AS CHALLENGE PAPER 2014 SOLUTIONS

Marking

The mark scheme is prescriptive, but markers must make some allowances for alternative answers.

A positive view should be taken for awarding marks where good physics ideas are rewarded.

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.

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 2 sf out) in the final answer to a question.

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

1. **D**
2. **C**
3. **C**
4. **B**

5. **D**
6. **C**
7. **C**
8. **A**

There is 1 mark for each correct answer.

Maximum 8 marks

Multiple Choice Solutions

Qu. 1 Ignore air resistance, the gpe reduces to 80% so 20% of the energy is lost

Qu. 2 ½ mv^2 is ½ $5 \times 10^{-26} \times 500^2 = 6.25 \times 10^{-21}$ J $= 6.25 \times 10^{-21}/1.6 \times 10^{-19}$ eV $= 39 \times 10^{-3}$ eV

Qu. 3 2 minutes in 24 hours is 1/720 of a full rotation of the earth. So the angle subtended by the moon at the eye is about ½ ^{o}. The distance earth – moon is a fixed value so the angle subtended by the earth at the moon is greater by 6400/1700. Hence $0.5 \times 6400/1700 = 1.9^{o}$

Qu. 4 Volume of the water of the film is fixed, so if the bubble has three times the radius, it has nine times the surface area, and as the film is very thin, this makes it thinner by a factor of nine in order to keep the volume of the film the same. This does expect that the thickness of the film, $t \ll R$, the radius of the bubble.

Qu. 5 A ratio question. The shapes are the same, and the ratio of the linear dimensions is 690/6.4 = 108, so the ratio of volumes is $\approx 10^6$

Qu. 6 The liquid has to flow faster through the narrower section because if unit volume passes a one point in the pipe every second, that same volume must flow through any other point each second otherwise there would be an accumulation of an incompressible fluid in the pipe.

Qu. 7 The power dissipates in a resistor is given by I^2R. If R_A is unit current through unit resistance, R_B has twice the resistance and half the current, so that I^2R will be half the value (½ W). R_C takes 3/2 units of current and is twice unit resistance so dissipates 9/2 W. Powers add up and so the total of these is 6W. The cell would supply the appropriate emf to supply these currents, otherwise the initial assumption of the 1 W that we are given in R_A would not be right.

Qu. 8 The rock only has to be lifted up to the neutral point and it will fall the rest of the way to earth.

Section B: Written Answers

Question 9.

Intensity is power/area $10^{-20} \times 1.4 \times 10^3$ (✓) = $\frac{100}{4\pi r^2}$ (✓)

$$r^2 = \frac{100}{4\pi}\frac{1}{10^{-20}\times 1.4\times 10^3}$$ ✓

$r = 7.5 \times 10^8$ m (8×10^8 m) ✓

answer with an order of magnitude correct gains the mark

Total 4

Question 10.

a) Simple argument: weight of liquid = mg = ρgAh ✓
and the pressure is $\frac{F}{A}$ (= ρgh) ✓

b) The air is compressible / the density varies with height / density at ground level is much greater than the density higher up. ✓

So ρ is not a constant *or* fixed *or* single value ✓
Ignore comments that the value of g may be different (a 3% effect).

c) The liquid transmits pressure, and equilibrium at a point is when the pressure is balanced (pressure to the left = pressure to the right) OWTTE (✓) and so the pressure at the bottom (of each column must) be equal ✓

d) When pushed down, the column of liquid is less tall (the column of liquid is taller on the left)

Or so the pressure at the bottom of the (right hand pipe) is less ✓

hence the mass/column will rise again to its former level ✓
ignore comments on oscillations

e) The narrow tube connects different heights so the pressure at the bottom of the tube is greater than the pressure at the top ✓

The pressure difference is determined by the height difference, and points ate the same height in the narrow or wide pipe are at the same pressure. So no flow in the tube. Indication of no flow, pressure in tube depends on height same as in the pipes, etc. ✓

(can use an energy conservation type argument going around a circuit in the piping)

f) use of pressure = ρgh being equated for the two columns ✓

$$\rho_w g h_L + \rho_{Fe} g x = \rho_w g h_R + \rho_{Fe} g 2x$$ ✓

$$h_L + \frac{\rho_{Fe}}{\rho_w} x = h_R + \frac{\rho_{Fe}}{\rho_w} 2x$$

$$\frac{\rho_{Fe}}{\rho_w} x = h_L - h_R$$ ✓

$$\frac{7.8}{1.0} x = 50.0$$

$$x = 6.4 \text{ cm}$$ ✓

g) Hence using $m = "\rho V" = \rho_{Fe} A x$ ✓

1000 = 7.8 x A x 6.4

A = 20 cm^2 ✓

Total 16

Question 11.

a) Heat is convected from the internal volume of the earth – evidence is continental drift particularly and volcanic activity ✓

Heat is conducted as the interior of the earth is a solid/liquid ✓

Some justification needed rather than merely the labels convection and conduction.

b) Heat is transferred into the vacuum/empty/"nothing there" space by radiation ✓

No credit for answers which include convection or conduction

Some reason needed to justify the statement of radiation.

c) (i) Because the temperature dependence is as a cube (or inverse cube), if T_i is 10 x T_f then one term will be 1000 times greater (or less) than the other, so it does not make a great difference (numerically) whether T_i is 4000 or 4 million K. OWTTE ✓

(ii)

$$t_{cooling} \approx \frac{Nk}{\sigma A}\left(\frac{1}{T_f^3}\right)$$ ✓

(iii) Mass of the earth = $\rho V = \rho \, {}^4\!/_3 \, \pi r^3 \approx 5500 \times 4 \times 6.4^3 \times 10^{18}$

$= 6.0 \times 10^{24}$ kg ✓

Hence $N = 6.0 \times 10^{24} / 6 \times 10^{-26} = 10^{50}$ atoms ✓

Any answer within an order of magnitude or so either way will be acceptable as the 4/3 and π may be muddled up or even ignored without penalty.

Lose a mark if km not converted into metres (so out by 10^9)

(iv) Substitution with ecf from previous sections.

$t_{cooling} = 1.8 \times 10^{12}$ seconds ✓

= 56,000 years ✓

(v) The age of the earth is about 4 billion years. A few tens of thousands of years is long after the dinosaurs, mankind has been on earth, or any sensible comment about this being an unrealistically short time period. ✓

No mark if they have ½ hour due to using R in km.

(the heat is due to radioactive decay, a process unknown in the 19th century)

Total 11

Question 12.

a) Centre of mass is the balance point of the rod, which with a mass ratio of 2:1 gives a position ratio of 1:2 from the two masses. ✓
And so the centre of mass is $3l$ from the pivot (or equivalent specification) ✓

A more formal approach would use $x = \frac{m_1 x_1 + m_2 x_2}{m_1 + m_2}$ measured from the pivot. So that

$$x = \frac{ml + 2m4l}{3m} = 3l$$

b) The rod accelerates downwards but <u>remains horizontal</u> ✓

C of M (and the whole rod) falls through height 3ℓ ✓
and so the potential energy lost is $3mg3\ell$ ($= 9mg\ell$)
KE gained by C of M: $\frac{1}{2}\,3mv^2 = 9mg\ell$ (allow ecf for C of M)
So $v_{CM} = \sqrt{6gl}$ ✓

c) The energy of the rod is made up of the translational kinetic energy due to the motion of the centre of mass ✓
and the rotational (kinetic) energy of the rod. ✓
(so the speed of the C of M will be less)
(if the rod was released from the support when it reached the vertical position, the centre of mass would fall in a parabolic path whilst the rod would rotate about the centre of mass).

d) The speeds of the two masses are different but they have the same angular velocity since the rod is rigid.
So equating the KE and gpe;
Expression of a KE as a $\frac{1}{2} m(\ell\omega)^2$ term ✓

$\underline{\tfrac{1}{2} m(\ell\omega)^2 + \tfrac{1}{2}\, 2m(4\ell\omega)^2}$ ✓ $=$ $\underline{mg\ell + 2mg4\ell}$ ✓ $(= 3m.g.3\ell)$ gpe of CofM

$$\omega^2 = \frac{6}{11}\frac{g}{\ell}$$

For the centre of mass, $v_{CM} = 3\ell\omega = 3\sqrt{\frac{6}{11}g\ell} = \sqrt{\frac{54}{11}g\ell}$ ✓

Total 11

END OF SOLUTIONS