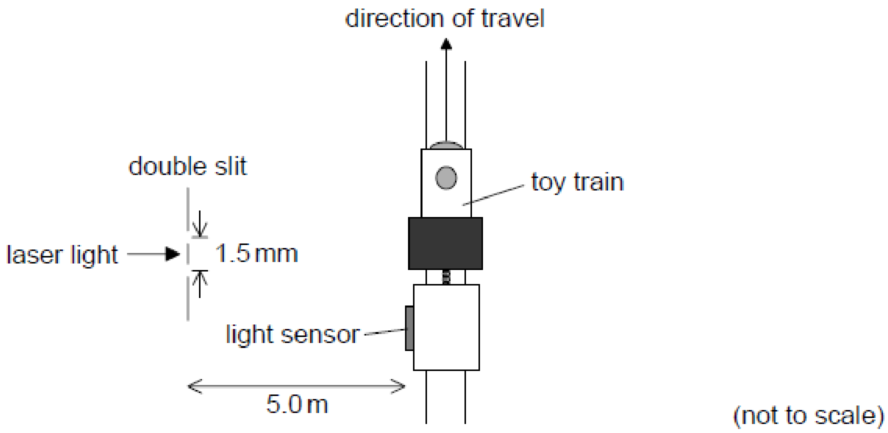
Waves-practice-1-Extended

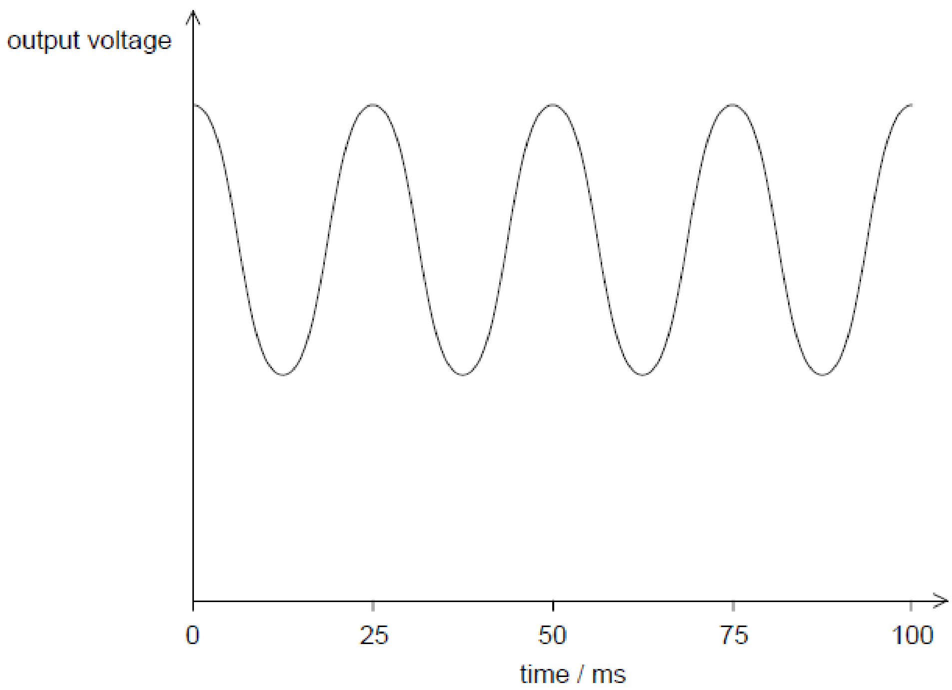
[164 marks]

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.

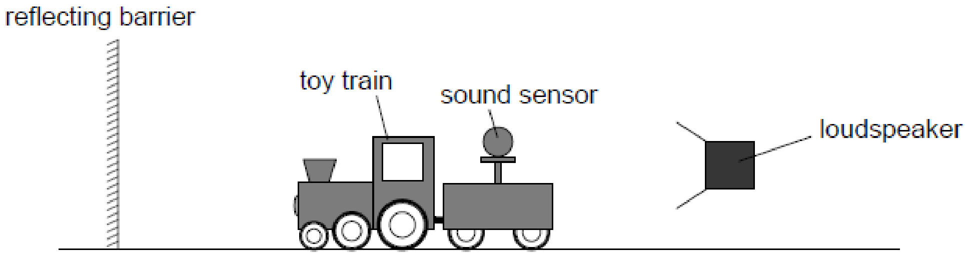


1a. Explain, with reference to the light passing through the slits, why a series of voltage peaks occurs. *[3 marks]*

1b. 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. Calculate the separation between two adjacent positions of the train when the output voltage is at a maximum. *[1 mark]*

1c. Estimate the speed of the train. *[2 marks]*

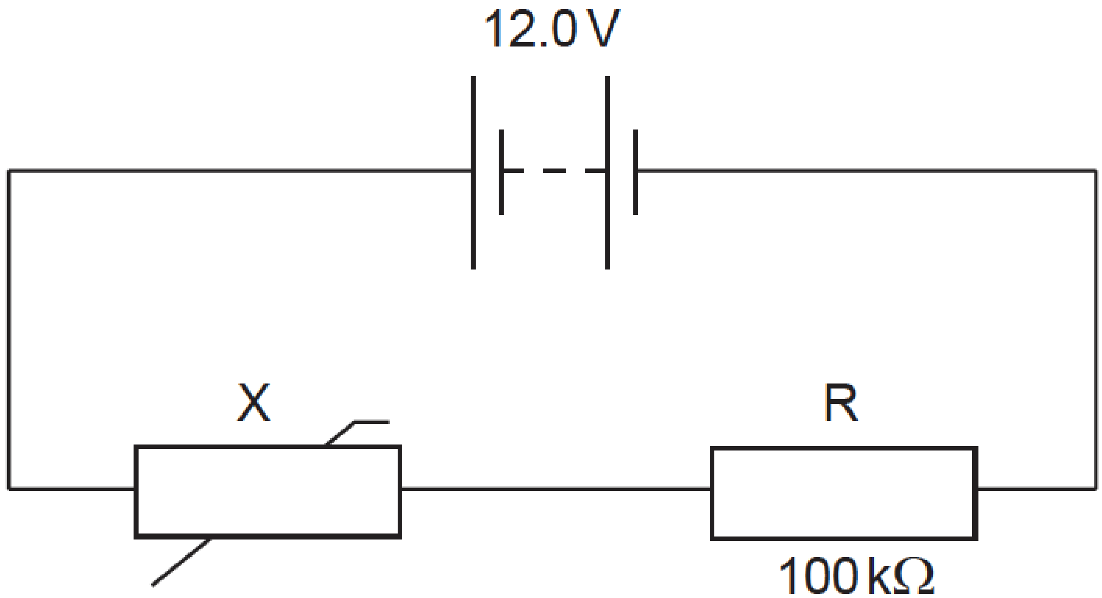
1d. In another experiment the student replaces the light sensor with a sound sensor. The train travels away from a loudspeaker that is emitting sound waves of constant amplitude and frequency towards a reflecting barrier. *[2 marks]*



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.

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.



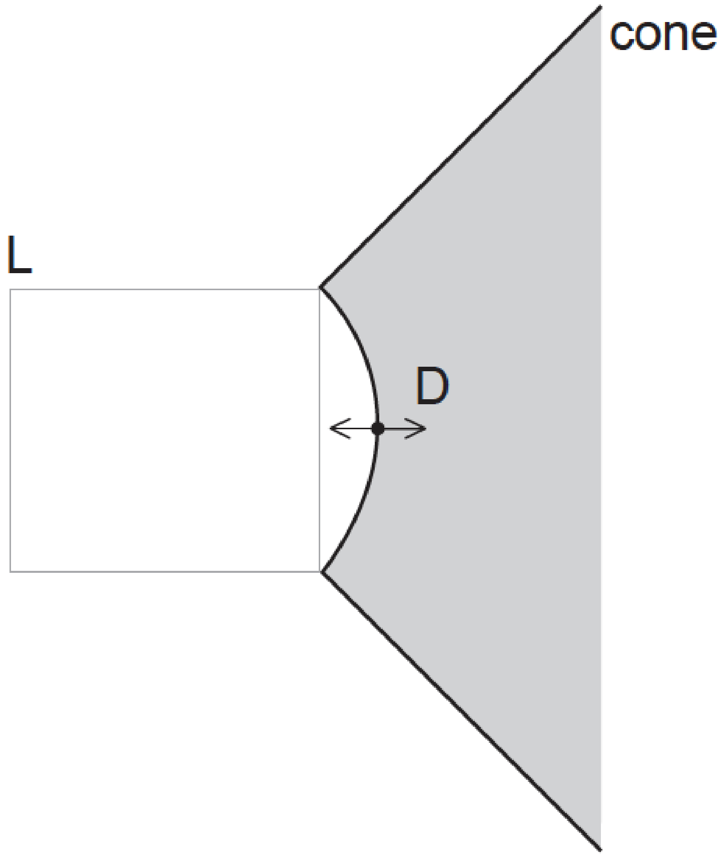
The battery has an electromotive force (emf) of 12.0 V and negligible internal resistance.

2a. (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).



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

2c. D has mass 6.5×10^{-3} kg and vibrates with amplitude 0.85 mm. *[4 marks]*

(i) Calculate the maximum acceleration of D.

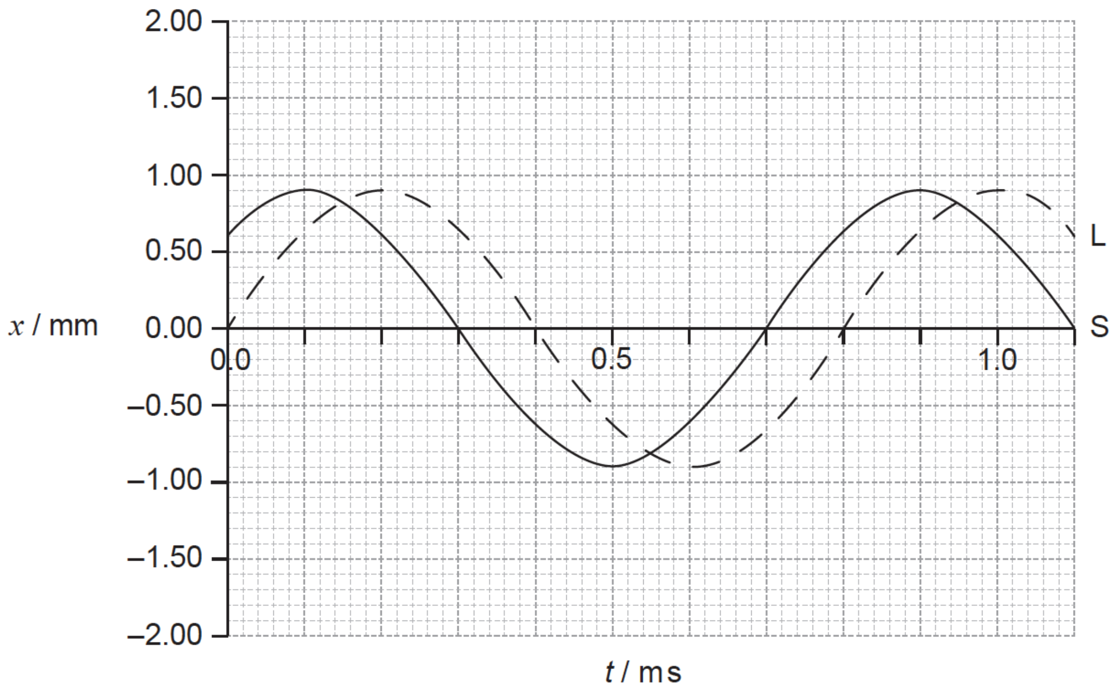
(ii) Determine the total energy of D.

2d. 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.

2e. 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 in **two** parts. **Part 1** is about solar radiation and the greenhouse effect. **Part 2** is about a mass on a spring.

Part 1 Solar radiation and the greenhouse effect

The following data are available.

Quantity	Symbol	Value
Radius of Sun	R	7.0×10^{8} m
Surface temperature of Sun	T	5.8×10^{3} K
Distance from Sun to Earth	d	1.5×10^{11} m
Stefan-Boltzmann constant	σ	5.7×10^{-8} W m^{-2} K^{-4}

3a. State the Stefan-Boltzmann law for a black body. *[2 marks]*

3b. Deduce that the solar power incident per unit area at distance *d* from the Sun is given by *[2 marks]*

$$\frac{\sigma R^2 T^4}{d^2}$$

3c. Calculate, using the data given, the solar power incident per unit area at distance *d* from the Sun. *[2 marks]*

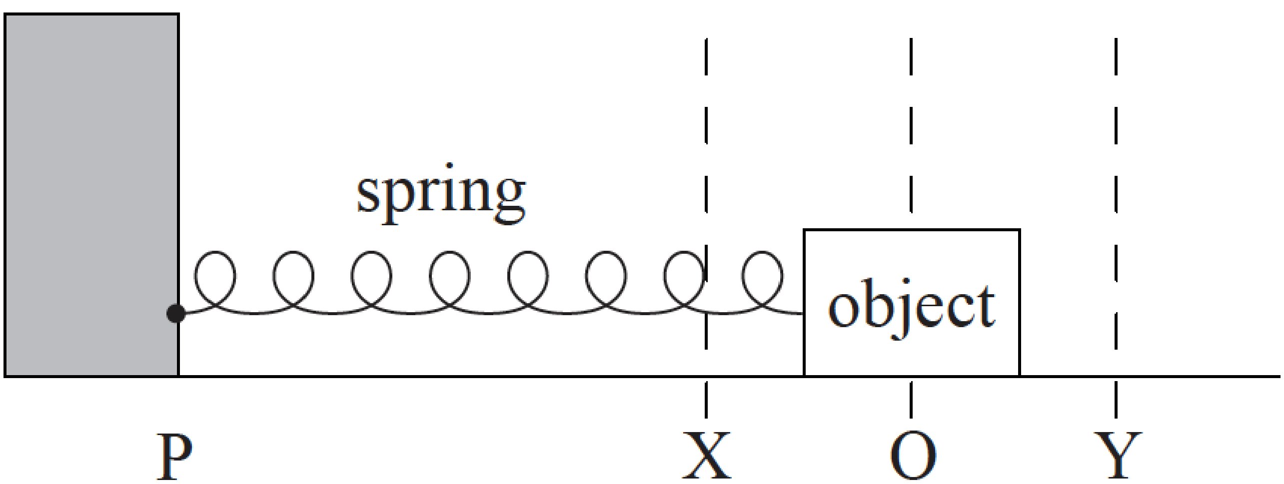
3d. State **two** reasons why the solar power incident per unit area at a point on the surface of the Earth is likely to be different from your answer in (c). *[2 marks]*

3e. The average power absorbed per unit area at the Earth's surface is $240 W m^{-2}$. By treating the Earth's surface as a black body, show that the average surface temperature of the Earth is approximately 250K. *[2 marks]*

3f. Explain why the actual surface temperature of the Earth is greater than the value in (e). *[3 marks]*

Part 2 A mass on a spring

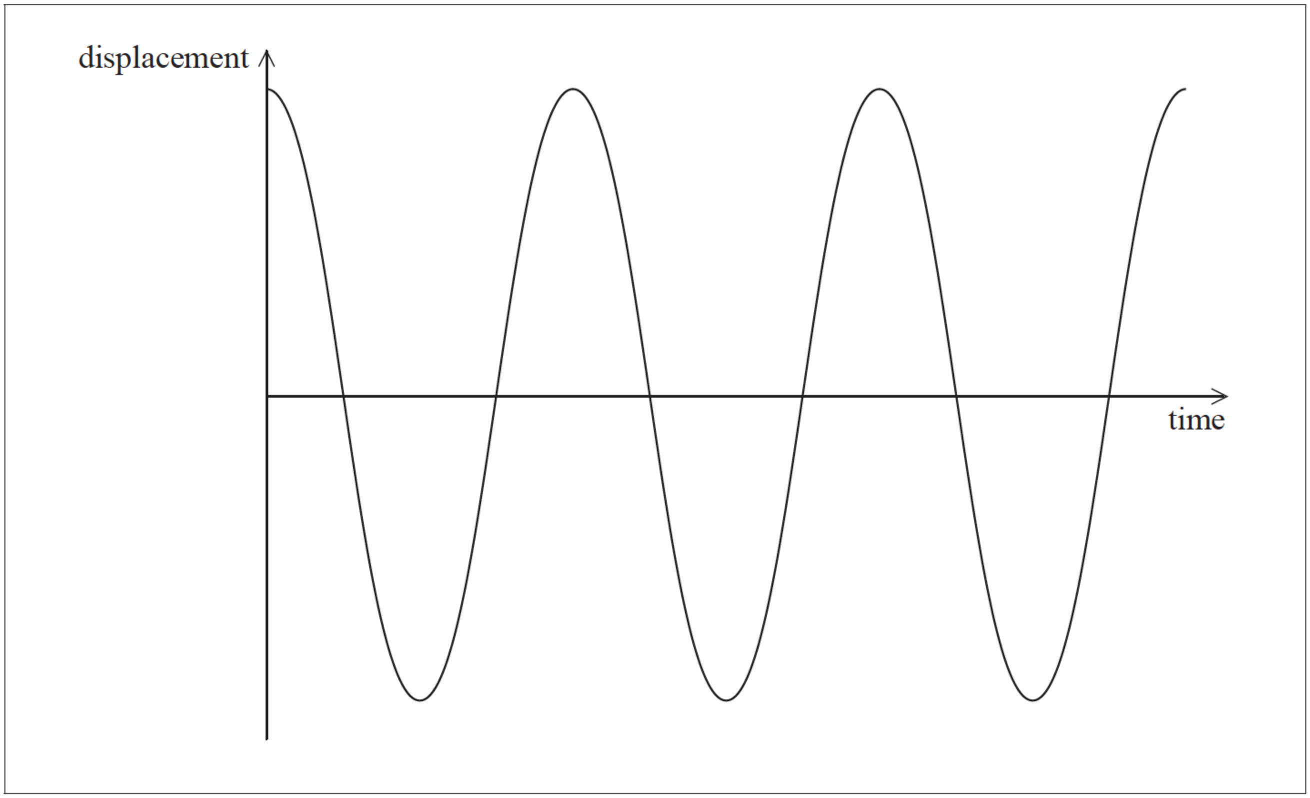
An object is placed on a frictionless surface and attached to a light horizontal spring.



The other end of the spring is attached to a stationary point P. Air resistance is negligible. The equilibrium position is at O. The object is moved to position Y and released.

3g. Outline the conditions necessary for the object to execute simple harmonic motion. *[2 marks]*

3h. The sketch graph below shows how the displacement of the object from point O varies with time over three time periods. *[4 marks]*



(i) Label with the letter A a point at which the magnitude of the acceleration of the object is a maximum.

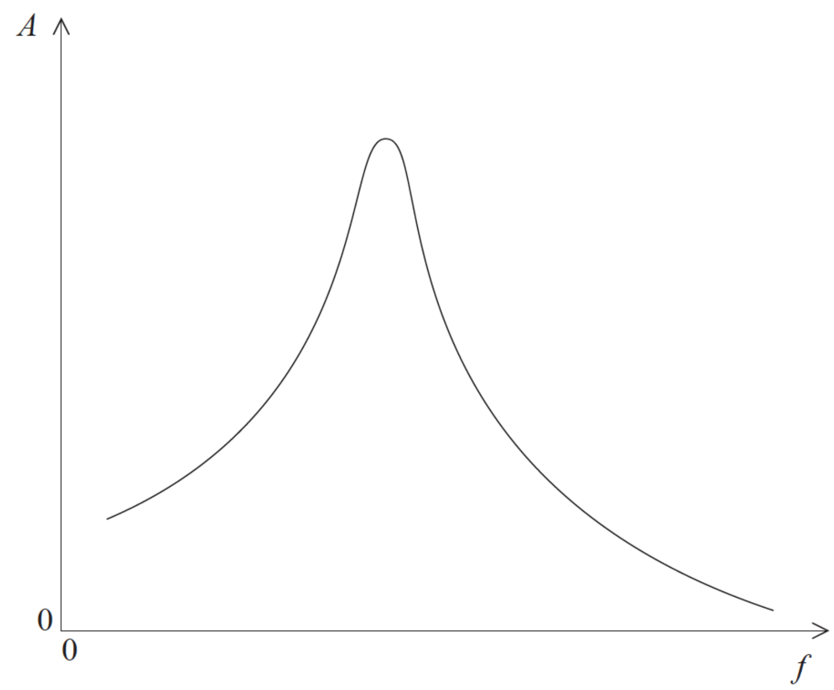
(ii) Label with the letter V a point at which the speed of the object is a maximum.

(iii) Sketch on the same axes a graph of how the displacement varies with time if a **small** frictional force acts on the object.

3i. Point P now begins to move from side to side with a small amplitude and at a variable driving frequency *f*. The frictional force is still small. *[4 marks]*

At each value of *f*, the object eventually reaches a constant amplitude *A*.

The graph shows the variation with *f* of *A*.



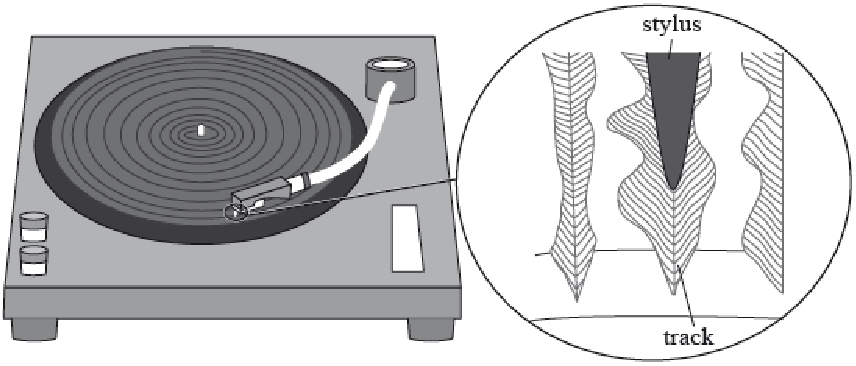
(i) With reference to resonance and resonant frequency, comment on the shape of the graph.

(ii) On the same axes, draw a graph to show the variation with *f* of *A* when the frictional force acting on the object is increased.

This question is in **two** parts. **Part 1** is about simple harmonic motion (SHM) and sound. **Part 2** is about electric and magnetic fields.

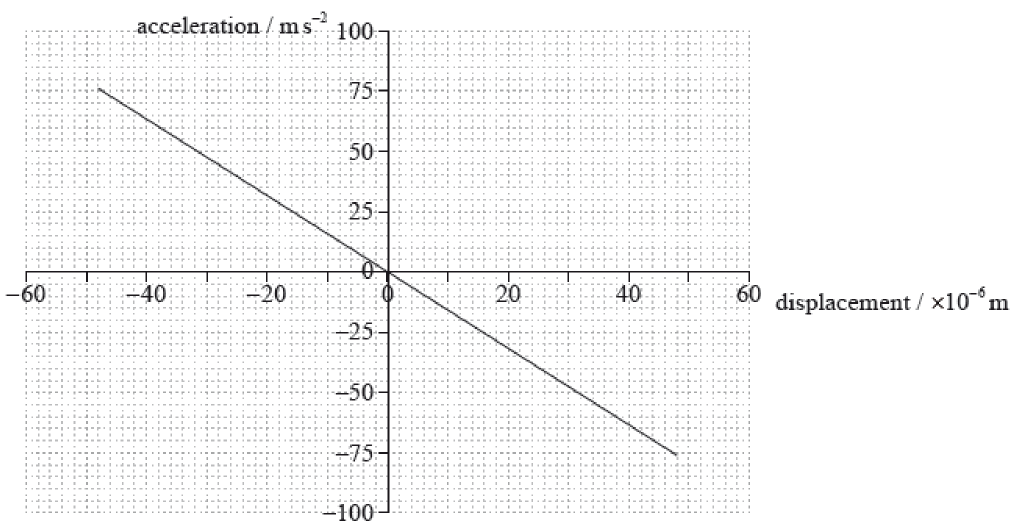
Part 1 Simple harmonic motion (SHM) and sound

The diagram shows a section of continuous track of a long-playing (LP) record. The stylus (needle) is placed in the track of the record.



As the LP record rotates, the stylus moves because of changes in the width and position of the track. These movements are converted into sound waves by an electrical system and a loudspeaker.

A recording of a single-frequency musical note is played. The graph shows the variation in horizontal acceleration of the stylus with horizontal displacement.



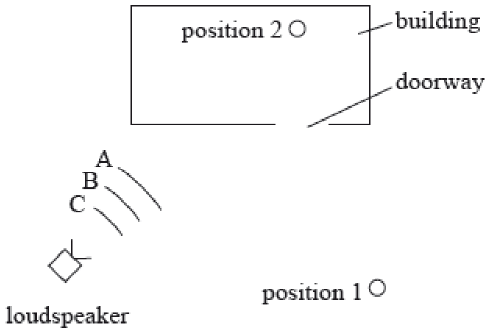
4a. Explain why the graph shows that the stylus undergoes simple harmonic motion. *[4 marks]*

4b. (i) Using the graph on page 14, show that the frequency of the note being played is about 200 Hz. *[5 marks]*

(ii) On the graph on page 14, identify, with the letter P, the position of the stylus at which the kinetic energy is at a maximum.

Sound is emitted from a loudspeaker which is outside a building. The loudspeaker emits a sound wave that has the same frequency as the recorded note.

A person standing at position 1 outside the building and a person standing at position 2 inside the building both hear the sound emitted by the loudspeaker.



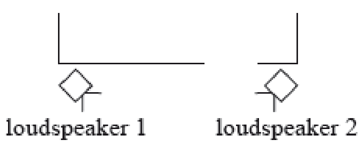
A, B and C are wavefronts emitted by the loudspeaker.

4c. (i) Draw rays to show how the person at **position 1** is able to hear the sound emitted by the loudspeaker. *[4 marks]*

(ii) The speed of sound in the air is $330\ \mathrm{m\,s^{-1}}$. Calculate the wavelength of the note.

(iii) The walls of the room are designed to absorb sound. Explain how the person at **position 2** is able to hear the sound emitted by the loudspeaker.

4d. The arrangement in (c) is changed and another loudspeaker is added. Both loudspeakers emit the same recorded note in phase with each other. *[3 marks]*



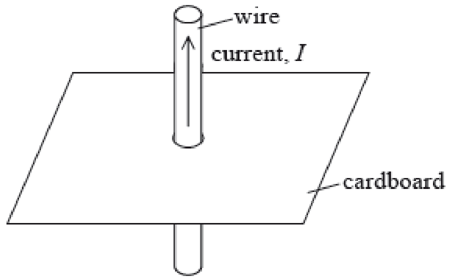
Outline why there are positions between the loudspeakers where the sound can only be heard faintly.

Part 2 Electric and magnetic fields

Electrical leads used in physics laboratories consist of a central conductor surrounded by an insulator.

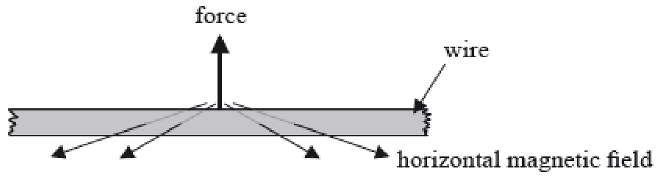
4e. Distinguish between an insulator and a conductor. *[2 marks]*

4f. The diagram shows a current *I* in a vertical wire that passes through a hole in a horizontal piece of cardboard. *[3 marks]*



On the cardboard, draw the magnetic field pattern due to the current.

4g. (i) The diagram shows a length of copper wire that is horizontal in the magnetic field of the Earth. *[4 marks]*

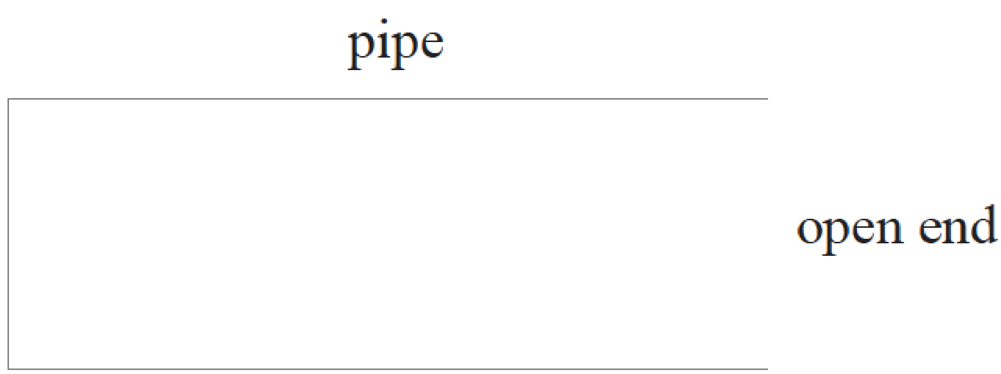


The wire carries an electric current and the force on the wire is as shown. Identify, with an arrow, the direction of electron flow in the wire.

(ii) The horizontal component of the magnetic field of the Earth at the position of the wire is $40\ \mu\text{T}$. The mass per unit length of the wire is $1.41 \times 10^{-4}\ \text{kg}\,\text{m}^{-2}$. The net force on the wire is zero. Determine the current in the wire.

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}.



5a. 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 marks]*

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

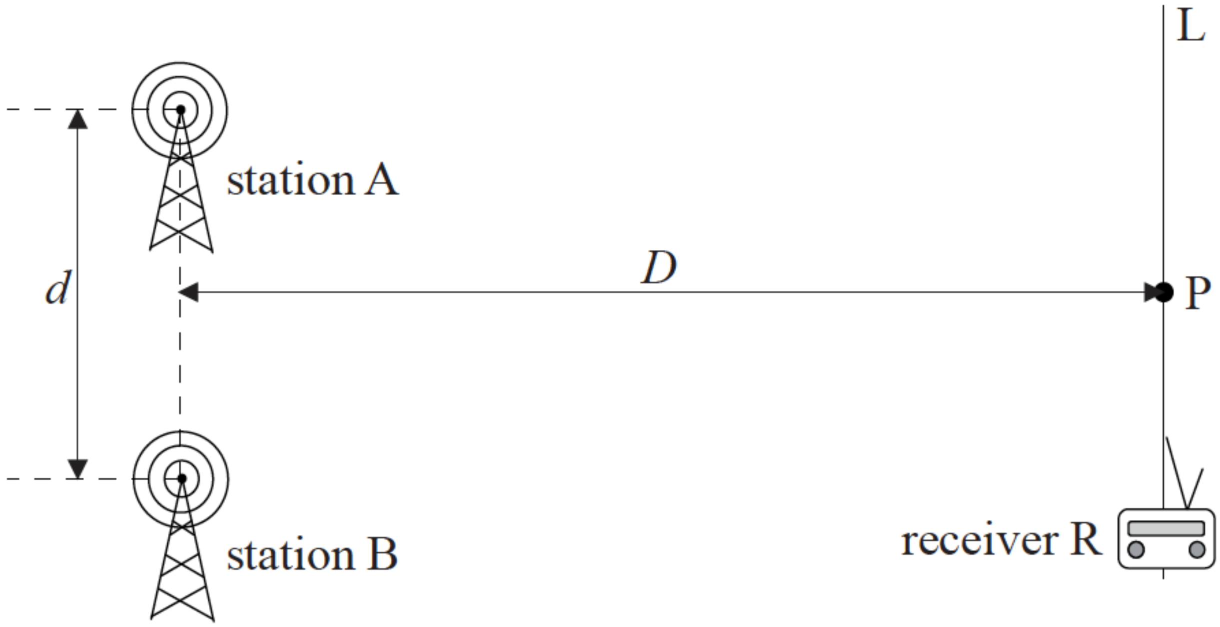
(ii) Show that the frequency of the first harmonic is about 410 Hz.

5b. (i) Describe what is meant by the Doppler effect. *[4 marks]*

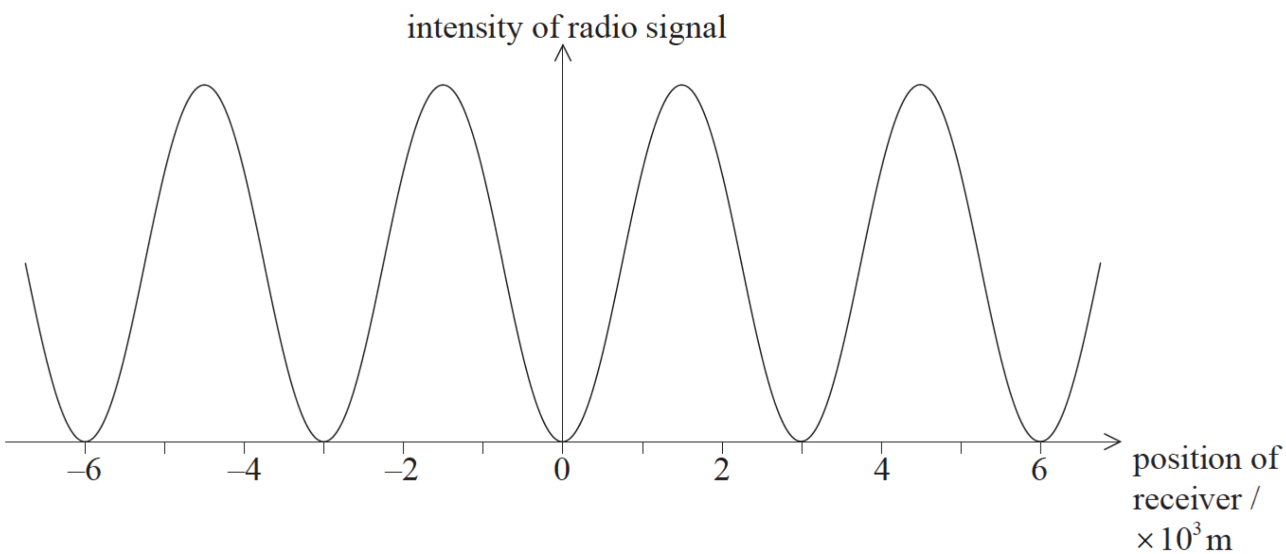
(ii) The train approaches a stationary observer at a constant velocity of $50ms^{-1}$ and sounds its horn at the same frequency as in (a)(ii). Calculate the frequency of the sound as measured by the observer.

This question is about interference.

6a. 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 marks]*



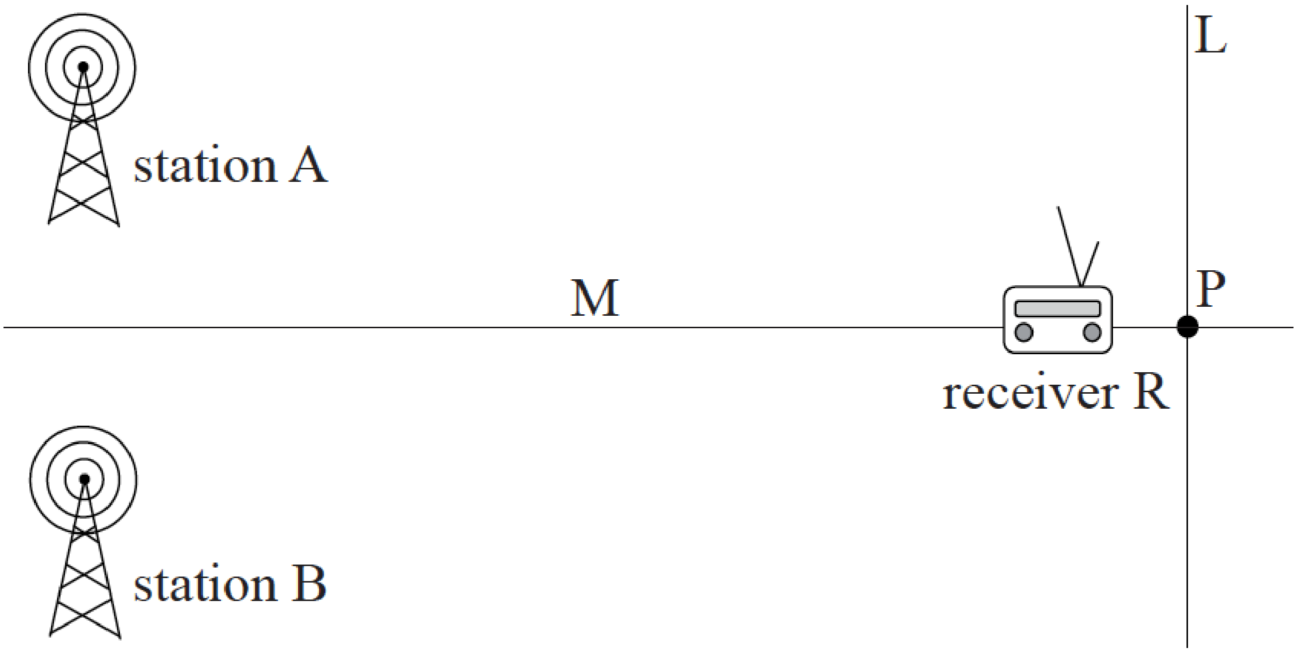
The graph shows how the intensity of the radio signal varies with position as the receiver is moved along line L. The position of the receiver is zero when the receiver is at P.



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

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

6b. The receiver R then moves along a different line M which is at 90º to line L. *[2 marks]*



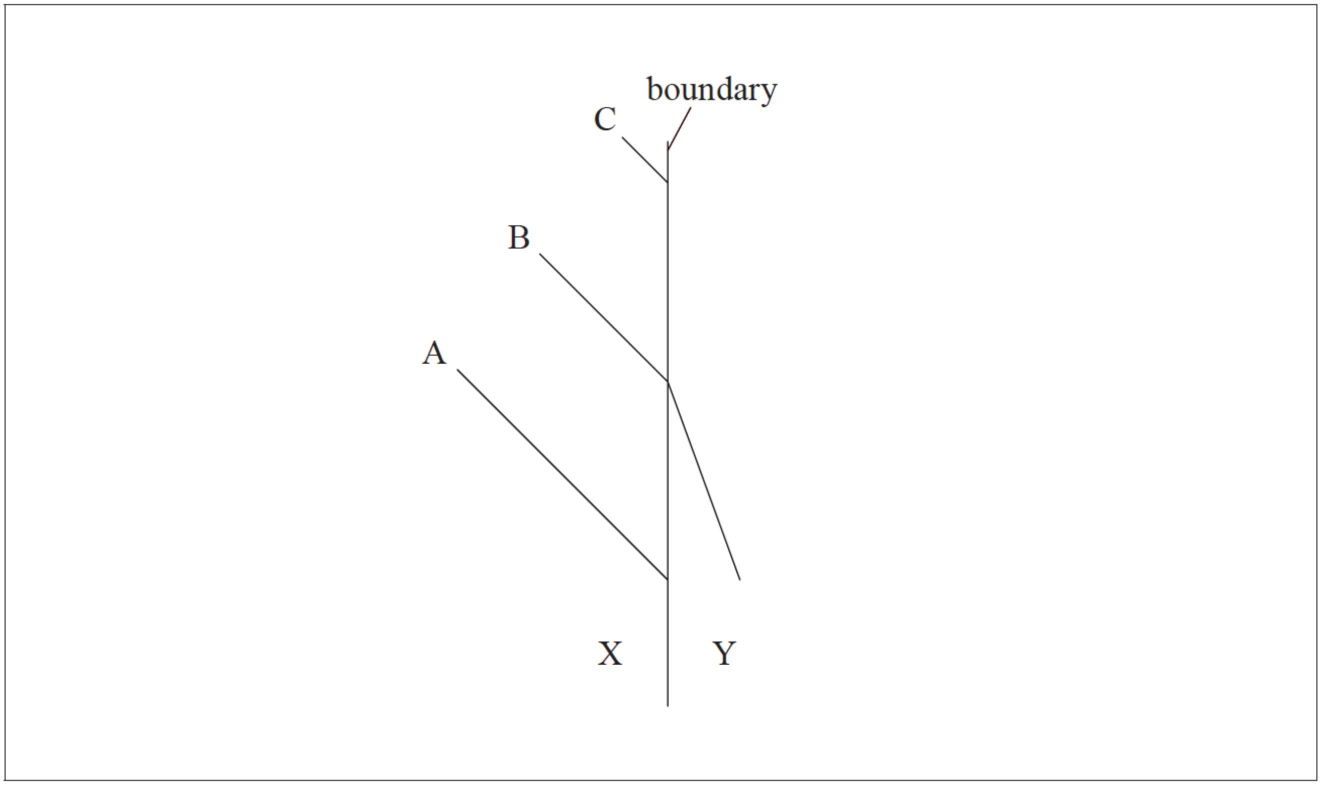
Discuss the variation of the intensity of the radio signal with position as the receiver is moved along line M.

This question is in **two** parts. **Part 1** is about wave motion. **Part 2** is about the melting of the Pobeda ice island.

Part 1 Wave motion

7a. State what is meant by the terms ray and wavefront and state the relationship between them. *[3 marks]*

7b. The diagram shows three wavefronts, A, B and C, of a wave at a particular instant in time incident on a boundary between media X and Y. Wavefront B is also shown in medium Y. *[4 marks]*

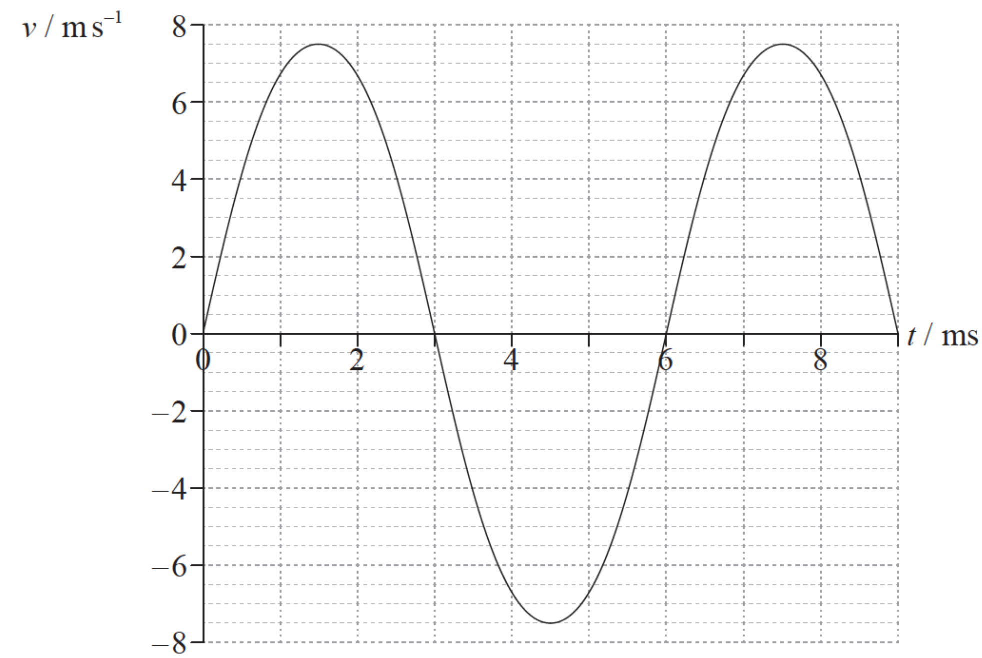


(i) Draw a line to show wavefront C in medium Y.

(ii) The refractive index of X is n_X and the refractive index of Y is n_Y. By making appropriate measurements, calculate $\frac{n_X}{n_Y}$.

7c. Describe the difference between transverse waves and longitudinal waves. *[2 marks]*

7d. The graph below shows the variation of the velocity *v* with time *t* for one oscillating particle of a medium. *[3 marks]*



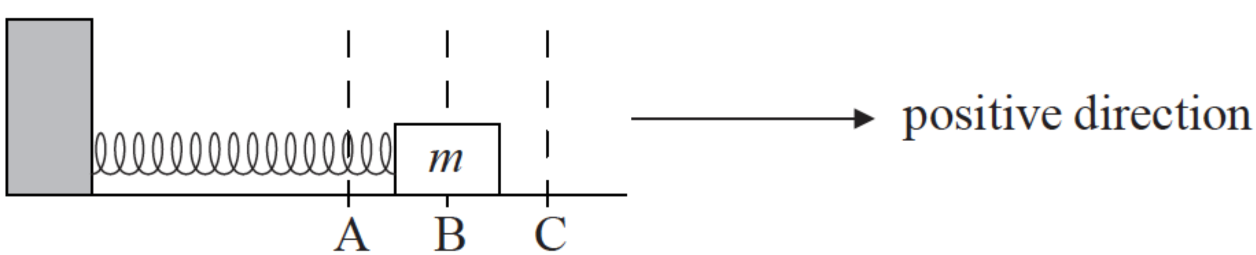
(i) Calculate the frequency of oscillation of the particle.

(ii) Identify on the graph, with the letter M, a time at which the displacement of the particle is a maximum.

This question is in **two** parts. **Part 1** is about simple harmonic motion and the superposition of waves. **Part 2** is about gravitational fields.

Part 1 Simple harmonic motion and the superposition of waves

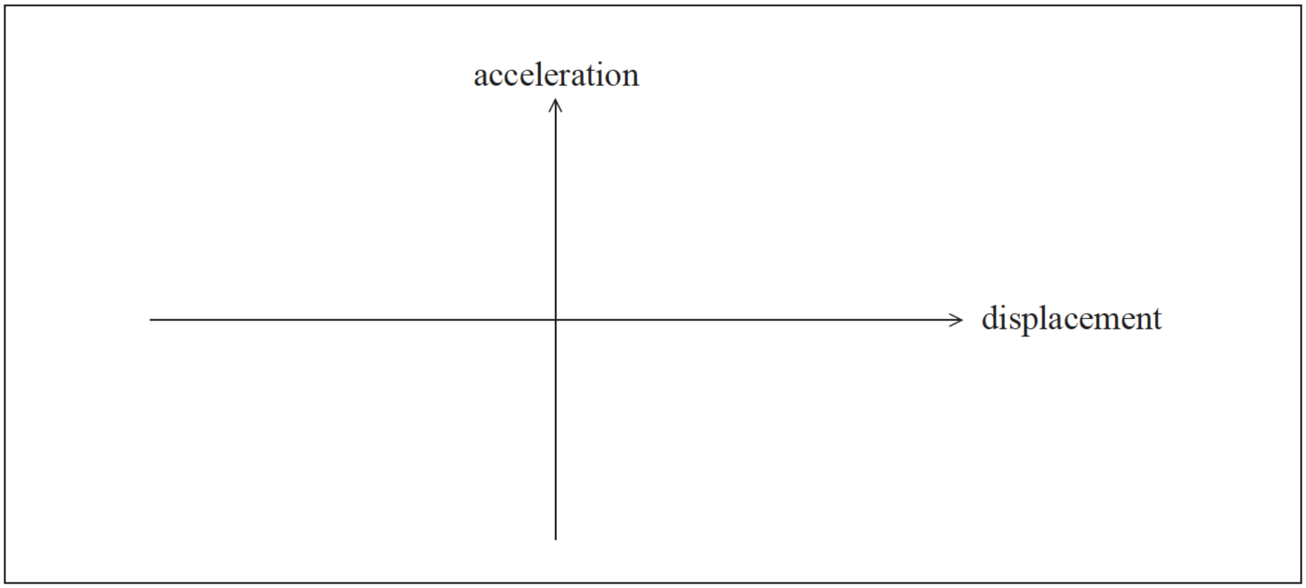
An object of mass *m* is placed on a frictionless surface and attached to a light horizontal spring. The other end of the spring is fixed.



The equilibrium position is at B. The direction B to C is taken to be positive. The object is released from position A and executes simple harmonic motion between positions A and C.

8a. Define *simple harmonic motion*. *[2 marks]*

8b. (i) On the axes below, sketch a graph to show how the acceleration of the mass varies with displacement from the equilibrium position B. *[3 marks]*



(ii) On your graph, label the points that correspond to the positions A, B and C.

8c. (i) On the axes below, sketch a graph to show how the velocity of the mass varies with
time from the moment of release from A until the mass returns to A for the first time. *[3 marks]*

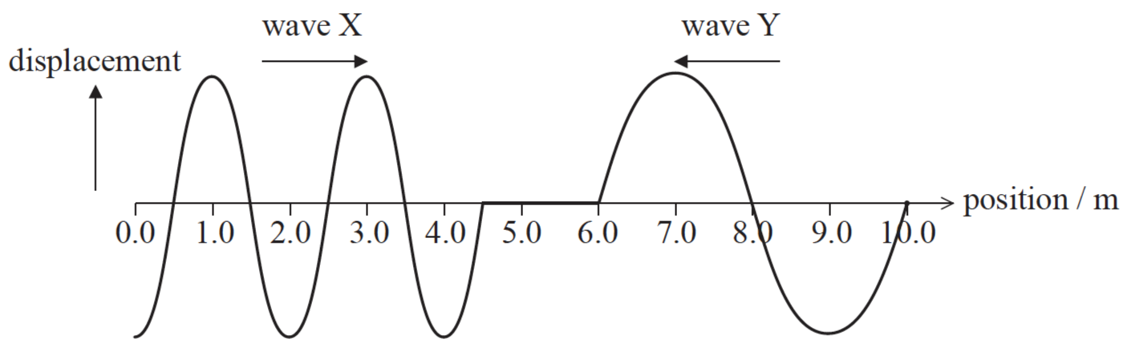
(ii) On your graph, label the points that correspond to the positions A, B and C.

8d. The period of oscillation is 0.20s and the distance from A to B is 0.040m. Determine the maximum speed of the mass. *[3 marks]*

8e. A long spring is stretched so that it has a length of 10.0 m. Both ends are made to oscillate with simple harmonic motion so that transverse waves of equal amplitude but different frequency are generated. *[4 marks]*

Wave X, travelling from left to right, has wavelength 2.0 m, and wave Y, travelling from right to left, has wavelength 4.0 m. Both waves move along the spring at speed 10.0 m s^{-1}.

The diagram below shows the waves at an instant in time.

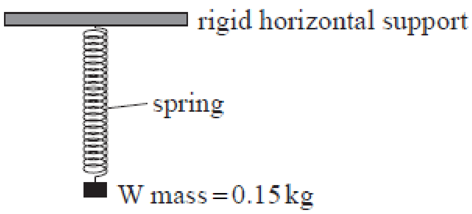


(i) State the principle of superposition as applied to waves.

(ii) By drawing on the diagram or otherwise, calculate the position at which the resultant wave will have maximum displacement 0.20 s later.

Part 2 Simple harmonic motion and waves

9a. One end of a light spring is attached to a rigid horizontal support. *[8 marks]*



An object W of mass 0.15 kg is suspended from the other end of the spring. The extension *x* of the spring is proportional to the force *F* causing the extension. The force per unit extension of the spring *k* is 18 Nm^{-1}.

A student pulls W down such that the extension of the spring increases by 0.040 m. The student releases W and as a result W performs simple harmonic motion (SHM).

(i) State what is meant by the expression “W performs SHM”.

(ii) Determine the maximum acceleration of W.

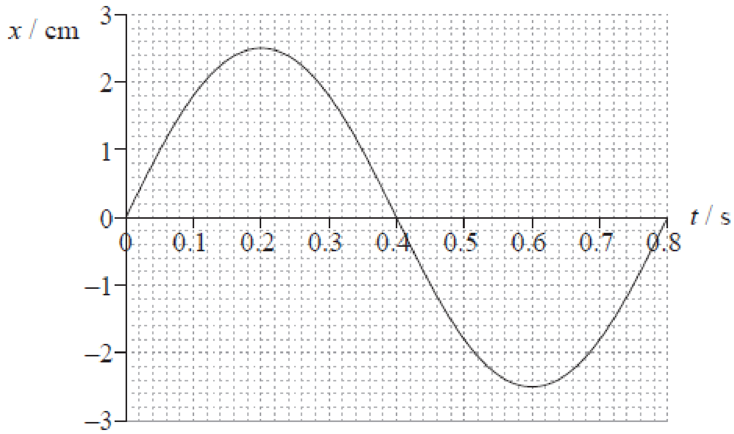
(iii) Determine the period of oscillation of the spring.

(iv) Determine the maximum kinetic energy of W.

9b. A light spring is stretched horizontally and a longitudinal travelling wave is set up in the spring, travelling to the right. *[6 marks]*

(i) Describe, in terms of the propagation of energy, what is meant by a longitudinal travelling wave.

(ii) The graph shows how the displacement *x* of one coil C of the spring varies with time *t*.



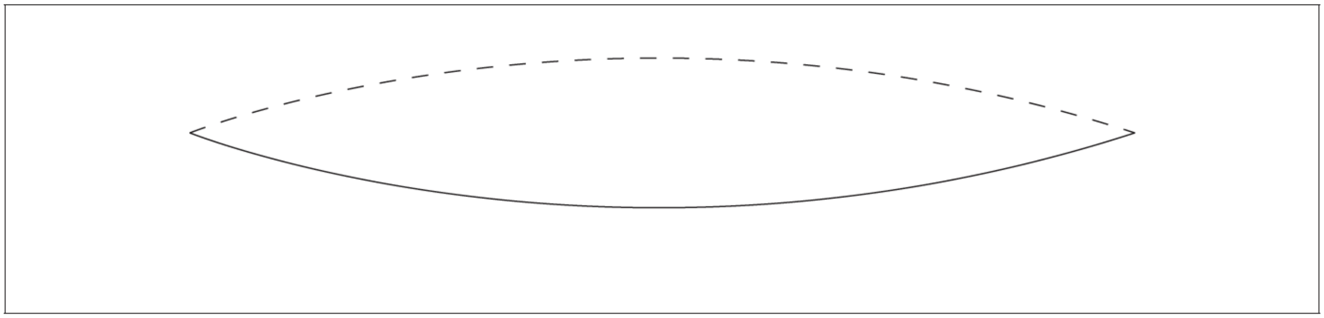
The speed of the wave is 3.0 cms^{-1}. Determine the wavelength of the wave.

(iii) Draw, on the graph in (c)(ii), the displacement of a coil of the spring that is 1.8 cm away from C in the direction of travel of the wave, explaining your answer.

This question is about standing waves on strings.

10a. 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 marks]*

10b. The diagram shows a string vibrating in its first harmonic mode. Both ends of the string are fixed. *[5 marks]*



(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.

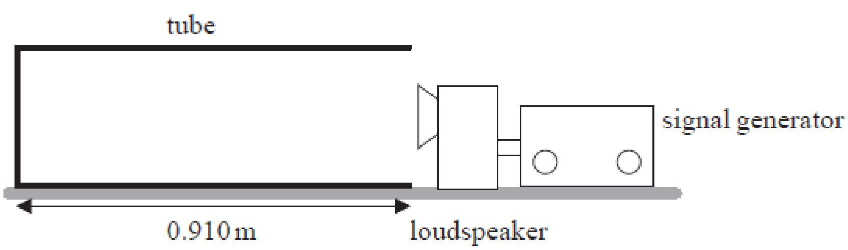
(iii) Sketch how the string will appear if it is vibrated at a frequency three times that of the first harmonic frequency.

(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 standing (stationary) waves.

11a. State **one** way in which a standing wave differs from a travelling (progressive) wave. *[1 mark]*

11b. A loudspeaker connected to a signal generator is placed in front of the open end of a tube. *[3 marks]*



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.

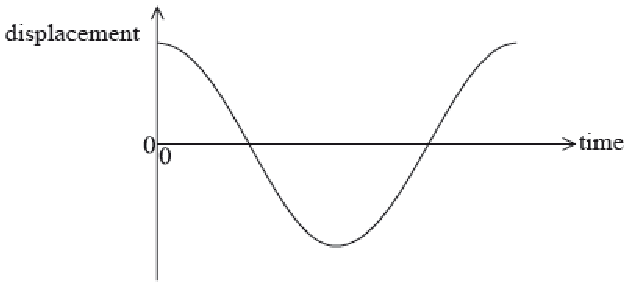
11c. The frequency of sound is continuously increased above 92.0Hz. *[2 marks]*

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

This question is in **two** parts. **Part 1** is about a simple pendulum. **Part 2** is about the Rutherford model of the atom.

Part 1 Simple pendulum

A pendulum consists of a bob suspended by a light inextensible string from a rigid support. The pendulum bob is moved to one side and then released. The sketch graph shows how the displacement of the pendulum bob undergoing simple harmonic motion varies with time over one time period.



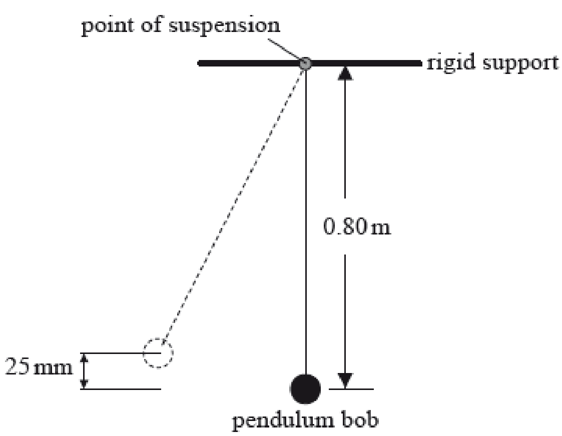
On the sketch graph above,

12a. (i) label with the letter A a point at which the acceleration of the pendulum bob is a maximum. *[2 marks]*

(ii) label with the letter V a point at which the speed of the pendulum bob is a maximum.

12b. Explain why the magnitude of the tension in the string at the midpoint of the oscillation is greater than the weight of the pendulum bob. *[3 marks]*

A pendulum bob is moved to one side until its centre is 25 mm above its rest position and then released.



12c. (i) Show that the speed of the pendulum bob at the midpoint of the oscillation is $0.70\ \mathrm{m\,s^{-1}}$. *[5 marks]*

(ii) The mass of the pendulum bob is 0.057 kg. The centre of the pendulum bob is 0.80 m below the support. Calculate the magnitude of the tension in the string when the pendulum bob is vertically below the point of suspension.

Part 2 Rutherford model of the atom

The isotope gold-197 $\left({}^{197}_{79}Au\right)$ is stable but the isotope gold-199 $\left({}^{199}_{79}Au\right)$ is not.

12d. (i) Outline, in terms of the forces acting between nucleons, why, for large stable nuclei such as gold-197, the number of neutrons exceeds the number of protons. *[4 marks]*

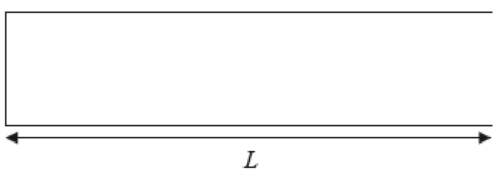
(ii) A nucleus of ${}^{199}_{79}\mathrm{Au}$ decays to a nucleus of ${}^{199}_{80}\mathrm{Hg}$ with the emission of an electron and another particle. State the name of this other particle.

This question is about standing waves and organ pipes.

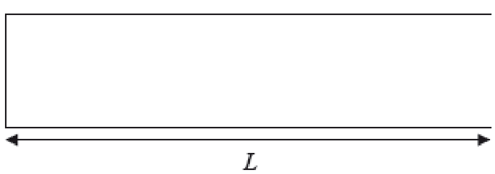
13a. State **one** way in which a standing wave differs from a travelling wave. *[1 mark]*

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

13b. (i) first harmonic frequency f_1. *[2 marks]*



(ii) second harmonic frequency f_2.



13c. Use your answer to (b) to deduce an expression for the ratio $\frac{f_1}{f_2}$. *[3 marks]*

13d. 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 mark]*