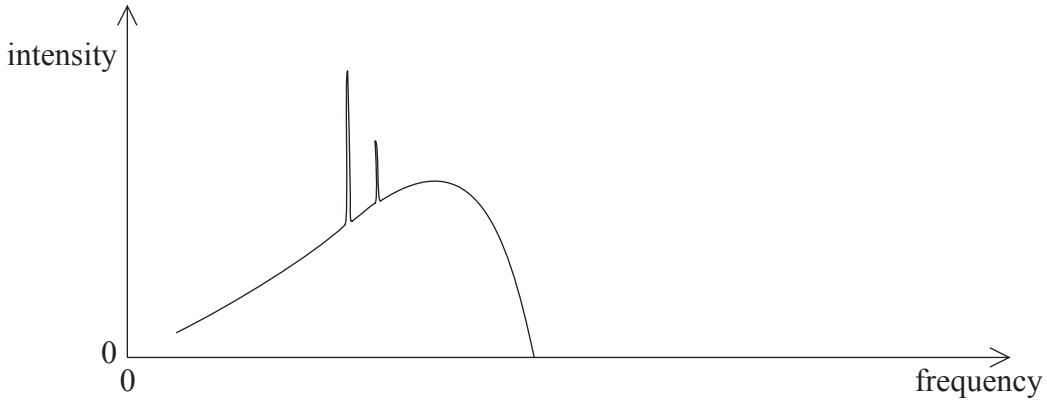
Option B — Quantum Physics and Nuclear Physics

B1. This question is about X-ray spectra.

The diagram shows the X-ray spectrum produced when electrons are accelerated from rest through a potential difference of 25 kV and are then incident on a metal target.



(a) Calculate the minimum X-ray wavelength. *[3]*

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(b) The electrons are now accelerated through a potential difference of 50 kV. On the diagram above draw the new X-ray spectrum. *[2]*

B2. This question is about atomic line spectra.

(a) Explain how the wavelengths of an atomic line spectrum relate to atomic energy levels. *[3]*

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(b) The wavelengths in the line spectrum of atomic hydrogen are 656 nm and 486 nm.

(i) A photon of wavelength 656 nm has an energy of 1.88 eV.

Deduce that a photon of wavelength 486 nm has an energy of 2.54 eV. *[1]*

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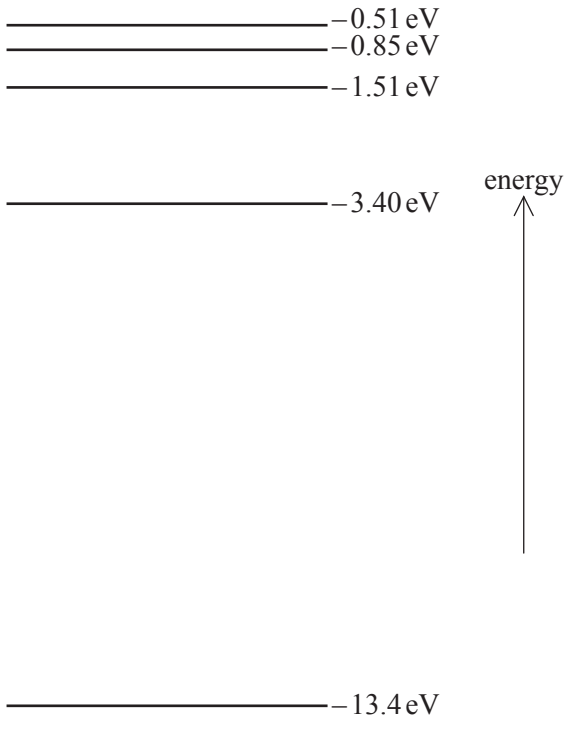
(ii) The diagram below shows some of the energy levels of atomic hydrogen.



On the diagram above, draw arrows to represent the electron transitions that produce these two wavelengths. *[2]*

B3. This question is about radioactivity.

(a) The nuclear decay equation for the radioactive isotope carbon-14 is shown below.

$$^{14}_{6}\mathrm{C} \rightarrow {}^{14}_{7}\mathrm{N} + {}^{0}_{-1}\mathrm{e} + \mathrm{X}$$

State the name of

(i) particle X. *[1]*

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(ii) the class of fundamental particle to which $^{0}_{-1}\mathrm{e}$ belongs. *[1]*

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(b) Wood in a living tree contains the isotope carbon-14. When the tree dies the amount of carbon-14 in the wood from the tree decreases.

(i) The half-life of carbon-14 is 5700 year. Deduce that the decay constant of carbon-14 is $1.2 \times 10^{-4}\,\text{year}^{-1}$. *[1]*

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(ii) The activity of carbon-14 in 1.0 g of living wood is 0.24 Bq. The activity of an ancient bowl made from the same type of wood is 0.075 Bq per gram.

Determine the age of the bowl. *[3]*

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(This question continues on the following page)

(Question B3 continued)

(c) Outline how the half-life of carbon-14 may be determined experimentally. *[3]*

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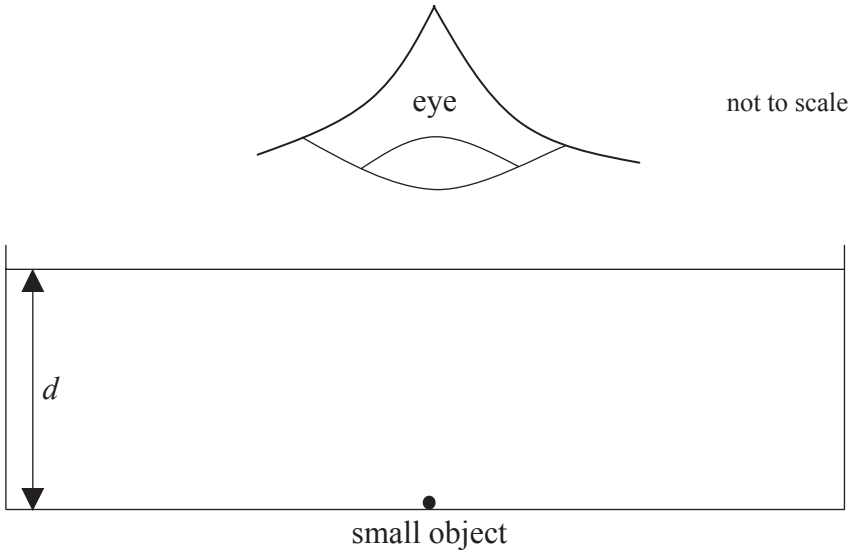
Option H — Optics

H1. This question is about refractive index.

(a) A small object rests at the bottom of a swimming pool of depth d. Viewed from directly above, the object appears to be 5.0 m below the surface of the water.



(i) On the diagram above, draw rays to locate the image of the object as seen from above. *[2]*

(ii) The refractive index of water = 1.3.

Determine the depth d of the swimming pool. *[2]*

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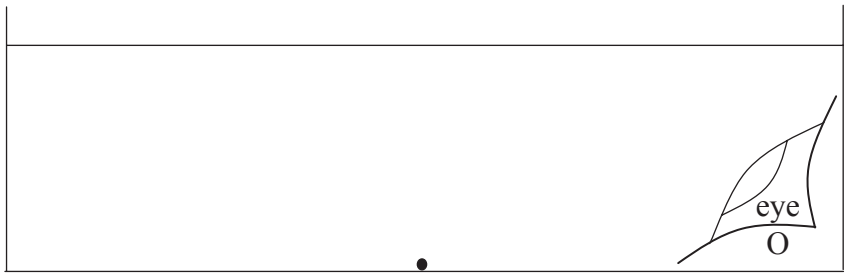
(Question H1 continued)

(b) A diver views the surface of the water from point O as shown in the diagram below.



not to scale

(i) On the diagram above, draw **two** rays to locate the image of the object as seen by the diver at O. *[3]*

(ii) Explain why the surface of the water needs to be undisturbed for the image to be seen. *[1]*

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