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 inreasing (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 <u>mean</u> of readings
and correct use of data to give 2_{max})✓ max (*2*)

(*13*)

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

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

$= 5.0 \times 10^{-3}$ m ✓

(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*)

<u>(*16*)</u>

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 ✓

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(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 × distance ✓
= <u>average</u> force × extension (= ½Fe) ✓
[or use work done = area under graph
area = ½ base × height]

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

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(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 ✓ $_{\text{max}}$(*4*)

Q6 Jan 2003

(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 ✓ (1.17×10^{11} Pa) (*3*)

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

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5(a)(i) X ✓
stress (force) $\propto$ strain (extension) for the whole length ✓

(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)

$$F\left(=\frac{EAe}{l}\right) = \frac{2.0\times10^{7}\times0.64\times10^{-6}\times30\times10^{-3}}{160\times10^{-3}}$$

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

(ii) (use of *energy stored* = ½*Fe* gives) energy $= \frac{2.4\times30\times10^{-3}}{2}$ ✓
$= 36 \times 10^{-3}$ J ✓
(allow C.E. for value of *F* from (i)) (*5*)
(*13*)

Q5 Jan 2004

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) ✓ max(*5*)
(*7*)

6

Q6 Jun 2004

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

(b)(i) $8 \times 9.81 = 78\,(5)$ N ✓
(allow C.E. in (ii), (iii) and (iv) for incorrect value)

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

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

(iv) (use of energy stored = ½Fe gives) energy stored = $\frac{1}{2} \times 78.5 \times 3.5 \times 10^{-3}$ ✓
= 0.14 J ✓ (7)

(c)(i) end A is lower ✓
(ii) = ½ $3.5 \times 10^{-3} = 1.8 \times 10^{-3}$ m ✓ (1.75×10^{-3} m) (2)
(11)

Question 6

Q6 Jan 2005

(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) $E_S = \frac{F_S}{A}\frac{l}{e}$ and $E_B = \frac{F_B}{A}\frac{l}{e}$ ✓ hence $\frac{E_S}{E_B} = \frac{F_S}{F_B}$

(ii) $\frac{E_S}{E_B} = 2$ ✓
$\therefore F_S = 2F_B$ ✓

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

(iii) $\left(E = \frac{F}{A}\frac{l}{e}\text{gives}\right)$ $e = \left(\frac{F}{A}\frac{l}{E}\right) = \frac{10 \times 1.5}{1.4 \times 10^{-6} \times 2.0 \times 10^{11}}$ ✓
$= 5.36 \times 10^{-5}$ m ✓ (6)
(9)

Q5 Jun 2005

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 $E = \frac{F}{A}\frac{l}{e}$ gives) $e_s = \frac{80 \times 0.8}{2.0 \times 10^{11} \times 2.4 \times 10^{-6}}$ ✓ $= 1.3 \times 10^{-4}$ (m) ✓ (1.33×10^{-4} (m)) $e_b = \frac{80 \times 1.4}{1.0 \times 10^{11} \times 2.4 \times 10^{-6}} = 4.7 \times 10^{-4}$ (m) ✓ (4.66×10^{-4} (m)) total extension = 6.0×10^{-4} m ✓	7
(ii)	$m = \rho \times V$ ✓ $m_s = 7.9 \times 10^3 \times 2.4 \times 10^{-6} \times 0.8 = 15.2 \times 10^{-3}$ (kg) ✓ $m_b = 8.5 \times 10^3 \times 2.4 \times 10^{-6} \times 1.4 = 28.6 \times 10^{-3}$ (kg) ✓ (to give total mass of 44 or 43.8×10^{-3} kg)	
(c)	(use of $m = \rho A l$ gives) $l = \frac{44 \times 10^{-3}}{8.5 \times 10^3 \times 2.4 \times 10^{-6}}$ ✓ = 2.2 m ✓ (2.16 m) (use of mass = 43.8×10^{-3} kg gives 2.14 m)	2

Q5 Jan 2006

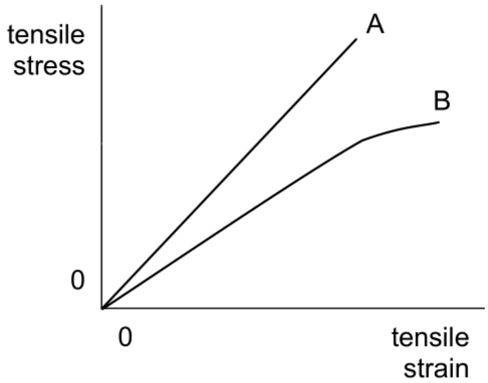
Question 5		
(a)	tensile stress: (normal) force per unit cross-sectional area ✓ tensile strain: ratio of extension to original length ✓	2
(b) (i)	loading: obeys Hooke's law from A to B ✓ B is limit of proportionality ✓ beyond/at B elastic limit reached ✓ beyond elastic limit, undergoes plastic deformation ✓ unloading: at C load is removed linear relation between stress and strain ✓ does not return to original length ✓	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)	$E = \frac{Fl}{Ae}$ ✓ $e = \frac{75 \times 3.0}{2.8 \times 10^{-7} \times 2.1 \times 10^{11}} = 3.8(3)$ mm ✓	2
	Total	**13**

Q5 Jun 2006

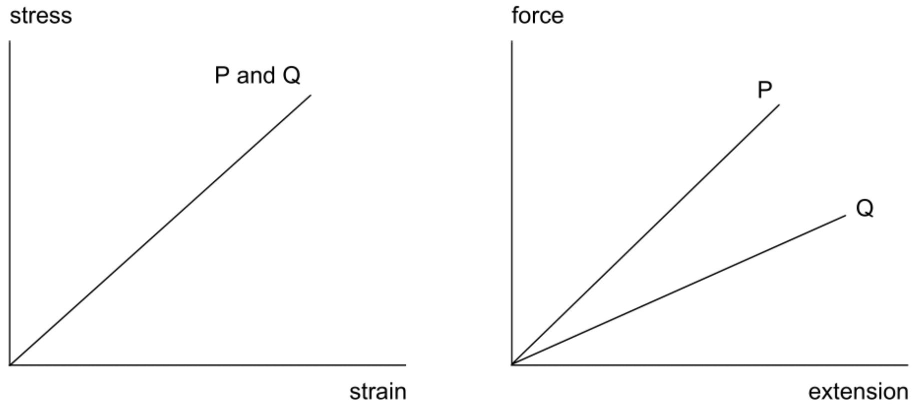
Question 5			
(a)	(i)	the extension produced (by a force) in a wire is directly proportional to the force applied ✓ applies up to the limit of proportionality ✓	5
	(ii)	elastic limit: the maximum amount that a material can be stretched (by a force) and still return to its original length (when the force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

Question 5			
(a)		correct scales and labelling of axes with units ✓ correct plotting of all points ✓✓ increasing load graph ✓ decreasing load graph ✓	**5**
(b)		(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 ✓	**max 3**
(c)	(i)	tensile stress $\left(=\frac{F}{A}\right) = \left(\frac{82}{2.8\times10^{-7}}\right)$ = $2.9(3)\times10^{8}\,N\,m^{-2}$/Pa ✓	**4**
	(ii)	tensile strain $\left(=\frac{e}{l}\right) = \left(\frac{7.6\times10^{-3}}{2.5}\right)$ = $3.0(4)\times10^{-3}$ ✓	
	(iii)	$E\left(\frac{\text{tensile stress}}{\text{tensile strain}} = \frac{2.93\times10^{8}}{3.04\times10^{-3}}\right)$ = $9.6(4)\times10^{10}\,N\,m^{-2}$/Pa ✓ (allow C.E. for values from (i) and (ii))	
	(iv)	energy $\left(=\frac{1}{2}Fe\right) = \left(\frac{1}{2}\times82\times7.6\times10^{-3}\right)$ = 0.31(1) J ✓	
		Total	**12**

Question 6			
(a)	(i)	**max 5 for (i) from:** **Q6 Jun 2007** (wire can be horizontal or vertical) add a mass to the holder ✓ measure extension ✓ description of how extension is measured ✓ add further masses, measuring extension each time ✓ repeat measurements with decreasing masses ✓ measure (original) length of wire ✓	**max 8**
	(ii)	(use of $E = \frac{F}{A}\frac{l}{e}$ to give) graph of (*mass/weight/force/tension/load*) vs *extension* ✓ (or *stress* vs *strain*) definition of quantity on *y* axis ✓ *E* from correct gradient ✓ of straight line ✓	
(b)	(i)	in the equation $E = \frac{F}{A}\frac{l}{e}$, F, l and e are same for both wires ✓ (rearranging with) correct deduction ✓	**4**
	(ii)	$2 \times 10^{11} = \frac{F \times 2.5}{1.6\times10^{-7} \times 4.8\times10^{-3}}$ ✓ F = 61 N ✓ (61.4 N)	
		Total	**12**

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

Q6 Jun 2008

Question 6		
(a)	F – applied force; l – length A – cross-sectional area; e – extension (all correct ✓)	**1**
(b) (i)(ii)	 graph to show: straight line for 1st graph ✓ straight line for 2nd graph ✓	**max 7**
(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 ✓ $m = E\dfrac{A}{l}$ so Q has the smaller gradient ✓ gradient of Q = ½ gradient of P ✓	
(c)	$e_P \left(= \dfrac{Fl}{Ae}\right) = \dfrac{5 \times 9.81 \times 1.8}{2 \times 10^{-7} \times 4.6 \times 10^{11}}$ = 0.96 (mm) ✓ for Q wire: area = A/2 and same value for F ✓ e_Q = 1.92 (mm) and total extension = 2.9 mm ✓ (2.88 mm) [or correct calculation for e_Q]	**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 × velocity **or** 2.3 kN × 8.3 m s^{-1} ✓ (ecf from 2 (b) (i)) = 1.9 × 10^4 (19037 or 19100) ✓ ecf **W** (or J s^{-1}) ✓ (or 19 W (or kJ s^{-1}))	
(c)		(area of cross-section of cable =) $\pi \times (½\ 0.014)^2$ ✓ = 1.5(4) × 10^{-4} (m^2) ✓ stress (= F/A) = $\frac{2800\,\text{N}}{1.54\times10^{-4}\,\text{m}^2}$ (allow ecf here if attempt to calculate area) ✓ = 1.8(2) × 10^7 ✓ ecf **Pa** (or N m^{-2}) ✓	5
		Total	**14**