AS CHALLENGE PAPER March 2019 SOLUTIONS

Marking

The mark scheme is prescriptive, but markers must make some allowances for alternative answers. It is not possible to provide notes of alternative solutions that students devise, since there is no opportunity to mark a selection of students' work before final publication. Hence alternative valid physics should be given full credit. If in doubt, email the BPhO office.

A positive view should be taken for awarding marks where good physics ideas are rewarded. These are problems, not mere questions. Students should be awarded for progress, even if they do not make it quite to the end point, as much as possible. Be consistent in your marking.

The worded explanations may be quite long in the mark scheme to help students understand. Much briefer responses than these solutions would be expected from candidates.

A value quoted at the end of a section must have the units included. Candidates lose a mark the first time that they fail to include a unit, but not on subsequent occasions, except where it is a specific part of the question.

The paper is not a test of significant figures. Significant figures are related to the number of figures given in the question. A single mark is lost the first time that there is a gross inconsistency (more than 3 sf out) in the final answer to a question. Almost all the answers can be given correctly to 2 sf. The mark scheme often gives 2 or 3 sf: either will do.

ecf: this is allowed in numerical sections provided that unreasonable answers are not being obtained.

owtte: "or words to that effect" – is the key physics idea present and used?

Section A: Multiple Choice

Question 1. **B**
Question 2. **A**
Question 3. **C**
Question 4. **C**
Question 5. **D**

There is 1 mark for each correct answer.

Maximum 5 marks

Multiple Choice Solutions

Qu. 1 A physicist should learn to develop an approach to measurement.

Qu. 2 Units: Js = $\frac{\text{kg.m}^2}{\text{s}^2}.\text{s} = \frac{(10^3\text{g}).\left(10^2\text{cm}\right)^2}{\text{s}^1} = 10^7\ \frac{\text{g.cm}^2}{\text{s}}$

Qu. 3 The dimensions or units on both sides of the equation must be the same. i.e. it must be dimensionally homogeneous. There is a mass on the LHS and so only a mass term should be present on the RHS. So we need to see how to eliminate the other units on the right.
$[M] = [M\ L^{-3}]\ [L\ T^{-1}]^6\ [L\ T^{-2}]^{-3}$

Qu. 4 Atoms are small. The scale factor linking atomic scales with everyday measurements is the Avogadro constant of ~ 10^{23} . 10^{13} is not visible to the eye, neither is 10^{18}, and 10^{28} is about a tonne – an enormous amount for a spoon.

Qu. 5 It moves over the edge and the plate tips down as the trailing edge is still on the table. So there is a torque acting and it subsequently rotates as it falls.

Total 5

Section B: Written Answers

Question 6.

In time T, the chain ring turns once.

A clear method shown and easy to follow ✓

The rear cog turns 48/15 times ✓

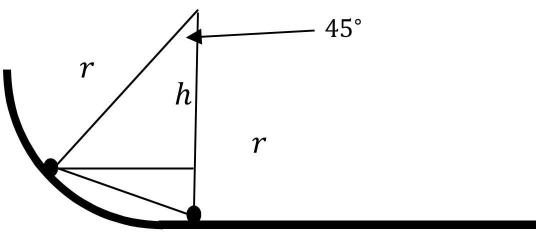
The rear wheel travels $\frac{48}{15} \times \pi d = \frac{48}{15} \times \{\pi \times 0.650\}$ m ✓

$v = \frac{\text{distance}}{\text{T}} = \frac{48}{15} \times \pi \times \frac{0.650}{1.2}$

$= 5.4(5) \text{m s}^{-1}$ ✓

Total 4

Question 7.



$h = r - r\cos\theta$ ✓

$= r(1 - \cos\ \theta$

$= 3.4(1 - \cos 45°)$

$= 1.7\big(2 - \sqrt{2}\big)$ m ✓

And from energy conservation, $mgh = \frac{1}{2}2mv^2$ ✓

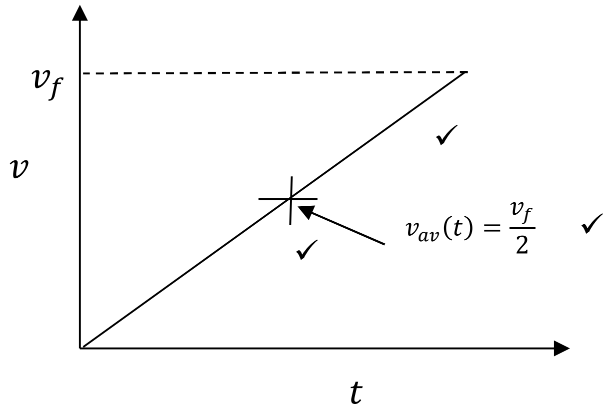
Hence, $v = \sqrt{gh} = \sqrt{9.81 \times 1.7\big(2 - \sqrt{2}\big)}$

$= 3.1 \text{ m s}^{-1}$ ✓

Total 4

Question 8.

a)



[3]

If air resistance has been included, the line is a curve going upwards, but of decreasing gradient. $V_{av}(t)$ will be greater than $\frac{v_f}{2}$.

b) $v_{av}(t)$ is the area under the line ($= \frac{1}{2} v_f t =$ distance travelled) divided by t to give $\frac{v_f}{2}$. ✓

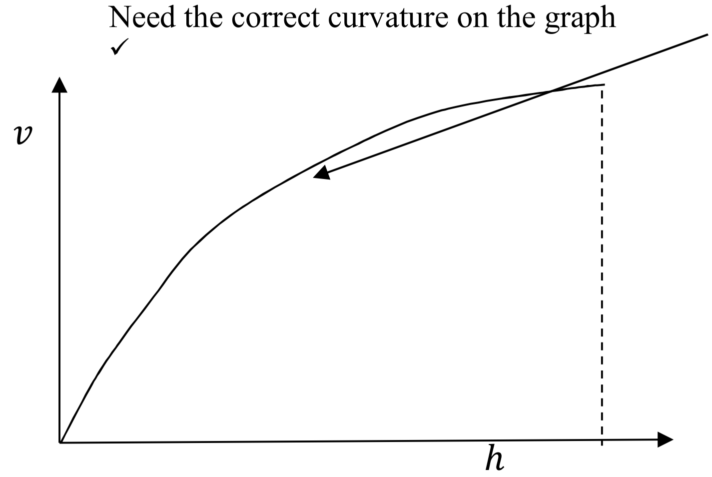
For air resistance effects, the idea is the same but not the value of $\frac{v_f}{2}$.

[1]

c) $v^2 = u^2 + 2as$ for this example means that $v = \sqrt{2gh}$. $v \propto \sqrt{h}$ ✓

Suitable graph axes ✓

Need the correct curvature on the graph ✓



[3]

With air resistance, the graph is of a similar curvature.

d) (i) $v_{av}(s)$ is the area under the $v - h$ curve divided by h. owtte ✓

[1]

(ii) The area under the curve is $\int_0^h v dh = \int_0^h \sqrt{2gh}\, dh = \frac{\sqrt{2g}\, h^{\frac{3}{2}}}{\frac{3}{2}} = \frac{2}{3}\sqrt{2g}\, h^{\frac{3}{2}}$

So $v_{av}(s) = \frac{\frac{2}{3}\sqrt{2g}\, h^{\frac{3}{2}}}{h} = \frac{2}{3}\sqrt{2gh} = \frac{2}{3} v_f$ ✓

[1]

Total 9

Question 9.

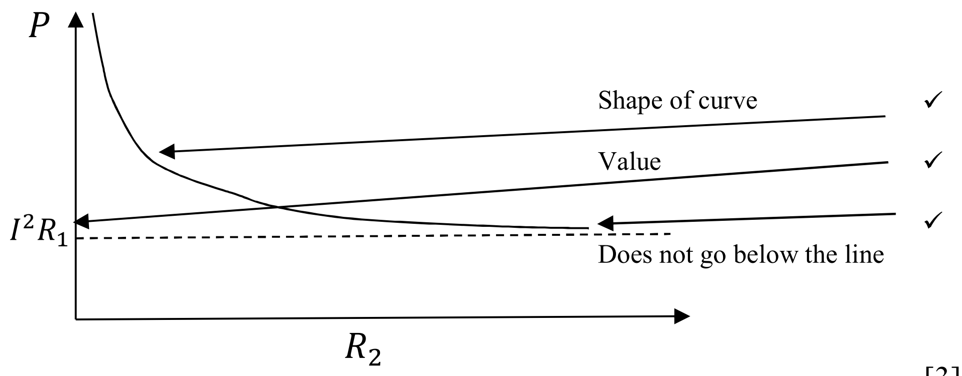
a) Various methods available. For example:

The current through R_2 is I_2.
The potential across R_2 is the same as that across R_1 so that $I_1R_1 = I_2R_2$ ✓
So $I_2 = \frac{I_1R_1}{R_2}$
$P_t = I_1^2R_1 + I_2^2R_2$ ✓
So that $P_t = I_1^2R_1 + \left(\frac{I_1R_1}{R_2}\right)^2 R_2$

$= I_1^2R_1(1 + \frac{R_1}{R_2})$ ✓

[3]

b)



[3]

Total 6

Question 10.

a) (i) $\lambda = \frac{2.9\times10^{-3}}{T}$
$= 2.9 \times 10^{-3} \div 5700 = 5.1 \times 10^{-7} = 510$ nm ✓

Visible light is 400 – 700 nm, so this is visible light. ✓

[2]

(ii) Core temperature greater by $\frac{1.5\times10^{7}}{5700} = 2630$,
So $\lambda \approx 0.19 \times 10^{-9}$ m $= 0.2$ nm ✓ so X ray or gamma ✓
$E = hf = \frac{hc}{\lambda} = \frac{6.63\times10^{-34}\times3\times10^{8}}{0.22\times10^{-9}} = 9.0 \times 10^{-16}$ joules ✓

[3]

b) The gas in the RZ is hot and the molecules move in random directions very fast. Heat is transferred by em radiation.
OR
In the CZ, large volumes of hot, lower density gas rise up transferring heat to the outer layer of the Sun. Suitable comment ------- ✓

[1]

c) Ratio of densities is $\frac{1.6\times10^5}{11300} = 14$ ✓

[1]

d) $P = \frac{k}{\mu}\rho T = 1.38 \times \frac{10^{-2}}{1.67\times10^{-27}} \times 1.6 \times 10^5 \times 1.5 \times 10^7$

$= 1.98 \times 10^{16}$ Pa *the mark for this result* ✓

$\frac{P}{P_{atm}} = \frac{1.98\times10^{16}}{1.01\times10^5} = 1.96 \times 10^{11}$

($\approx$ 200 billion times atmospheric pressure). [1]

e) $\frac{\Delta V}{V} = \left(\frac{0.25}{1}\right)^3 = \frac{1}{64}$ which is 2% (this is the energy generating volume) ✓

[1]

This is only valid to a single sf as a +/-0.005 change in 0.25 is a 2% variation, which when cubed amounts to a 6% variation. So no need to give more figures.

f) (i) Energy = area × energy per unit area ✓

$= 4\pi r^2 \times \text{intensity at Earth}$

$= 4\pi \times (1.5 \times 10^{11})^2 \times 1300 = 3.7 \times 10^{26}$ W ✓

[2]

(ii) Two neutrinos are released with every 4.27×10^{-12} J
So that the number generated per second is

$2 \times \frac{3.7\times10^{26}}{4.27\times10^{-1}} = 1.7 \times 10^{38}$ neutrinos emitted per second. ✓

Factor 2 ✓

[2]

(iii) Number of neutrino per square metre at the Earth is $\frac{N}{\text{area}}$

$\frac{1.7\times10^{38}}{4\pi\times(1.5\times10^{11})^2}$ ✓

$\left.\begin{array}{l} = 6.0 \times 10^{14} \text{ through each square metre} \\ = 6.0 \times 10^{10} \text{ through a cm}^2 \text{ per second} \end{array}\right\}$ either ✓

[2]

That is 60 billion through a square centimetre each second!

Total 15

Question 11.

a) k will depend on the material used for the lagging/insulation. ✓

Not to do with temperature or colour/shininess of the object.

(the question asks about his sample not samples in general – k is sample specific)

[1]

b) The temperatures are measured a short distance from the heater and it takes time for the thermal energy to conduct through the sample. owtte ✓

[1]

c) Graph is temperature versus time so Area is $\approx (T - T_{\text{room}}) \times t$ ✓

OR $A_2 = \int (T - T_{\text{room}})\text{dt}$

Law of cooling gives the rate of heat loss

so heat loss ΔQ is $\frac{\Delta Q}{\Delta t} \times t = k(T - T_{\text{room}}) \times \text{t} = \text{rate} \times t$ ✓

OR $\Delta Q = \int (\text{rate})\ dt$

So $A_2 \propto \Delta Q$ [2]

An argument of the form $A_2 \propto t$ and also $A_2 \propto (T - T_0)$ which is the same as the quantities proportional to Q in Newton's Law of Cooling. So $Q_2 \propto A_2$ although expressed rather simplistically, will suffice.

d) Same reasoning applies to heating the material up - heat is lost to the surroundings when compared to the ideal curve. ✓

[1]

This is the same idea. It does not matter which way you are going along the curve.

e) From graph measure A_1, A_2 and ΔT_3. Use to calculate ΔT_2. ✓

Use ΔT_2 to find the temperature the block would have risen to $(T + \Delta T_2)$.

Find energy supplied in time $(t_2 - t_1)$, which is $VI\Delta t$

and so $c = \frac{VI\Delta t}{m(T+\Delta T_2)}$ ✓

[2]

Total 7

END OF SOLUTIONS