

British Physics Olympiad Paper 1: Solutions

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Mark Scheme

Sept/Oct 2009

Allow ecf where this gives sensible answers

Q1.

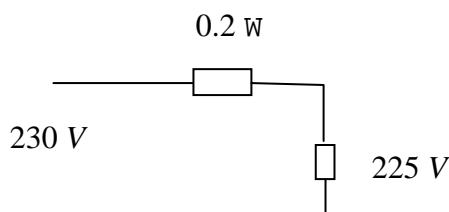
- (a) The mass is simply the sum of the two individual masses
i.e. 97 kg

✓
✓

(2 marks)

(b)

- i) Diagram of the form:



✓

- ii) 5 V drop across 0.2 W resistor
leads to a current of 25 A maximum
So power available at 225 V is 5.63 kW

✓
✓
✓

(4 marks)

(c)

- i) Sound energy = $0.1 \times mgh = 0.1 \times 2 \times 10^{-4} \times 9.8 \times 1$
 $= 2 \times 10^{-4} \text{ J}$

✓

- ii) Assume (maybe implicit) - Energy is spread over half of a sphere
Or allow for whole sphere and energy absorbed by ground
But some comment should be made about the assumption

✓

$$\begin{aligned} \text{Ear receives energy} &= 2 \times 10^{-4} \times \frac{\pi(6 \times 10^{-3})^2}{4} \bigg/ \frac{1}{2} 4\pi 5^2 \\ &= 3.6 \times 10^{-11} \text{ J} \end{aligned}$$

✓

✓

(4 marks)

- (d) An image is formed on the screen (✓) and your eye now focuses rays of light which come from each point on the screen to form a new image. A mirror would direct rays from the room to your eye from other parts of the room. (✓)

(2 marks)

(e) There are several approaches:

For (a), since $E = V/d$ then E halves (as d doubles), ✓
so Q halves, V is constant and hence energy stored halves. ✓

For (b), Q is constant, so E is constant, so V doubles ✓

For constant Q then the energy doubles ✓

Ratio is 1:4 allow marks if answer given (not guessed)

(4 marks)

(f) Amplitude \rightarrow amplitude/4, so energy \rightarrow energy/16 ✓

This is four half lives ✓

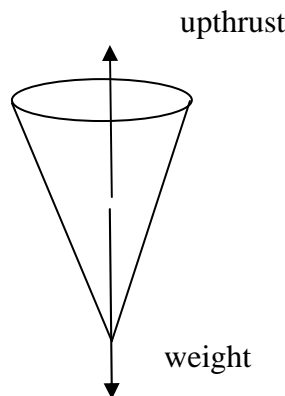
so time taken is 8.0 seconds, i.e. 1800 oscillations (ecf) ✓

(3 marks)

(g)

i) Archimedes upthrust/weight of the liquid displaced/ etc. ✓

ii) Sketch:



iii) By similar triangles: ✓

$$\frac{R}{r} = \frac{h}{\ell}$$

✓

iv) From the forces: weight of cone = weight of liquid displaced

$$\rho_c \frac{1}{3} \pi R^2 h g = \rho_w \frac{1}{3} \pi r^2 \ell g$$

substituting for $\frac{h}{\ell}$

✓✓✓

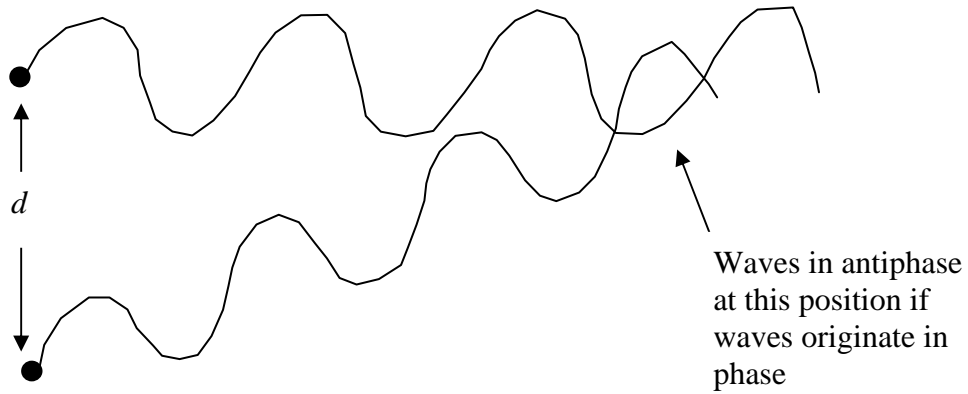
$$\rho_c h^3 = \rho_w \ell^3$$

$$\frac{\rho_c}{\rho_w} = \left(\frac{\ell}{h}\right)^3$$

(6 marks)

- (h) i) Frequency remains the same ✓
 the speed increases (as the ray bends away from the normal) ✓
 wavelength increases ✓

- iii) Diagram of the form shown below, ✓
 or with semicircles emerging
 or any alternative clear and reasonable interpretation ✓



- iii) minimum d is $d_{min} \approx \lambda/2$ ✓
 orientation: the two waves are collinear with the centres of the speakers ✓
 (6 marks)

- (i) Angles shown to indicate angle α_e with angle of 102° inside the glass - 3 marks

Or statement that emerging ray is “above” the normal justified ✓

Two marks for suitable correct rays and angles ✓✓

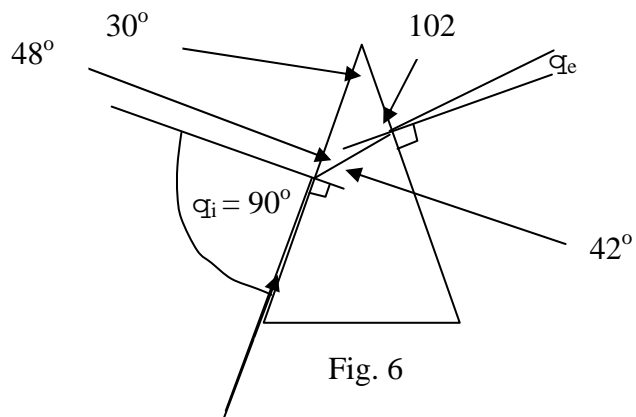


Fig. 6

(3 marks)

(j) Field increases as $1/r^2$. So calculation is

$$\frac{B_1}{B_2} = \frac{R_2^2}{R_1^2}$$

$$\frac{10^{-2}}{B_2} = \frac{(10)^2}{(1.4 \times 10^6)^2}$$

$$B_2 = 10^{-2} \times 10^{-2} \times 1.96 \times 10^{12}$$

$$B_2 = 2.0 \times 10^8 \text{ T}$$

Right idea ✓, numbers substituted ✓✓, answer ✓

(4 marks)

[Q1: 38]

Q2.

i) $m = \text{const} \times v^a \times g^b \times \rho^c$ ✓

(1 mark)

ii) The dimensions are given by

$$[v] = \text{LT}^{-1}, \quad [g] = \text{L T}^{-2}, \quad [\rho] = \text{ML}^{-3} \quad \checkmark\checkmark\checkmark$$

So then we can write

$$M = (\text{LT}^{-1})^a \times (\text{L T}^{-2})^b \times (\text{ML}^{-3})^c \quad \checkmark$$

(4 marks)

iii) The powers of M, L, T on each side of the equation must be the same

For M: $M^1 = M^c$ so that $c = 1$ ✓

For L: $L^0 = L^{a+b-3c}$ so that $a + b - 3c = 0$ ✓

For T: $T^0 = T^{-a-2b}$ so that $-a - 2b = 0$ ✓

$b = -3$ and $a = 6$ ✓

(4 marks)

iv)

$$m = \text{const} \times v^6 \times g^{-3} \times \rho$$

or all correct: ✓✓

$$m = \text{const} \frac{v^6 \rho}{g^3}$$

(2 marks)

v) The high power of v means that for a small increase in v there will be a relatively large increase in v^6 . owtte ✓

(1 mark)

[Q2: 12]