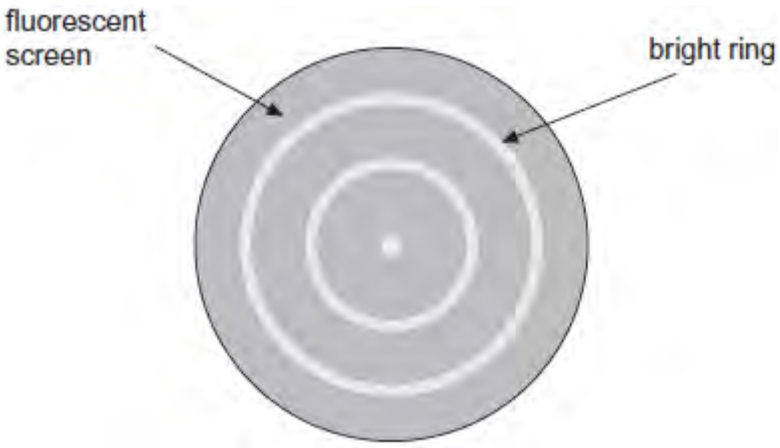
Q1. In an electron diffraction tube, high speed electrons are produced by an electron gun at one end of the tube. The electrons are incident on a thin slice of a polycrystalline material. The diagram shows the pattern of bright rings that is formed on the fluorescent screen at the other end of the tube.



(a) Explain how the production of bright rings suggests that the electrons behave like waves.

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(1)

(b) The electrons in the tube have a velocity of 3.5×10^7 m s^{-1}.

Calculate the de Broglie wavelength of the electrons.

de Broglie wavelength ..... m

(2)

(Total 3 marks)

Q2. Electrons and protons in two beams are travelling at the same speed. The beams are diffracted by objects of the same size.

Which correctly compares the de Broglie wavelength λ_e of the electrons with the de Broglie wavelength λ_p of the protons and the width of the diffraction patterns that are produced by these beams?

	comparison of de Broglie wavelength	diffraction pattern	
A	$\lambda_e > \lambda_p$	electron beam width > proton beam width	⬭
B	$\lambda_e < \lambda_p$	electron beam width > proton beam width	⬭
C	$\lambda_e > \lambda_p$	electron beam width < proton beam width	⬭
D	$\lambda_e < \lambda_p$	electron beam width < proton beam width	⬭

(Total 1 mark)

Q3. The intensity of a monochromatic light source is increased. Which of the following is correct?

	Energy of an emitted photon	**Number of photons emitted per second**	
A	increases	increases	⬭
B	increases	unchanged	⬭
C	unchanged	increases	⬭
D	unchanged	unchanged	⬭

(Total 1 mark)

Q4. When comparing X-rays with UV radiation, which statement is correct?

A X-rays have a lower frequency. ⬭

B X-rays travel faster in a vacuum. ⬭

C X-rays do not show diffraction and interference effects. ⬭

D Using the same element, photoelectrons emitted using X-rays have the greater maximum kinetic energy. ⬭

(Total 1 mark)

Q5. An electron has a kinetic energy E and a de Broglie wavelength λ. The kinetic energy is increased to $4E$. What is the new de Broglie wavelength?

A $\frac{\lambda}{4}$ ⬭

B $\frac{\lambda}{2}$ ⬭

C λ ⬭

D 4λ ⬭

(Total 1 mark)

Q6.(a) What phenomenon can be used to demonstrate the wave properties of electrons?

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(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)

Q7. (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.

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(2)

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

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(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.

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(2)
(Total 12 marks)

Q8. (a) J.J. Thompson investigated the nature of cathode rays in discharge tubes. Suggest how he could have demonstrated that the cathode rays were negatively charged particles.

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(2)

(b) In an experiment, electrons are incident on a thin piece of graphite. The electrons emerging from the graphite strike a fluorescent screen and produce the pattern

shown in the figure below.

State and explain the evidence this provides about the nature of moving electrons.

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(2)

(c) High energy electrons may be used to investigate the nature of protons of diameter 2.4×10^{-15} m.

(i) Calculate the lowest value of the momentum of the high energy electrons that would be suitable for this investigation.
State an appropriate unit for your answer.

momentum ..... unit .....

(3)

(ii) Calculate the kinetic energy of the electrons.

kinetic energy ..... J

(2)
(Total 9 marks)

Q9. (a) When free electrons collide with atoms in their *ground state*, the atoms can be excited or ionised.

(i) State what is meant by ground state.

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(1)

(ii) Explain the difference between excitation and ionisation.

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(3)

(b) An atom can also become excited by the absorption of photons. Explain why only photons of certain frequencies cause excitation in a particular atom.

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(4)

(c) The ionisation energy of hydrogen is 13.6 eV. Calculate the minimum frequency necessary for a photon to cause the ionisation of a hydrogen atom. Give your answer to an appropriate number of significant figures.

answer .....Hz

(4)
(Total 12 marks)

Q10. An electron has a speed of 8.4×10^5 m s^{-1}.

Calculate the de Broglie wavelength of this electron.

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de Broglie wavelength ..... m

(Total 2 marks)

Q11. When a clean metal surface in a vacuum is irradiated with ultraviolet radiation of a certain frequency, electrons are emitted from the metal.

(a) (i) Explain why the kinetic energy of the emitted electrons has a maximum value.

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(2)

(ii) Explain with reference to the work function why, if the frequency of the radiation is below a certain value, electrons are not emitted.

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(2)

(iii) State a unit for work function.

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(1)

(b) Light energy is incident on each square millimetre of the surface at a rate of 3.0×10^{-10} J s^{-1}. The frequency of the light is 1.5×10^{15} Hz.

(i) Calculate the energy of an incident photon.

answer = ... J

(2)

(ii) Calculate the number of photons incident per second on each square millimetre of the metal surface.

answer = ...

(2)

(c) In the wave theory model of light, electrons on the surface of a metal absorb energy from a small area of the surface.

(i) The light striking the surface delivers energy to this small area at a rate of 3.0×10^{-22} J s^{-1}.
The minimum energy required to liberate the electron is 6.8×10^{-19} J.
Calculate the minimum time it would take an electron to absorb this amount of energy.

answer = ... s

(1)

(ii) In practice the time delay calculated in part c (i) does not occur. Explain how this experimental evidence was used to develop the particle model for the behaviour of light.

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(2)
(Total 12 marks)