Chapter 11: Superposition

- Stationary Waves
- Diffraction
- Interference
- Two-source interference patterns
- Diffraction grafting

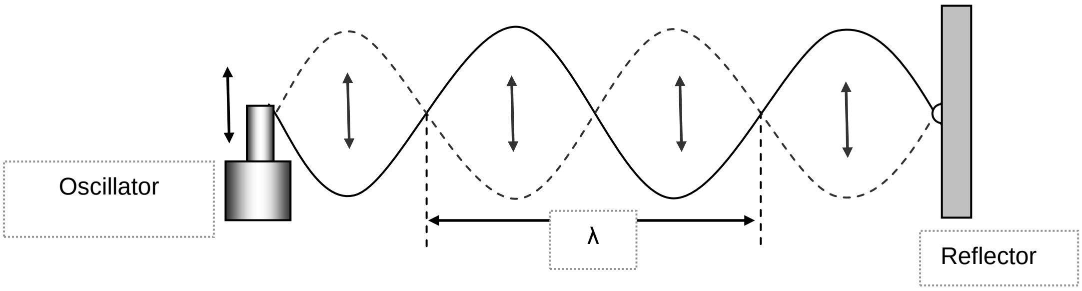
a. **Explain and use the principle of superposition in simple applications.**

Principle of Superposition: When two or more waves of the same type meet at a point, the resultant *displacement* of the waves is equal to the *vector sum* of their individual displacements at that point.

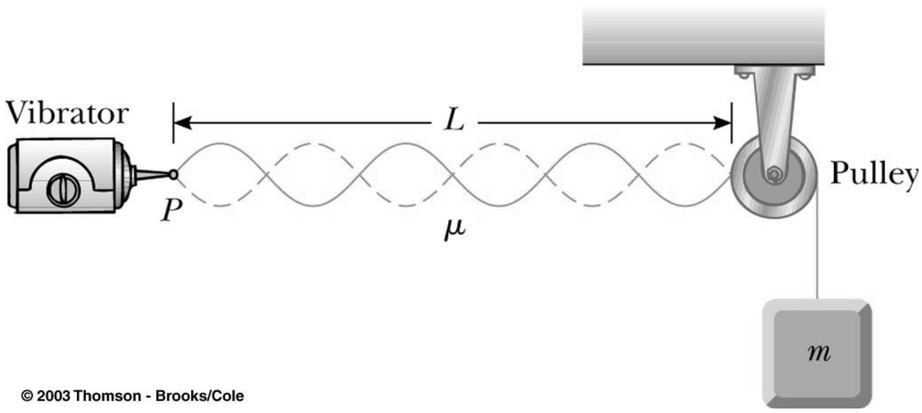
b. **Show an understanding of experiments which demonstrate stationary waves using microwaves, stretched strings and air columns.**

<u>Stretched String</u>

A horizontal rope with one end fixed and another attached to a vertical oscillator. Stationary waves will be produced by the direct and reflected waves in the string.

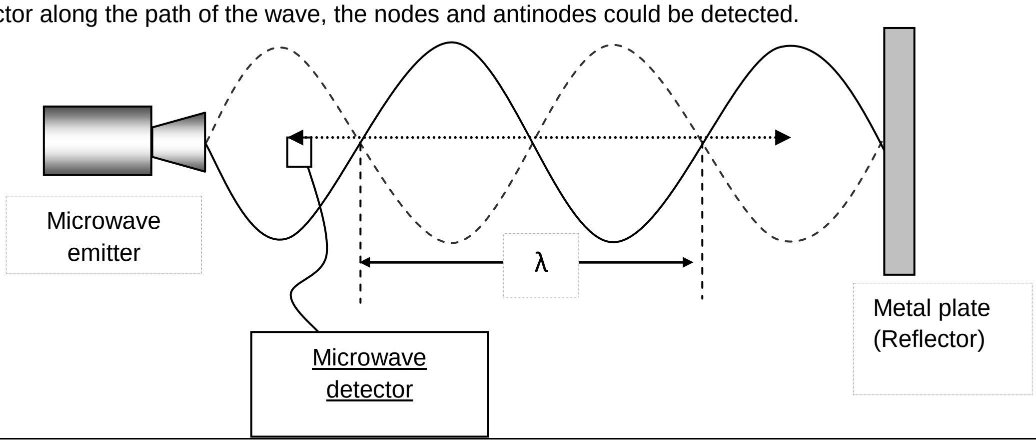


Or we can have the string stopped at one end with a pulley as shown below.



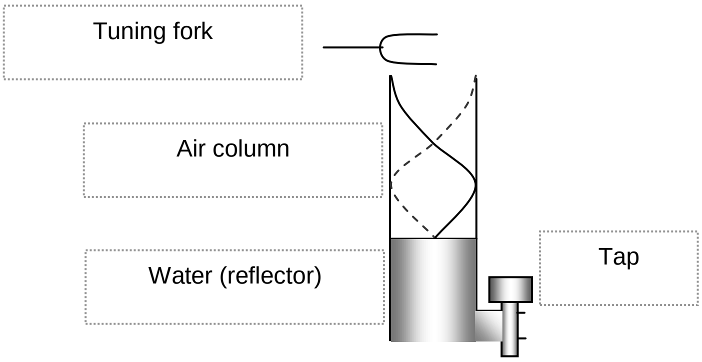
<u>Microwaves</u>

A microwave emitter placed a distance away from a metal plate that reflects the emitted wave. By moving a detector along the path of the wave, the nodes and antinodes could be detected.



Air column

A tuning fork held at the mouth of a open tube projects a sound wave into the column of air in the tube. The length of the tube can be changed by varying the water level. At certain lengths of the tube, the air column resonates with the tuning fork. This is due to the formation of stationary waves by the incident and reflected sound waves at the water surface.



c. Explain the formation of a stationary wave using a graphical method, and identify nodes and antinodes.

Stationary (Standing) Wave) is one

- whose waveform/wave profile does not advance {move},
- where there is no net transport of energy, and
- where the positions of antinodes and nodes do not change (with time).

A stationary wave is formed when two progressive waves of the same *frequency*, *amplitude* and *speed*, travelling in *opposite directions* are superposed. {Assume boundary conditions are met}

	Stationary Waves	**Progressive Waves**
Amplitude	Varies from maximum at the anti-nodes to zero at the nodes.	Same for all particles in the wave (provided no energy is lost).
Wavelength	Twice the distance between a pair of adjacent nodes or anti-nodes.	The distance between two consecutive points on a wave, that are in phase.
Phase	Particles in the same segment/ between 2 adjacent nodes, are in phase. Particles in adjacent segments are in anti-phase.	All particles within one wavelength have different phases.
Wave Profile	The wave profile does not advance.	The wave profile advances.
Energy	No energy is transported by the wave.	Energy is transported in the direction of the wave.

Node is a region of destructive superposition where the waves always meet out of phase by π radians**.** Hence displacement here is permanently zero {or minimum}.

Antinode is a region of constructive superposition where the waves always meet in phase**.** Hence a particle here vibrates with maximum amplitude {but it is NOT a pt with a *permanent* large displacement!}

Dist between 2 successive nodes/antinodes = $\frac{\lambda}{2}$

Max pressure change occurs at the nodes {NOT the antinodes} because every node changes fr being a pt of compression to become a pt of rarefaction {half a period later}

d. Explain the meaning of the term diffraction.
j. Recall and solve problems by using the formula dsinθ = nλ and describe the use of a diffraction grating to determine the wavelength of light. (The structure and use of the spectrometer is not required.)

Diffraction: refers to the spreading {or bending} of waves when they pass through an opening {gap}, or round an obstacle (into the "shadow" region). {Illustrate with diag}

For significant diffraction to occur, the size of the gap $\approx \lambda$ of the wave

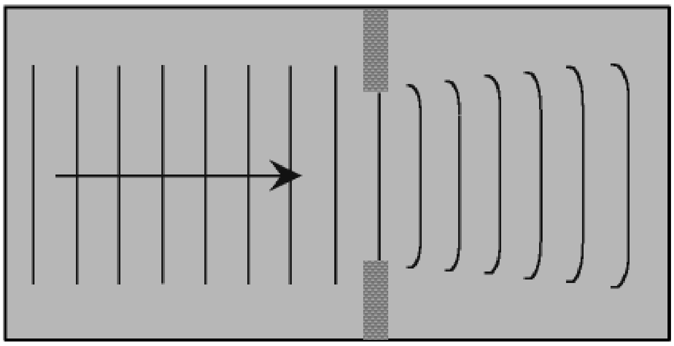
For a diffraction grating, $\mathbf{d \sin\theta = n\lambda}$, d = dist between successive slits {grating spacing}
= reciprocal of number of lines per metre

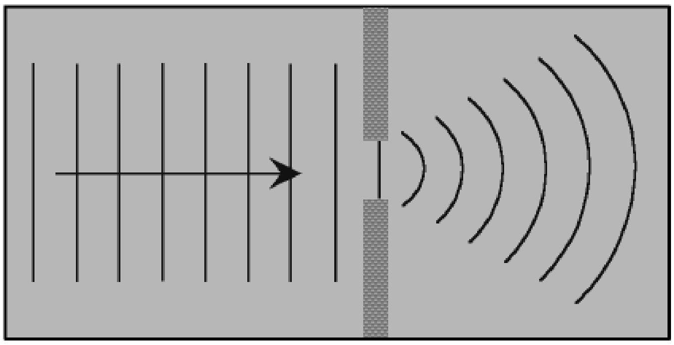
When a "*white* light" passes through a diffraction grating, for each order of diffraction, a longer wavelength {red} diffracts more than a shorter wavelength {violet} {as $\sin\theta \propto \lambda$}.

e. Show an understanding of experiments which demonstrate diffraction including the diffraction of water waves in a ripple tank with both a wide gap and a narrow gap.

Diffraction refers to the spreading of waves as they pass through a narrow slit or near an obstacle.

For diffraction to occur, the size of the gap should approximately be equal to the wavelength of the wave.





f. Show an understanding of the terms interference and coherence.

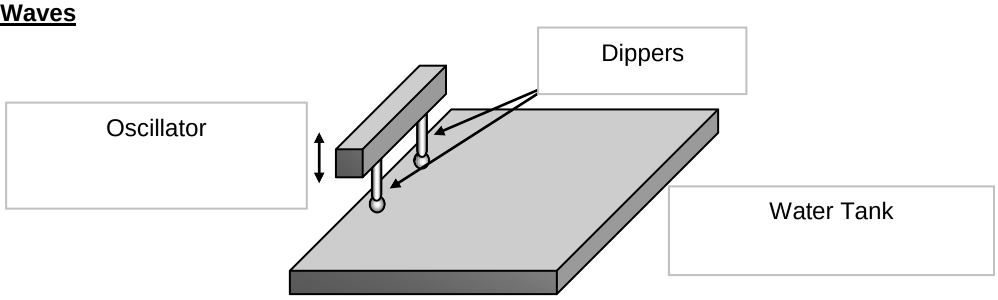
Coherent waves: Waves having a constant phase difference {not: zero phase difference/in phase}

Interference may be described as the superposition of waves **from 2 coherent sources**.

For an **observable/well-defined interference pattern**, the waves must be *coherent*, have about the *amplitude*, be *unpolarised* or *polarised in the same direction*, & be of the same type.

g. Show an understanding of experiments which demonstrate two-source interference using water, light and microwaves.

Water Waves

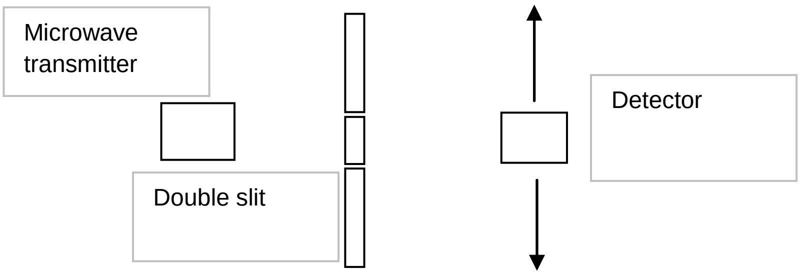


Interference patterns could be observed when two dippers are attached to the vibrator of the ripple tank. The ripples produce constructive and destructive interference. The dippers are coherent sources because they are fixed to the same vibrator.

ON THE NET

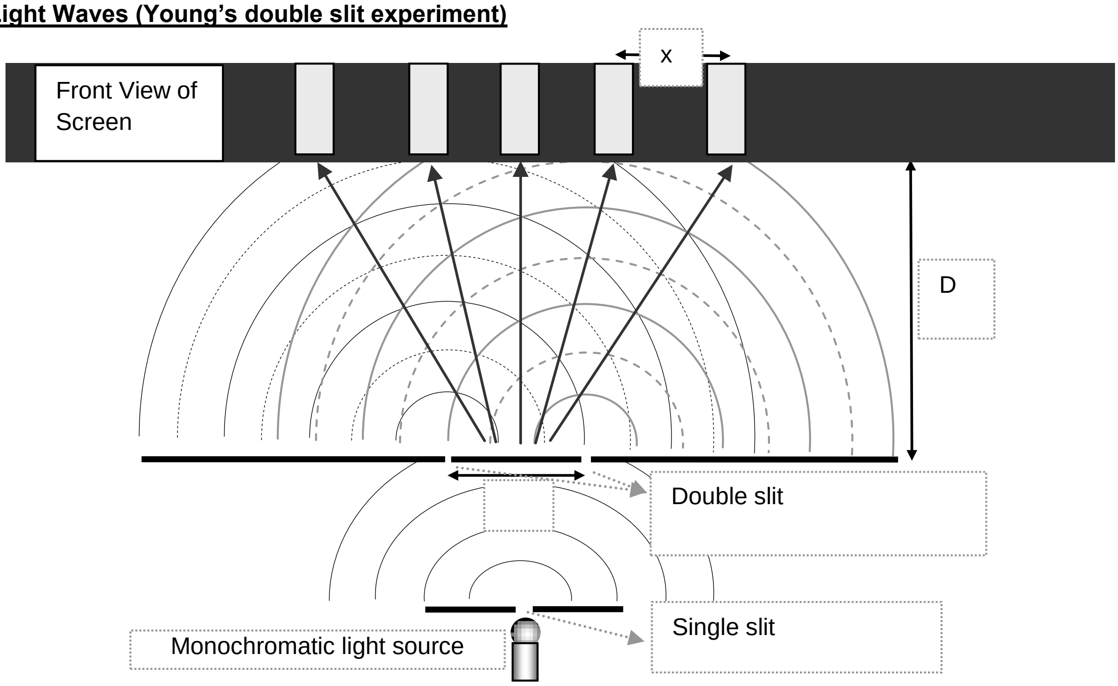
Refer to the applet on http://www.ngsir.netfirms.com/englishhtm/Interference.htm, and http://www.glenbrook.k12.il.us/gbssci/phys/Class/light/u12l3a.html.

Microwaves



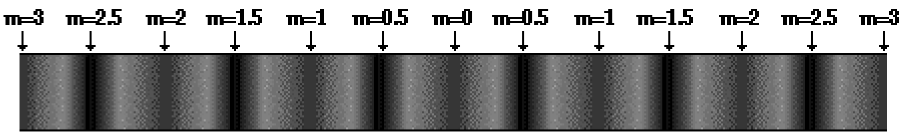
Microwave emitted from a transmitter through 2 slits on a metal plate would also produce interference patterns. By moving a detector on the opposite side of the metal plate, a series of rise and fall in amplitude of the wave would be registered.

Light Waves (Young's double slit experiment)



Since light is emitted from a bulb randomly, the way to obtain two coherent light sources is by splitting light from a single slit.

The 2 beams from the double slit would then interfere with each other, creating a pattern of alternate bright and dark fringes (or high and low intensities) at regular intervals, which is also known as our *interference pattern*.



h.	**Show an understanding of the conditions required if two-source interference fringes are to be observed.**

	<u>Condition for **Constructive Interference** at a pt P:</u> **phase difference** of the 2 waves at P **= 0** {or 2π, 4π, etc} Thus, with 2 ***in-phase*** **sources**, * implies **path difference = nλ;** with 2 ***antiphase*** **sources**: **path difference = (n + ½)λ** <u>Condition for **Destructive Interference** at a pt P:</u> **phase difference** of the 2 waves at P **= π** { or 3π, 5π, etc } With 2 ***in-phase*** **sources**, + implies **path difference = (n+ ½ λ),** with 2 ***antiphase*** **sources**: **path difference = n λ**
i.	**Recall and solve problems using the equation $\lambda = \frac{\lambda D}{a}$ for double-slit interference using light.**
	Fringe separation $x = \frac{\lambda D}{a}$, if a<<D **{**applies **only** to Young's Double Slit interference of ***light***, Ie, NOT for microwaves, sound waves, water waves} Phase difference $\Delta\phi$ betw the 2 waves at any pt X {betw the central & 1st maxima) is (approx) proportional to the dist of X from the central maxima. {N01 & N06} Using 2 sources of equal amplitude x_0, the resultant amplitude of a bright fringe would be doubled {$2x_0$}, & the resultant intensity increases by *4 times* {not 2 times}. {$I_{Resultant} \propto (2\ x_0)^2$] }