

British Physics Olympiad 2017-18

A2 Challenge - Mark Scheme

September/October 2017

Instructions

Give equivalent credit for alternative solutions which are correct physics.
Generally allow leeway of ± 1 significant figure.

1. a) (i) zero resultant force
zero resultant moment ✓
- (ii) equilateral triangle (sketch) arrows, etc. (labelled P, Q, R ✓) ✓
- (iii) all leads to an anticlockwise moment (easiest to see if moments taken
about any point inside **ABC**) **owtte** ✓
- (iv) If concurrent, zero moment about their point of concurrency **owtte** ✓
- (v) Draw vector figure, angles $(180^\circ - \alpha), (180^\circ - \beta), (180^\circ - \gamma)$ ✓
Apply sine rule
As $\sin(\theta) = \sin(180^\circ - \theta)$, this leads to result. ✓
- (7)
- b) (i) $F = pA = 1.0 \times 10^5 \times 0.040 = 4.0 \text{ kN}$ ✓
- (ii) equal force on either side ✓
- (iii) no pressure between panes as air excluded ✓
so 4 kN from each side pushing panes together
- (iv) $F = \mu R = 0.95 \times 4.0 \text{ kN} = 3.8 \text{ kN}$ ✓
so equally difficult to slide apart
- (v) paper porous/rough/compressible, so does not exclude air; allows air in **owtte** ✓
- (5)
- c) (i) $F = DLp = 2T; A = 2Lt;$ ✓ $\sigma_H = F/A = DLp/2Lt = Dp/2t$ ✓
- (ii) $F = \pi D^2 p/4 = \pi Dt;$ ✓ $\sigma_A = F/A = (\pi D^2 p/4)/\pi Dt = Dp/4t$ ✓
- (iii) Hence $\sigma_H : \sigma_A = 2:1$ ✓
- (iv) Wrapped as hoops around the curved surface. ✓
(This is the result to counteract the direction of maximum stress. However, to use the bands most effectively, they would be wrapped around in a helical form, at angle $\tan^{-1} \frac{1}{2}$ i.e. forces $F, 2F$ at right angles, as can be observed in the stranding within a reinforced hose pipe.)
Bonus mark for the idea of helical wrapping. (✓)
- (6)
- [18 marks]**
2. a) (i) $V = 1.00 \text{ k}\Omega \times 10.0 \mu\text{A} = 10.0 \text{ mV}$ ✓
- (ii) shunt current = 9.999 99 A (= 10.0 A) ✓
 $pd = 10.0 \text{ mV} \rightarrow R = 1.00(0001) \text{ m}\Omega$ ✓
- (iii) $pd = 10.00 - 0.01 = 9.99 \text{ V}$ ✓
current = $10.0 \mu\text{A} \rightarrow R = 999 \text{ k}\Omega$ ✓
- (5)

- b) Each of **FAE, FBE, FCE, FDE** is a potential divider, and they are all equivalent. ✓
Diagram(s) required to illustrate equipotential points; such as below (may be combined)

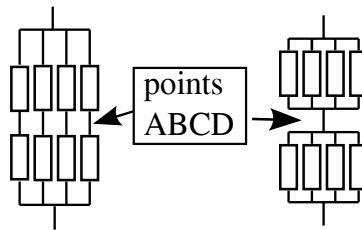


Figure 1: equivalent circuit of the form...

giving zero pd between **AB, BC, CD, DA**, **OR** making these redundant ✓
 system is $4 \times 20 \Omega$ in parallel ✓
 So 5Ω ✓

(4)

[9 marks]

3. a) (i) 6 } these two steps ✓
 (ii) a^2 } ✓
 (iii) F/a^2 } ✓
 (iv) x/a ✓
 (v) $E = \sigma/\varepsilon = (F/a^2)/(x/a) = F/xa$ ✓
 so $E = k/a$ ✓

(5)

- b) (i) 6 } both answers ✓
 (ii) 3 } ✓
 (iii) 12 ✓
 (this arrangement would be *hexagonal close packed* and, whilst *fcc* would also have a coord no. of 6, *bcc* would be 8)
 (iv) all bonds intact, so no relative movement of atoms / still solid ✓
 smaller k ('weaker') means lower E **or** elastically softer material ✓
 Reference to expansion is due to the anharmonic nature of the bond, i.e. the force to compress and the force to expand are slightly different. For this a non-ideal spring is needed. Allow a mark if reference to the microscopic and macroscopic behaviour together.

(v) Specific latent heats for some simple elements:

Element	SLH (Fusion) /kJ kg ⁻¹	SLH (Vaporisation) /kJ kg ⁻¹	F : (F + V) no units	✓
argon	29.5	161	0.155	} ✓
helium	3.45	20.7	0.143	
hydrogen (H ₂)	59.5	445	0.118	
krypton	16.3	108	0.131	
neon	16.8	84.8	0.165	
			0.142 average	✓

So 14% or approximately one in seven bonds are broken on fusion and the remainder on vaporisation ✓

Bonus mark realise that H₂ is the odd-one-out; average now 0.15 (✓)

(8)

[13 marks]

4. a) (i) phase change produces a dark line at the line joining the glass slides
Alternate bright and dark labels at the three reflections

✓
✓

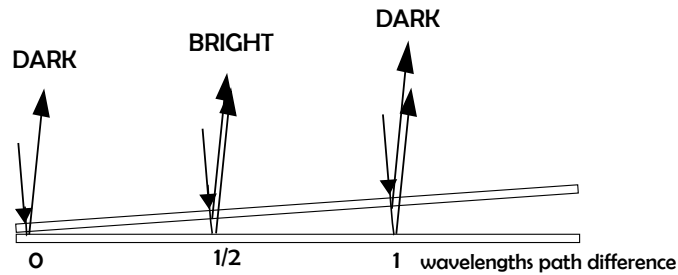


Figure 2: path difference diagram

- (ii) bright/dark straight fringes; parallel to line of contact between the slides; evenly spaced fringes. *Any two*
- (iii) coloured fringes; line of contact black
- (iv) at any point one wavelength only (therefore only one of ROYGBIV) is of zero intensity (so complement of that colour is seen (i.e. no G \rightarrow magenta)) **owtte**
- b) (i) gradient of surface ABD increases with distance from the centre
so horizontal distance for path to increase by λ lessens **owtte**
- (ii) $n\lambda$
- (iii) using hint or otherwise: $r^2 \approx 2R \times \text{gap at } r$
gap at $r = n\lambda/2$
combine to give $r \approx \sqrt{R\lambda n}$

(5)

(5)

[10 marks]

END OF SOLUTIONS