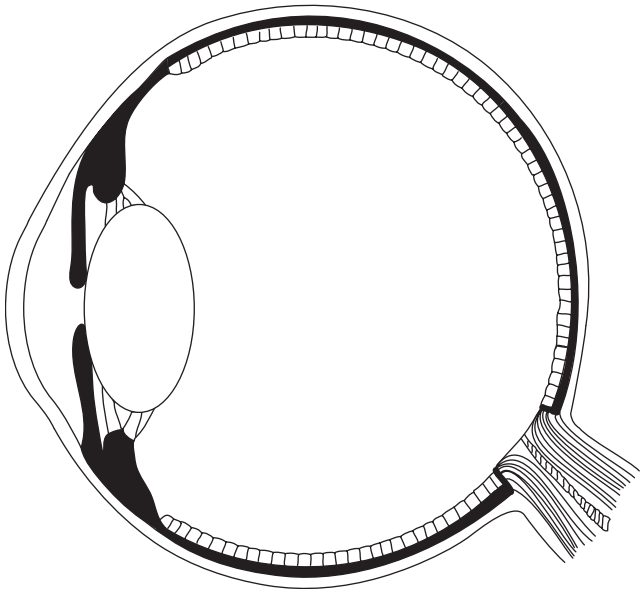
Option A — Sight and wave phenomena

A1. This question is about the human eye.

(a) (i) Label the diagram of the human eye to show the lens, retina and optic nerve. *[1]*



(ii) Outline the function of the rods and the cones in the retina. *[3]*

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(b) Outline what is meant by accommodation in the eye. *[3]*

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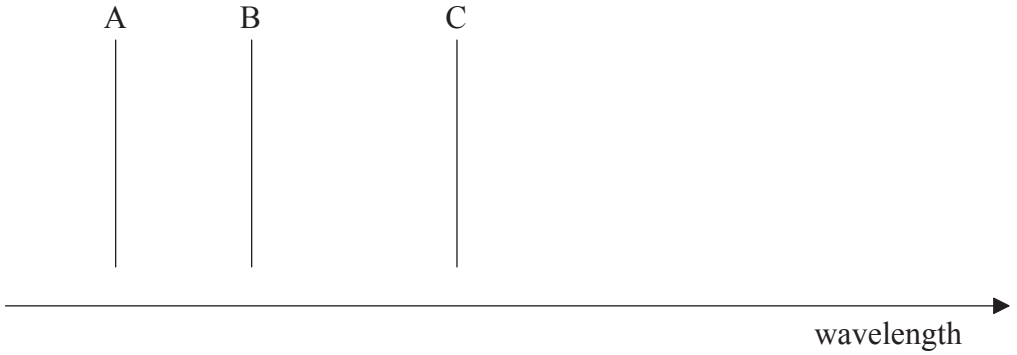
A2. This question is about the Doppler effect.

The wavelength diagram shown represents three lines in the emission spectrum sample of calcium in a laboratory.



A distant star is known to be moving directly away from the Earth at a speed of 0.1 c. The light emitted from the star contains the emission spectra of calcium. On the diagram sketch the emission spectrum of the star as observed in the laboratory. Label the lines that correspond to A, B, and C with the letters A*, B*, and C*. Numerical values of the wavelengths are **not** required. *[3]*

A3. This question is about optical resolution.

(a) The separation of two objects on the surface of Earth is d. The objects are photographed by a camera in a spy satellite orbiting Earth. The photographic images of the objects are just resolved. Use the following data to determine d. *[3]*

Wavelength of light emitted by the objects $= 500\,\text{nm}$
Distance of satellite above surface of Earth $= 4.0 \times 10^5\,\text{m}$
Diameter of camera lens $= 0.10\,\text{m}$

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(b) State **one** way in which the resolution of the camera could be improved. *[1]*

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A4. This question is about polarizing filters and sources.

You are given two unlabelled light sources, one of which emits polarized light and the other does not. You are also given two unlabelled transparent plastic sheets, one of which is a polarizer and the other is not.

(a) Describe how you would determine which one of the sources emits polarized light and which sheet is a polarizing filter. *[2]*

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(b) You are given a glass tube that contains an optically active solution. Explain how you would use the apparatus in (a) to measure the concentration of the solution. *[4]*

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Option A — Sight and wave phenomena

A1. This question is about vision and resolution.

(a) Compare scotopic with photopic vision. *[2]*

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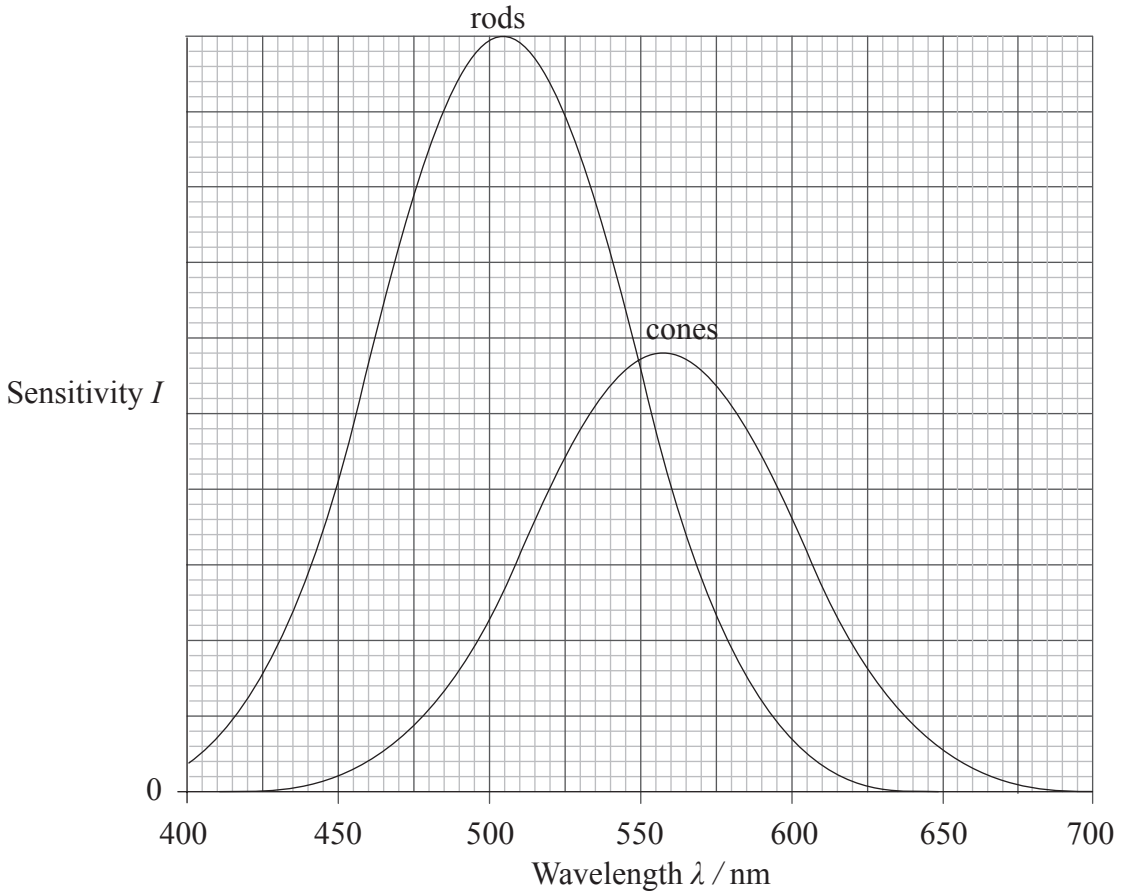
(b) The graph shows the variation with wavelength λ of the sensitivity I, of the rod and the cone cells of a human eye.



(This question continues on the following page)

(Question A1 continued)

A red piece of paper and a blue piece of paper are both viewed in very low intensity light. Each piece of paper reflects the same intensity of light.

With reference to the graph, state and explain which one of the two pieces of paper will be more clearly visible. *[3]*

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(c) The diameter of the pupil of a human eye is 1.5 mm.

(i) Calculate the minimum angular separation of two points that can be resolved by the human eye for light of wavelength 680 nm. *[1]*

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(ii) Two stars, the same distance from Earth, are separated by a distance of 4.0×10^{13} m . Both stars emit light of wavelength 680 nm.

The two stars are just resolved by an observer on Earth. Estimate the distance to the two stars. *[2]*

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A2. This question is about polarization.

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

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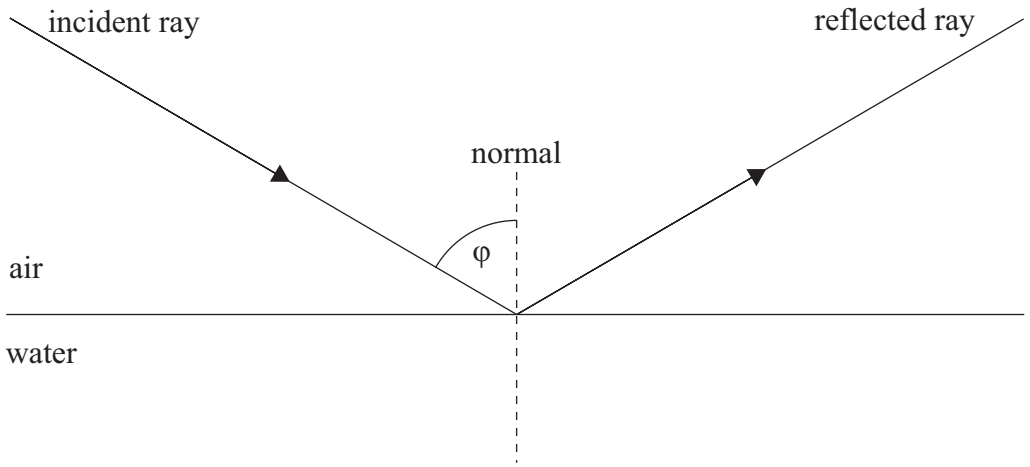
(b) A ray of light is incident on the surface of a lake. The angle of incidence is φ.



The reflected light is completely polarized horizontally.
The refractive index of water is *n*.

(i) On the diagram above draw the refracted ray. *[1]*

(ii) Use the diagram to deduce the relationship between φ and n. *[3]*

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(iii) The refractive index of the water is 1.3. Calculate the value of φ. *[1]*

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A3. This question is about the Doppler effect.

(a) State what is meant by the Doppler effect. *[2]*

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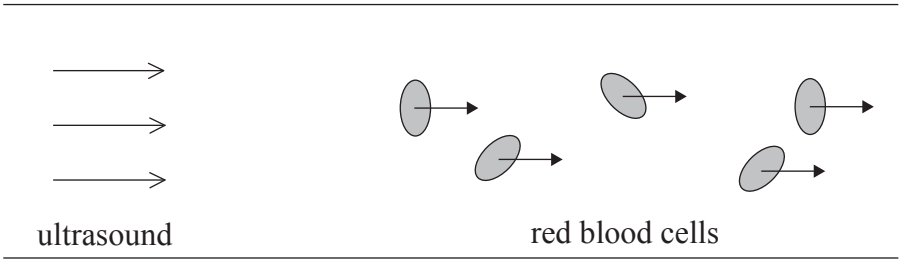
(b) Ultrasound of frequency 5.2 MHz is directed from a stationary source towards red blood cells in an artery. A simplified diagram is shown below in which the blood cells are travelling in the same direction.



The ultrasound is reflected from the cells and is received back at the source. The measured frequency shift is 3.5 kHz. The speed of ultrasound in blood is $c = 1.5\times10^{3}\ \text{m s}^{-1}$. The frequency shift is determined from $\frac{\Delta f}{f} = \frac{2v}{c}$.

(i) State the significance of the factor of 2 in the formula for the frequency shift. *[1]*

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(ii) Determine the speed of the red blood cells. *[1]*

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(iii) State **two** reasons why, in practice, the frequency shift will have a range of values. *[2]*

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Option A — Sight and wave phenomena

A1. This question is about the eye and sight.

(a) A white object is illuminated with red light and green light at the same time. State the colour that the object will appear to an observer. *[1]*

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(b) The average wavelength of red light is 650 nm and that of blue light is 488 nm. The refractive index of water is 1.3. Jim argues that since wavelengths in water compared with those in air are reduced by a factor of 1.3, a red cricket ball placed under water should appear to be blue to a person with normal sight. Suggest why Jim's reasoning is incorrect. *[2]*

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A2. This question is about standing waves.

A string is attached between two rigid supports and is made to vibrate at its fundamental frequency (first harmonic) f.

The diagram shows the displacement of the string at $t = 0$.

(a) Draw the displacement of the string at time

(i) $t = \frac{1}{4f}$ *[1]*

(ii) $t = \frac{1}{2f}$ *[1]*

(b) The distance between the supports is 1.0 m. A wave in the string travels at a speed of $240\,\text{m}\,\text{s}^{-1}$. Calculate the frequency of the vibration of the string. *[2]*

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(c) An organ pipe that is open at one end has the same fundamental frequency as the string in part (b). The speed of sound in air is $330\,\text{m}\,\text{s}^{-1}$. Determine the length of the pipe. *[2]*

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A3. This question is about the Doppler effect.

A stationary loudspeaker emits sound of frequency of 1000 Hz. Nadine attaches the loudspeaker to a string. She moves the loudspeaker in a horizontal circle above her head at a speed of $30\,m\,s^{-1}$. The speed of sound in air is $330\,m\,s^{-1}$.

An observer is standing well away from Nadine.

(a) Explain why the sound heard by the observer changes regularly. *[3]*

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(b) Determine the maximum frequency of the sound heard by the observer. *[3]*

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A4. This question is about polarization.

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

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(b) A beam of unpolarized light of intensity $1.0\,\text{Wm}^{-2}$ is incident on an ideal polarizing filter. State the value of the intensity of the transmitted light. Explain your answer. *[2]*

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(c) Outline how polarized light may be used to measure the concentration of a sugar solution. *[2]*

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