BRITISH PHYSICS OLYMPIAD 2016-17

A2 Challenge - SOLUTIONS

September/October 2016

Mark scheme

Alternative answers may be allowed. It is not intended that answers should be restricted to those illustrated below. Good physics is to be rewarded.
The layout of a student's solution should indicate that the student has thought about the question even if a final solution is not achieved.

Qu. 1

(a) (i) F_A parallel to v (ii) F_C from body towards C - both answers ☑

(iii) direction changes (iv) F_C has no component parallel to v - both answers ☑

2 marks

(b) (i) $F = v\frac{dm}{dt} + m\frac{dv}{dt}$ ☑ (ii) $m\frac{dv}{dt}$ ☑

(iii) **A.** $F = v\frac{dm}{dt} = v\rho\frac{dV}{dt}$ ☑ $= 30 \times 1200 \times 5 \times 10^{-6} = 0.18\ \mathrm{N}$ ☑

B. replace 1200 by 8000, and factor of 2 for rebound Ans is 2.4 N ☑

5 marks

(c) (i) $\boldsymbol{W}$ down through person and $\boldsymbol{R}$ up through centre of Earth ☑

(ii) $\boldsymbol{W}$ (as before) and $\boldsymbol{F}$ up through seat of person ☑

(iii) $\boldsymbol{F}$ elastic force from deformation of table owtte
(answers may be given in terms of atoms/electrons repelling, but this is a rather deep and technical issue, but something that sounds reasonable may be accepted)
$\boldsymbol{W}$ gravitational attraction of Earth on person - both answers owtte (both) ☑

(iv) 'not of like kind' or 'action and reaction can't be on the same body' or other sensible comment ☑

4 marks

11

Qu. 2

(a) Strain, $\varepsilon = \frac{\Delta l}{l_0} = \alpha\Delta T = \frac{l - l_0}{l_0}$ and re-arrange for required formula ☑

(b) (i) $\Delta l = l_0\alpha\Delta T = 632 \times 10^3 \times 1.2 \times 10^{-5} \times 25 = 190(189.6)\ \mathrm{m}$ ☑

(ii) $F = E\varepsilon A = E\ \alpha\Delta T\ A$ ☑ $= 2 \times 10^{11} \times 1.2 \times 10^{-5} \times 25 \times 0.01 = 600\ \mathrm{kN}$ ☑

4 marks

(c) (i) Hole in sheet expands so it does fit ☑ (ii) will not fit ☑

2 marks

(d) (i) $V = l_0^3$ ☑ (ii) $V = l_0^3\,(1 + \alpha\Delta T)^3$ owtte ☑

(iii) $\Delta V = l_0^3\,(1 + \alpha\Delta T)^3 - l_0^3$ ☑

(iv) $V = V_0(1 + \gamma\Delta T)$ ☑

$\Delta V = V_0\gamma\Delta T$ expand (iii) (ignoring higher powers of $\alpha\Delta T$) ☑

$\Delta V = 3l_0^3\alpha\Delta T$ ☑

As $l_0^3 = V_0$ it follows that $\gamma = 3\alpha$ ☑

7 marks

13

Qu. 3

(a) (i) at 200 Hz: 200; 100; 50 ☑

at 202 Hz: 202; 101; 50.5 ☑

(ii) 1 s: in phase (or 4π phase difference); 0.5 s: in phase (or 2π phase diff);
0.25 s: in antiphase (or π phase difference) ☑

(iii) loud-silent-loud-silent-loud (i.e. 2 cycles) owtte ☑

(iv) beat frequency is 2 Hz ☑

(v) beat frequency = difference in frequencies owtte ☑

6 marks

(b) (i) $\lambda = 1000\ /\ 10\,000 = 0.1\ \mathrm{m}$ ☑ so separation = 0.05 m ☑

(ii) microphone intersects 100 internodal spacings per second, so 100 Hz
Or $\Delta t = 0.05\ /\ 0.5\ \Rightarrow f = 100\ \mathrm{Hz}$ ☑

(iii) $v/c = 0.005$ so $\Delta f = 10^4 \times 0.005 = 50\ \mathrm{Hz}$
so frequencies are 10 050 Hz and 9950 Hz owtte ☑

(iv) & (v) beat frequency is difference of these i.e. 100 Hz: agrees with above ☑
or other sensible idea

5 marks

(c) (i) $d\cos\theta$ ☑ (ii) pd = OO' – OA = $d - d\cos\theta = d(1-\cos\theta)$ ☑

(iii) $d(1-\cos\theta) = n\lambda$ ☑

(iv) $d = \frac{1\times5\times10^{-7}}{(1-\cos 12°)} = 2.3\ (2.29)\times10^{-5}\ \mathrm{m}$ ☑

4 marks

15

Qu. 4

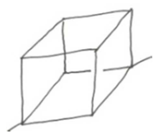
(a) (i) $6\ \Omega$ ☑ (ii) $4\ \Omega$ ☑ (iii) R/n ☑

(iv) $12\ \Omega$ ☑

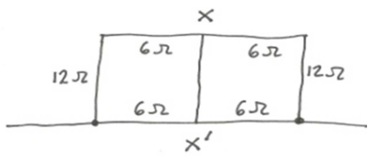
(v) Always R ☑

5 marks

(b) (i) Figure starts as

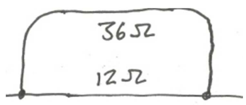


and simplifying all parallel parts as per (a) (i) above this becomes



☑

looking at the potential dividers implicit in this diagram, XX' is redundant (zero p.d., so no current). System is now:

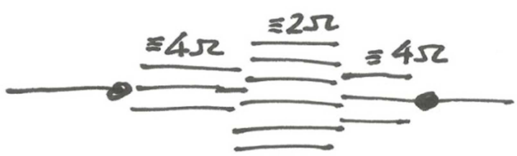


☑

giving answer 9Ω ☑

Alternative wording of this might be: wires which have the same potential at each end will carry no current, and so can be removed from the circuit – i.e. the wires FG and AD, since F is halfway along the route CBFEH and G is halfway between C and H. Similarly for points A and D, meaning that AD can be removed. Then you will see the simple series and parallel arrangement (EF +FB || EA + AB)$= 12 + 12 + 12 = 36$) giving the diagram above (36 Ω || 12 Ω) resulting in 9 Ω.

(ii) System equivalent to



which reduces to $4\ \Omega, 2\ \Omega, 4\ \Omega$ in series i.e. $10\ \Omega$ ☑ ☑

Alternative wording:

Resistors which are between equal potential points can be added in parallel even if the resistors are not directly connected together in parallel.

Stand the cube on one corner (say F at the top and D at the bottom). Then there are three resistors from F going to a lower potential (three $12\ \Omega$ in parallel $\Rightarrow 4\ \Omega$) at points G,E,B. Below these points are six resistors connecting point of equal potentials $(2\ \Omega)$ (GH,GC,EH,EA,BA,BC) and then the lower three resistors connecting D to points of equal potential above (another $4\ \Omega$) at points A,H,C), to give a total of $10\ \Omega$.

(iii) Using the argument as in (ii), this becomes $2\ \Omega, 2\ \Omega, 2\ \Omega$ in series, i.e. $6\ \Omega$ ☑

6 marks

If the geometry is not quite clear to the student, then the cube can be dealt with in a standard manner by labelling the currents. For part (ii), at F, the current I enters and splits into $I/3$ along each of the three identical paths. These currents then split into two $I/6$ along each path such as GH and GC, and then currents combine to give $I/3$ along the three paths into D. The resistance between F and D is $IR_{FD} = 12\frac{I}{3} + 12\frac{I}{6} + 12\frac{I}{3} = 10I$. So $R_{FD} = 10\ \Omega$.

This is using the symmetry (the cube can be rotated about the axis FD and will be equivalent), but is an alternative approach. It does not simplify the circuit into series and parallel resistors arrangements.

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End of Solutions