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 abotu their point of concurrency **owtte** ✓
(v) Draw vector figure, angles $(180° - \alpha), (180° - \beta), (180° - \gamma)$ ✓
Apply sine rule
As $\sin(\theta) = \sin(180° - \theta)$, 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 $4\,\text{kN}$ 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) $F = DLp = 2T$; $A = 2Lt$; ✓ $\sigma_\text{H} = F/A = DLp/2Lt = Dp/2t$ ✓
(ii) $F = \pi D^2 p/4 = \pi Dt$; ✓ $\sigma_\text{A} = F/A = (\pi D^2 p/4)/\pi DT = Dp/4t$ ✓
(iii) Hence $\sigma_\text{H} : \sigma_\text{A} = 2{:}1$ ✓

(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 $= 9.999\,99\,\text{A}$ $(= 10.0\,\text{A})$ ✓
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) ✓

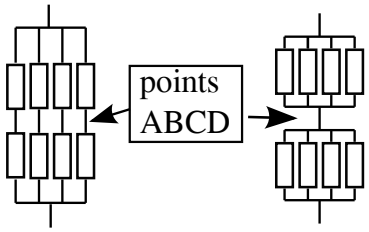

Figure 1: equivalent circuit of the form....

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

(4)

[9 marks]

3. a) (i) 6 ✓
(ii) a^2 } these two steps ✓
(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 H_2 is the odd-one-out; average now 0.15 (✓)

(8)

[13 marks]

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

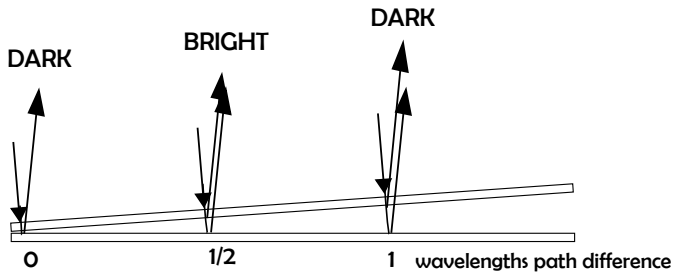

Figure 2: path difference diagram

(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**

(5)

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: $r^2 \approx 2R\times$ gap at r ✓
gap at $r = n\lambda/2$ ✓
combine to give $r \approx \sqrt{R\lambda n}$ ✓

(5)

[10 marks]

END OF SOLUTIONS