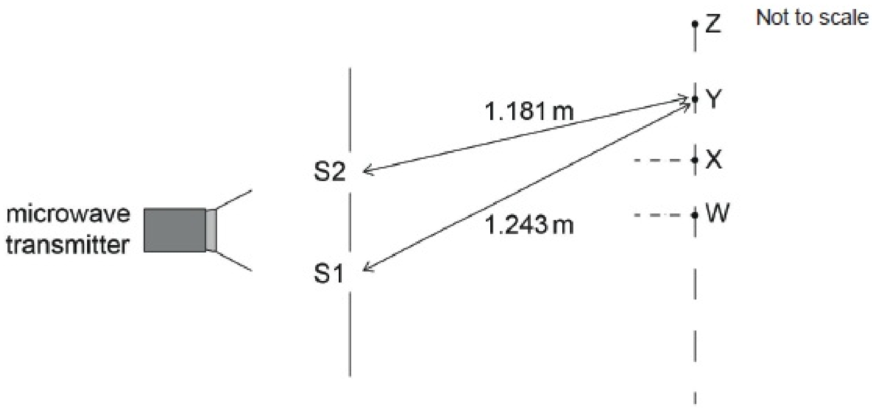
Waves-practice-1-ShortA *[207 marks]*

A beam of microwaves is incident normally on a pair of identical narrow slits S1 and S2.



When a microwave receiver is initially placed at W which is equidistant from the slits, a maximum in intensity is observed. The receiver is then moved towards Z along a line parallel to the slits. Intensity maxima are observed at X and Y with one minimum between them. W, X and Y are consecutive maxima.

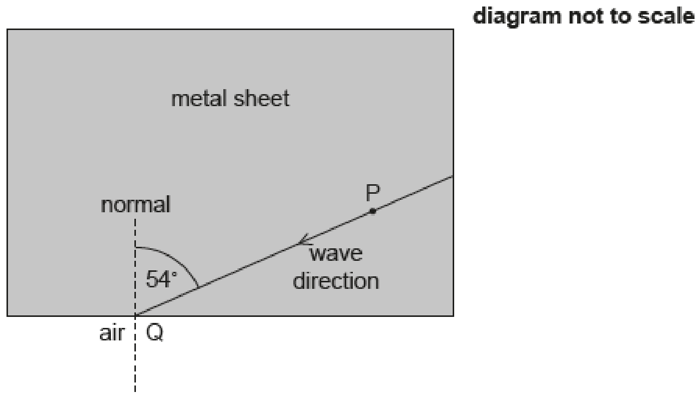
1a. Explain why intensity maxima are observed at X and Y. *[2 marks]*

1b. The distance from S1 to Y is 1.243 m and the distance from S2 to Y is 1.181 m. *[3 marks]*

Determine the frequency of the microwaves.

1c. Outline **one** reason why the maxima observed at W, X and Y will have different intensities from each other. *[1 mark]*

The diagram shows the direction of a sound wave travelling in a metal sheet.



2a. Particle P in the metal sheet performs simple harmonic oscillations. When the displacement of P is 3.2 μm the magnitude of its acceleration is 7.9 m s^{-2}. Calculate the magnitude of the acceleration of P when its displacement is 2.3 μm. *[2 marks]*

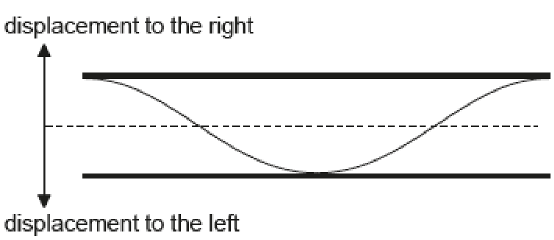
2b. The wave is incident at point Q on the metal–air boundary. The wave makes an angle of 54° with the normal at Q. The speed of sound in the metal is 6010 m s^{-1} and the speed of sound in air is 340 m s^{-1}. Calculate the angle between the normal at Q and the direction of the wave in air. *[2 marks]*

The frequency of the sound wave in the metal is 250 Hz.

2c. State the frequency of the wave in air. *[1 mark]*

2d. Determine the wavelength of the wave in air. *[1 mark]*

2e. The sound wave in air in (c) enters a pipe that is open at both ends. The diagram shows the displacement, at a particular time *T*, of the standing wave that is set up in the pipe. *[1 mark]*



On the diagram, at time *T*, label with the letter C a point in the pipe that is at the centre of a compression.

3a. Outline the differences between step-index and graded-index optic fibres. *[2 marks]*

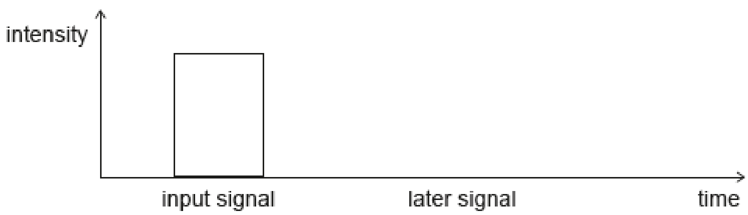
The refractive index n of a material is the ratio of the speed of light in a vacuum c, to the speed of light in the material v or $n = \frac{c}{v}$.

The speed of light in a vacuum c is 2.99792 × 10^8 m s^{-1}. The following data are available for the refractive indices of the fibre core for two wavelengths of light:

Wavelength (λ)	Refractive index (n)
1299 nm	1.45061
1301 nm	1.45059

3b. Determine the difference between the speed of light corresponding to these two wavelengths in the core glass. *[2 marks]*

3c. An input signal to the fibre consists of wavelengths that range from 1299 nm to 1301 nm. The diagram shows the variation of intensity with time of the input signal. *[2 marks]*

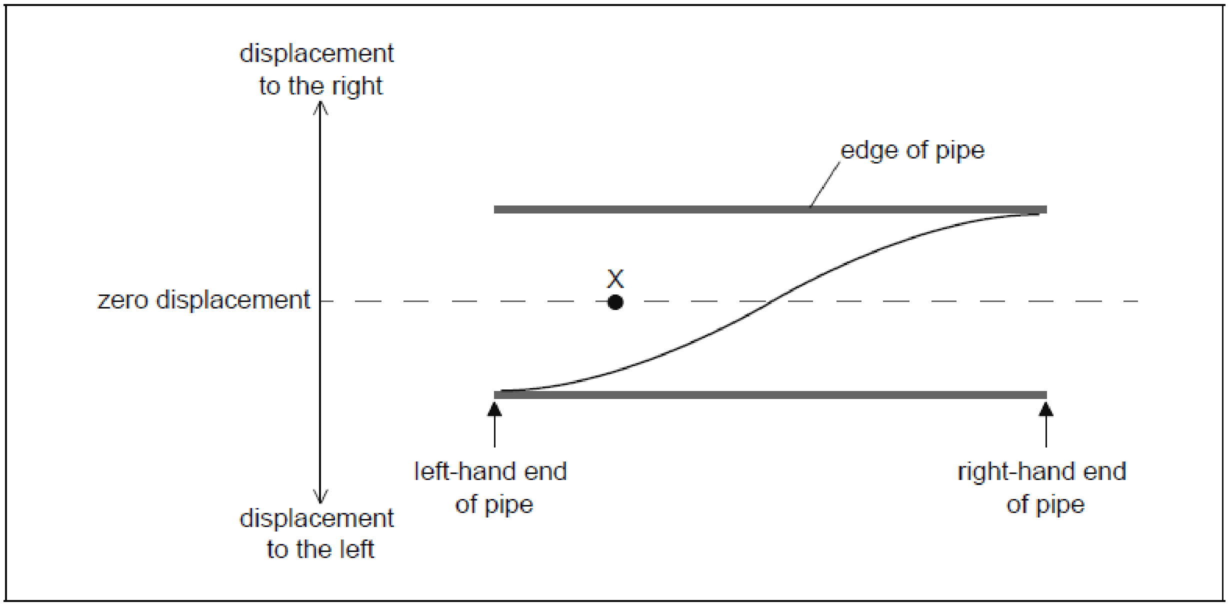


Sketch, on the axes, the variation of signal intensity with time after the signal has travelled a long distance along the fibre.

3d. Explain the shape of the signal you sketched in (b)(ii). *[2 marks]*

3e. A signal consists of a series of pulses. Outline how the length of the fibre optic cable limits the time between transmission of pulses in a practical system. *[2 marks]*

A pipe is open at both ends. A first-harmonic standing wave is set up in the pipe. The diagram shows the variation of displacement of air molecules in the pipe with distance along the pipe at time $t = 0$. The frequency of the first harmonic is f.



4a. An air molecule is situated at point X in the pipe at $t = 0$. Describe the motion of this air molecule during one complete cycle of the standing wave beginning from $t = 0$. *[2 marks]*

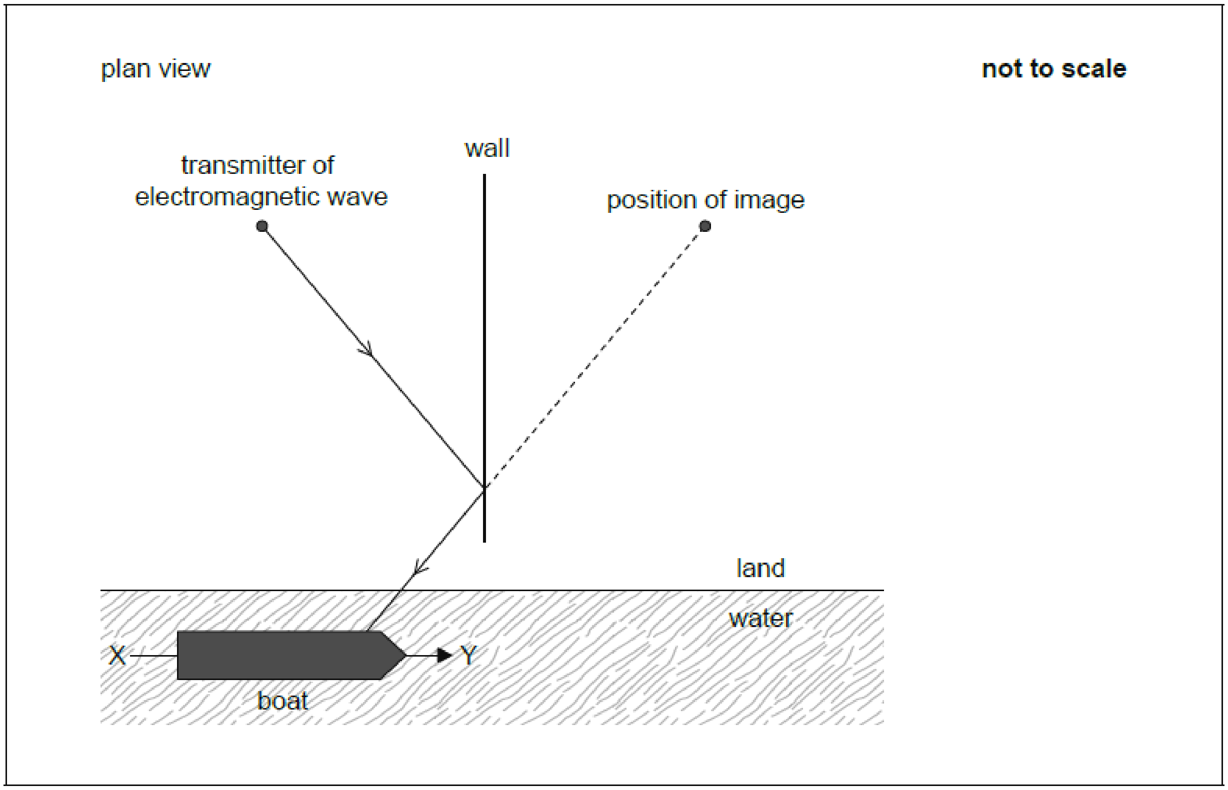
4b. The speed of sound c for longitudinal waves in air is given by *[3 marks]*

$$c = \sqrt{\frac{K}{\rho}}$$

where ρ is the density of the air and K is a constant.

A student measures f to be 120 Hz when the length of the pipe is 1.4 m. The density of the air in the pipe is 1.3 kg m^{-3}. Determine, in kg m^{-1} s^{-2}, the value of K for air.

A transmitter of electromagnetic waves is next to a long straight vertical wall that acts as a plane mirror to the waves. An observer on a boat detects the waves both directly and as an image from the other side of the wall. The diagram shows one ray from the transmitter reflected at the wall and the position of the image.



4c. Demonstrate, using a second ray, that the image appears to come from the position indicated. *[1 mark]*

4d. Outline why the observer detects a series of increases and decreases in the intensity of the received signal as the boat moves along the line XY. *[2 marks]*

The ratio $\frac{\text{distance of Mars from the Sun}}{\text{distance of Earth from the Sun}} = 1.5$.

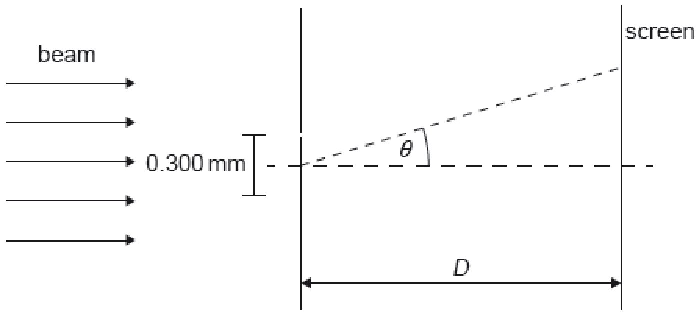
5a. Show that the intensity of solar radiation at the orbit of Mars is about 600 $\mathrm{W\,m^{-2}}$. *[2 marks]*

5b. Determine, in K, the mean surface temperature of Mars. Assume that Mars acts as a black body. *[2 marks]*

5c. The atmosphere of Mars is composed mainly of carbon dioxide and has a pressure less than 1 % of that on the Earth. Outline why the greenhouse effect is not significant on Mars. *[2 marks]*

A beam of coherent monochromatic light from a distant galaxy is used in an optics experiment on Earth.

The beam is incident normally on a double slit. The distance between the slits is 0.300 mm. A screen is at a distance *D* from the slits. The diffraction angle θ is labelled.



6a. A series of dark and bright fringes appears on the screen. Explain how a dark fringe is formed. *[3 marks]*

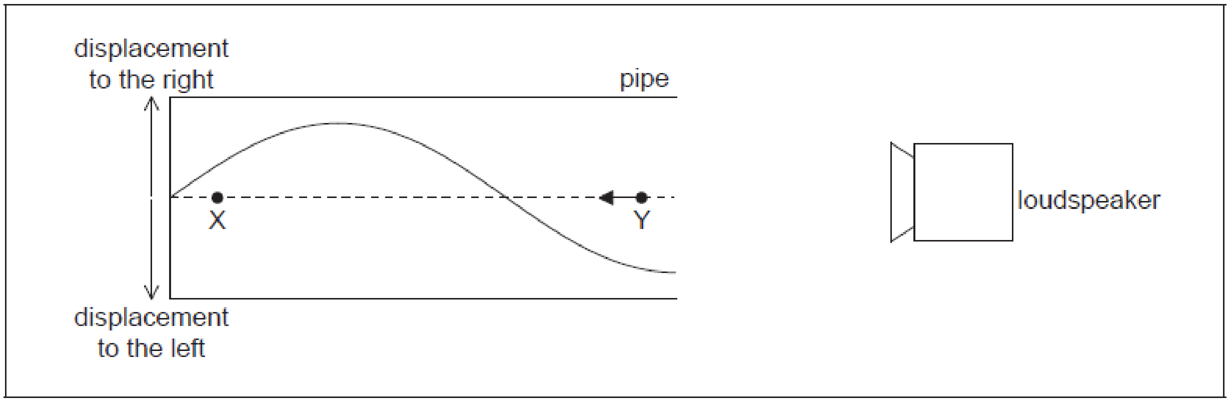
6b. The wavelength of the beam as observed on Earth is 633.0 nm. The separation between a dark and a bright fringe on the screen is 4.50 mm. Calculate *D*. *[2 marks]*

The air between the slits and the screen is replaced with water. The refractive index of water is 1.33.

6c. Calculate the wavelength of the light in water. *[1 mark]*

6d. State **two** ways in which the intensity pattern on the screen changes. *[2 marks]*

A loudspeaker emits sound towards the open end of a pipe. The other end is closed. A standing wave is formed in the pipe. The diagram represents the displacement of molecules of air in the pipe at an instant of time.



7a. Outline how the standing wave is formed. *[1 mark]*

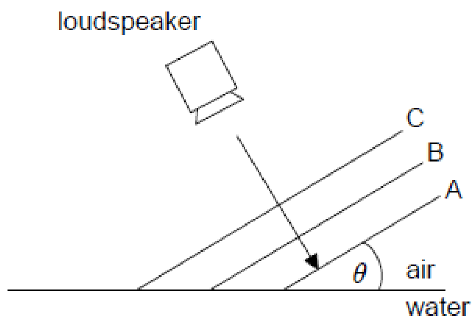
X and Y represent the equilibrium positions of two air molecules in the pipe. The arrow represents the velocity of the molecule at Y.

7b. Draw an arrow on the diagram to represent the direction of motion of the molecule at X. *[1 mark]*

7c. Label a position N that is a node of the standing wave. *[1 mark]*

7d. The speed of sound is 340 m s^{-1} and the length of the pipe is 0.30 m. Calculate, in Hz, the frequency of the sound. *[2 marks]*

The loudspeaker in (a) now emits sound towards an air–water boundary. A, B and C are parallel wavefronts emitted by the loudspeaker. The parts of wavefronts A and B in water are not shown. Wavefront C has not yet entered the water.

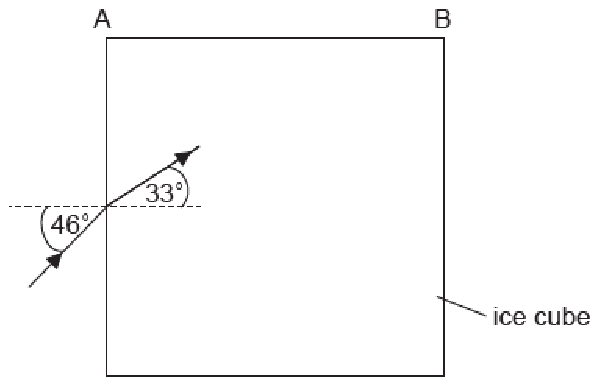


7e. The speed of sound in air is 340 m s^{-1} and in water it is 1500 m s^{-1}. *[2 marks]*

The wavefronts make an angle θ with the surface of the water. Determine the maximum angle, θ_{max}, at which the sound can enter water. Give your answer to the correct number of significant figures.

7f. Draw lines on the diagram to complete wavefronts A and B in water for $\theta < \theta_{max}$. *[2 marks]*

A large cube is formed from ice. A light ray is incident from a vacuum at an angle of 46° to the normal on one surface of the cube. The light ray is parallel to the plane of one of the sides of the cube. The angle of refraction inside the cube is 33°.



8a. Calculate the speed of light inside the ice cube. *[2 marks]*

8b. Show that no light emerges from side AB. *[3 marks]*

8c. Sketch, on the diagram, the subsequent path of the light ray. *[2 marks]*

Each side of the ice cube is 0.75 m in length. The initial temperature of the ice cube is –20 °C.

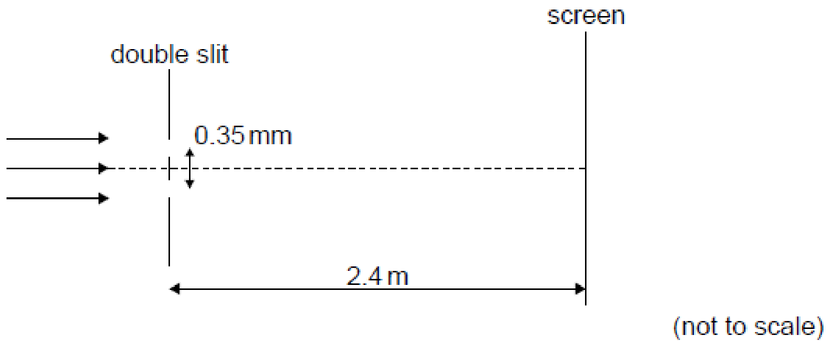
8d. Determine the energy required to melt all of the ice from –20 °C to water at a temperature of 0 °C. *[4 marks]*

Specific latent heat of fusion of ice = 330 kJ kg^{-1}
Specific heat capacity of ice = 2.1 kJ kg^{-1} k^{-1}
Density of ice = 920 kg m^{-3}

8e. Outline the difference between the molecular structure of a solid and a liquid. *[1 mark]*

9a. Outline what is meant by the principle of superposition of waves. *[2 marks]*

9b. Red laser light is incident on a double slit with a slit separation of 0.35 mm. *[3 marks]*
A double-slit interference pattern is observed on a screen 2.4 m from the slits.
The distance between successive maxima on the screen is 4.7 mm.



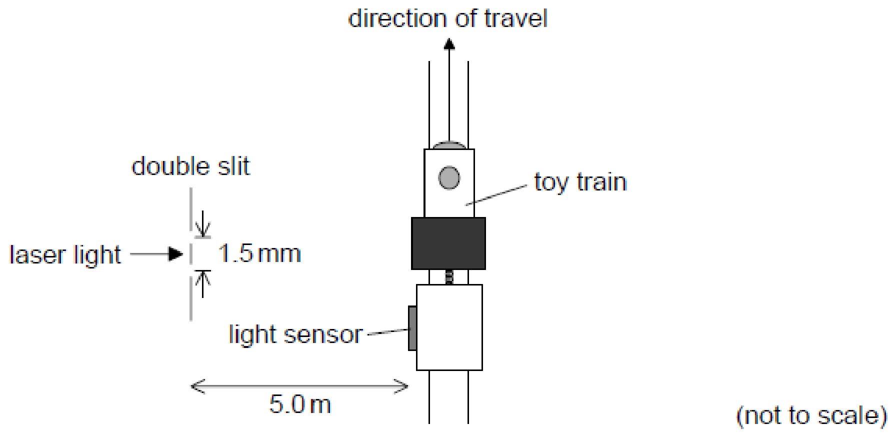
Calculate the wavelength of the light. Give your answer to an appropriate number of significant figures.

9c. Explain the change to the appearance of the interference pattern when the red-light laser is replaced by one that emits green light. *[2 marks]*

9d. One of the slits is now covered. *[2 marks]*

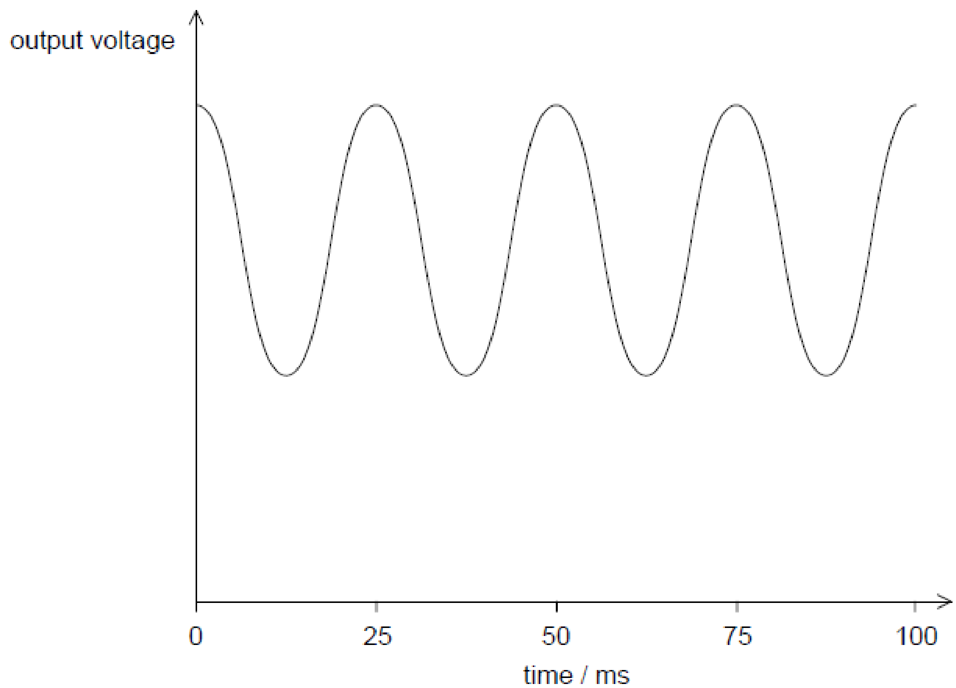
Describe the appearance of the pattern on the screen.

A student investigates how light can be used to measure the speed of a toy train.



Light from a laser is incident on a double slit. The light from the slits is detected by a light sensor attached to the train.

The graph shows the variation with time of the output voltage from the light sensor as the train moves parallel to the slits. The output voltage is proportional to the intensity of light incident on the sensor.



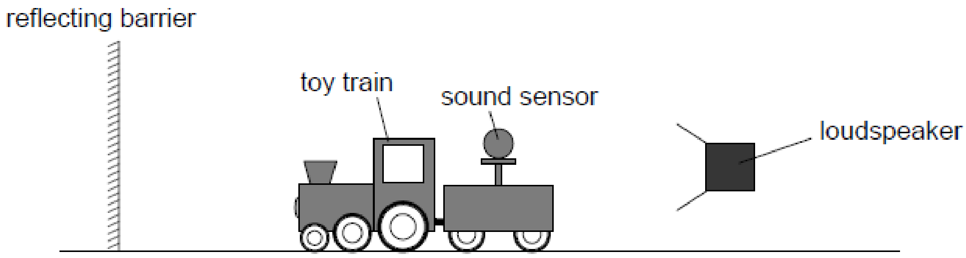
10a. Explain, with reference to the light passing through the slits, why a series of voltage peaks occurs. *[3 marks]*

10b. The slits are separated by 1.5 mm and the laser light has a wavelength of 6.3×10^{-7} m. The slits are 5.0 m from the train track. *[1 mark]*

Calculate the separation between two adjacent positions of the train when the output voltage is at a maximum.

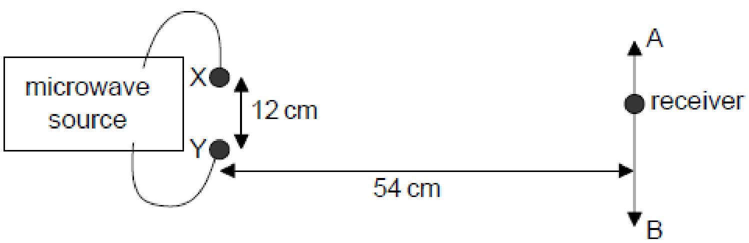
10c. Estimate the speed of the train. *[2 marks]*

10d. In another experiment the student replaces the light sensor with a sound sensor. The train travels away from a loudspeaker that is emitting sound waves of constant amplitude and frequency towards a reflecting barrier. *[2 marks]*



The sound sensor gives a graph of the variation of output voltage with time along the track that is similar in shape to the graph shown in the resource. Explain how this effect arises.

11a. Two microwave transmitters, X and Y, are placed 12 cm apart and are connected to the same source. A single receiver is placed 54 cm away and moves along a line AB that is parallel to the line joining X and Y. *[4 marks]*

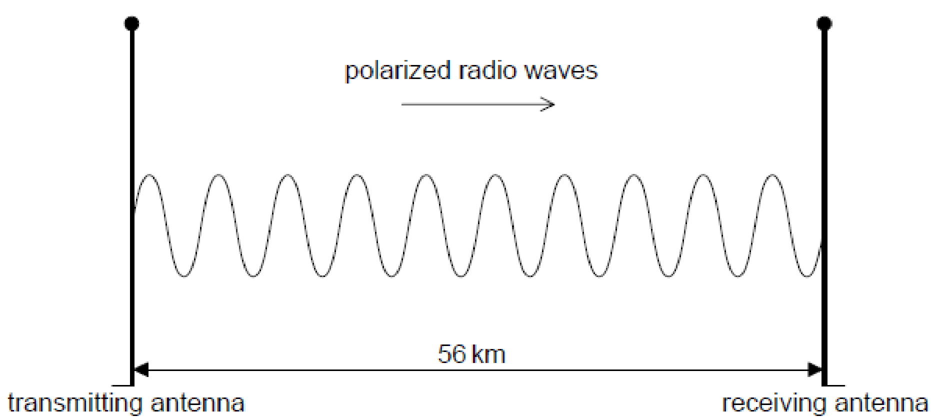


Maxima and minima of intensity are detected at several points along AB.

(i) Explain the formation of the intensity **minima**.

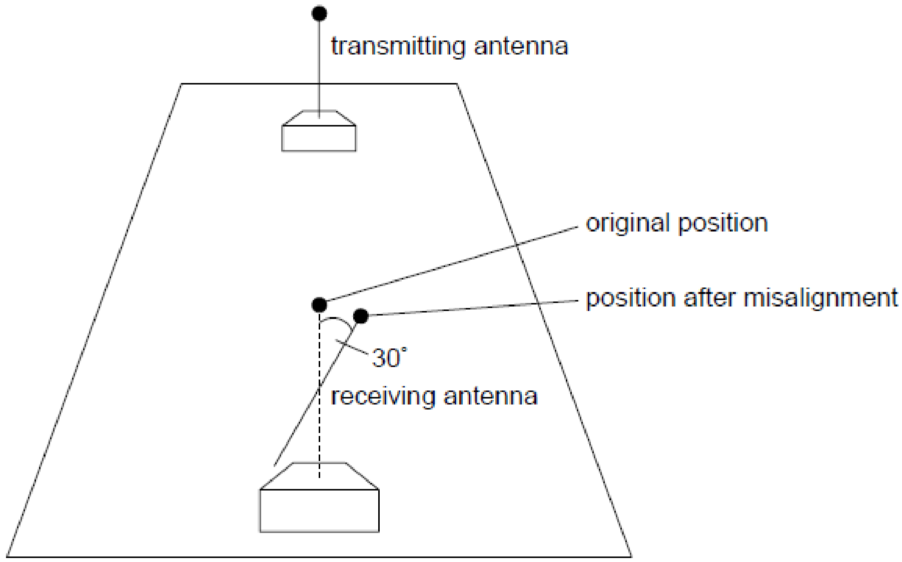
(ii) The distance between the central maximum and the first minimum is 7.2 cm. Calculate the wavelength of the microwaves.

11b. Radio waves are emitted by a straight conducting rod antenna (aerial). The plane of polarization of these waves is parallel to the transmitting antenna. *[2 marks]*



An identical antenna is used for reception. Suggest why the receiving antenna needs to be be parallel to the transmitting antenna.

11c. The receiving antenna becomes misaligned by 30° to its original position. *[3 marks]*

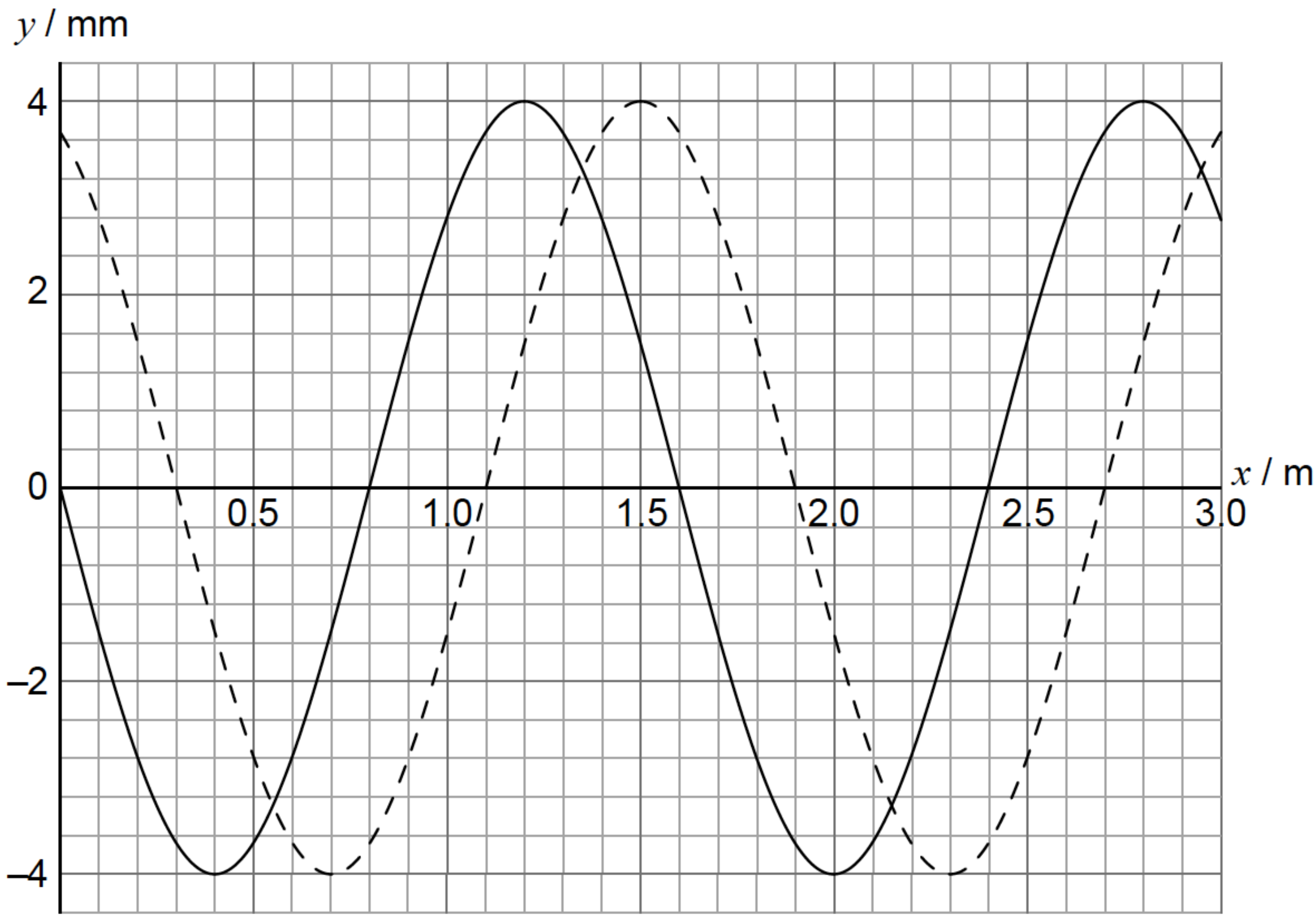


The power of the received signal in this new position is 12 μW.

(i) Calculate the power that was received in the original position.

(ii) Calculate the minimum time between the wave leaving the transmitting antenna and its reception.

A longitudinal wave is travelling in a medium from left to right. The graph shows the variation with distance *x* of the displacement *y* of the particles in the medium. The solid line and the dotted line show the displacement at *t*=0 and *t*=0.882 ms, respectively.



The period of the wave is greater than 0.882 ms. A displacement to the right of the equilibrium position is positive.

12a. State what is meant by a longitudinal travelling wave. *[1 mark]*

12b. Calculate, for this wave, *[4 marks]*

(i) the speed.

(ii) the frequency.

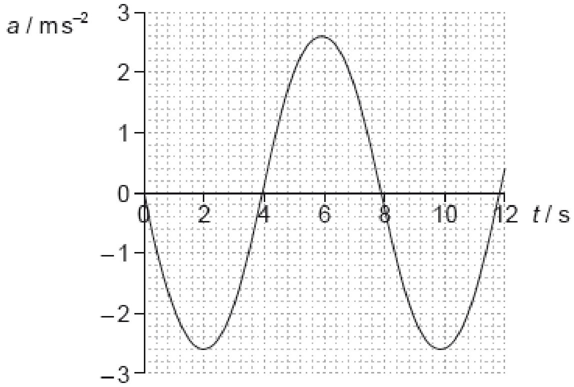
12c. The equilibrium position of a particle in the medium is at *x*=0.80 m. For this particle at *t*=0, state and explain *[4 marks]*

(i) the direction of motion.

(ii) whether the particle is at the centre of a compression or a rarefaction.

This question is about simple harmonic motion (SHM).

The graph shows the variation with time t of the acceleration a of an object X undergoing simple harmonic motion (SHM).



13a. Define *simple harmonic motion (SHM)*. *[2 marks]*

13b. X has a mass of 0.28 kg. Calculate the maximum force acting on X. *[1 mark]*

13c. Determine the maximum displacement of X. Give your answer to an appropriate number of significant figures. *[4 marks]*

13d. A second object Y oscillates with the same frequency as X but with a phase difference of $\frac{\pi}{4}$. Sketch, using the graph opposite, how the acceleration of object Y varies with t. *[2 marks]*

This question is in **two** parts. **Part 1** is about the nuclear model of the atom and radioactive decay. **Part 2** is about waves.

Part 1 Nuclear model of the atom and radioactive decay

14a. Outline how the evidence supplied by the Geiger–Marsden experiment supports the nuclear model of the atom. *[4 marks]*

14b. Outline why classical physics does not permit a model of an electron orbiting the nucleus. *[3 marks]*

The nuclide radium-226 $\left({}^{226}_{88}\mathrm{Ra}\right)$ decays into an isotope of radon (Rn) by the emission of an alpha particle and a gamma-ray photon.

14c. State what is meant by the terms nuclide and isotope. *[2 marks]*

Nuclide:

Isotope:

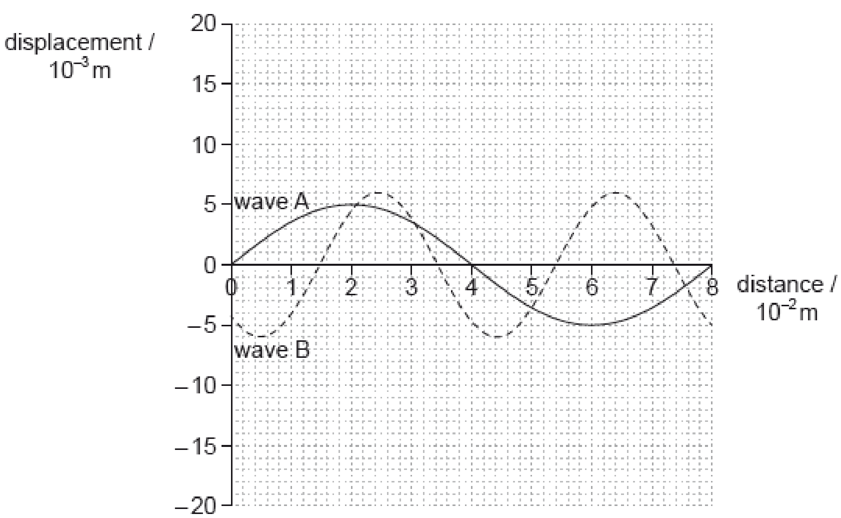
14d. Construct the nuclear equation for the decay of radium-226. *[3 marks]*

$${}^{226}_{88}\mathrm{Ra} \rightarrow {}^{\cdots}_{\cdots}\mathrm{Rn} + {}^{\cdots}_{\cdots}\mathrm{He} + {}^{\cdots}_{\cdots}\gamma$$

14e. Radium-226 has a half-life of 1600 years. Determine the time, in years, it takes for the activity of radium-226 to fall to $\frac{1}{64}$ of its original activity. *[2 marks]*

Part 2 Waves

Two waves, A and B, are travelling in opposite directions in a tank of water. The graph shows the variation of displacement of the water surface with distance along the wave at a particular instant.



14f. State the amplitude of wave A. *[1 mark]*

14g. Wave A has a frequency of 9.0 Hz. Calculate the velocity of wave A. *[2 marks]*

14h. Deduce the frequency of wave B. *[3 marks]*

14i. State what is meant by the principle of superposition of waves. *[2 marks]*

14j. On the graph opposite, sketch the wave that results from the superposition of wave A and wave B at that instant. *[3 marks]*

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 $340\ \mathrm{m\,s^{-1}}$.

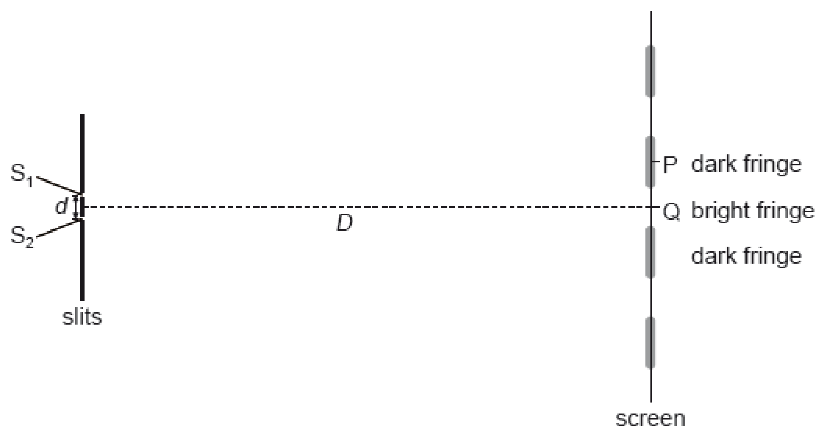
15a. Show that there must be a node at a distance of 0.18 m from the closed end of the pipe. *[1 mark]*

15b. Calculate the frequency of the whistle sound. *[2 marks]*

15c. 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 marks]*

This question is about interference of light.

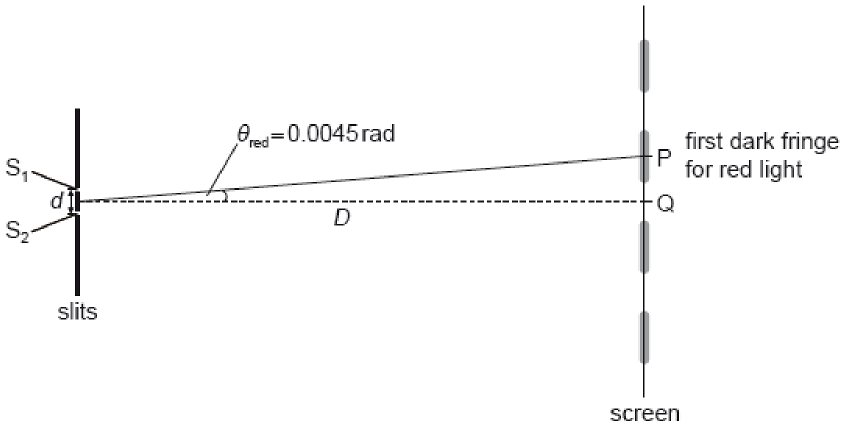
Coherent monochromatic light is incident on two narrow slits $\mathrm{S_1}$ and $\mathrm{S_2}$ a distance d apart. A screen is placed a distance D from the slits. An interference pattern of bright fringes and dark fringes appears on the screen. The central maximum is at Q.



16a. State **one** way to ensure that the light incident on the slits is coherent. *[1 mark]*

16b. Light emerging from S_1 and S_2 reaches the screen. Explain why the screen appears dark at point P. *[2 marks]*

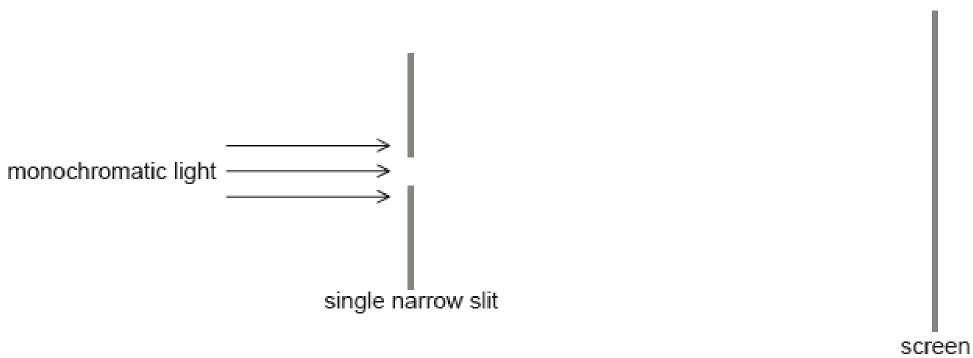
When red light of wavelength 660 nm is used the first fringe at P subtends an angle 0.0045 rad from midpoint of S_1 and S_2.



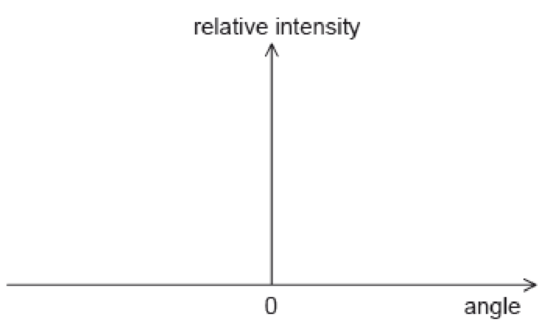
16c. Determine the change in angle when blue light of wavelength 440 nm is used. *[2 marks]*

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.



17a. 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 marks]*

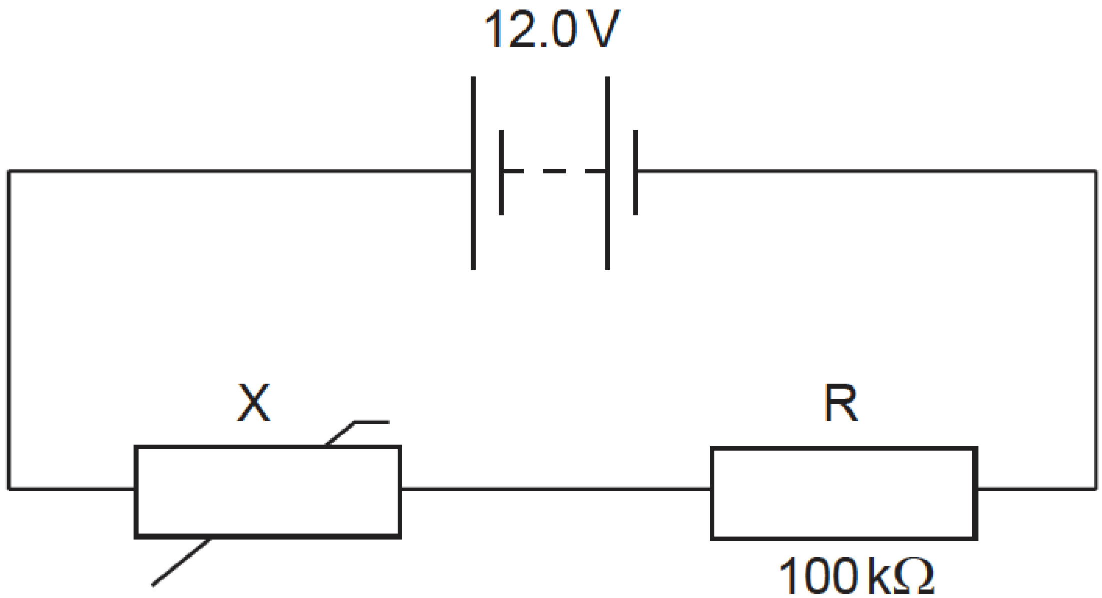


17b. The single narrow slit is replaced by a double narrow slit. Explain, with reference to your answer to (a), how the Rayleigh criterion applies to the diffraction patterns produced by the light emerging from the two slits. *[3 marks]*

17c. 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 marks]*

This question is in two parts. Part 1 is about a thermistor circuit. Part 2 is about vibrations and waves.

Part 1 Thermistor circuit
The circuit shows a negative temperature coefficient (NTC) thermistor X and a 100 kΩ fixed resistor R connected across a battery.



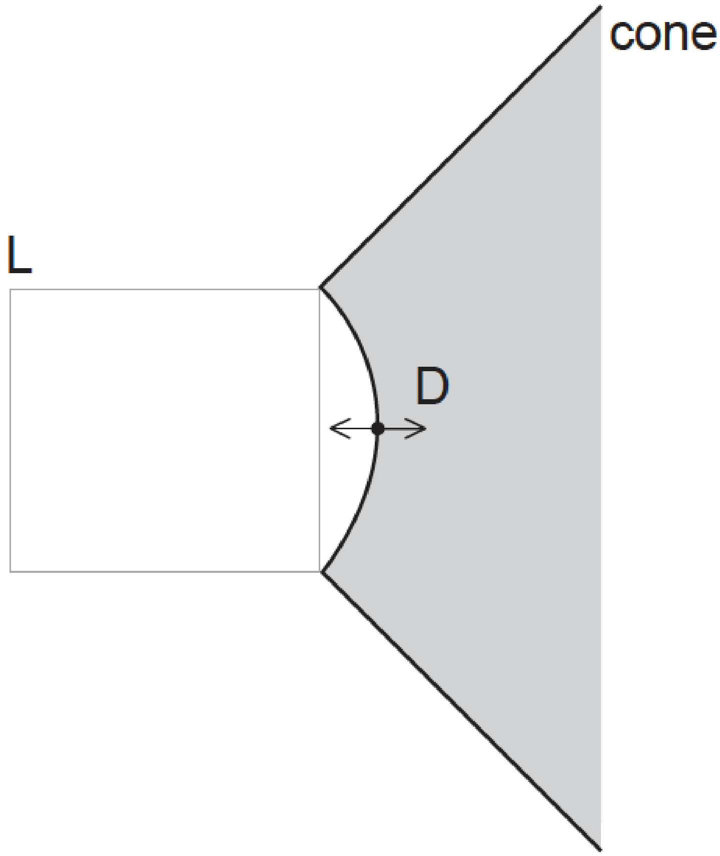
The battery has an electromotive force (emf) of 12.0 V and negligible internal resistance.

18a. (i) Define *electromotive force (emf)*. *[2 marks]*

(ii) State how the emf of the battery can be measured.

Part 2 Vibrations and waves

The cone and dust cap D of a loudspeaker L vibrates with a frequency of 1.25 kHz with simple harmonic motion (SHM).



18b. Define *simple harmonic motion (SHM)*. *[2 marks]*

18c. D has mass 6.5×10^{-3} kg and vibrates with amplitude 0.85 mm. *[4 marks]*

(i) Calculate the maximum acceleration of D.

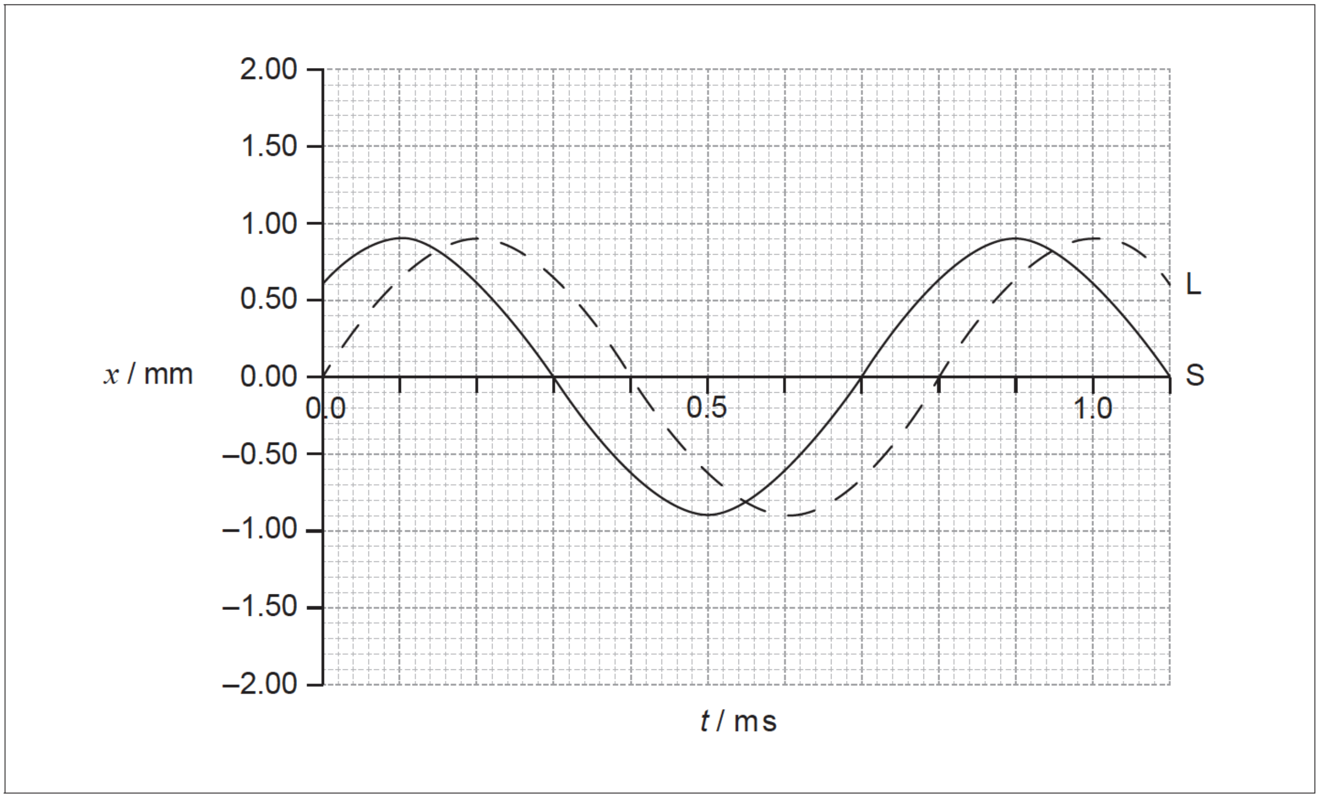
(ii) Determine the total energy of D.

18d. The sound waves from the loudspeaker travel in air with speed 330 ms^{-1}. *[2 marks]*

(i) Calculate the wavelength of the sound waves.

(ii) Describe the characteristics of sound waves in air.

18e. A second loudspeaker S emits the same frequency as L but vibrates out of phase with L. The graph below shows the variation with time *t* of the displacement *x* of the waves emitted by S and L. *[6 marks]*

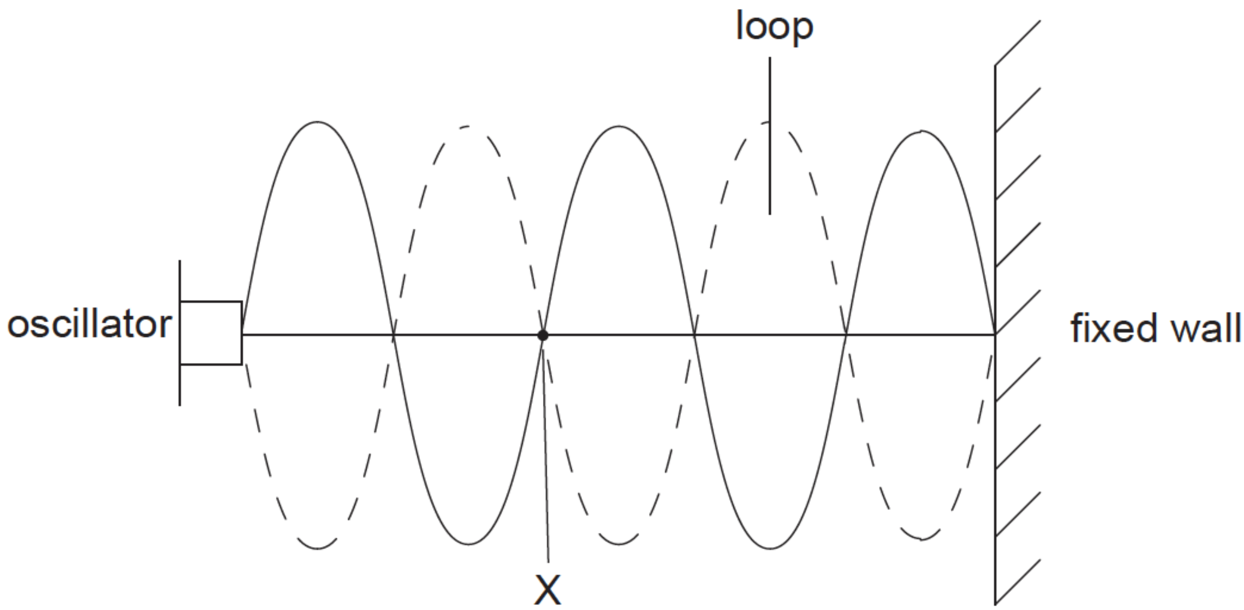


(i) Deduce the relationship between the phase of L and the phase of S.

(ii) On the graph, sketch the variation with *t* of *x* for the wave formed by the superposition of the two waves.

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.



19a. State the name given to point X on the string. *[1 mark]*

19b. (i) Calculate the speed of the wave along the string. *[3 marks]*

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

This question is about polarized light.

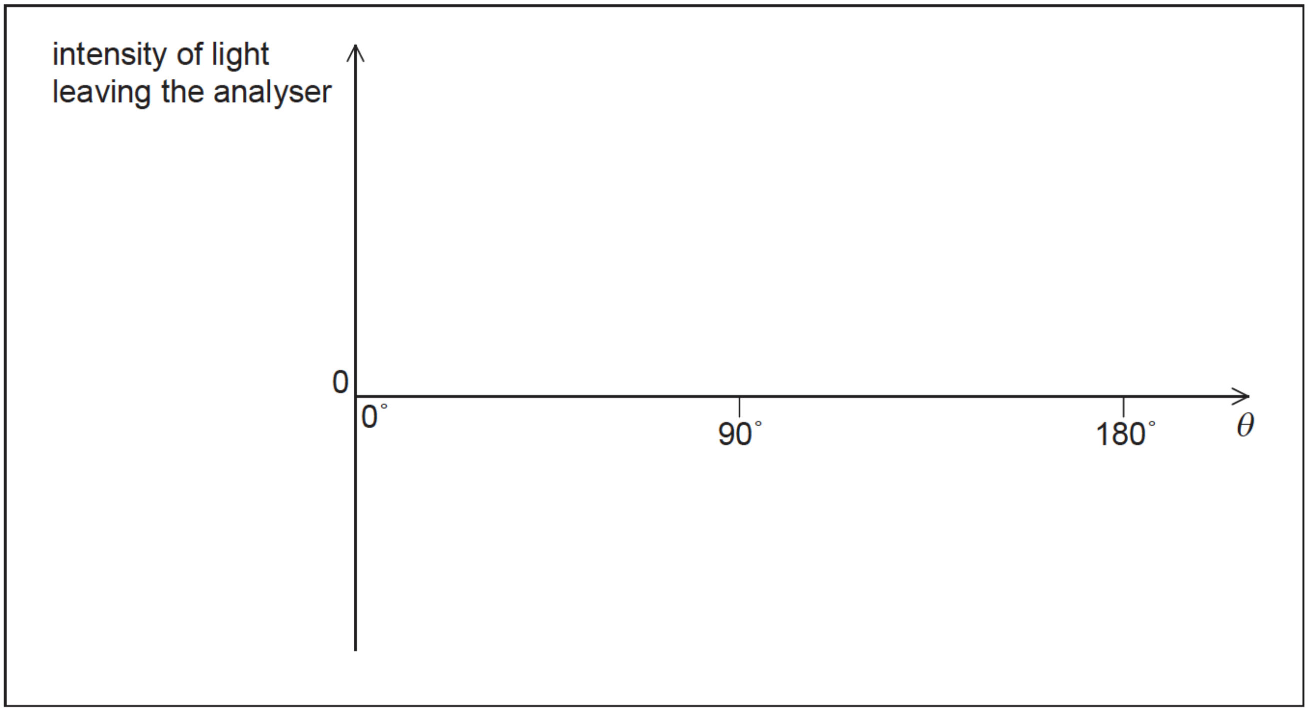
An analyser is used with polarized light.

20a. Outline the function of an analyser in this context. *[2 marks]*

20b. Polarized light of intensity I_0 is incident on the analyser. *[3 marks]*

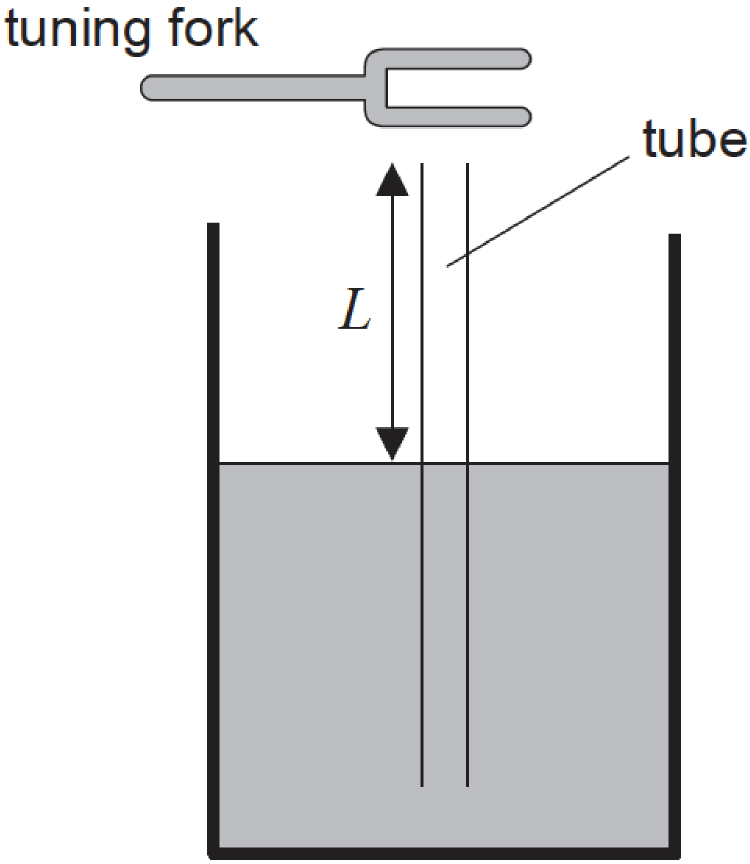
(i) The transmission axis of the analyser is at an angle of 25° to the electric field of the polarized light. Calculate, in terms of I_0, the intensity of the light that leaves the analyser.

(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 standing (stationary) waves in a tube.

21a. A thin tube is immersed in a container of water. A length L of the tube extends above the surface of water. *[4 marks]*

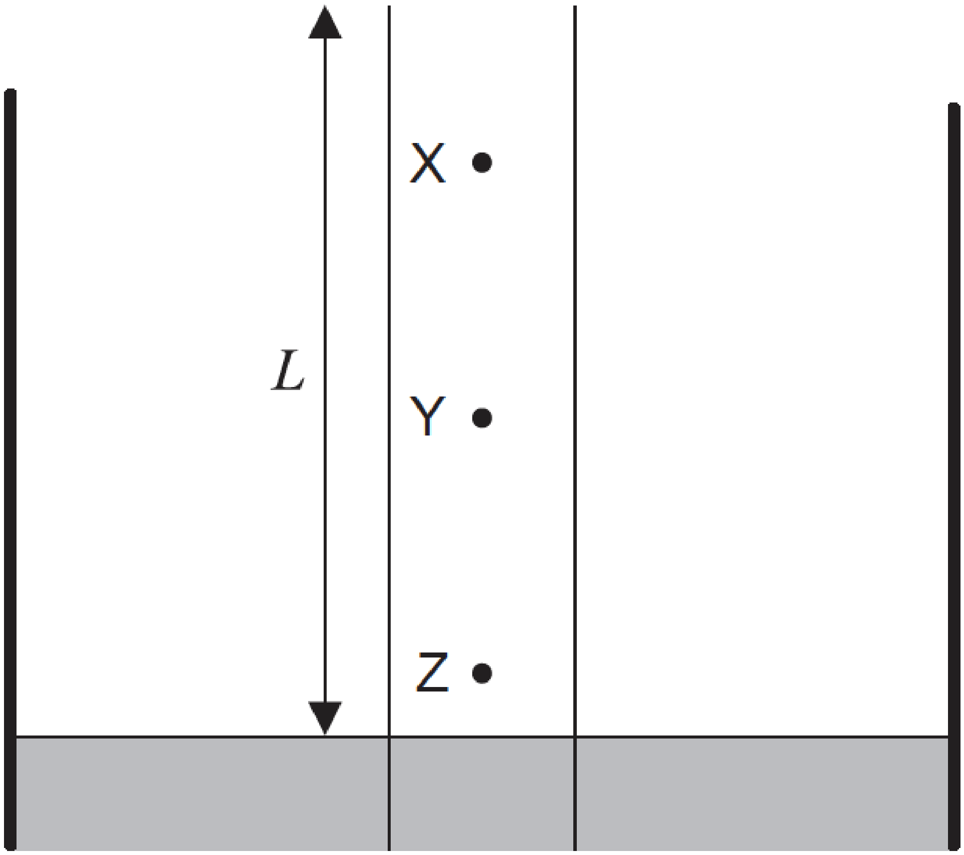


A tuning fork is sounded above the tube. For particular values of *L*, a standing wave is established in the tube.

(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.

21b. 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 marks]*



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.

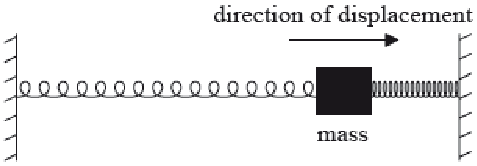
22. State what is meant by polarized light. *[1 mark]*

This question is in **two** parts. **Part 1** is about the oscillation of a mass. **Part 2** is about nuclear fission.

Part 1 Oscillation of a mass

A mass of 0.80 kg rests on a frictionless surface and is connected to two identical springs both of which are fixed at their other ends. A force of 0.030 N is required to extend or compress each spring by 1.0 mm. When the mass is at rest in the centre of the arrangement, the springs are not extended.

The mass is displaced to the right by 60 mm and released.



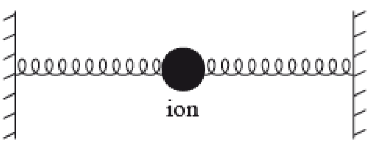
(not to scale)

23a. Determine the acceleration of the mass at the moment of release. *[3 marks]*

23b. Outline why the mass subsequently performs simple harmonic motion (SHM). *[2 marks]*

23c. Calculate the period of oscillation of the mass. *[2 marks]*

The motion of an ion in a crystal lattice can be modelled using the mass–spring arrangement. The inter-atomic forces may be modelled as forces due to springs as in the arrangement shown.



The frequency of vibration of a particular ion is $7 \times 10^{12}\ \mathrm{Hz}$ and the mass of the ion is $5 \times 10^{-26}\ \mathrm{kg}$. The amplitude of vibration of the ion is $1 \times 10^{-11}\ \mathrm{m}$.

23d. Estimate the maximum kinetic energy of the ion. *[2 marks]*

23e. On the axes, draw a graph to show the variation with time of the kinetic energy of mass and the elastic potential energy stored in the springs. *[3 marks]*

You should add appropriate values to the axes, showing the variation over one period.

23f. Calculate the wavelength of an infrared wave with a frequency equal to that of the model in (b). *[1 mark]*

Part 2 Nuclear fission

A reaction that takes place in the core of a particular nuclear reactor is as shown.

$$^{235}_{92}\mathrm{U} + ^{1}_{0}\mathrm{n} \rightarrow ^{144}_{56}\mathrm{Ba} + ^{89}_{36}\mathrm{Kr} + 3^{1}_{0}\mathrm{n}$$

In the nuclear reactor, 9.5×10^{19} fissions take place every second. Each fission gives rise to 200 MeV of energy that is available for conversion to electrical energy. The overall efficiency of the nuclear power station is 32%.

23g. Determine the mass of U-235 that undergoes fission in the reactor every day. *[3 marks]*

23h. Calculate the power output of the nuclear power station. *[2 marks]*

In addition to the U-235, the nuclear reactor contains a moderator and control rods. Explain the function of the

23i. moderator. *[3 marks]*

23j. control rods. *[2 marks]*