# 2. Graphing and Analysing Waves

| | Topic | Heinemann | | |
|---|---|---|---|---|
| | | Section | Pages | Qs |
| | 2. Graphing and Analysing Waves | Displacement-Distance graphs<br>The speed of waves<br>Frequency and Period<br>Displacement-Time graphs<br>Wavelength and amplitude<br>Wave Equation | Pg 10<br>Pg 11-12<br>Pg 13<br>Pg 14<br>Pg 14-15<br>Pg 18-19 | Pg 16<br>Pg 16 2<br>Pg 16 1, 4, 5<br><br>Pg 16 3, 6, 7, 8, 9, 10<br>Pg 24 1, 2, 3, 4 |

## Graphing Waves – Displacement / Distance

These graphs show "snapshots" of a wave moving to the right.

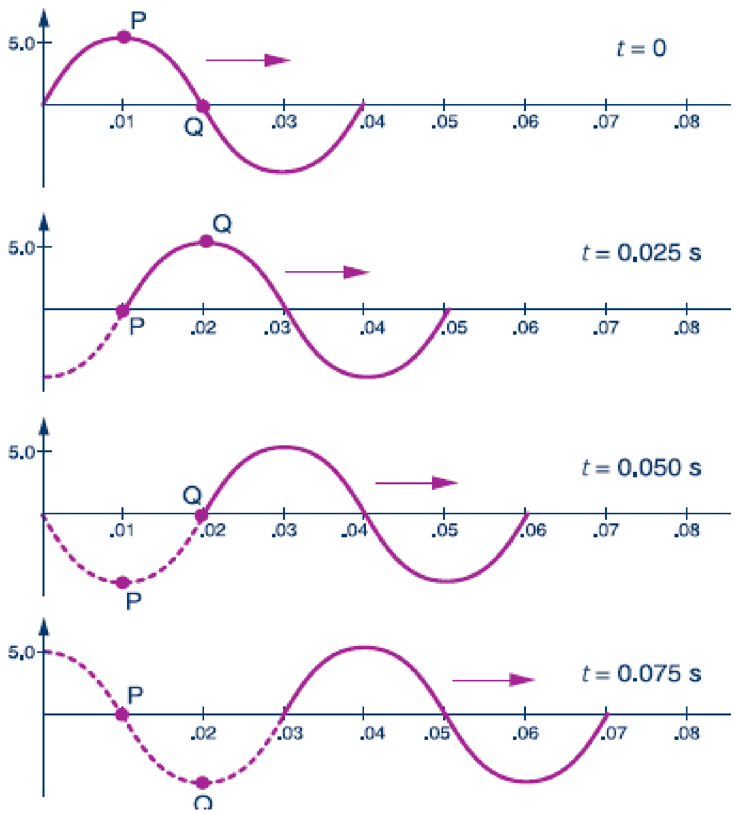
See that the points on the string P and Q are moving **up and down**, not to the right.

A continuous wave is being created, not a single pulse. This means that point P will keep moving up and down.

P begins at the highest point, the peak (5.0) and moves back to the middle (0.0) before then moving further down to the lowest point, the trough (-5.0) and finally moving back to the middle position.

Point Q follows a similar up and down motion, although it begins and ends at different positions to that of P.

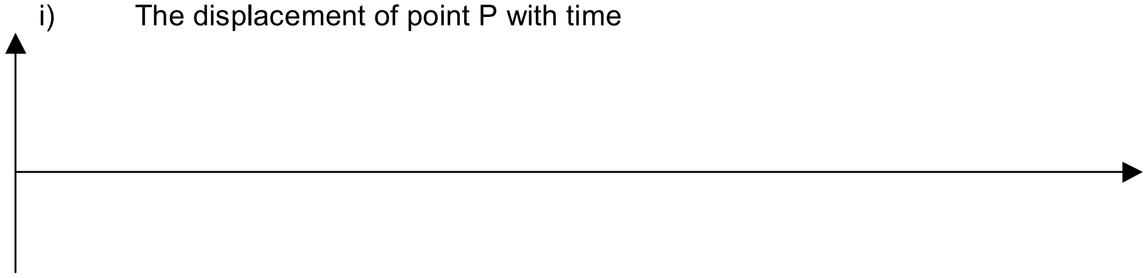
We can use these graphs to analyse the wave, such as calculating its **speed** and **length**. We can also draw other graphs.



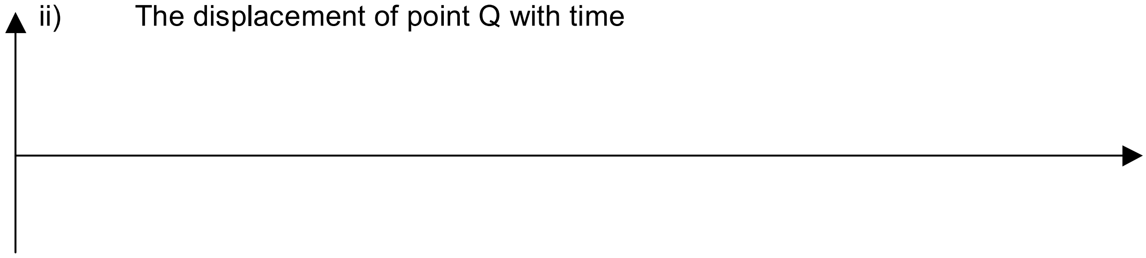

## Graphing Waves – Displacement / Time

It is possible to complete a different graph that plots the movement of an individual particle. Complete the following graphs:

i) The displacement of point P with time



ii) The displacement of point Q with time



## Describing Waves

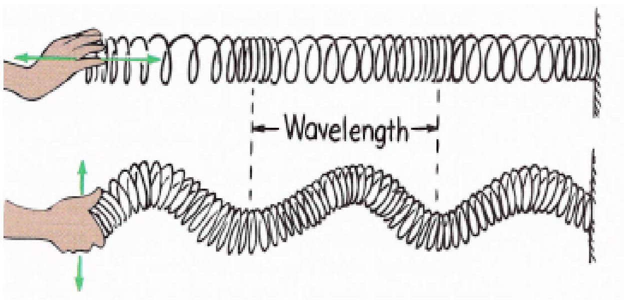
Waves can be characterised by the following: speed, amplitude, wavelength, frequency, period,

| MATERIAL | SPEED OF SOUND ($m\ s^{-1}$) |
|---|---|
| Air (0°C) | 331 |
| Air (20°C) | 343 |
| Carbon dioxide | 260 |
| Helium | 1005 |
| Water | 1440 |
| Sea water | 1560 |
| Glass | ≈4500 |
| Iron and steel | ≈5100 |

***Speed (v)***
The speed of sound in 20° air is about 330 m/s, and the speed of light in 20° air is about $3 \times 10^8$ m/s (or 300 000 km/s.)

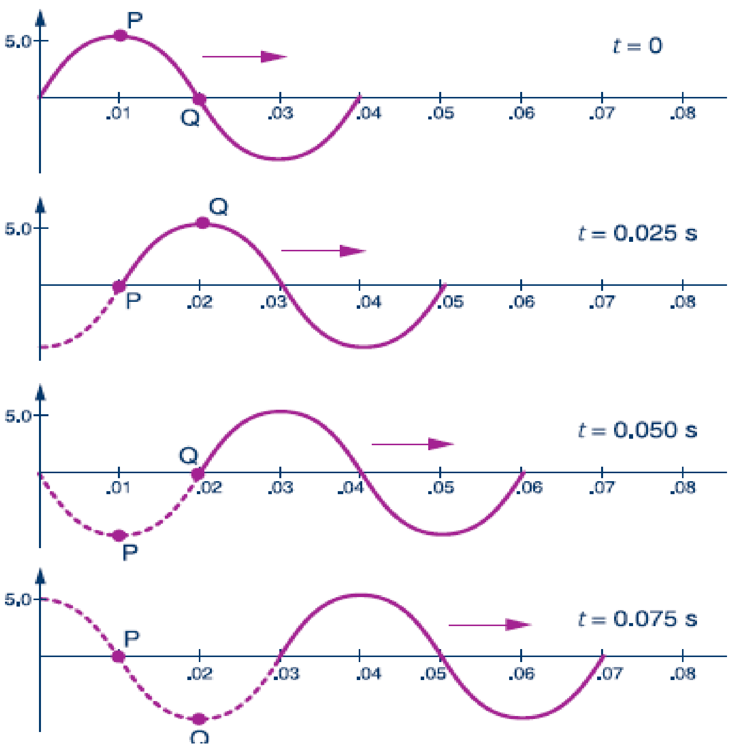
***Amplitude***
The amplitude of a wave is the distance from the rest (middle) position to the peak. The higher the amplitude of a wave, the more energy the wave is carrying.

***Wavelength(λ)***
The wavelength is the distance between two similar features of a wave, such as the distance between two compressions or between two rarefactions.
It can also be measured from a graph. Each compression is represented as the highest point (the peak), so the wavelength can be found as the distance between two peaks.




***Period (T)***
The period is the amount of time required for one full cycle of the wave to completely pass a point, or the amount of time for one point to do a complete cycle of the wave. Frequency is the measured in waves per second, or cycles per second, also called Hertz.

***Frequency (f)***
Frequency is a measure of how rapidly the source of the wave is vibrating. The frequency is defined as the number of vibrations per second. The units for frequency are Hertz, Hz, which are cycles per second.




## Questions
(Both axes are measured in metres)

**What is amplitude of the wave?**

**What is the wavelength of the wave?**

**What is the period of the wave?**

**What is the frequency of the wave?**

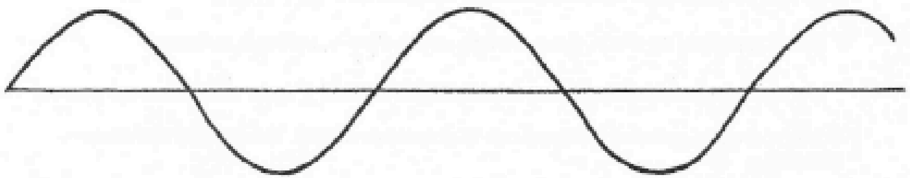
**It is possible to find the speed of this wave. Find it if you can.**

CONCEPTUAL **Physics** PRACTICE PAGE

## Chapter 19 Vibrations and Waves

### *Vibration and Wave Fundamentals*

1. A sine curve that represents a transverse wave is drawn below. With a ruler, measure the wavelength and amplitude of the wave.



a. Wavelength = ________

b. Amplitude = ________

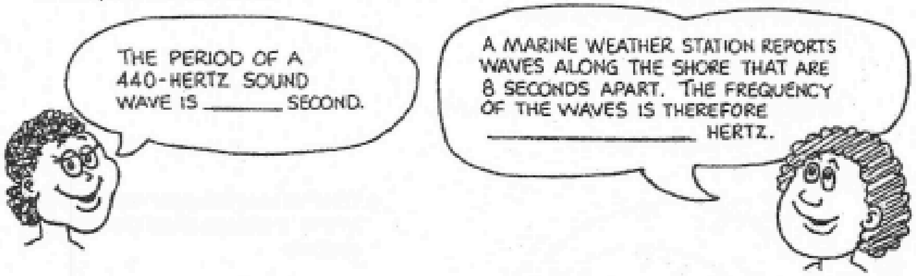
2. A kid on a playground swing makes a complete to-and-fro swing each 2 seconds. The frequency of swing is

[0.5 hertz] [1 hertz] [2 hertz]

and the period is

[0.5 seconds] [1 second] [2 seconds].

3. *Complete the statements*:



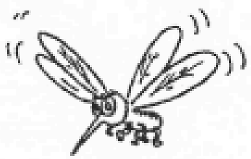

4. The annoying sound from a mosquito is produced when it beats its wings at the average rate of 600 wing beats per second.

a. What is the frequency of the sound waves?

________

b. What is the wavelength?
(Assume the speed of sound is 340 m/s.)

________



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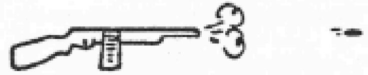
## Chapter 19 Vibrations and Waves

### *Vibration and Wave Fundamentals—continued*



5. A machine gun fires 10 rounds per second. The speed of the bullets is 300 m/s.

a. What is the distance in the air between the flying bullets? ________

b. What happens to the distance between the bullets if the rate of fire is increased?

________

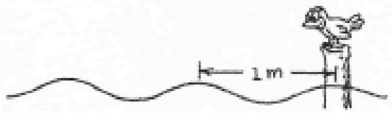
6. Consider a wave generator that produces 10 pulses per second. The speed of the waves is 300 cm/s.

a. What is the wavelength of the waves? ________

b. What happens to the wavelength if the frequency of pulses is increased?

________

7. The bird at the right watches the waves. If the portion of a wave between 2 crests passes the pole each second,




a. what is the speed of the waves? ________

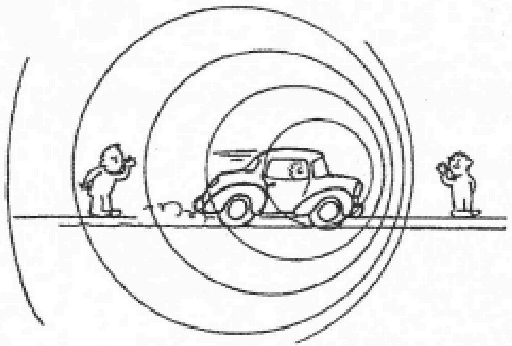
b. what is the period of wave motion? ________

c. If the distance between crests were 1.5 meters apart, and 2 crests pass the pole each second, what would be the speed of the wave?

________

d. What would the period of wave motion be for 7.c ?

________



8. When an automobile moves toward a listener, the sound of its horn seems relatively

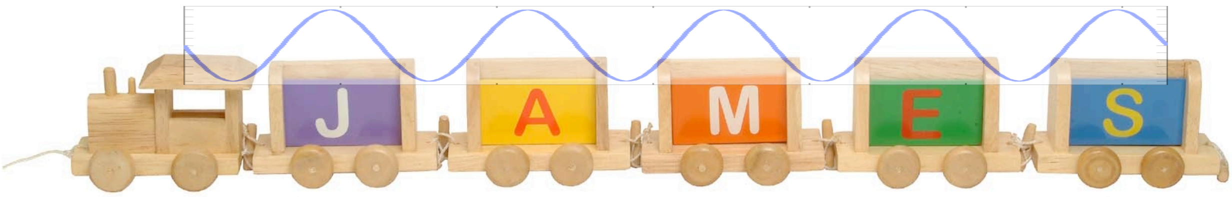
[low pitched] [high pitched] [normal]

and when moving away from the listener, its horn seems

[low pitched] [high pitched] [normal].

9. The changed pitch of the Doppler effect is due to changes in wave

[speed] [frequency] [both].




A train with connected carriages is like a wave. Imagine a train that is moving at 15m/s, with each train carriage (each wavelength) being 30 metres long.

## Questions

**What is the speed of the wave (train)?**

**What is the length of one wave (one carriage)?**

**How long does is take for 1 wave (carriage) to travel past a point? In other words, what is the period of the wave?**

**What is the frequency of the wave? (How many carriages move past a point each second?)**

## The Connection between λ, *v* and *f*

The frequency of a wave depends on the speed and the wavelength of the wave.

- If the wave is travelling slower, less wave crests will pass you every second. (If the speed **v** is smaller, then the frequency **f** is also smaller)
- If the wavelength is large, then successive crests would take longer to reach you than originally. Hence you would again detect a lower frequency.

The exact relationship between frequency, wavelength and velocity is given by the *wave equation*.

$$f = \frac{v}{\lambda} \quad \text{or} \quad v = f\lambda$$

where $v$ is the velocity in m/s, $f$ is the frequency in Hz and $\lambda$ is the wavelength in metres.

## Questions

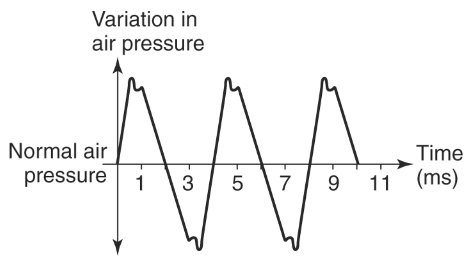
**If Triple M has a frequency of 105.1MHz, what is the wavelength of the signal?**

**If a Helium Neon laser has a wavelength of 632.8 nm, what is the frequency of the light emitted?**

**If a satellite is 210 km above the earths surface, how long would it take to send a signal to the satellite and back?**

**If you are 2.45km from the nearest mobile phone tower, how long would it take for the signal to go from your phone to the tower?**

The graph to the right shows how air pressure varies with time at a point near a musical instrument.




## Questions

**What is the period of the sound produced by the musical instrument?**

**What is the frequency of the sound produced by the musical instrument?**

**If the speed of sound in air is 340 m $s^{-1}$, what is the wavelength of the sound produced by the musical instrument?**

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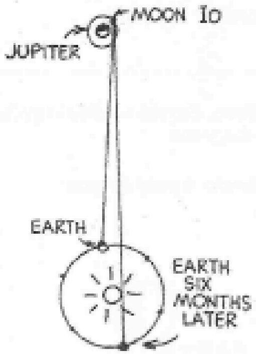
## Chapter 26 Properties of Light
### *Speed, Wavelength, and Frequency*

1. The first investigation that led to a determination of the speed of light was performed in about 1675 by the Danish astronomer Olaus Roemer. He made careful measurements of the period of Io, a moon about the planet Jupiter, and was surprised to find an irregularity in Io's observed period. While Earth was moving away from Jupiter, the measured periods were slightly longer than average. While Earth approached Jupiter, they were shorter than average. Roemer estimated that the cumulative discrepancy amounted to about 16.5 minutes. Later interpretations showed that what occurs is that light takes about 16.5 minutes to travel the extra 300,000,000-km distance across Earth's orbit. Aha! We have enough information to calculate the speed of light!




a. Write a formula for speed in terms of the distance traveled and the time spent traveling that distance.

______________________

b. Using Roemer's data, and changing 16.5 minutes to seconds, calculate the speed of light.

______________________

*Study Figure 26.3 in your textbook and answer the following:*

2. a. Which has the longer *wavelengths*? [radio waves] [light waves].

b. Which has the longer *wavelengths*? [light waves] [gamma waves].

c. Which has the higher *frequencies*? [ultraviolet waves] [infrared waves].

d. Which has the higher *frequencies*? [ultraviolet waves] [gamma rays].


*Carefully study the section "Transparent Materials" in your textbook and answer the following:*

3. a. Exactly what do vibrating electrons emit?

______________________

b. When ultraviolet light shines on glass, what does it do to electrons in the glass structure?

______________________

c. When energetic electrons in the glass structure vibrate against neighboring atoms, what happens to the energy of vibration?

______________________

d. What happens to the energy of a vibrating electron that does not collide with neighboring atoms?

______________________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## Chapter 26 Properties of Light
### *Speed, Wavelength, and Frequency—continued*

e. Light in which range of frequencies is absorbed in glass? [visible] [ultraviolet].

f. Light in which range of frequencies is transmitted through glass? [visible] [ultraviolet].

g. How is the speed of light in glass affected by the succession of time delays that accompany the absorption and re-emission of light from atom to atom in the glass?

______________________

h. How does the speed of light compare in water, glass, and diamond?

______________________

4. The Sun normally shines on both Earth and Moon. Both cast shadows. Sometimes the Moon's shadow falls on Earth, and at other times Earth's shadow falls on the Moon.

a. The sketch shows the Sun and Earth. Draw the Moon at a position for a solar eclipse.


b. This sketch also shows the Sun and Earth. Draw the Moon at a position for a lunar eclipse.


5. The diagram shows the limits of light rays when a large lamp makes a shadow of a small object on a screen. Make a sketch of the shadow on the screen, shading the umbra darker than the penumbra. In what part of the shadow could an ant on the screen see part of the lamp?

______________________