Option A — Sight and wave phenomena

A1. This question is about the eye.

(a) State, with reference to the definitions of near point and far point, what is meant by accommodation. *[3]*

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(b) Explain how accommodation is achieved by the eye. *[2]*

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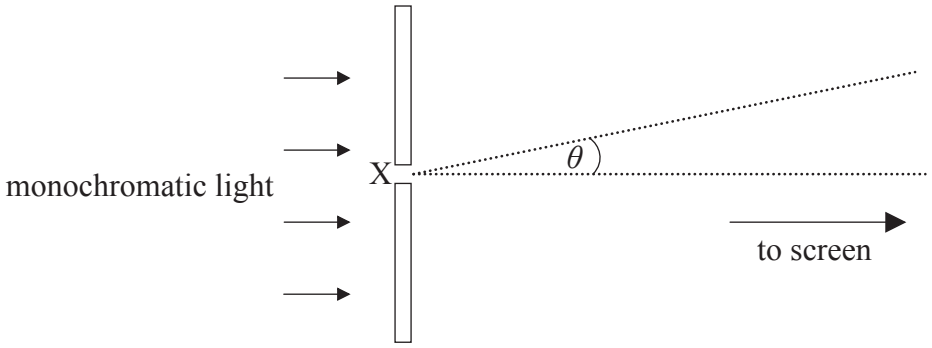
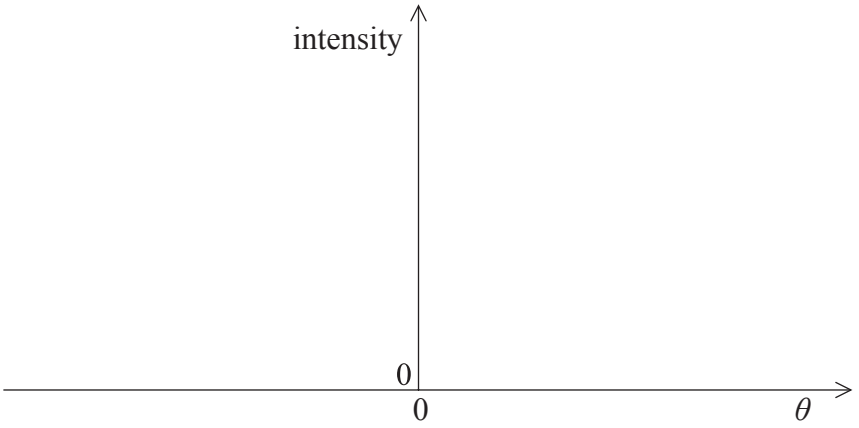
A2. This question is about diffraction and resolution.

(a) A parallel beam of monochromatic light is incident on a narrow rectangular slit. After passing through the slit, the light is incident on a distant screen.



Point X is the midpoint of the slit.

(i) On the axes below, sketch a graph to show how the intensity of the light on the screen varies with the angle θ shown in the diagram. *[3]*



(ii) The wavelength of the light is 520 nm, the width of the slit is 0.04 mm and the screen is 1.2 m from the slit. Show that the width of the central maximum of intensity on the screen is about 3 cm. *[2]*

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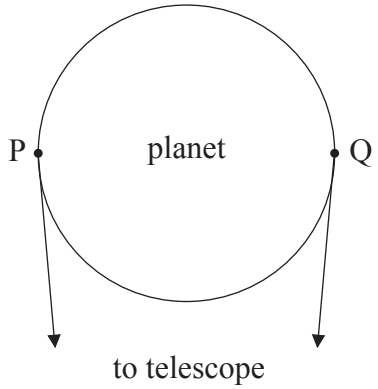
(Question A2 continued)

(b) Points P and Q are on the circumference of a planet as shown.



By considering the two points, outline why diffraction limits the ability of an astronomical telescope to resolve the image of the planet as a disc. *[3]*

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A3. This question is about standing waves and organ pipes.

(a) State **one** way in which a standing wave differs from a travelling wave. *[1]*

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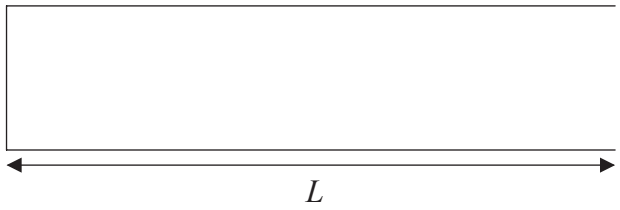
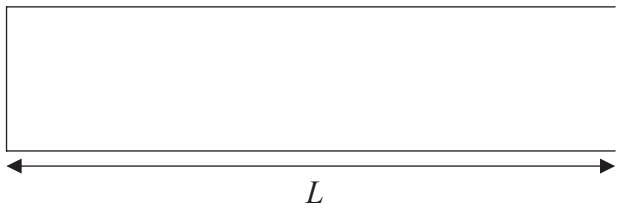
(b) An organ pipe of length L is closed at one end. On the diagrams, draw a representation of the displacement of the air in the pipe when the frequency of the note emitted by the pipe is the

(i) fundamental (first harmonic) frequency f_1. *[1]*



(ii) second harmonic frequency f_2. *[1]*



(c) Use your answer to (b) to deduce an expression for the ratio $\frac{f_1}{f_2}$. *[3]*

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(d) State, in terms of the boundary conditions of the standing waves that can be formed in the pipe, the reason why the ratio of the higher frequencies of the harmonics to that of the fundamental must always be an integer number. *[1]*

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Option A — Sight and wave phenomena

A1. This question is about the eye and sight.

(a) State, by reference to human vision, what is meant by accommodation. *[2]*

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(b) Explain how accommodation is achieved in the human eye. *[3]*

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(c) The light output from two particular lamps is described as "warm-white" and as "cold-white". Both lamps emit the full spectrum of colours. State how the visual impression of temperature difference may be achieved. *[2]*

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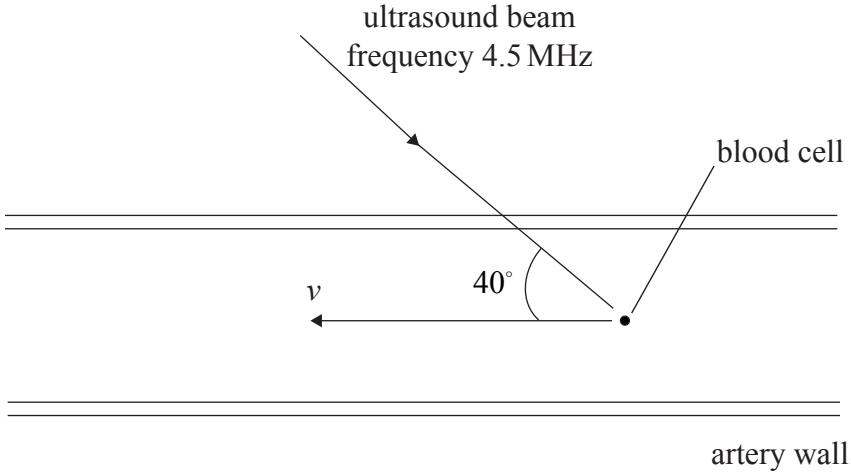
A2. This question is about the Doppler effect.

At one point in an artery, blood cells flow along the axis of the artery with speed v, as shown.



(This question continues on the following page)

(Question A2 continued)

A parallel beam of ultrasound of frequency 4.5 MHz is incident on the artery at an angle of 40°.
The speed of ultrasound in the body tissues is $c = 1.5 \times 10^3 \,\text{m s}^{-1}$.
The ultrasound detected after reflection from the blood cells is found to be Doppler-shifted in frequency by 740 Hz.
The expression for the Doppler shift Δf of the ultrasound of frequency f may be assumed to be

$$\Delta f = \frac{(2fv\cos\theta)}{c}.$$

(a) For this stated expression, explain the inclusion of

(i) the factor of 2. *[2]*

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(ii) the factor $\cos\theta$. *[1]*

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(b) Determine a value for the speed of the blood cells in the artery. *[2]*

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A3. This question is about polarization.

(a) State what is meant by *polarized* light. *[2]*

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(b) Describe and explain how polarization may be used in stress analysis. You may draw a diagram if you wish. *[6]*

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Option A — Sight and wave phenomena

A1. This question is about vision and the eye.

(a) State **one** function of

(i) cone cells. *[1]*

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(ii) rod cells. *[1]*

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(b) Describe the distribution of cone and rod cells on the retina. *[2]*

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(c) An object is to be viewed in very dim light. With reference to your answer to (b) explain why the object is most clearly seen when looked at sideways rather than directly. *[2]*

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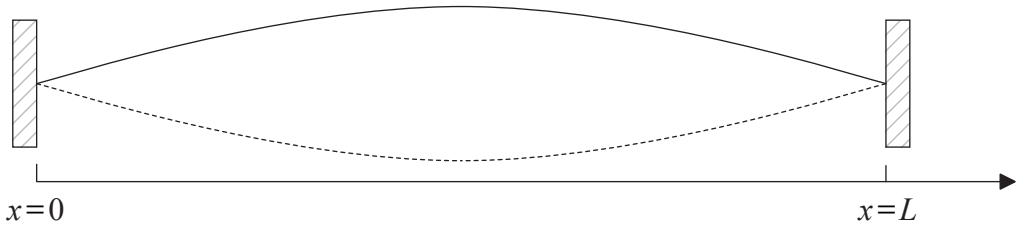
A2. This question is about standing waves.

A string that is fixed at both ends is made to vibrate in the fundamental (first harmonic) mode.



The fixed ends of the string are at $x = 0$ and $x = L$.

Each point on the string oscillates in simple harmonic motion. The displacement y of the string at a point x at time t is given by the equation

$$y = A\cos(500\pi t)$$

where $A = 12\sin\left(\frac{\pi x}{2}\right)$.

In these formulae x is in metres and t is in seconds. Using this equation,

(a) explain why the amplitude of the standing wave is not constant. *[1]*

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(b) calculate the frequency of the standing wave. *[2]*

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(c) show that $L = 2.0\,\text{m}$. *[1]*

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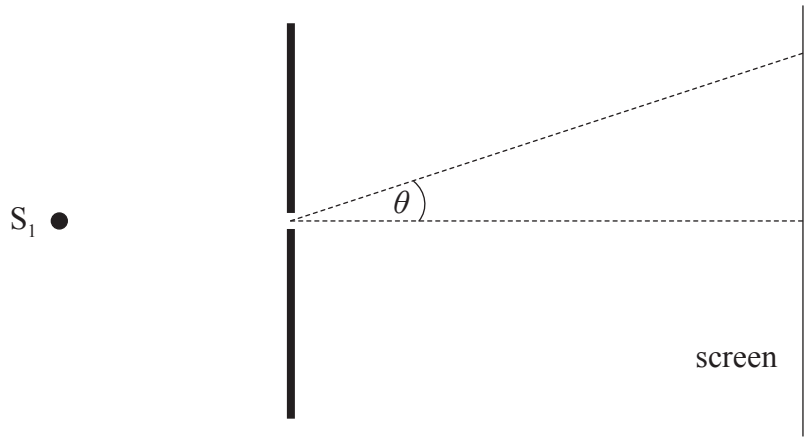
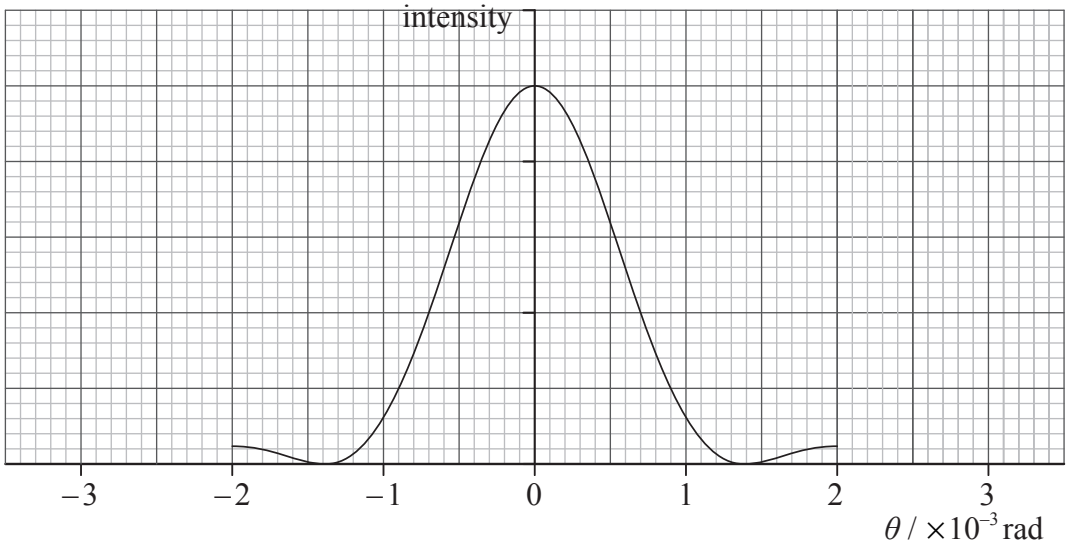
A3. This question is about diffraction and resolution.

(a) Light from a monochromatic point source S_1 is incident on a narrow rectangular slit.



After passing through the slit, the light is incident on a screen some distance away from the slit. The graph shows how the intensity distribution on the screen varies with the angle θ shown in the diagram.



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(Question A3 continued)

(i) The width of the slit is 4.0×10^{-4} m. Use data from the graph to calculate the wavelength of the light. *[2]*

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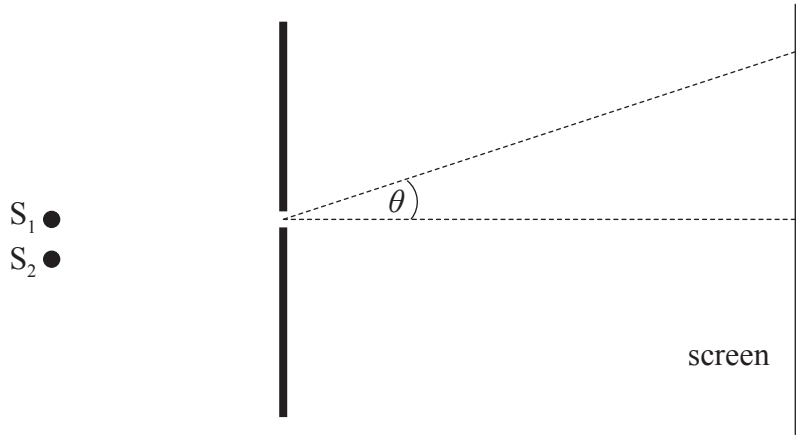
(ii) An identical source S_2 is placed close to S_1 as shown.



The images of the two sources on the screen are just resolved according to the Rayleigh criterion. On the graph opposite, draw the intensity distribution of the second source. *[1]*

(b) The Very Large Array (VLA) is used to analyse radio signals from distant galaxies. The combined diameter of the VLA is 36 km. A region of linear size L inside the radio galaxy M87 emits radio waves with a frequency of 43 GHz. The galaxy is a distance 4.7×10^{23} m from Earth. The VLA can just resolve the radio emitting region. Estimate the value of L. *[3]*

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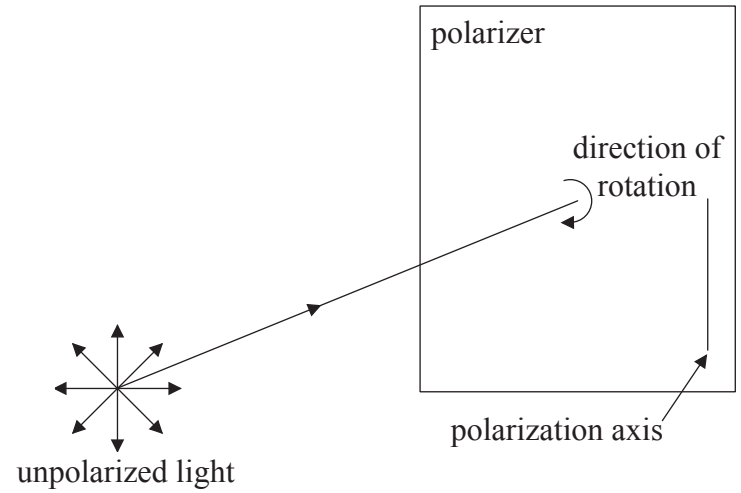
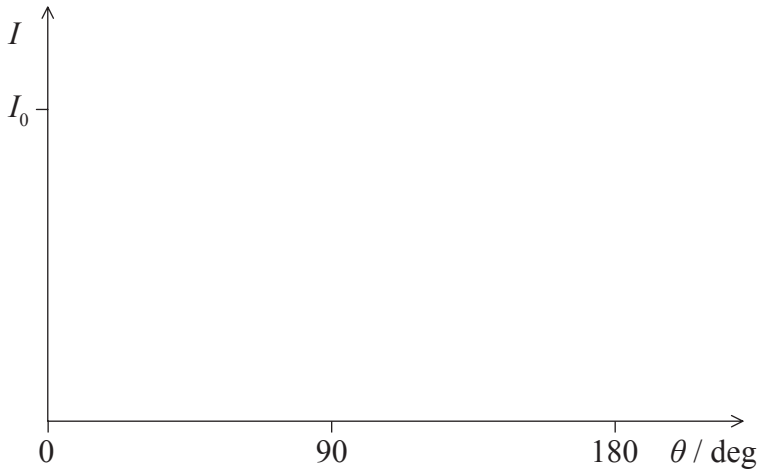
A4. This question is about polarization.

(a) A beam of unpolarized light of intensity I_0 is incident on a polarizer. The polarization axis of the polarizer is initially vertical as shown.



The polarizer is then rotated by 180° in the direction shown. On the axes below, sketch a graph to show the variation with the rotation angle θ, of the transmitted light intensity I, as θ varies from 0° to 180°. Label your sketch-graph with the letter U. *[2]*



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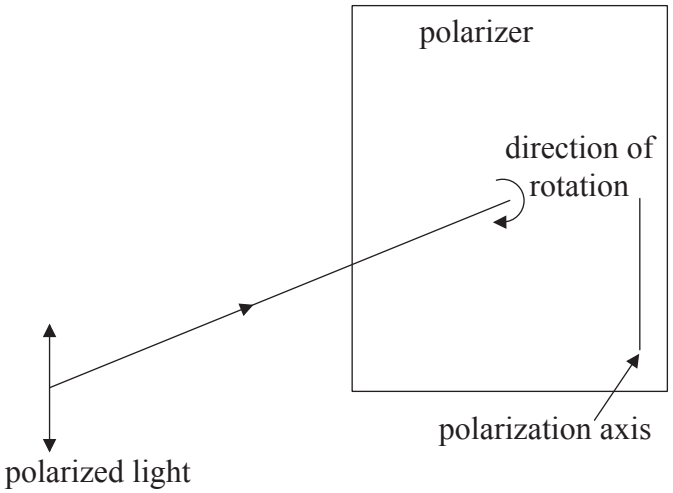
(Question A4 continued)

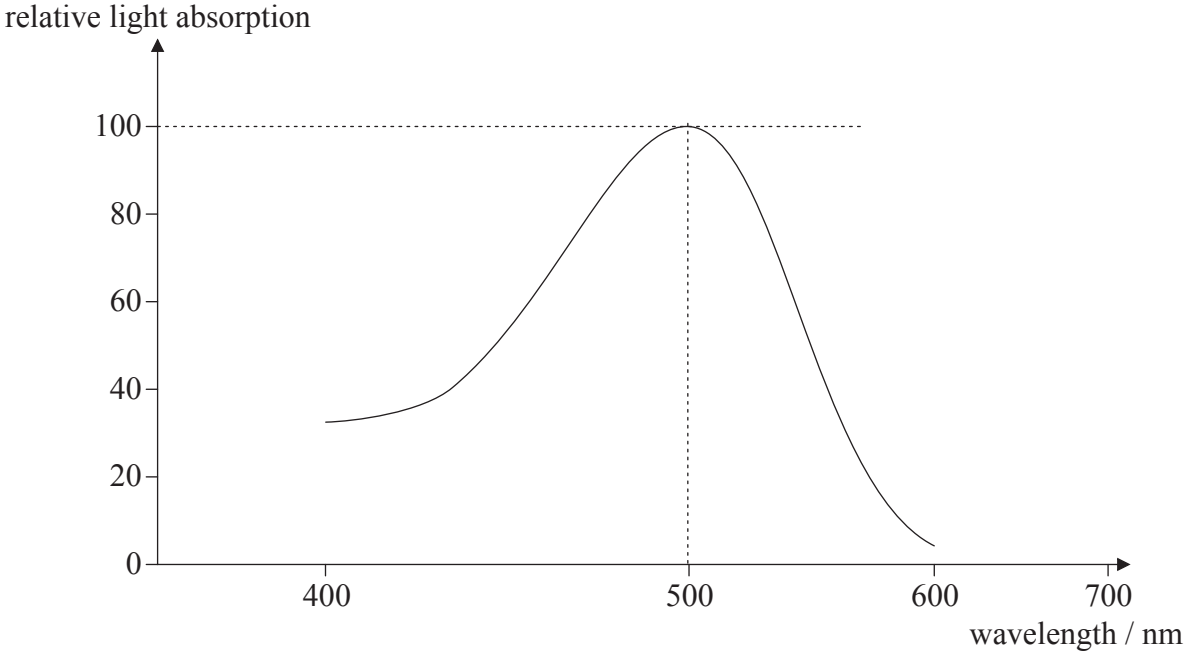
(b) The beam in (a) is now replaced with a polarized beam of light of the same intensity. The plane of polarization of the light is initially parallel to the polarization axis of the polarizer.



The polarizer is then rotated by 180° in the direction shown. On the same axes in (a), sketch a graph to show the variation with the rotation angle θ, of the transmitted light intensity I, as θ varies from 0° to 180°. Label your sketch-graph with the letter P. *[2]*

Option A — Sight and wave phenomena

A1. The graph below shows the overall relative light absorption curve for the light-sensitive cells involved in scotopic vision. The relative light absorption is expressed as a percentage of the maximum.



(a) State the name of the cells involved in **scotopic** vision. *[1]*

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(b) (i) On the axes above, sketch a relative light absorption curve for a cell involved in **photopic** vision. *[2]*

(ii) State the colour to which the cell is most sensitive. *[1]*

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(c) Outline how colour blindness may arise from defects in the retina's light sensitive cells. *[3]*

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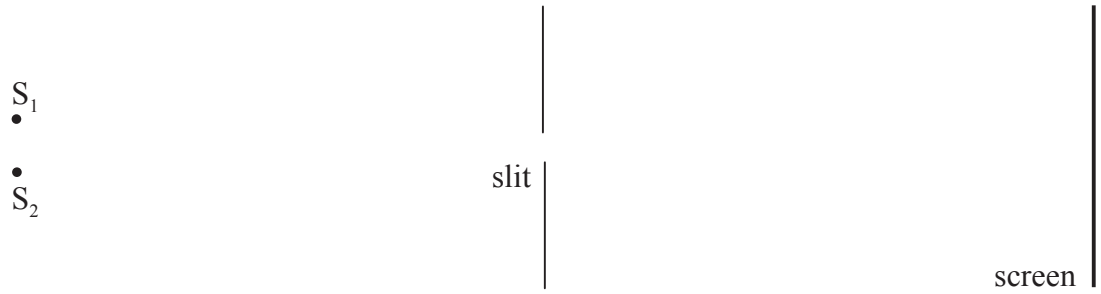
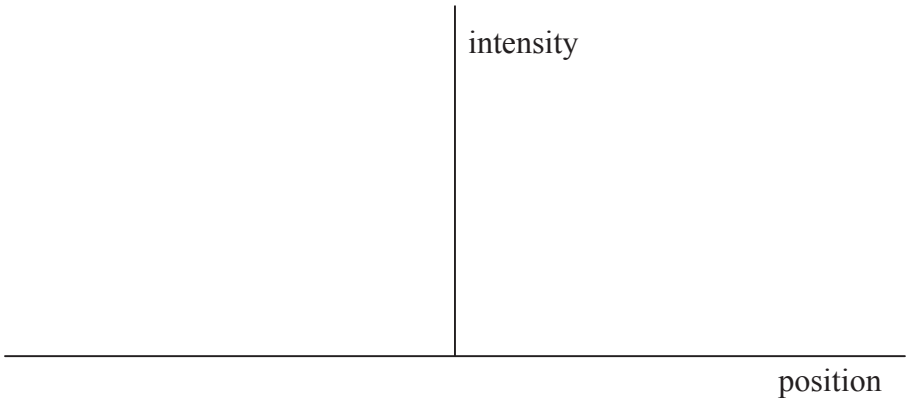
A2. This question is about the Rayleigh criterion.

(a) Light from two monochromatic distant point sources, S_1 and S_2, is incident on a narrow slit. After passing through the slit, the light is incident on a screen.



On the axes below, draw the intensity distribution of the diffracted light on the screen from each source when the images of S_1 and S_2 are just resolved according to the Rayleigh criterion. *[3]*



(b) A woman views an approaching car at night. The apertures of her eyes are each of diameter 3.0 mm. The headlamps of the car are separated by a distance of 1.2 m and emit light of wavelength 400 nm.

Calculate the distance of the car from the woman at which the images of the two headlamps are just resolved. *[3]*

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A3. This question is about polarization.

(a) State what is meant by polarized light. *[1]*

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(b) Polarized light of intensity I_0 is incident on an analyser. The transmission axis of the analyser makes an angle θ with the direction of the electric field of the light.

(i) Calculate, in terms of I_0, the intensity of light transmitted through the analyser when $\theta = 60^\circ$. *[1]*

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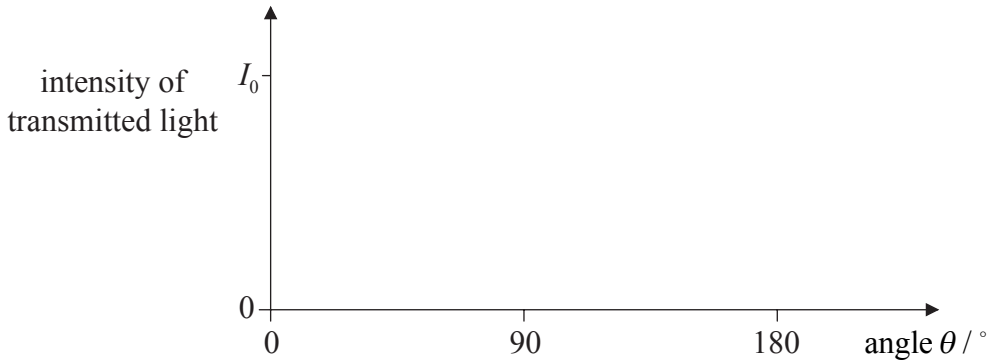
(ii) On the axes below, sketch a graph to show the variation with angle θ of the intensity of the transmitted light. *[2]*



(c) Outline how polarizing sunglasses reduce glare from a reflecting surface. *[3]*

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