Neap

Trial Examination 2023

Suggested Solutions

QCE Physics Units 3&4

Paper 2

SECTION 1

QUESTION 1 (4 marks)

$$\frac{V_{\text{p}}}{V_{\text{s}}} = \frac{n_{\text{p}}}{n_{\text{s}}}$$

$$\frac{240}{V_{\text{s}}} = \frac{4800}{480}$$

$$V_{\text{s}} = 24 \text{ V}$$

$$I_{\text{p}}V_{\text{p}} = I_{\text{s}}V_{\text{s}}$$

$$\begin{aligned} I_{\text{p}} &= \frac{I_{\text{s}}V_{\text{s}}}{V_{\text{p}}} \\ &= \frac{0.5 \times 24}{240} \\ &= 0.05 \text{ mA} \end{aligned}$$

[4 marks]

1 mark for substituting into the formula $\frac{V_p}{V_s} = \frac{n_p}{n_s}$.

1 mark for calculating V_s.

1 mark for substituting into the formula $I_pV_p = I_sV_s$

1 mark for determining the current.

QUESTION 2 (2 marks)

$$\begin{aligned} \lambda &= \frac{h}{p} = \frac{h}{mv} \\ &= \frac{6.626 \times 10^{-34}}{(9.1093835 \times 10^{-31}) \times (1.0 \times 10^{5})} \\ &= 7.3 \times 10^{-9} \text{ m} \end{aligned}$$

[2 marks]

1 mark for determining the momentum of an electron. Note: Showing substitution is sufficient to obtain this mark.

1 mark for calculating the wavelength.

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QUESTION 3 (4 marks)

Black-body radiation is independent of chemical composition. The peak wavelength of the light emitted by the lava is inversely proportional to the temperature of the lava. Rhyolitic lava glows red, which has a longer wavelength (620–750 nm) and so has a lower temperature. As yellow light has a shorter wavelength (570–590 nm), basaltic lava has a higher temperature than rhyolitic lava. As basaltic lava cools, the peak wavelength of light increases, so the lava then glows orange-red.

[4 marks]
1 mark for stating that black-body radiation is independent of chemical composition.
1 mark for explaining that peak wavelength is inversely proportional to temperature.
1 mark for explaining the relationship between peak wavelength and temperature for rhyolitic lava.
1 mark for explaining the relationship between peak wavelength and temperature for basaltic lava.
Note: Responses that refer to 'wavelength' instead of 'peak wavelength' may obtain full marks.

QUESTION 4 (4 marks)

a) As the blocks are at rest, there is no net force; therefore, $|F_{\text{up}}| = |F_{\text{down}}|$.

Defining the positive direction to be down the ramp (which is up for block B) gives:

$$\begin{aligned} Bg + Ag\sin(30) + F_{\text{friction}} &= 0 \\ 0.75 \times (-9.8) + 1.0 \times 9.8\sin(30) + F_{\text{friction}} &= 0 \\ F_{\text{friction}} &= 2.45 \\ &= 2.5 \text{ N} \end{aligned}$$

[3 marks]
1 mark for identifying that there is no net force/no net acceleration/all forces are balanced.
1 mark for substituting into an appropriate formula.
1 mark for determining the magnitude of the frictional force.
Note: The direction is not required, so accept positive or negative values.

b) downwards

[1 mark]
1 mark for identifying the direction.

QUESTION 5 (5 marks)

Finding the electrostatic force gives:

$$F_{\text{electrostatic}} = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{r^2}$$

$$= \left(9\times10^{9}\right)\times\frac{\left(1.60\times10^{-19}\right)^2}{\left(6.0\times10^{-11}\right)^2}$$

$$= 6.4\times10^{-8}\text{ N}$$

Finding the gravitational force gives:

$$F_{\text{gravitational}} = \frac{GMm}{r^2}$$

$$= \frac{\left(6.67\times10^{-11}\right)\times\left(9.1093835\times10^{-31}\right)\times\left(1.6726219\times10^{-27}\right)}{\left(6.0\times10^{-11}\right)^2}$$

$$= 2.8230\times10^{-47}\text{ N}$$

Finding the factor by which the electrostatic force is greater gives:

$$\text{factor} = \frac{F_{\text{electrostatic}}}{F_{\text{gravitational}}}$$

$$= 2.3\times10^{39}$$

[5 marks]
1 mark for substituting into the formula for electrostatic force.
1 mark for calculating the electrostatic force.
1 mark for substituting into the formula for gravitational force.
1 mark for calculating the gravitational force.
1 mark determining the factor by which the electrostatic force is greater.

QUESTION 6 (3 marks)

Any two of the following:

- Rutherford's model did not account for the stability of an atom as it could not explain why an accelerating electron does not fall into the nucleus. Bohr's model accounted for stability by showing electrons existing in stationary states/resonance states/standing waves.
- Rutherford's model did not explain light emission/absorption spectra. In contrast, Bohr's model showed how electrons gain or lose energy to move between energy levels, which accounted for the discrete energy of light in emission/absorption spectra.
- Rutherford's model did not quantise the angular momentum of electrons. Bohr's model allowed for the quantisation of angular momentum by conceptualising the electron as a circular standing wave around the nucleus, which only allows the electron to exist in definite-radius orbits around the nucleus.

[3 marks]
1 mark for identifying any two limitations of Rutherford's model. Note: This mark should not be awarded for one limitation only.
1 mark for each valid explanation of how Bohr's model addressed an identified limitation of Rutherford's model.

QUESTION 7 (5 marks)

a) $E = \dfrac{hc}{\lambda}$

$= \dfrac{(6.626 \times 10^{-34}) \times (3 \times 10^{8})}{121.6 \times 10^{-9}}$

$= 1.6347 \times 10^{-18}$ J

$E = \dfrac{1.6347 \times 10^{-18}}{1.60 \times 10^{-19}}$

$= 10.22$ eV

This corresponds to the transition from $n = 2$ to $n = 1$.

($\Delta E = E_f - E_i = -3.40 - (-13.59) = 10.19$ eV)

[3 marks]

1 mark for calculating the energy photon in joules.

1 mark for converting the energy photon to electron volts.

1 mark for determining the energy level transition. Note: Do not award this mark if the response states n = 1 to n = 2.

b) It is possible. A shorter wavelength corresponds to a photon with greater energy. Any transition from other energy levels to $n = 1$ would result in a photon of greater energy and thus shorter wavelength than the Lyman-α emission.

[2 marks]

1 mark for stating that the emission of a shorter wavelength photon is possible.

1 mark for explaining how a shorter wavelength corresponds to greater energy. Note: Do not award this mark if the response refers to 'transitions between n = x and n = 1' as the emission must be to n = 1.

QUESTION 8 (7 marks)

a) Using Fleming's left-hand rule, the magnetic field is directed out of the page.

[1 mark]

1 mark for stating the direction of the magnetic field.

b) Using the mass of an alpha particle from the Formula and Data Booklet gives:

$F_c = \dfrac{mv^2}{r}$

$= \dfrac{6.6447 \times 10^{-27} \times (1.38 \times 10^{7})^2}{0.78}$

$= 1.6223 \times 10^{-12}$

$\approx 1.62 \times 10^{-12}$ N

[3 marks]

1 mark for identifying the appropriate formula.

1 mark for substituting into the formula.

1 mark for determining the centripetal force.

c)

$$F = qvB\sin\theta$$

$$1.6223\times10^{-12} = 2\times(1.60\times10^{-19})\times(1.38\times10^{7})\times B\times1$$

$$B = \frac{1.6223\times10^{-12}}{2\times(1.60\times10^{-19})\times(1.38\times10^{7})}$$

$$= 0.367\ \text{T}$$

[3 marks]
1 mark for identifying the appropriate formula.
1 mark for substituting into the formula.
1 mark for calculating the strength of the magnetic field.
Note: Allow follow-through errors. Consequential on answer to ***Question 8b)****.*

QUESTION 9 (4 marks)

$$\frac{T^2}{r^3} = \frac{4\pi^2}{GM}$$

$$T_{\text{Earth}} = 365\times24\times60\times60$$

$$= 3.1536\times10^{7}\ \text{seconds}$$

Therefore:

$$\frac{(3.1536\times10^{7})^2}{r^3} = \frac{4\pi^2}{(6.67\times10^{-11})\times(2.0\times10^{30})}$$

$$r = 1.5\times10^{11}\ \text{m}$$

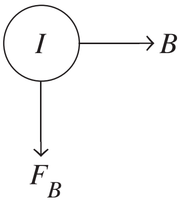
[4 marks]
1 mark for relating the problem to Kepler's third law. Note: This mark may be implied by subsequent working.
1 mark for calculating the period.
1 mark for substituting into Kepler's third law formula.
1 mark for determining the average distance.

QUESTION 10 (5 marks)

The scenario involves the balancing of forces.

$$F_g = F_B$$
$$mg = BIL$$
$$0.005 \times 9.8 = 0.7 \times I \times 0.05$$
$$I = \frac{0.005 \times 9.8}{0.7 \times 0.05}$$
$$= 1.4 \text{ A}$$

Using the left-hand rule:



Therefore, *I* is into the page.

[5 marks]

1 mark for recognising that the forces must be balanced and identifying that the two forces are equal and are gravitational and magnetic forces. Note: This mark may be implied by subsequent working.

1 mark for using the appropriate formula.

1 mark for substituting into the formula.

1 mark for determining the magnitude of the current.

1 mark for determining the direction of the current.

QUESTION 11 (7 marks)

a)
$$E = hf$$
$$= (6.626 \times 10^{-34}) \times (6.60 \times 10^{14})$$
$$= 4.37 \times 10^{-19} \text{ J}$$

[2 marks]

1 mark for substituting into the formula.

1 mark for determining the energy.

b)
$$W = hf_0$$
$$= (6.626 \times 10^{-34}) \times (2.50 \times 10^{14})$$
$$= 1.66 \times 10^{-19} \text{ J}$$

[2 marks]

1 mark for substituting into the formula.

1 mark for determining the work function.

c)

$$E_k = hf - W$$
$$= (4.37\times10^{-19}) - (1.66\times10^{-19})$$
$$= 2.71\times10^{-19}\ \text{J}$$

$$E_k = \frac{1}{2}m_\text{e}v^2$$
$$v = \sqrt{\frac{2E_k}{m_\text{e}}}$$
$$= \sqrt{\frac{2\times(2.71\times10^{-19})}{9.1093835\times10^{-31}}}$$
$$= 7.71\times10^{5}\ \text{ms}^{-1}$$

[3 marks]

1 mark for calculating E_k.

1 mark for substituting into the formula.

1 mark for determining the maximum velocity.

Note: Accept answers that are rounded to either 7.71 or 7.72 ($\times 10^5$).

*Consequential on answers to **Questions 11a)** and **11b)**.*