UNIT 1: PROPERTIES OF WAVES

1. Types of Waves
2. Wave Characteristics
3. Doppler Effect
4. Diffraction
5. Interference

1. TYPES OF WAVES

Q: What kinds of waves have you seen?
What is the medium in your examples?
How would you define “a wave”?

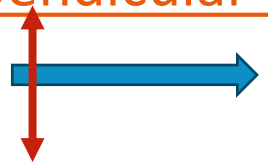
A wave is a disturbance in a medium that carries energy, without a net movement of matter.

Look at animations of the main types of waves:
http://www.acs.psu.edu/drussell/demos/waves/wavemotion.html
Credit: Acoustics and Vibration Animations - Dan Russell, Grad. Prog. Acoustics, Penn State

Q: How do the particles of the medium move in each of these waves?

EXAMPLES OF LONGITUDINAL AND TRANSVERSE WAVES:

A **transverse wave** has a disturbance perpendicular to its direction of propagation:



A **longitudinal wave** has a disturbance parallel to its direction of propagation:

- *Create a "stadium wave".*
- *Create the 2 types of waves in a slinky*

- The main types of earthquake waves: P-wave and S-wave

Play the animations on pages 3 to 7 here:
http://www.classzone.com/books/earth_science/terc/content/investigations/es0402/es0402page03.cfm

- Which wave can pass through both solids and liquids?
- Which wave can only travel in solids?
- Which wave travels faster?

- What do these earthquake waves tell us about Earth's interior?

2. WAVE CHARACTERISTICS

Waves have crests (peaks) and troughs (valleys).

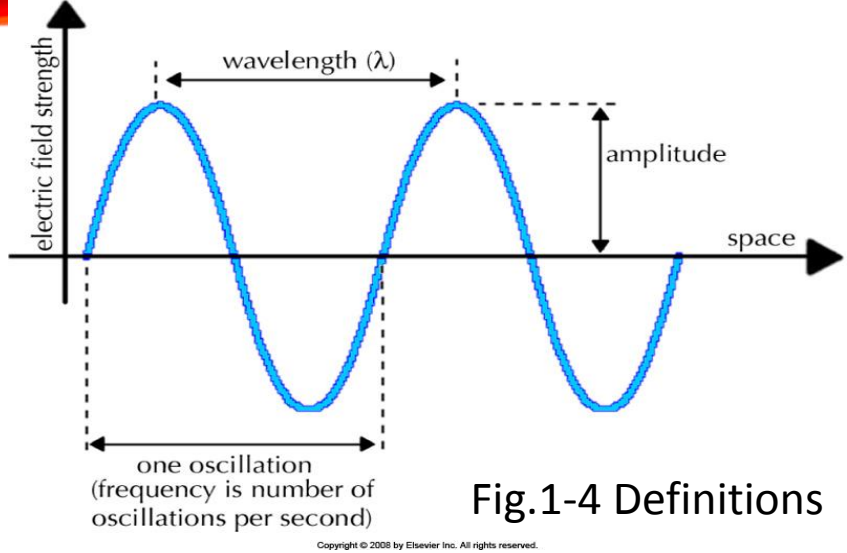


Fig.1-4 Definitions

- Wavelength (λ) – the distance from one crest to the next (peak-to-peak).
- Period (T) – the time from one crest to the next, as they pass.
- Frequency (f) – the number of crests passing a point per second,
  $f = 1/T$, f is in units of [Hz]
- Amplitude – the maximum displacement from equilibrium level
  (or, ½ of the distance from crest to trough)

ANSWER PRACTICE QUESTIONS IN WS_1

- *If the peak-to-valley distance of a wave is 10 cm, what is its amplitude?*
- *If the distance from one wave crest to the next is 15 cm, what is the wavelength?*
- *What do all kinds of waves have in common?*

➢ Speed of a travelling wave: $\mathbf{v = \frac{Distance}{Time} = \frac{\lambda}{T}}$

Since $\mathbf{f = \frac{1}{T}}$, we obtain the relation that the wave speed equals wavelength*frequency:

$$v = \lambda f$$

APPLICATION IN SONARS

Sound is a wave in materials. In fluids sound travels as a longitudinal wave.

Q4. A boat uses a sonar to measure the depth of a lake. If the time delay between the sent and received signal is 0.05 seconds, what is the depth of the lake?
Take the speed of sound in water as 1440 m/s.

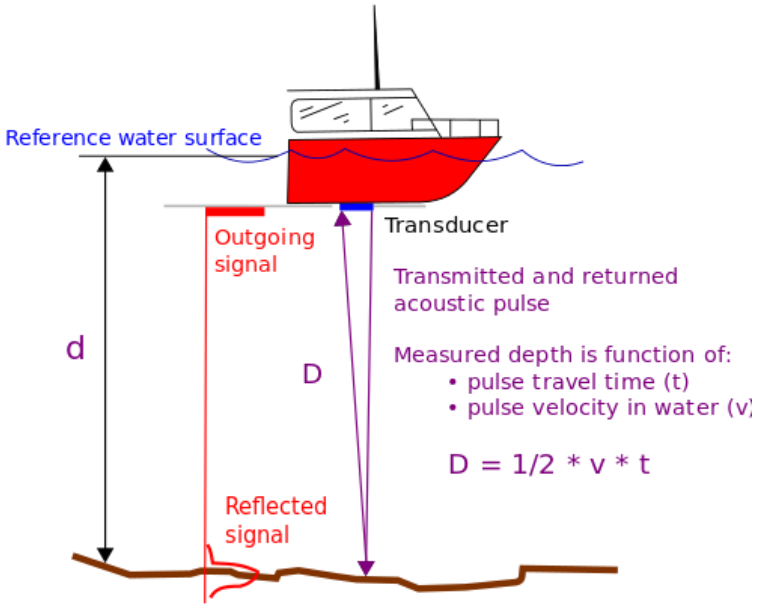


Figure 9-1. Acoustic depth measurement

3. DOPPLER EFFECT

Play the interactive: select the speed of the source of sound waves and move the microphone around it. What changes do you notice?

When the wave source approaches us, we detect a higher frequency (shorter wavelength);
When the wave source recedes, we detect a higher frequency (shorter wavelength).

Q: Have you seen (experienced) this effect?
What could be the possible applications of Doppler effect?

Q. WHAT HAPPENS WHEN WAVES ENCOUNTER OBSTACLES?

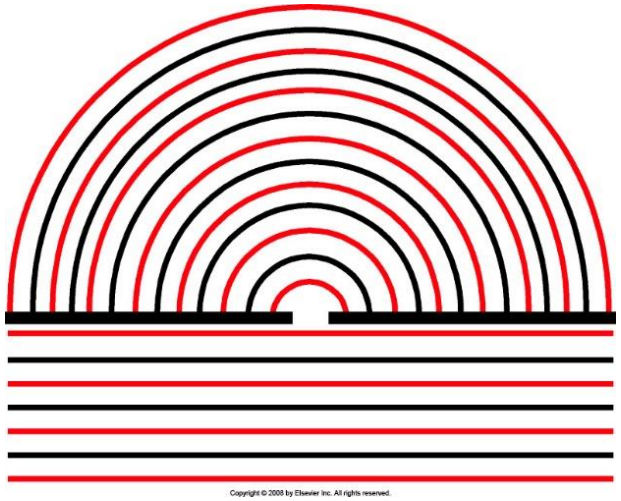


Fig.1-1 A plane wave in water meets a wall with a small opening. Wave crests are in red.

Play the animations:
http://www.acoustics.salford.ac.uk/feschools/waves/diffract.php

Q: How does the shape of the wave change?

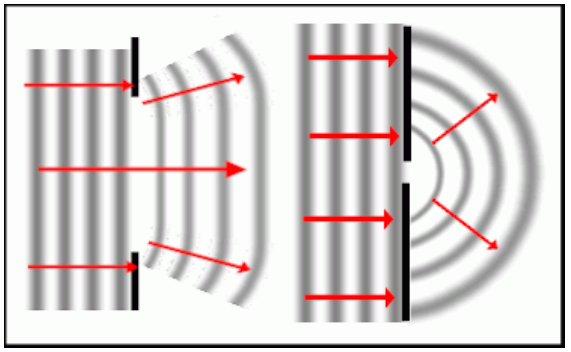
A plane wave passes through a small opening and changes to a circular wave behind the screen. The wave travels behind the wall!

Q: What if particles were passing through the opening?

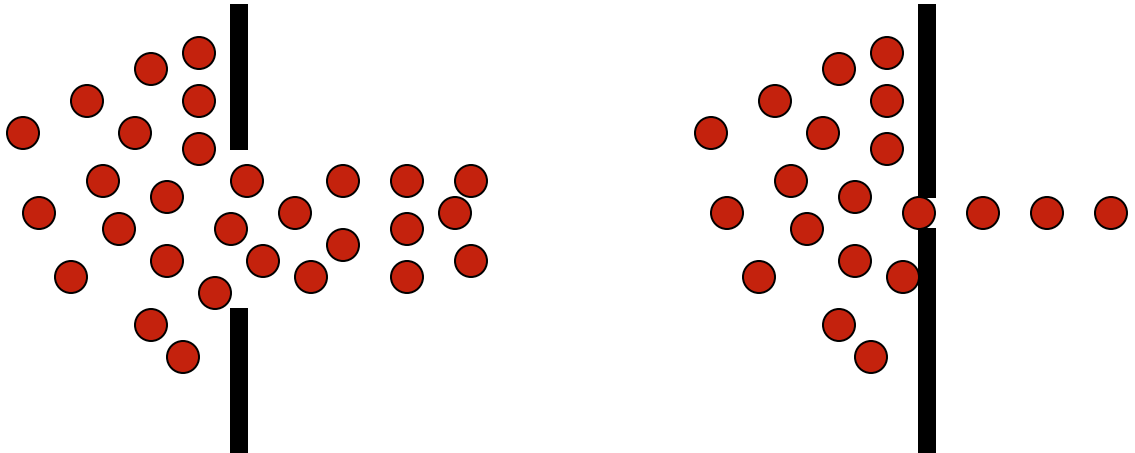
4. DIFFRACTION –

WHEN WAVES PROPAGATE BEHIND SCREENS OR BEND AROUND EDGES.

Waves will diffract when the size of the obstacle is equal to their wavelength: $d = \lambda$



Compare waves to particles: Waves will diffract through an opening, but particles will not show diffraction. Particles can't go behind screens!



DIFFRACTION FROM A SINGLE OPENING

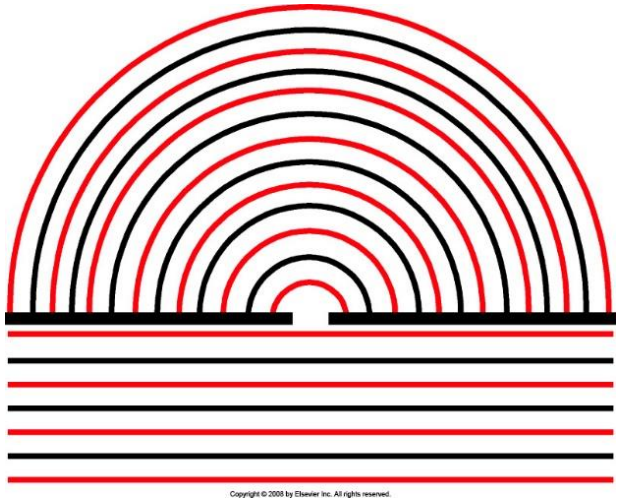


Fig.1-1 A plane wave in water meets a wall with a small opening. Wave crests are in red.

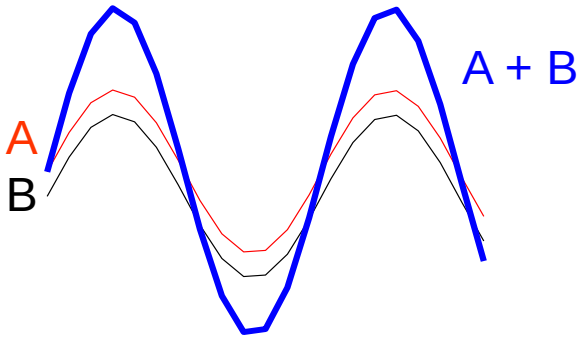
Q: When can we see diffraction of waves?

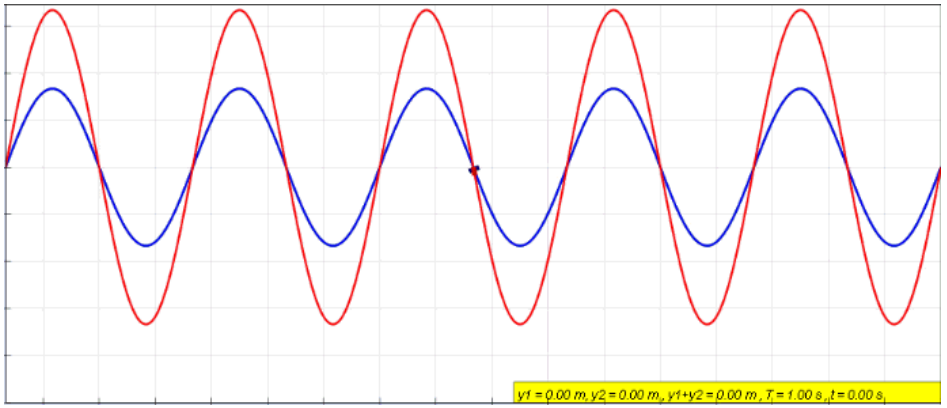
Play the interactive and state a condition for diffraction:
http://www.acoustics.salford.ac.uk/feschools/waves/diffract3.php

5. ADDITION OF WAVES (SUPERPOSITION)

When two waves are added they can amplify or cancel each other:

Waves can amplify each other:





Credit: Loo Kang Lawrence WEE
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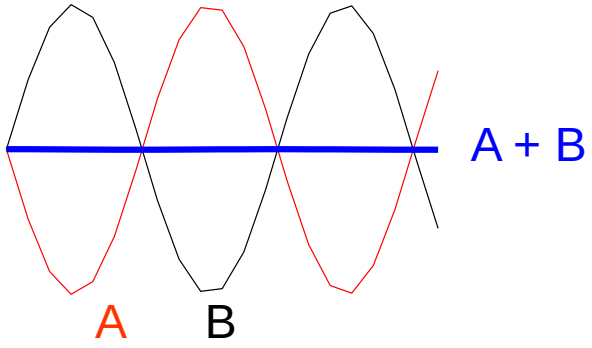
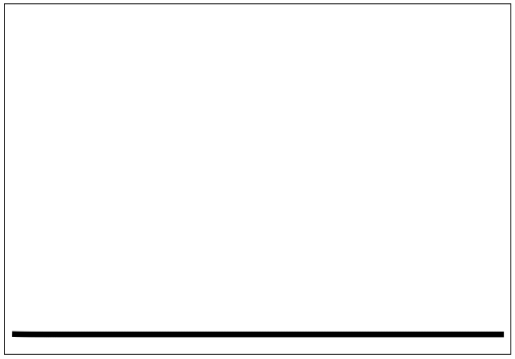
Waves can cancel each other:





Superposition of 2 waves.
Credit: Acoustics and Vibration Animations –Prof. Dan Russell, Grad. Prog. Acoustics, Penn State

DOUBLE SLIT INTERFERENCE OF WAVES

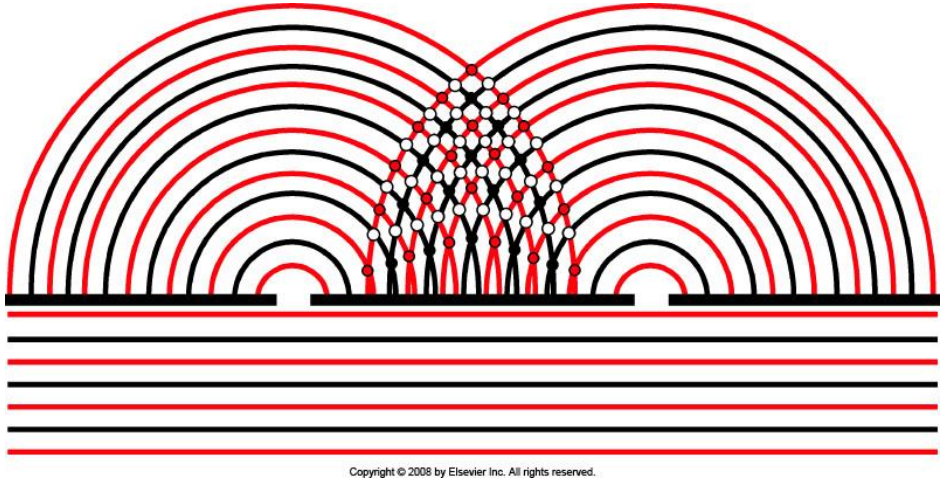
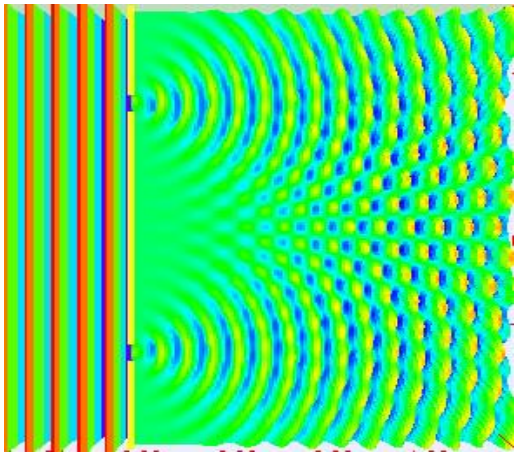


Fig.1-2 Interference of two waves



Play the interactives of addition of 2 circular waves:
http://www.acoustics.salford.ac.uk/feschools/waves/super2.php
or, http://zonalandeducation.com/mstm/physics/waves/interference/twoSource/TwoSourceInterference1.html

The two diffracted waves add or cancel each other at various points.

Q: What determines whether we see “peaks” or “valleys”?

DOUBLE-SLIT EXPERIMENT WITH WATER WAVES:

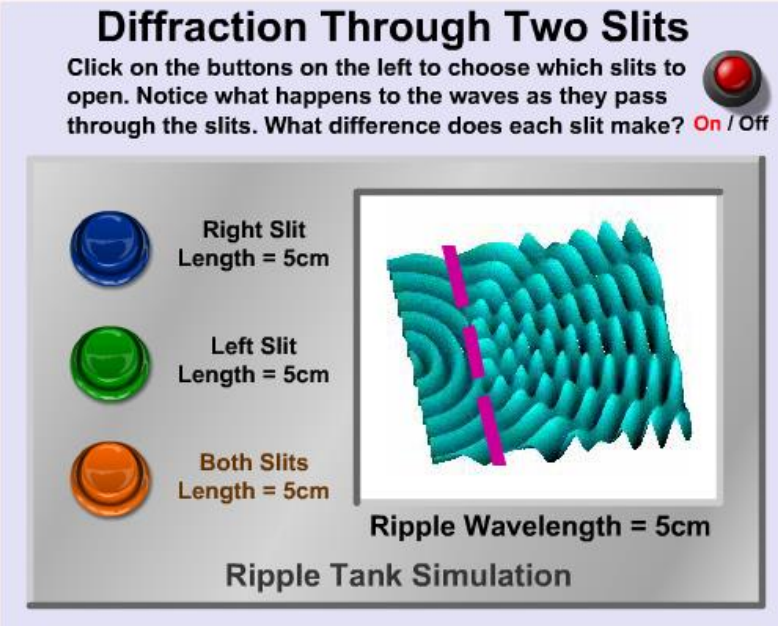
The waves diffracted by each slit interfere with each other.

There will be a peak (constructive interference) only in directions θ, which satisfy the condition:

$$d \sin \theta = n\lambda,$$

where $n = 0, 1, 2, 3...$

d is the distance between the slits.



There will be constructive interference at points where the peaks of each wave meet – where they arrive "in phase". This happens where the difference between the distance travelled by waves is a whole number of wavelengths.