

Mark Scheme Young's Modulus Past Paper Questions

Q6 Jan 2002

6(a)(i) diagram to show:

- (long) wire fixed at one end ✓
- mass/weight at other end ✓
- measuring scale ✓
- mark on wire, or means to measure extension ✓

max (3)

[alternative for two vertical wires:

- two wires fixed to rigid support ✓
- mass/weight at end of one wire ✓
- other wire kept taut ✓
- spirit level and micrometer or sliding vernier scale ✓]

(ii) measurements:

- length of the wire between clamp and mark ✓
- diameter of the wire ✓
- extension of the wire ✓
- for a known mass ✓

max (3)

(iii) length measured by metre rule ✓

- diameter measured by micrometer ✓
- at several positions and mean taken ✓
- (known) mass added and extension measured ✓
- by noting movement of fixed mark against vernier scale
(or any suitable alternative) ✓
- repeat readings for increasing (or decreasing) load ✓

max (5)

(iv) graph of mass added/force against extension ✓

gradient gives $\frac{F}{e}$ or $\frac{m}{e}$ ✓

correct use of data in $E = \frac{Fl}{eA}$ where A is cross-sectional area ✓

[if no graph drawn, then mean of readings
and correct use of data to give 2_{\max}] ✓

max (2)

(13)

(b)(i) for steel $\left(\text{use of } E = \frac{Fl}{eA} \text{ gives} \right) e = \frac{Fl}{EA}$ ✓

$$e = \frac{125 \times 2}{2.0 \times 10^{11} \times 2.5 \times 10^{-7}} \quad \checkmark$$

$$= 5.0 \times 10^{-3} \text{ m} \quad \checkmark$$

(ii) extension for brass would be 10×10^{-3} (m) (or twice that of steel) ✓
end A is lower by 5 mm ✓ (allow C.E. from (b)(i))

max (3)

(16)

- 5(a)(i) the Young modulus: tensile stress/tensile strain ✓
 (ii) maximum force or load which can be applied without wire being permanently deformed
 [or point beyond which (when stress removed,) material does not regain original length] ✓ (2)

- (b)(i) graph: suitable scale ✓
 correct points ✓ ✓
 best straight line followed by curve ✓

Q5 June 2002

- (ii) indication of region or range of Hooke's law ✓

- (iii) (use of $E = \frac{Fl}{Ae}$)
 values of F and e within range or correct gradient ✓
 to give $E = \frac{6.7}{4 \times 10^{-3}} \times \frac{1.6}{8.0 \times 10^{-8}}$ ✓
 $= 3.3(5) \times 10^{10}$ Pa ✓ (8)

- (c)(i) work done = force \times distance ✓
 $=$ average force \times extension ($= \frac{1}{2}Fe$) ✓
 [or use work done = area under graph
 area = $\frac{1}{2}$ base \times height]

- (ii) energy stored = $\frac{6.7 \times 4 \times 10^{-3}}{2}$ ✓
 $= 13.(4) \times 10^{-3}$ J ✓ (4)
(14)

6

- (a) correct plotting of points ✓ ✓
 increasing load graph ✓
 decreasing load graph ✓ (4)

- (b) (initially) the material/wire obeys Hooke's law
 [or behaves elastically] ✓
 up to the limit of proportionality ✓
 (beyond this), elastic limit is reached ✓
 undergoes plastic deformation ✓
 undergoes permanent change ✓
 reference to Hooke's law obeyed as load decreases ✓

Q6 Jan 2003

- max(4)

- (c) ($E = \frac{Fl}{Ae}$ gives $E = \frac{F}{e} \times \frac{l}{A}$)
 gradient = (e.g.) $\frac{46}{4.2 \times 10^{-3}}$ ✓ ($= 1.095 \times 10^4$)
 $E = 1.095 \times 10^4 \times \frac{3}{2.8 \times 10^{-7}} = 1.2 \times 10^{11}$ Pa ✓ (1.17 $\times 10^{11}$ Pa) (3)

- (d) area under the graph at any given point ✓ (1)
(12)

5(a)(i) X ✓
stress (force) \propto strain (extension) for the whole length ✓ **Q5 Jun 2003**

(ii) Y ✓
has lower breaking stress (or force/unit area is less) ✓

(iii) Y ✓
exhibits plastic behaviour ✓

(iv) Y ✓
for given stress, Y has greater extension
[or greater area under graph] ✓

(8)

(b)(i) (use of $E = \frac{F}{A} \times \frac{l}{e}$ gives)

$$F \left(= \frac{EAe}{l} \right) = \frac{2.0 \times 10^7 \times 0.64 \times 10^{-6} \times 30 \times 10^{-3}}{160 \times 10^{-3}}$$

✓ for data into correct equation, ✓ for correct area
= 2.4 N ✓
(allow C.E. for incorrect area conversion)

(ii) (use of $\text{energy stored} = \frac{1}{2}Fe$ gives) energy = $\frac{2.4 \times 30 \times 10^{-3}}{2}$ ✓
= 36×10^{-3} J ✓

(allow C.E. for value of F from (i))

(5)

(13)

5

(a) tensile stress: (stretching) force (applied) per unit cross-sectional area ✓
tensile strain: extension (produced) per unit length ✓

(2)

(b) Hooke's law (or stress \propto strain) obeyed up to point A ✓
A is limit of proportionality ✓
elastic limit between A and region B ✓
region C shows plastic behaviour or wire is ductile ✓
region B to C wire will not regain original length ✓
beyond region C necking occurs (and wire breaks) ✓

Q5 Jan 2004

max(5)

(7)

6

(a) extension proportional to the applied force ✓ **Q6 Jun 2004**
 up to the limit of proportionality
 [or provided the extension is small] ✓ (2)

(b)(i) $8 \times 9.81 = 78.5 \text{ N}$ ✓
 (allow C.E. in (ii), (iii) and (iv) for incorrect value)

(ii) (use of $E = \frac{F l}{A e}$ gives) $2.0 \times 10^{11} = \frac{78.5}{2.8 \times 10^{-7}} \times \frac{2.5}{e}$ ✓
 $e = 3.5 \times 10^{-3} \text{ m}$ ✓

(iii) similar calculation ✓
 to give $A_S = 5.6 \times 10^{-7} \text{ m}^2$ ✓
 [or $A_B = 2A_S$ ✓ and correct answer ✓]

(iv) (use of energy stored = $\frac{1}{2}Fe$ gives) energy stored = $\frac{1}{2} \times 78.5 \times 3.5 \times 10^{-3}$ ✓
 $= 0.14 \text{ J}$ ✓ (7)

(c)(i) end A is lower ✓

(ii) $= \frac{1}{2} 3.5 \times 10^{-3} = 1.8 \times 10^{-3} \text{ m}$ ✓ ($1.75 \times 10^{-3} \text{ m}$) (2)
(11)

Question 6

(a) tensile stress: force/tension per unit cross-sectional area or $\frac{F}{A}$
 with F and A defined ✓

tensile strain: extension per unit length or $\frac{e}{l}$ with e and l defined ✓

the Young modulus: $\frac{\text{tensile stress}}{\text{tensile strain}}$ ✓ (3)

(b)(i) $E_S = \frac{F_S l}{A e}$ and $E_B = \frac{F_B l}{A e}$ ✓ hence $\frac{E_S}{E_B} = \frac{F_S}{F_B}$ **Q6 Jan 2005**

(ii) $\frac{E_S}{E_B} = 2$ ✓

$\therefore F_S = 2 F_B$ ✓

$F_S + F_B = 15 \text{ N}$ ✓ gives $F_S = 10 \text{ N}$
 [or any alternative method]

(iii) $\left(E = \frac{F l}{A e} \text{ gives} \right) e = \left(\frac{F l}{A E} \right) = \frac{10 \times 15}{1.4 \times 10^{-6} \times 2.0 \times 10^{11}}$ ✓
 $= 5.36 \times 10^{-5} \text{ m}$ ✓

(6)
(9)

Question 5		
(a)	Hooke's law: the extension is proportional to the force applied ✓ up to the limit of proportionality or elastic limit [or for small extensions] ✓	2
(b) (i)	(use of $E = \frac{Fl}{Ae}$ gives) $e_s = \frac{80 \times 0.8}{2.0 \times 10^{11} \times 2.4 \times 10^{-6}} \checkmark$ $= 1.3 \times 10^{-4} \text{ (m)} \checkmark$ (1.33 $\times 10^{-4}$ (m)) $e_b = \frac{80 \times 1.4}{1.0 \times 10^{11} \times 2.4 \times 10^{-6}} = 4.7 \times 10^{-4} \text{ (m)} \checkmark$ (4.66 $\times 10^{-4}$ (m)) total extension = 6.0 $\times 10^{-4}$ m ✓	Q5 Jun 2005 7
(ii)	$m = \rho \times V \checkmark$ $m_s = 7.9 \times 10^3 \times 2.4 \times 10^{-6} \times 0.8 = 15.2 \times 10^{-3} \text{ (kg)} \checkmark$ $m_b = 8.5 \times 10^3 \times 2.4 \times 10^{-6} \times 1.4 = 28.6 \times 10^{-3} \text{ (kg)} \checkmark$ (to give total mass of 44 or 43.8 $\times 10^{-3}$ kg)	
(c)	(use of $m = \rho Al$ gives) $l = \frac{44 \times 10^{-3}}{8.5 \times 10^3 \times 2.4 \times 10^{-6}} \checkmark$ $= 2.2 \text{ m} \checkmark$ (2.16 m) (use of mass = 43.8 $\times 10^{-3}$ kg gives 2.14 m)	2

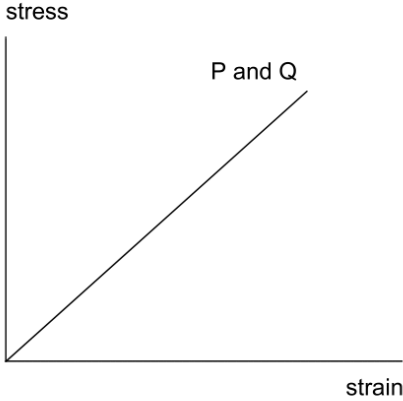
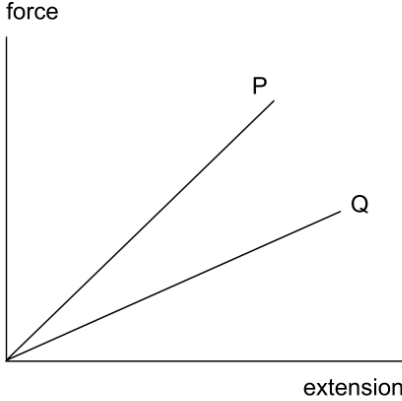
Question 5		
(a)	tensile stress: (normal) force per unit cross-sectional area ✓ tensile strain: ratio of extension to original length ✓	2
(b) (i)	loading: obeys Hooke's law from A to B ✓ B is limit of proportionality ✓ beyond/at B elastic limit reached ✓ beyond elastic limit, undergoes plastic deformation ✓ unloading: at C load is removed linear relation between stress and strain ✓ does not return to original length ✓	Q5 Jan 2006 Max 9
(ii)	ductile ✓ permanently stretched ✓ [or undergoes plastic deformation or does not break]	
(iii)	AD: permanent strain (or extension) ✓	
(iv)	gradient of the (straight) line AB (or DC) ✓	
(v)	area under the graph ABC ✓	
(c)	$E = \frac{Fl}{Ae} \checkmark$ $e = \frac{75 \times 3.0}{2.8 \times 10^{-7} \times 2.1 \times 10^{11}} = 3.8(3) \text{ mm} \checkmark$	2
Total		13

Question 5		
(a)	<p>(i) the extension produced (by a force) in a wire is directly proportional to the force applied ✓ applies up to the limit of proportionality ✓</p> <p>(ii) elastic limit: the maximum amount that a material can be stretched (by a force) and still return to its original length (when the force is removed) ✓ [or correct use of permanent deformation]</p> <p>(iii) the Young modulus: ratio of tensile stress to tensile strain ✓ unit: Pa or N m^{-2} ✓</p>	5
(b)	<p>(i) length of wire ✓ diameter (of wire) ✓</p> <p style="text-align: center;">Q5 Jun 2006</p> <p>(ii) graph of force vs extension ✓ reference to gradient ✓ $\text{gradient} = E \frac{A}{l}$ ✓ [or graph of stress vs strain, with both defined reference to gradient $\text{gradient} = E$] area under the line of F vs e ✓ [or energy per unit volume = area under graph of stress vs strain]</p>	6
Total		11

Question 5		
(a)	<p>correct scales and labelling of axes with units ✓ correct plotting of all points ✓✓ increasing load graph ✓ decreasing load graph ✓</p>	5
(b)	<p>(initially) wire obeys Hooke's law (or behaves elastically) ✓ up to limit of proportionality (or to elastic limit) ✓ then undergoes plastic deformation ✓ suffers permanent extension ✓</p>	max 3
(c)	<p>(i) tensile stress $\left(= \frac{F}{A} \right) = \left(\frac{82}{2.8 \times 10^{-7}} \right) = 2.9(3) \times 10^8 \text{ N m}^{-2} / \text{Pa}$ ✓</p> <p>(ii) tensile strain $\left(= \frac{e}{l} \right) = \left(\frac{7.6 \times 10^{-3}}{2.5} \right) = 3.0(4) \times 10^{-3}$ ✓</p> <p>(iii) $E \left(\frac{\text{tensile stress}}{\text{tensile strain}} = \frac{2.93 \times 10^8}{3.04 \times 10^{-3}} \right) = 9.6(4) \times 10^{10} \text{ N m}^{-2} / \text{Pa}$ ✓ (allow C.E. for values from (i) and (ii))</p> <p>(iv) energy $\left(= \frac{1}{2} Fe \right) = \left(\frac{1}{2} \times 82 \times 7.6 \times 10^{-3} \right) = 0.31(1) \text{ J}$ ✓</p>	4
Total		12

Question 6				
(a)	(i)	<p>max 5 for (i) from:</p> <p>(wire can be horizontal or vertical)</p> <p>add a mass to the holder ✓</p> <p>measure extension ✓</p> <p>description of how extension is measured ✓</p> <p>add further masses, measuring extension each time ✓</p> <p>repeat measurements with decreasing masses ✓</p> <p>measure (original) length of wire ✓</p>	Q6 Jun 2007	
	(ii)	<p>(use of $E = \frac{F l}{A e}$ to give) graph of</p> <p>(mass/weight/force/tension/load) vs extension ✓</p> <p>(or stress vs strain)</p> <p>definition of quantity on y axis ✓</p> <p>E from correct gradient ✓</p> <p>of straight line ✓</p>		max 8
(b)	(i)	<p>in the equation $E = \frac{F l}{A e}$, F, l and e are same for both wires ✓</p> <p>(rearranging with) correct deduction ✓</p>		
	(ii)	$2 \times 10^{11} = \frac{F \times 2.5}{1.6 \times 10^{-7} \times 4.8 \times 10^{-3}} \quad \checkmark$ <p>$F = 61 \text{ N} \quad \checkmark$ (61.4 N)</p>		4
			Total	12

Question 5		
(a)	tensile stress: (normal) force per unit cross-sectional area ✓ tensile strain: extension per unit (original) length ✓	2
(b) (i)	<div style="display: flex; justify-content: space-between; align-items: flex-start;"> <div style="flex: 1;"> </div> <div style="flex: 1; text-align: right;"> <p>Q5 Jan 2008</p> <p>graph A: straight line ✓</p> <p>graph B: straight with smaller gradient ✓ curving at the end ✓</p> </div> </div>	max 8
(b) (ii)	<p>graph A: initially stress \propto strain (obeying Hooke's law) ✓ wire breaks without significant plastic deformation [or breaks without warning] ✓</p> <p>graph B: (stress \propto strain) smaller gradient because E is less ✓ curves at limit of proportionality or elastic limit ✓ showing plastic behaviour ✓ 'necking', then breaks ✓</p>	
(c)	$\left(E = \frac{F l}{A e}\right) \text{ gives } e \left(= \frac{Fl}{AE}\right) = \frac{10 \times 9.81 \times 1.5}{2.4 \times 10^{-6} \times 2.0 \times 10^{11}} \checkmark$ $= 0.31 \text{ mm } \checkmark$	2
	Total	12

Question 6		
(a)	F – applied force A – cross-sectional area (all correct ✓) l – length e – extension	1
(b) (i)(ii)	<p style="text-align: right;">Q6 Jun 2008</p> <div style="display: flex; justify-content: space-around;">   </div> <p>graph to show: straight line for 1st graph ✓ straight line for 2nd graph ✓</p> <p>(iii) graphs to show: 1st graph: two straight coinciding lines ✓ 2nd graph: Q line smaller gradient than P line ✓ 1st graph: lines coincide because gradient (of both) = E ✓ 2nd graph: gradients differ because of different cross-sectional area ✓</p> <p>$m = E \frac{A}{l}$ so Q has the smaller gradient ✓</p> <p>gradient of Q = $\frac{1}{2}$ gradient of P ✓</p>	max 7
(c)	$e_P \left(= \frac{Fl}{Ae} \right) = \frac{5 \times 9.81 \times 1.8}{2 \times 10^{-7} \times 4.6 \times 10^{11}} = 0.96 \text{ (mm)} \checkmark$ <p>for Q wire: area = $A/2$ and same value for F ✓ $e_Q = 1.92 \text{ (mm)}$ and total extension = 2.9 mm ✓ (2.88 mm) [or correct calculation for e_Q]</p>	3
	Total	11

Question 2	Q2 Jan 2009	
(a) (i)	vector has direction and a scalar does not ✓	4
(ii)	scalar examples; any two e.g. speed, mass, energy, time, power vector examples; any two e.g. displacement, velocity, acceleration, force or weight ✓✓✓ for 4 correct, ✓✓ for 3 correct, ✓ for 2 correct	
(b) (i)	horizontal component (= $2.8 \cos 35$) = 2.3 (kN) (2293.6) ✓ vertical component (= $2.8 \sin 35$) = 1.6 (kN) (1606.0) ✓	5
(ii)	power = force \times velocity or $2.3 \text{ kN} \times 8.3 \text{ m s}^{-1}$ ✓ (ecf from 2 (b)(i)) = 1.9×10^4 (19037 or 19100) ✓ ecf W (or J s^{-1}) ✓ (or 19W (or kJ s^{-1}))	
(c)	(area of cross-section of cable =) $\pi \times (\frac{1}{2} 0.014)^2$ ✓ = $1.5(4) \times 10^{-4} (\text{m}^2)$ ✓ stress (= F/A) = $\frac{2800 \text{ N}}{1.54 \times 10^{-4} \text{ m}^2}$ (allow ecf here if attempt to calculate area) ✓ = $1.8(2) \times 10^7$ ✓ ecf Pa (or N m^{-2}) ✓	5
Total		14