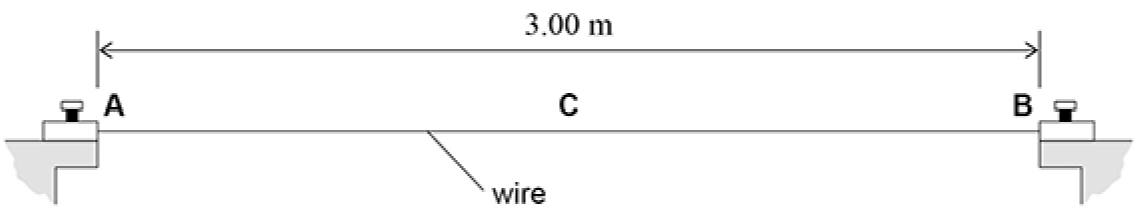
1. A student does an experiment to determine the Young modulus of a metal.
Figure 1 shows a wire made from the metal clamped at points **A** and **B** so that the wire is horizontal. The horizontal distance between **A** and **B** = 3.00 m.
C is the mid-point on the wire between **A** and **B**.

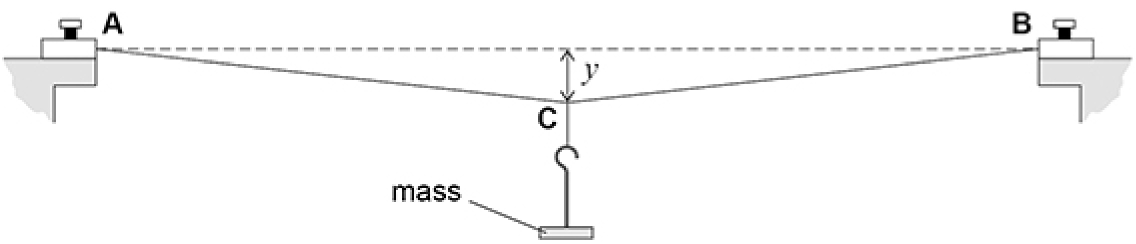
Figure 1



A mass of weight W is suspended at **C** to extend the wire. **Figure 2** shows that **C** moves vertically downwards by a distance y.

Figure 2

not to scale



(a) When W is 1.0 N, y is 6.34 cm.

Show that the wire extends by approximately 3 mm.

(1)

(b) Calculate the tension in the wire when W is 1.0 N.

tension = _______________ N

(2)

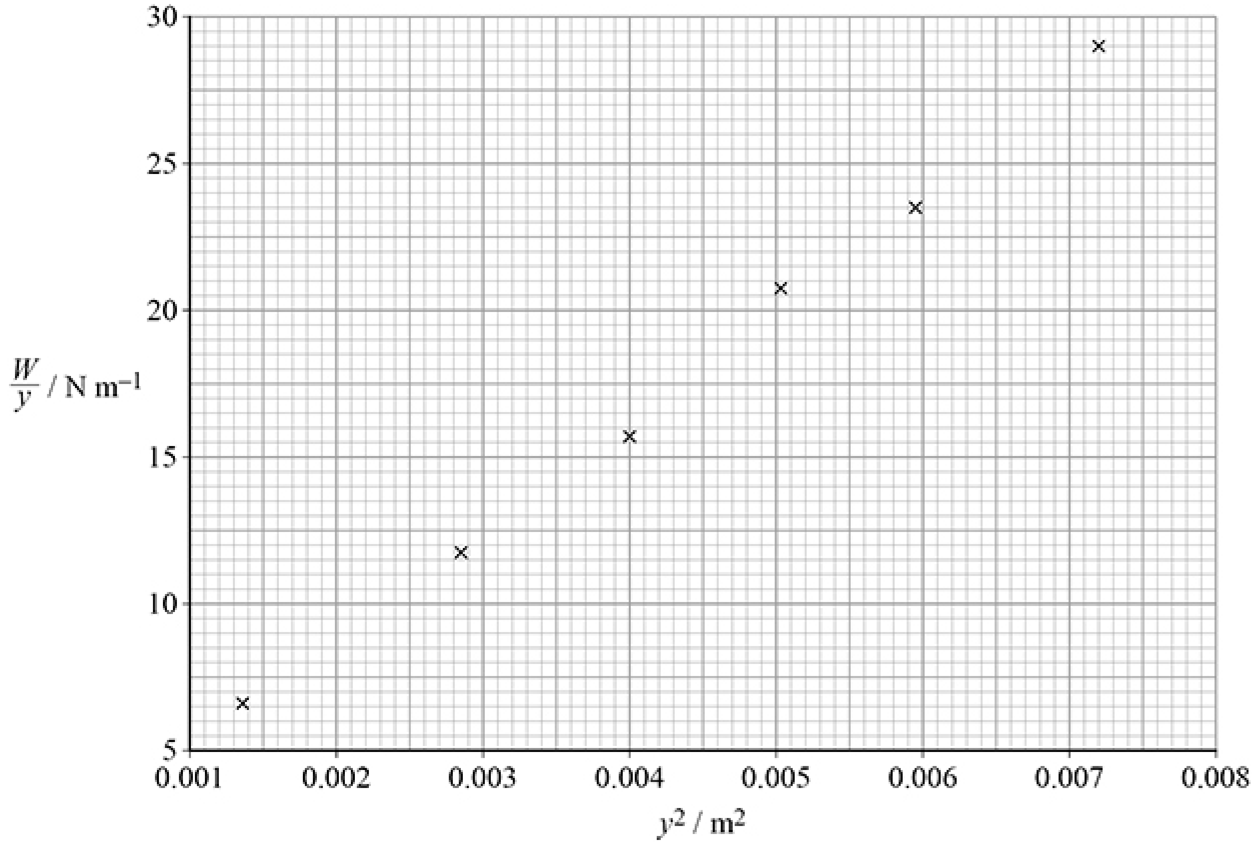
It can be shown that

$$\frac{W}{y} = \frac{EAy^2}{x^3} + k$$

where E = Young modulus of the metal
$A = 1.11 \times 10^{-7}\ \text{m}^2$
$x = 1.50$ m
k = a constant.

A student measures y for different values of W and plots the graph shown in **Figure 3**.

Figure 3



(c) Determine E using **Figure 3**.

E = ________________ Pa

(4)

(d) Deduce the fundamental base units for k.

fundamental base units for k = _______________

(1)

(Total 8 marks)

2. A mass m is added to a vertical spring that is initially unextended, as shown in **Diagram 1**.

The mass is then lowered until it hangs stationary on the spring, as shown in **Diagram 2**.

The extension of the spring is now ΔL.

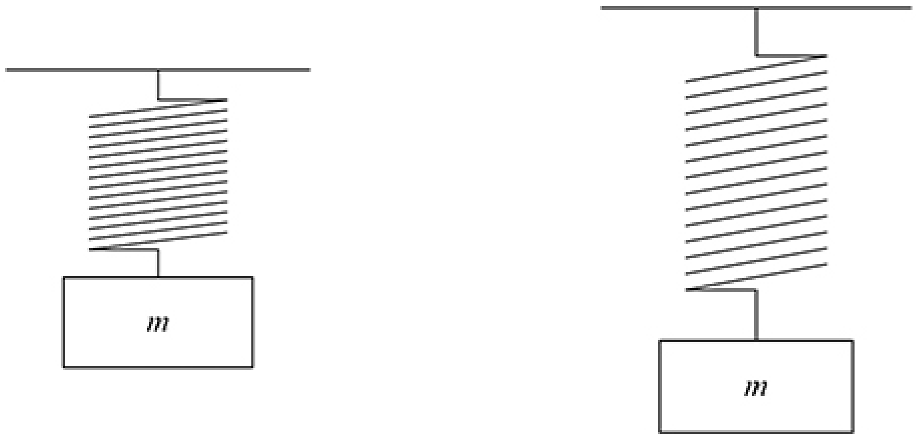


Diagram 1 **Diagram 2**

How much energy is transferred from the mass–spring system?

A $\frac{mg\Delta L}{2}$ ○

B $mg\Delta L$ ○

C $\frac{3mg\Delta L}{2}$ ○

D $2mg\Delta L$ ○

(Total 1 mark)

3. A wire is made from a material of density ρ.
The wire has a mass m and an initial length L.
When the tensile force in the wire is F the extension of the wire is ΔL.

What is the Young modulus of the material?

A $\frac{F\rho L^2}{m\Delta L}$ ⬭

B $\frac{FL^2}{m\rho\Delta L}$ ⬭

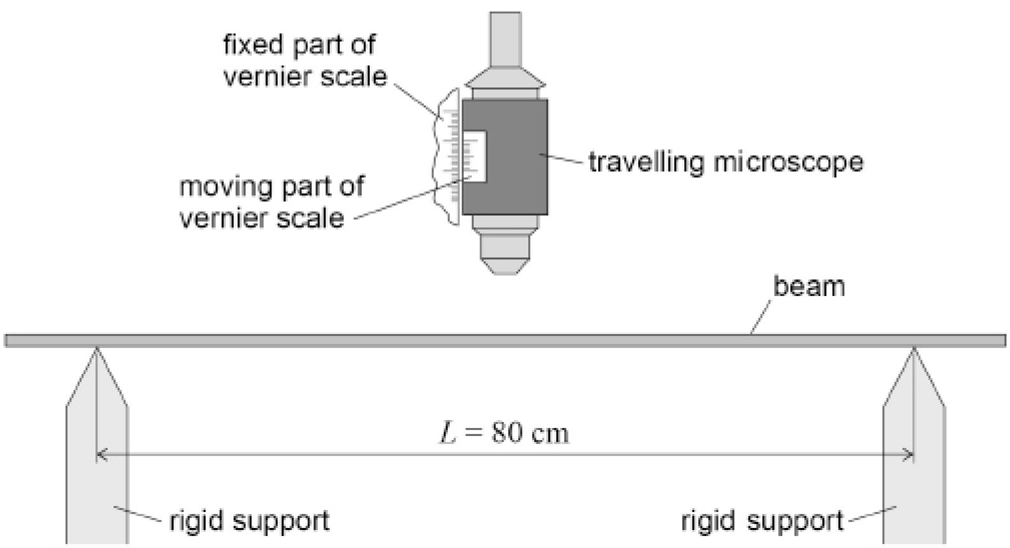
C $\frac{F\rho}{m\Delta L}$ ⬭

D $\frac{FmL^2}{\rho\Delta L}$ ⬭

(Total 1 mark)

4. **Figure 1** shows apparatus used to investigate the bending of a beam.

Figure 1

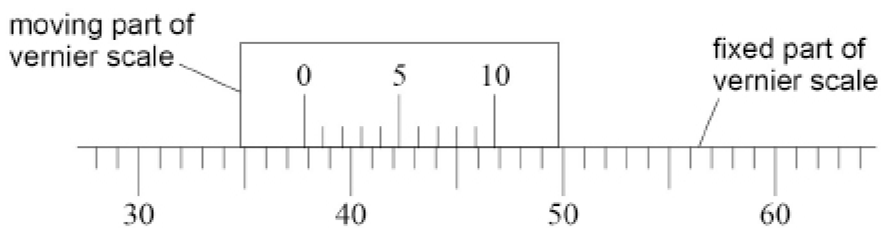


The beam is placed horizontally on rigid supports.
The distance L between the supports is 80 cm.

A travelling microscope is positioned above the midpoint of the beam and focused on the upper surface.

(a) **Figure 2** shows an enlarged view of both parts of the vernier scale.

Figure 2



The smallest division on the fixed part of the scale is 1 mm.

What is the value of the vernier reading R_0 in mm?
Tick (✓) **one** box.

34.8 ☐

37.8 ☐

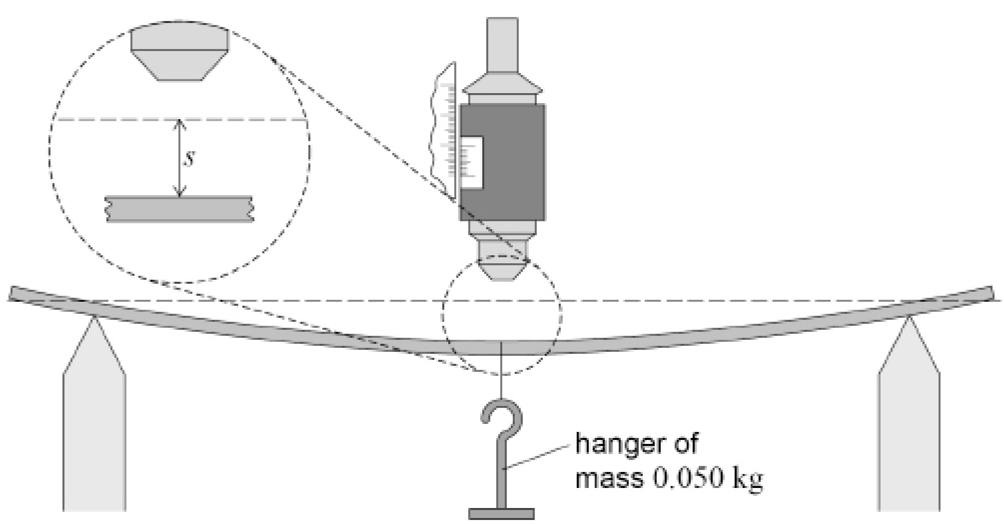
45.8 ☐

49.8 ☐

(1)

(b) **Figure 3** shows the beam bending when a hanger of mass 0.050 kg is suspended from the midpoint.

Figure 3



The microscope is refocused on the upper surface and the new vernier reading R is recorded.
The vertical deflection s of the beam is equal to $(R - R_0)$.

The total mass m suspended from the beam is increased in steps of 0.050 kg.
A value of s is recorded for each m up to a value of m = 0.450 kg.
Further values of s are then recorded as m is decreased in 0.050 kg steps until m is zero.

Student **A** performs the experiment and observes that values of s during unloading are **sometimes** different from the corresponding values for loading.

State the type of error that causes the differences student **A** observes.

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(1)

(c) Student **B** performs the experiment using a thinner beam but with the same width and made from the same material as before.

Discuss **one** possible advantage and **one** possible disadvantage of using the thinner beam.

Advantage ____

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Disadvantage ____

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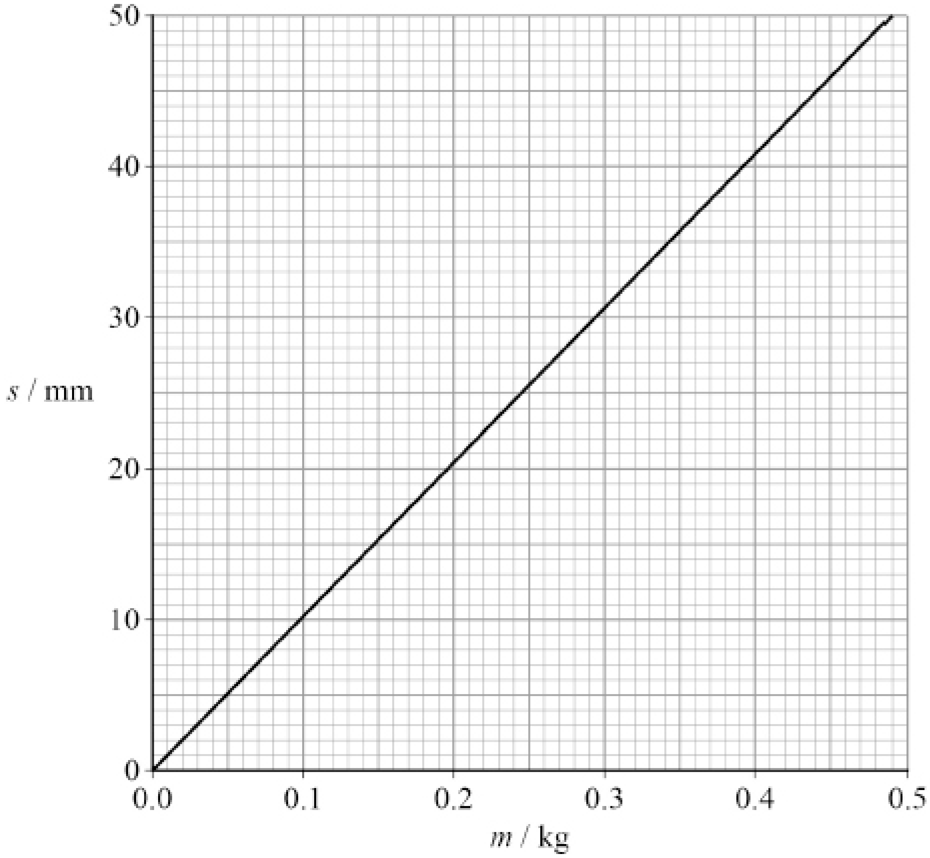
(3)

(d) **Figure 4** shows the best-fit line produced using the data collected by student **A**.

Figure 4



It can be shown that $s = \dfrac{\eta m}{E}$

where E is the Young modulus of the material of the beam and η is a constant.

Deduce in s^{-2} the order of magnitude of η.

E = 1.14 GPa

order of magnitude of η = _______________ s^{-2}

(e) Student **C** performs a different experiment using the same apparatus shown in **Figure 1**.
A mass M is suspended from the midpoint of the beam.
The vertical deflection s of the beam is measured for different values of L.

Figure 5 shows a graph of the results for this experiment.

Figure 5

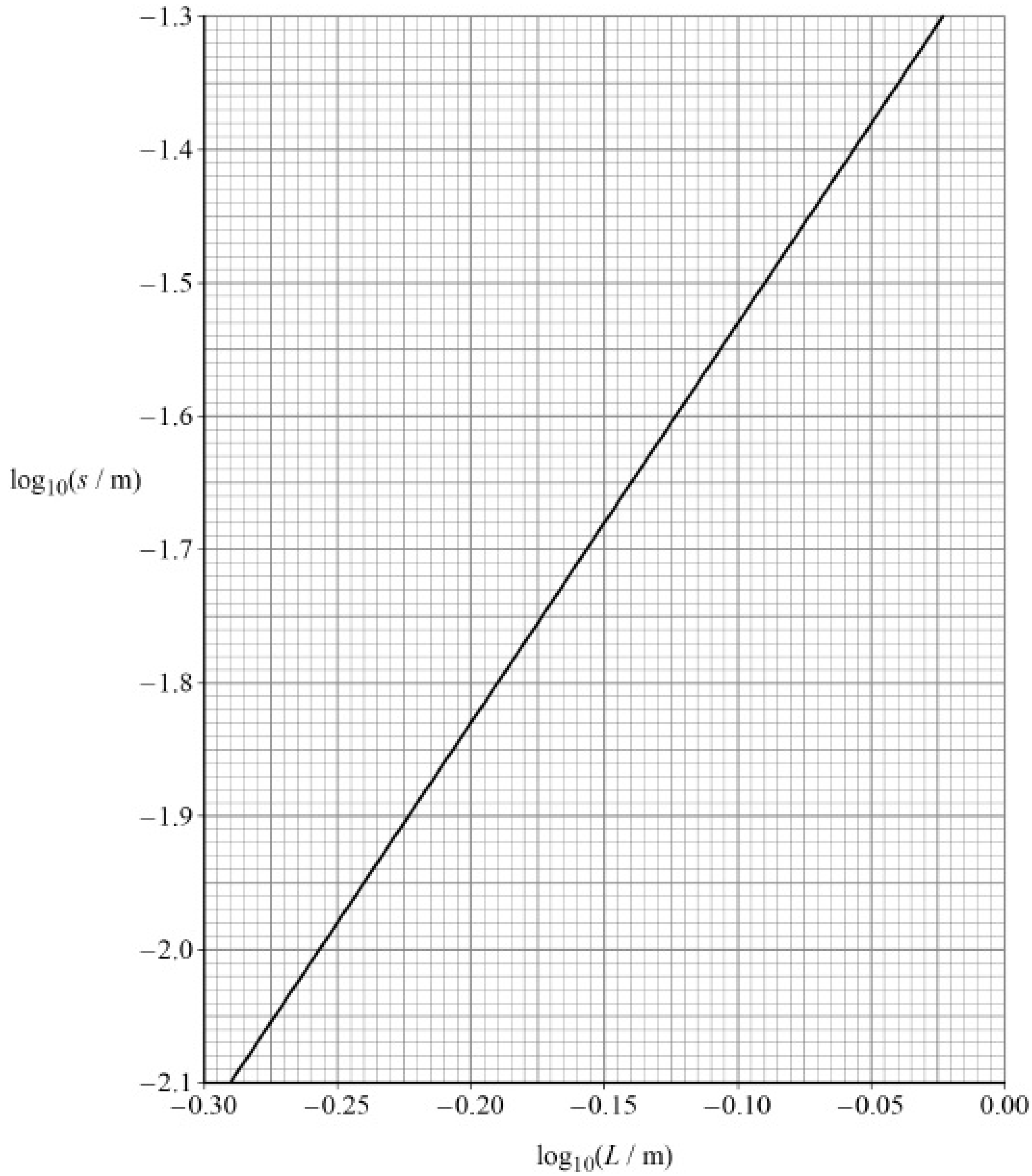


Figure 5 shows that log10(s / m) varies linearly with log10(L / m).

State what this shows about the mathematical relationship between s and L. You do **not** need to do a calculation.

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____

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(1)

(f) Deduce, using **Figure 5**, the value of s when L = 80 cm.

s = ____________________ m

(2)

(g) Determine M using **Figure 4**.

M = ____________________ kg

(1)

(Total 13 marks)

5. Two wires **X** and **Y** have the same extension for the same load.
X has a diameter d and is made of a metal of density ρ and Young modulus E.
Y has the same mass and length as **X** but its diameter is $2d$.

What are the density and the Young modulus of the metal from which **Y** is made?

	Density	Young modulus	
A	$\frac{\rho}{2}$	$\frac{E}{4}$	⬭
B	$\frac{\rho}{2}$	$4E$	⬭
C	$\frac{\rho}{4}$	$\frac{E}{4}$	⬭
D	$\frac{\rho}{4}$	$4E$	⬭

(Total 1 mark)

6. A tensile force produces an extension ΔL in a steel wire of initial length L and diameter d.

The same steel is used to make a second wire of initial length $2L$ and diameter $\frac{d}{2}$

What is the extension when the same force is applied to the second wire?

A $\frac{\Delta L}{2}$ ⬭

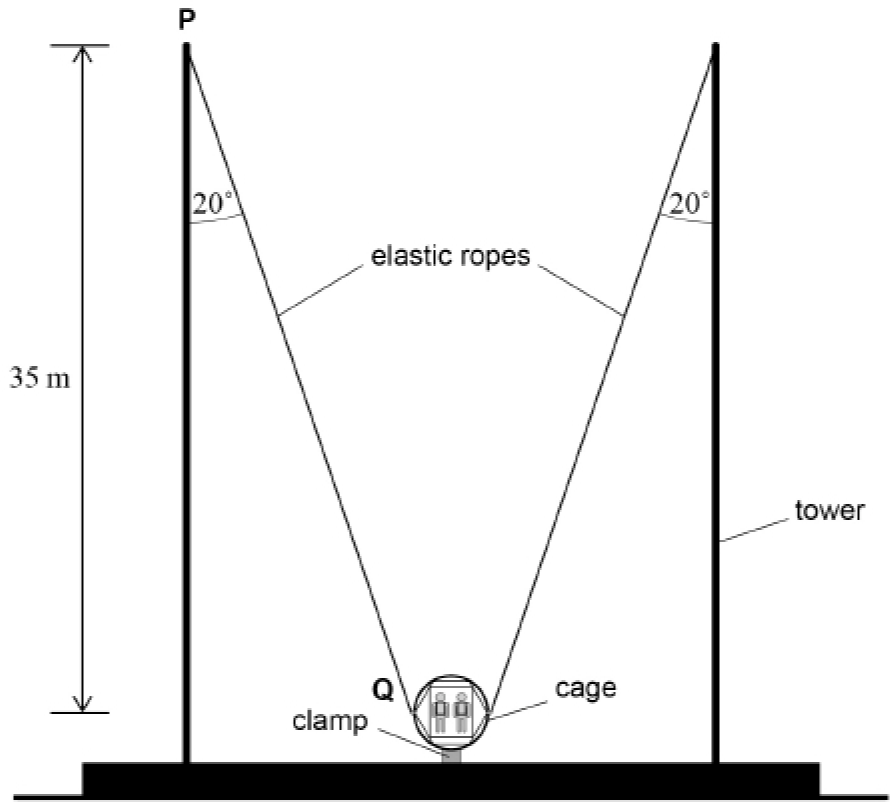
B $2\Delta L$ ⬭

C $4\Delta L$ ⬭

D $8\Delta L$ ⬭

(Total 1 mark)

7. The diagram shows a fairground ride called a ‘reverse bungee’.



Two identical stretched elastic ropes are fixed to a cage with passengers inside. The loaded cage is held in place by a clamp. When the clamp is released the elastic ropes accelerate the loaded cage vertically into the air.

P is the point where the rope attaches to the top of the vertical tower.
Q is the point where the rope attaches to the cage. **Q** is level with the centre of mass of the loaded cage.

Before release, the tension T in each elastic rope is 3.7×10^4 N and each rope makes an angle of 20° with the vertical tower.

The total mass M of the loaded cage is 1.2×10^3 kg and the mass of the elastic ropes is negligible.

(a) Show that the downward force F exerted by the clamp on the loaded cage is about 6×10^4 N.

(4)

(b) Calculate the initial acceleration of the loaded cage when the clamp is released.

acceleration = ____________________ $m\ s^{-2}$

(2)

(c) The unstretched length of each elastic rope is 24 m. The ropes obey Hooke's Law for all extensions used in the ride.
The **vertical** distance between points **P** and **Q** on the diagram above is 35 m.

Show that the total elastic potential energy stored in both ropes before the loaded cage is released is about 5×10^5 J.

(4)

(d) The designers of the ride claim that the loaded cage will reach a height of 50 m above **Q**.

Deduce whether this claim is justified.

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(3)

(e) The designers also claim that the loaded cage reaches a maximum speed of at least 90 km h^{-1}.

Calculate, in J, the kinetic energy of the loaded cage when it travels at 90 km h^{-1}.

kinetic energy = ____________________ J

(3)

(f) Deduce without further calculation whether the maximum speed claim is justified.

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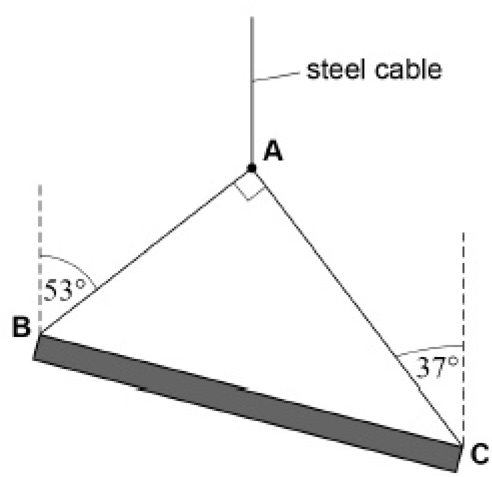
(1)

(Total 17 marks)

8. The diagram shows a uniform beam supported by two light cables, **AB** and **AC**, which are attached to a single steel cable from a crane. The beam is stationary and in equilibrium.



(a) State **two** necessary conditions for the beam to be in equilibrium.

Condition 1 ____

____

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Condition 2 ____

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(2)

(b) State what is meant by the centre of mass.

____

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(1)

(c) Explain why the centre of mass of the beam in the diagram must be vertically below **A**.

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(2)

(d) The weight of the beam is 12 000 N

Calculate the tension T_1 in cable **AB** and the tension T_2 in cable **AC**.

T_1 = ____________________ N

T_2 = ____________________ N

(4)

(e) The steel cable from the crane has a circular cross-section of diameter 1.5×10^{-2} m
The cable is 12 m long.

Calculate the extension of the cable caused by the weight of the beam. You can assume that the weights of **all cables** are negligible.

Young modulus of steel = 2.0×10^{11} Pa

extension = ______________________ m

(3)

(Total 12 marks)

9. Which combination of properties would produce the smallest extension of a wire when the same tensile force is applied to the wire?

	Cross-sectional area	**Length**	**Young modulus of material**	
A	X	$3L$	E	⬭
B	$2X$	L	E	⬭
C	X	$3L$	$4E$	⬭
D	$2X$	L	$4E$	⬭

(Total 1 mark)

10. The table contains information on four wires. It shows the stiffness of each wire and the maximum strain energy stored in the wire when extended to the breaking point.

Assume each wire has the same initial dimensions and obeys Hooke's law.

Which wire extends the least before reaching the breaking point?

	Stiffness / N m^{-1}	Maximum strain energy / J	
A	4.0	1	⬭
B	9.0	1	⬭
C	16	3	⬭
D	25	3	⬭

(Total 1 mark)

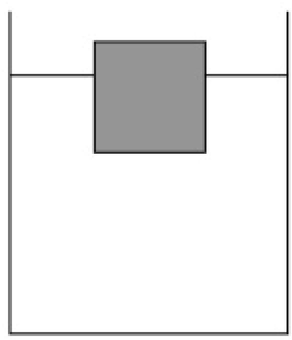
11. (a) Calculate the weight of an ice cube that has volume 4.0×10^{-6} m^3

density of ice = 920 kg m^{-3}

weight = ______________________ N

(2)

(b) The diagram shows the ice cube floating in a beaker of water.



When the ice cube is placed in the beaker, it displaces a volume of water causing the water level to rise.
The weight of water displaced is equal to the weight of the ice cube.

Calculate the volume of water displaced by the ice cube.

density of water = 1000 kg m^{-3}

volume = ____________________ m^3

(1)

(c) The ice cube in the diagram is replaced by another cube also with volume 4.0×10^{-6} m^3
This cube is made of ice containing a small piece of iron.
The mass of water now displaced is 3.9×10^{-3} kg

Calculate the volume of the piece of iron.

density of iron = 7800 kg m^{-3}

volume = ____________________ m^3

(3)

(Total 6 marks)

12. A steel wire **W** has a length l and a circular cross-section of radius r. When **W** hangs vertically and a load is attached to the bottom end, it extends by e.
Another wire **X** made from the same material has the same load attached to it.

Which length and radius for **X** will produce an extension of $\frac{e}{4}$?

	Length of X	Radius of X	
A	$0.5l$	$2r$	⬭
B	l	$4r$	⬭
C	$2l$	$2r$	⬭
D	$4l$	$4r$	⬭

(Total 1 mark)

13. What is the name given to a material that breaks without deformation when a force is applied to it?

A Plastic ⬭

B Brittle ⬭

C Stiff ⬭

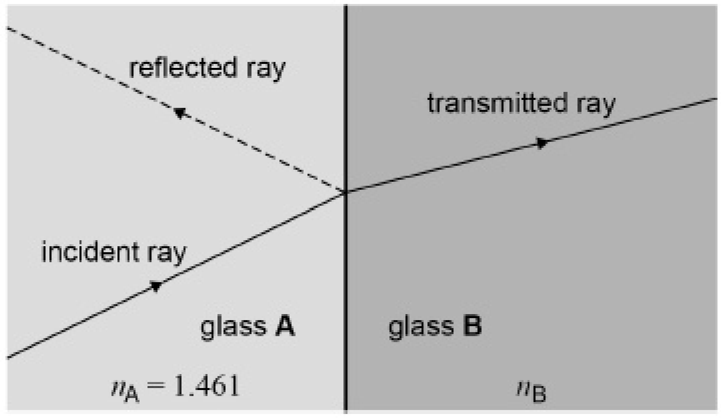
D Elastic ⬭

(Total 1 mark)

14. (a) **Figure 1** shows an incident ray of light being partially reflected at the boundary between glass **A** and glass **B**. The refractive index n_A of glass **A** is 1.461

The speed of light in glass **B** is 3.252% less than the speed of light in glass **A**.

Figure 1



Calculate the refractive index n_B of glass **B**.

Give your answer to an appropriate number of significant figures.

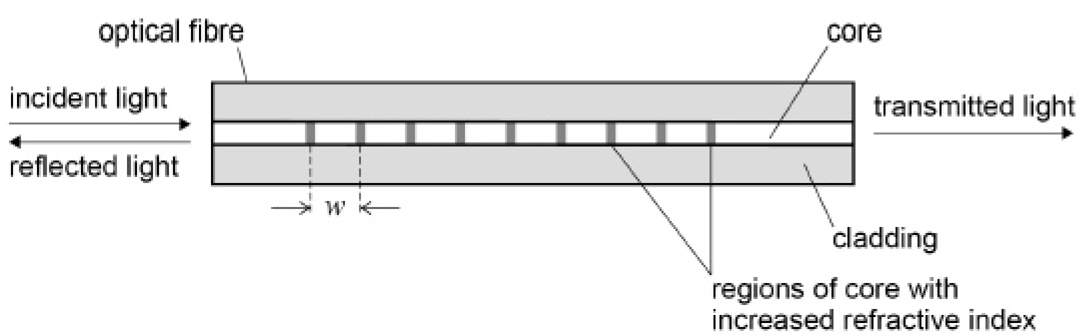
speed of light in a vacuum = 2.998×10^8 m s^{-1}

n_B = ____________________

(3)

(b) **Figure 2** shows a cross-sectional view of an optical fibre strain gauge.

Figure 2

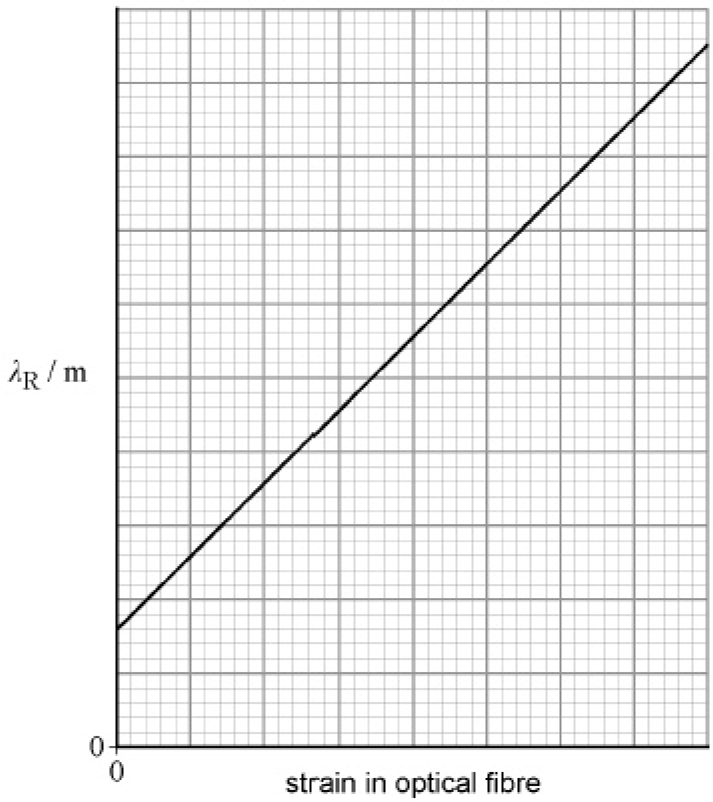


A maximum intensity of the reflected light is produced due to superposition of the light reflected from each of the regions with increased refractive index in the core.

This maximum intensity occurs at a particular wavelength λ_R.

Figure 3 shows the relationship between λ_R and the strain in the optical fibre.

Figure 3



A cable is used to raise and lower a lift. An engineer fixes the optical fibre strain gauge to the cable to monitor changes of the strain in the cable.

The lift is initially at rest and then accelerates downwards for a short time before reaching a constant velocity.

Discuss how the value of λ_R changes.

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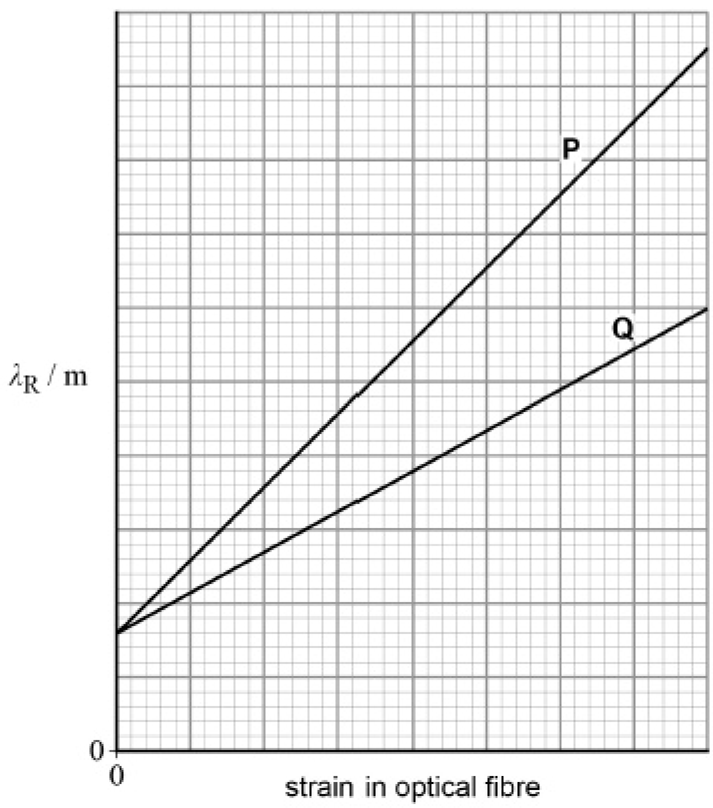
(3)

(c) **Figure 4** shows the relationship between λ_R and the strain in two optical fibre strain gauges **P** and **Q**. The engineer wishes to measure small accelerations in another lift. She can choose to fix either optical fibre strain gauge **P** or optical fibre strain gauge **Q** to the lift's cable.

Figure 4



Explain which gauge the engineer should select.

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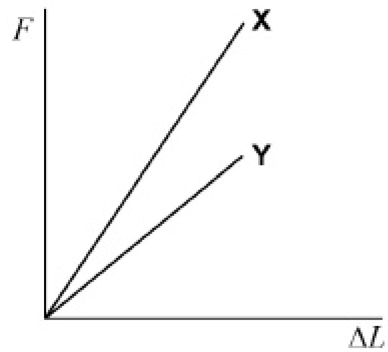
(2)

(Total 8 marks)

15. Two separate wires **X** and **Y** have the same original length and cross-sectional area.

The graph shows the extension ΔL produced in **X** and **Y** when the tensile force F applied to the wires is increased up to the point where they break.



Which statement is **incorrect**?

A For a given extension more energy is stored in **X** than in **Y**. ⬭

B The Young modulus of the material of wire **Y** is greater than that of wire **X**. ⬭

C Both wire **X** and wire **Y** obey Hooke's law. ⬭

D Wire **X** has a greater breaking stress than wire **Y**. ⬭

(Total 1 mark)

16. What **cannot** be used as a unit for the Young modulus?

A N m^{-2} ⬭

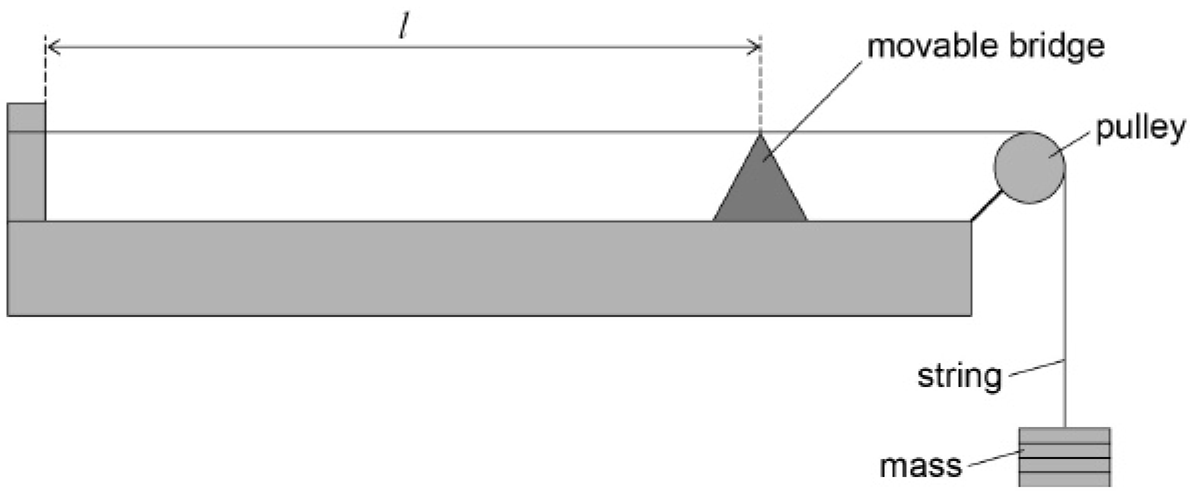
B Pa ⬭

C kg m^{-2} s^{-2} ⬭

D kg m^{-1} s^{-2} ⬭

(Total 1 mark)

17. The diagram shows an arrangement used by a student to investigate vibrations in a stretched nylon string of fixed length l. He measures how the frequency f of first-harmonic vibrations for the string varies with the mass m suspended from it.



The table shows the results of the experiment.

m / kg	f / Hz
0.50	110
0.80	140
1.20	170

(a) Show that the data in the table are consistent with the relationship

$$f \propto \sqrt{T}$$

where T is the tension in the nylon string.

(2)

(b) The nylon string used has a density of 1150 kg m^{-3} and a uniform diameter of 5.0×10^{-4} m.

Determine the length l of the string used.

l = ____________________ m

(3)

(c) The student uses the relationship in question (a) to predict frequencies for tensions that are much larger than those used in the original experiment.

Explain how the actual frequencies produced would be different from those that the student predicts.

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(2)

(Total 7 marks)

18. (a) State the law of conservation of energy.

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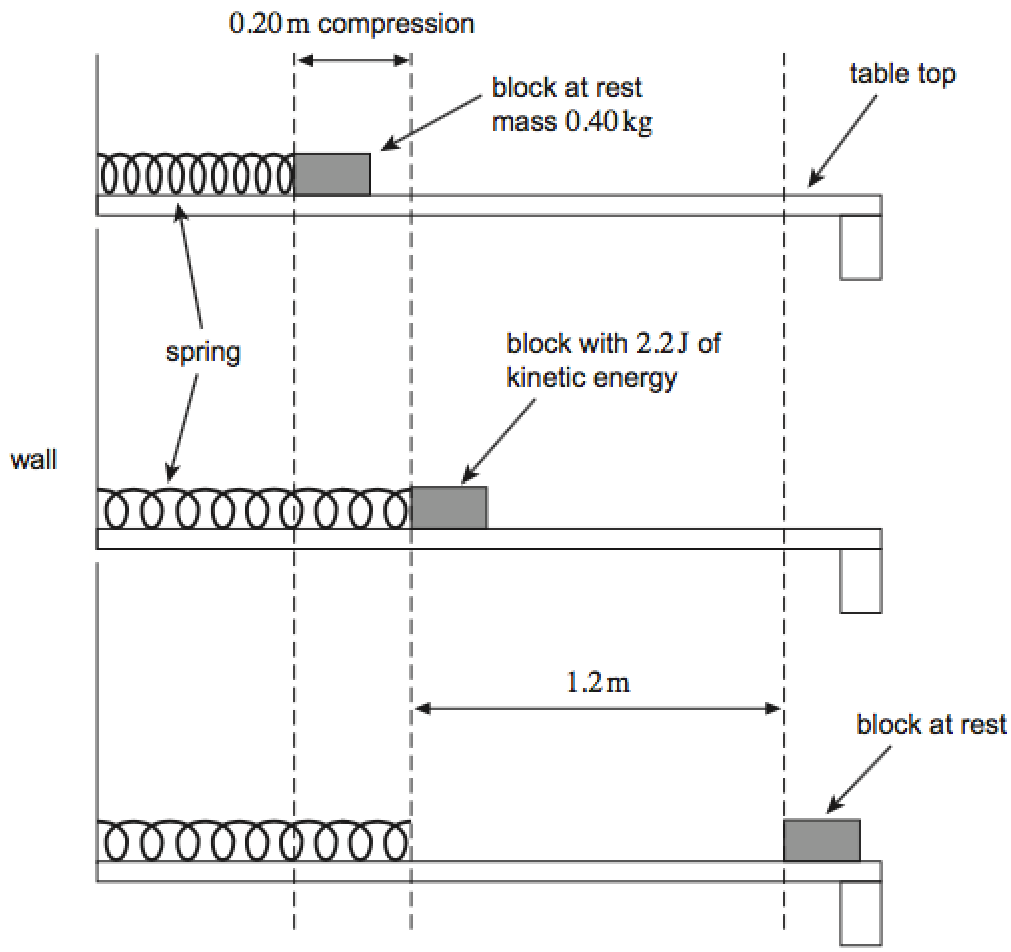
(2)

(b) The diagram shows a block on a horizontal table top initially held against a spring so that the spring is compressed. The other end of the spring is fixed to a wall. When released the block is pushed away by the spring. When the spring reaches its natural length the block leaves the spring and then slides along the table top. A constant frictional force acting between the moving block and the table top eventually brings the block to rest.



(i) When the block leaves the spring, the block has a kinetic energy of 2.2 J. The mass of the block is 0.40 kg.
Calculate the maximum velocity of the block.

maximum velocity = ____________________ m s^{-1}

(1)

(ii) The block travels 1.2 m after leaving the spring before coming to rest.
Show that the frictional force between the block and the table top is about 1.8 N.

(1)

(iii) The spring was initially compressed through 0.20 m. The constant frictional force acts on the block whenever it is moving.
Calculate the elastic potential energy in the spring when in its initial compressed position.
Assume the spring has negligible mass.
State an appropriate unit for your answer.

elastic potential energy = __________ unit = _________

(3)

(iv) The force exerted on the block by the spring is proportional to the compression of the spring.
Calculate the maximum force exerted on the block by the spring.

maximum force = ____________________ N

(1)

(Total 8 marks)