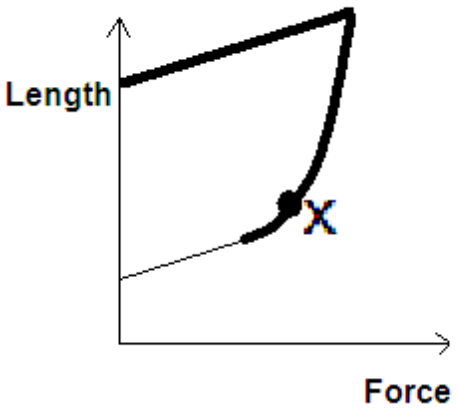
Question Number	Answer	Mark
1(a)	Statement showing that the candidate has realised that this graph is of length and not extension **(1)** [e.g. subtract starting length for extension this graph is for length not extension the spring has a length between 2.0 and 3.0cm if the line (for this graph) had passed through the origin then the spring would not have any length] (To obey Hooke's law) Force $\propto$ extension **Or** extension *v* force (or vice-versa) graph should go through the origin **(1)**	**2**
1(b)	Use of $F = k\Delta x$ **(1)** [Either evidence of attempt at $\frac{1}{\text{gradient}}$ with sensible values that could have been obtained from the graph or selection of a pair of values and the original length, 2.5 cm (accept range from 2.0 to 3.0 cm) subtracted from the length] k = 27 – 29 (N m^{-1}) **(1)** Example of calculation K = $\frac{\Delta F}{\Delta x}$ = $\frac{8\text{N}}{(0.310\text{ m} - 0.025\text{ m})}$ = 27.68 N m^{-1}	**2**
1(c)(i)	Use of 1/2 $F\Delta x$ **Or** use of $\frac{1}{2} k\Delta x^2$ **(1)** [Allow F = 5.7 to 5.9 N] Energy = 0.59(J) **(1)** Example of calculation Energy = ½ × 5.8 N × (0.23 m – 0.025 m) = 0.59 J) Or Energy = $\frac{1}{2} k\Delta x^2 = \frac{1}{2} \times 27.68\text{ N m}^{-1} \times (0.23\text{m} - 0.025\text{ m})^2 = 0.59$ (J)	**2**
1(c)(ii)	energy stored → gpe **Or** energy stored = mgh seen or substituted into **(1)** Use of stored energy = mgh **(1)** height = 12 m **(1)** Example of calculation 0.59 J = 0.005 kg × 9.81 m s^{-2} × h h = 12.0 m	**3**

1(d)	 **Max 3 for the graph** • Line continues from where graph for spring A ends and curves • Direction of graph curves upwards • Line continued back to show an extended length [Gradient of line not important] • Elastic limit **Or** the yield point marked and labelled or identified in response.(X on the diagram) [Candidates that decide to start a new line are omitting themselves from getting marking point 1] **Max 3 for description of graph** • More force used/masses added with spring C • Spring A not extended past elastic limit or yield point **Or** Spring C is extended past elastic limit or yield point • Spring A shows elastic (behaviour/deformation) • Spring C shows plastic (behaviour/deformation) • Spring C permanently extended/ did not return to its original length (when force removed) **and** spring **A** returns to original length (when the force is removed)	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**6**
	Total for question		**15**

Question Number	Answer	Mark
2(a)(i)	Straight line shown / constant gradient (1) (So) extension or change in length proportional to force (accept Δx or Δl or e proportional to F) / k constant. (NOT Length α force) (1) [Just stating $F = k\Delta x$ does not get the mark] (Yes, because extension or change in length proportional to force gets 2)	**2**
2(a)(ii)	Indication of use of (inverse) gradient, e.g. $k = F/\Delta x$ or with values obtainable from graph (accept extension/force for first mark) (1) Substitution of values as force/extension (1) Stiffness = 0.66 to 0.80 (N m^{-1}) [no ue] (1) Range is due to tolerance of + or – half a square on reading graph. [Allow answers of 0.7 N m^{-1} or 0.8 N m^{-1} without extra sig fig if that is the exact value produced from their figures, e.g. from F = 0.7 N, where length = 260 cm] Example of calculation $k = F/\Delta x$ k = 0.8 N / (2.7 m – 1.6 m) k = 0.8 N / 1.1 m = 0.73 N m^{-1} (Read graph to half a square)	**3**
2(a)(iii)	Use of $E = \frac{1}{2} F\Delta x = \frac{1}{2} k(\Delta x)^2$ OR Use of an area between a line and an axis (allow line shown and force axis) (1) Identify correct extension OR correct area (1) E = 0.31 J to 0.35 J from $E = \frac{1}{2} F\Delta x$ E = 0.27 J to 0.40 J from $\frac{1}{2} k(\Delta x)^2$ if k in range [allow ecf for k] (1) Example of calculation $E = 1/2\ F\Delta x$ = 0.5 x 0.7 N x (2.55 m – 1.6 m) = 0.33 J	**3**
2(b)(i)	Coils at top support coils below (1) (So) a greater force acts (on top coils) (1) Coils at the top support the weight of the coils below as well = 2 marks	**2**
2 (b)(ii)	Clearly below centre and above bottom – accept if no label (1)	**1**
2 (b)(iii) (1)*	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) Ball acted on by its weight (alone) / by gravity (alone) (1) Top coils acted on by their weight and/also acted on by elastic/tension force / force due to extension of coils (1) So the acceleration is greater (1) Energy explanation – max 2 for ball, transfer to ke from gpe alone - 1 mark for top coils, transfer to ke from gpe and elastic pe – 1 mark (allow 'has' energy instead of transfer to ke)	**3**
2(b)(iii) (2)	They are acted on by weight downwards and (elastic) force upwards/ the forces on them are/remain balanced (1)	**1**
	Total for question	**15**

Question Number	Answer	Mark
3(a) (i)	Explain the shape of the graph in the part labelled AB Force proportional to extension / obeys Hooke's law (1)	**1**
3(a) (ii)	Explain what is happening in the part of the graph labelled CD. Fully compressed / coils closed (accept cup/bug/toy touches base) (1)	**1**
3(b)	Show that the stiffness of the spring is about 1000 N m^{-1}. State k = 1/gradient or use of values in $k = F / x$ (1) Correct answer to at least 2 s.f. [1100 N m^{-1}] (1) (Values from graph must be within half a square) (Accept 1000 N m^{-1} to only 1 s.f. if the answer given by the values used from the graph is 1.0 x 10^3 N m^{-1} to 2 s.f.) **Example of calculation** $k = F / x$ = 20 N / 0.019 m = 1050 N m^{-1}	**2**
3(c) (i)	Calculate the energy stored in the spring at this stage State area under graph or use of energy = 1/2 $F\Delta x$ or state energy = 1/2 kx^2 (1) correct answer [0.17 J] (1) [ecf for k] (Values from graph must be within half a square) **Example of calculation** energy = 1/2 $F\Delta x$ = 1/2 x 19.2 N x 0.018 m = 0.17 J	**2**

3(c) (ii)	Calculate the maximum height reached by the bug. Use of gpe = *mgh* (1) correct answer [2.4 m] (1) [ecf] **Example of calculation** 0.17 J = *mgh* *h* = 0.17 m / 7.3 x 10^{-3} kg x 9.81 N kg^{-1} = 2.4 m	**2**
3(c) (iii)	State an assumption made in your calculation all elastic pe → ke of bug → gpe of bug (2 out of 3) / all stored energy (of the spring) transferred to the 'toy' / no energy lost due to air resistance (1)	**1**
3(d)	Explain the advantage of using the video camera improves accuracy/reliability/precision (1) eliminate reaction time in looking / can slow down and stop (to take reading) etc (1)	**2**
3(e)	Comment on this data Has not included 0.36 / has not included the anomalous result / 0.36 is anomalous/outlier etc (1)	**1**
	Total for question	**12**

Question Number		Mark
4(a)	(The line) AB (extended)does not pass through the origin /initially **Or** the graph is curved as it passes through the origin **Or** the graph (before A) is not a straight line through the origin. (1) The device does not obey Hooke's law (conditional mark) (1)	**2**
4(b) (i)	Reference to finding area (1) **Detail** count squares **OR** approximate the shape of the graph to a triangle **Or** reference to using a trapezium(could be described as rectangles and triangles) (1)	**2**
4 (b) (ii)	Identifies that force is the problem. (1) Explains why force used is an overestimate e.g. maximum force has been used (each time) **Or** average force was not used (each time) **Or** the force is changing (continuously) **Or** should have used the trapezium rule **Or** area of rectangle has been used (1)	**2**
4(c)	Use of 25% of 540 kJ i.e. find the energy to be used (1) Use of $\frac{\text{total available energy (either 540 000 J or 135 000 J)}}{\text{energy per stretch or energy per unit time}}$ (1) Time = 612 min (1) Example of calculation 540 000 J x 25% = 135 000 J 135 000 J / 14.7 J = 9184 stretches 9184 / 15 stretches per minute = 612 minutes (36 720 s **Or** 10.2 h)	**3**
4(d)	smaller extension **Or** will not stretch as much (1) less work with reference to either same force applied **Or** to work done being force x extension (1) (Do not accept displacement or distance in place of extension for MP1or MP2)	**2**
	Total for question	**11**

Question Number	Answer		Mark
***5(a**	**(QWC – work must be clear and organised in a logical manner using technical terminology where appropriate)** Measure the initial length (of the spring) **Or** record position of a 'fixed point' **Or** record the position of the bottom of the spring (with no masses on the spring) Add mass/weight and record the new length/position Repeat for a range of masses/weights Reference to a precaution taken to ensure measurements were accurate e.g. use of set square, method to reduce parallax, hang spring close to rule, do not exceed proportional/elastic limit	**(1)** **(1)** **(1)** **(1)**	**4**
5(b)	Plot appropriate graph of extension/length and force/mass Calculate the gradient (of linear region) Appropriate method to find k from their graph (**Max 1** if no graph is suggested i.e. use $k = F/\Delta x$ and average k)	**(1)** **(1)** **(1)**	**3**
5(c)	k would not be constant for the spring **Or** the graph would not be a straight line **Or** the idea that Hooke's law would not be obeyed **Or** $F = k\ (\Delta)x$ does not apply	**(1)**	**1**
	Total for Question		**8**