AS CHALLENGE PAPER 2017 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 which 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.

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 2 sf out) in the final answer to a question. Almost all the answers can be given correctly to 2 sf.

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. **A**
Question 2. **C**
Question 3. **B**
Question 4. **D**
Question 5. **D**
Question 6. **C**

There is 1 mark for each correct answer.

Maximum 6 marks

Multiple Choice Solutions

Qu. 1 force = mass × acceleration = $\mathrm{M} \times \mathrm{LT}^{-2} = \mathrm{M}\frac{\mathrm{L}}{\mathrm{T}^2}$

Qu. 2 Dimensions: $\mathrm{M}\frac{\mathrm{L}}{\mathrm{T}^2} = L^2 \ \frac{L^2}{T^2} \ \frac{M}{L^3} = Av^2\rho$

Qu. 3 Energy = $7.0 \times 10^{12} \times 1.6 \times 10^{-19} \times 2808 \times 1.15 \times 10^{11}$ = 362 MJ

Qu. 4 Current = charge passing a point / time

$$I = 1.15 \times 10^{11} \times 2808 \times \frac{1.6 \times 10^{-19}}{27000 \div 3 \times 10^{8}} = 0.6\ \mathrm{A}$$

Qu. 5 $10 \times 10^9 = \frac{1}{2} 35 \times 10^3 v^2$

$v = 22$ m s^{-1}

Qu. 6 $\frac{10^{10}\ \mathrm{J}}{4.7 \times 10^7\ \mathrm{J\ kg^{-1}}} = 2130\ \mathrm{kg}$

Section B: Written Answers

Question 7.

If the whole blade is used the force per unit length (area) is small ✓
Cutting at an angle, the same force acts on a smaller length to cut through ✓
By changing the angle, another part of the blade can be applied to a short length of uncut cheese using the same applied force. ✓
Comments must not be general or vague. They must employ a key idea.

[3]

Total 3

Question 8.

The elastic provides an upward force on the spider is **NOT** sufficient for a mark

The work done to climb up is force × distance upwards ✓
The elastic does work on the spider as it climbs. ✓
which reduces the amount of work that the spider must do to climb through $2\ell_0$
owtte

OR as a mechanism:

If it holds on with its front legs, its back legs will push down on an elastic which is pushing up on the back legs. ✓
When it then pulls up with its front legs, the force to pull its body up is reduced ✓
so less work is done by the spider as it climbs $2\ell_0$ with a reduced force.
owtte

[2]

WD by spider = Work done to move up $2\ell_0$ – work done (stored) by the spring ✓

WD $= 2mg\ell_o - \frac{1}{2}k\ell_0^2$

$= 2mg\ell_0 - \frac{1}{2}\frac{mg}{\ell_0}\ell_0^2$

$= \frac{3}{2}mg\ell_0$ mark for this result

So ¼ of the work needed is saved OR ✓

[2]

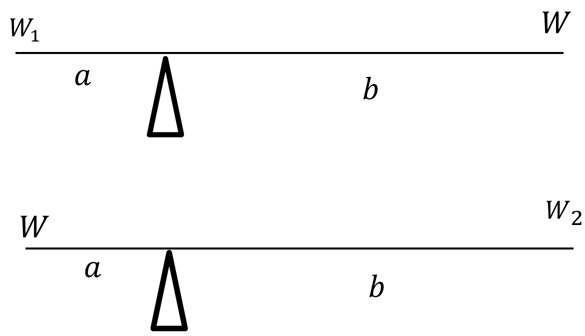
Total 4

Question 9.

The spring balance uses the force-extension property of the spring which has been calibrated with a specified force on a known mass specifically in the Earth's field. ✓
OR
It does not measure a mass but a force and deduces what the mass must be in the field of the Earth. ✓

The lever balance compares (finds the ratio of) two masses in the same uniform gravitational field. The force is proportional to the mass and the constant of proportionality is the same for each mass. ✓
OR
This compares the forces and does not use a calibrated property based on a different physics effect. ✓

Two marks from two statements above
owtte. **[2]**



$$W_1 a = Wb$$

$$Wa = W_2 b$$

Clear work shown to provide relations by diagram or by algebra ✓

Multiplying or dividing, finding a or b as the subject, eliminating a or b, etc.
We obtain

$$W^2 = W_1 W_2$$
$$W = \sqrt{W_1 W_2}$$ a and b eliminated ✓

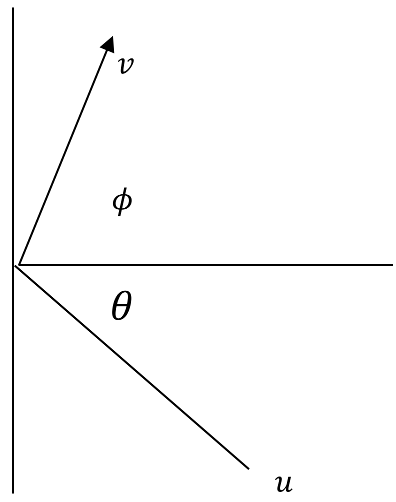
Symbol analysis **required** rather than starting from numbers alone

So that $W = 1.52$ kg ✓

[3]

Total 5

Question 10.



a) u, v, θ, ϕ all shown **AND** an arrow for direction included ✓
$\angle\theta < \angle\phi$ ✓

[2]

b) three relations**:**

(1) $u = \sqrt{2}v$ ✓

(2) $u \sin\theta = v \sin\phi$ ✓

(3) $u \cos\theta = \sqrt{3}v \cos\phi$ ✓

[3]

c) Squaring (2) and (3) and adding $u^2 = v^2 \sin^2\phi + 3v^2 \cos^2\phi$ ✓

Using (1) $2v^2 = v^2 \sin^2\phi + 3v^2 \cos^2\phi$
$= v^2 - v^2 \cos^2\phi + 3v^2 \cos^2\phi$

So $2v^2 = v^2 + 2v^2 \cos^2\phi$
Giving $1 = 2\cos^2\phi$

Hence $\cos\phi = \frac{1}{\sqrt{2}}$ so $\phi = \frac{\pi}{4}$ (45°) ✓

And from (3) $u \cos\theta = \sqrt{3}\frac{u}{\sqrt{2}}.\frac{1}{\sqrt{2}}$
To give $\cos\theta = \frac{\sqrt{3}}{2}$ so $\theta = \frac{\pi}{6}$ (30°) ✓

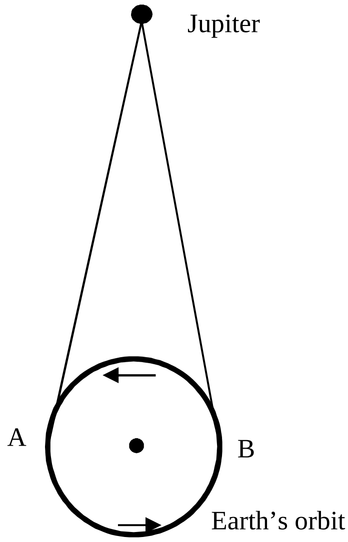
[3]

Total 8

Question 11.

a) Clear labelled diagram ✓
The variations from the mean are greatest at points A and B. (as the Earth is moving away from and towards Jupiter).
The two points must be labeled not inferred ✓

[2]



b) The speed of the Earth, $v = 29\ 900\ \text{m s}^{-1}$ ✓

In 42 hours 28 min 42 s the Earth has travelled 4.57×10^9 m ✓

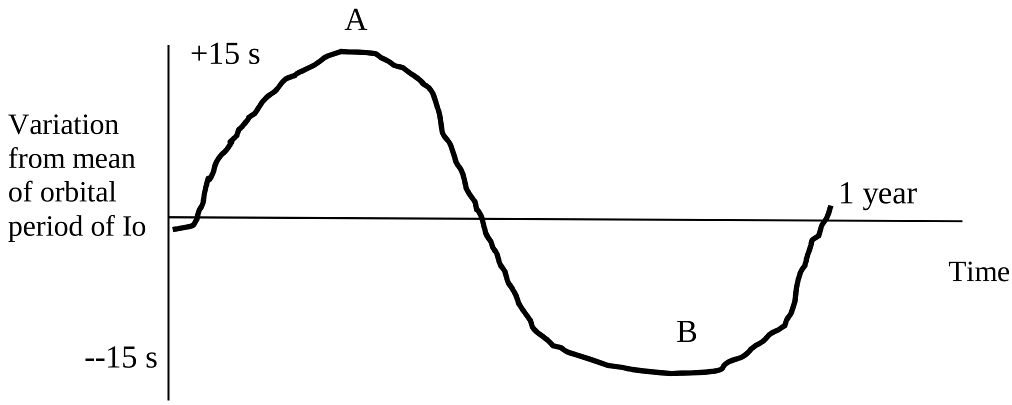
So the light has to travel this distance extra, taking 15 seconds, giving

$$c = \frac{4.57 \times 10^9}{15} = 3.0 \times 10^8\ \text{s}$$

✓

[3]

c) Need sine/cosine curve (i.e. up down aspect), and **A** and **B** marked. ✓



[1]

Total 6

Question 12.

a) Current in R_1 is half the current in R_2 ✓

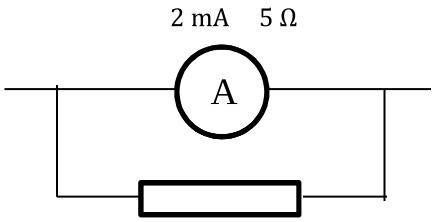
Equate powers dissipated $I^2 R_1 = \left(\frac{I}{2}\right)^2 R_2$

Hence $R_1 = \frac{R_2}{4}$ or $\frac{R_1}{R_2} = \frac{1}{4}$ ✓

Only 1 mark in total if use both $R_2 s$ $I^2 = 2\left(\frac{I}{2}\right)^2 R_2$

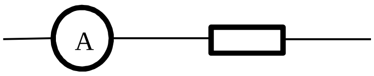
which would give $R_1 = \frac{R_2}{2}$ **[2]**

b) Sketch of meter and parallel resistor: ✓



10 mV across the meter, so 10 mV across the resistor
198 mA through the resistor
So $R = \frac{10}{198} = 0.0505\ \Omega$ ✓ **[2]**

c)



At f.s.d. voltage across the meter is $IR = 2.0\text{ mA} \times 5.0\ \Omega = 10\text{ mV}$ ✓

So resistor required is $R = \frac{4.0\text{ V} - 10\text{ mV}}{2\text{ mA}} = 1.995\text{ k}\Omega = 2.00\text{ k}\Omega = 1.99\text{ k}\Omega$ ✓

[2]

d) The potentials must be shown, not the PDs between the wires.

C 2.0 μV, **D** 0 V, **E** -2.0 V, **F** 0 V ✓

(**C** & **E** required with opposite signs) **[1]**

e)

$$I_{R_1} = \frac{V_{in} + \frac{V_{out}}{10^6}}{R_1}$$

✓

¶ And also

$$I_{R_2} = \frac{-\frac{V_{out}}{10^6} - V_{out}}{R_2}$$

✓

Currents are the same as no current enters at C, so that $I_{R_1} = I_{R_2}$

So with the approximation that $V_{out}/10^6$ is small compared to V_{out} and V_{in}
Then

$$\frac{V_{in}}{R_1} = -\frac{V_{out}}{R_2}$$

✓

Or

$$\text{gain} = \frac{V_{out}}{V_{in}} = -\frac{R_2}{R_1}$$

(1 mark off for missing the minus sign in the answer)

[3]

Total 10

Question 13.

a) The mass falls to the ground and it gains kinetic energy.
The total energy is converted to photons, reflected back up and converted to a greater mass. ✓
If this mass was dropped again, there is still more energy to be converted to photons this time,
and the energy can be seen to be increasing indefinitely through this process. ✓

[2]

b)
$$E_{gr} = E_{sat} + m_{\gamma}gh$$
$$E_{gr} = E_{sat} + \frac{hf_{sat}gH}{c^2}$$ ✓
$$hf_{gr} = hf_{sat}(1 + \frac{gH}{c^2})$$
$$\Delta f = f_{gr} - f_{sat} = \frac{f_{sat}gH}{c^2}$$
$$\Delta f = 4.2 \times 10^{14} \times 9.81 \times \frac{4.5\times10^5}{9\times10^{16}}$$
$$= 20\,600 \text{ Hz} \quad = 21 \text{ kHz}$$ ✓

[2]

c) No of wavelengths, N', is the distance ÷ λ
$$N' = \frac{4.5 \times 10^5}{3 \times 10^8} \times 4.2 \times 10^{14}$$
$$N' = 6.1 \times 10^{11}$$ ✓

[1]

d) The change in frequency $\Delta f \propto H$ and is very small relative to f so that the wavelength will also change linearly with H.
The wavelength will (uniformly) reduce as the photon/em wave approaches the ground. ✓

[1]

e) Extra waves are given by
$$N - N' = \Delta t\left(f_{sat} + \frac{\Delta f}{2}\right) - \Delta t f_{sat}$$
$$\Delta N = \Delta t.\frac{\Delta f}{2}$$ ✓
$$= \frac{4.5 \times 10^5}{3 \times 10^8} \times \frac{20600}{2}$$
$$= 1.5 \times 10^{-3} \times \frac{200}{2}$$
$$= 15.45 = 15$$ ✓

[2]

Total 8

END OF SOLUTIONS