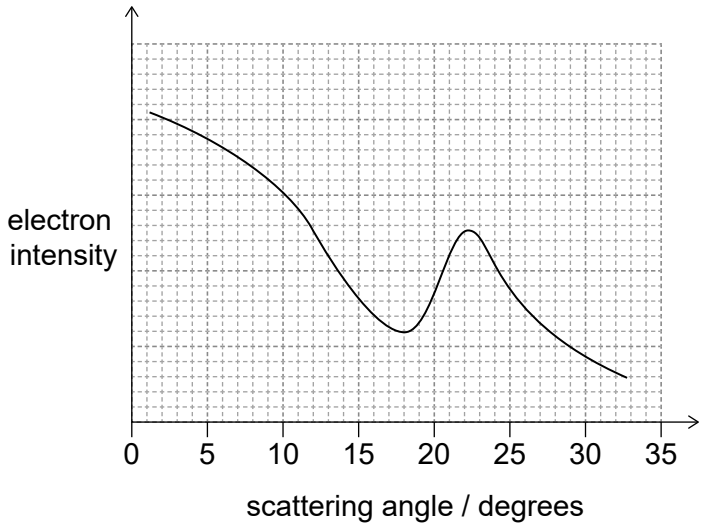
2. (a) A beam of electrons each of de Broglie wavelength 2.4×10^{-15} m is incident on a thin film of silicon-30 $\left({}^{30}_{14}\text{Si}\right)$. The variation in the electron intensity of the beam with scattering angle is shown.



(i) Use the graph to show that the nuclear radius of silicon-30 is about 4 fm. [3]

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(ii) Estimate, using the result from (a)(i), the nuclear radius of thorium-232 $\left({}^{232}_{90}\text{Th}\right)$. [2]

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(This question continues on the following page)

(Question 2 continued)

(iii) Suggest **one** reason why a beam of electrons is better for investigating the size of a nucleus than a beam of alpha particles of the same energy. [1]

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(iv) Outline why deviations from Rutherford scattering are observed when high-energy alpha particles are incident on nuclei. [2]

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(This question continues on the following page)

(Question 8 continued)

(b) The Bohr model for hydrogen can be applied to the singly-ionized helium atom. In this model the radius r, in m, of the orbit of the electron is given by $r = 2.7 \times 10^{-11} \times n^2$ where n is a positive integer.

(i) Show that the de Broglie wavelength λ of the electron in the $n = 3$ state is $\lambda = 5.1 \times 10^{-10}$ m.

The formula for the de Broglie wavelength of a particle is $\lambda = \frac{h}{mv}$. [2]

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(ii) Estimate for $n = 3$, the ratio $\frac{\text{circumference of orbit}}{\text{de Broglie wavelength of electron}}$.

State your answer to one significant figure. [1]

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(c) The description of the electron is different in the Schrodinger theory than in the Bohr model. Compare and contrast the description of the electron according to the Bohr model and to the Schrodinger theory. [3]

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11. (a) Monochromatic light of very low intensity is incident on a metal surface. The light causes the emission of electrons almost instantaneously. Explain how this observation

(i) does not support the wave nature of light. [2]

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(ii) does support the photon nature of light. [2]

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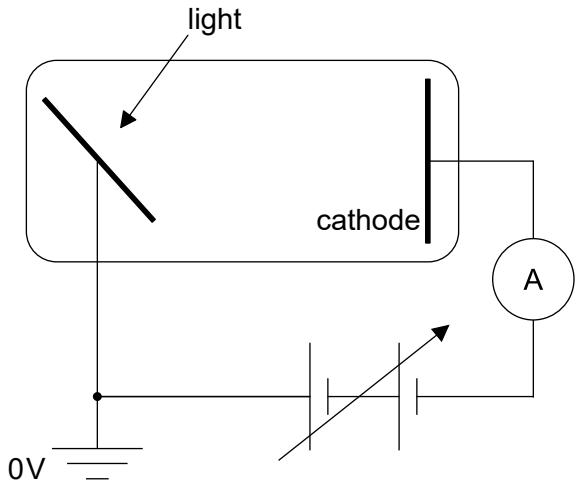
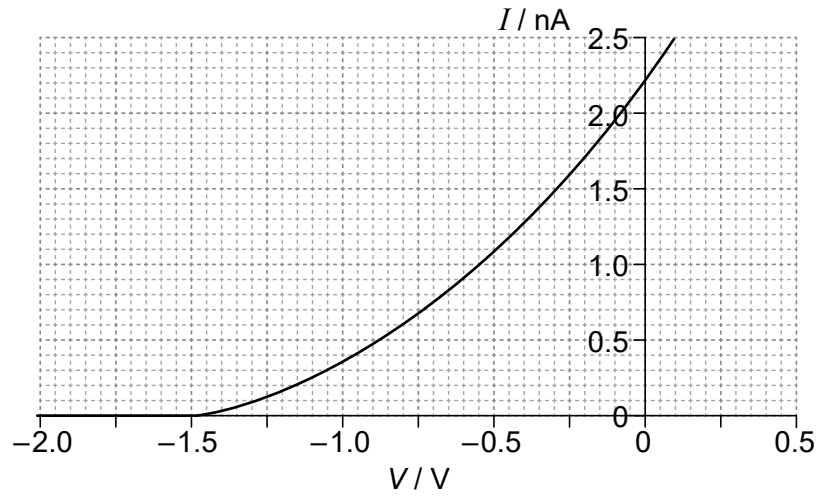
(Question 11 continued)

(b) In an experiment to demonstrate the photoelectric effect, light of wavelength 480 nm is incident on a metal surface.



The graph shows the variation of the current I in the ammeter with the potential V of the cathode.



(i) Calculate, in eV, the work function of the metal surface. [3]

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(This question continues on the following page)

(Question 11 continued)

(ii) The intensity of the light incident on the surface is reduced by half without changing the wavelength. Draw, on the graph, the variation of the current I with potential V after this change. [2]

11. (a) Suggest why de Broglie's hypothesis is **not** consistent with Bohr's conclusion that the electron's orbit in the hydrogen atom has a well defined radius. [2]

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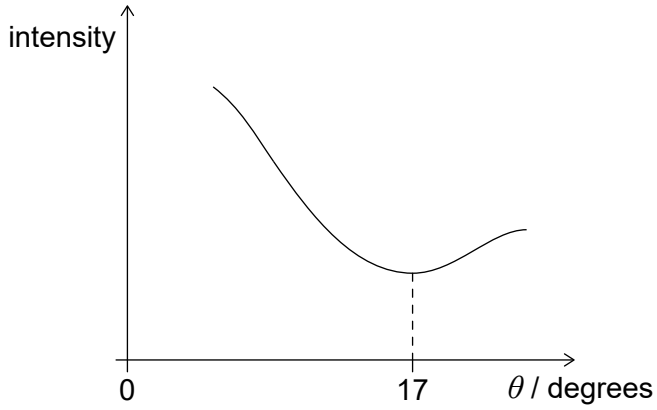
(b) In an experiment to determine the radius of a carbon-12 nucleus, a beam of neutrons is scattered by a thin film of carbon-12. The graph shows the variation of intensity of the scattered neutrons with scattering angle. The de Broglie wavelength of the neutrons is 1.6×10^{-15} m.



(i) Estimate, using the graph, the radius of a carbon-12 nucleus. [2]

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(ii) The ratio $\frac{\text{volume of a nucleus of mass number } A}{\text{volume of a nucleon}}$ is approximately A.

Comment on this observation by reference to the strong nuclear force. [2]

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(This question continues on the following page)

(Question 11 continued)

(c) A pure sample of copper-64 has a mass of 28 mg. The decay constant of copper-64 is 5.5×10^{-2} hour^{-1}.

(i) Estimate, in Bq, the initial activity of the sample. [2]

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(ii) Calculate, in hours, the time at which the activity of the sample has decreased to one-third of the initial activity. [2]

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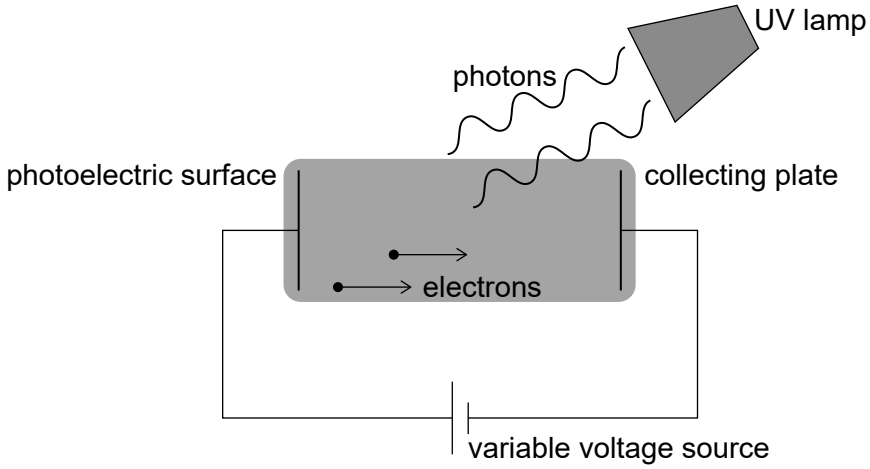
8. Hydrogen atoms in an ultraviolet (UV) lamp make transitions from the first excited state to the ground state. Photons are emitted and are incident on a photoelectric surface as shown.



(a) Show that the energy of photons from the UV lamp is about 10 eV. [2]

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(b) The photons cause the emission of electrons from the photoelectric surface. The work function of the photoelectric surface is 5.1 eV.

(i) Calculate, in J, the maximum kinetic energy of the emitted electrons. [2]

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(ii) Suggest, with reference to conservation of energy, how the variable voltage source can be used to stop all emitted electrons from reaching the collecting plate. [2]

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(This question continues on the following page)

(Question 8 continued)

(iii) The variable voltage can be adjusted so that no electrons reach the collecting plate. Write down the minimum value of the voltage for which no electrons reach the collecting plate. [1]

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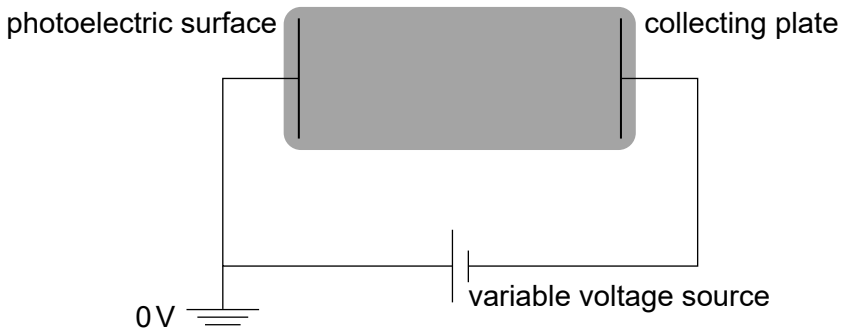
(c) The electric potential of the photoelectric surface is 0 V. The variable voltage is adjusted so that the collecting plate is at −1.2 V.



(i) On the diagram, draw and label the equipotential lines at −0.4 V and −0.8 V. [2]

(ii) An electron is emitted from the photoelectric surface with kinetic energy 2.1 eV. Calculate the speed of the electron at the collecting plate. [2]

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(Question 8 continued)

(d) State **one** assumption that needs to be made so that the Earth-thundercloud system may be modelled by a parallel plate capacitor. [1]

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9. (a) Rutherford constructed a model of the atom based on the results of the alpha particle scattering experiment. Describe this model. [2]

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(b) Bohr modified the Rutherford model by introducing the condition $mvr = n\frac{h}{2\pi}$. Outline the reason for this modification. [3]

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(This question continues on the following page)

(Question 9 continued)

(c) (i) Show that the speed v of an electron in the hydrogen atom is related to the radius r of the orbit by the expression

$$v = \sqrt{\frac{ke^2}{m_e r}}$$

where k is the Coulomb constant. [1]

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(ii) Using the answer in (b) and (c)(i), deduce that the radius r of the electron's orbit in the ground state of hydrogen is given by the following expression. [2]

$$r = \frac{h^2}{4\pi^2 k m_e e^2}$$

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(iii) Calculate the electron's orbital radius in (c)(ii). [1]

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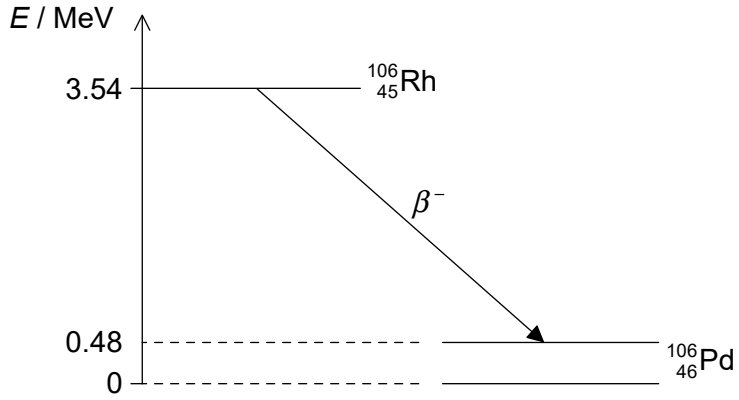
(Question 9 continued)

(d) Rhodium-106 $\left({}^{106}_{45}\text{Rh}\right)$ decays into palladium-106 $\left({}^{106}_{46}\text{Pd}\right)$ by beta minus (β^-) decay. The diagram shows some of the nuclear energy levels of rhodium-106 and palladium-106. The arrow represents the β^- decay.



(i) Explain what may be deduced about the energy of the electron in the β^- decay. [3]

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(ii) Suggest why the β^- decay is followed by the emission of a gamma ray photon. [1]

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(iii) Calculate the wavelength of the gamma ray photon in (d)(ii). [2]

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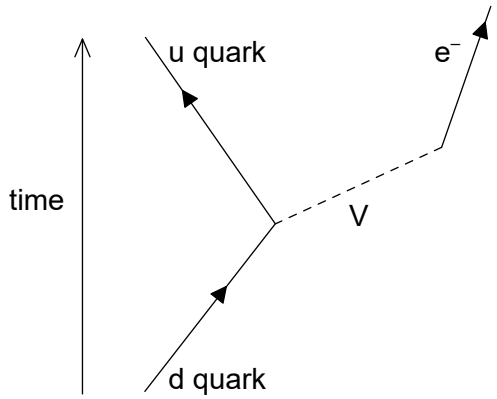
(Question 9 continued)

(e) β^- decay is described by the following incomplete Feynman diagram.



(i) Draw a labelled arrow to complete the Feynman diagram. [1]

(ii) Identify particle V. [1]

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