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.

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.

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

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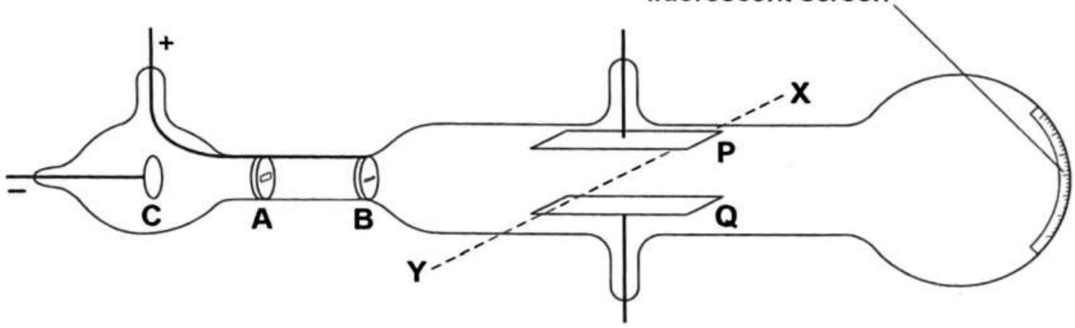
Section B

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]

~~A is the filament and B is the anode~~. A high electric field pulls electrons from the gas atoms. positive ions in the tube are accelerated to the cathode and strike the surface. Electrons are emitted and accelerated towards A (and B).

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

Turn over ▶

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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 when the path is Straight, electric force = magnetic force.
∴ $Eq = BqV$, rearranging to give $V = \frac{E}{B}$.

∴ To restore to the original path, increase electric field

magnetic flux density only

or decrease magnetic flux density because this will increase V, the ~~sp~~ velocity

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]

Magnitude of their specific charge is much greater than the specific charge of hydrogen. The cathode ray particles mass is much small than the hydrogen ~~and therefore~~
and ∴ they are Smaller.

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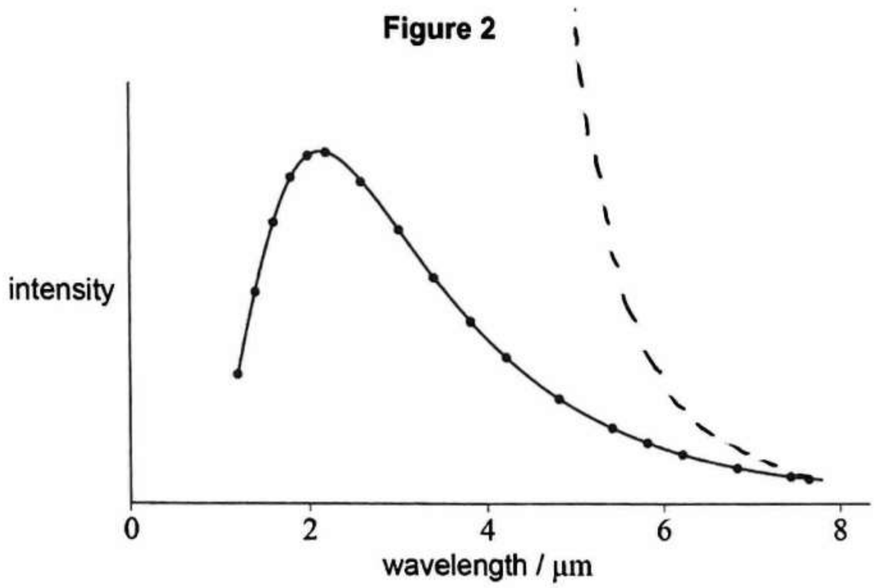
0 2 At the end of the 19th century new information was obtained about black-body radiation and the photoelectric effect. This information challenged classical physics theories.

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]

It is electro-magnetic radiation that has a spectrum as depicted in the diagram, with a peak that depends on temperature

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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]

~~Descr~~ Classical theory said that instead of a peak intensity, there is an intensity increase that is infinity at short wavelengths. Classical theory did agree though that there would be similar intensities at long wavelengths

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]

He suggested that electromagnetic radiation is emitted in quanta, and that the energy of a quantum is related to a single frequency

i.e $E = hf$

Question 2 continues on the next page

Turn over ▶

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]

In photoelectric experiments, one observation was that there is no photoelectric emission if the incident light is below the threshold frequency. Another observation was that ~~the~~ ~~Aum~~ photoelectric emission is instantaneous and occurs as soon as light is incident on the metal surface

classical physics was problematic because it stated that ~~intensity~~ of the wave energy is spread over the surface meaning it should take longer for the electrons to accumulate enough energy to be emitted. Meaning classical wave theory said that it was not instantaneous. Classical physics also said that light of any frequency

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should cause emission, which is incorrect as it must be above the threshold frequency.

Einstein could explain these observations. He said that light is made up of photons, and that photoelectrons are emitted in the photoelectric effect because one photon interacts with one electron. He stated that there is a minimum energy needed for an electron emitted, and the remaining energy of the photon becomes the maximum kinetic energy of the photo electron. A brighter source means more photons and ∴ more photoelectrons.

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Turn over for the next question

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]

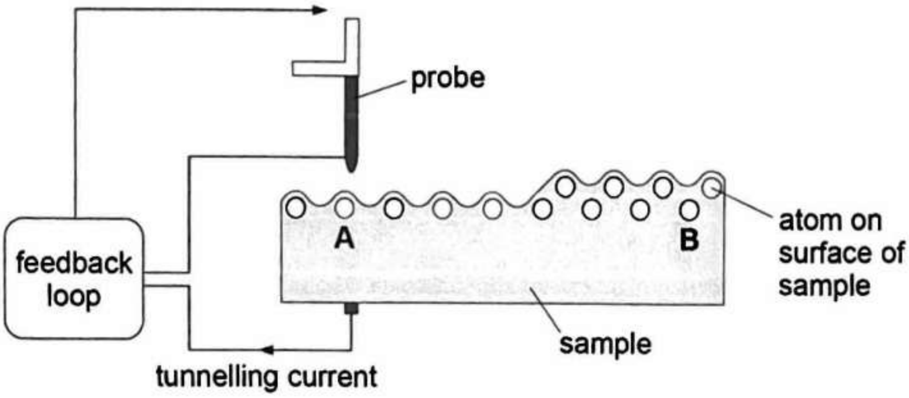
The electrons don't have enough energy to overcome the potential barrier. However, a fraction of the electrons will move from sample to tip by quantum tunneling.

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]

The tip of the probe is kept at around 1nm above the surface of the sample. There is a current in the probe due to tunnelling, and when the probe moves over a higher layer of electrons, the current increases. Through a feedback process, the tip is moved higher to reduce the current to the original value. Hence the surface is mapped by the position of the tip.

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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 eV are suitable to map the surface in **Figure 3**.

[3 marks]

KE = electron energy

$\frac{1}{2}mv^2 = eV$

$\frac{1}{2} \times 9.11\times10^{-3} \times v^2 = e \times 1.5$

$= 2.4 \times 10^{-19}$ J

$v = \sqrt{\frac{2.4\times10^{-19}\times2}{9.11\times10^{-31}}} = 7.26\times10^5$

$\lambda = \frac{h}{mv} = \frac{6.63\times10^{-34}}{9.11\times10^{-31}\times7.26\times10^5} = 1.0\times10^{-9}$ m

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They are not suitable because λ should be less than 1 nm

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 2.5×10^3 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]

$l_0 = 2500$ m

$l = 2500 \times \sqrt{1 - 0.95^2}$

$= 780.6$ m

distance = 781 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]

Measure no. of muons passing through a detector per second in the upper atmosphere and on the ground. Measurements show that far less muons decay than expected in the time taken for muons to travel from the upper atmosphere to the ground, in the observers frame of reference.

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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]

~~Low velocity~~ A lower velocity means that the muons take longer to travel to the ground in either frame of reference. Thus the time dilation is less in Earths frame of reference. So more muons decay before reaching the ground. So the rate of detection is reduced.

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END OF QUESTIONS