General Certificate of Education
Advanced Subsidiary Examination
June 2015

Physics A

Unit 1  Particles, Quantum Phenomena and Electricity

Tuesday 19 May 2015  9.00 am to 10.15 am

For this paper you must have:
• a pencil and a ruler
• a calculator
• a Data and Formulae Booklet (enclosed).

Time allowed
• 1 hour 15 minutes

Instructions
• Use black ink or black ball-point pen.
• Fill in the boxes at the top of this page.
• Answer all questions.
• You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
• Do all rough work in this book. Cross through any work you do not want to be marked.
• Show all your working.

Information
• The marks for questions are shown in brackets.
• The maximum mark for this paper is 70.
• You are expected to use a calculator, where appropriate.
• A Data and Formulae Booklet is provided as a loose insert.
• You will be marked on your ability to:
  – use good English
  – organise information clearly
  – use specialist vocabulary where appropriate.
Answer all questions in the spaces provided.

1 Table 1 contains five statements that refer to isotopes and some radium isotopes.

Table 1

<table>
<thead>
<tr>
<th>Isotope with the smallest mass number</th>
<th>$^{223}_{88}$Ra</th>
<th>$^{224}_{88}$Ra</th>
<th>$^{225}_{88}$Ra</th>
<th>$^{226}_{88}$Ra</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isotope with most neutrons in nucleus</td>
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<tr>
<td>Isotope with nucleus which has the largest specific charge</td>
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<td>Isotope decays by β$^-$ decay to form $^{225}_{89}$Ac</td>
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<td></td>
<td></td>
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<tr>
<td>Isotope decays by alpha decay to form $^{220}_{86}$Rn</td>
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</tbody>
</table>

1 (a) Complete Table 1 by ticking one box in each row to identify the appropriate isotope. The first row has been completed for you. [4 marks]

1 (b) (i) An atom of one of the radium isotopes in Table 1 is ionised so that it has a charge of $+3.2 \times 10^{-19}$ C. State what happens in the process of ionising this radium atom. [1 mark]

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1 (b) (ii) The specific charge of the ion formed is $8.57 \times 10^5$ C kg$^{-1}$. Deduce which isotope in the table has been ionised. Assume that both the mass of a proton and the mass of a neutron in the nucleus is $1.66 \times 10^{-27}$ kg. [3 marks]

isotope = ...........................................................................................................
2 The equation shows an interaction between a proton and a negative kaon that results in the formation of particle, X.

\[ K^- + p \rightarrow K^+ + K^0 + X \]

2 (a) (i) State and explain whether X is a charged particle. [2 marks]

2 (a) (ii) State and explain whether X is a lepton, baryon or meson. [2 marks]

2 (a) (iii) State the quark structure of the \( K^- \), \( K^+ \) and the \( K^0 \). [3 marks]

\[ K^- \ldots \]
\[ K^+ \ldots \]
\[ K^0 \ldots \]

2 (a) (iv) Strangeness is conserved in the interaction.

Determine, explaining your answer, the quark structure of X. [3 marks]

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Baryons, mesons and leptons are affected by particle interactions.

Write an account of these interactions. Your account should:

- include the names of the interactions
- identify the groups of particles that are affected by the interaction
- identify the exchange particles involved in the interaction
- give examples of two of the interactions you mention.

The quality of your written communication will be assessed in your answer. [6 marks]
3 (b) Draw a labelled Feynman diagram that represents a particle interaction. [3 marks]
4 Sodium metal has a work function of 2.28 eV. An atom of sodium has an ionisation energy of 5.15 eV.

4 (a) (i) State what is meant by work function. [2 marks]

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4 (a) (ii) State what is meant by ionisation energy. [2 marks]

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4 (b) Show that the minimum frequency of electromagnetic radiation needed for a photon to ionise an atom of sodium is about $1.2 \times 10^{15}$ Hz. [2 marks]
4 (c) Electromagnetic radiation with the frequency calculated in part (b) is incident on the surface of a piece of sodium.

Calculate the maximum possible kinetic energy of an electron that is emitted when a photon of this radiation is incident on the surface. Give your answer to an appropriate number of significant figures.

[3 marks]

maximum kinetic energy = ................................................... J

4 (d) Calculate the speed of an electron that has the same de Broglie wavelength as the electromagnetic radiation in part (b).

[3 marks]

speed = ........................................... m s⁻¹
5 (a) Sketch, on Figure 1, the current–voltage ($I/V$) characteristic for a filament lamp for currents up to its working power. [2 marks]

![Figure 1](image)

5 (b) (i) State what happens to the resistance of the filament lamp as the current increases. [1 mark]

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5 (b) (ii) State and explain whether a filament lamp is an ohmic or non-ohmic conductor up to its working power. [1 mark]

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Three identical filament lamps, P, Q and R are connected in the circuit shown in Figure 2.

The filament in lamp Q melts so that it no longer conducts. Explain why lamp P becomes brighter and lamp R becomes dimmer.

[2 marks]

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Question 5 continues on the next page
5 (d) A filament lamp, X, is rated at 60 W 230 V. Another type of lamp, Y, described as ‘energy saving’ has the same light intensity output but is rated at 11 W 230 V.

5 (d) (i) Calculate the electrical energy converted by each lamp if both are on for 4 hours a day for a period of 30 days.

[2 marks]

\[
\text{electrical energy converted by } X = \text{...................................................} \ J
\]

\[
\text{electrical energy converted by } Y = \text{...................................................} \ J
\]

5 (d) (ii) Suggest why the two lamps can have different power ratings but have the same light intensity output.

[2 marks]

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A ‘potato cell’ is formed by inserting a copper plate and a zinc plate into a potato. The circuit shown in Figure 3 is used in an investigation to determine the electromotive force and internal resistance of the potato cell.

Figure 3

6 (a) State what is meant by electromotive force.  

[2 marks]  

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Question 6 continues on the next page
6 (b) The plotted points on Figure 4 show the data for current and voltage that were obtained in the investigation.
6 (b) (i) Suggest what was done to obtain the data for the plotted points. [1 mark]

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6 (b) (ii) The electromotive force (emf) of the potato cell is 0.89 V. Explain why the voltages plotted on Figure 4 are always less than this and why the difference between the emf and the plotted voltage becomes larger with increasing current. [3 marks]

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6 (b) (iii) Use Figure 4 to determine the internal resistance of the potato cell. [3 marks]

internal resistance = .................................................  Ω

Question 6 continues on the next page
A student decides to use two potato cells in series as a power supply for a light emitting diode (LED). In order for the LED to work as required, it needs a voltage of at least 1.6 V and a current of 20 mA.

Explain whether the LED will work as required. [2 marks]

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A cable used in high-voltage power transmission consists of six aluminium wires surrounding a steel wire. A cross-section is shown in Figure 5.

Figure 5

The resistance of a length of 1.0 km of the steel wire is 3.3 \( \Omega \). The resistance of a length of 1.0 km of one of the aluminium wires is 1.1 \( \Omega \).

7 (a) The steel wire has a diameter of 7.4 mm. Calculate the resistivity of steel. State an appropriate unit.

\[ \text{resistivity} = \text{......................... unit ..................} \]

]4 marks]

Question 7 continues on the next page
7 (b) Explain why only a small percentage of the total current in the cable passes through the steel wire.

[3 marks]

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7 (c) The potential difference across a length of 1.0 km of the cable is 75 V.

Calculate the total power loss for a 1.0 km length of cable.

[3 marks]

Total power loss .................................................. W