Physics Olympiad Competition 2012 Paper 1: Solutions

Mark Scheme — Sept/Oct 2011

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Allow error carried forward where this gives sensible answers

Question 1

(a) $17 \times 3.7 \times 10^{10} = 6.3 \times 10^{11}$ decays per second ✓

[1]

(b) $6.3 \times 10^{11} \times 5.5 \times 10^{6} \times 1.6 \times 10^{-19} = 0.55$ W per g ✓✓

Mark lost for incorrect order of magnitude

[2]

(c) Mass required = 4,500 ÷ 0.55 = 8,100 g = 8.1 kg ✓

[1]

(d) 4,500 W x 0.07 = 315 W ✓

[1]

(e) Satellites far from the sun receive too little power / area of panels would need to be too great / intensity of solar radiation is too low owtte* ✓

[1]

[Q1: 6 marks]

Question 2

Various approaches:

(a) $g \propto \frac{1}{r^2}$ therefore $g\,r^2$ = constant ✓

$6{,}400^2 \times 9.81 = 6{,}700^2 \times g'$ mark for use of 6,700 value ✓

$g' = \left(\frac{6{,}400}{6{,}700}\right)^2 \times 9.81$ mark for $\left(\frac{6{,}400}{6{,}700}\right)^2$ term ✓

$= 8.95 \text{ m s}^{-2}$

Reduced by 8.8 % full marks for correct answer

[3]

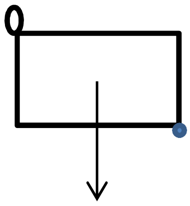
(b) $g' = \left(\frac{6{,}400}{406{,}400}\right)^2 \times 9.81$ 400,000 acceptable ✓

$= (2.4 – 2.5) \times 10^{-3} \text{ m s}^{-2} = 2.4 – 2.5 \text{ mm s}^{-2}$ ✓

[2]

[Q2: 5 marks]

Question 3

(a)  Owtte* OR centre of suitcase indicated

✓

[1]

(b)

Example	Workings out	Load at handle	
1	14 + 5 x ½ = 16 ½	16 ½ kg	✓
2	4 + 5 x ½ = 6 ½	6 ½ kg	✓
3	4 + 5 x ½ = 6 ½	6 ½ kg	✓
4	14 + 5 x ½ = 16 ½	16 ½ kg	✓

[4]

(c) 4 kg at B & 14 kg at C gives a load of 2½ kg ✓

Or 14 kg at B & 4 kg at C gives a load of 2½ kg ✓

[2]

(d) A lower centre of gravity is best to stop the case falling over.
Hence the second of the two examples in part (c).
OR a justified alternative reason. ✓

[1]

[Q3: 8 marks]

Question 4

(a) 2 x 2 = 4 ✓

[1]

(b) Beginning of

1935	1 cm
1936	4 cm
1937	4^2
1938	4^3
1939	4^4
1940	4^5 cm

answer; ✓

clear working – table/calculation; ✓

[2]

(c) 1×10^3 cm or 1×10^1 m ✓

[1]

(d) Beginning of

1941 40 m = 4 x 10 m

1942 160 m = 4^2 x 10 m

1943 640 m = 4^3 x 10 m

[2]

(e) After n years beginning in 1941 the volume thickness will be 4^n x 10 m

The velocity of the front page will be 4^n x 10 ÷ 6 months ✓

Year when this is equal to the speed of light is when

$$3 \times 10^8 = \frac{4^n \times 10}{364 \times 3600 \times 24 / 2} \quad ✓$$

$$4.73 \times 10^{14} = 4^n$$

Taking logs to base 10

$$14.67 = n \log 4 \quad ✓$$

$$n = 24.4$$

So the year will be 1964 ✓

[4]

[Q4: 10 marks]

Question 5

(a) $[E] = \text{kg m s}^{-2}\ \text{m}^{-2} = \text{kg m}^{-1}\ \text{s}^{-2}$ ✓

$[\rho] = \text{kg m}^{-3}$ ✓

$[g] = \text{m s}^{-2}$ ✓

[3]

(b) Units $\text{m} = \text{kg m}^{-1}\ \text{s}^{-2} \times (\text{kg m}^{-3})^{\alpha} \times (\text{m s}^{-2})^{\beta}$ ✓

$\text{m} = \text{m}^{-1} \times \text{m}^{-3\alpha} \times \text{m}^{\beta}$ $\beta = 2 + 3\alpha$

$(\text{kg})^0 = \text{kg} \times (\text{kg})^{\alpha}$ $\alpha = -1$

$\text{s}^0 = \text{s}^{-2} \times \text{s}^{-2\beta}$ $\beta = -1$

only two equations needed to solve for α and β

one mark each for a correct equation ✓✓

$h = \text{constant} \times \frac{E}{\rho g}$ ✓

(α and β are not specifically required – correct result will suffice)

[4]

(c) $h = 1 \times \frac{10^{10}}{3 \times 10^3 \times 10}$ ✓

$= 3.3 \times 10^5$ metres $\approx$ 300 km ✓

[2]

[Q5: 9 marks]

Question 6

(a) No heater $\frac{\Delta m}{\Delta t} = 0.330 \text{ g s}^{-1}$ ✓

With heater $\frac{\Delta m}{\Delta t} = 0.350 \text{ g s}^{-1}$ ✓

Must be a clear indication of which is which and units needed.

[2]

(b) Electrical power = $V \times I = 3.9 \times 1.2$

$= 4.68 = 4.7$ W ✓

[1]

(c) 4.68 J/s boils away 0.020 g/s owtte ✓

So 234 J needed to boil away 1 g ✓

[2]

(d) 234 J/g x 0.330 g/s ✓

= 77 W ✓

[2]

(e) Mass of liquid nitrogen = ρV

$= 810 \frac{\text{kg}}{\text{m}^3} \times \frac{25}{1000} \frac{\text{litres}}{\text{litres m}^{-3}}$

= 20.3 kg ✓

Heat Energy required = 20.3 (kg) x 1000 (g/kg) x 234 (J/g) ✓

$= 4.7(5) \times 10^6$ J ✓

Power input to Dewar $= \frac{4.75 \times 10^6}{100 \times 24 \times 3600}$ 100 days in seconds ✓

= 0.55 W ✓

[5]

[Q5: 12 marks]

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*owtte *(Or Words To That Effect)*

BPhO 2012 - A2 CHALLENGE

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