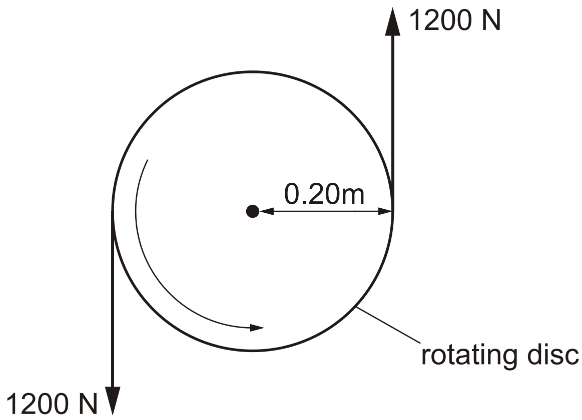
Questions on Work & Energy

1. Describe one example where elastic potential energy is stored.

....

[Total 1 mark]

2. The figure below shows two forces, each of magnitude 1200 N, acting on the edge of a disc of radius 0.20 m.



(a) (i) Define the *torque of a couple.*

....

....

[1]

(ii) Calculate the torque produced by these forces.

torque = ...N m

[2]

(b) This torque is needed to overcome friction and keep the disc rotating at a constant rate.

(i) Show that the work done by the **two** forces when the disc rotates one complete revolution is about 3000 J.

[2]

(ii) Calculate the power required to keep the disc rotating at 40 revolutions per second.

power = ... W

[2]

[Total 7 marks]

3. Fig. 1 shows part of the force-extension graph for a spring. The spring obeys Hooke's law for forces up to 5.0 N.

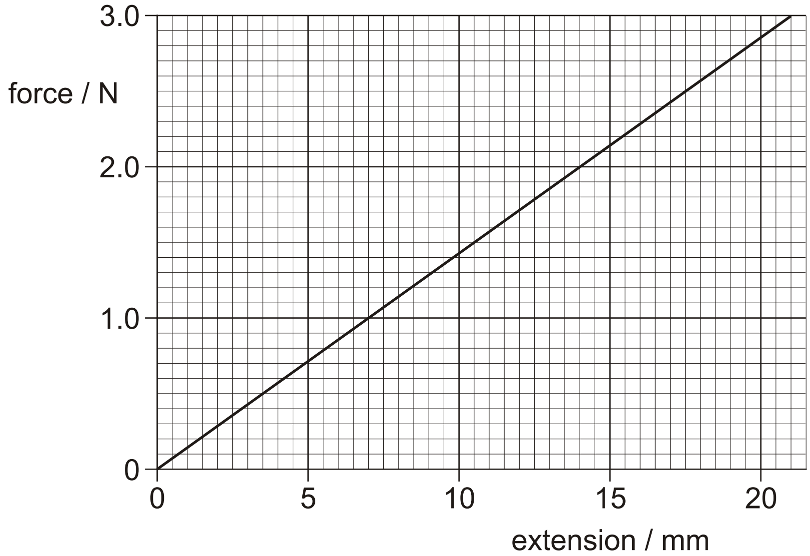


Fig. 1

(a) Calculate the extension produced by a force of 5.0 N.

extension = ... mm

[2]

(b) Fig. 2 shows a second identical spring that has been put in parallel with the first spring. A force of 5.0 N is applied to this combination of springs.

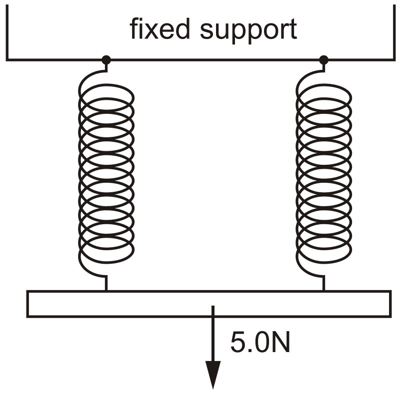


Fig. 2

For the arrangement shown in Fig. 2, calculate

(i) the extension of each spring

extension = ... mm

[2]

(ii) the total strain energy stored in the springs.

strain energy = ... J

[2]

(c) The Young modulus of the wire used in the springs is 2.0×10^{11} Pa. Each spring is made from a straight wire of length 0.40 m and cross-sectional area 2.0×10^{-7} m^2. Calculate the extension produced when a force of 5.0 N is applied to this straight wire.

extension = ...m

[3]

(d) Describe and explain, without further calculations, the difference in the strain energies stored in the straight wire and in the spring when a 5.0 N force is applied to each.

....

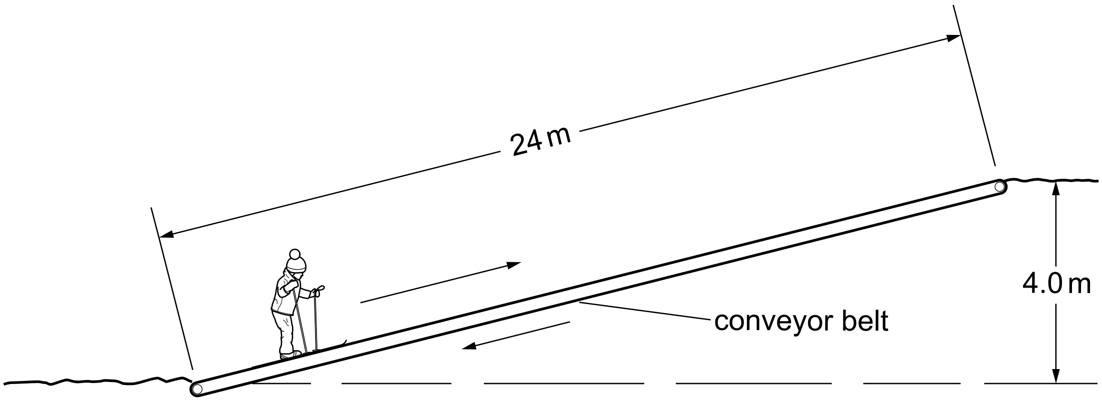
....

....

[2]

[Total 11 marks]

4. The figure below illustrates a conveyor belt for transporting young children up a snow-covered bank so that they can ski back down.



A child of mass 20 kg travels up the conveyor belt at a constant speed. The distance travelled up the slope is 24 m and the time taken is 55 s. The vertical height climbed in this time is 4.0 m.

(a) For the child on the conveyor belt, calculate

(i) her speed

speed = ... m s^{-1}

[2]

(ii) her kinetic energy

kinetic energy = ... J

[2]

(iii) the increase in her potential energy for the complete journey up the slope.

potential energy = ... J

[2]

(b) (i) The conveyor belt is designed to take a maximum of 15 children at any one time. Calculate the power needed to lift 15 children of average mass 20 kg through a height of 4.0 m in 55 s.

power = ... W

[2]

(ii) The belt is driven by an electric motor. State **two** reasons why the motor needs a greater output power than that calculated in **(b)(i)**.

....

....

....

....

[2]

[Total 10 marks]

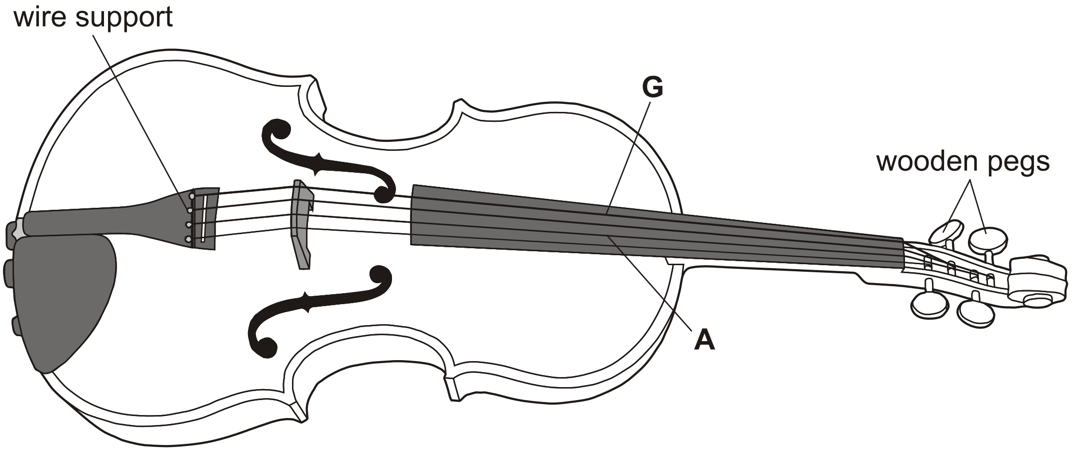
5. State the principle of conservation of energy.

....

....

[Total 1 mark]

6. The figure below shows a violin.



Two of the wires used on the violin, labelled **A** and **G** are made of steel. The two wires are both 500 mm long between the pegs and support. The 500 mm length of wire labelled **G** has a mass of 2.0×10^{-3} kg. The density of steel is 7.8×10^{3} kg m^{-3}.

(i) Show that the cross-sectional area of wire **G** is 5.1×10^{-7} m^2.

[2]

(ii) The wires are put under tension by turning the wooden pegs shown in the figure. The Young modulus of steel is 2.0×10^{11} Pa.
Calculate the tension required in wire **G** to produce an extension of 4.0×10^{-4} m.

tension = ...N

[3]

(iii) Wire **A** has a diameter that is half that of wire **G**. Determine the tension required for wire **A** to produce an extension of 16×10^{-4} m.

tension = ...N

[1]

(iv) State the law that has been assumed in the calculations in **(ii)** and **(iii)**.

....

[1]

[Total 7 marks]

7. The results given in the table below are obtained in an experiment to determine the Young modulus of a metal in the form of a wire. The wire is loaded in steps of 5.0 N up to 25.0 N and then unloaded.

	loading	unloading
load / N	extension / mm	extension /mm
0.0	0.00	0.00
5.0	0.24	0.24
10.0	0.47	0.48
15.0	0.71	0.71
20.0	0.96	0.95
25.0	1.20	1.20

(i) Using the results in the table and without plotting a graph, state and explain whether the deformation of the wire

1 is plastic or elastic

....

....

....

[1]

2 obeys Hooke's law.

....

....

....

[2]

(ii) Explain how the extension and length of the wire may be determined experimentally.

....

....

....

....

[2]

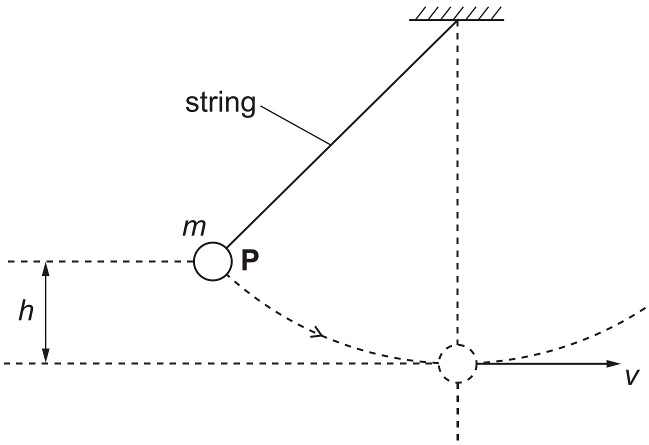
(iii) The wire tested is 1.72 m long and has a cross-sectional area of 1.80×10^{-7} m^2. Use the extension value given in the table for a load of 25.0 N to calculate the Young modulus of the metal of the wire.

Young modulus = ... Pa

[3]

[Total 8 marks]

8. The figure below shows a simple pendulum with a metal ball attached to the end of a string.



When the ball is released from **P**, it describes a circular path. The ball has a maximum speed *v* at the bottom of its swing. The vertical distance between **P** and bottom of the swing is *h*. The mass of the ball is *m*.

(i) Write the equations for the change in gravitational potential energy, E_p, of the ball as it drops through the height *h* and for the kinetic energy, E_k, of the ball at the bottom of its swing when travelling at speed *v*.

E_p =

E_k =

[1]

(ii) Use the principle of conservation of energy to derive an equation for the speed *v*. Assume that there are no energy losses due to air resistance.

[2]

[Total 3 marks]

9. Some countries in the world have frequent thunderstorms. A group of scientists plan to use the energy from the falling rain to generate electricity. A typical thunderstorm deposits rain to a depth of 1.2×10^{-2} m over a surface area of 2.0×10^{7} m^2 during a time of 900 s. The rain falls from an average height of 2.5×10^{3} m. The density of rainwater is 1.0×10^{3} kg m^{-3}. About 30% of the gravitational potential energy of the rain can be converted into electrical energy at the ground.

(i) Show that the total mass of water deposited in 900 s is 2.4×10^{8} kg.

[2]

(ii) Hence show that the average electrical power available from this thunderstorm is about 2 GW.

[3]

(iii) Suggest one problem with this scheme of energy production.

....

....

[1]

[Total 6 marks]

10. The force against length graph for a spring is shown in Fig. 1.

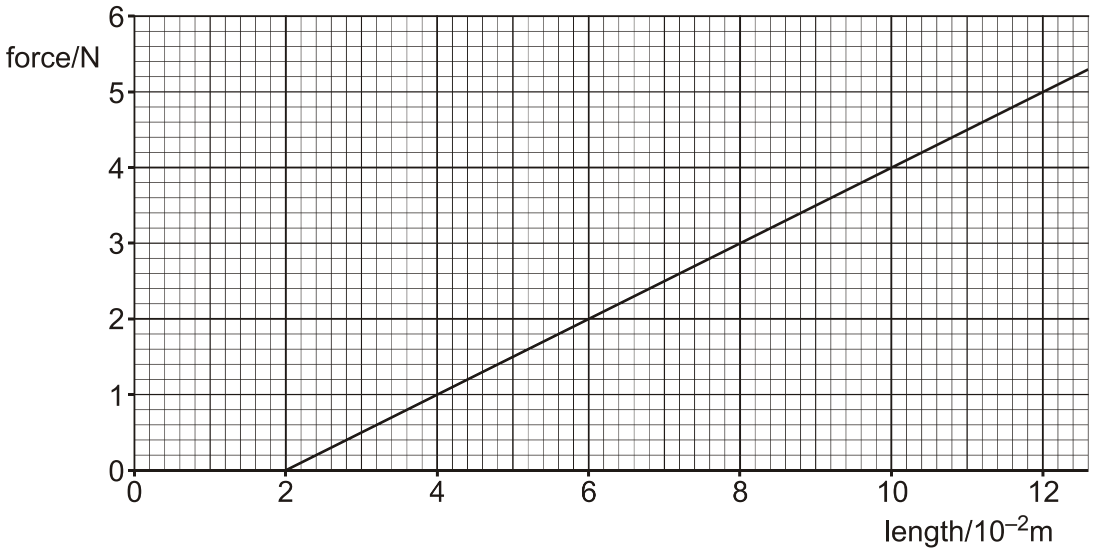


Fig. 1

(a) Explain why the graph does not pass through the origin.

....

....

[1]

(b) State what feature of the graph shows that the spring obeys Hooke's law.

....

....

[1]

(c) The gradient of the graph is equal to the force constant *k* of the spring. Determine the force constant of the spring.

force constant = ... N m^{-1}

[2]

(d) Calculate the work done on the spring when its length is increased from 2.0×10^{-2} m to 8.0×10^{-2} m.

work done = ... J

[2]

(e) One end of the spring is fixed and a mass is hung vertically from the other end. The mass is pulled down and then released. The mass oscillates up and down. Fig. 2 shows the displacement *s* against time *t* graph for the mass.

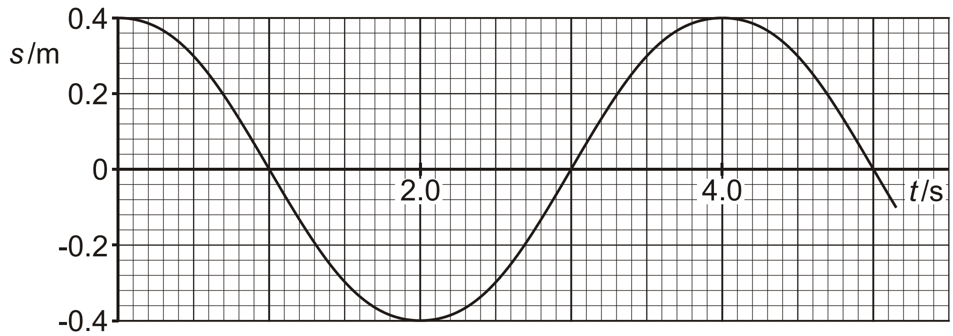


Fig. 2

Explain how you can use Fig. 2 to determine the **maximum** speed of the mass. You are not expected to do the calculations.

....

....

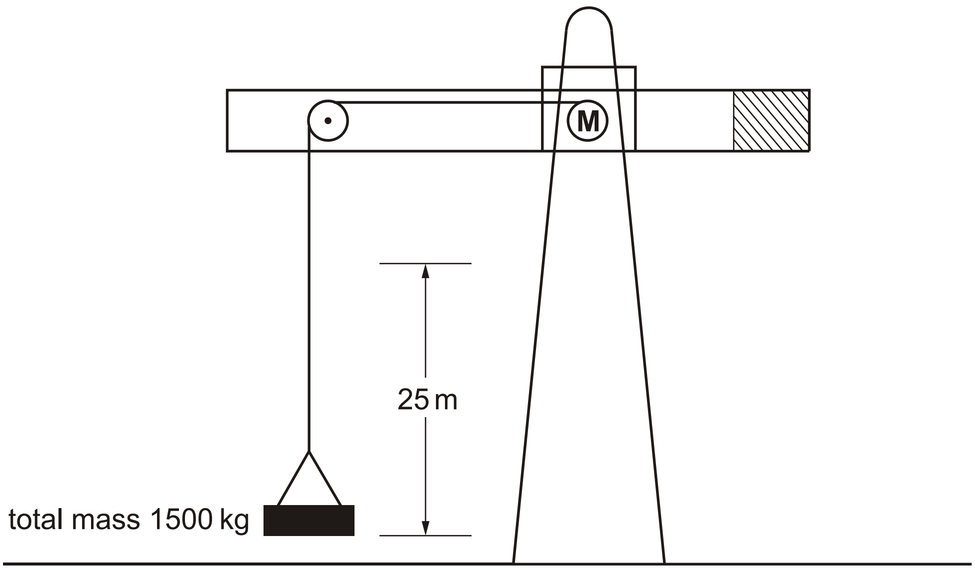
....

....

[2]

[Total 8 marks]

11. The figure below shows a crane that is used to move heavy objects.



The motor **M** in the crane lifts a total mass of 1500 kg through a height of 25 m at a constant velocity of 1.6 m s^{-1}.

Calculate

(i) the tension in the lifting cable

tension = ... N

[2]

(ii) the time taken for the mass to be raised through the height of 25 m

time = ... s

[1]

(iii) the rate of gain of potential energy of the mass

rate of gain of potential energy = ... J s^{-1}

[3]

(iv) the minimum output power of the motor used to raise the mass.

power = ... W

[1]

[Total 7 marks]

12. (a) Define *the Young modulus* of a material.

....

....

[1]

(b) Explain why the quantity strain has no units.

....

....

[1]

[Total 2 marks]

Questions on Work & Energy – Mark Scheme

1. Any suitable example of something strained (eg: stretched elastic band) **B1**

[1]

2. (a) (i) (one of the) force × perpendicular distance between the forces B1

(ii) torque = 1200 × 0.4 C1

= 480 Nm A1

[allow one mark for 1200 × 0.2 = 240 (N m)]

(b) (i) work = force × distance (moved) B1

= 2 × 1200 × 2 × π × 0.2 B1

= 3016 (J) A0

(ii) power = work done / time C1

= 3000 / (1/40)

= 1.2×10^5 (W) A1

[7]

3. (a) One reading from the graph e.g. 1.0 N causes 7 mm C1

Hence 5.0 (N) causes 35 ± 0.5 (mm) A1

(allow one mark for 35 ± 1 (mm)

(b) (i) Force on each spring is 2.5 (N) C1

extension = 17.5 (mm) allow 18 (mm) or reading from graph A1

[allow ecf from (a)]

(ii) strain energy = area under graph / ½ F × e C1

= $2 \times 0.5 \times 2.5 \times 17.5 \times 10^{-3}$

= 0.044 (J) A1

[allow ecf from (b)(i)]

(c) E = stress / strain C1

Stress = force / area and strain = extension / length C1

extension = (F × L) / (A × E)

= $(5 \times 0.4) / (2 \times 10^{-7} \times 2 \times 10^{11})$

= $5.(0) \times 10^{-5}$ (m) A1

(d)		strain <u>energy</u> is larger in the spring	B1	
		extension is (very much larger) (for the same force) for the spring	B1	
				[11]

4.	(a)	(i)	speed = d / t	C1	
			= 24 / 55		
			= 0.436 (m s^{-1}) allow 0.44 *do not allow one sf*	A1	
		(ii)	kinetic energy = ½ m v^2	C1	
			= 0.5 × 20 × $(0.436)^2$		
			= 1.9 (J) note ecf from (a)(i)	A1	
		(iii)	potential energy = mg h	C1	
			= 20 × 9.8 × 4		
			= 784 (J)	A1	
			penalise the use of g = 10		
	(b)	(i)	power = energy / time or work done / time	C1	
			= (15 × 784) / 55		
			note ecf from (a)(iii)		
			= 214 (W)	A1	
		(ii)	needs to supply children with kinetic energy	B1	
			air resistance	B1	
			friction in the bearings of the rollers / belt	B1	
			total mass of children gives an average mass of greater than 20 kg	B1	
			Max B2		
					[10]

5. Energy cannot be created or destroyed; it can only be transferred/transformed into other forms
or
The (total) energy of a system remains constant
or
(total) initial energy = (total) final energy (AW)

Allow: *'Energy cannot be created / destroyed / lost'* **B1**

[1]

6.	(i)	Density = mass / volume	B1
		Area × length = mass / density	
		Area = $(2.0 \times 10^{-3}) / (7800 \times 0.5)$ or $2.56 \times 10^{-7} / 0.5$	B1
		$= 5.1(3) \times 10^{-7}$ m^2	A0
	(ii)	E = (F × l) / (A × e) / stress = F / A (1.6×10^8 and strain = e / l (8×10^{-4})	C1
		F = (E × A × e) / l	
		$= (2 \times 10^{11} \times 5.1 \times 10^{-7} \times 4.0 \times 10^{-4}) / 0.5$	C1
		=82 (N) (81.6)	A1
	(iii)	Diameter for D is half G hence area is ¼ of G Extension is 4 × greater Tension required is the same = 82 (N)	A1
	(iv)	The extension is proportional to the force / Hooke's law (OWTE)	B1

[7]

7.	(i)	1	Elastic as returns to original length (when load is removed)	B1
		2	Hooke's law is obeyed as force is proportional to the extension Example of values given in support from table	B1 B1
	(ii)		Measure (original) length with a (metre) rule / tape	B1
			Suitable method for measuring the extension e.g. levelling micrometer and comparison wire or fixed scale plus vernier or travelling microscope and marker / pointer	B1
	(iii)		E = stress / strain	C1
			$= (25 \times 1.72) / (1.8 \times 10^{-7} \times 1.20 \times 10^{-3})$	C1
			$= 1.99 \times 10^{11}$ (Pa)	A1

[8]

8.	(i)	$E_p = mgh$ <u>and</u> $E_k = \frac{1}{2}mv^2$ (Allow Δh for h) ***Not:*** $E_k = mgh$	**B1**

(ii) $mgh = \frac{1}{2}mv^2$

B1

$v^2 = 2gh$ or $v = \sqrt{2gh}$

B1

[3]

9. (i) $m = \rho V$

Allow any subject for the density equation

C1

$m = 1.0 \times 10^3 \times (1.2 \times 10^{-2} \times 2.0 \times 10^7)$

C1

mass of water = 2.4×10^8 (kg)

A0

(ii) loss in potential energy = $2.4 \times 10^8 \times 9.81 \times 2.5 \times 10^3$

Allow *1 mark for '5.89×10^{12} (J)*

C1

30% of GPE = $0.3 \times 5.89 \times 10^{12}$ (= 1.77×10^{12})

Allow *2 marks for '1.77×10^{12} (J)'*

C1

power = $\frac{1.77 \times 10^{12}}{900}$

C1

power = $1.9(63) \times 10^9$ (W) (≈ 2 GW)

Note: $\frac{5.89 \times 10^{12}}{900}$ *(= 6.5 GW) scores 2 marks*

A0

(iii) Any correct suitable suggestion; eg: the energy supply is not constant/ cannot capture all the rain water / large area (for collection)

Note: *Do not allow reference to 'inefficiency' / 'cost'*

B1

[6]

10. (a) The graph shows length and not extension of the spring / spring has original length (of 2.0 cm) (AW)

Allow: *'length cannot be zero'*

B1

(b) Straight line (graph) / linear graph / force ∝ extension / constant gradient (graph)

Not 'force $\propto$ length'

B1

(c) force constant = $\dfrac{2.0}{0.04}$

***Note**: The mark is for any correct substitution*

C1

force constant = 50 (N m^{-1})

***Allow:** 1 mark for 0.5 (N m^{-1}) – 10^n error*

***Allow** 1 mark for 5/12 × 10^{-2} = 41.7 or 4/10 × 10^{-2} = 40 or 3/8 × 10^{-2} = 37.5 or 2/6 × 10^{-2} = 33.3 or 1/4 × 10^{-2} = 25*

A1

(d) work done = $\frac{1}{2}Fx$ or $\frac{1}{2}kx^2$ or 'area under graph'

C1

work done = $\frac{1}{2} \times 3.0 \times 0.06$ or $\frac{1}{2} \times 50 \times 0.06^2$

Possible ecf

work done = 0.09 (J)

***Note:** 1 sf answer is allowed*

A1

(e) Find the gradient / slope (of the tangent / graph)

B1

Maximum speed at 1.0s / 3.0s / 5.0s / steepest 'part' of graph / displacement = 0

***Allow:** 2 marks for 'steepest / maximum gradient'*

B1

[8]

11.	(i)	Tension = Weight / mg	C1
		$= 1.5 \times 10^3 \times 9.8$ using g =10 –1	
		= 14700 (N)	A1
	(ii)	time = 25 / 1.6 = 15.6 (s)	A1
	(iii)	PE = mgh	C1
		PE / t = (14700 × 25) / 15.6 or 14700 × 1.6	C1
		= 24000 (23520) ($J\ s^{-1}$)	A1
		or power = F × v	C1
		= 14700 × 1.6	C1
		= 24000 (23520) ($J\ s^{-1}$)	A1
	(iv)	(gain in PE per second = output power used to lift weight) power = 24000 (23520) (W) / allow those answers that suggest greater due to friction in lifting mechanism	B1

[7]

12.	(a)	Young modulus = stress/strain (As long as elastic limit is not exceeded)	B1
	(b)	Strain has no units because it is the ratio of two lengths.	B1

[2]