Access Tuition

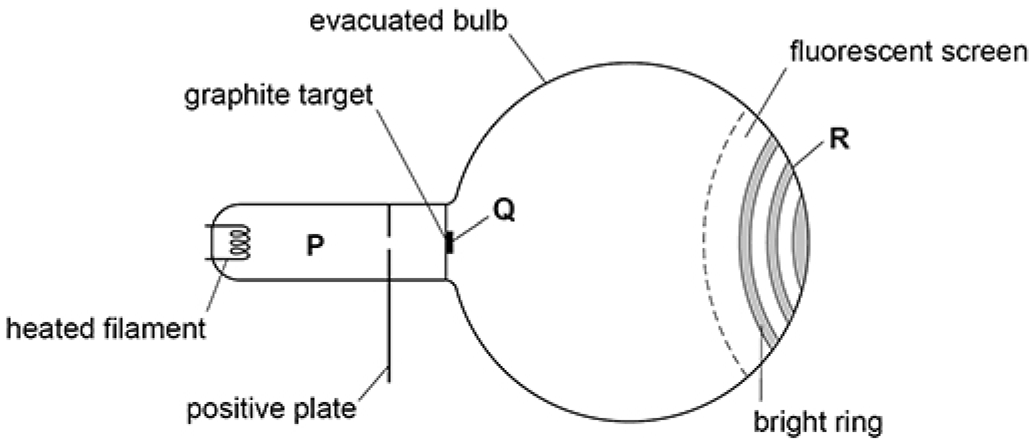
A-Level Physics

Waves Particle Duality

Question Paper

Time available: 62 minutes
Marks available: 51 marks

1. The figure below shows apparatus used to demonstrate the wave–particle duality of electrons.



The heated filament emits slow-moving electrons.

In region **P**, the electrons are accelerated to a high speed.
At **Q**, the fast-moving electrons are incident on the graphite target.
R is a point on one of the bright rings that are formed where the electrons strike the fluorescent screen.

(a) The electrons demonstrate wave-like and particle-like behaviour as they travel from the filament to the screen.

State and explain at which of **P**, **Q** or **R** the electrons are demonstrating wave-like behaviour.

____

____

____

____

(2)

(b) The apparatus is adjusted so that the electrons are incident on the graphite target with a greater speed.

Explain why the bright rings formed on the screen now have a smaller diameter.

____

____

____

____

____

____

(3)

(Total 5 marks)

2. The table shows results of an experiment to investigate how the de Broglie wavelength λ of an electron varies with its velocity v.

v / 10^7 m s^{-1}	λ / 10^{-11} m
1.5	4.9
2.5	2.9
3.5	2.1

(a) Show that the data in the table are consistent with the relationship $\lambda \propto \frac{1}{v}$

____

(2)

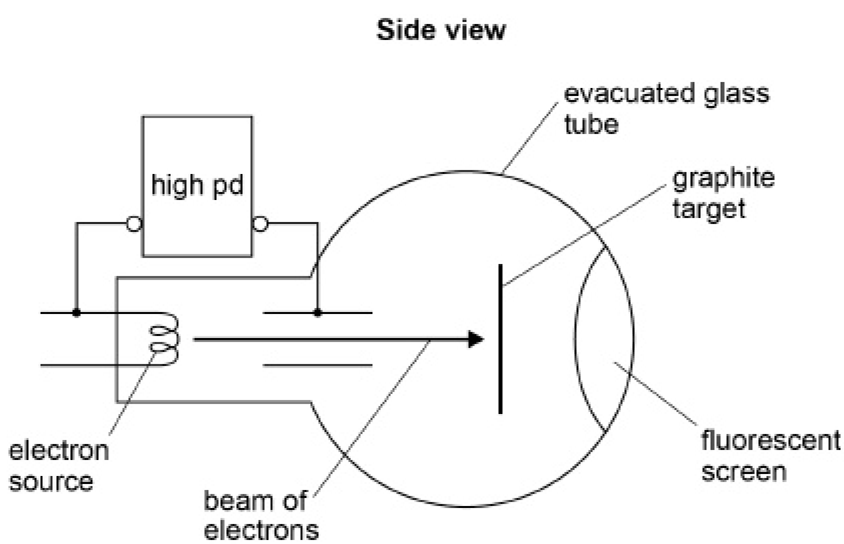
(b) Calculate a value for the Planck constant suggested by the data in the table.

Planck constant = ____________________ J s

(2)

(c) **Figure 1** shows the side view of an electron diffraction tube used to demonstrate the wave properties of an electron.

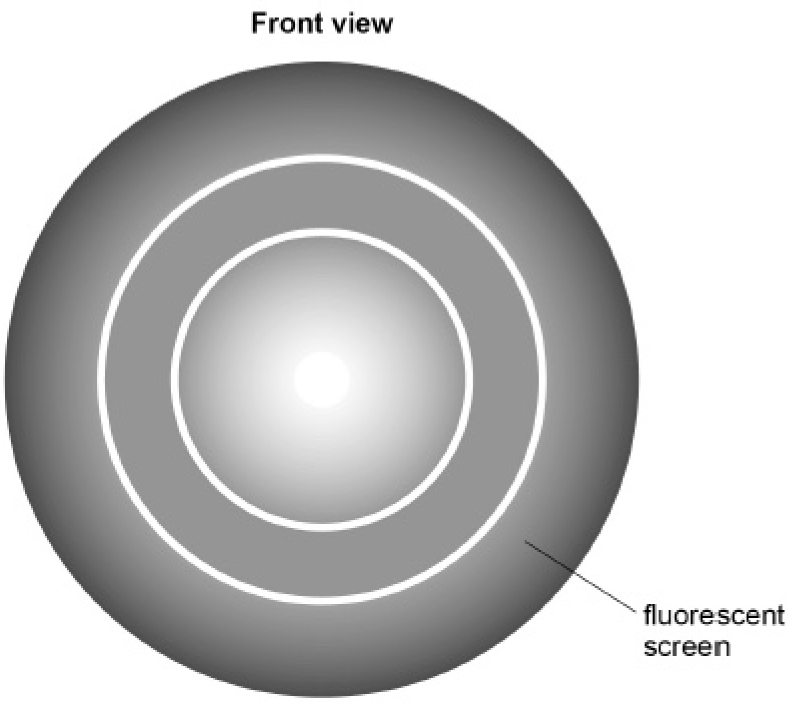
Figure 1



An electron beam is incident on a thin graphite target that behaves like the slits in a diffraction grating experiment. After passing through the graphite target the electrons strike a fluorescent screen.

Figure 2 shows the appearance of the fluorescent screen when the electrons are incident on it.

Figure 2



Explain how the pattern produced on the screen supports the idea that the electron beam is behaving as a wave rather than as a stream of particles.

____

____

____

____

____

____

____

____

____

(3)

(d) Explain how the emission of light from the fluorescent screen shows that the electrons incident on it are behaving as particles.

____

____

____

____

____

____

____

____

____

(3)

(Total 10 marks)

3. (a) What phenomenon can be used to demonstrate the wave properties of electrons?

____

(1)

(b) Calculate the wavelength of electrons travelling at a speed of 2.5×10^5 ms^{-1}.

Give your answer to an appropriate number of significant figures.

wavelength ______________________ m

(3)

(c) Calculate the speed of muons with the same wavelength as these electrons.

mass of muon = 207 × mass of electron

speed ____________________ ms^{-1}

(2)

(Total 6 marks)

4. (a) When monochromatic light is shone on a clean cadmium surface, electrons with a range of kinetic energies up to a maximum of 3.51×10^{-20} J are released. The *work function* of cadmium is 4.07 eV.

(i) State what is meant by work function.

____

____

____

____

(2)

(ii) Explain why the emitted electrons have a range of kinetic energies up to a maximum value.

____

____

____

____

____

____

(4)

(iii) Calculate the frequency of the light. Give your answer to an appropriate number of significant figures.

answer = ____________________ Hz

(4)

(b) In order to explain the photoelectric effect the wave model of electromagnetic radiation was replaced by the photon model. Explain what must happen in order for an existing scientific theory to be modified or replaced with a new theory.

___

___

___

(2)

(Total 12 marks)

5. (a) State what is meant by the wave-particle duality of electrons.

___

___

___

(1)

(b) Electrons of wavelength 1.2×10^{-10} m are required to investigate the spacing between planes of atoms in a crystal.

(i) Calculate the momentum of an electron of this wavelength stating an appropriate unit.

momentum of electron = ____________________

(3)

(ii) Calculate the speed of such an electron.

speed of electron = ____________________ m s^{-1}

(2)

(iii) Calculate the kinetic energy of such an electron.

kinetic energy of electron = ____________________ J

(2)

(Total 8 marks)

6. (a) (i) State what is meant by the *wave-particle duality* of electromagnetic radiation.

____

____

(ii) Which aspect of the dual nature of electromagnetic radiation is demonstrated by the photoelectric effect?

____

____

____

(2)

(b) A metal plate is illuminated with ultra violet radiation of frequency 1.67×10^{15} Hz. The maximum kinetic energy of the liberated electrons is 3.0×10^{-19} J.

(i) Calculate the work function of the metal.

____

____

____

____

____

(ii) The radiation is maintained at the same frequency but the intensity is doubled. State what changes, if any, occur to the number of electrons released per second and to the maximum kinetic energy of these electrons.

number per second ____

maximum kinetic energy ____

(iii) The metal plate is replaced by another metal plate of different material. When illuminated by radiation of the same frequency no electrons are liberated. Explain why this happens and what can be deduced about the work function of the new metal.

____

____

____

____

____

(8)

(Total 10 marks)