WORKSHEET

AS Physics – Structured

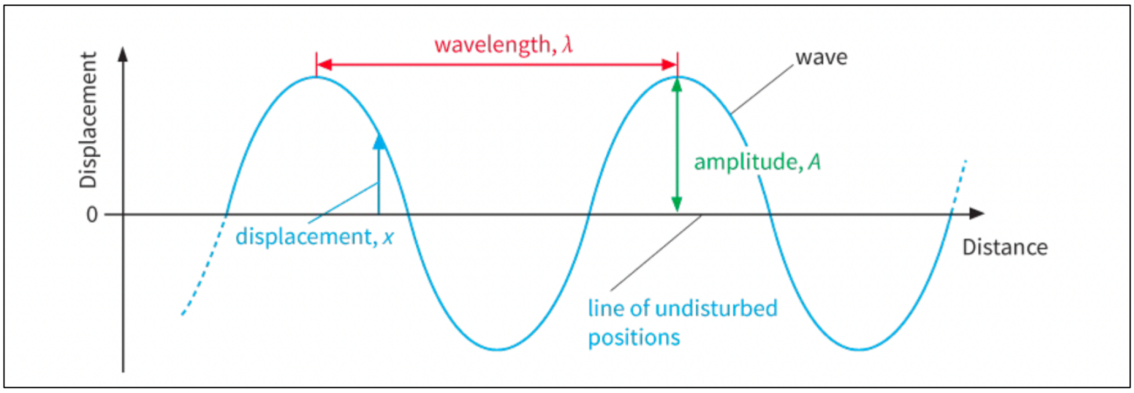
Waves Question

(1) Waves

Energy can be transferred through moving oscillations or vibrations. These can be modelled in physics by Progressive waves.

Progressive waves transfer energy from one point to another. (Two types: Longitudinal & Transverse)

- Longitudinal waves have vibrations parallel to the wave direction.
- Transverse waves have vibrations perpendicular to the wave direction.



- Amplitude is the maximum displacement of a wave from its equilibrium position.

- The Period (T) is the time taken for one complete oscillation.

- Wavelength (λ) is the distance between two adjacent points one oscillation apart.

- The frequency (f) is the number of oscillations per unit time. Measured in Hertz (Hz), 1 Hz = 1 oscillation per second.

(1)

$$\therefore \boxed{f = \frac{1}{T}}$$

Wave Equation Proof

$$v = \frac{d}{t} = \frac{\lambda}{T} = \left(\frac{1}{T}\right)\lambda = f\lambda$$

(2)

$$\therefore \boxed{v = f\lambda}$$

Intensity vs Amplitude

(3)

$$\boxed{I \propto A^2}$$

② Electromagnetic waves

All electromagnetic waves travel at the same speed in a vacuum of '3×10^8 m/s', but have different wavelength and frequencies.

Type of electromagnetic waves	**Wavelength range / m**
radio waves	$>10^6$ to 10^{-1}
microwaves	10^{-1} to 10^{-3}
infrared	10^{-3} to 7×10^{-7}
visible	7×10^{-7} (red) to 4×10^{-7} (violet)
ultraviolet	4×10^{-7} to 10^{-8}
X-rays	10^{-8} to 10^{-13}
γ-rays	10^{-10} to 10^{-16}

③ Doppler Effect

An increase (or decrease) in frequency of sound, light, or other waves as the source and observer move towards (or away from) each other.

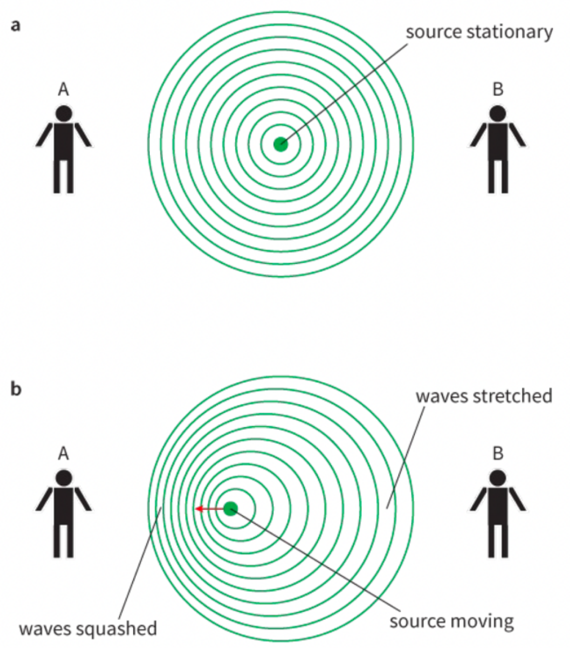


Figure 12.11: Sound waves (green lines) emitted at constant frequency by **a** a stationary source, and **b** a source moving with speed v_s. The separation between adjacent green lines is equal to one wavelength.

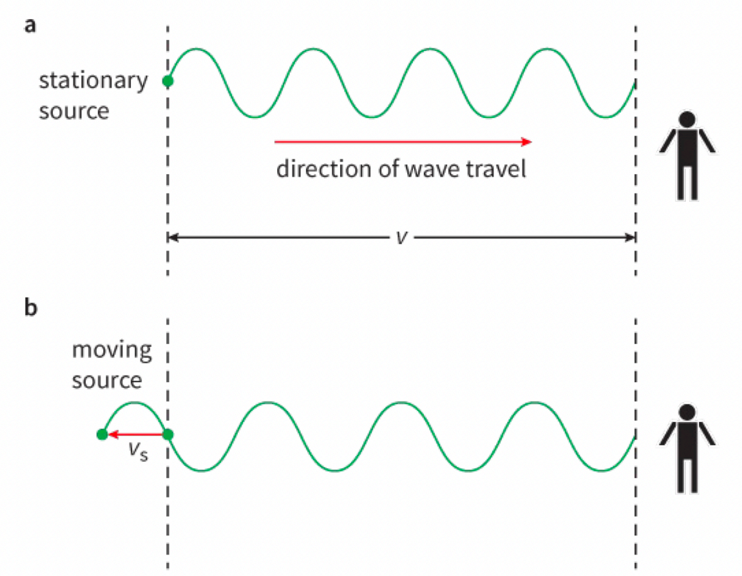


Figure 12.12: Sound waves, emitted at constant frequency by **a** a stationary source, and **b** a source moving with speed v_s *away* from the observer (that is, the person hearing the sound).

$v = f\lambda$

$\therefore$ from (a) : $\lambda_o = \dfrac{v}{f_s}$

λ_o = observed wavelength

f_s = source frequency

v = wave velocity

v_s = source velocity

$\therefore$ from (b) : $\lambda_o = \dfrac{(v+v_s)}{f_s}$

Thus, observed frequency (f_o) :

$$\therefore f_o = \frac{v}{\lambda_o} = \frac{v}{\left(\frac{(v+v_s)}{f_s}\right)} = \frac{f_s v}{(v+v_s)}$$

And, if source was instead moving towards observer wavelengths will be compressed $\left(\lambda_o = \dfrac{(v-v_s)}{f_s}\right)$

$$\therefore f_o = \frac{f_s v}{(v-v_s)}$$

Thus, Doppler Effect :

4

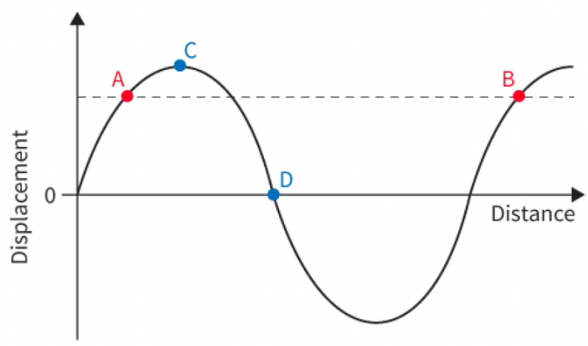
$$\boxed{f_o = \frac{f_s\, v}{(v \pm v_s)}}$$

This is given on your formula sheet.

4 Superposition

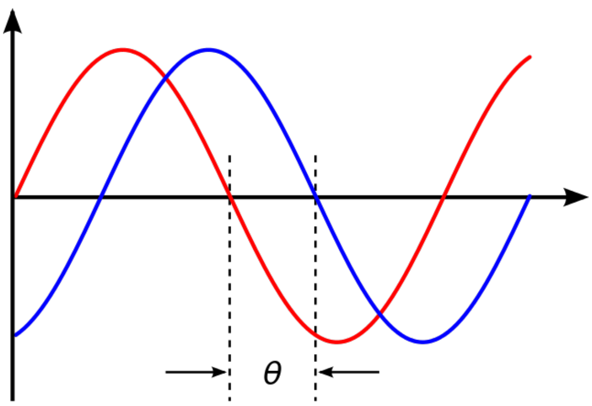
The Principle of Superposition states that when two or more waves meet at a point, the resultant displacement is the sum of the displacements of the individual waves.

· Phase Difference :



Points A and B are vibrating; they have a phase difference of 360° or 0°. They are 'in phase'.

Points C and D have a phase difference of 90°.



distance between points.

$$\phi = \frac{x}{\lambda} \times 360^\circ$$

phase difference

(5) Stationary Waves

Stationary waves are formed when two identical progressive waves travelling in opposite directions meet and superpose.

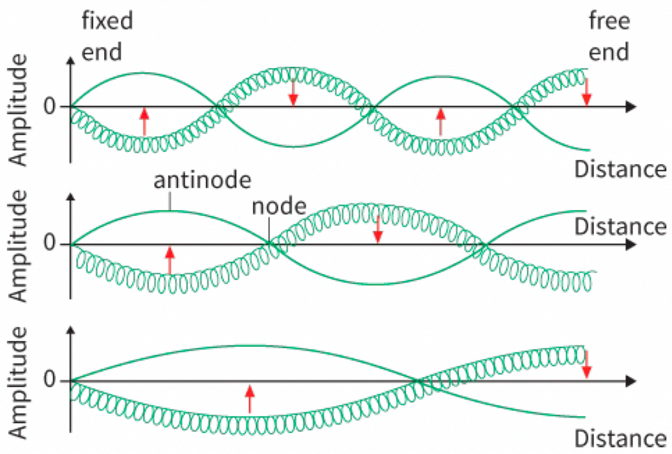


Figure 14.3: Different stationary wave patterns are possible, depending on the frequency of vibration.

· **Nodes** : Points that don't move.

· **Antinodes** : Points of maximum amplitude.

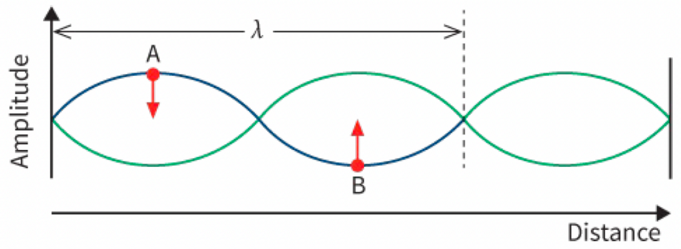


Figure 14.4: The fixed ends of a long spring must be nodes in the stationary wave pattern.

14.3 Formation of stationary waves

Imagine a string stretched between two fixed points, for example, a guitar string. Pulling the middle of the string and then releasing it produces a stationary wave. There is a node at each of the fixed ends and an antinode in the middle. Releasing the string produces two progressive waves travelling in opposite directions. These are reflected at the fixed ends. The reflected waves combine to produce the stationary wave.

Figure 14.3 shows how a stationary wave can be set up using a long spring. A stationary wave is formed whenever two progressive waves of the same amplitude and wavelength, travelling in **opposite** directions, superpose. Figure 14.5 uses a displacement–distance graph (s–x) to illustrate the formation of a stationary wave along a long spring (or a stretched length of string):

- At time $t = 0$, the progressive waves travelling to the left and right are in phase. The waves combine **constructively**, giving an amplitude twice that of each wave.
- After a time equal to one-quarter of a period $\left(t = \frac{T}{4}\right)$, each wave has travelled a distance of one quarter of a wavelength to the left or right. Consequently, the two waves are in antiphase (phase difference = 180°). The waves combine **destructively**, giving zero displacement.
- After a time equal to one-half of a period $\left(t = \frac{T}{2}\right)$, the two waves are back in phase again. They once again combine **constructively**.
- After a time equal to three-quarters of a period $\left(t = \frac{3T}{4}\right)$, the waves are in antiphase again. They combine **destructively**, with the resultant wave showing zero displacement.
- After a time equal to one whole period ($t = T$), the waves combine **constructively**. The profile of the spring is as it was at $t = 0$.

This cycle repeats itself, with the long spring showing nodes and antinodes along its length. The separation between adjacent nodes or antinodes tells us about the progressive waves that produce the stationary wave.

A closer inspection of the graphs in Figure 14.5 shows that the separation between adjacent nodes or antinodes is related to the wavelength λ of the progressive wave. The important conclusions are:

- separation between two adjacent nodes (or between two adjacent antinodes) = $\frac{\lambda}{2}$
- separation between adjacent node and antinode = $\frac{\lambda}{4}$

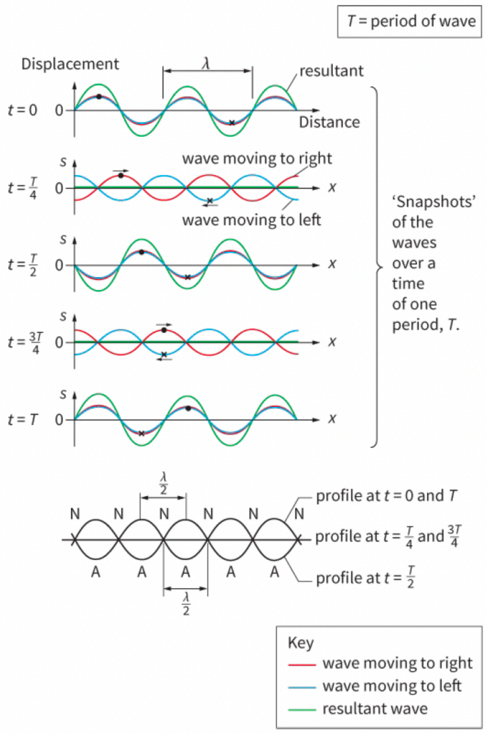


Figure 14.5: The blue-coloured wave is moving to the left and the red-coloured wave to the right. The *principle of superposition* of waves is used to determine the resultant displacement. The profile of the long spring is shown in green.

• Note: A stationary wave doesn't travel, thus has no speed ($v = 0\,m/s$). It doesn't transfer energy between two points like progressive waves.

Examples of Stationary Waves :

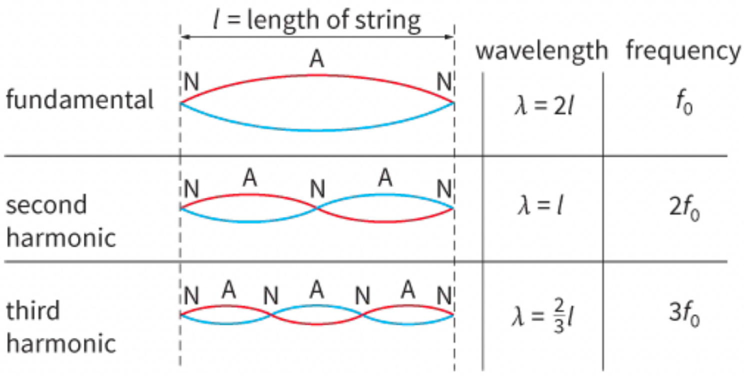


Figure 14.14: Some of the possible stationary waves for a fixed string of length l. The frequency of the harmonics is a multiple of the fundamental frequency f_0.

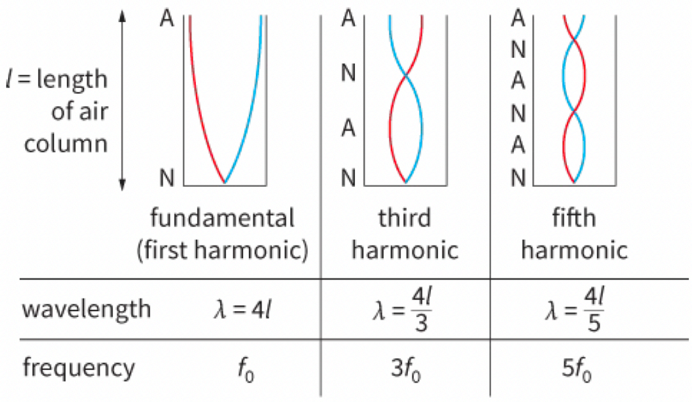


Figure 14.15: Some of the possible stationary waves for an air column, closed at one end. The frequency of each harmonic is an odd multiple of the fundamental frequency f_0.

QUESTIONS

Progressive & Standing Waves - Exam Questions

Q1 w2020_23

(a) An electromagnetic wave has a wavelength of 85 μm.

(i) State the wavelength, in m, of the wave.

wavelength = ... m [1]

(ii) Calculate the frequency, in THz, of the wave.

frequency = ... THz [2]

(iii) State the name of the region of the electromagnetic spectrum that contains this wave.

.... [1]

Q2 s2018_22

(a) **(i)** Define the *wavelength* of a progressive wave.

....

....[1]

(ii) State what is meant by an *antinode* of a stationary wave.

....

....[1]

(b) A loudspeaker producing sound of constant frequency is placed near the open end of a pipe, as shown in Fig. 4.1.

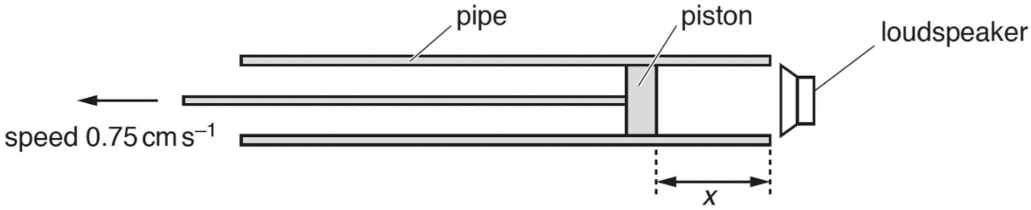


Fig. 4.1

A movable piston is at distance x from the open end of the pipe. Distance x is increased from $x = 0$ by moving the piston to the left with a constant speed of $0.75\,\text{cm s}^{-1}$.

The speed of the sound in the pipe is $340\,\text{m s}^{-1}$.

(i) A much louder sound is first heard when $x = 4.5\,\text{cm}$. Assume that there is an antinode of a stationary wave at the open end of the pipe.

Determine the frequency of the sound in the pipe.

frequency = ... Hz [3]

(ii) After a time interval, a second much louder sound is heard. Calculate the time interval between the first louder sound and the second louder sound being heard.

time interval = ... s [2]

[Total: 7]

Q3 w2018_22

(a) Sound waves are longitudinal waves. By reference to the direction of propagation of energy, state what is meant by a *longitudinal* wave.

....

....[1]

(b) A stationary sound wave in air has amplitude A. In an experiment, a detector is used to determine A^2. The variation of A^2 with distance x along the wave is shown in Fig. 4.1.

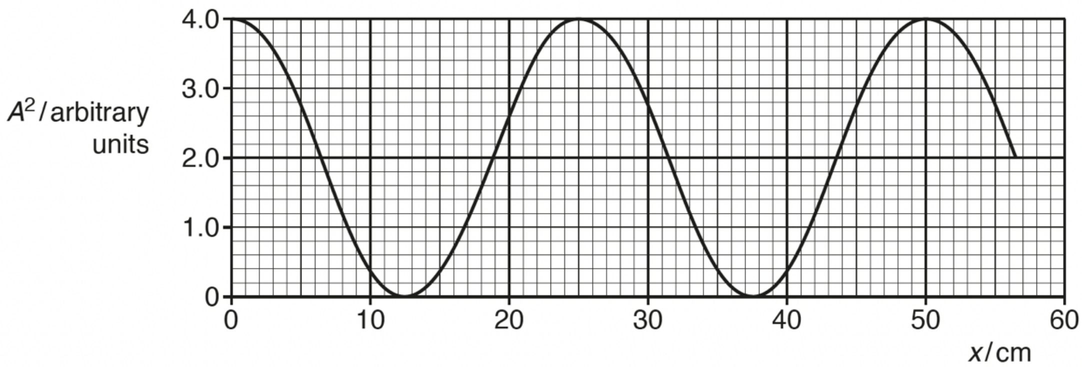


Fig. 4.1

(i) State the phase difference between the vibrations of an air particle at $x = 25$ cm and the vibrations of an air particle at $x = 50$ cm.

phase difference = ... ° [1]

(ii) The speed of the sound in the air is $330\,\text{m}\,\text{s}^{-1}$. Determine the frequency of the sound wave.

frequency = ... Hz [3]

(iii) Determine the ratio

$$\frac{\text{amplitude } A \text{ of wave at } x = 20\,\text{cm}}{\text{amplitude } A \text{ of wave at } x = 25\,\text{cm}}.$$

ratio = ... [2]

[Total: 7]

Q4 w2018_23

(a) On Fig. 4.1, complete the two graphs to illustrate what is meant by the amplitude A, the wavelength λ and the period T of a progressive wave.

Ensure that you label the axes of each graph.

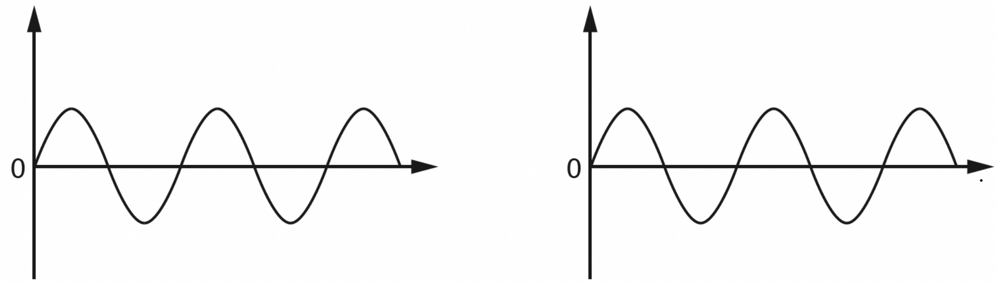


Fig. 4.1

[3]

(b) A horizontal string is stretched between two fixed points X and Y. A vibrator is used to oscillate the string and produce a stationary wave. Fig. 4.2 shows the string at one instant in time.

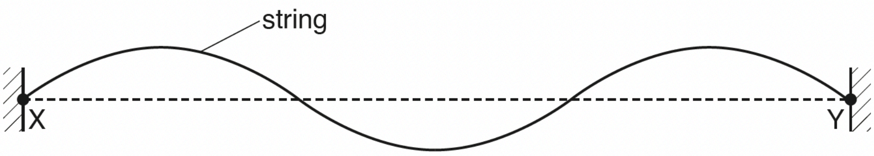


Fig. 4.2

The speed of a progressive wave along the string is $30\,\mathrm{m\,s^{-1}}$. The stationary wave has a period of 40 ms.

(i) Explain how the stationary wave is formed on the string.

....

....

....

....[2]

(ii) A particle on the string oscillates with an amplitude of 13 mm. At time t, the particle has zero displacement.

Calculate

1. the displacement of the particle at time (t + 100 ms),

displacement = ... mm

2. the total distance moved by the particle from time t to time (t + 100 ms).

distance = ... mm
[3]

(iii) Determine

1. the frequency of the wave,

frequency = ... Hz [1]

2. the horizontal distance from X to Y.

distance = ... m [3]

[Total: 12]

Q5 s2019_23

A vertical tube of length 0.60 m is open at both ends, as shown in Fig. 5.1.

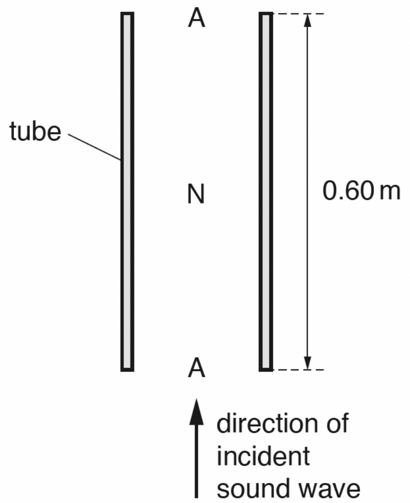


Fig. 5.1

An incident sinusoidal sound wave of a single frequency travels up the tube. A stationary wave is then formed in the air column in the tube with antinodes A at both ends and a node N at the midpoint.

(a) Explain how the stationary wave is formed from the incident sound wave.

....

....

....

....[2]

(b) On Fig. 5.2, sketch a graph to show the variation of the amplitude of the stationary wave with height *h* above the bottom of the tube.

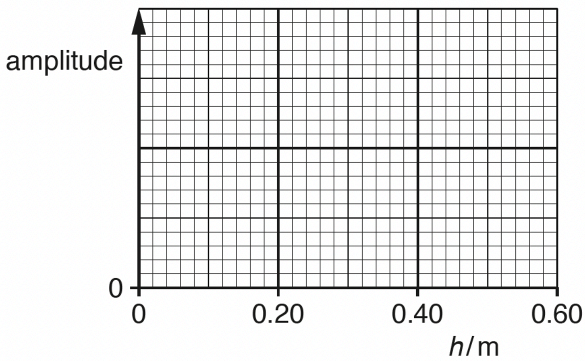


Fig. 5.2

[2]

(c) For the stationary wave, state:

(i) the direction of the oscillations of an air particle at a height of 0.15 m above the bottom of the tube

....[1]

(ii) the phase difference between the oscillations of a particle at a height of 0.10 m and a particle at a height of 0.20 m above the bottom of the tube.

phase difference = ... ° [1]

(d) The speed of the sound wave is $340\,m\,s^{-1}$.

Calculate the frequency of the sound wave.

frequency = ... Hz [2]

(e) The frequency of the sound wave is gradually increased.

Determine the frequency of the wave when a stationary wave is next formed.

frequency = ... Hz [1]

[Total: 9]

Q6 s2020_22

(a) State the difference between progressive waves and stationary waves in terms of the transfer of energy along the wave.

....

.... [1]

(b) A progressive wave travels from left to right along a stretched string. Fig. 4.1 shows part of the string at one instant.

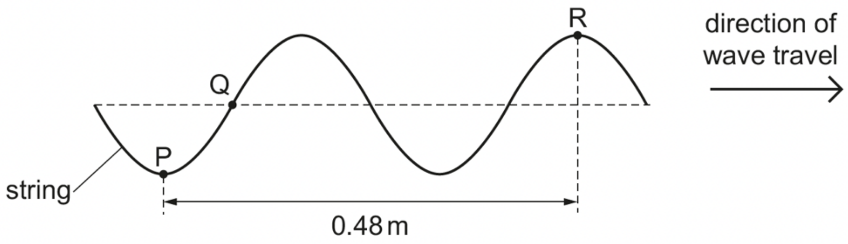


Fig. 4.1

P, Q and R are three different points on the string. The distance between P and R is 0.48 m. The wave has a period of 0.020 s.

(i) Use Fig. 4.1 to determine the wavelength of the wave.

wavelength = ... m [1]

(ii) Calculate the speed of the wave.

speed = ... $m\,s^{-1}$ [2]

(iii) Determine the phase difference between points Q and R.

phase difference = ... ° [1]

(iv) Fig. 4.1 shows the position of the string at time $t = 0$. Describe how the displacement of point Q on the string varies with time from $t = 0$ to $t = 0.010$ s.

....

....

....

.... [2]

(c) A stationary wave is formed on a different string that is stretched between two fixed points X and Y. Fig. 4.2 shows the position of the string when each point is at its maximum displacement.

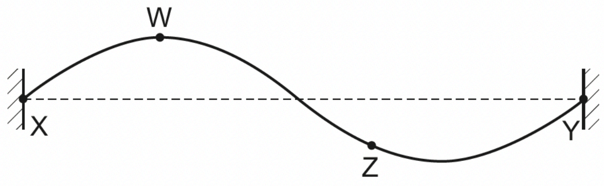


Fig. 4.2

(i) Explain what is meant by a *node* of a stationary wave.

.... [1]

(ii) State the number of antinodes of the wave shown in Fig. 4.2.

number = ... [1]

(iii) State the phase difference between points W and Z on the string.

phase difference = ...° [1]

(iv) A new stationary wave is now formed on the string. The new wave has a frequency that is half of the frequency of the wave shown in Fig. 4.2. The speed of the wave is unchanged.

On Fig. 4.3, draw a position of the string, for this new wave, when each point is at its maximum displacement.

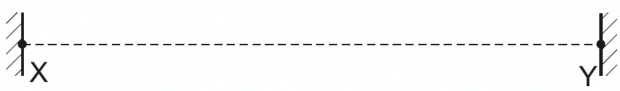


Fig. 4.3

[1]

[Total: 11]

Q7 w2020_21

(a) Describe the conditions required for two waves to be able to form a stationary wave.

....

....

....

.... [2]

(b) A stationary wave on a string has nodes and antinodes. The distance between a node and an adjacent antinode is 6.0 cm.

(i) State what is meant by a *node*.

.... [1]

(ii) Calculate the wavelength of the two waves forming the stationary wave.

wavelength = ... cm [1]

(iii) State the phase difference between the particles at two adjacent antinodes of the stationary wave.

phase difference = ... ° [1]

[Total: 5]

Q8 w2021_22

A tube is initially fully submerged in water. The axis of the tube is kept vertical as the tube is slowly raised out of the water, as shown in Fig. 5.1.

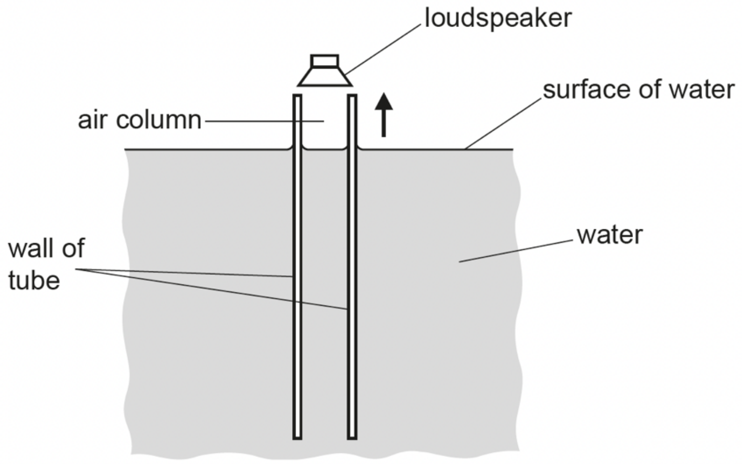


Fig. 5.1

A loudspeaker producing sound of frequency 530 Hz is positioned at the open top end of the tube as it is raised. The water surface inside the tube is always level with the water surface outside the tube. The speed of the sound in the air column in the tube is $340\,\mathrm{m\,s^{-1}}$.

(a) Describe a simple way that a student, without requiring any additional equipment, can detect when a stationary wave is formed in the air column as the tube is being raised.

....

.... [1]

(b) Determine the height of the top end of the tube above the surface of the water when a stationary wave is first produced in the tube. Assume that an antinode is formed level with the top of the tube.

height = ... m [3]

(c) Determine the distance moved by the tube between the positions at which the first and second stationary waves are formed.

distance = ... m [1]

[Total: 5]

Q9 s2022_21

A horizontal string is stretched between two fixed points A and B. A vibrator is used to oscillate the string and produce an observable stationary wave.

At one instant, the moving string is straight, as shown in Fig. 5.1.

Fig. 5.1

The dots in the diagram represent the positions of the nodes on the string. Point P on the string is moving downwards.

The wave on the string has a speed of $35\,m\,s^{-1}$ and a period of 0.040 s.

(a) Explain how the stationary wave is formed on the string.

....

....

....

.... [2]

(b) On Fig. 5.1, sketch a line to show a possible position of the string a quarter of a cycle later than the position shown in the diagram. [1]

(c) Determine the horizontal distance from A to B.

distance = ... m [3]

(d) A particle on the string has zero displacement at time $t = 0$. From time $t = 0$ to time $t = 0.060\,\text{s}$, the particle moves through a total distance of 72 mm.

Calculate the amplitude of oscillation of the particle.

amplitude = ... mm [2]

[Total: 8]

Q10 w2022_23

(a) A progressive longitudinal wave travels through a medium from left to right. Fig. 4.1 shows the positions of some of the particles of the medium at time t_0 and a graph showing the particle displacements at the same time t_0.

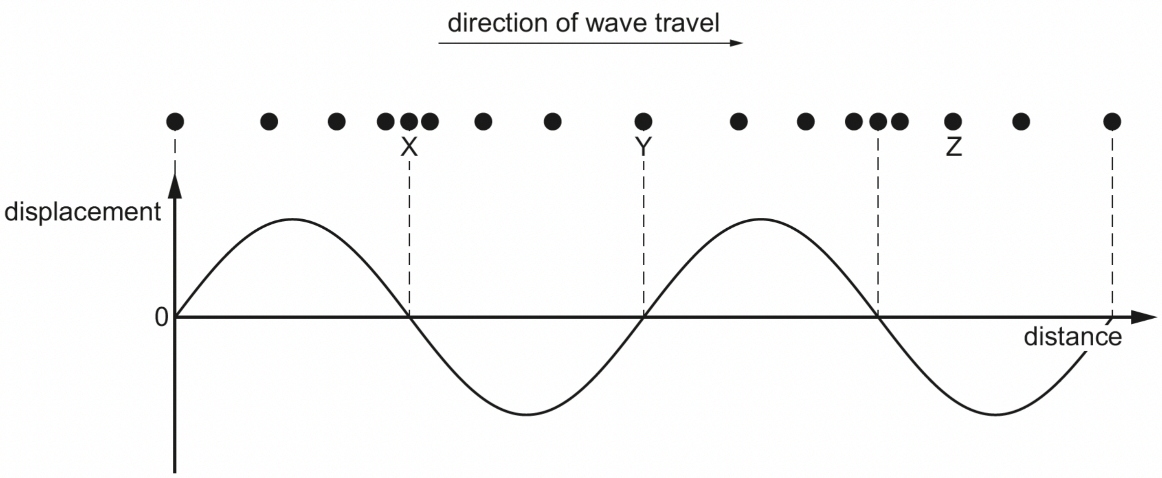


Fig. 4.1

Particle displacements to the right of their equilibrium positions are shown as positive on the graph and particle displacements to the left are shown as negative on the graph.

The period of the wave is T.

(i) On Fig. 4.1, draw circles around two particles which are exactly one wavelength apart. [1]

(ii) On Fig. 4.1, sketch a line on the graph to represent the displacements of the particles for the longitudinal wave at time $t_0 + \frac{T}{4}$. [3]

(iii) State the direction of motion of particle Z at time $t_0 + \frac{T}{4}$.

.... [1]

(b) The frequency of the wave in **(a)** is 16 kHz. The distance between particles X and Y is 0.19 m.

Calculate the speed of the wave as it travels through the medium.

speed = ... $m\,s^{-1}$ [3]

(c) A longitudinal sound wave is travelling through a solid. The initial intensity of the wave is I_0. The frequency of the wave remains constant and the amplitude falls to half of its original value.

Determine, in terms of I_0, the final intensity of the wave.

intensity = ... I_0 [2]

(d) The sound wave in **(c)** now meets another sound wave travelling in the opposite direction.

(i) State a condition necessary for these two waves to form a stationary wave.

.... [1]

(ii) State **two** ways in which a stationary wave differs from a progressive wave.

1 ....

....

2 ....

....

[2]

[Total: 13]

Simple Superposition – Exam Questions

Q1 s2018_21

(a) For a progressive wave, state what is meant by

(i) the *period*,

....

....[1]

(ii) the *wavelength*.

....

....[1]

(b) Fig. 4.1 shows the variation with time *t* of the displacement *x* of two progressive waves P and Q passing the same point.

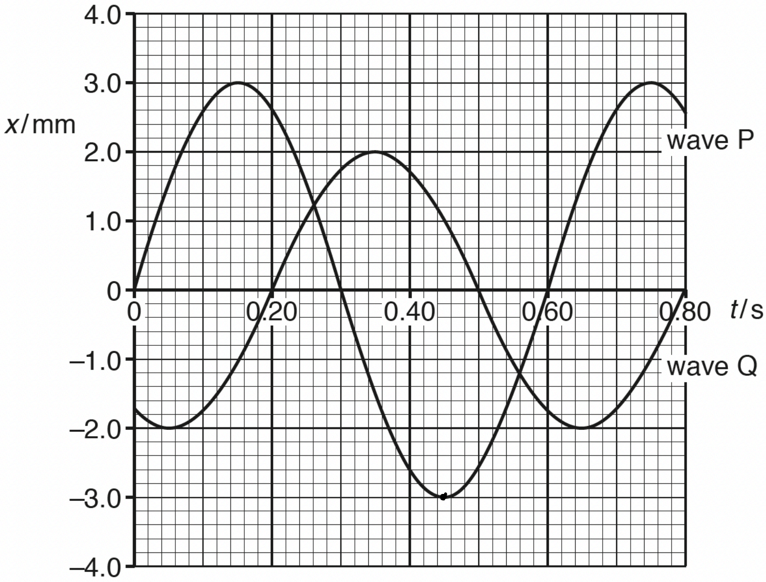


Fig. 4.1

The speed of the waves is $20\,cm\,s^{-1}$.

(i) Calculate the wavelength of the waves.

wavelength = ... cm [2]

(ii) Determine the phase difference between the two waves.

phase difference = ... ° [1]

(iii) Calculate the ratio

$$\frac{\text{intensity of wave Q}}{\text{intensity of wave P}}.$$

ratio = ... [2]

(iv) The two waves superpose as they pass the same point. Use Fig. 4.1 to determine the resultant displacement at time $t = 0.45\,s$.

displacement = ... mm [1]

[Total: 8]

Q2 s2020_23

Two progressive sound waves Y and Z meet at a fixed point P. The variation with time t of the displacement x of each wave at point P is shown in Fig. 4.1.

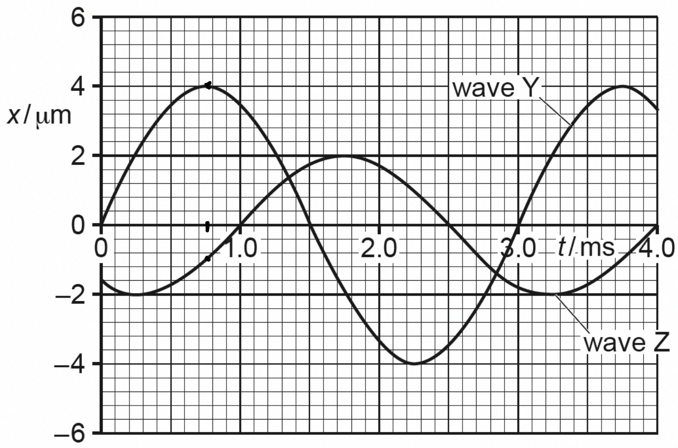


Fig. 4.1

(a) Use Fig. 4.1 to state **one** quantity of waves Y and Z that is:

(i) the same

.... [1]

(ii) different.

.... [1]

(b) State and explain whether waves Y and Z are coherent.

....

.... [1]

(c) Determine the phase difference between the waves.

phase difference = ... ° [1]

(d) The two waves superpose at P. Use Fig. 4.1 to determine the resultant displacement at time t = 0.75 ms.

resultant displacement = ... μm [1]

(e) The intensity of wave Y at point P is I.

Determine, in terms of I, the intensity of wave Z.

intensity = ... [2]

(f) The speed of wave Z is $330\,m\,s^{-1}$.

Determine the wavelength of wave Z.

wavelength = ... m [3]

[Total: 10]

Q3 w2020_21

A progressive wave Y passes a point P. The variation with time t of the displacement x for the wave at P is shown in Fig. 5.1.

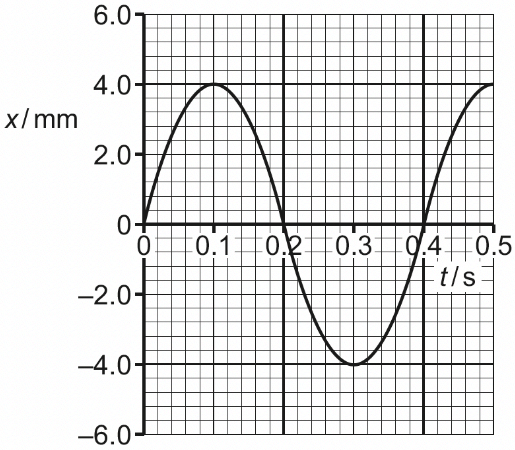


Fig. 5.1

The wave has a wavelength of 8.0 cm.

(a) Determine the speed of the wave.

speed = ... m s^{-1} [2]

(b) A second wave Z has wavelength 8.0 cm and amplitude 2.0 mm at point P. Waves Y and Z have the same speed.

For the waves at point P, calculate the ratio

$$\frac{\text{intensity of wave Z}}{\text{intensity of wave Y}}.$$

ratio = ... [3]

[Total: 5]

Doppler Effect –Exam Questions

Q1 w2021_21

(a) By reference to the direction of transfer of energy, state what is meant by a *longitudinal* wave.

....

.... [1]

(b) A vehicle travels at constant speed around a wide circular track. It continuously sounds its horn, which emits a single note of frequency 1.2 kHz. An observer is a large distance away from the track, as shown in the view from above in Fig. 4.1.

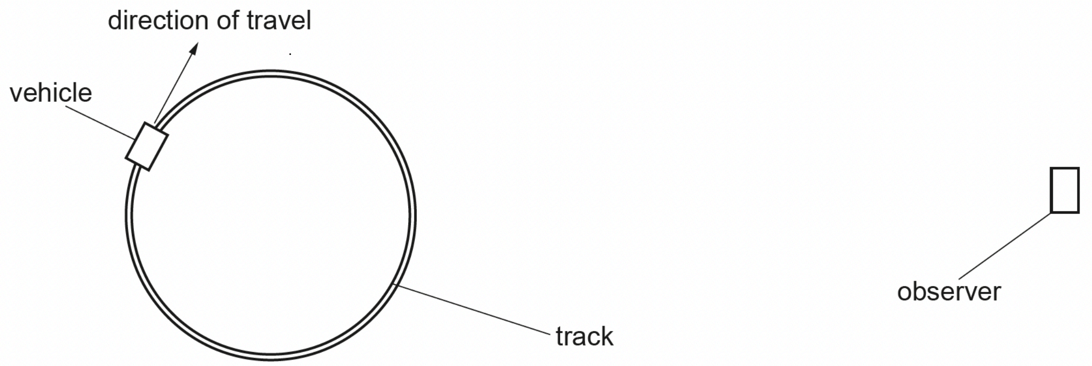


Fig. 4.1 (not to scale)

Fig. 4.2 shows the variation with time of the frequency f of the sound of the horn that is detected by the observer. The time taken for the vehicle to travel once around the track is T.

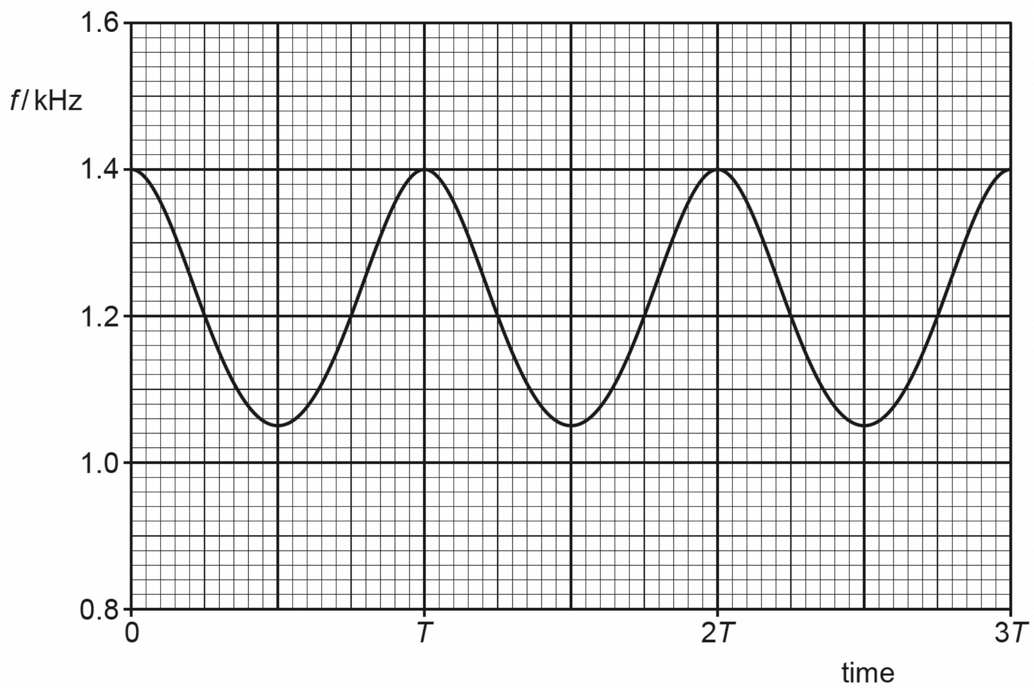


Fig. 4.2

(i) Explain why the frequency of the sound detected by the observer is sometimes above and sometimes below 1.2 kHz.

....

....

....

.... [2]

(ii) State the name of the phenomenon in **(b)(i)**.

.... [1]

(iii) On Fig. 4.1, mark with a letter X the position of the vehicle when it emitted the sound that is detected at time T. [1]

(iv) On Fig. 4.1, mark with a letter Y the position of the vehicle when it emitted the sound that is detected at time $\frac{9T}{4}$. [1]

(c) The speed of the sound in the air is $320\,\mathrm{m\,s^{-1}}$.

Use Fig. 4.2 to determine the speed of the vehicle in **(b)**.

speed = ... $\mathrm{m\,s^{-1}}$ [3]

[Total: 9]

Q2 w2021_22

A child sits on the ground next to a remote-controlled toy car. At time $t = 0$, the car begins to move in a straight line directly away from the child. The variation with time t of the velocity of the car along this line is shown in Fig. 4.1.

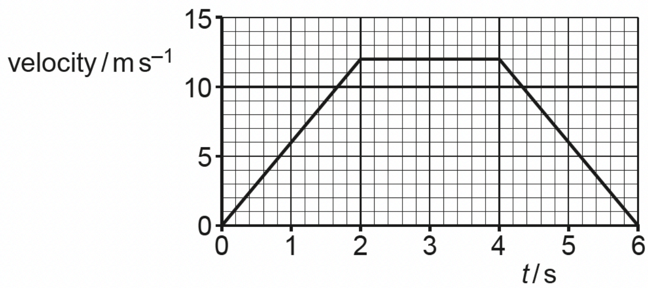


Fig. 4.1

The car's horn continually emits sound of frequency 925 Hz between time $t = 0$ and time $t = 6.0$ s. The speed of the sound in the air is 338 m s^{-1}.

(a) Describe qualitatively the variation, if any, in the frequency of the sound heard, by the child, that was emitted from the car horn:

(i) from time $t = 0$ to time $t = 2.0$ s

.... [1]

(ii) from time $t = 4.0$ s to time $t = 6.0$ s.

.... [1]

(b) Determine the frequency, to three significant figures, of the sound heard, by the child, that was emitted from the car horn at time $t = 3.0$ s.

frequency = ... Hz [2]

(c) Determine the time taken for the sound emitted at time $t = 4.0\,\text{s}$ to travel to the child.

time taken = ... s [2]

[Total: 6]

Q3 s2018_22

A child on a sledge slides down a steep hill and then travels in a straight line up an ice-covered slope, as illustrated in Fig. 3.1.

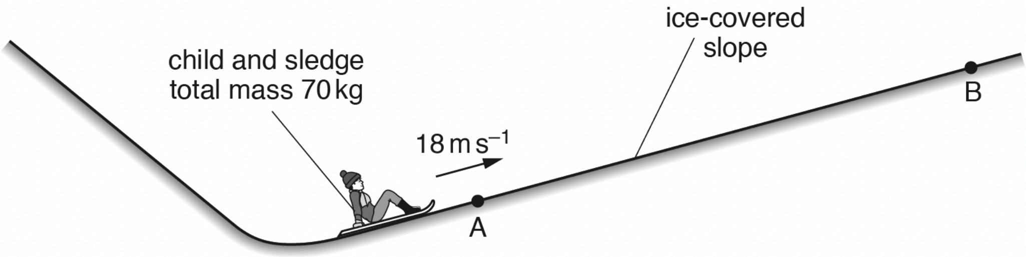


Fig. 3.1 (not to scale)

The sledge passes point A with speed 18 m s^{-1} at time $t = 0$ and then comes to rest at point B. The child applies a brake to the sledge at point B. The brake does not keep the sledge stationary and it immediately slides back down the slope towards A.

The variation with time t of the velocity v of the sledge from $t = 0$ to $t = 24$ s is shown in Fig. 3.2.

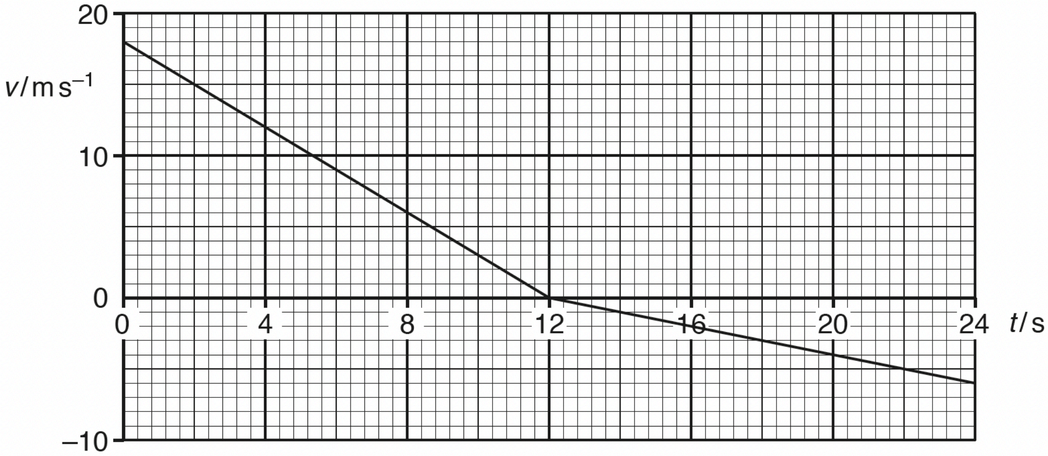


Fig. 3.2

(a) State the time taken for the sledge to travel from A to B.

time = ... s [1]

(b) Determine the displacement of the sledge up the slope from point A at time $t = 24$ s.

displacement = ...m [3]

(c) Show that the acceleration of the sledge as it moves from B back towards A is $0.50\,m\,s^{-2}$.

[2]

(d) The child and sledge have a total mass of 70 kg. The component of the total weight of the child and sledge that acts down the slope is 80 N.

Determine

(i) the frictional force on the sledge as it moves from B towards A,

frictional force = ... N [2]

(ii) the angle θ of the slope to the horizontal.

θ = ... ° [2]

(e) The child on the sledge blows a whistle between $t = 4.0\,s$ and $t = 8.0\,s$. The whistle emits sound of frequency 900 Hz. The speed of the sound in the air is $340\,m\,s^{-1}$. A man standing at point A hears the sound.

Use Fig. 3.2 to

(i) determine the initial frequency of the sound heard by the man,

initial frequency = ... Hz [2]

(ii) describe and explain qualitatively the variation, if any, in the frequency of the sound heard by the man.

....

....[1]

[Total: 13]

Q4 w2019_21

A small remote-controlled model aircraft has two propellers, each of diameter 16 cm.
Fig. 3.1 is a side view of the aircraft when hovering.

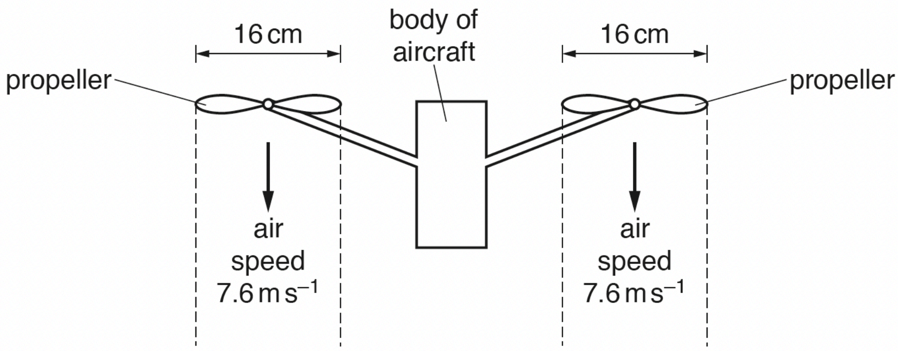


Fig. 3.1

Air is propelled vertically downwards by each propeller so that the aircraft hovers at a fixed position. The density of the air is $1.2\,\mathrm{kg\,m^{-3}}$. Assume that the air from each propeller moves with a constant speed of $7.6\,\mathrm{m\,s^{-1}}$ in a uniform cylinder of diameter 16 cm. Also assume that the air above each propeller is stationary.

(a) Show that, in a time interval of 3.0 s, the mass of air propelled downwards by **one** propeller is 0.55 kg.

[3]

(b) Calculate:

(i) the increase in momentum of the mass of air in **(a)**

increase in momentum = ... N s [1]

(ii) the downward force exerted on this mass of air by the propeller.

force = ... N [1]

(c) State:

(i) the upward force acting on **one** propeller

force = ... N [1]

(ii) the name of the law that explains the relationship between the force in **(b)(ii)** and the force in **(c)(i)**.

.... [1]

(d) Determine the mass of the aircraft.

mass = ... kg [1]

(e) In order for the aircraft to hover at a very high altitude (height), the propellers must propel the air downwards with a greater speed than when the aircraft hovers at a low altitude. Suggest the reason for this.

....

.... [1]

(f) When the aircraft is hovering at a high altitude, an electric fault causes the propellers to stop rotating. The aircraft falls vertically downwards. When the aircraft reaches a constant speed of $22\,m\,s^{-1}$, it emits sound of frequency 3.0 kHz from an alarm. The speed of the sound in the air is $340\,m\,s^{-1}$.

Determine the frequency of the sound heard by a person standing vertically below the falling aircraft.

frequency = ... Hz [2]

[Total: 11]

Q5 w2021_23

(a) Define *velocity*.

....

.... [1]

(b) A remote-controlled toy aircraft is flying horizontally in a wind. Fig. 3.1 shows the velocity vectors, to scale, of the wind and of the aircraft in still air.

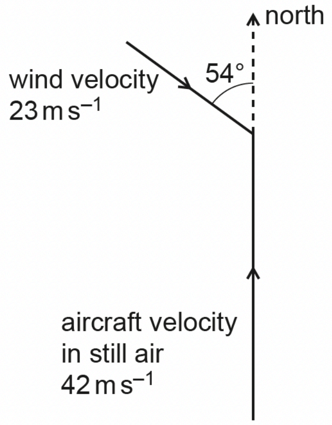


Fig. 3.1

The velocity of the aircraft in still air is 42 m s^{-1} to the north. The velocity of the wind is 23 m s^{-1} in a direction of 54° east of south.

Determine the magnitude of the resultant velocity of the aircraft.

magnitude of velocity = ... m s^{-1} [2]

(c) The engine of the aircraft in **(b)** stops. The aircraft then glides towards the ground with a constant velocity at an angle θ to the horizontal, as illustrated in Fig. 3.2.

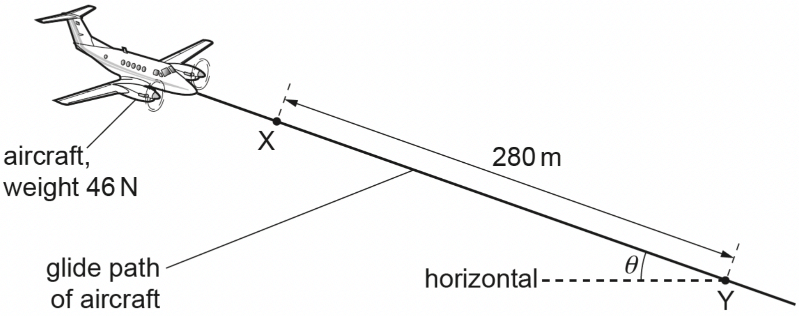


Fig. 3.2 (not to scale)

The aircraft has a weight of 46 N and travels a distance of 280 m from point X to point Y. The change in gravitational potential energy of the aircraft for its movement from X to Y is 6100 J.

Assume that there is now no wind.

(i) Calculate angle θ.

θ = ... ° [3]

(ii) Calculate the magnitude of the force acting on the aircraft due to air resistance.

force = ... N [2]

(d) The aircraft in **(c)** travels from X to Y in a time of 14 s. Fig. 3.3 shows that, as the aircraft travels from X to Y, it moves directly towards an observer who is standing on the ground.

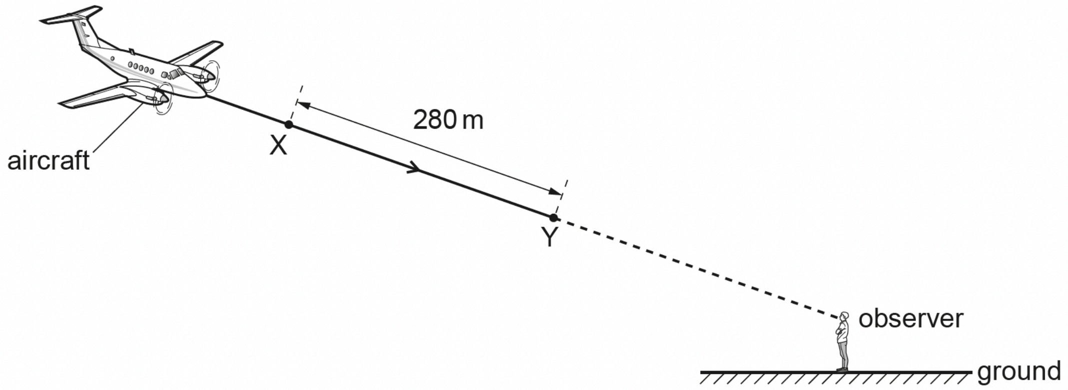


Fig. 3.3 (not to scale)

The aircraft emits sound as it travels from X to Y. The observer hears sound of frequency 450 Hz. The speed of the sound in the air is $340\,\text{m}\,\text{s}^{-1}$.

Calculate the frequency of the sound that is emitted by the aircraft.

frequency = ... Hz [3]

[Total: 11]