AQA

Please write clearly in block capitals.

Centre number | | | | | Candidate number | | | |

Surname ______________________

Forename(s) ______________________

Candidate signature ______________________

A-level
PHYSICS A

Unit 5D Turning Points in Physics
Section B

Tuesday 28 June 2016 Morning

Time allowed: The total time for both sections of this paper is 1 hour 45 minutes. You are advised to spend approximately 50 minutes on this section.

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

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 section is 35.
- 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.

Section B

The maximum mark for this section is 35. You are advised to spend approximately 50 minutes on this section.

1 (a) J J Thomson devised the first experiments to determine the specific charge for cathode rays produced in discharge tubes. He found that the value did not depend on the gas in the tube. He also discovered that particles emitted by a heated filament and particles emitted in the photoelectric effect had the same specific charge.

State **two** conclusions that were drawn from Thomson's experiments.

[2 marks]

1 ____

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2 ____

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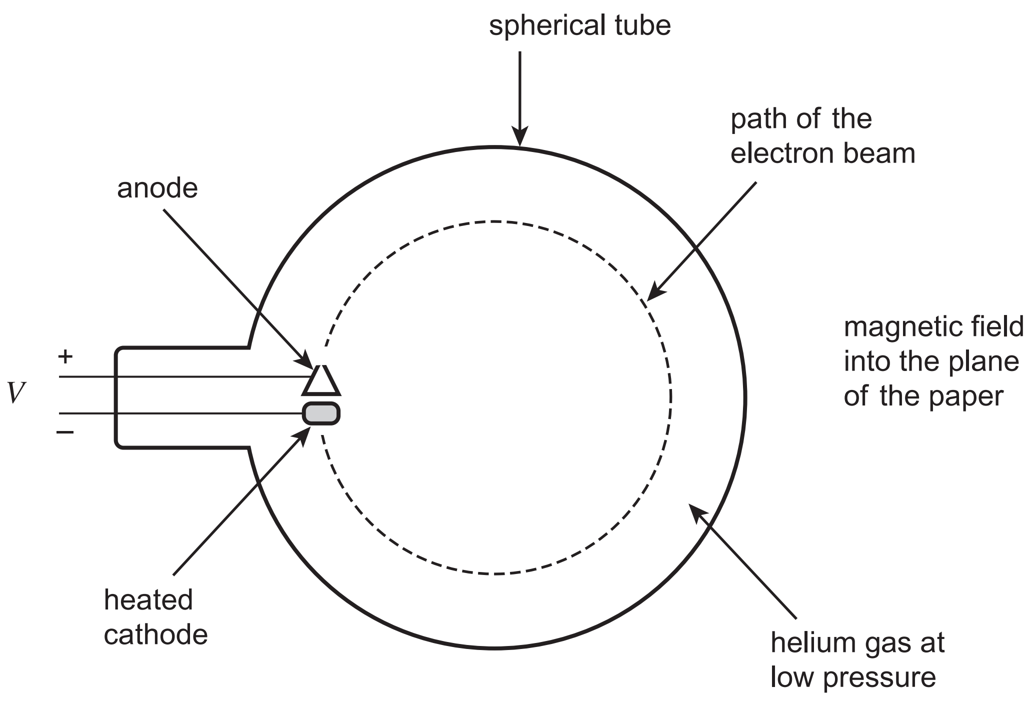
1 (b) **Figure 1** shows a spherical tube, filled with low-pressure helium gas, that is used in an experiment to determine the specific charge of an electron.

Figure 1



Electrons are accelerated by a potential difference (pd) V applied between the cathode and anode. A magnetic field of known flux density B, directed into the plane of the diagram, causes the electrons to move in a circular path.

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1 (b) (i) Explain the process that causes the low-pressure helium gas to emit light so that the path of the electron beam can be seen.

[3 marks]

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1 (b) (ii) In one experiment using the apparatus in **Figure 1**, the accelerating pd is $1.6\ \mathrm{kV}$ and the flux density of the magnetic field is $2.2\ \mathrm{mT}$. The path of the electron beam has a radius of $0.059\ \mathrm{m}$.

Determine a value for the specific charge of an electron using these data.
State an appropriate unit for your answer.

[4 marks]

specific charge = ____________________ unit = ____________

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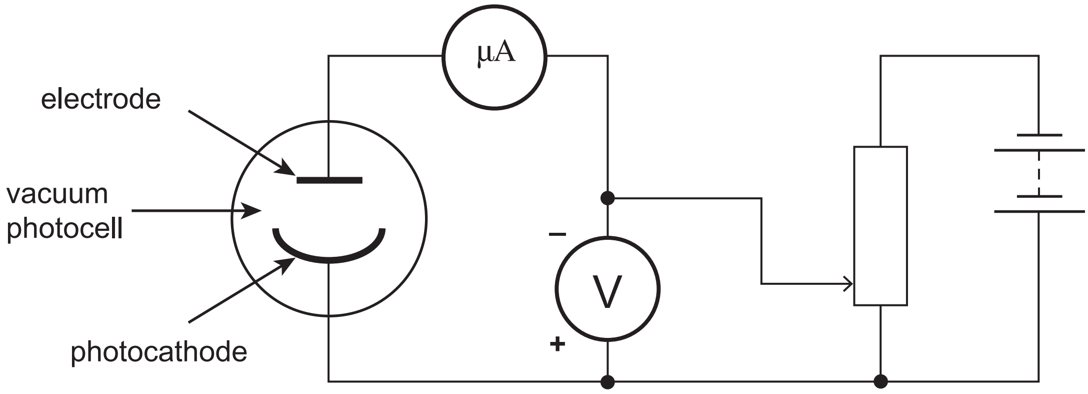
2 (a) The arrangement shown in **Figure 2** is used by a student in a photoelectric effect experiment.

Figure 2



Monochromatic light falls on the photocathode. A current is recorded when the potential difference (pd) between the photocathode and the electrode is zero.
The student gradually increases the magnitude of the pd between the photocathode and electrode and makes observations of the effect this has on the current.

Describe and explain the observations that you would expect the student to make.
In your answer you should refer to:

- the stopping potential
- the kinetic energy of the photoelectrons
- how Einstein's photoelectric equation applies to this experiment.

The quality of your written communication will be assessed in your answer.

[6 marks]

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Question 2 continues on the next page

Turn over ▶

2 (b) Using the circuit in **Figure 2**, the stopping potential recorded is $0.24\ \mathrm{V}$ when light of wavelength $490\ \mathrm{nm}$ is incident on the surface of the photocathode.

2 (b) (i) Calculate the work function of the surface material.

[3 marks]

work function = ____________________________ J

2 (b) (ii) The polarity of the battery in **Figure 2** is now reversed and light of $490\ \mathrm{nm}$ is incident on the photocathode. The energy of the light falling on the surface of the photocathode each second is $6.1\ \mu\mathrm{J}$.

Calculate the maximum current that the microammeter could record.

[2 marks]

maximum current = __________________________ $\mu\mathrm{A}$

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Turn over for the next question

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3 (a) Maxwell predicted the existence of electromagnetic waves that travelled in free space.

Identify the **two** quantities that vary in an electromagnetic wave and state the phase relationship between them.

[2 marks]

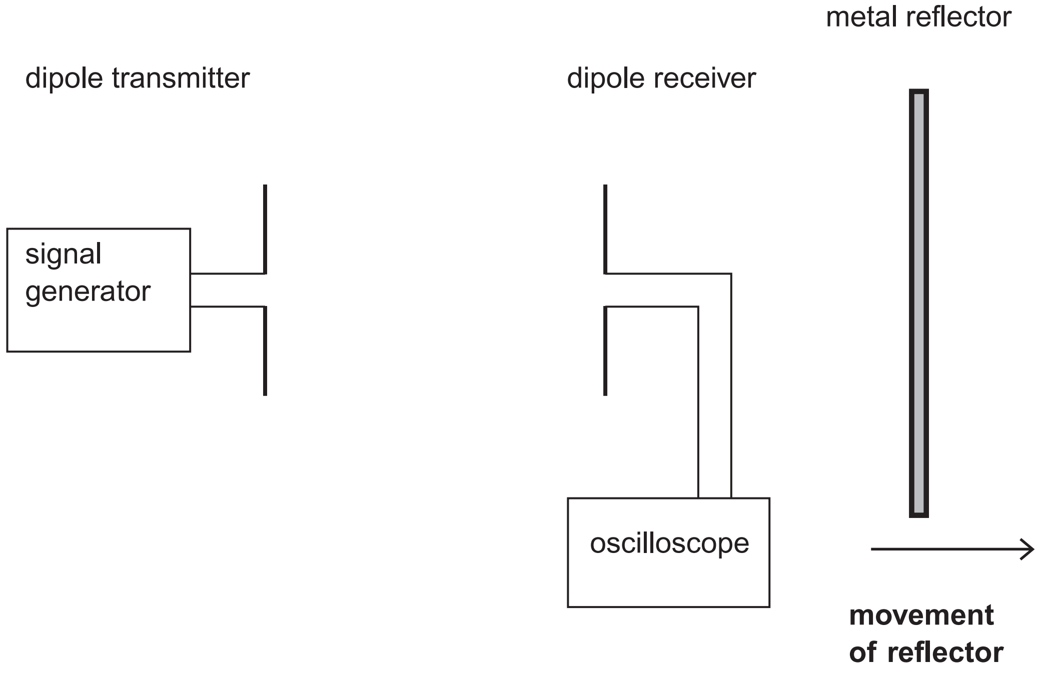
Quantity 1 ______________________________

Quantity 2 ______________________________

Phase relationship ______________________________

3 (b) Hertz determined the speed of electromagnetic waves and found that they travelled at 3.0×10^8 m s^{-1}. **Figure 3** shows an arrangement using radio waves that is similar to that used by Hertz in his determination.

Figure 3



The dipole transmitter radiates an electromagnetic wave of frequency 2.2 GHz.
A signal is detected by the dipole receiver.
When the metal reflector is moved in the direction shown in **Figure 3**, the detected signal strength alternates between maximum and minimum intensities.

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3 (b) (i) Explain why the detected signal strength changes from a maximum to a minimum as the metal reflector is moved.

[3 marks]

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3 (b) (ii) Determine the least distance the reflector has to move for the detected signal strength to change from a maximum to a minimum to confirm Hertz's value for the speed of electromagnetic radiation.

[2 marks]

least distance = ____________________ m

3 (c) Which **one** of the following observations originally led to the conclusion that light is an electromagnetic wave?

Place a tick (✓) in the right-hand column to show the correct answer.

[1 mark]

	✓ if correct
Light is diffracted when it falls on a narrow slit.	
Light travels at 3×10^{8} m s^{-1} in free space.	
Light changes speed when it enters a medium of different optical density.	
Light can be polarised when it passes through Polaroid.	

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4 (a) The theory of special relativity is based on two postulates. One of these postulates is that the speed of light in free space is invariant.
State the other postulate.

[1 mark]

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4 (b) An electron in the Stanford linear accelerator is accelerated to an energy of $24.0\ \mathrm{GeV}$.

4 (b) (i) An electron travelling with this energy has a velocity v.

Show that the value of $\left(1-\frac{v^2}{c^2}\right)^{\frac{1}{2}}$ is about 2.1×10^{-5}.

[3 marks]

4 (b) (ii) The Stanford linear accelerator has a length of $3.0\ \mathrm{km}$. Assume that the electron travels for the full length of the accelerator with an energy of $24\ \mathrm{GeV}$.

Calculate the length, in m, of the accelerator in the reference frame of the electron.

[1 mark]

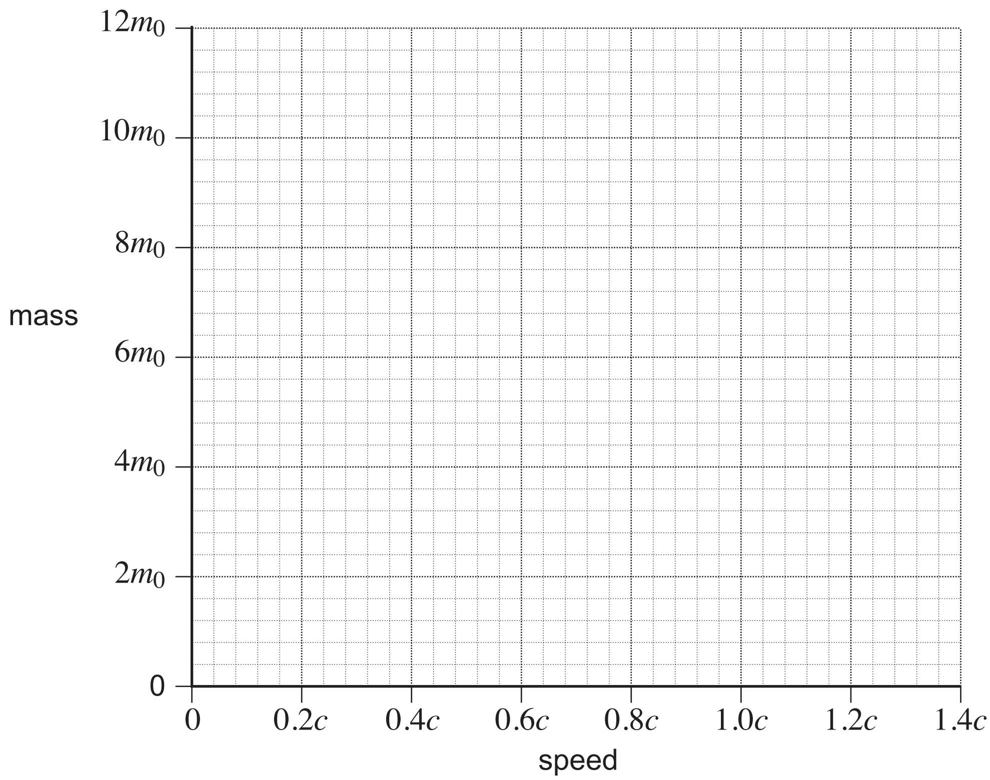
length of accelerator = ____________________________ m

4 (c) Draw a graph on **Figure 4** to show how the relativistic mass of an electron varies with speed as it is accelerated from rest.

Rest mass of an electron = m_0

[2 marks]

Figure 4



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END OF QUESTIONS

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