question. Many correctly used $W = 0.5kx^2$. Other candidates correctly used $W = 0.5Fx$ using their value for F from the previous part. Some lower scoring candidates incorrectly determined the change in gravitational potential energy.

	b	i	Evidence that gradient = $\frac{AE}{L}$ $A = \frac{1600 \times 4.4}{120 \times 10^9}$ 5.9×10^{-8} (m^2)	C1 C1 A1	e.g. $F = \frac{AE}{L}x$ **ALLOW** *F* and *x* correctly read from linear section and substituted into *A* =*FL*/*Ex* **Note** 5.9×10^n scores two marks **<u>Examiner's Comments</u>** Many candidates did not understand the significance of the gradient. More able candidates derived an equation into a $y = mx$ format and then successful calculated an answer. A number of candidates did not use an appropriate power of ten for the Young modulus or convert the gradient to be consistent with the length of the wire. Candidates who read a value of force and extension directly from the graph could still gain full credit – often the read-offs were from the non-linear section of the graph. **Assessment for learning** Candidates should make sure that they are using consistent units when calculating quantities and should know the common prefixes for units.
		ii	Area under graph = energy Evidence of <u>area</u> under graph determined, e.g. Counting squares (1cm^3 = 1.25×10^{-4} J and number of squares counted squares) OR Adding/subtracting shapes in the non-linear part 4.0×10^{-3} (J) to 4.4×10^{-3} (J)	C1 M1 A1	**IGNORE** sf **<u>Examiner's Comments</u>** For this question it was essential that candidates showed their working. Many candidates incorrectly used the extension for a force of 3.5 N and substituted it into an equation. More able candidates stated that the area under the line would be equal to the work done and then clearly showed the method used to work out the area under the line.
			Total	**12**	

6	a	i	newton in base units is kg m s^{-2} Substitution and cancelling of kg and m arriving at s^2 –> s^2	C1 A1	
		ii	One force is increased by kx and one is reduced by kx /AW Some working to include kx − (-kx)	B1 B1	reject 2 springs in series or 2 springs in parallel idea XP accept one extension is reduced by x and one is increased by x / AW **<u>Examiner's Comments</u>** Question 21 (a) (ii) is considerably more challenging. The two springs are not in series nor are they in parallel. When there is a displacement *x* one spring is extended by an *extra* amount *x* i.e. an extension of (*e* + *x*) and the other is extended by a reduced amount *x i.e.* an extension of (*e* − *x)* where *e* is the equilibrium extension. This meant that the resultant force was *k*(*e* + *x*) − k(*e* − x), which is clearly 2*kx*. Neither spring goes into compression, although we condoned candidates who suggested that a reduction in extension meant the same as a compression.
		iii	period is independent of <u>amplitude</u> / AW No effect	M1 A1	Allow isochronous **<u>Examiner's Comments</u>** A reasonably large proportion of candidates did not link the idea of initial displacement to the amplitude of this motion. Those that did often scored both marks as they also recalled that SHM is isochronous. **Assessment for learning** Merely repeating the words in the question, in this case 'the initial displacement' instead of 'amplitude', is unlikely to give access to full marks. Think about which piece or pieces of technical language on the specification are the likely target of each question.

	b		maximum four from: EPE gain (in stretched spring) > EPE lost (in relaxed spring) EPE is dependent on x^2 Total energy increases (and so KE increases since EPE −> KE) Max KE when the system has minimum EPE / at equilibrium position/when x=0 Minimum EPE is unchanged Omega is same, amplitude has increased v_{max} when x=0 so v_{max} has increased (omega^2 = sqrt(A^2-x^2)) v_{max} increased so KE_{max} increased	4 x B1	Allow EPE max is dependent on A^2 NOT EPE dependent on x alone Allow EPE dependent on x and F which is dependent on x (EPE = ½ Fx idea) KE = ½ kx^2 is XP **<u>Examiner's Comments</u>** The language around energy and energy transfers is challenging and this question was pitched as a high demand question. Once more, the technical language needed to be relatively accurate for marks to be given. As soon as the glider is displaced, the total elastic potential energy (EPE) is increased. The spring that is longer than at equilibrium stores more energy than before and the spring that is shorter than at equilibrium stores less. Since the amount of EPE is given by ½ kx^2, the increase in EPE in the longer spring is larger than the decrease in EPE for the shorter spring. A few candidates attempted to prove this algebraically which was not required. Finally, the EPE at equilibrium position is not zero but a minimum. This is why the maximum KE occurs at this point. Some candidates attempted the slightly more accessible route of comparing v_{max} with the amplitude yet did not mention that the angular velocity was the same, although there was still some credit available.
			Total	**10**	
7			B	1	**<u>Examiner's Comments</u>** Most candidates deduced the correct answer by remembering that the ultimate tensile strength is given by the highest point on the graph, in this case, point Q.
			Total	**1**	

8			D	1	**Examiner's Comments** Just under half of all candidates got this correct. While the stress, given by force/area was straightforward to calculate, the strain was given as a percentage. This should have been converted to a decimal, i.e. 0.0030 to get the correct value of Young modulus.
			Total	**1**	
9	a	i	$E = \frac{\sigma}{\varepsilon}$ and F = kx and $\sigma = \frac{F}{A}$ and $\varepsilon = \frac{x}{L}$ Clear substitution leading to $E = \frac{kL}{A}$	M1 A1	**ALLOW** E = F/A ÷ x/l and F =kx **Examiner's Comments** Over half of candidates correctly selected the equations *E = σ/ε, ε = x/L, σ = F/A and F = kx* and showed clear substitution to give the expression for the Young modulus *E*. Some candidates did confuse the quantity of *E* and selected the incorrect equation *E* = ½ *Fx* ; *E* = ½kx^2 from the Data, Formulae and Relationships booklet.
		ii	$E = \frac{1670 \times 2.0}{2.9 \times 10^{-8}}$ 1.2×10^{11} N m^{-2} (Uncertainty = 0.05 + 2 + 1.25) 3.3%	C1 A1 B1	**ALLOW** 3sf 1.15×10^{11} N m^{-2} **Examiner's Comments** Candidates performed well on this question with about 90% of candidates correctly calculating a value for the Young modulus. About two thirds of candidates correctly determined the percentage uncertainty by calculating the sum of the individual percentage uncertainty values for each of the results.
		iii	% difference = $\frac{(1.17-1.20) \times 10^{11}}{1.17 \times 10^{11}}$ = 2.6% % diff < % uncertainty so consistent / accurate / AW	M1 A1	**ALLOW** other quantitative comparisons e.g. 1.11 to 1.19 using 1.15, and 1.16 to 1.24 using 1.2 all within range of 1.17. **ALLOW** calculation using 3 s.f. answer from (ii) to give 1.7% **ALLOW ECF** for correct calculation using uncertainty value from 21c(ii) **Examiner's Comments** Candidates performed less well on this question, over half the candidates

					did not achieve marks. Candidates were required to make a quantitative comparison to determine that the researched value was consistent with their calculated value from 21(c)(ii). A significant number of candidates gave a qualitative comparison or simply calculated the difference between the two values to state that the researched value was consistent with their answer to (c)(ii). **Misconception** When attempting to calculate a percentage difference to compare the calculated and researched 'true' value candidates would often find the difference in the calculated and researched value i.e. 0.02×10^{11} and divide by the calculated value of 1.15×10^{11}. Candidates would obtain a decimal value, but it would not be a correct percentage difference. The method to calculate a percentage difference is $\frac{\text{(measured value − accepted value)}}{\text{accepted value}} \times 100\%$ Refer to page 47 in the Practical Skills Handbook on correct methodology on calculating percentage difference for uncertainty in measured and accepted values.
	b		$10.0 \times (2.5 \times 10^{-3})$ 4000	C1 A1	**ALLOW** corresponding points read from line. **ALLOW** 4 (Nm^{-1}) 1 mark **<u>Examiner's Comments</u>** Candidates performed well on this question as they correctly applied $F = kx$ to determine the gradient of the graph to give the force constant. Most candidates converted mm to m but about a quarter of candidates did not recognise that a unit conversion was

					required so gave an answer of 4 (N m^{-1}) which was given 1 mark.
	c		Micrometer (to measure diameter) Measure <u>diameter</u> in different places **and** calculate a mean/average Use $A = \pi r^2$ and $r = \frac{diameter}{2}$ Or $A = \frac{\pi d^2}{4}$	B1 B1 B1	**ALLOW** callipers **<u>Examiner's Comments</u>** Candidates scored well on this question with about half of candidates being given 3 marks for correctly describing how the cross-sectional area could be determined. About a third of candidates only achieved 2 marks as they didn't describe that the diameter needed to be measured in different places on the wire rather than just repeat readings. Nearly all candidates were able to identify the correct equipment required to measure the diameter of the wire.
			Total	**12**	
10	a	i	(area of shaded region =) 1.9 × 6.0 or 11.4 (m^2) (volume of air in 3.0 s =) 11.4 × 3.0 × 12 (mass of air = 11.4 × 3.0 × 12 × 1.2) mass of air = 492(.48) (kg)	C1 C1 A1	**Allow** volume found in one second leading to mass per second multiplied by 3 for 2nd and 3rd mark **Note**: volume of air is 410 (m^3)
		ii	Δp = 12 × 490 or 5900 (kg ms^{-1}) (force = Δp / Δt = 5900/3.0) F = 2000 (N)	C1 A1	Expect to see mass of 490, 492, 492.5, 492.48 **Note** answer is 1970 to 3 SF using 492.48 **Note** answer is 1960 to 3 SF using 490 **<u>Examiner's Comments</u>** Candidate's answers to this part were either jumbled or grounded in incorrect physics. This question is correctly answered by thinking about a cuboid of air that is 36 m long and has a cross-sectional area equal to that of the shaded side of the tent.

					That cuboid corresponds to the air that hits the tent in the three second period. The force applied will be equal to the rate of momentum change. This means multiplying the mass of air that hits the tent by the velocity change (i.e. 12 m/s) and then dividing by the time taken for that momentum change.
	b		***Level 3 (5–6 marks)** Clear descriptions **and** explanations, supported by quantitative 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 explanation or quantitative analysis **or** Clear explanation **or** Clear description **or** Clear quantitative 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 **or** Limited explanation *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 or no response worthy of credit.*	B1×6	**Indicative scientific points may include**: **Description** • Increasing the area/diameter of the guy ropes • A different material with a larger breaking or yield stress • A more streamlined shape that allows the wind to pass over or around the tent **Explanation** • Correct reference/use of $F = \Delta p / \Delta t$ • Greater cross-sectional area of rope would reduce the stress • The rope would not exceed a higher breaking/yield stress • Changing shape produces a smaller momentum change and a smaller force • If the air passes over/around the tent, it still has some forward momentum and hence the change and force is less • Reduction of angle of ropes from ground reduces component of tension perpendicular to ground so tension decreases. **Quantitative analysis** • Mass (per unit time) and velocity **both** double (at 40 m/s) • Momentum change is ×4

- Force would increase by a factor of 4
- Rope cross section must be × 4 (or diameter × 2)
- Breaking or yield stress of material would need to be × 4
- Use of trigonometry to determine the angle of deflection that would reduce the momentum change by a factor of 4 (about 15° compared to the original 90°)

Examiner's Comments

This question tested ideas about forces, resolution of forces, behaviour of materials under stress and rate of change of momentum transfer. Level 1 answers were restricted to merely suggestions of what could be done to make the support of the tent stronger. Level 2 answers developed at least one of those suggestions by referring, qualitatively, to the underlying physics. Level 3 answers were rare, as the requirement was for some quantitative physics. Candidates that attempted a quantitative answer often believed that the force would be doubled, when in fact it is quadrupled. This is because both the mass of the air depends on the velocity of air, so doubling the speed will also double the mass, thus quadrupling the momentum transfer.

This candidate clearly states, on lines 3–5, that the force is directly proportional to the square of the

					speed by thinking about their answers to previous parts of the question. The statements following this, after the page break, are sensible and grounded in physics in topics typically covered in the first year of study. The candidate mentions about quadrupling the number of ropes and reducing the area presented to the wind by a factor of four. The candidate goes on, in the additional answer space, to refer to the thickness of the ropes and how the radius would need to double. Level 3 response.
			Total	**11**	
11	a		Hang (known) masses/weights on the cord **or** pull with a newtonmeter to different tensions Determine the extension Graph of force against extension Force constant is the gradient (of force-extension graph)	B1 B1 B1 B1	**Allow** mention of spring **Allow** measure the length **Allow** length for extension **Note** if axes swapped, must be 1/gradient
	b	i	Extension (from graph) is 6.0 (cm) Use of $E = ½ kx^2$ elastic potential energy = 0.90 (J)	M1 M1 A1	**Allow** Use of E = ½ Fx and F = kx **Allow** 1 SF of 0.9 (J)
		ii	($KE = ½ mv^2$) $0.90 = ½ × 0.030 × v^2$ v =7.7 (ms^{-1})	M1 A1	**Allow** 1 J instead of 0.90 J **Note** using 1 J gives an answer of 8.2 ms^{-1} **Note** allow possible ECF with energy approx 1 J
		iii	$1.5 = ½ gt^2$ t = 0.55 (s) (R = 7.7 × 0.55) R = 4.2 (m)	C1 C1 A1	**Allow** 8 ms^{-1} or 8.2 ms^{-1} instead of 7.7 ms^{-1} **i.e**. 4.4, 4.5 (m) **Possible** ECF from **(b)(ii)**
		iv	(Actual distance is smaller than calculated R)	M1	Examples of valid explanation include:

			Valid explanation The velocity /speed (in flight) smaller than expected **or** The initial velocity / speed will be smaller than expected	A1	For velocity / speed decreases • drag/air resistance For initial velocity /speed is smaller • not all the energy transfers to the ball • the cord also has KE • hysteresis (so cord heats up) **Ignore** references to efficiency and unqualified energy dissipation. **<u>Examiner's Comments</u>** Questions 16 (a), (b) (i) and (ii) were answered very well indeed. Most candidates recalled the experimental procedure for investigating force-extension relationships well. Question16 (b) (iii) required knowledge of independent motion. Successful candidates used the vertical motion of the object to find the time taken for it to hit the ground. After that, they used that time to find the horizontal range. Question 16 (b) (iv) was answered well by candidates that realised the distance in real life would be less and could explain why that was the case.
			Total	**14**	
12	a		$E = ½ \times 1.7 \times 10^4 \times (0.45 – 0.25)^2$ E = 340 (J)	C1 A1	**Allow** gain in GPE = 68g(0.76 – 0.25) **Ignore** E = ½ Fx **<u>Examiner's Comments</u>** Candidates were required to select the equation $E = ½ kx^2$ which about a half of candidates did to calculate the energy stored in the compressed spring when the clown jumped vertically on the pogo stick but about a third of candidates dropped 1 mark for not converting cm to m for the value of compression.

	b		Add (a range of) loads/force/weights to the spring **and** determine the compression (for each load) Plot a graph for force against compression **and** gradient is the force constant	B1 B1	**Allow** extension for compression throughout **Allow** W = mg **Not** length for compression **Allow** force constant = $\frac{\text{force}}{\text{compression}}$ and k = F/x (k must be subject) **<u>Examiner's Comments</u>** Most candidates accessed this question and were given 1 mark for either describing a method to measure the compression (extension) of a spring or using these measurements to determine the spring constant either from the gradient of a force–extension graph or manipulation of $F = kx$. Candidates often were not given the first marking point as even though they described a correct practical procedure in adding masses they did not qualify this by multiplying the mass by g to obtain the weight compressing the spring as it is this quantity along with the compression that is used to verify the force constant. Also, candidates did not always describe their method that could suitably be carried out in the lab as they described adding the 'clown' or a 'person' to the spring and then measuring the compression (extension).
			Total	**4**	
13			A	1	**<u>Examiner's Comments</u>** Candidates performed less well on this question, answer A. The most common distractor was answer D where candidates had doubled the extension rather than using and applying $E = \sigma / \varepsilon$ correctly.
			Total	**1**	