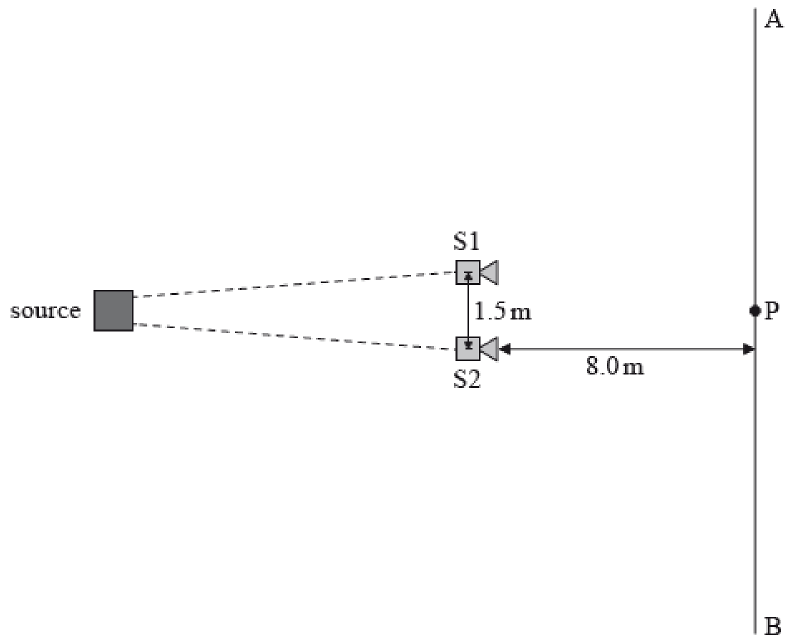
SL Paper 3

This question is about polarization.

Distinguish between polarized light and unpolarized light.

This question is about the interference of sound waves.

Two loudspeakers, S1 and S2, each emit a musical note of frequency 2.5 kHz with identical signal amplitude. Point P lies on the line AB and is equidistant from S1 and S2. The speakers are placed 1.5 m apart from each other and 8.0 m from line AB. The speed of sound is $330\ \mathrm{m\,s^{-1}}$.



A person walking in a straight line from A to B observes that the intensity of sound alternates between high and low.

a. With reference to interference, explain why the intensity of sound alternates along line AB. [3]

b. The sound has a maximum intensity at P. Calculate the distance along line AB to the next intensity maximum when S1 and S2 emit a musical note of frequency 2.5 kHz. [2]

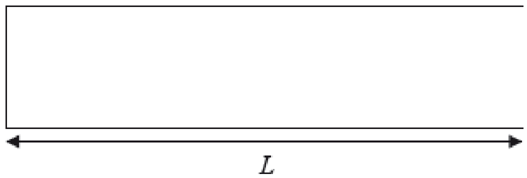
c. S1 and S2 are moved so that they are now 3.0 m apart. They remain at the same distance from line AB. Discuss the changes, if any, in the rate at which the intensity of sound alternates when a person is walking along line AB at half the speed. [2]

This question is about standing waves and organ pipes.

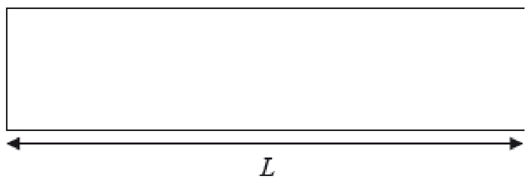
An organ pipe of length L is closed at one end. On the diagrams, draw a representation of the displacement of the air in the pipe when the frequency of the note emitted by the pipe is the

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

b. (i) first harmonic frequency f_1. [2]



(ii) second harmonic frequency f_2.



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

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 first harmonic must always be an integer number. [1]

This question is about lasers.

With reference to the light waves emitted by a laser, state what is meant by the terms

(i) monochromatic.

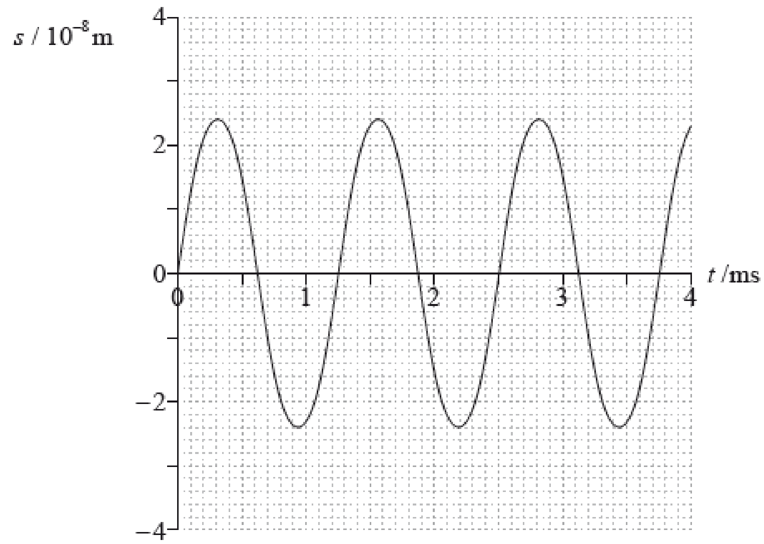
(ii) coherent.

This question is about standing (stationary) waves.

The diagram shows a tube that is open at both ends.

Point A shows the position of one air molecule in the tube. A standing sound wave (not shown in the diagram) is set up in the tube.

The graph shows the variation of displacement s with time t for the molecule at point A.



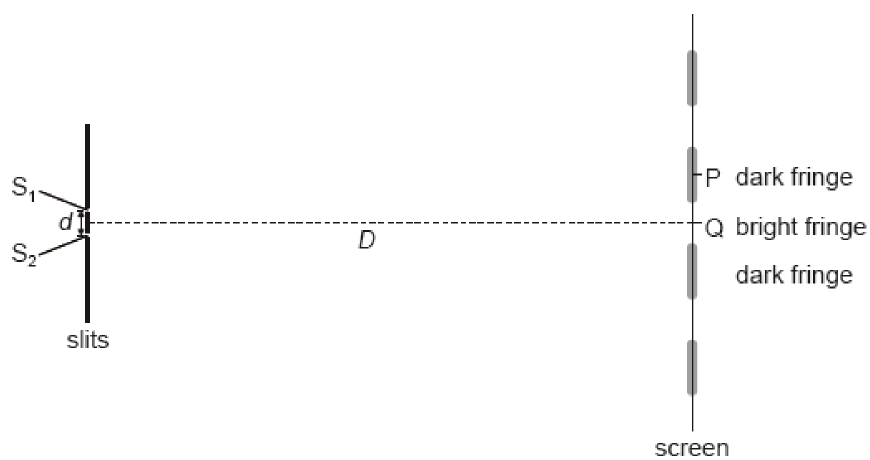
a. Outline whether the standing wave is transverse **or** longitudinal. [1]

b. The standing wave in the tube corresponds to the fourth harmonic. The speed of sound in the tube is $340\ \mathrm{m\,s^{-1}}$. Using the graph, determine the length of the tube. [3]

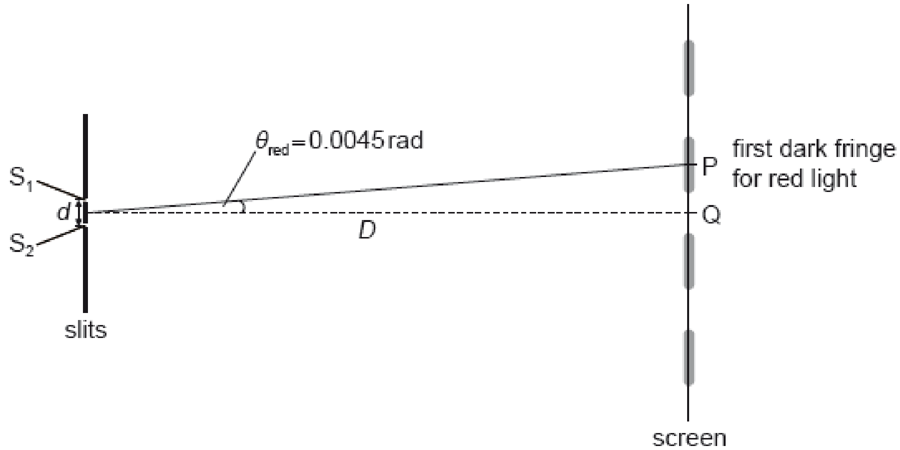
c. The tube is now closed at one end and the first harmonic is sounded. Outline why the tube that is open at both ends produces a first harmonic with a wavelength shorter than the first harmonic of the tube that is closed at one end. [1]

This question is about interference of light.

Coherent monochromatic light is incident on two narrow slits $\mathrm{S_1}$ and $\mathrm{S_2}$ a distance d apart. A screen is placed a distance D from the slits. An interference pattern of bright fringes and dark fringes appears on the screen. The central maximum is at Q.



When red light of wavelength 660 nm is used the first fringe at P subtends an angle 0.0045 rad from midpoint of $\mathrm{S_1}$ and $\mathrm{S_2}$.



a. State **one** way to ensure that the light incident on the slits is coherent. [1]

b. Light emerging from S_1 and S_2 reaches the screen. Explain why the screen appears dark at point P. [2]

c.i. Determine the change in angle when blue light of wavelength 440 nm is used. [2]

c.ii. Using the diagram below, draw the approximate position of the first bright fringe using blue light. The position of the first dark fringe with red light is labelled P. [1]

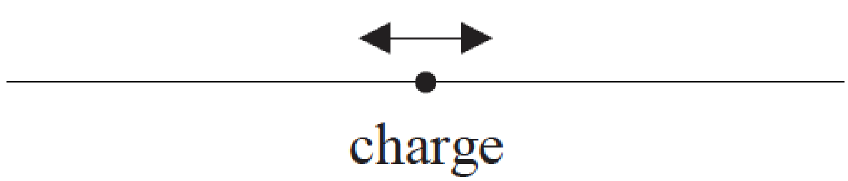
This question is about polarization.

State what is meant by polarized light.

This question is about the nature and properties of electromagnetic waves.

a. Electromagnetic waves propagating in a medium suffer dispersion. Describe what is meant by dispersion. [2]

b. A charge moves backwards and forwards along a wire, as shown in the diagram below. [2]



Outline, with reference to the motion of the charge, why electromagnetic radiation is produced by the moving charge.

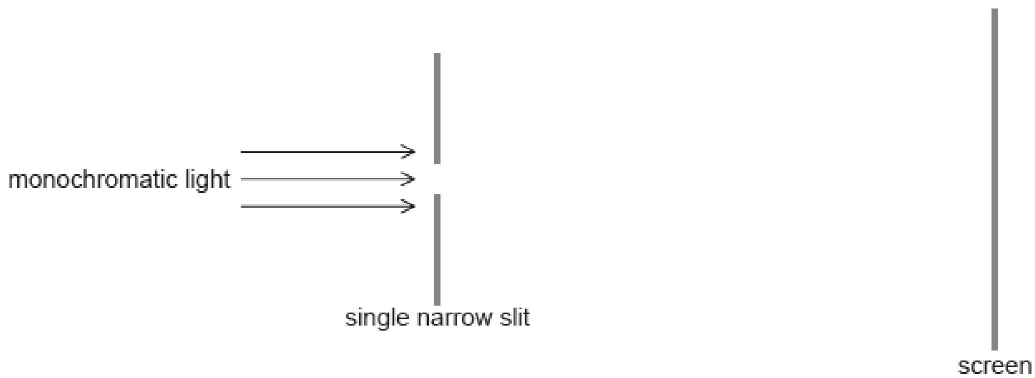
This question is about the nature of electromagnetic waves.

a. Outline what is meant by an electromagnetic wave. [2]

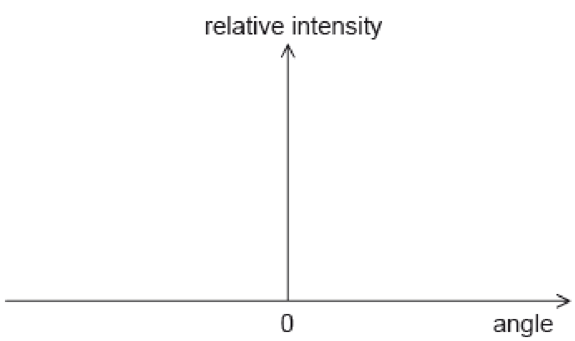
b. State **two** cases in which electrons may produce electromagnetic waves. [2]

This question is about diffraction and resolution.

Monochromatic light is incident normally on a single narrow slit and gives rise to a diffraction pattern on a screen.



a. Sketch, for the diffraction pattern produced, a graph showing the variation of the relative intensity of the light with the angle measured from the centre of the slit. [2]

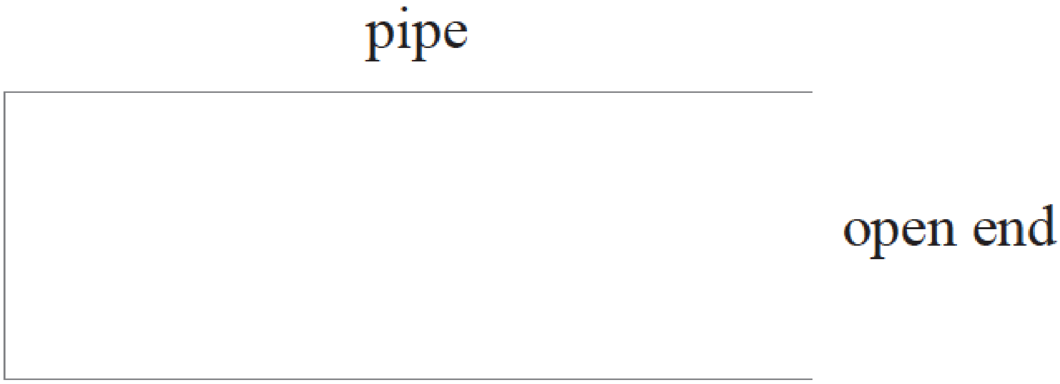


b. The single narrow slit is replaced by a double narrow slit. Explain, with reference to your answer to (a), how the Rayleigh criterion applies to the diffraction patterns produced by the light emerging from the two slits. [3]

c. Two lamps emit light of wavelength 620 nm. The lights are observed through a circular aperture of diameter 1.5 mm from a distance of 850 m. Calculate the minimum distance between the lamps so that they are resolved. [2]

This question is about standing waves and the Doppler effect.

The horn of a train can be modeled as a pipe with one open end and one closed end. The speed of sound in air is $330 ms^{-1}$.



a. On leaving the station, the train blows its horn. Both the first harmonic and the next highest harmonic are produced by the horn. The difference in frequency between the harmonics emitted by the horn is measured as 820 Hz. [5]

(i) Deduce that the length of the horn is about 0.20 m.

(ii) Show that the frequency of the first harmonic is about 410 Hz.

b. (i) Describe what is meant by the Doppler effect. [4]

(ii) The train approaches a stationary observer at a constant velocity of $50 ms^{-1}$ and sounds its horn at the same frequency as in (a)(ii). Calculate the frequency of the sound as measured by the observer.

This question is about sound waves.

A whistle on a steam train consists of a pipe that is open at one end and closed at the other. The sounding length of the whistle is 0.27 m and the steam pressure in the whistle is so great that the third harmonic of the pipe is sounding. The speed of sound in air is $340\ \mathrm{m\,s^{-1}}$.

a.i. Show that there must be a node at a distance of 0.18 m from the closed end of the pipe. [1]

a.ii. Calculate the frequency of the whistle sound. [2]

b. The train is moving directly away from a stationary observer at a speed of $22\ \mathrm{m\,s^{-1}}$ while the whistle is sounding. Calculate the frequency heard by the observer. [2]

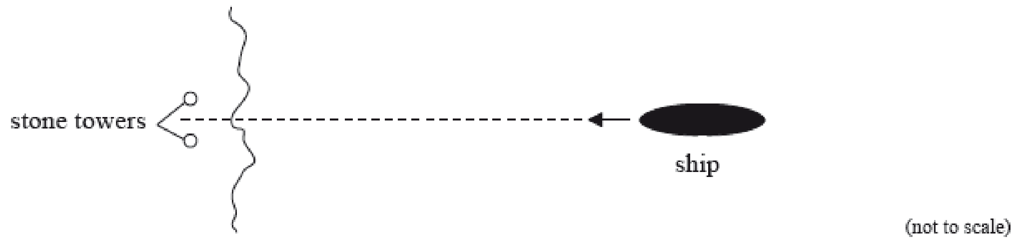
This question is about properties of electromagnetic waves.

a. State **two** properties that are common to all electromagnetic waves. [2]

b. A single lens is used to form a magnified real image of an object. Explain, with reference to the dispersion of light, why the image has coloured edges. [3]

This question is about resolution and polarization.

A ship sails towards two stone towers built on land.



Emlyn, who is on the ship, views the towers. The pupils of Emlyn's eyes are each of diameter 2.0 mm. The average wavelength of the sunlight is 550 nm.

a. State the Rayleigh criterion. [2]

b. (i) Calculate the angular separation of the two towers when the images of the towers are just resolved by Emlyn. [3]

(ii) Emlyn can just resolve the images of the two towers when his distance from the towers is 11 km. Determine the distance between the two towers.

d. Emlyn puts on a pair of polarizing sunglasses. Explain how these sunglasses reduce the intensity of the light, reflected from the sea, that enters Emlyn's eyes. [2]

This question is about standing waves in a vibrating string.

A guitar string vibrates at 330 Hz in its fundamental mode.

a. Describe the formation of standing waves in a string fixed at both ends. [2]

b. The length of the string is 0.64 m. Calculate the velocity of the wave in the string. [2]

This question is about dispersion.

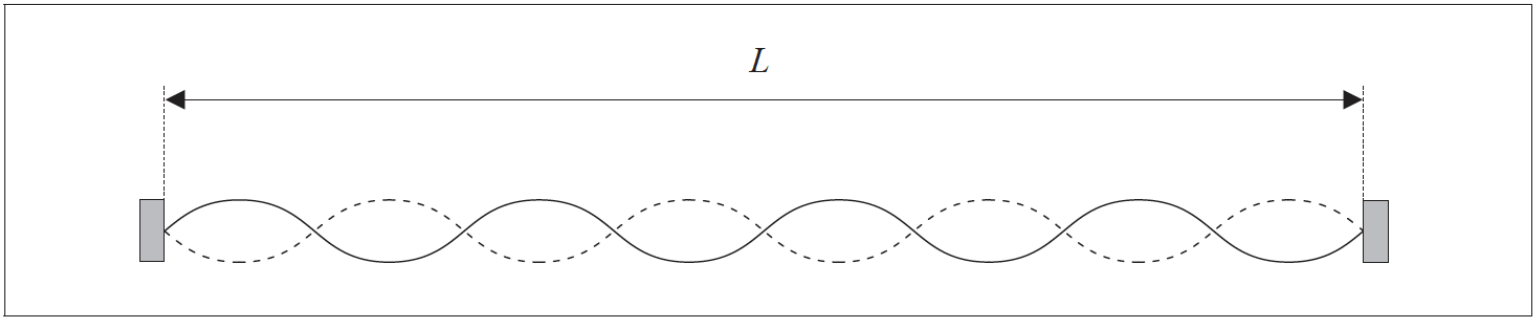
State an approximate value for the wavelength of visible light.

This question is about the electromagnetic spectrum.

Outline the nature of electromagnetic waves.

This question is about standing (stationary) waves.

The diagram represents a standing wave of wavelength λ set up on a string of length L.



The string is fixed at both ends.

a. For this standing wave [3]

(i) state the relationship between λ and L.

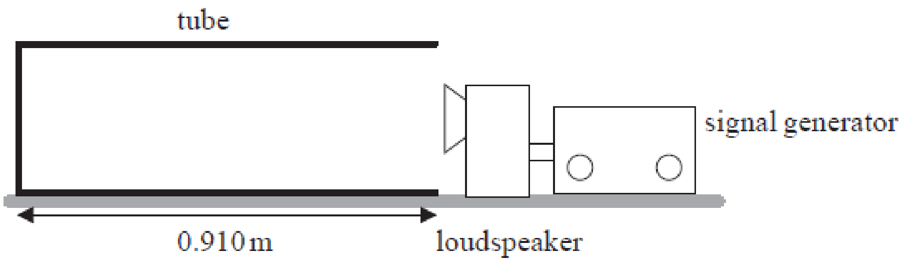
(ii) label, on the diagram, **two** antinodes where the string is vibrating in phase. Label the antinodes with the letter A.

b. The standing wave has wavelength λ and frequency f. State and explain, with respect to a standing wave, what is represented by the product $f\lambda$. [3]

This question is about standing (stationary) waves.

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

b. A loudspeaker connected to a signal generator is placed in front of the open end of a tube. [3]



The frequency of the sound is slowly increased from zero. At a frequency of 92.0 Hz the first large increase in the intensity of the sound is heard.

(i) On the diagram above, draw a representation of the wave in the tube for the frequency of 92.0 Hz.

(ii) The length of the tube is 0.910 m. Determine the speed of sound in the tube.

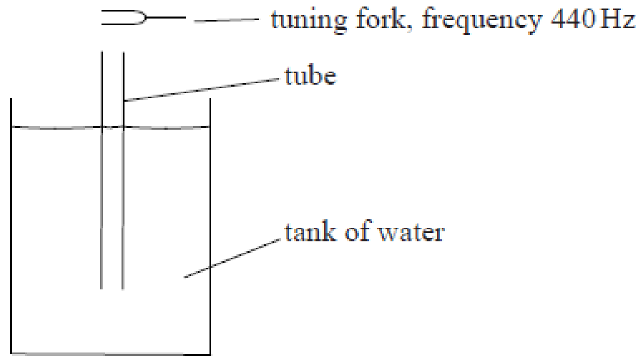
c. The frequency of sound is continuously increased above 92.0Hz. [2]

Calculate the frequency at which the next large increase in the intensity of the sound is heard.

This question is about standing (stationary) waves.

a. Describe **two** ways that standing waves are different from travelling waves. [2]

b. An experiment is carried out to measure the speed of sound in air, using the apparatus shown below. [3]



A tube that is open at both ends is placed vertically in a tank of water, until the top of the tube is just at the surface of the water. A tuning fork of frequency 440 Hz is sounded above the tube. The tube is slowly raised out of the water until the loudness of the sound reaches a maximum for the first time, due to the formation of a standing wave.

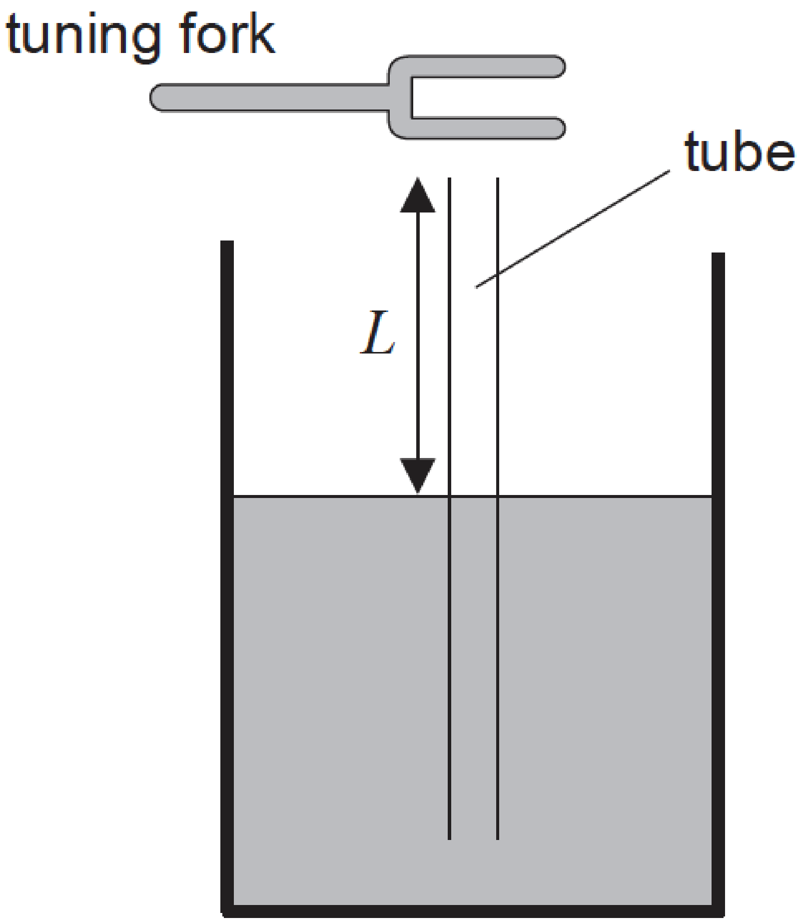
(i) Explain the formation of a standing wave in the tube.

(ii) State the position in the tube that is always a node.

c. The tube is raised until the loudness of the sound reaches a maximum for a second time. Between the two positions of maximum loudness, the tube has been raised by 36.8 cm. The frequency of the sound is 440 Hz. Estimate the speed of sound in air. [2]

This question is about standing (stationary) waves in a tube.

a. A thin tube is immersed in a container of water. A length L of the tube extends above the surface of water. [4]

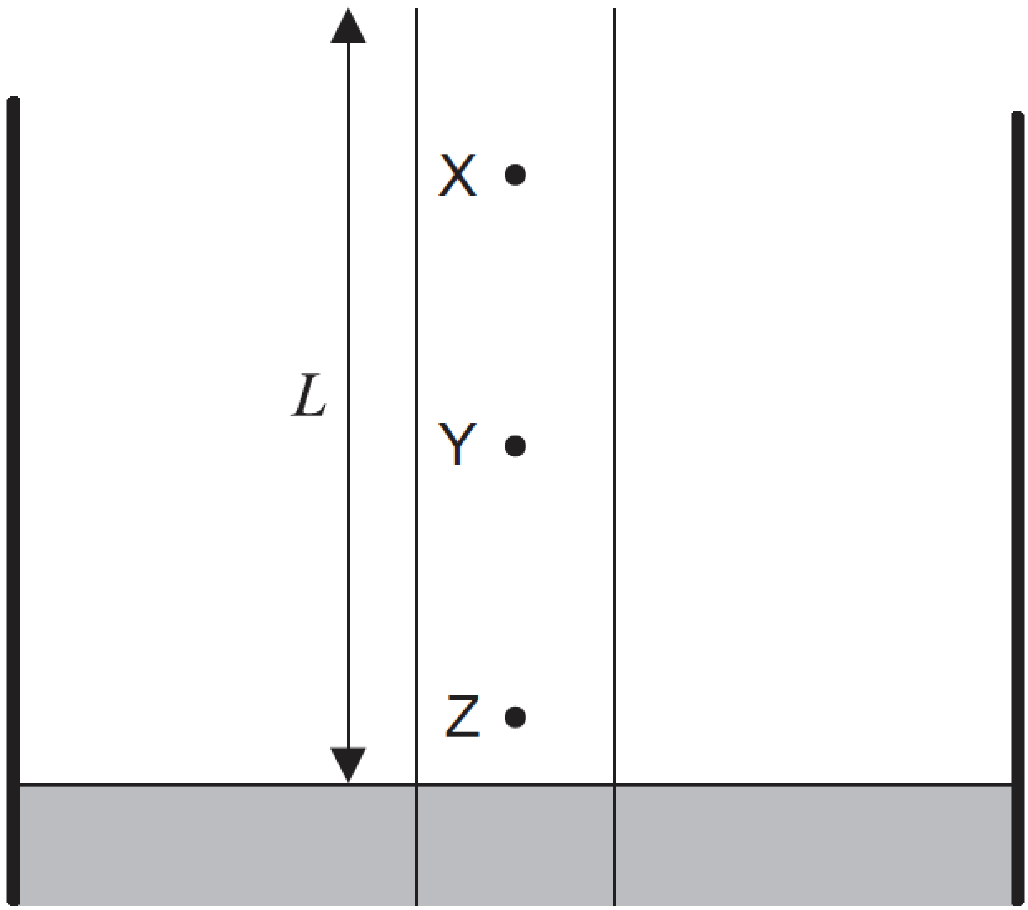


A tuning fork is sounded above the tube. For particular values of *L*, a standing wave is established in the tube.

(i) Explain how a standing wave is formed in this tube.

(ii) The frequency of the tuning fork is 256 Hz. The smallest length *L* for which a standing wave is established in the tube is 33.0 cm. Estimate the speed of sound in the tube.

b. The diagram shows an enlarged view of the tube shown in (a). X, Y and Z are three molecules of air in the tube. [2]



The length L is 33.0 cm.

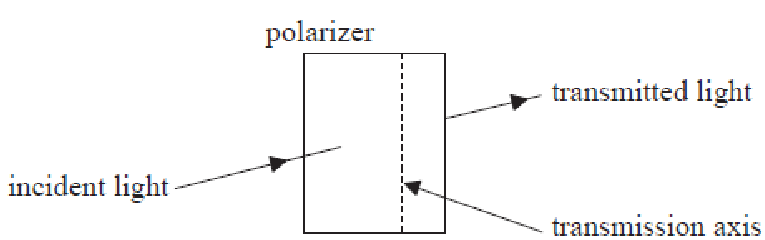
(i) State the direction of oscillation of molecule Y.

(ii) Identify the molecule that has the greatest amplitude.

This question is about polarization.

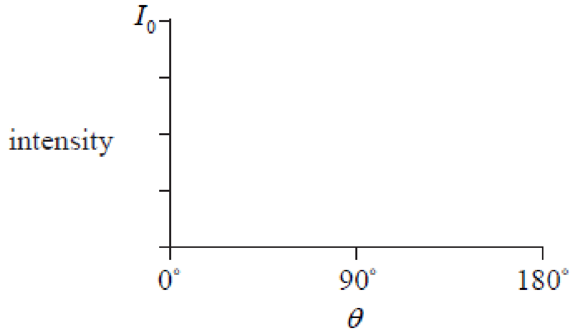
a. State what is meant by polarized light. [1]

b. Light of intensity I_0 is incident on a polarizer. The transmission axis of the polarizer is vertical. The polarizer is rotated by an angle θ about the direction of the incident light. The intensity of the transmitted light is measured for various angles θ. [4]

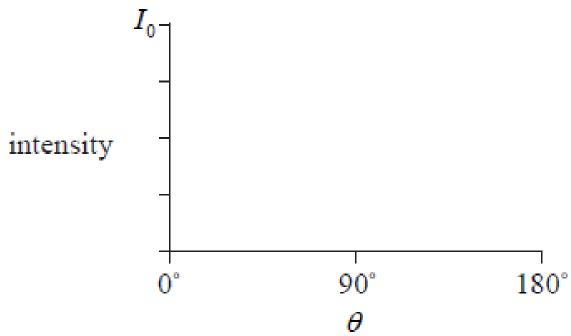


On the axes below, sketch graphs to show the variation of the transmitted intensity I with θ when the incident light is

(i) horizontally polarized.

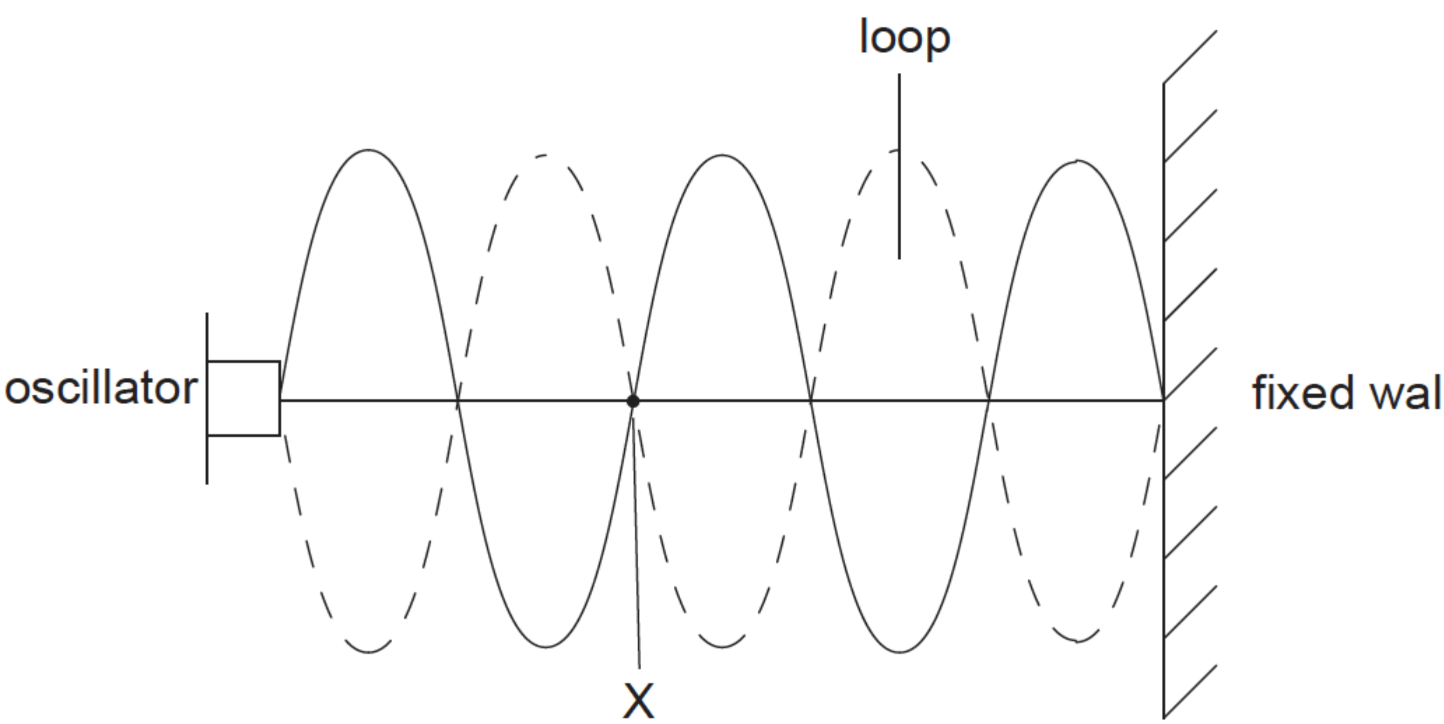


(ii) unpolarized.



This question is about standing (stationary) waves.

The diagram shows an arrangement used to produce a standing (stationary) wave on a stretched string of length 2.4 m. A standing wave with five loops appears when the frequency of the oscillator is set to 150 Hz, as shown below.



a. State the name given to point X on the string. [1]

b. (i) Calculate the speed of the wave along the string. [3]

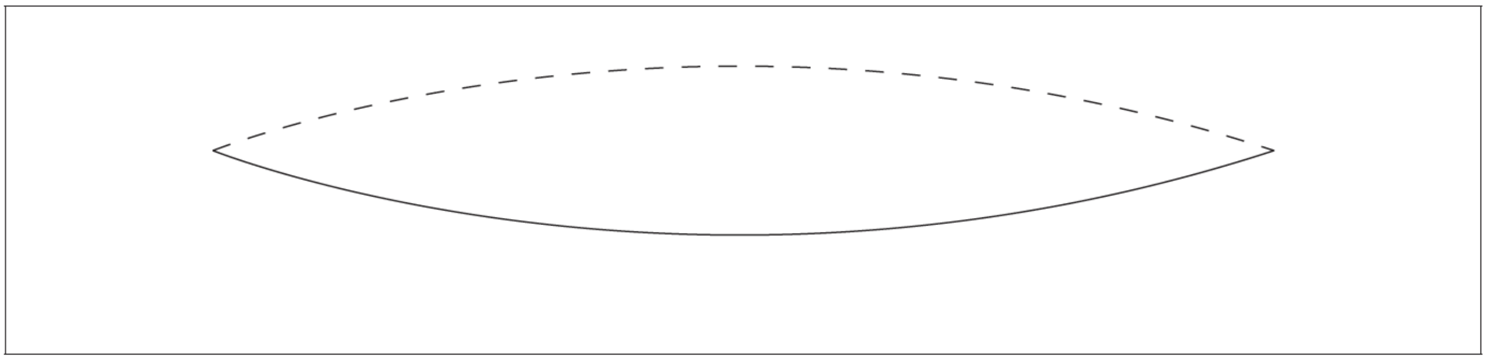
(ii) Calculate the frequency of the oscillator that would produce a standing wave with two loops on this string.

This question is about standing waves on strings.

a. A string is fixed at one end and the other free end is moved up and down. Explain how a standing wave can be formed on the string. [3]

b. The diagram shows a string vibrating in its first harmonic mode. Both ends [5]

of the string are fixed.



(i) Label an antinode on the diagram.

(ii) The length of the string is 0.85 m and its first harmonic frequency is 73 Hz. Calculate the speed of the waves on the string.

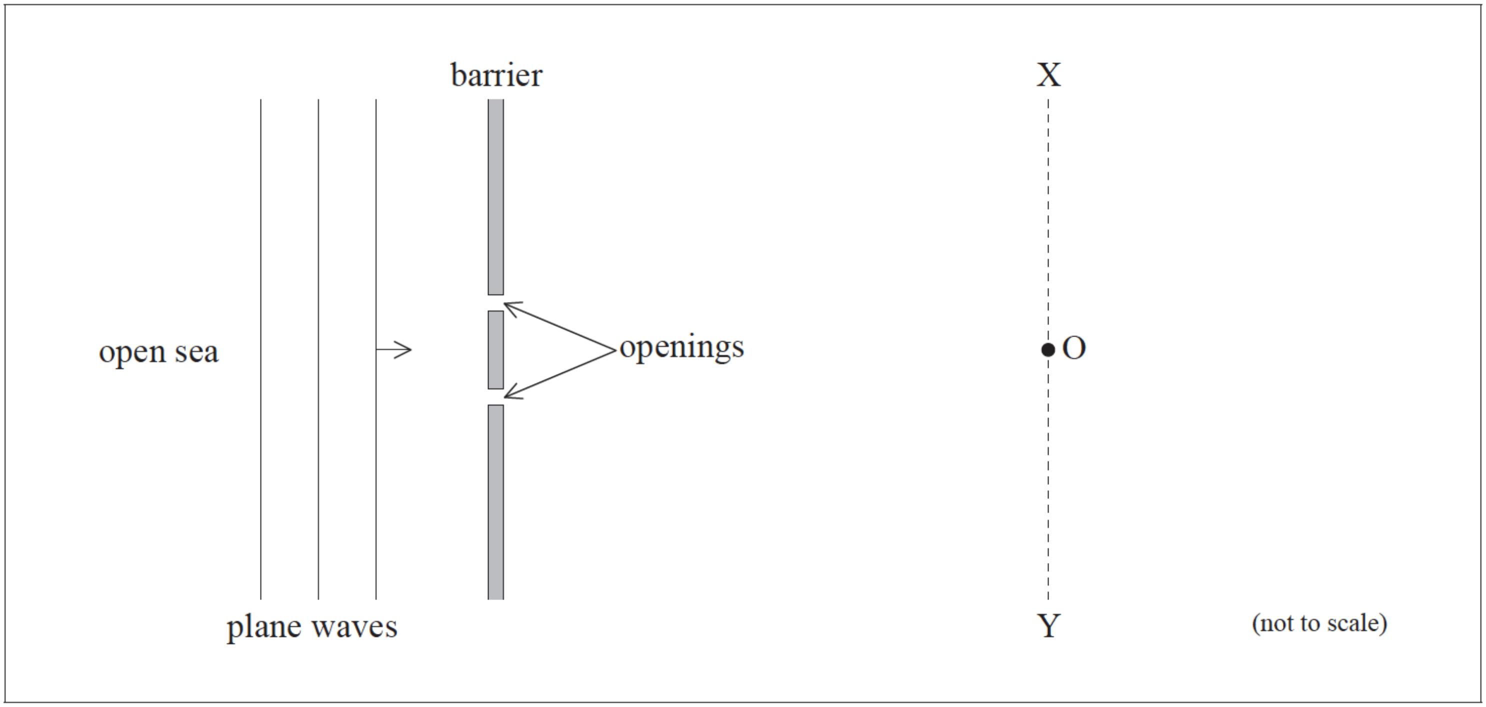
(iii) Sketch how the string will appear if it is vibrated at a frequency three times that of the first harmonic frequency.

(iv) State the speed of the wave when the string is vibrated at a frequency three times that of the first harmonic frequency.

This question is about waves.

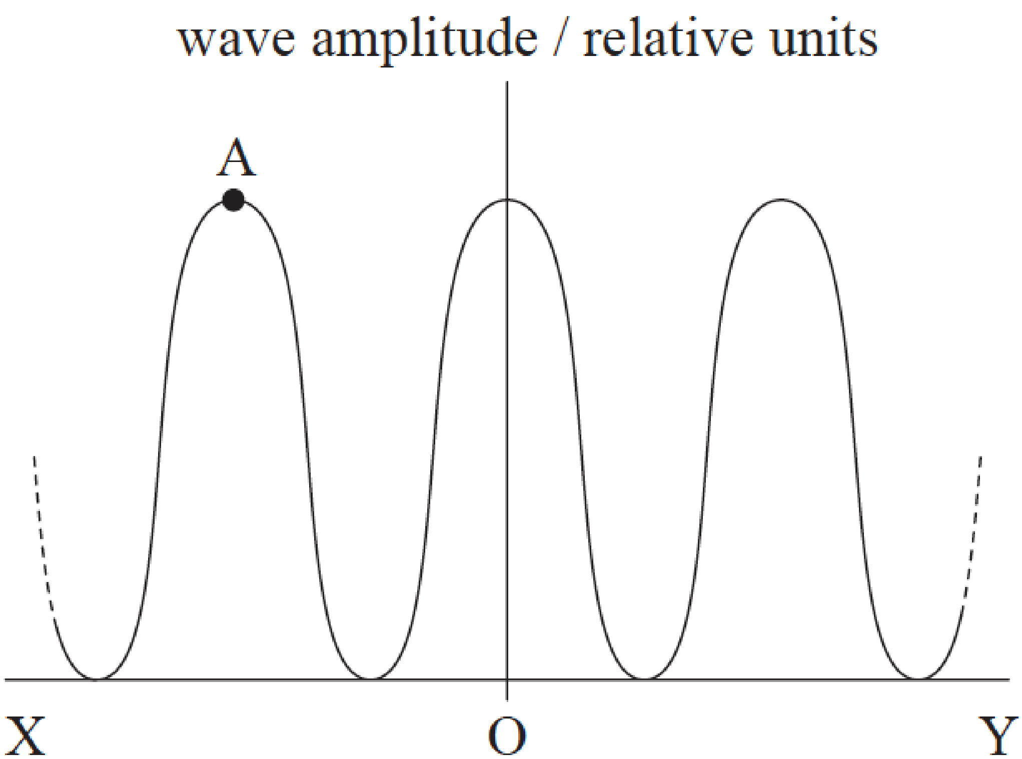
a. State the principle of superposition. [2]

b. The diagram shows a plan view of a harbour with a floating barrier that has two openings of equal width. [7]



Plane water waves from the open sea are incident on the barrier and the openings act as point sources of waves. The distance from the openings to XOY is much greater than the wavelength of the wave. O is equidistant from the openings.

The graph shows the variation of the magnitude of the wave amplitude that is observed along the line XOY.



(i) State why the two sets of waves emerging from the openings are coherent.

(ii) Explain how the disturbance at point A arises. You may draw on the diagram **of the harbour** to illustrate your answer.

(iii) The wavelength of the waves is doubled. State and explain the effect that this change will have on the graph.

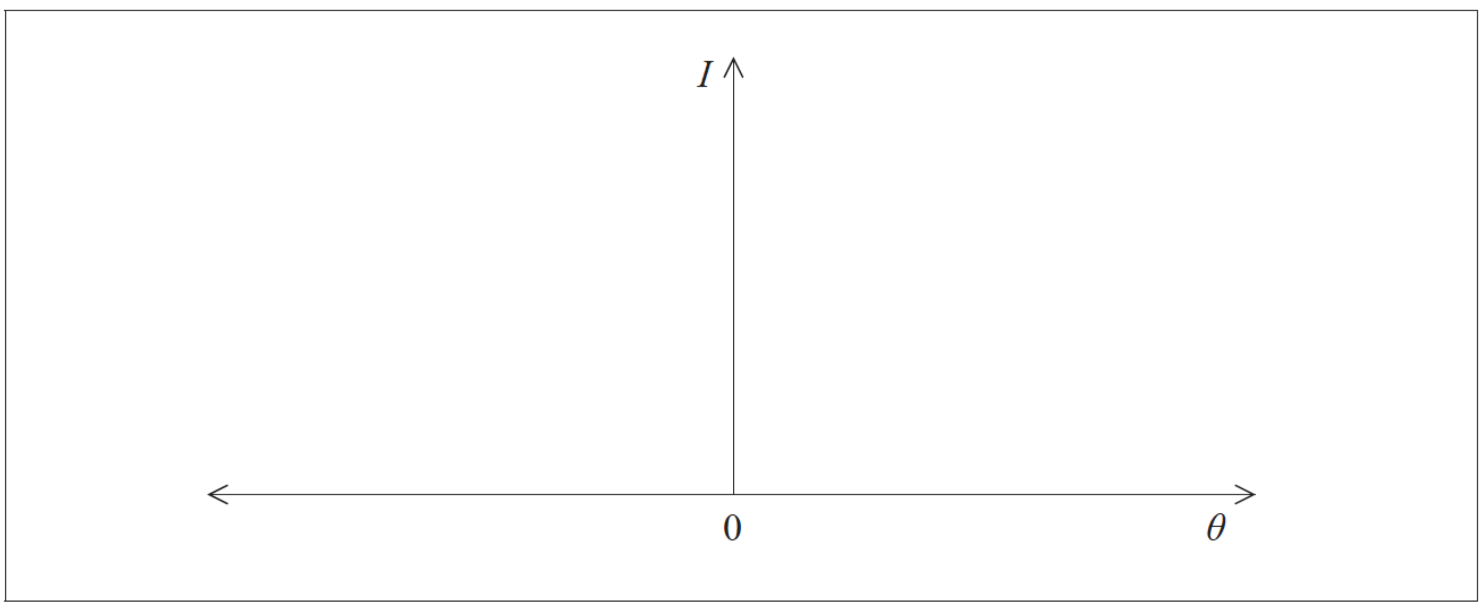
c. The harbour in (b) is modified to have many narrower openings. The total width of the openings remains the same. Outline **two** ways in which the variation of wave amplitude along XY changes from that shown on the graph in (b). [2]

This question is about diffraction and polarization.

a. Light from a monochromatic point source S_1 is incident on a narrow, rectangular slit. [5]

After passing through the slit the light is incident on a screen. The distance between the slit and screen is very large compared with the width of the slit.

(i) On the axes below, sketch the variation with angle of diffraction θ of the relative intensity I of the light diffracted at the slit.



(ii) The wavelength of the light is 480 nm. The slit width is 0.1 mm and its distance from the screen is 1.2 m. Determine the width of the central diffraction maximum observed on the screen.

b. Judy looks at two point sources identical to the source S_1 in (a). The distance between the sources is 8.0 mm and Judy's eye is at a distance *d* from the sources. [3]

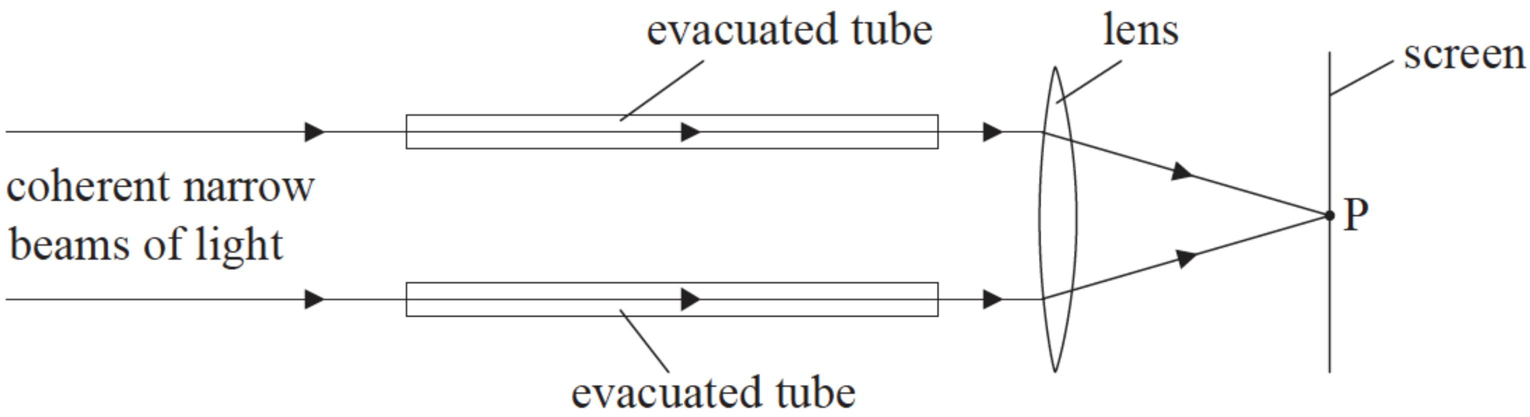
Estimate the value of *d* for which the images of the two sources formed on the retina of Judy's eye are just resolved.

c. The light from a point source is unpolarized. The light can be polarized by passing it through a polarizer. [3]

Explain, with reference to the electric (field) vector of unpolarized light and polarized light, the term polarizer.

This question is about interference of light.

Two coherent narrow beams of light pass through two identical evacuated tubes, as shown below.



The two coherent narrow beams are brought to a focus at point P on a screen.

a. State what is meant by coherence. [1]

b. State, with reference to the wavelength, the condition that must be satisfied for a bright fringe to be formed on the screen at point P. [1]

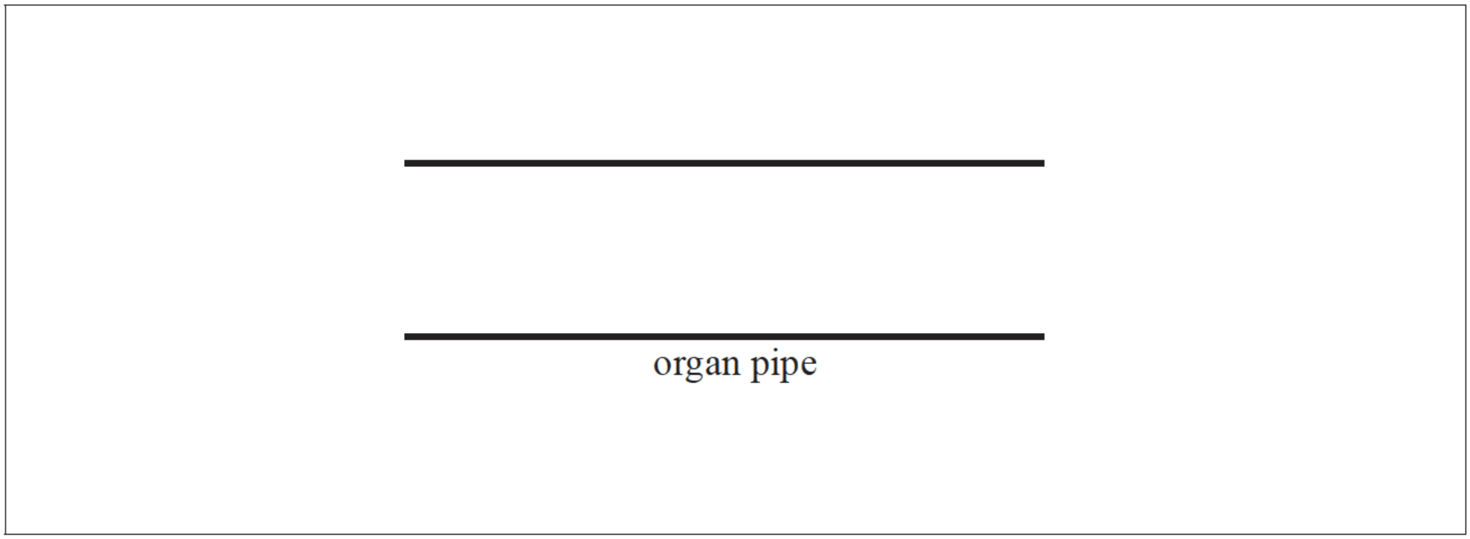
c. Air is allowed to enter gradually into one of the evacuated tubes. The brightness of the light at point P is seen to decrease and then increase again repeatedly. [2]

(i) State the effect on the wavelength of the light in the evacuated tube as the air is introduced.

(ii) Suggest why there is a variation in the brightness of the light at point P.

This question is about standing waves in an organ pipe.

a. The diagram shows an organ pipe that is open at both ends. [3]



The pipe is emitting its lowest frequency note.

On the diagram above,

(i) sketch a representation of the standing wave set up in the pipe.

(ii) label with the letter P, the point or points within the pipe where the air pressure is a maximum.

(iii) label with the letter A, the displacement antinodes.

b. The length of the pipe in (a) is 1.5 m. An organ pipe that is closed at one end has the same lowest frequency note as the pipe in (a). [3]

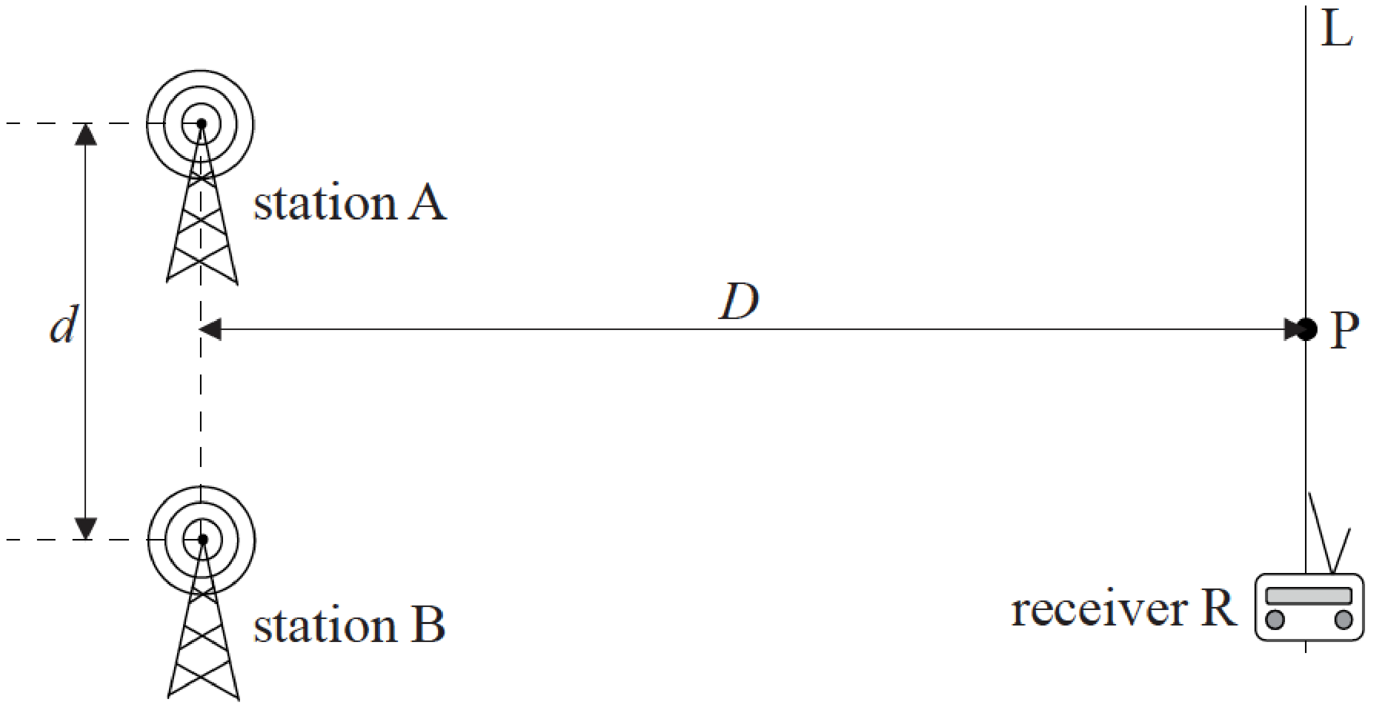
Show that the length of this pipe is 0.75 m.

This question is about polarized light.

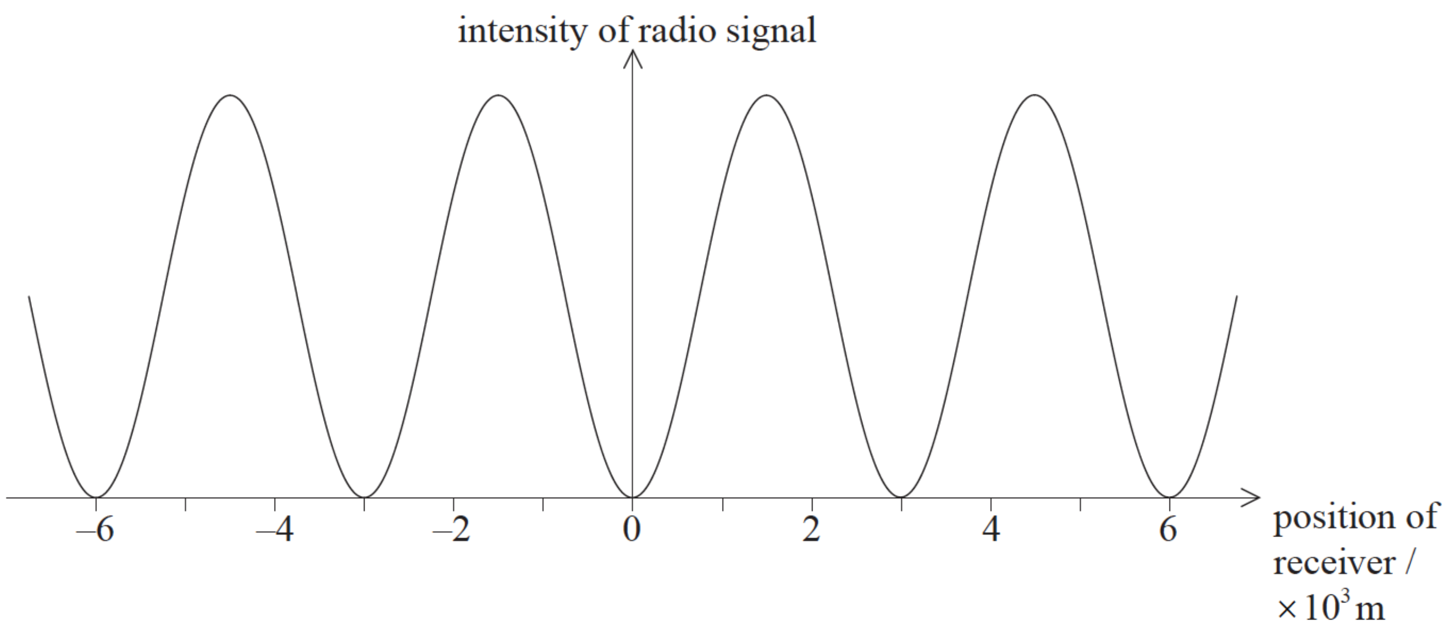
Describe what is meant by polarized light.

This question is about interference.

a. Two radio stations, A and B, broadcast two coherent signals. The separation *d* between A and B is much less than the distance *D* from the stations to the receiver R. Point P is at the same distance from A and B. [5]



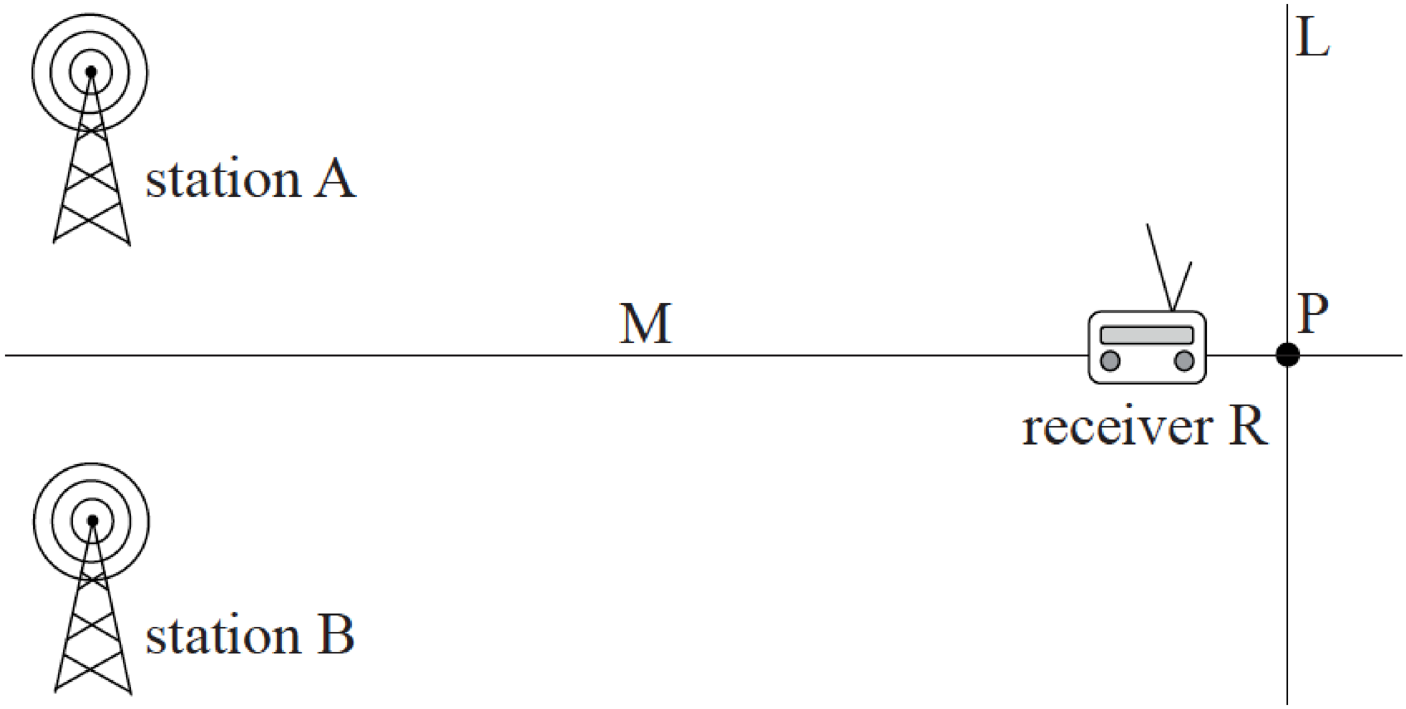
The graph shows how the intensity of the radio signal varies with position as the receiver is moved along line L. The position of the receiver is zero when the receiver is at P.



(i) Deduce that the two sources A and B are 180° out-of-phase.

(ii) The wavelength of the radio signal is 40m. Calculate the ratio $\frac{D}{d}$.

b. The receiver R then moves along a different line M which is at 90° to line L. [2]



Discuss the variation of the intensity of the radio signal with position as the receiver is moved along line M.

This question is about polarized light.

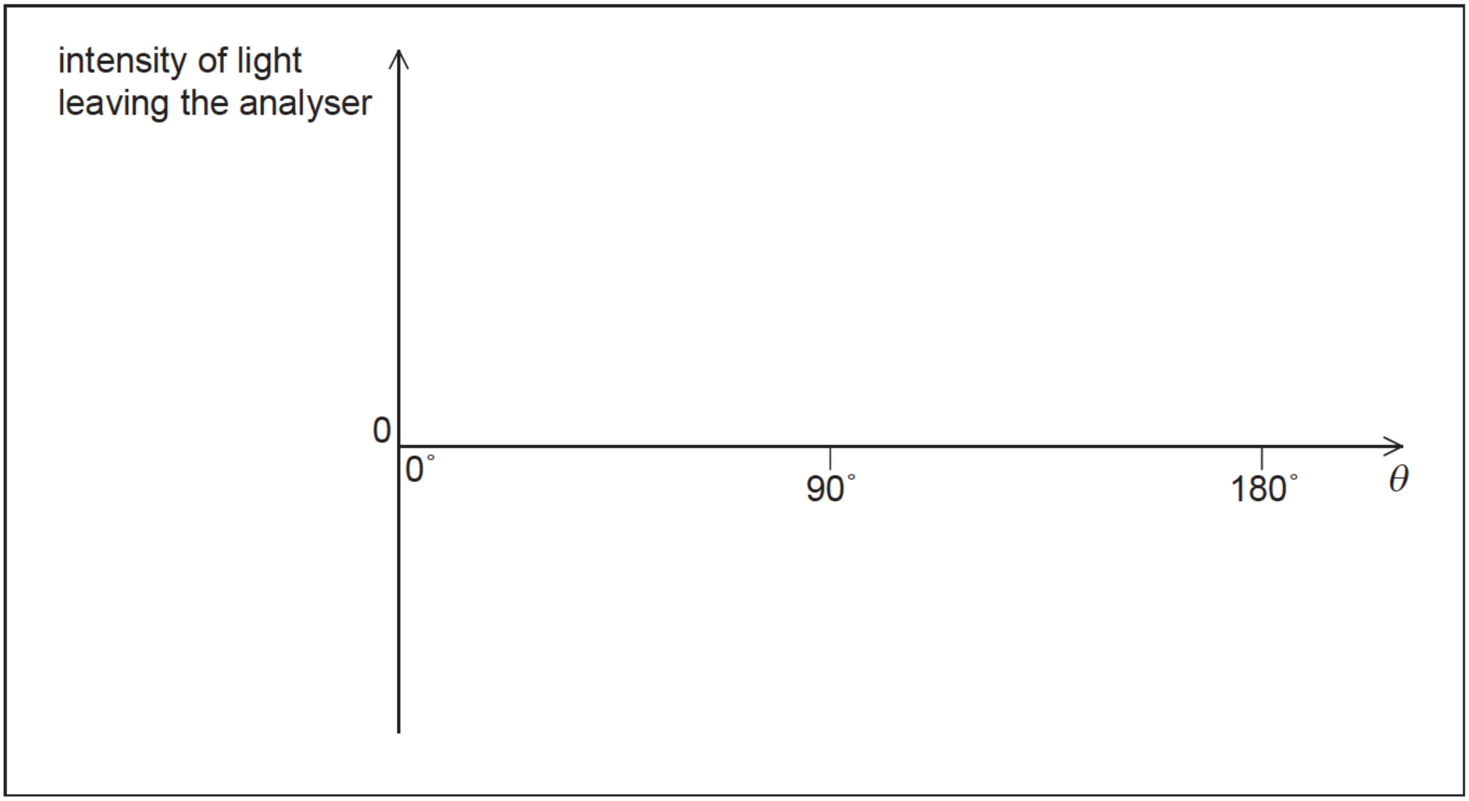
An analyser is used with polarized light.

a. Outline the function of an analyser in this context. [2]

b. Polarized light of intensity I_0 is incident on the analyser. [3]

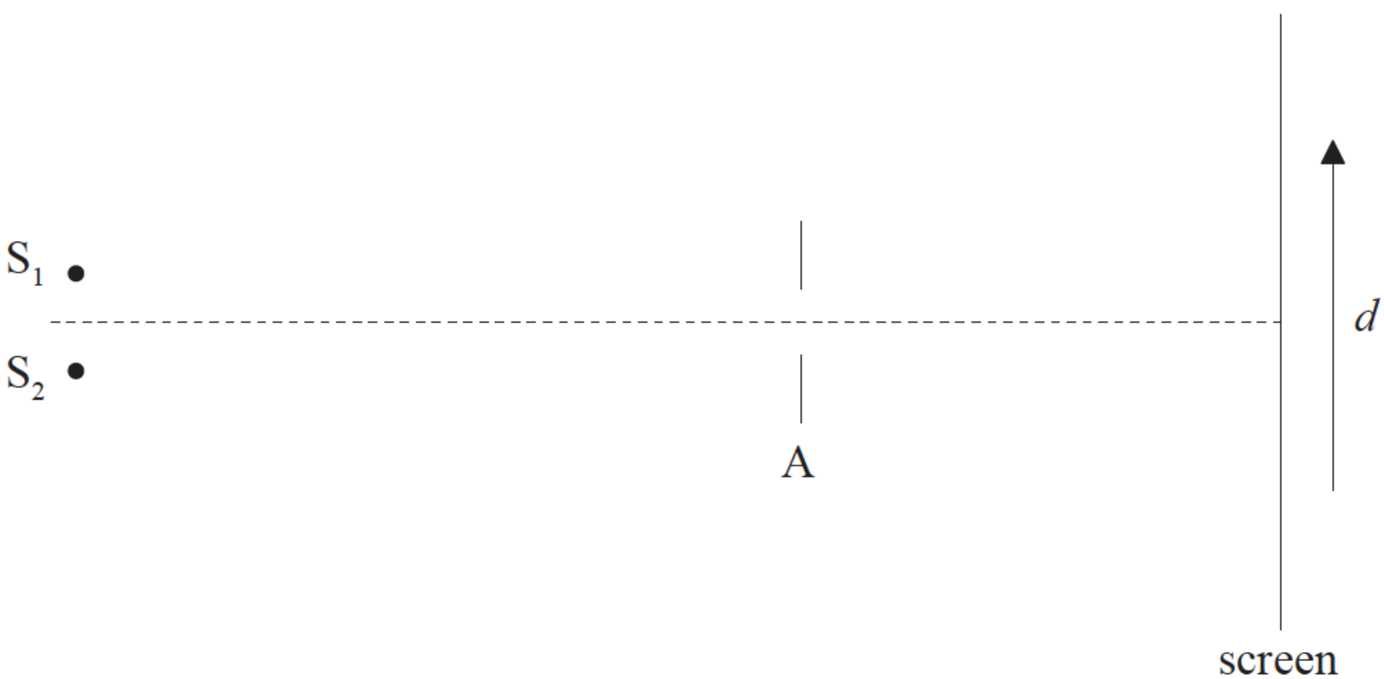
(i) The transmission axis of the analyser is at an angle of 25° to the electric field of the polarized light. Calculate, in terms of I_0, the intensity of the light that leaves the analyser.

(ii) The angle θ between the transmission axis of the analyser and the electric field of the polarized light is varied. On the axes, sketch a graph to show the variation with θ of the intensity of the light leaving the analyser.



This question is about resolution.

a. Two point sources S_1 and S_2 emit monochromatic light of the same wavelength. The light is incident on a small aperture A and is then brought to focus on a screen. [3]



The images of the two sources on the screen are just resolved according to the Rayleigh criterion. Sketch, using the axes below, how the relative intensity *I* of light on the screen varies with distance along the screen *d*.

b. A car is travelling at night along a straight road. Diane is walking towards the car. She sees the headlights of the car as one single light. [3]

Estimate, using the data below, the separation *d* between Diane and the car at which, according to the Rayleigh criterion, Diane will just be able to see the headlights as two separate sources.

Distance between the headlights = 1.4 m
Average wavelength of light emitted by the headlights = 500 nm
Diameter of the pupils of Diane's eyes = 1.9 mm

c. The light from the car headlights in (b) is not polarized. State what is meant by polarized light. [1]