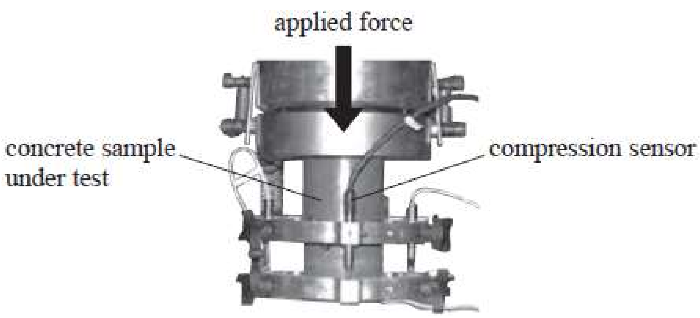
Hooke's Law and Young's Modulus - Questions by Topic

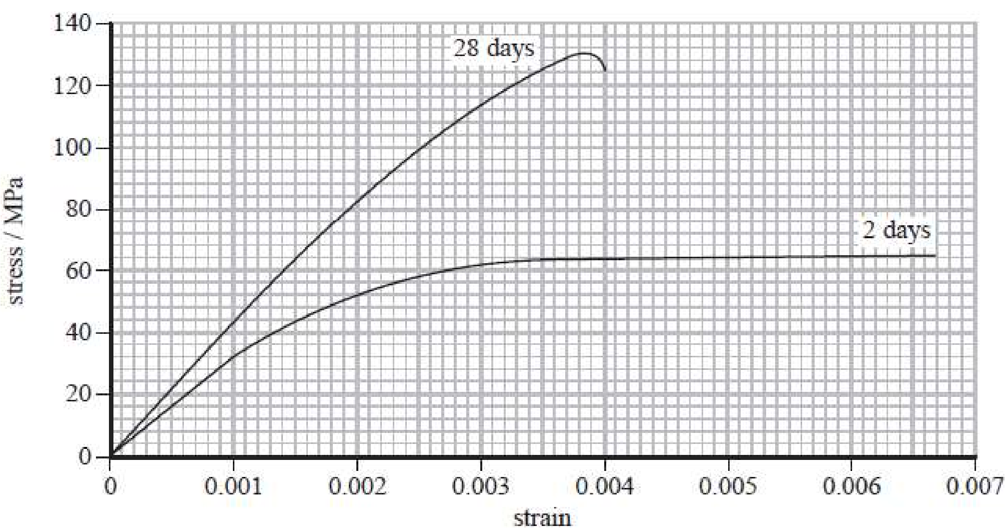
Q1.

When concrete is first made it has a high moisture content. As the concrete dries its properties change.

A manufacturer of concrete carried out compression testing of cylindrical samples of concrete using the equipment shown.



The diagram shows stress-strain graphs, up to the fracture point, for concrete samples 2 days and 28 days after being made.



(a) As the concrete dries its Young modulus increases.

Show that the value for the Young modulus of the concrete after it has dried is at least 1.3 times greater.

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(b) The energy absorbed before fracture by the 28-day old sample is less than the energy absorbed before fracture by the 2-day old sample.

The area under a stress-strain graph gives the energy absorbed per unit volume of the sample.

The energy absorbed before fracture by the 2-day old sample is 0.35 MJ m^{-3}.

Determine the percentage reduction in the energy absorbed before fracture between the 2-day old and the 28-day old samples.
You may assume that the volumes of the cylindrical samples are the same.

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(c) Manufacturers recommend leaving concrete blocks to dry for at least 28 days before use.

Discuss why.

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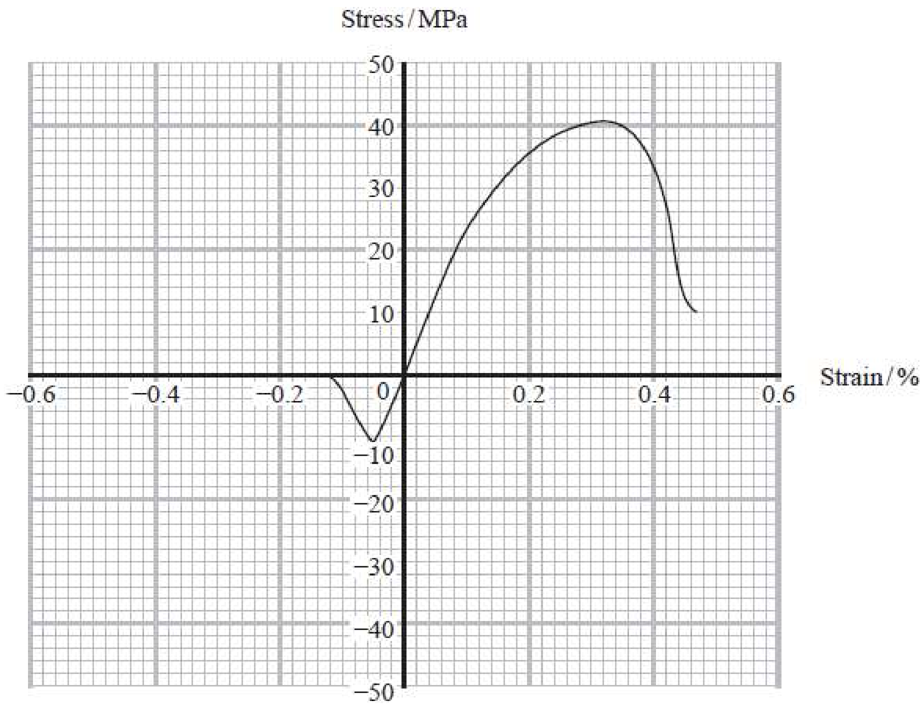
(Total for question = 10 marks)

Q2.

Concrete is a material often used for building.

A stress-strain graph for one type of concrete is shown. Positive values of strain represent compression and negative values of strain represent tension.



(a) Explain how the stress-strain graph shows that concrete is more suitable for use under compression than under tension.

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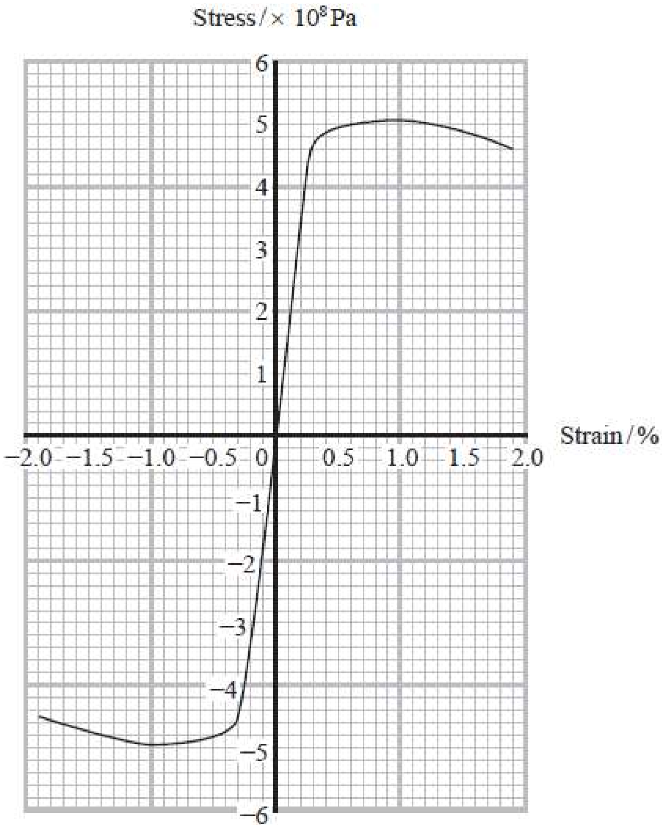
(b) Steel is a metal often used in building. The stress-strain graph for steel is shown.



A steel rod has a diameter of 45 mm.

Calculate the maximum force that could be applied to the steel rod before it fractures.

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Maximum force = ...

(c) To make concrete suitable for use under large forces steel rods are sometimes embedded in the concrete.

An external tensile force is applied to the steel rods. Concrete is poured into a mould around the rods. Once the concrete has set the external force is removed from the steel rods, placing the concrete in compression.

Source: www.designingbuildings.co.uk

(i) Explain how this process increases the maximum tensile force that the concrete can withstand before fracture.

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(ii) Explain why the external tensile force in the rods must not take the steel beyond its elastic limit.

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(Total for question = 11 marks)

Q3.

A student carried out an experiment to determine the Young modulus of copper.

She added a mass *m* to the free end of a sample of copper in the form of a long thin wire and the corresponding extension Δx was measured. This was repeated for increasing masses.

(a) State the meaning of the term Young modulus.

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(b) The student repeated the measurement of the diameter of the wire at different positions and orientations of the wire. She obtained the following results.

Diameter / mm	0.230	0.235	0.230	0.240

(i) Determine the cross-sectional area of the sample of wire used.

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Cross-sectional area = ...

(ii) The student plotted a graph of *m* against Δx. She measured the gradient and obtained a value of 195 kg m^{-1}.

Determine the Young modulus of the copper.

length of sample of copper used = 3.50 m

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Young modulus = ...

(iii) The experiment was repeated by another student, using a 2.00 m length of the copper wire.

Suggest how the values obtained for the gradient and hence the Young modulus will differ between the students.

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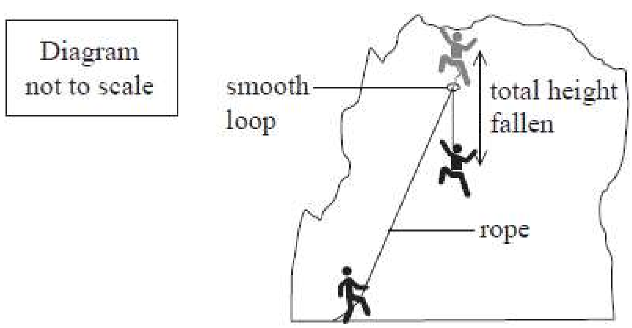
(Total for question = 9 marks)

Q4.

The diagram shows a climber on a rock face. A rope is kept firmly anchored by a person on the ground and passes through a smooth loop to the climber. The climber slips and falls a short distance as shown.



(a) The 'fall factor' is used by climbers to estimate the severity of a climbing fall and is given by

$$\text{'fall factor'} = \frac{\text{height fallen before the rope begins to stretch}}{\text{total unstretched length of rope}}$$

A climber slips and falls with a 'fall factor' of 0.80 before coming to rest.
The energy from the fall is absorbed by the climbing rope.
The maximum strain in the rope is 9.0%.

(i) Show that the maximum force acting on the climber due to the rope is about 10 kN.

Assume the extension of the rope is proportional to its tension.

total unstretched length of rope = 15.0 m
mass of climber = 71 kg

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(ii) A new climber suggests using a longer length of rope between the loop and the

climber, as this would absorb more energy after a fall.

Comment on this suggestion.

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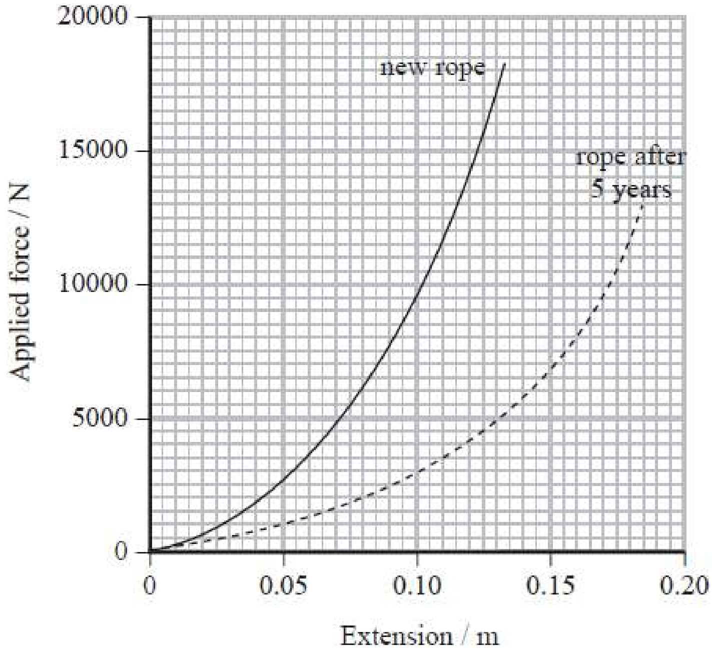
(b) Climbing rope manufacturers recommend that ropes are replaced every 5 years.

The force-extension graphs, up to the breaking point, for a one metre length of a rope when new and after 5 years are shown.



Comment on the manufacturers' recommendation. Your answer should include calculations.

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(Total for question = 13 marks)

Q5.

One end of a 50 cm length of wire is attached to a support. A load is attached to the free end of the wire, which extends by 2 mm.

Which of the following is the strain for the length of wire?

☐ **A** 0.004

☐ **B** 0.04

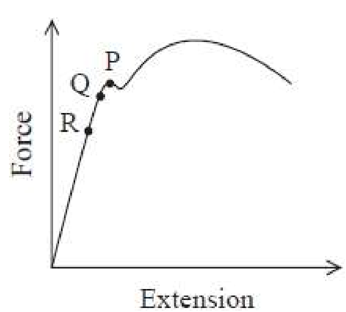
☐ **C** 25

☐ **D** 250

(Total for question = 1 mark)

Q6.

A length of steel wire is fixed at one end. An increasing force is applied to the other end of the wire. The force extension graph for the wire is shown.



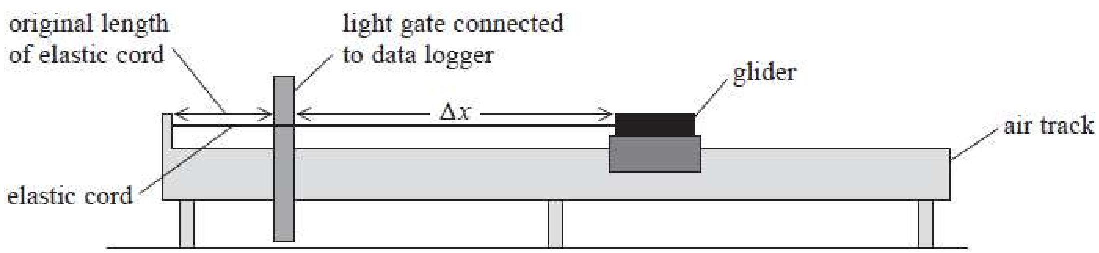
Which row of the table identifies points P, Q and R on the graph?

		P	Q	R
☒	A	elastic limit	limit of proportionality	yield point
☒	B	elastic limit	yield point	limit of proportionality
☒	C	yield point	elastic limit	limit of proportionality
☒	D	yield point	limit of proportionality	elastic limit

(Total for question = 1 mark)

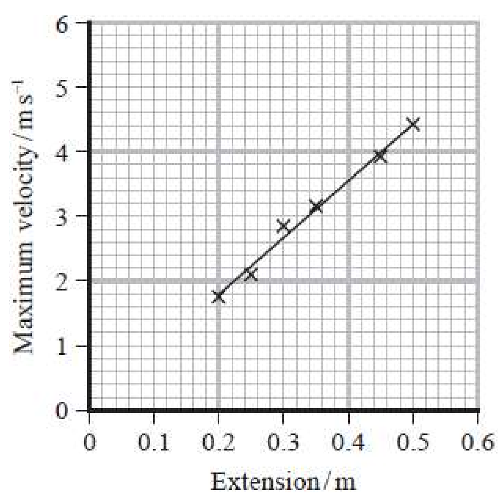
Q7.

An elastic cord was fixed between the end of an air track and a glider.
The glider was pulled to the right, giving the elastic cord an extension Δ *x* as shown.



The glider was released, and it moved to the left. A light gate was used to measure the maximum velocity of the glider. This was repeated for different values of Δ *x*.

A student obtained the following results.



(a) The principle of conservation of energy predicts that the graph should be a straight line through the origin. For the range of values of Δ *x* used, the elastic cord obeyed Hooke's law.

(i) Explain this prediction.

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(ii) Determine the stiffness *k* of the elastic cord.

mass of glider = 300 g

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k = ...

(b) When the glider was moved to the right by more than 0.5 m, the graph began to curve.

Explain why the shape of the graph changed.

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(Total for question = 9 marks)