Option B — Quantum Physics and Nuclear Physics

B1. This question is about the evidence for the quantization of energy in atoms.

(a) State what is meant by the phrase *the quantization of energy in atoms*. *[2]*

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(b) By means of a labelled diagram, outline an experimental set-up by which X-rays can be emitted from a sample of tungsten. *[3]*

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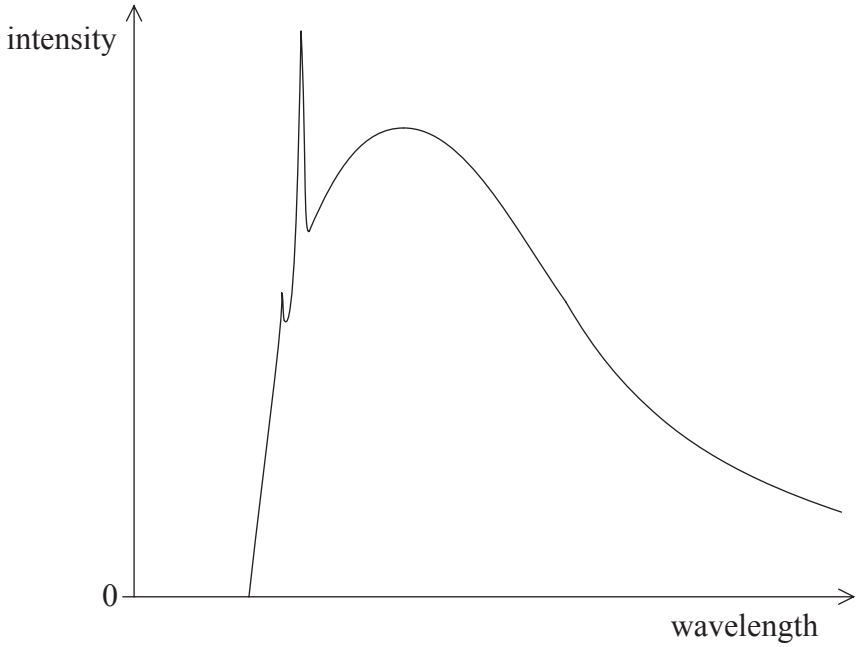
(Question B1 continued)

(c) The graph below shows the X-ray spectrum of a sample of tungsten.



Explain which features of this X-ray spectrum provide evidence for the quantization of energy levels in tungsten atoms. *[2]*

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(d) One of the lines in the emission spectrum of atomic hydrogen has a wavelength of 410 nm. Determine what quantitative information can be deduced about some of the energy levels in the hydrogen atom from this wavelength value. *[3]*

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B2. This question is about β^+-decay.

A nucleus of nitrogen-13, ${}^{13}_{7}\mathrm{N}$, undergoes β^+-decay to produce an isotope of carbon.

(a) Determine the **three** particles that result from the decay of a nucleus of nitrogen-13. State the mass number and the atomic number for each particle. *[3]*

1. . . . . .

2. . . . . .

3. . . . . .

(b) Identify which particle from your answer to (a) contains quarks. *[1]*

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(c) The half-life of nitrogen-13 is 10 minutes. Determine the decay constant for nitrogen-13. *[2]*

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(d) A sample initially contains 0.13 mg of nitrogen-13.

Calculate the

(i) initial rate of emission of β^+ particles from the sample. *[2]*

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(ii) mass of nitrogen-13 remaining after 15 minutes. *[2]*

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H2. This question is about the reflection and refraction of laser light.

(a) Define *refractive index*. *[1]*

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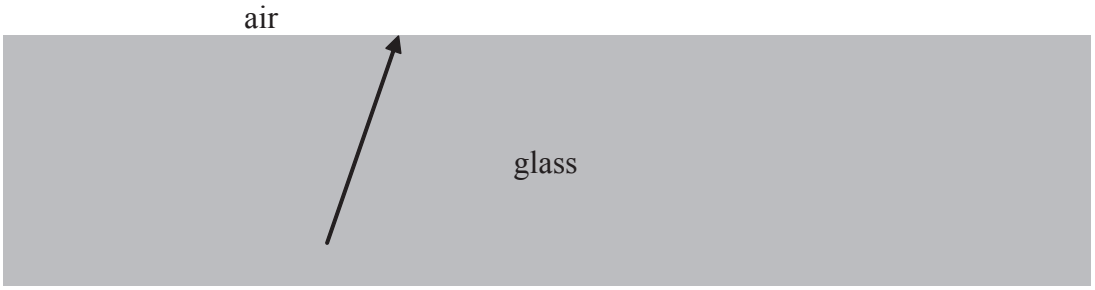
(b) A beam of laser light is incident on a glass/air boundary.



(i) On the diagram above, draw rays to show the reflected ray (label this L) and the refracted ray (label this R). *[1]*

(ii) The angle of incidence of the beam is gradually increased. Deduce how the path of the laser light would change for angles of incidence up to 80°. The refractive index of the glass is 1.5. *[4]*

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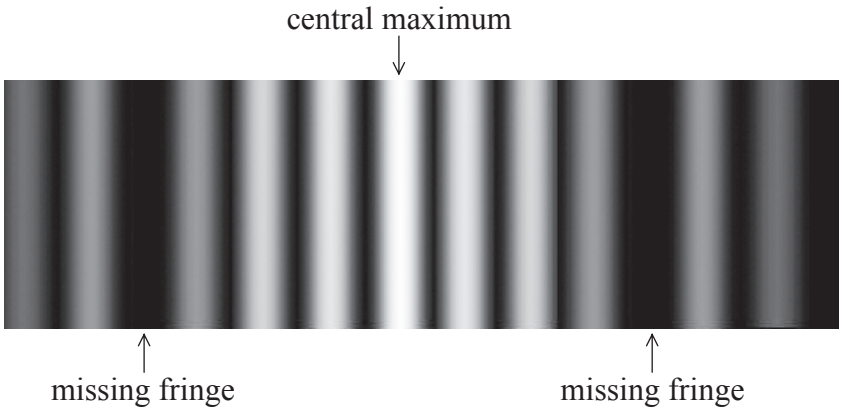
H4. This question is about double slit and multiple slit diffraction.

In a Young's double slit type experiment, laser light of wavelength 650 nm is shone onto two slits. The resulting fringe pattern on a screen placed beyond the slits is shown below. The separation of the slits is 1.4×10^{-4} m.



(a) (i) Explain the reason for the missing fringes. *[2]*

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(ii) Calculate the width of each slit. *[2]*

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(b) The double slit is replaced with a very large number of slits. Each of the slits is of a smaller width than those of the double slit but their separation is the same as in (a). Describe and explain any changes in the appearance of the fringe pattern as shown in (a). *[3]*

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