AQA

Please write clearly in block capitals.

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

Surname _____

Forename(s) _____

Candidate signature _____

I declare this is my own work.

# A-level PHYSICS

## Paper 3
## Section B Turning points in physics

Friday 5 June 2020 Afternoon

Time allowed: The total time for both sections of this paper is 2 hours. You are advised to spend approximately 50 minutes on this section.

**Materials**

For this paper you must have:
- a pencil and a ruler
- a scientific calculator
- a Data and Formulae Booklet.

**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.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Show all your working.

| For Examiner's Use | |
|---|---|
| Question | Mark |
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| **TOTAL** | |

**Information**
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 35.
- You are expected to use a scientific calculator where appropriate.
- A Data and Formulae Booklet is provided as a loose insert.

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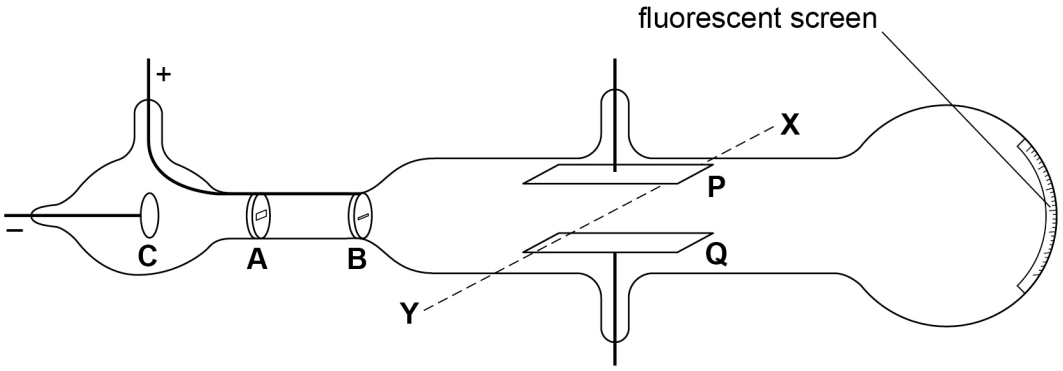
## Section B

Answer **all** questions in this section.

**0 1** **Figure 1** shows a diagram of a discharge tube used by JJ Thomson to investigate cathode rays.

**Figure 1**




The direction **XY** is horizontal and at right angles to the axis of the tube.

**0 1 . 1** When correct connections are made to a high-voltage power supply, a cathode ray is produced. The cathode ray hits the centre of the fluorescent screen.

Describe how a cathode ray is produced in the discharge tube in **Figure 1**.

**[2 marks]**

*Do not write outside the box*

**0 1 . 2** **P** and **Q** are metal plates that can be attached to a second power supply.

In an experiment, a potential difference (pd) is applied across **P** and **Q** so that **P** is positively charged and **Q** is negatively charged. This deflects the cathode ray.

Then a magnetic field is applied between the plates so that the cathode ray follows its original path to the centre of the screen.

What is the direction of the magnetic field?
Tick (✓) **one** box.

**[1 mark]**

from **P** to **Q** ☐

from **Q** to **P** ☐

from **X** to **Y** ☐

from **Y** to **X** ☐

**Question 1 continues on the next page**

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**0 1 . 3** Changes are made to the apparatus so that the particles in the cathode ray travel with a greater speed as they pass between plates **P** and **Q**.

Explain how the cathode ray is restored to its original path by adjusting:

- only the electric field strength between **P** and **Q**
- only the magnetic flux density.

**[3 marks]**

electric field strength only _____

magnetic flux density only _____

**0 1 . 4** Using the apparatus in **Figure 1**, Thomson determined the specific charge of the particles in the cathode rays. Thomson compared this result with the specific charge of the hydrogen ion.

Discuss the significance of Thomson's results for the particles in cathode rays, when compared with the specific charge of the hydrogen ion.

**[2 marks]**

**8**

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**Turn over for the next question**

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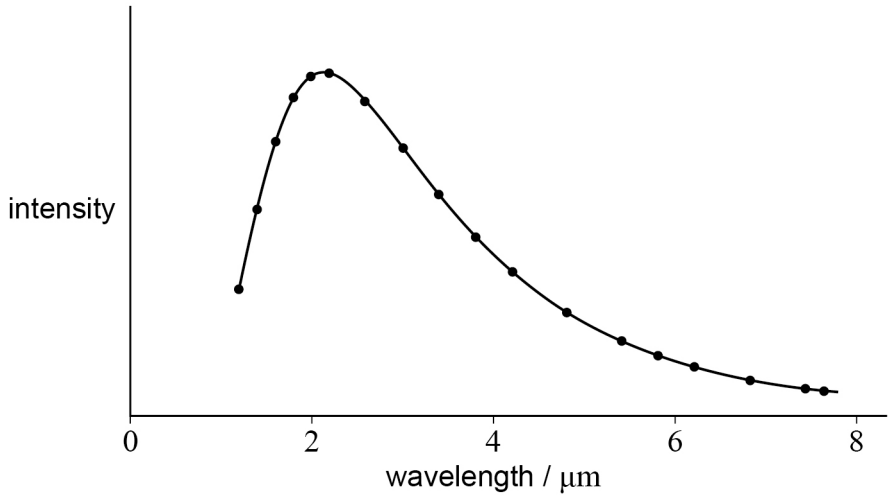
**ANSWER IN THE SPACES PROVIDED**

**0 2** At the end of the 19th century new information was obtained about black-body radiation and the photoelectric effect. This information challenged classical physics theories.

In 1895, Wien and Lummer carried out experiments to measure black-body radiation accurately.

**Figure 2** shows a typical black-body radiation curve of the type obtained by Wien and Lummer.

**Figure 2**




**0 2 . 1** State what is meant by black-body radiation.

**[2 marks]**

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**0 2 . 2** Describe how the predictions of classical theory compare with Wien and Lummer's experimental results.

Annotate **Figure 2** as part of your answer.

**[2 marks]**

**0 2 . 3** In 1900 Max Planck suggested a solution to the problems of the classical theory.

Outline the main aspects of his suggestion.

**[2 marks]**

**Question 2 continues on the next page**

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**0 2 . 4** Planck's suggestion was developed by Albert Einstein to explain the results of photoelectric effect experiments.

Discuss Einstein's explanation of photoelectricity and its significance in terms of the nature of electromagnetic radiation.

In your answer you should

- describe **two** relevant observations made in photoelectric experiments
- explain the failure of classical physics to account for these observations
- include the main aspects of Einstein's theory and how he explained the observations.

**[6 marks]**

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12

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**0 3 . 1** The scanning tunnelling microscope (STM) uses a process called quantum tunnelling.

Explain what is meant by quantum tunnelling of an electron in an STM.
You may include a diagram as part of your answer.

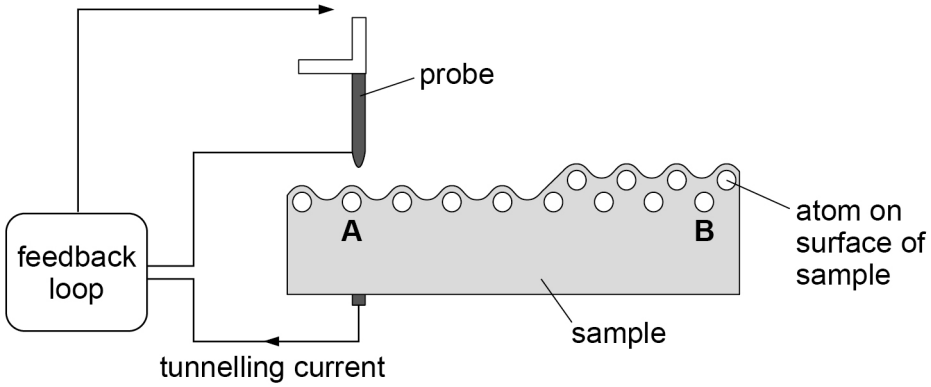
**[2 marks]**

**Question 3 continues on the next page**

**0 3 . 2** An STM is used to map the positions of the atoms between points **A** and **B** on the surface of a sample.

**Figure 3** shows some of the features of the operation of an STM.

**Figure 3**




The STM in **Figure 3** is in constant-current mode.

Describe how the STM creates a map of the positions of one row of atoms on the surface of the sample from **A** to **B**.

**[3 marks]**

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**0 3 . 3** The smallest size of objects that the STM can resolve is similar to the de Broglie wavelength of the tunnelling electrons.

Deduce whether electrons with kinetic energies less than $1.5\ \text{eV}$ are suitable to map the surface in **Figure 3**.

**[3 marks]**

8

**Turn over for the next question**

**0 4 . 1** A muon travels at a speed of $0.95c$ relative to an observer.

The muon travels a distance of $2.5 \times 10^3$ m between two points in the frame of reference of the observer.

Calculate the distance between these two points in the frame of reference of the muon.

**[2 marks]**

distance = _____ m

**0 4 . 2** Measurements of muons created by cosmic rays can be used to demonstrate relativistic time dilation.

State the measurements made and the observation that provides evidence for relativistic time dilation.

**[2 marks]**

_____

_____

_____

_____

_____

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**0 4 . 3** As the muons travel through the atmosphere, their speeds are reduced by interaction with the particles in the air.

Discuss, with reference to relativity, the effect that this reduction of speed has on the rate of detection of the muons on the surface of the Earth.

**[3 marks]**

7

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