Past-paper walk-through

Stress and strain ▪ 6.1

eXercise

Questions in this set

- 9702/11 N25 Q21 ▪ 1 mark
- 9702/12 N25 Q21 ▪ 1 mark
- 9702/12 N25 Q22 ▪ 1 mark
- 9702/14 N25 Q20 ▪ 1 mark
- 9702/14 N25 Q23 ▪ 1 mark
- 9702/21 N25 Q3 ▪ 9 marks
- 9702/11 J25 Q21 ▪ 1 mark
- 9702/11 J25 Q22 ▪ 1 mark
- 9702/11 J25 Q23 ▪ 1 mark
- 9702/12 J25 Q21 ▪ 1 mark

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 21

9702/11 N25 ▪ Q21 ▪ 1 mark

A wire has an unstretched length of 2.00 m.
A stress of 1.6×10^5 Pa is applied to the wire, and the new length of the wire is 2.10 m.
The wire obeys Hooke's law.
What is the Young modulus of the wire? **[1]**

A 8.0×10^3 Pa

B 7.8×10^4 Pa

C 1.5×10^5 Pa

D 3.2×10^6 Pa

Solution 21

A 8.0×10^3 Pa

B 7.8×10^4 Pa

C 1.5×10^5 Pa

D 3.2×10^6 Pa ✓

Why

- The extension is $2.10 - 2.00 = 0.10$ m, so the strain is $0.10/2.00 = 0.050$.
- Young modulus is stress divided by strain.
- $E = 1.6 \times 10^5/0.050 = 3.2 \times 10^6$ Pa.

Question 21

9702/12 N25 ▪ Q21 ▪ 1 mark

A platform is supported by a spring. A box is placed onto the platform. The diagram shows the spring before and after the box is placed onto it.

What is the term for the quantity marked as x? **[1]**

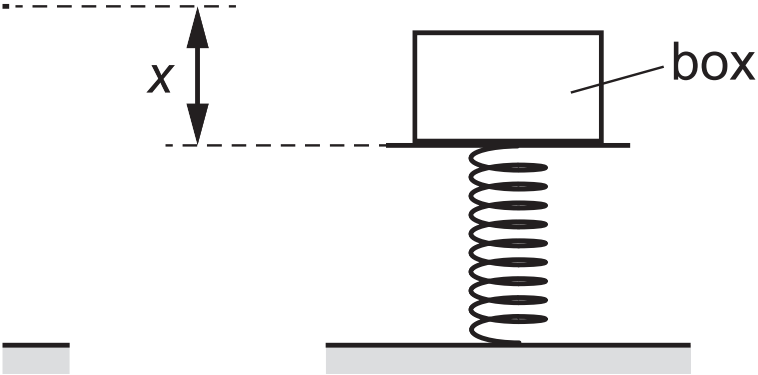
A compression

B load

C strain

D stress

Question 21



Solution 21

- **A** compression ✓
- **B** load
- **C** strain
- **D** stress

Why

- The spring is *shorter* after the box is added, so x is the decrease in its length.
- A change in length under a squashing load is the compression.
- Load is the force itself, strain is a ratio with no unit, and stress is force per unit area.

Question 22

9702/12 N25 ▪ Q22 ▪ 1 mark

A copper wire has length 1.7 m and uniform diameter 0.64 mm.
The Young modulus of copper is 1.2×10^{11} Pa.
What is the spring constant of the wire? **[1]**

A 2.3×10^4 N m^{-1}

B 9.1×10^4 N m^{-1}

C 4.5×10^7 N m^{-1}

D 7.1×10^7 N m^{-1}

Solution 22

A 2.3×10^4 N m^{-1} ✓

B 9.1×10^4 N m^{-1}

C 4.5×10^7 N m^{-1}

D 7.1×10^7 N m^{-1}

Why

- Rearranging $E = (F/A)(L/x)$ gives the spring constant $k = F/x = EA/L$.
- $A = \pi(0.32 \times 10^{-3})^2 = 3.22 \times 10^{-7}$ m^2 – note the radius, not the diameter.
- $k = (1.2 \times 10^{11})(3.22 \times 10^{-7})/1.7 = 2.3 \times 10^4$ N m^{-1}.

Question 20

9702/14 N25 ▪ Q20 ▪ 1 mark

A cylindrical steel rod with negligible weight has a diameter of 1.5 cm and a length of 5.2 cm.

The rod is firmly attached at the top end.

The rod is firmly attached to a machine at the other end that applies a constant force of 363 N to the rod.

This causes the rod to extend to a length of 7.4 cm and to have a minimum diameter of 0.60 cm in the position shown.

What is the maximum stress acting on the steel rod when the length is 7.4 cm? **[1]**

A 2.1×10^6 Pa

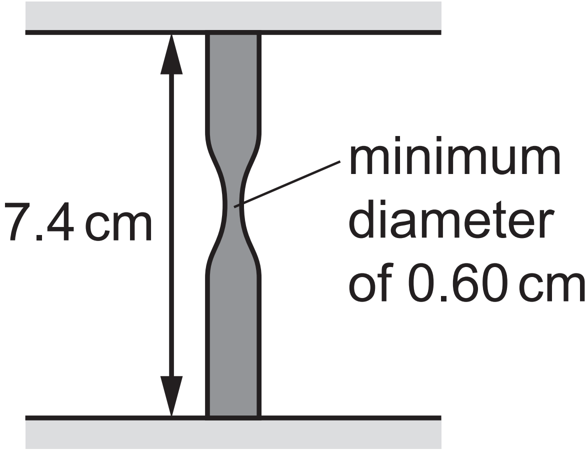
B 3.2×10^6 Pa

Question 20

C 5.7×10^{6} Pa

D 1.3×10^{7} Pa

Question 20



Solution 20

A 2.1×10^6 Pa

B 3.2×10^6 Pa

C 5.7×10^6 Pa

D 1.3×10^7 Pa ✓

Why

- Stress is force over area, so the *maximum* stress occurs where the area is smallest.
- The narrowest point has diameter 0.60 cm, so $A = \pi(0.30 \times 10^{-2})^2 = 2.83 \times 10^{-5}$ m^2.
- $\sigma = 363/(2.83 \times 10^{-5}) = 1.3 \times 10^7$ Pa; the original 1.5 cm diameter gives A.

Question 23

9702/14 N25 ▪ Q23 ▪ 1 mark

Which expression gives the formula for the spring constant? **[1]**

A Fx

B $2Fx^2$

C $\frac{F}{x}$

D $\frac{F}{x^2}$

Solution 23

- **A** Fx
- **B** $2Fx^2$
- **C** $\frac{F}{x}$ ✓
- **D** $\frac{F}{x^2}$

Why

- The spring constant is the force per unit extension, $k = F/x$.
- It is the gradient of a force–extension graph.
- A and B are products with the units of energy, not a ratio.

Question 3

9702/21 N25 ▪ Q3 ▪ 9 marks

A wire has length L and cross-sectional area A. The wire is made from a metal that has Young modulus E and resistivity ρ.

(a) Define the Young modulus of a material. **[1]**

(b)(i) State an expression, in terms of some or all of L, A, E and ρ, for the resistance R_0 of the wire. **[1]**

(b)(ii) Show that the spring constant k_0 of the wire is given by

$$k_0 = \frac{EA}{L}$$

[2]

(c)(i) On Fig. 3.1, sketch the variation with F of the resistance R of the wire. **[1]**

(c)(ii) On Fig. 3.2, sketch the variation with F of the spring constant k of the wire. **[1]**

Question 3

(d)(i) A copper wire of diameter $1.6\,\text{mm}$ has a resistance of $0.034\,\Omega$.
Show that the length of the wire is $3.8\,\text{m}$. **[1]**

(d)(ii) Use the equation in **(b)(ii)** to determine the spring constant of the wire. **[2]**

Solution 3

(a)

Mark scheme

- ratio of stress to strain **B1**

Solution 3

(b)(i)

Mark scheme

- $R0 = \rho L \,/\, A$ **A1**

Solution 3

(b)(ii) Worked steps

Put the two definitions side by side and eliminate the force and the extension.

- Spring constant: $k_0 = \dfrac{F}{x}$
- Young modulus: $E = \dfrac{\text{stress}}{\text{strain}} = \dfrac{F/A}{x/L} = \dfrac{FL}{Ax}$
- Group the same ratio: $E = \left(\dfrac{F}{x}\right)\dfrac{L}{A} = \dfrac{k_0 L}{A}$
- So $k_0 = \dfrac{EA}{L}$, as required.

Solution 3

Mark scheme

- $k = F / x$ **C1**
- $E = FL / Ax = ((F / x) \times (L / A)) = kL / A$ leading to $k0 = EA / L$ **A1**

Solution 3

(c)(i)

Worked steps

- $R = \dfrac{\rho L}{A}$. Stretching the wire makes L larger and A smaller, so R rises.
- Draw a **straight line with a positive gradient**, starting at $(0, R_0)$.

Mark scheme

- straight line with positive gradient starting at (0, R0) **B1**

Solution 3

(c)(ii)

Worked steps

- $k_0 = \dfrac{EA}{L}$ depends only on the material and the wire's dimensions, not on the load.
- Within the elastic limit the wire obeys Hooke's law, so k does not change with F.
- Draw a **horizontal straight line** starting at $(0, k_0)$.

Mark scheme

- straight horizontal line starting at (0, k0) **B1**

Solution 3

(d)(i) Worked steps

- $R = \dfrac{\rho L}{A}$, so $L = \dfrac{RA}{\rho}$.
- The **diameter** is 1.6 mm, so the radius is 0.80 mm and $A = \pi(0.80 \times 10^{-3})^2 = 2.01 \times 10^{-6}$ m^2.
- $L = \dfrac{0.034 \times 2.01 \times 10^{-6}}{1.8 \times 10^{-8}}$
- $L = 3.8$ m, as required.

Solution 3

Mark scheme

- $L = [0.034 \times \pi \times (0.80 \times 10–3)2] \ / \ 1.8 \times 10–8 = 3.8$ (m) **A1**

Solution 3

(d)(ii) Worked steps

- $k = \dfrac{EA}{L} = \dfrac{1.3 \times 10^{11} \times 2.01 \times 10^{-6}}{3.8}$
- $k = 6.9 \times 10^{4}$ N m^{-1}

Solution 3

Neater still: substituting $L = RA/\rho$ gives $k = \dfrac{E\rho}{R}$, so the area cancels and you never need it — $\dfrac{1.3 \times 10^{11} \times 1.8 \times 10^{-8}}{0.034}$ gives the same answer.

Mark scheme

- k = [1.3 × 1011 × π × (0.80 × 10–3)2] / 3.8 or k = EA / [RA / ρ] = Eρ / R
- = [1.3 × 1011 × 1.8 × 10–8] / 0.034 **C1**
- k = 6.9 × 104 N m–1 **A1**

Question 21

9702/11 J25 ▪ Q21 ▪ 1 mark

A student investigates a spring. The variation of the length of the spring with the force applied to the spring is shown.

What is the spring constant of the spring? **[1]**

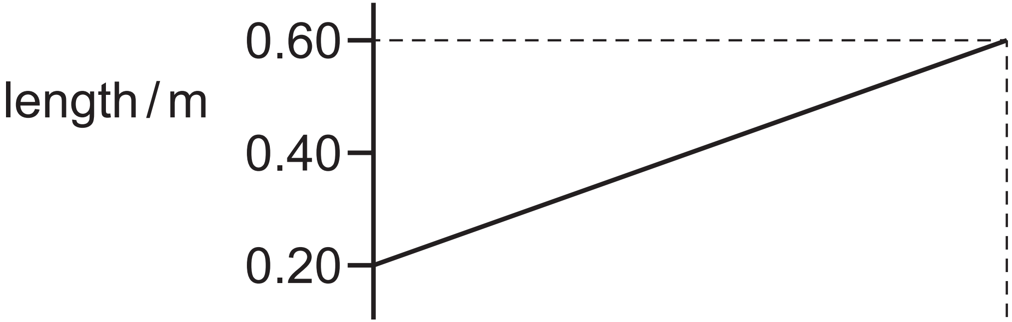
A $0.17\ \mathrm{N\,m^{-1}}$

B $0.25\ \mathrm{N\,m^{-1}}$

C $4.0\ \mathrm{N\,m^{-1}}$

D $6.0\ \mathrm{N\,m^{-1}}$

Question 21



Solution 21

A $0.17\ \mathrm{N\,m^{-1}}$

B $0.25\ \mathrm{N\,m^{-1}}$

C $4.0\ \mathrm{N\,m^{-1}}$

D $6.0\ \mathrm{N\,m^{-1}}$ ✓

Why

- The graph plots *length*, not extension, so subtract the natural length first.
- At $F = 0$ the length is 0.20 m and at $F = 2.4$ N it is 0.60 m, so the extension is 0.40 m.
- $k = F/x = 2.4/0.40 = 6.0$ N m^{-1}; C comes from dividing by the length 0.60 m instead.

Question 22

9702/11 J25 ▪ Q22 ▪ 1 mark

The graph shows the variation with force of the extension of a wire.
The force is gradually increased to a maximum at Q and then gradually decreased to zero at R.
Which statement is correct? **[1]**

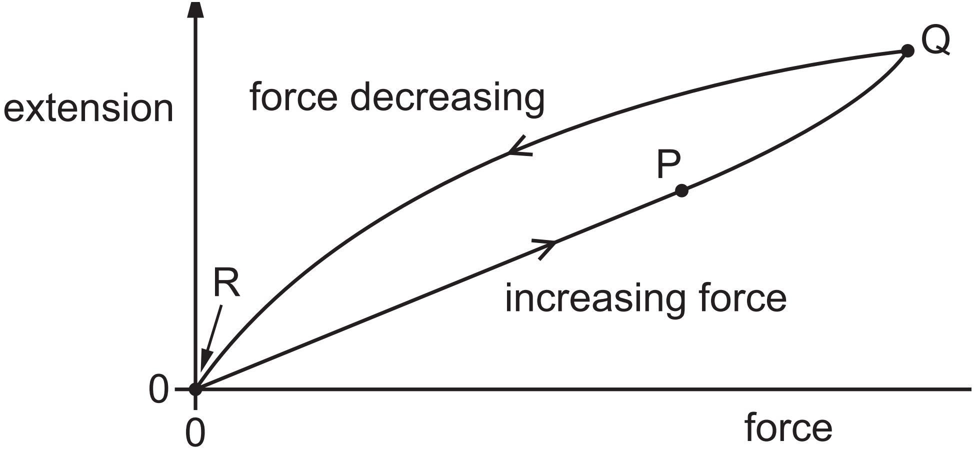
A Along the line PQ, the wire obeys Hooke's law.

B Along the line RP, the spring constant is equal to $\frac{\text{extension}}{\text{force}}$.

C The wire has elastic deformation at point Q.

D The work done in stretching the wire to P is equal to (force $\times$ extension) at point P.

Question 22



Solution 22

A Along the line PQ, the wire obeys Hooke's law.

B Along the line RP, the spring constant is equal to $\frac{\text{extension}}{\text{force}}$.

C The wire has elastic deformation at point Q. ✓

D The work done in stretching the wire to P is equal to (force $\times$ extension) at point P.

Why

- Both curves start and finish at the origin: when the force returns to zero, so does the extension.
- That means the wire recovers completely, so the deformation at Q is still elastic.
- The loading line is curved, so Hooke's law fails along PQ; note the axes are swapped, so the work done to P is the area under the curve, not force $\times$ extension.

Question 23

9702/11 J25 ▪ Q23 ▪ 1 mark

A uniform metal wire of length L and diameter d has spring constant k.

What is the Young modulus of the metal? **[1]**

A $\frac{\pi d^2}{4kL}$

B $\frac{\pi d^2}{kL}$

C $\frac{kL}{\pi d^2}$

D $\frac{4kL}{\pi d^2}$

Solution 23

- **A** $\frac{\pi d^2}{4kL}$
- **B** $\frac{\pi d^2}{kL}$
- **C** $\frac{kL}{\pi d^2}$
- **D** $\frac{4kL}{\pi d^2}$ ✓

Why

- Young modulus is stress over strain: $E = (F/A)/(x/L) = (F/x)(L/A)$.
- F/x is the spring constant k, and the area is $A = \pi d^2/4$.
- So $E = kL/(\pi d^2/4) = 4kL/\pi d^2$.

Question 21

9702/12 J25 ▪ Q21 ▪ 1 mark

21 A student has a copper wire and a steel wire with equal lengths and cross-sectional areas.

The student hangs identical loads on the two wires.

The extensions of the two wires are different.

The student calculates the stress, strain and Young modulus of each wire.

Which row identifies with a tick (✓) the calculated values that are equal for both wires?

	stress	strain	Young modulus
A	✓		
B		✓	
C		✓	✓

Question 21

D	✓		✓

Solution 21

Answer: **A**

Why

- Stress is F/A, and both the load and the cross-section are the same, so the stresses are equal.
- The extensions differ and the lengths are equal, so the strains differ.
- Young modulus is a property of the material, so copper and steel differ there too.