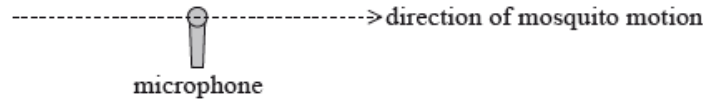# SL Paper 3

This question is about the Doppler effect.

Georgia carries out an experiment to measure the speed of mosquitoes. She sets up a microphone to record the sounds of passing mosquitoes.

------------------$\ominus$----------------> direction of mosquito motion
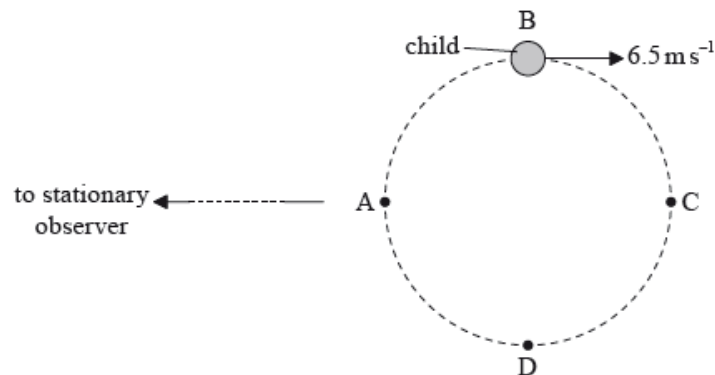
microphone

One mosquito is moving in a straight line with constant speed and passes very close to the microphone as seen in the diagram. The mosquito produces a sound of constant frequency.

The speed of sound in air is 340 m s^{-1}.

a. The maximum frequency recorded is 751 Hz and the minimum frequency recorded is 749 Hz. Explain this observation.   [2]

b. Determine the speed of the mosquito.   [3]

This question is about the Doppler effect.

A child on a carousel (merry-go-round) moves with a speed of 6.5 m s^{-1} along a horizontal circular path ABCDA. A stationary observer is at a large
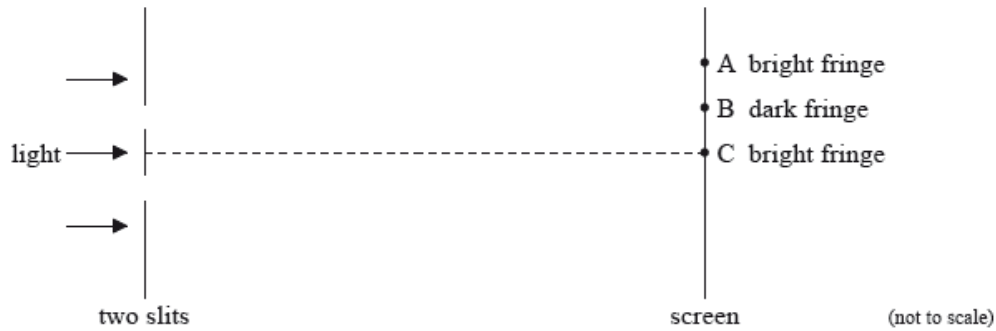
distance from the carousel.

The child blows a whistle while moving from position B to position D. The whistle emits sound of frequency 850 Hz. The speed of sound in air is 330 m s^{-1}.

a. Describe what is meant by the Doppler effect.   [2]

b. (i)   Determine the minimum frequency of the sound heard by the observer.   [4]

    (ii)   Describe the variation of the frequency of the sound heard by the observer.

This question is about interference.

Light from a laser is incident on two identical parallel slits. The light from the two slits produces a fringe pattern on a screen.

A central bright fringe is produced at C. The next bright fringe is produced at A. There is a dark fringe at B.
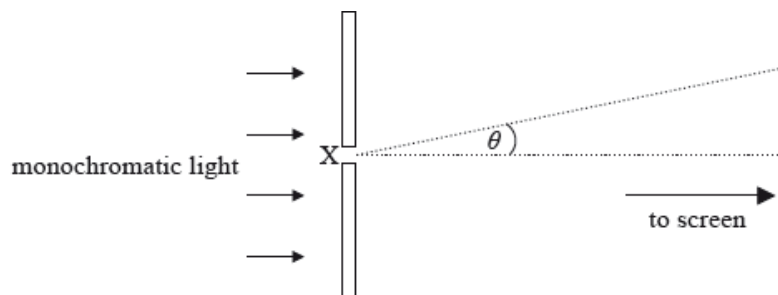
The light from the laser is coherent and monochromatic.

The distance from the two slits to the screen is 1.5 m. The distance BC is 1.8 mm and the distance between the slits is 0.30 mm.

a. Outline what is meant by the term   [2]

   (i)   coherent.

   (ii)   monochromatic.

b. State the phase difference between the light waves from the two slits that meet at B.   [1]

c. (i)   Show that the laser produces light of wavelength equal to 720 nm.   [4]

   (ii)   State the path difference, in metres, between the waves that meet at B.

d. Determine the number of lines per metre of the diffraction grating.   [3]
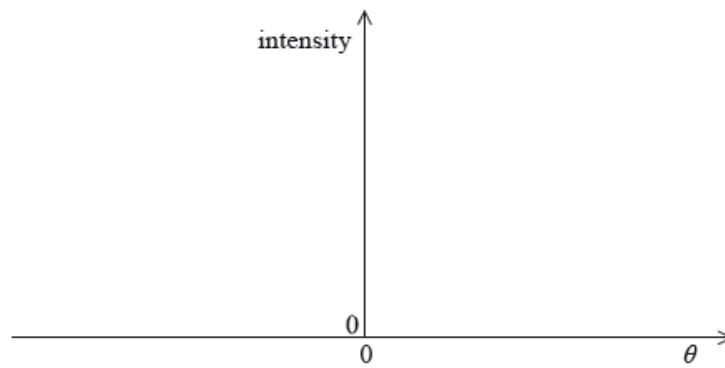

This question is about diffraction and resolution.

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.

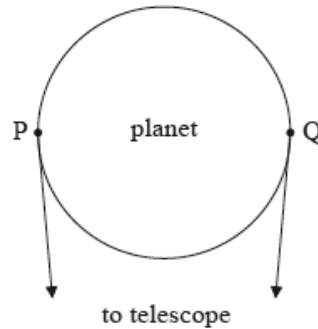Point X is the midpoint of the slit.

a. (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.   [5]

intensity

0

0   θ

(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.

b. Points P and Q are on the circumference of a planet as shown.   [3]

P •   planet   • Q

to telescope

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.

This question is about a diffraction grating.

For a particular grating, the distance between adjacent slits is 2.0×10^{-6} m. Determine, for light of wavelength 520 nm, the maximum theoretical

order of diffraction.

This question is about the Doppler effect.

a. Describe what is meant by the Doppler effect as it relates to sound.   [2]

b. An ambulance is travelling at a speed of 28.0 ms^{-1} along a straight road. Its siren emits a continuous sound of frequency 520 Hz. The   [3]

ambulance is approaching a stationary observer. The observer measures the frequency of the note to be 566 Hz. Determine the speed of sound.
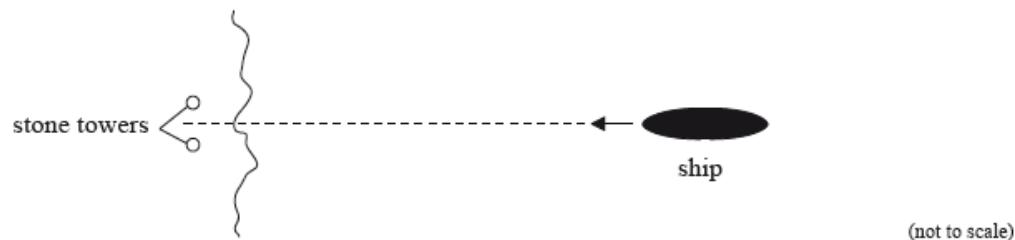

This question is about radio telescopes.

A distant galaxy emits radio waves of frequency 6.0×10^9 Hz and is moving with speed 6.0×10^6 ms^{-1} directly away from an observer on Earth.

a. Determine the wavelength of the radio wave as measured by the observer on Earth. [3]

b. The radio signals from two stars on opposite sides of the galaxy are detected on Earth using a radio telescope. The telescope has a circular [4] receiving dish.

(i) State the Rayleigh criterion for the images of two point sources to be just resolved.

(ii) The galaxy is 2.0×10^{21}m from Earth and the stars are separated by 5.0×10^{19}m. Determine the minimum size of the telescope dish required to resolve the images of the two stars at a wavelength of 5.1×10^{-2}m.

This question is about resolution and polarization.

A ship sails towards two stone towers built on land.

(not to scale)

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 [2] Emlyn's eyes.

This question is about the Doppler effect.

The sound emitted by a car's horn has frequency f , as measured by the driver. An observer moves towards the stationary car at constant speed and measures the frequency of the sound to be f '.

a. Explain, using a diagram, any difference between f and f'. [3]

b. The frequency f is 3.00×10^2Hz. An observer moves towards the stationary car at a constant speed of 15.0ms^{-1}. Calculate the observed [2] frequency f' of the sound. The speed of sound in air is $3.30\times10^2\text{ms}^{-1}$.

This question is about using a diffraction grating to view the emission spectrum of sodium.

Light from a sodium discharge tube is incident normally upon a diffraction grating having 8.00×10^5 lines per metre. The spectrum contains a double yellow line of wavelengths 589 nm and 590 nm.
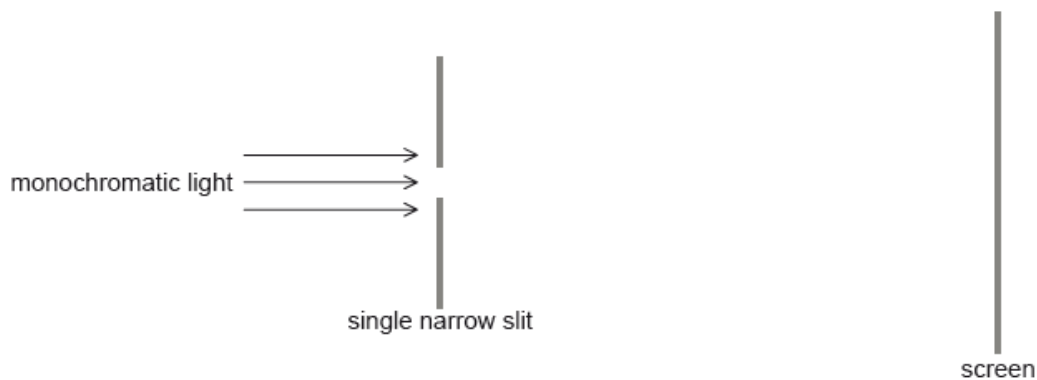
a. Determine the angular separation of the two lines when viewed in the second order spectrum.   [4]

b. State why it is more difficult to observe the double yellow line when viewed in the first order spectrum.   [1]
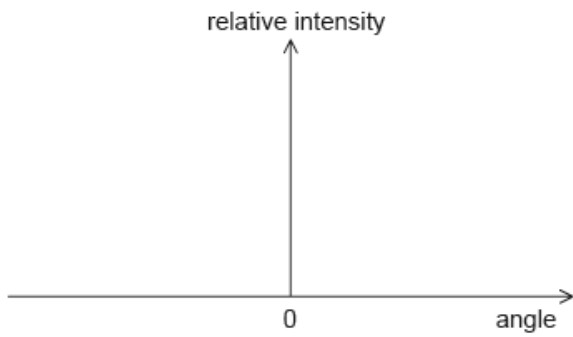

This question is about the Doppler effect.

a. Describe the Doppler effect.   [3]

b. A spectral line from a source on Earth has a frequency of 4.672×10^{14} Hz. When this same line is observed from a distant galaxy it is found to   [4]

have shifted to 4.669×10^{14} Hz.

(i) State the direction of the motion of the galaxy relative to Earth.

(ii) Deduce the speed of the galaxy relative to Earth.

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   [2]

centre of the slit.

relative intensity

0   angle

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   [3]

diffraction patterns produced by the light emerging from the two slits.

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.   [2]

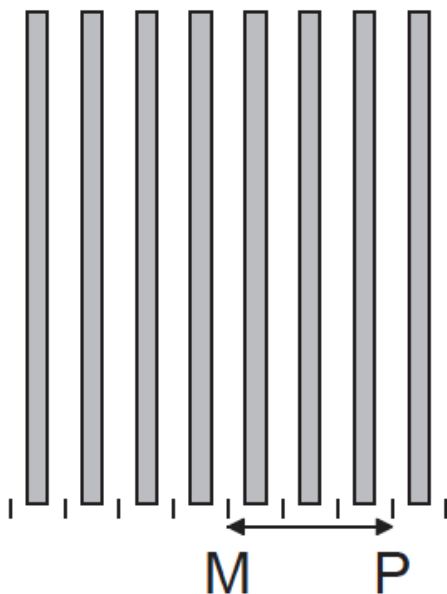Calculate the minimum distance between the lamps so that they are resolved.

This question is about two-source interference.

Coherent light is incident at right angles to a double slit. An interference pattern is observed on a distant screen.

The number of slits is now increased. State and explain the effect, if any, this has on the appearance of the bright fringes.

This question is about a double-slit experiment.

Coherent monochromatic light is incident on two narrow rectangular slits. The diagram shows the fringes produced on a screen that is some distance from the slits. M is the middle of the central bright fringe and P is the middle of the third bright fringe.

M   P   (not to scale)

a. Explain why an interference pattern is produced on the screen.   [2]

b. The two slits are separated by 2.2 mm and the distance from the slits to the screen is 1.8 m. The wavelength of the light is 650 nm. Calculate   [2]

the distance MP.

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 $330ms^{-1}$.
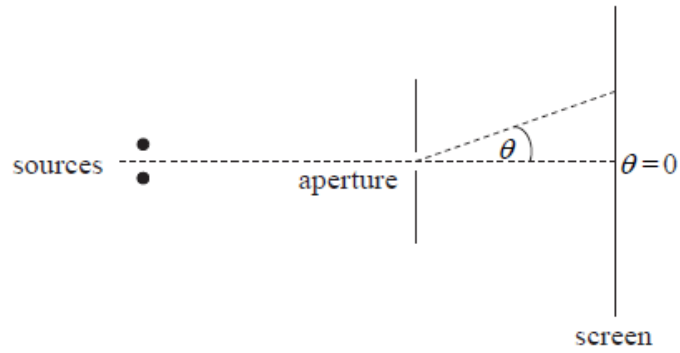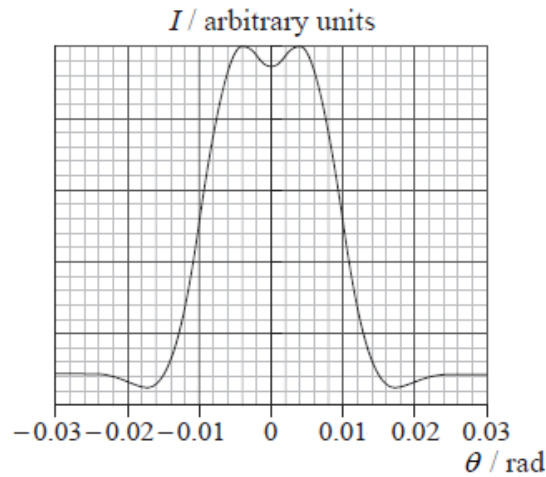
pipe

open end

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   [5]

in frequency between the harmonics emitted by the horn is measured as 820 Hz.

(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 $50ms^{-1}$ 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 the Doppler effect in sound.

a. A fire engine is travelling at a constant velocity towards a stationary observer. Its siren emits a note of constant frequency. As the engine passes   [3]

close to the observer, the frequency of the note perceived by the observer decreases. Explain this decrease in terms of the wavefronts of the

note emitted by the siren.

b. The frequency of the note emitted by the siren is 400 Hz. After the fire engine has passed, the frequency of the note detected by the observer is   [2]

360 Hz. Calculate the speed of the fire engine. (Take the speed of sound in air to be 340 ms^{-1}.)

This question is about resolution.

The graph shows how the intensity *I* of the light on the screen varies with the angle θ .

The two sources are just resolved according to the Rayleigh criterion.

a. State what is meant by resolved in this context.   [1]

b. The wavelength of the light from the two sources is 528 nm. The distance of the two sources from the aperture is 1.60 m.   [3]
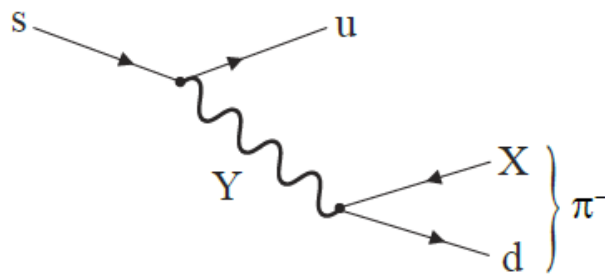
Using data from the graph opposite, determine the

(i) separation of the two sources.

(ii) diameter of the aperture.

This question is about the Ω^- particle.

The Ω^- particle is a baryon which contains only strange quarks.

This question is about laser light.

a. Deduce the strangeness of the Ω^- particle.   [1]

b. The Feynman diagram shows a quark change that gives rise to a possible decay of the Ω^- particle.   [2]
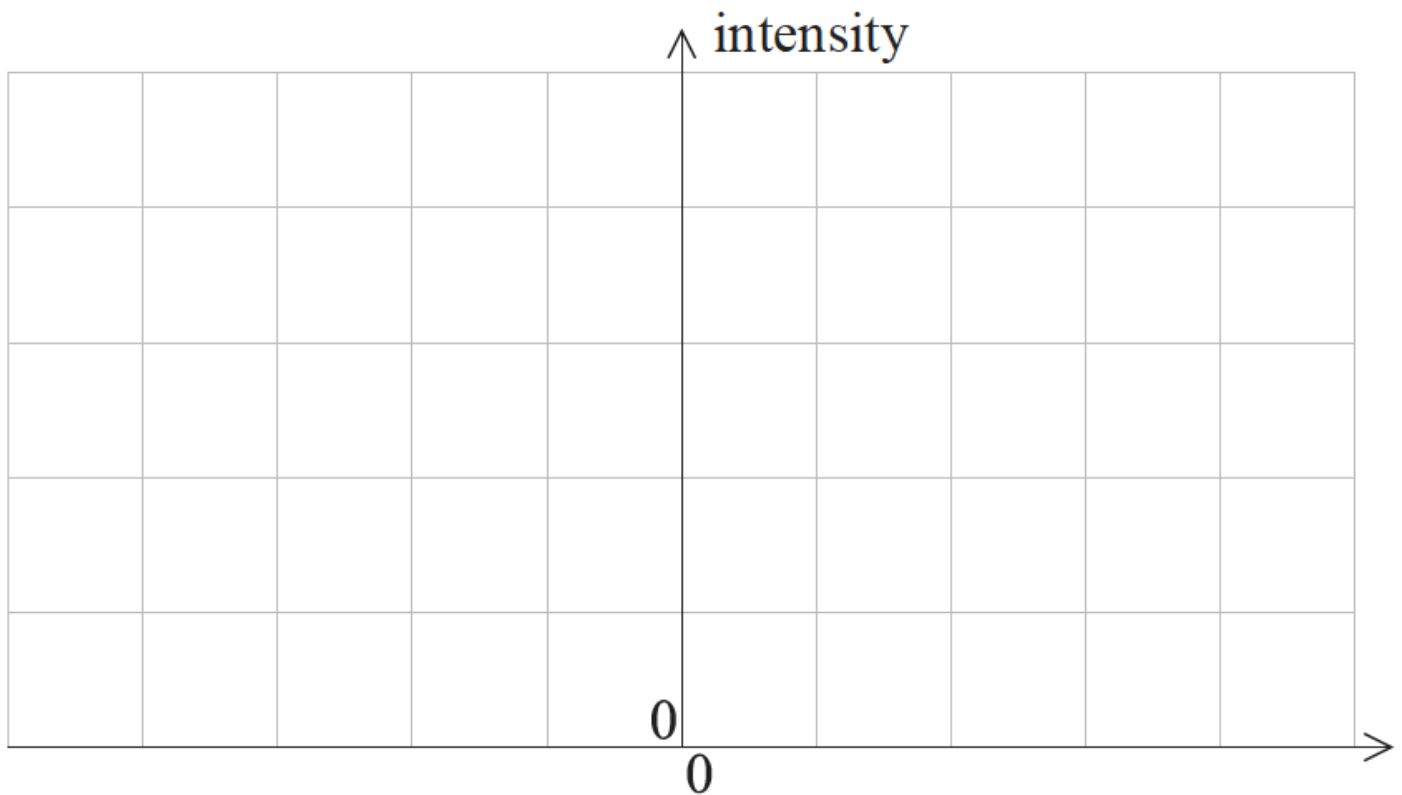
(i) Identify X.

(ii) Identify Y.

c. The number of lines per millimetre in the diffraction grating in (b) is reduced. Describe the effects of this change on the fringe pattern in (b).   [2]
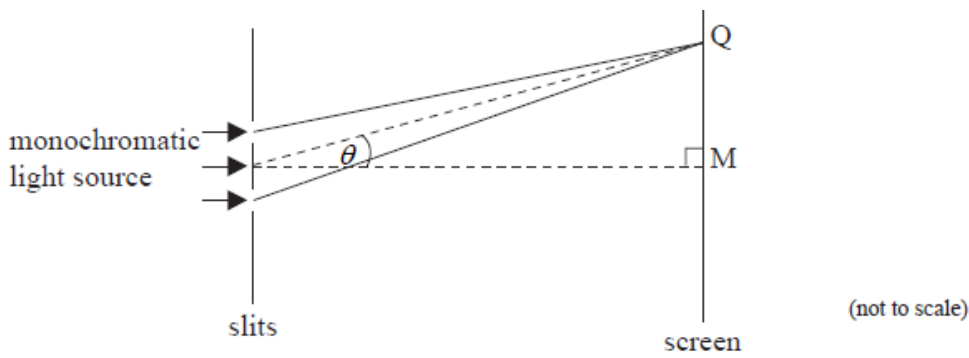

This question is about resolution.

A car is travelling along a straight road at night. To a distant observer the two headlamps of the car appear as a single point source. With the aid of an appropriately labelled sketch graph, explain this observation.

This question is about two-source interference.

a. Light from a monochromatic source is incident at right angles to two slits. After passing through the slits the light is incident on a distant screen. [6]

Point M is the mid-point of the screen.

(not to scale)

The separation of the slits is large compared to their width. A pattern of light and dark fringes is observed on the screen.
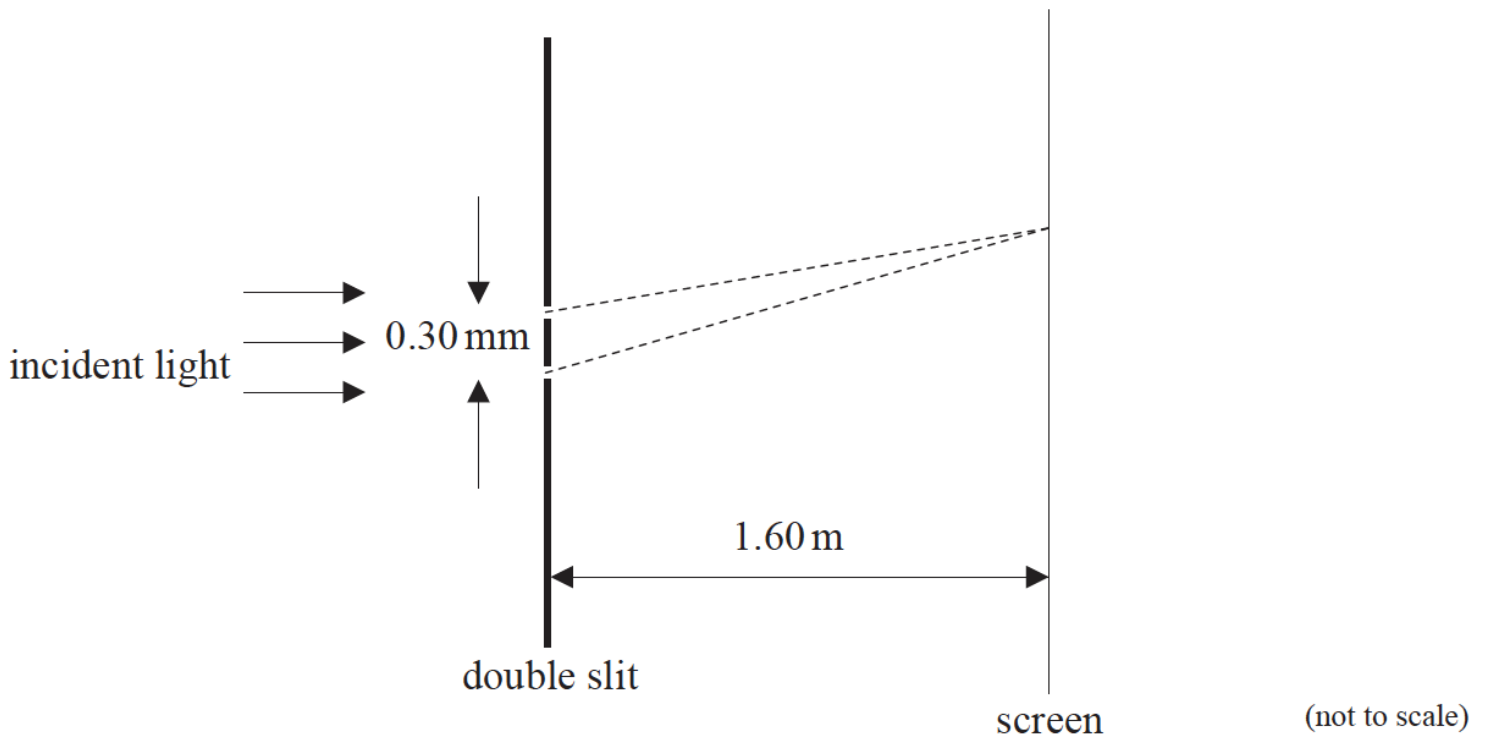
(i) State the phenomenon that enables light to reach point M on the screen.

(ii) On the axes below, sketch the intensity of light as observed on the screen as a function of the angle θ. (You do not have to put any numbers on the axes.)

(iii) The distance of the screen from the slits is 1.8 m and the slit separation is 0.12 mm. The wavelength of the light is 650 nm. Point Q on the screen shows the position of the first dark fringe.

Calculate the distance MQ.

b. Suggest why, even though there are dark fringes in the pattern, no energy is lost.   [2]

This question is about interference of light at two parallel slits.

a. State the condition necessary to observe interference between two light sources.   [1]

b. The diagram below shows an arrangement for observing a double slit interference pattern. A parallel beam of coherent light of wavelength 410   [2]

nm is incident on two parallel narrow slits separated by 0.30 mm. A screen is placed 1.60 m beyond the slits.

@Calculate the fringe spacing on the screen.

c. The slits in (b) are replaced by a large number of slits of the same width and separation as the double slit. Describe the effects that this change [3]
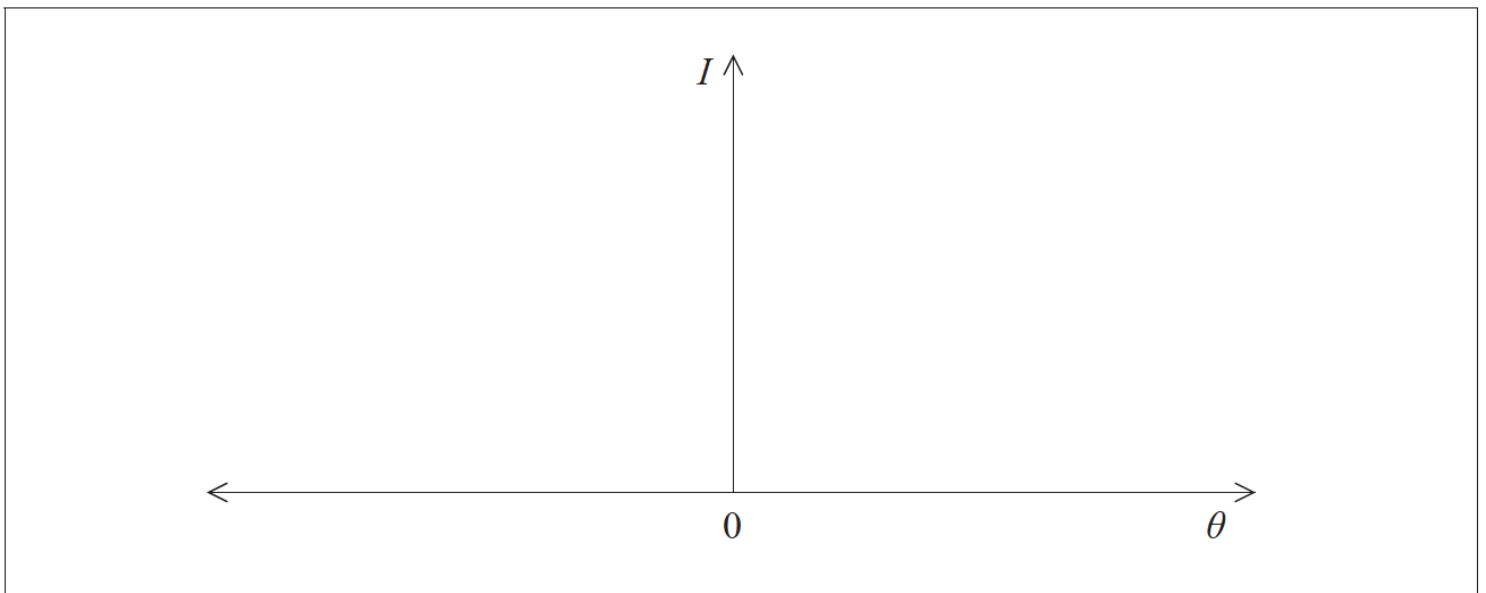will have on the appearance of the fringes on the screen.

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 [3]
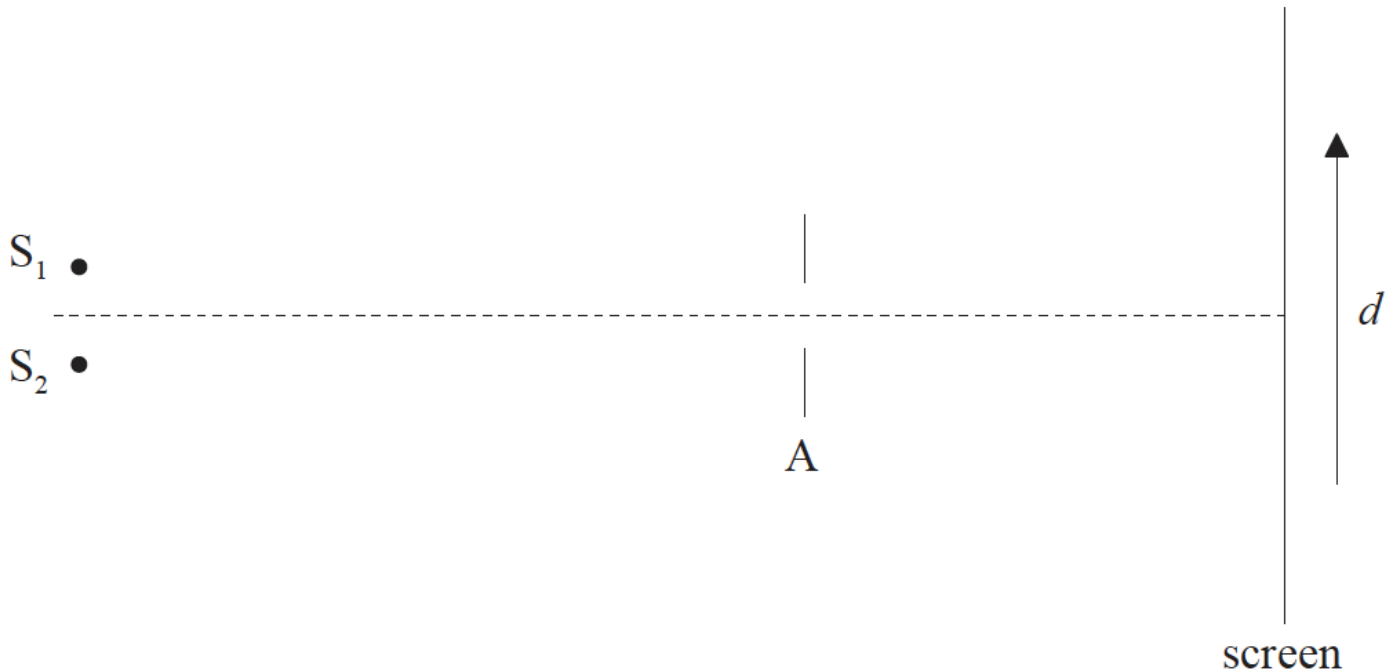
from the sources.

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 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 [3]

to focus on a screen.

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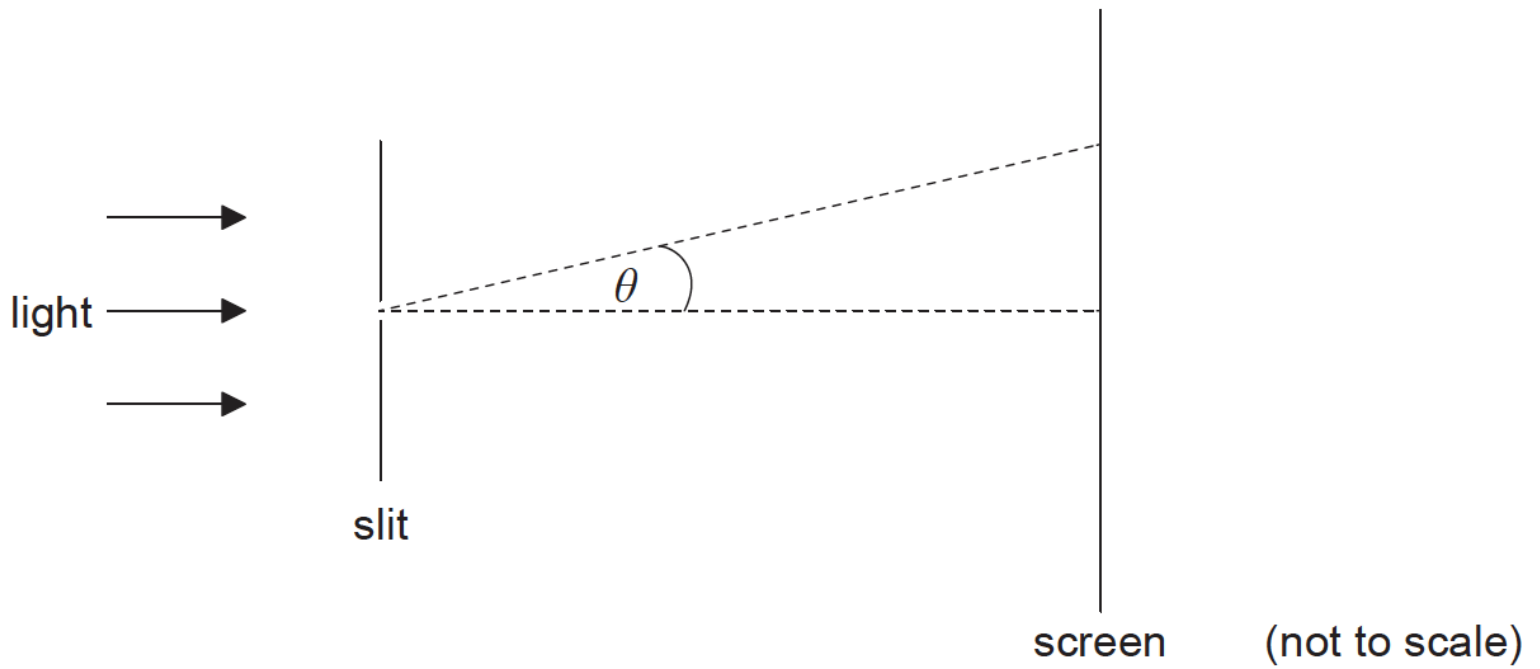
   Distance between the headlights = 1.4 m
   Average wavelength of light emitted by the headlights = 500 nm
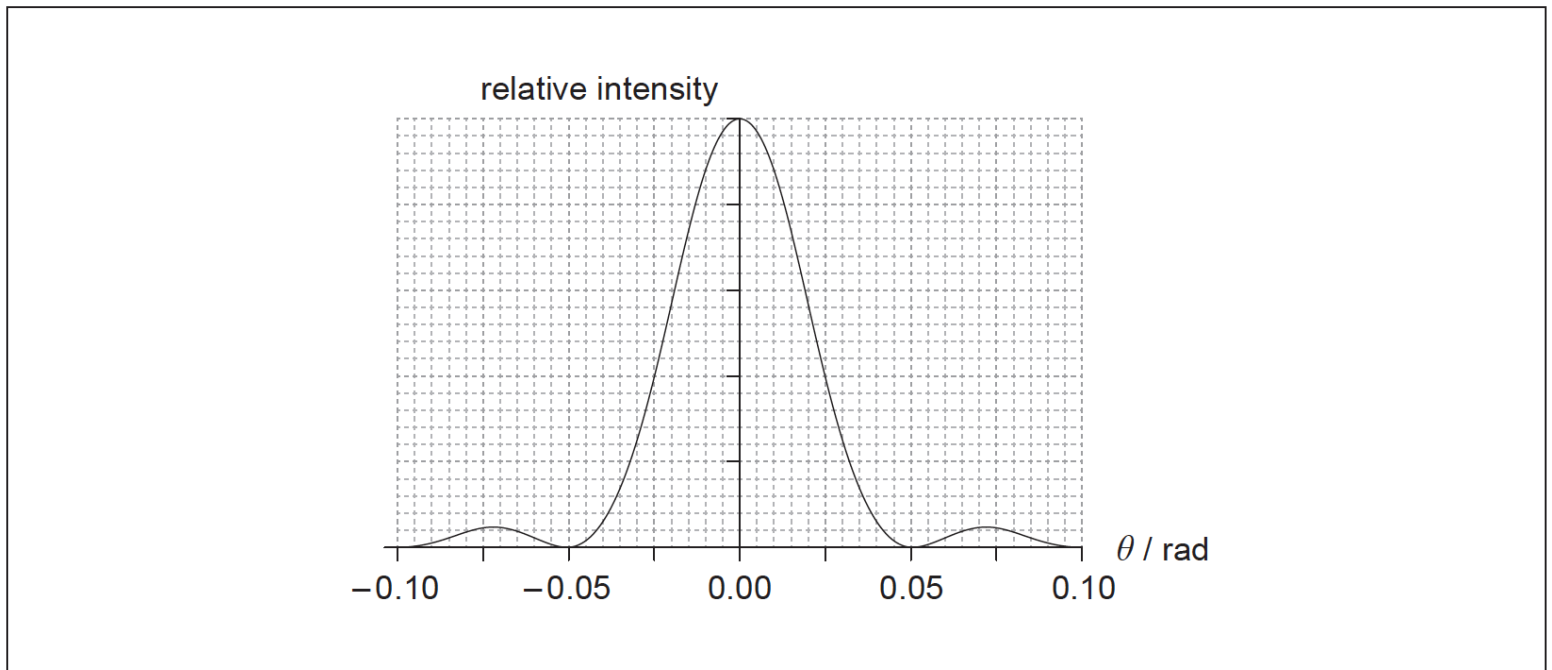   Diameter of the pupils of Diane's eyes = 1.9 mm

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

This question is about diffraction and resolution.

Monochromatic light is incident on a narrow rectangular slit.

The light is observed on a screen far from the slit. The graph shows the variation with angle θ of the relative intensity for light of wavelength 7.0×10^{-7}m.

a. Estimate the width of the slit. [2]

b. On the graph, sketch the variation of the relative intensity with θ when the wavelength of the light is reduced. [1]

c. State and explain, with reference to your sketch in (b), whether it is easier to resolve two objects in blue light **or** in red light. [2]
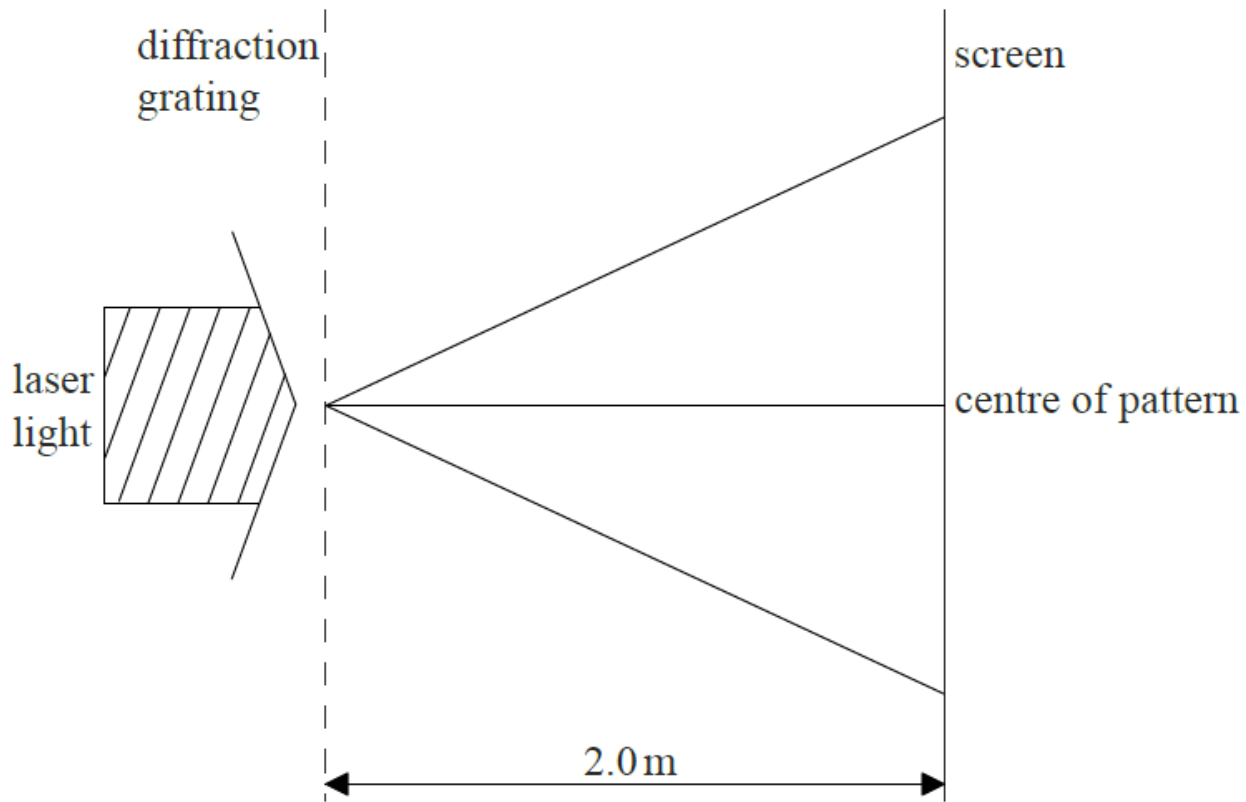
This question is about laser light.

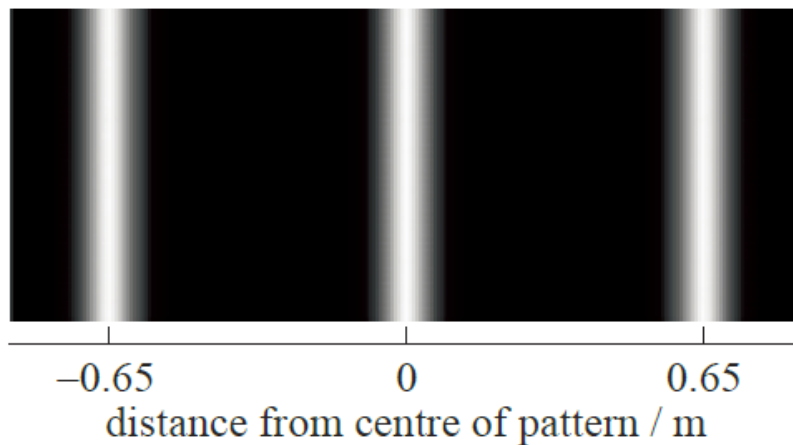a. Laser light is monochromatic and coherent. Explain what is meant by

(i) monochromatic.

(ii) coherent.

b. A beam of laser light is incident normally on a diffraction grating which has 600 lines per millimetre. A fringe pattern is formed on a screen 2.0 m [4]
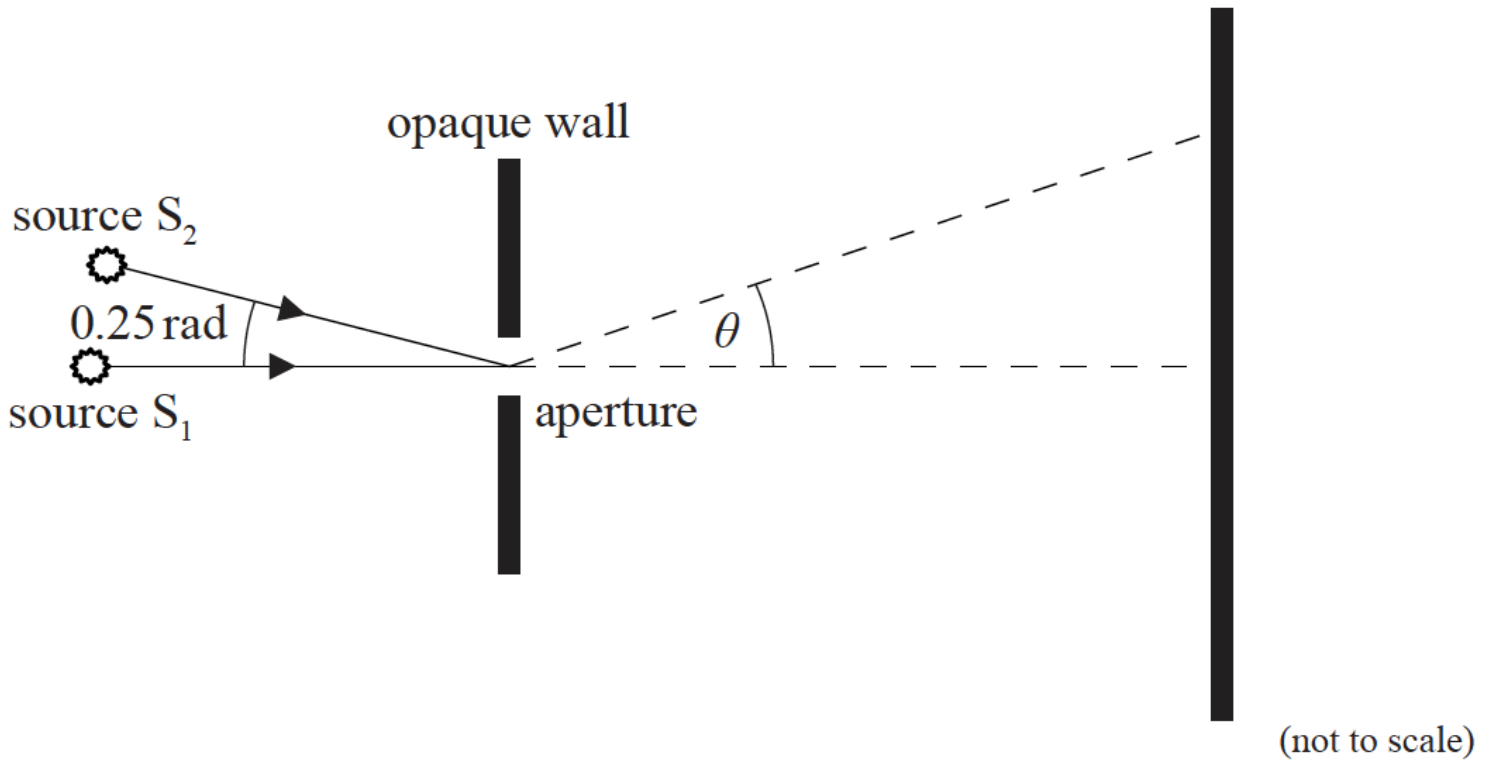
from the diffraction grating.

The fringe pattern formed on the screen is shown below.

Determine the wavelength of the laser light.

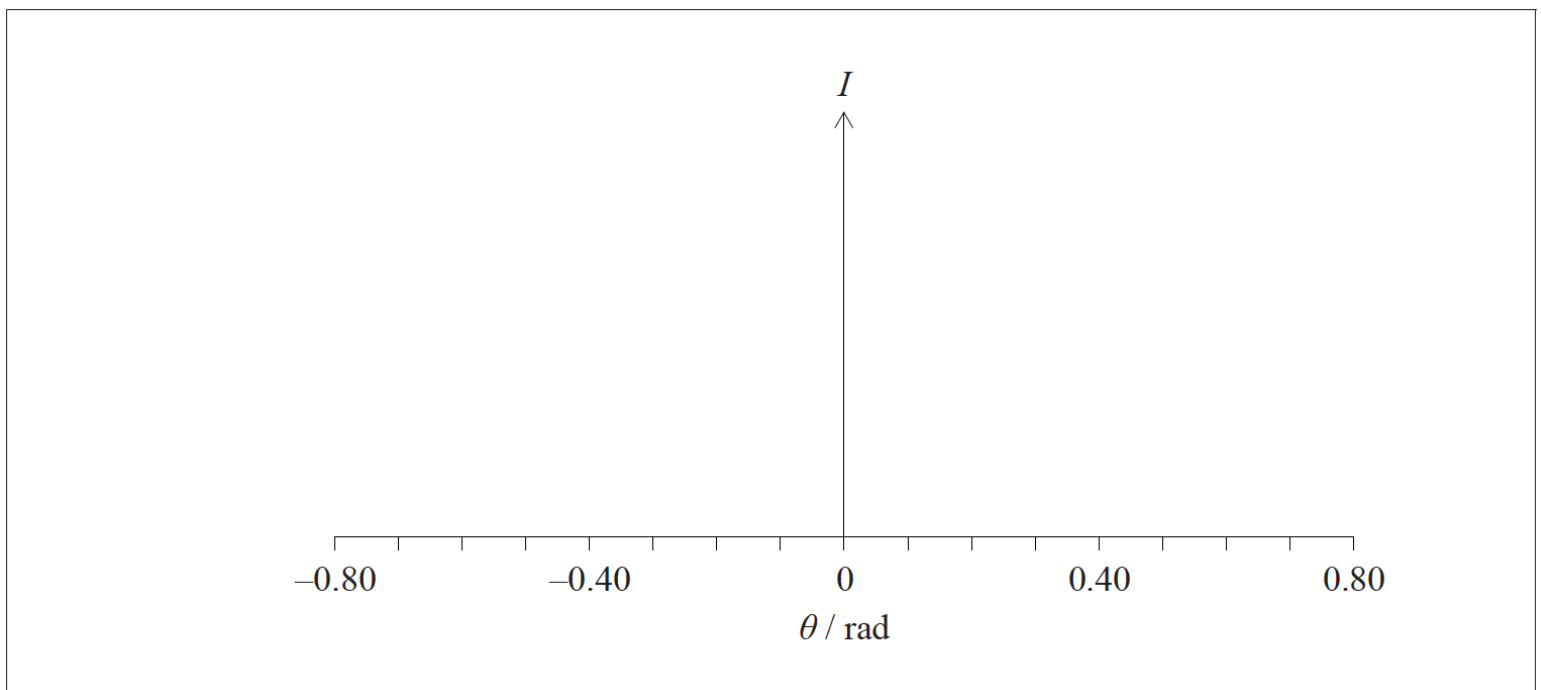This question is about diffraction and resolution.

Two identical sources of electromagnetic radiation, S_1 and S_2, emit monochromatic coherent waves of wavelength 59 μm. The waves pass through a circular aperture and are incident on a screen.

opaque wall

source S₂

0.25 rad

source S₁

aperture

θ

(not to scale)

S₁ and S₂ are at the same distance from the aperture. The diameter of the aperture is 0.18 mm. The angle between the lines joining the sources to the aperture is 0.25 rad.
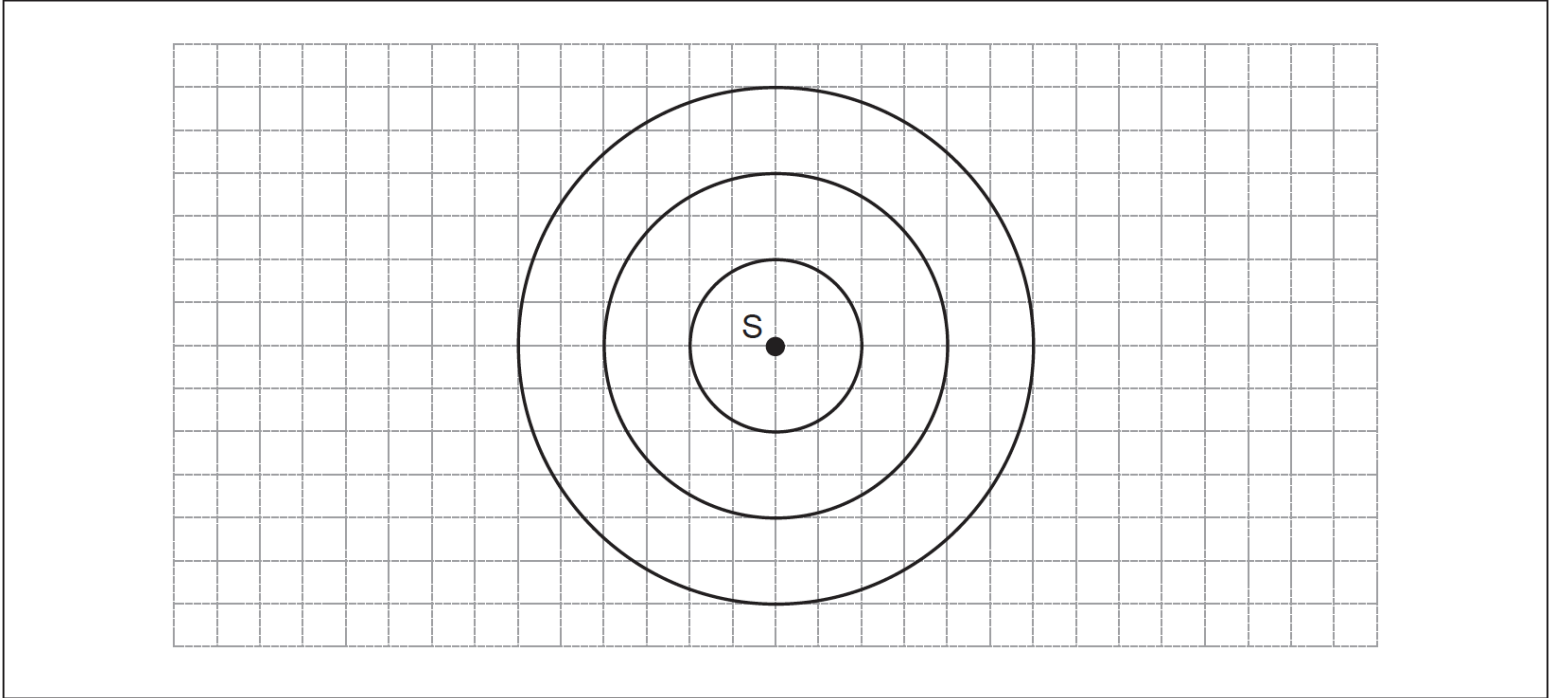
S₁ is turned on and S₂ is turned off.

(i) Show that the angle at which the first minimum of the diffraction pattern occurs is 0.40 rad.

(ii) On the axes below, sketch a graph to show how the intensity *I* of the radiation from S₁ varies with the diffraction angle θ.

I

−0.80   −0.40   0   0.40   0.80

θ / rad

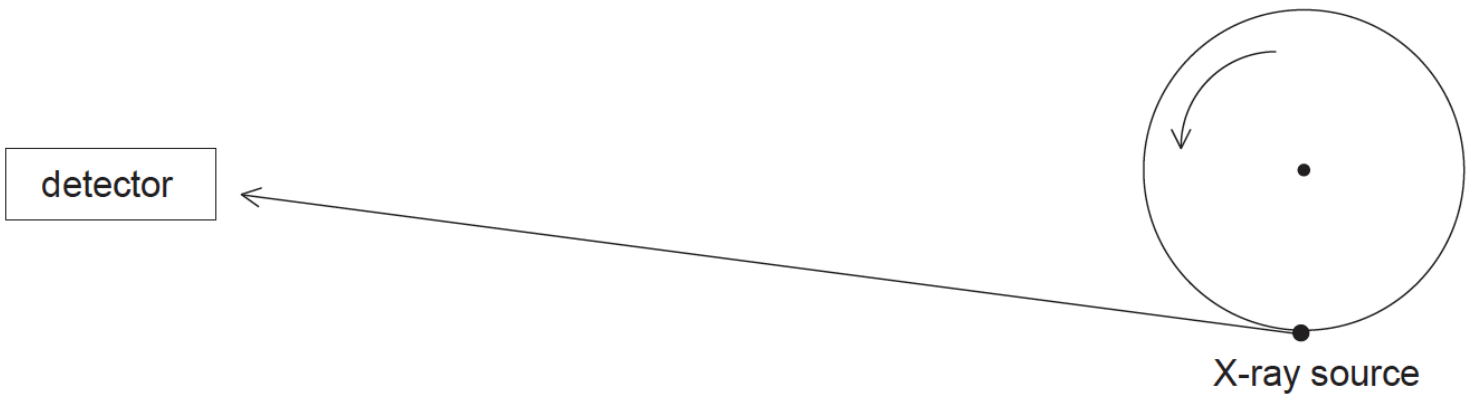This question is about the Doppler effect.

The diagram shows wavefronts in air produced by a stationary source S of sound. The distance between successive wavefronts is equal to the wavelength of the sound. The speed of sound is c.

a. On the diagram, sketch three successive wavefronts produced when S is moving to the left at a speed of 0.5c. [2]

b. A source of X-rays rotates on a turntable. Radiation of wavelength 7.5 nm is emitted by the source and undergoes a maximum shift of 0.50 fm. [3]

The distance between the source and the detector is large in comparison to the diameter of the turntable.

(i) Determine the speed of a point on the edge of the turntable.

(ii) State the assumption you made in your answer to (b)(i).