Option B — Quantum Physics and Nuclear Physics

B1. This question is about the de Broglie hypothesis.

(a) State the de Broglie hypothesis. *[2]*

. . . . . .

. . . . . .

. . . . . .

(b) Calculate the de Broglie wavelength associated with an adult of mass 80 kg running at a speed of $5.0\,m\,s^{-1}$. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

B3. This question is about nuclear reactions.

(a) A nucleus of barium-129, atomic number (proton number) 56 undergoes β^+ decay to form a nucleus of caesium.

State, for this decay,

(i) the proton number and neutron number of a nucleus of caesium. *[2]*

proton number: . . . . . .

neutron number: . . . . . .

(ii) the name of the other particle produced. *[1]*

. . . . . .

(iii) the name of the interaction responsible. *[1]*

. . . . . .

(iv) the change in quark structure of a nucleus of caesium. *[1]*

. . . . . .

. . . . . .

. . . . . .

(b) The half-life of barium-129 is 2.2 hours. Determine the percentage decrease in the activity during a period of 6 hours of a sample of barium-129. *[3]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

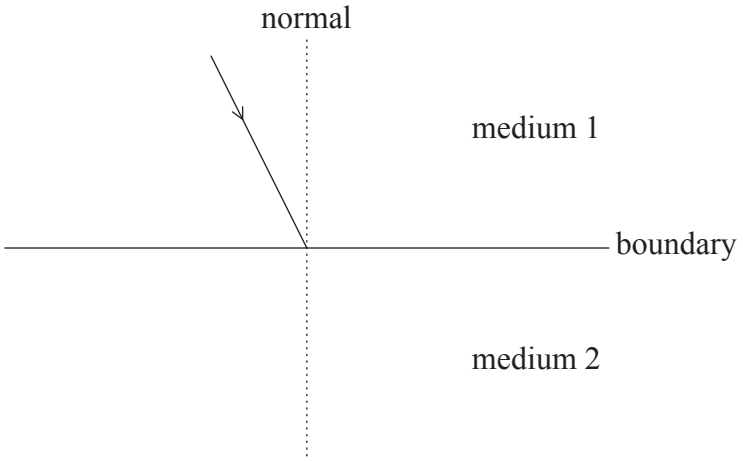
Option H — Optics

H1. The table below relates to the electromagnetic spectrum. Complete the table by stating the name of the region of the spectrum and the name of a possible source of the radiation associated with the given frequency. *[4]*

Name of associated region	Frequency / Hz	Possible source
gamma radiation	10^{18}	radioactive decay
	10^{13}	
	10^{6}	

H2. This question is about refraction.

(a) The diagram below shows a ray of monochromatic light incident on the boundary between two media. The dotted line is the normal to the boundary.



The refractive index of medium 1 is n_1 and that of medium 2 is n_2 and $n_1 > n_2$. The ray is incident at an angle to the normal that is less than the critical angle.

(i) Explain what is meant by critical angle. *[2]*

. . . . . .

. . . . . .

. . . . . .

(ii) On the diagram above, draw lines to show the paths of the ray after it is incident on the boundary. *[2]*

(b) Derive a relationship between n_1, n_2 and the critical angle ϕ_c. *[2]*

. . . . . .

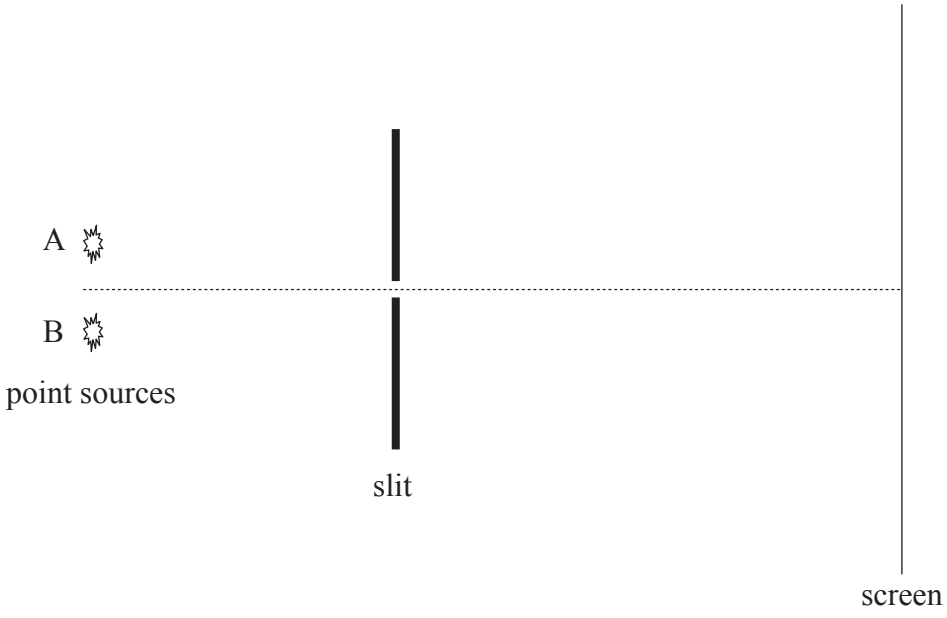
. . . . . .

. . . . . .

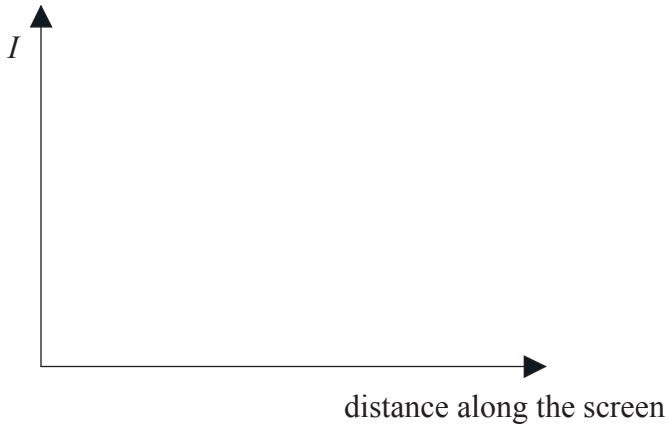
. . . . . .

A2. This question is about optical resolution.

The two point sources shown in the diagram below (not to scale) emit light of the same frequency. The light is incident on a rectangular narrow slit and, after passing through the slit, is brought to a focus on the screen.



(a) Point source B is covered. Using the axes below, sketch a graph to show how the intensity I of the light from point source A varies with distance along the screen. Label the curve you have drawn A. *[2]*



(b) Point source B is now uncovered. The images of A and B on the screen are just resolved. Using the axes above, sketch a graph to show how the intensity I of the light from point source B varies with distance along the screen. Label this curve B. *[1]*

(This question continues on the following page)

(Question A2 continued)

(c) The bright star Sirius A is accompanied by a much fainter star, Sirius B. The mean distance of the stars from Earth is 8.1×10^{16} m. Under ideal atmospheric conditions, a telescope with an objective lens of diameter 25 cm can just resolve the stars as two separate images.

Assuming that the average wavelength emitted by the stars is 500 nm, estimate the apparent, linear separation of the two stars. *[3]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

A3. This question is about polarization and liquid crystals.

(a) A liquid crystal has the property of being able to rotate the plane of polarization of light. Explain what is meant by the expression "able to rotate the plane of polarization of light". *[2]*

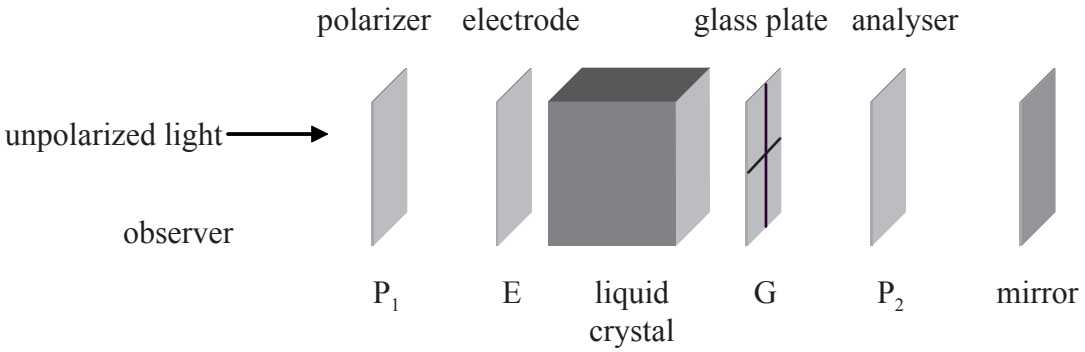
. . . . . .

. . . . . .

. . . . . .

. . . . . .

(b) The diagram below is a representation of a liquid crystal display.



P_1 is a polarizer and P_2 is an analyser. The transmission axis of P_2 is at right angles to that of P_1. E is an electrode. G is a glass plate upon which a shaped electrode is etched. Unpolarized light is incident on P_1.

(i) State, and explain, what the observer would see if the liquid crystal were not present. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(ii) Outline how the application of a potential difference between E and the electrode etched on G enables the observer to see the shape of the electrode. *[3]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .