Advanced Higher

WAVE PHENOMENA

Waves

1. State that in wave motion energy is transferred with no net mass transport.
2. State that the intensity of a wave is directly proportional to $(\text{amplitude})^2$.
3. State that the sine or cosine variation is the simplest mathematical form of a wave.
4. State that all waveforms can be described by the superposition of sine or cosine waves.
5. Explain that the relationship $y = a \sin 2\pi(ft - \frac{x}{\lambda})$, represents a travelling wave.
6. Carry out calculations on travelling waves using the above relationship.
7. Explain the meaning of phase difference.
8. Explain what is meant by a stationary wave.
9. Define the terms 'node' and 'antinode'.
10. State that the Doppler effect is the change in frequency observed when a source of sound waves is moving relative to an observer.
11. Derive the expression for the apparent frequency detected when a source of sound waves moves relative to a stationary observer.
12. Derive the expression for the apparent frequency detected when an observer moves relative to a stationary source of sound waves.
13. Carry out calculations using the above relationships.

NOTES

- **State that in wave motion, energy is transferred with no net mass transport.**
- **State that the intensity of a wave is directly proportional to (amplitude)^2.**

- **State that the sine and cosine variation is the simplest mathematical form of a wave.**
- **State that all waveforms can be described by the superposition of sine or cosine waves.**
- **Explain that this relationship represents a travelling wave: $y = a \sin 2\pi(ft - x/\lambda)$.**

- **Explain the meaning of phase difference.**
- **Explain what is meant by a stationary wave.**
- **Define the terms 'node' and 'antinode'.**

- **State that the Doppler effect is the change in frequency observed when a source of sound waves is moving relative to an observer.**
- **Derive the expression for the apparent frequency detected when a source of sound waves moves relative to a stationary observer.**
- **Derive the expression for the apparent frequency detected when an observer moves relative to a stationary source of sound waves.**

- **State that in wave motion, energy is transferred with no net mass transport.**

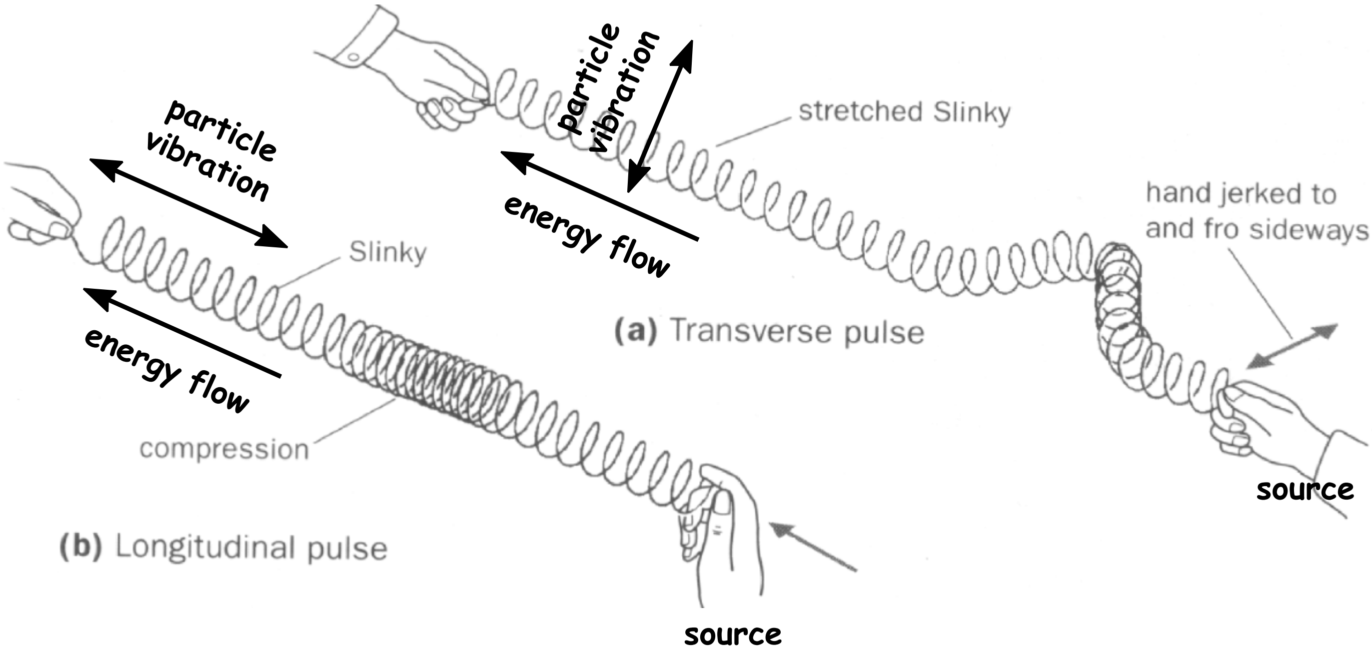
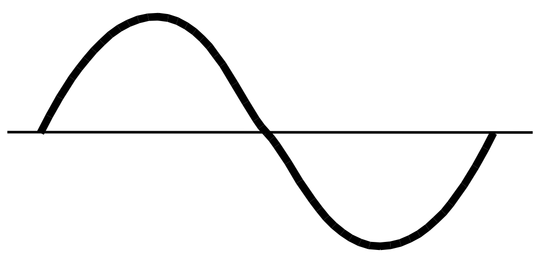
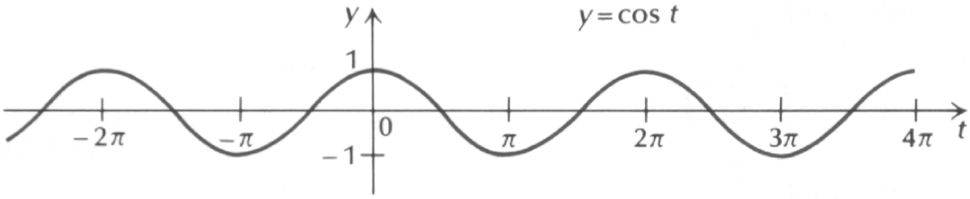


Diagram adapted from "ADVANCED PHYSICS, FOURTH EDITION" by Tom Duncan, page 330, ISBN 0-7195-5199-4.

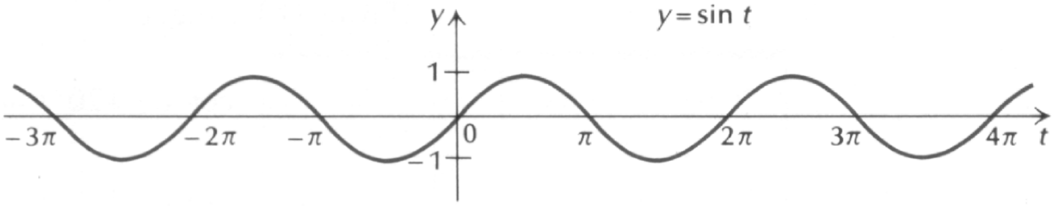
- **State that the intensity of a wave is directly proportional to $(\text{amplitude})^2$.**



- **State that the sine and cosine variation is the simplest mathematical form of a wave.**



The cosine function

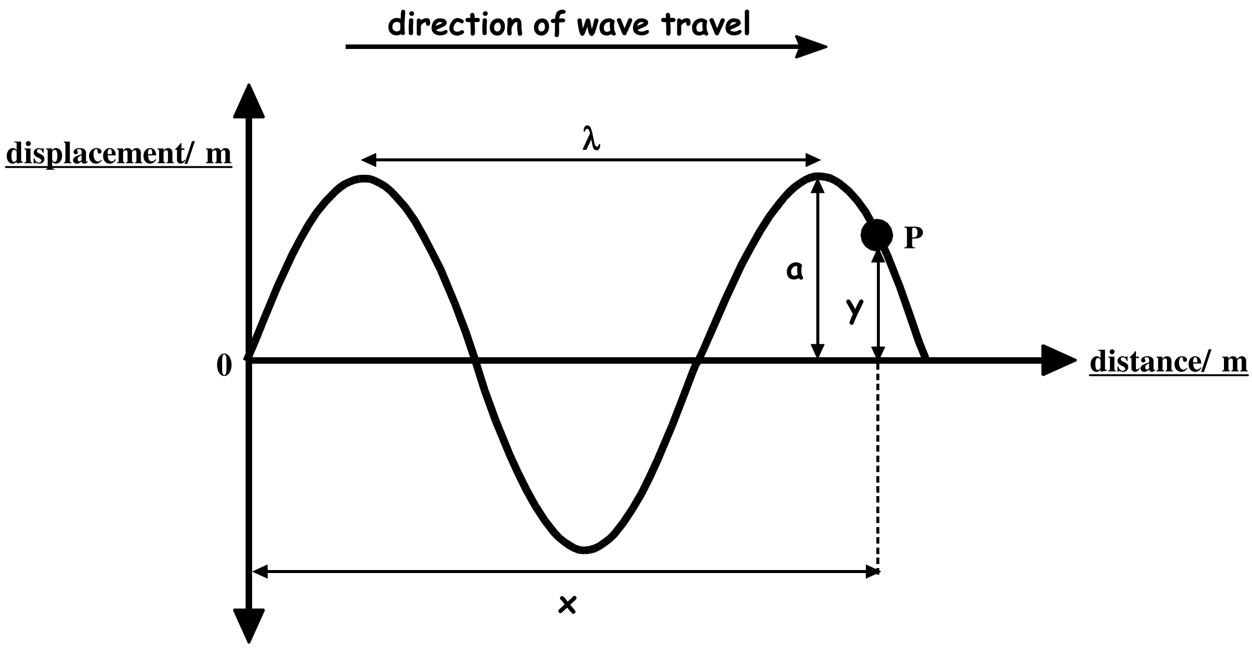


The sine function

Diagram taken from "CALCULUS, FOURTH EDITION" by Marvin L. Bittinger, page 496, ISBN 0-201-12216-2.

- **State that all waveforms can be described by the superposition of sine or cosine waves.**

- **Explain that this relationship represents a travelling wave: $y = a \sin 2\pi(ft - x/\lambda)$.**



$$y = a \sin 2\pi(ft - x/\lambda)$$

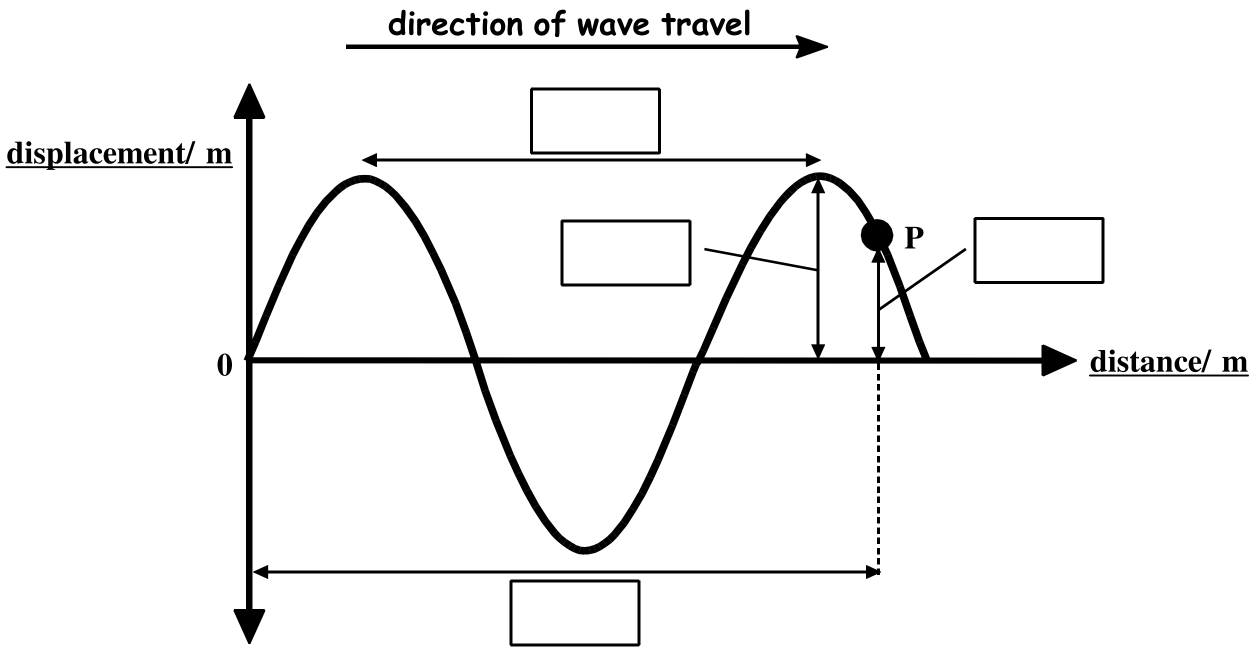
You should also know the wave equations:

$$v = f\lambda \qquad\qquad f = 1/T$$

- **Carry out calculations on travelling waves using the relationship y = a sin2π(ft - x/λ).**

1) The travelling wave shown below is represented by this equation, where all distances are in metres:

$$0.05 = 0.08 \sin 2\pi(5t - 0.25/0.15)$$

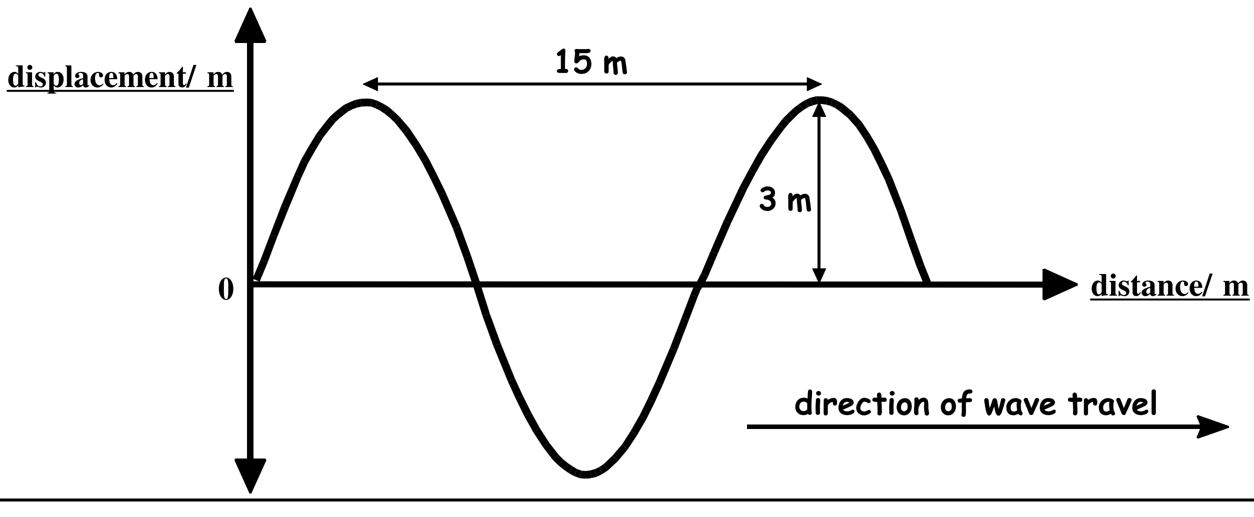


(a) Fill in the **4 numerical values** on the diagram.

(b) Calculate the **speed** of the wave.

2) (a) Write an **expression** to describe the travelling wave shown below, which has a frequency of 0.25 Hz.

(b) Calculate the **wave speed**.



3) (a) This equation represents a travelling wave:

$$y = a \sin 2\pi(ft - x/\lambda)$$

What quantities do the symbols **y**, **a**, **f** and **λ** represent?

(b) (i) State the numerical values for the **frequency** and **wavelength** of the travelling wave represented by the equation below.

(ii) Hence, calculate the **wave speed**.

$$y = 0.1 \sin 2\pi(3t - x/0.2)$$

4) A loudspeaker emits a travelling sound wave of frequency 1 100 Hz. The wave has an amplitude of 3.0×10^{-4} m and travels through the air at 340 m s^{-1}.

(a) Calculate the **wavelength** of the sound wave.

(b) Write an **equation**, with appropriate numerical values, to represent the travelling sound wave.

5) Write an **equation**, with appropriate numerical values, to represent a sound wave travelling at 320 m s^{-1} which has an amplitude of 2.0×10^{-4} m and a frequency of 250 Hz.

6) A travelling wave has a speed of 6 m s^{-1}, an amplitude of 0.3 m and a wavelength of 12m.

(a) Calculate the **frequency** of the travelling wave.

(b) Write an **equation**, with appropriate numerical values, to represent the travelling wave.

7) Using appropriate numerical values, write an **equation** to represent a wave of amplitude 0.5 m and wavelength 0.2 m which travels to the **left** along a rope at 2.4 m s^{-1}.

8) A travelling wave is represented by the expression

$$y = 0.005 \sin 2\pi(12t - x/3)$$

(a) Find values for the wave's **frequency**, **wavelength** and **speed**.

(b) Write an **expression** to represent another travelling wave which travels in the **opposite direction** at the **same speed** as the wave above but which has **five times the amplitude** and **twice the frequency**.

9) The equation for a travelling wave is given below:

$$y = 0.5 \sin 2\pi(0.4t - x/12)$$

Calculate the **displacement** (**y**) of a particle from its equilibrium position 2.5 s after the energy has left the source (origin) if the distance between the source and particle's equilibrium position is 7 m.

[The angle $2\pi(ft - x/\lambda)$ is expressed in radians.]

10) This equation represents a travelling wave:

$$y = 0.2 \sin(4\pi t - 0.1x)$$

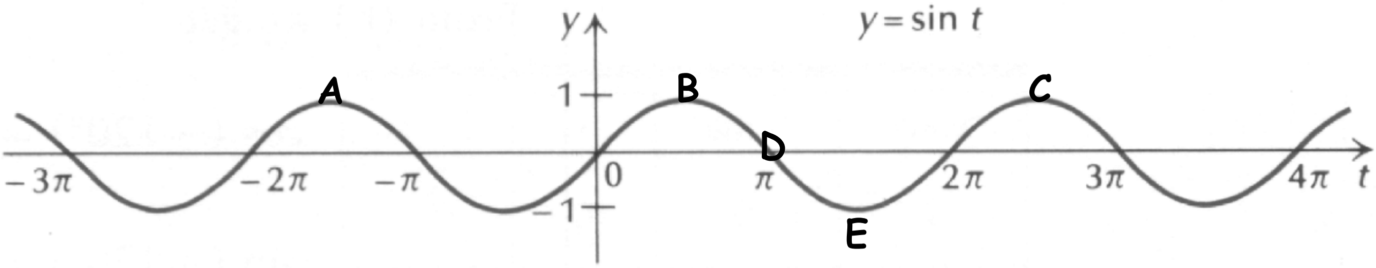
(a) Rewrite the equation in a more familiar form.

(b) Determine the wave's **amplitude**, **frequency**, **wavelength** and **speed**.

(c) Calculate the **displacement** (**y**) of a particle from its equilibrium position 0.3 s after the energy has left the source (origin) if the distance between the source and particle's equilibrium position is 25 m.

[The angle $2\pi(ft - x/\lambda)$ is expressed in radians.]

- **Explain the meaning of phase difference.**



The sine function

Diagrams adapted from "CALCULUS, FOURTH EDITION" by Marvin L. Bittinger, page 496, ISBN 0-201-12216-2.

11) The wave diagram below represents a wave travelling to the right. On the diagram:

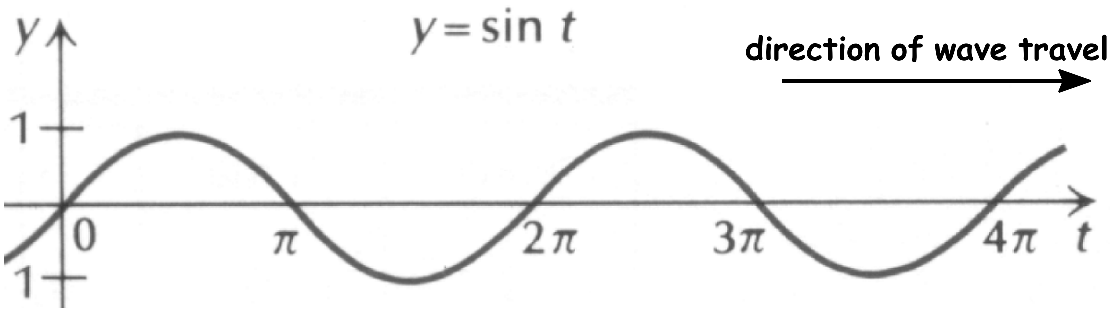
(a) Use the letters **A** and **B** to show 2 points which are **<u>in phase</u>**.

(b) Use the letters **C** and **D** to show 2 points which are **<u>exactly out of phase</u>**.

(c) Use the letters **E** and **F** to show 2 points which are **<u>out of phase by λ/4</u>**.

(d) Use the letters **G** and **H** to show 2 points which are **<u>out of phase by π/4 radians</u>**.

(e) Draw (using a **dashed line**) a wave of **identical amplitude and wavelength** which moves **<u>90º</u>** (**<u>π/2 radians</u>**) **<u>behind</u>** the wave shown.



12) (a) Write down the equation for the **"phase difference"** between 2 points on a travelling wave. Define all the symbols used.

(b) Calculate the **"phase difference"** in **radians** between the 2 specified points on the travelling waves whose wavelength is given:

- **λ = 0.25 m;**
- **distance between origin and equilibrium position of point A = 0.20 m;**
- **distance between origin and equilibrium position of point B = 0.35 m.**

- **λ = 2.5 m;**
- **distance between origin and equilibrium position of point X = 2.25 m;**
- **distance between origin and equilibrium position of point Y = 2.50 m.**

13) This equation represents a travelling wave. All distances are in metres. Time is in seconds:

$$y = 3 \sin 2\pi(5t - x/1.6)$$

(a) State the **wavelength** of the travelling wave.

(b) The distance between the equilibrium position of 2 points on the wave is 2.4 m. Calculate the **phase difference** (in **radians**) between these 2 points.

(c) Another 2 points on the wave are described as being **"in phase"**. Suggest a possible value for the **horizontal distance** between these 2 points. Explain your answer.

14) The equation of a travelling wave is shown below. All distances are in metres Time is in seconds.

$$y = 4 \sin 2\pi(12t - 0.25x)$$

(a) Rewrite the equation in a more familiar form.

(b) State the **wavelength** of the wave.

(c) Calculate the **phase difference** (in **radians**) between the point at x = 3.0 m and x = 5.0 m.

(d) Calculate the **time** the wave will take to travel between these 2 points.

15) State the **differences** between a "**travelling wave**" and a "**stationary wave**".

16) (a) Describe how a "**stationary wave**" is formed.

(b) Sketch and label part of a "**stationary wave**", showing at least **3** "**nodes**".

(c) (i) What is a "**node**"? (ii) What causes the formation of "**nodes**"?

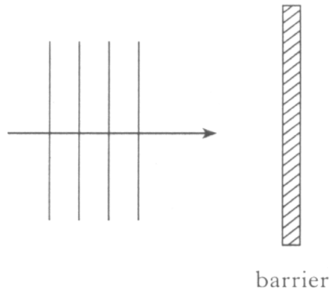
(d) (i) What is an "**antinode**"? (ii) What causes the formation of "**antinodes**"?

(e) Two adjacent (neighbouring) "**nodes**" on a "**stationary wave**" are separated by a distance of 0.16 m.
State the **wavelength** of the two "**travelling waves**" which form the "**stationary wave**".
Explain your answer.

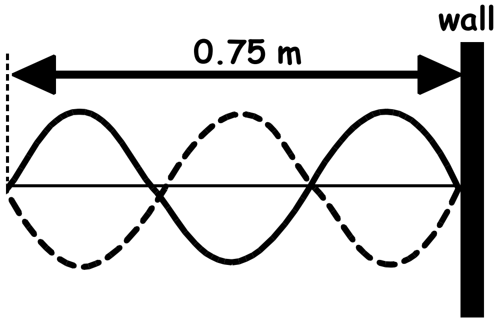
17) Plane travelling waves are incident at right-angles to a plane barrier so that the reflected waves pass through the incident waves.

In the region where the incident and reflected waves overlap, it is noticed that the waves are **more closely spaced**, are **not moving along** and have **increased amplitude**.

Explain each of these 3 observations.



18) A "**travelling wave**" approaches a wall at 0.90 m s^{-1}.
The wave is reflected, forming a "**stationary wave**", as shown in the diagram.



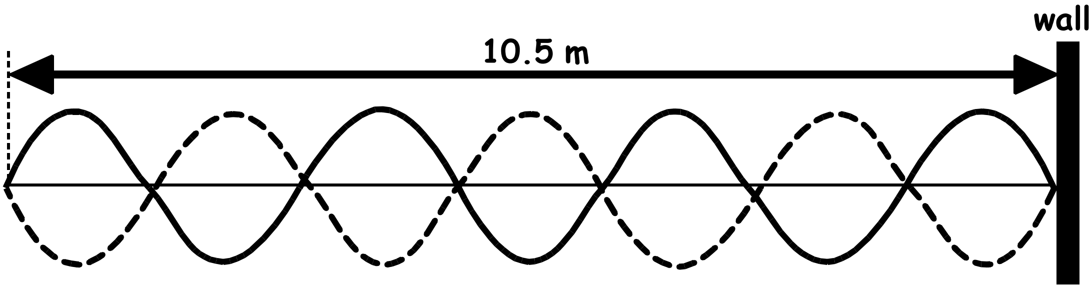
(a) State the **speed** of the reflected wave.

(b) How does the **phase** of the reflected wave compare with the **phase** of the incident (incoming) wave?

(c) Use the diagram to determine the **wavelength** of the "**travelling wave**" which approaches the wall.

(d) Calculate the **frequency** of the "**travelling wave**" which approaches the wall.

19) The diagram shows the "**stationary wave**" set up when a skipping rope is fixed to a wall and the free end is shaken up and down with a frequency of 1.5 Hz.

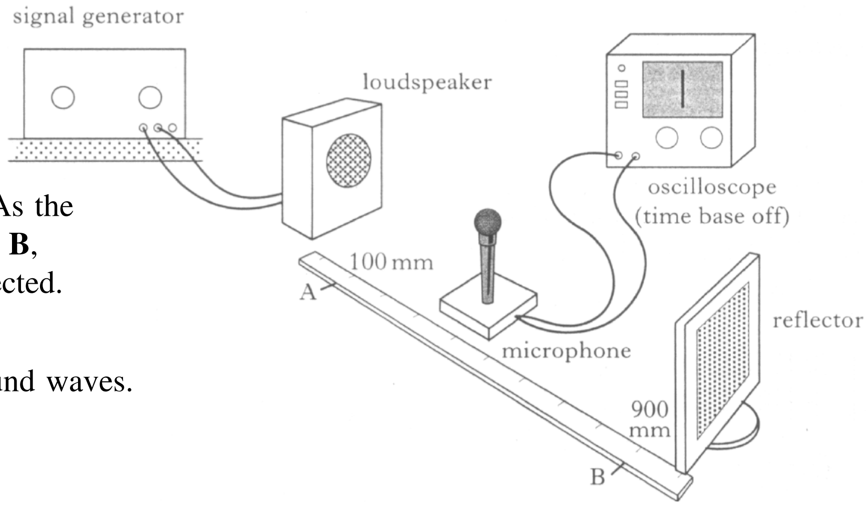


(a) Determine the **horizontal distance** between neighbouring **nodes**.

(b) Determine the **wavelength** of the "**travelling wave**" which approaches the wall.

(c) Calculate the **speed** of the "**travelling wave**" which approaches the wall.

20) The apparatus shown is used to determine the **wavelength** and **speed** of sound in air.



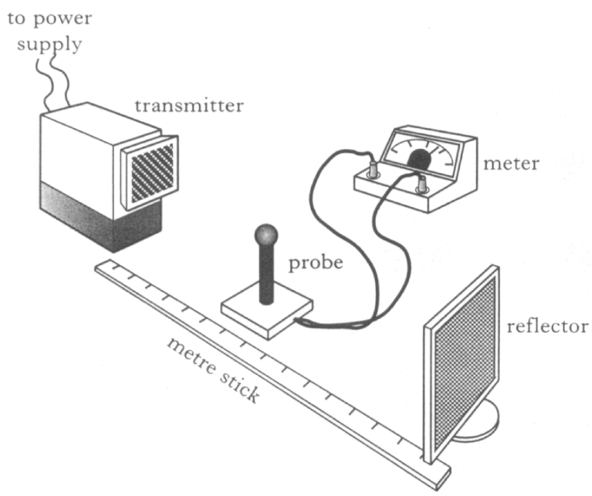
Minima are detected at **A** and **B**. As the microphone is moved from **A** to **B**, **seven additional minima** are detected.

(a) Calculate the **wavelength** of the sound waves.
(A **diagram** will help you!)

(b) If the **frequency** of the signal generator is 1 700 Hz, calculate the **speed** of the sound waves in air.

(c) State one change which could be made to the apparatus to **decrease** the separation of the **mimima**.

21) The diagram shows a **"stationary wave"** experiment using **microwaves**. Waves sent out by the transmitter are reflected by the reflector, with **nodes** and **antinodes** being detected by the probe and meter.



(a) Describe how you would use the apparatus to determine the **wavelength** of the **microwaves**.

(b) A **node** is detected when the probe is at the 21.2 cm mark on the metre stick. A further **20 nodes** are detected as the probe is moved along the metre stick, with the **last node** occurring at the 49.8 cm mark.

For these **microwaves**, calculate the **wavelength** and **frequency**.