Waves Changing Medium

What happens to an EM wave when it changes from a medium with a certain index of refraction to a different medium with a different index of refraction? As previously mentioned, we can define the index of refraction as

$$n = \frac{\text{speed of light in vacuum}}{\text{speed of light in material}} = \frac{c}{v}$$

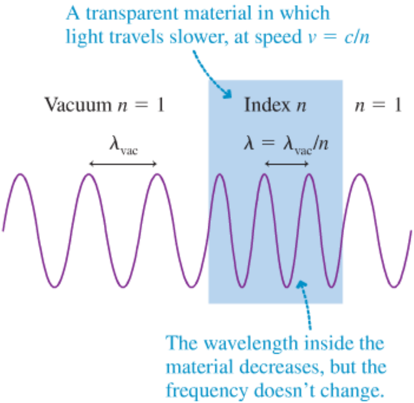
It is clear that $v < c$ means that $n > 1$ always (remember this on assignments and in P131). The speed of light changes when the

medium changes. We also know that

$$v = \lambda f$$

So, if v changes, then either λ changes or f changes or both change.

Waves Changing Medium



The frequency depends only on the source, not the medium. However, the wavelength changes. So, in $v = \lambda f$ we have v and λ changing while f is fixed when the medium changes.

Wave Power and Intensity

The power of a wave is the rate at which it transfers energy. The intensity also includes the area over which that power is spread:

$$I = \frac{P}{a}$$

measured in W/m^2. This is particularly interesting in the case of spherical waves

$$I = \frac{P_{source}}{4\pi r^2}$$

Now think about the Sun...

Wave Power and Intensity

For SHM with amplitude A you have seen that energy is

$$E = \frac{1}{2}kA^2$$

So, if energy is proportional to the square of the amplitide, then so is intensity:

$$I = cA^2$$

where c is some constant which depends on which sort of wave we are talking about.

Thomas Young (1773-1829)

...whenever two portions of the same light arrive at the eye by different routes, either exactly or very nearly in the same direction, the light becomes most intense when the difference in their routes is any multiple of a certain length, and least intense in the intermediate state of the interfering portions; and this length is different for light of different colours.

Thomas Young was a pretty brilliant experimentalist...

Superposition

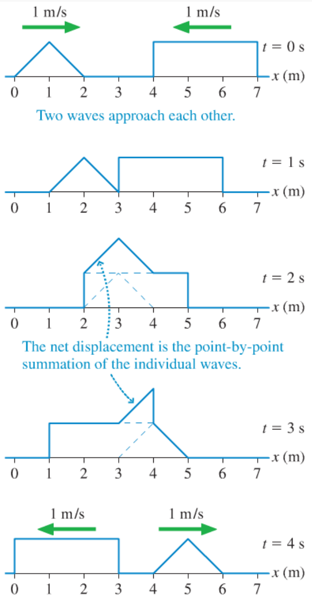
What happens when two waves of the same type meet? They interfere. That interference can be constructive or destructive or, if the frequecies are different, can create beats. To simplify things, we will study interfering waves of equal frequency and amplitude.

Principle of Superposition

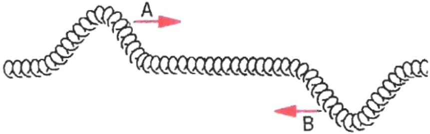
When two or more waves are simultaneously present at a single point in space, the displacement of the medium at that point is the sum of the displacements due to each individual wave.

$$D_{net} = D_1 + D_2 + \cdots = \sum_i D_i$$

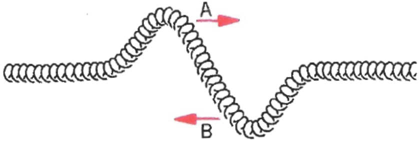
Illustrated Principle of Superposition



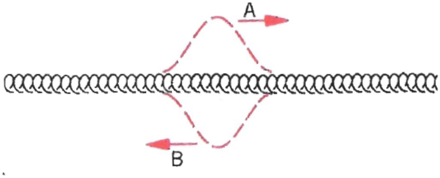
Illustrated Principle of Superposition



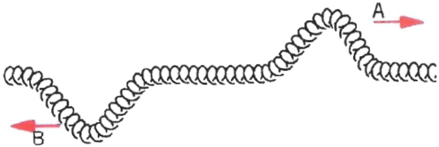
(*a*) The approaching pulses



(*b*) Overlap begins



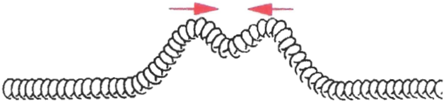
(*c*) Total overlap



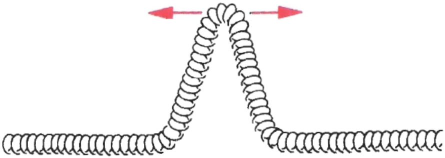
(*d*) The receding pulses

Illustrated Principle of Superposition

(*a*) The approaching pulses



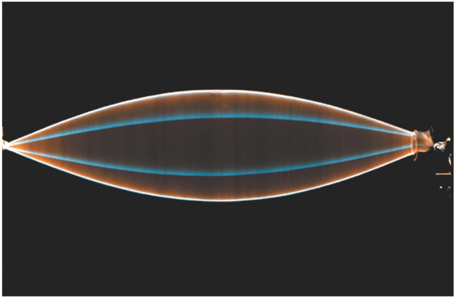
(*b*) Overlap begins

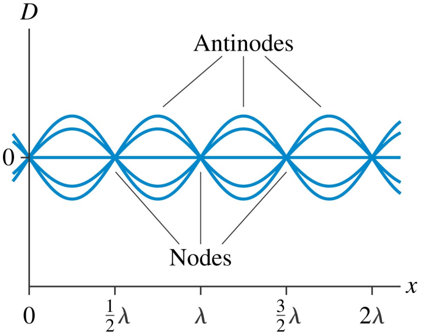


(*c*) Total overlap; the slinky has twice the height of either pulse

(*d*) The receding pulses

Standing Waves





The nodes and antinodes are spaced $\lambda/2$ apart.

- A standing wave is a superposition of two waves travelling in opposite directions.
- Constructive interference creates antinodes, destructive interference creates nodes.
- Nodes on a standing wave are spaced $\lambda/2$ apart and never move
- Antinodes are halfway between nodes.

The Mathematics of Standing Waves

We can write two equal waves travelling in opposite directions like:

$$D(x,t) = D_R + D_L = a\sin(kx - \omega t) + a\sin(kx + \omega t)$$

This can be simplified to (see your text)

$$D(x,t) = (2a\sin kx)\cos\omega t = A(x)\cos\omega t$$

Notice the form!! This is not a travelling wave. This is the equation of a medium in which each point is executing SHM (with varying amplitude).