IV. Waves and Optics

A. Wave Motion
B. Physical Optics

A. Wave Motion

1. Traveling waves
2. Wave Propagation
3. Standing Waves
4. Superposition

1. Traveling Waves

Understand the descriptions of traveling waves

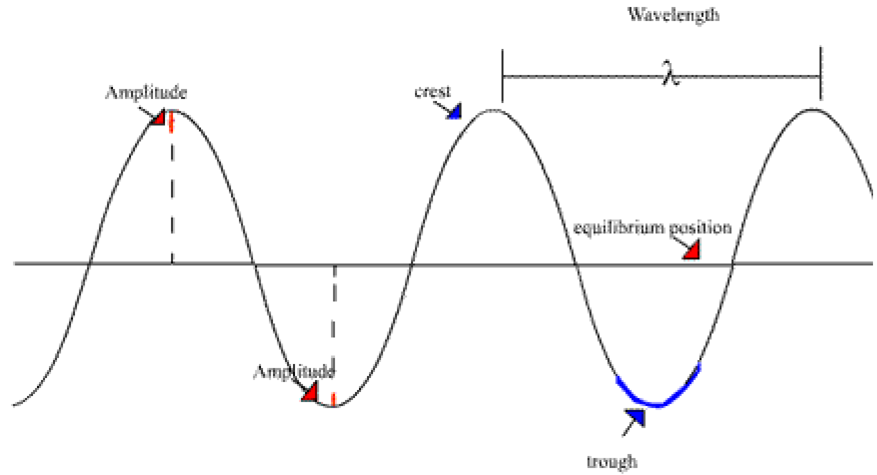
a) Sketch or identify graphs that represent traveling waves and determine the amplitude, wavelength, and frequency of a wave from such a graph.

b) Apply the relation among wavelength, frequency, and velocity for a wave.

c) Understand qualitatively the Doppler effect for sound in order to explain why there is a frequency shift in both the moving-source and moving-observer case.

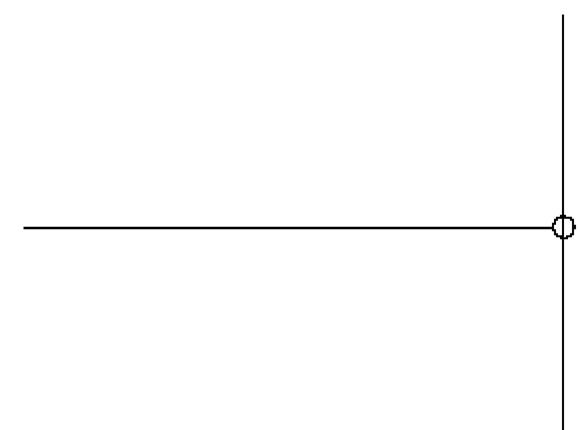
d) Describe reflection of a wave from the fixed or free end of a string.

e) Describe qualitatively what factors determine the speed of waves on a string and the speed of sound.



- $v=f\lambda$
- Sound faster in
  - Dense material
  - Warm material
- String wave faster in
  - Tight strings
  - Light (less dense) strings

$$v=\sqrt{\frac{T}{\mu}}$$

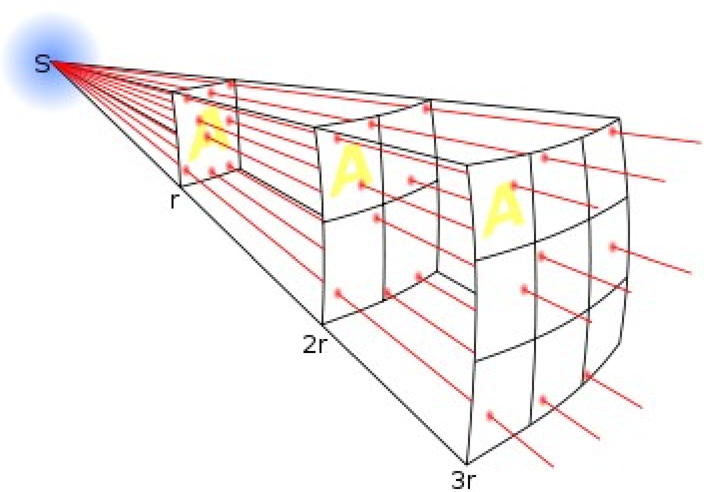


2. Wave Propagation

a) Students should understand the difference between transverse and longitudinal waves, and be able to explain qualitatively why transverse waves can exhibit polarization.

b) Students should understand the inverse-square law, so they can calculate the intensity of waves at a given distance from a source of specified power and compare the intensities at different distances from the source.

$$I \ \alpha \ \frac{1}{r^2}$$



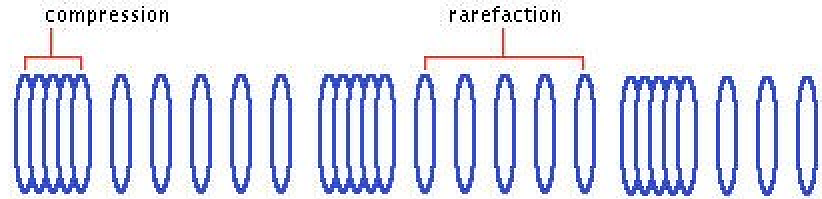


Figure 1: Longitudinal Wave

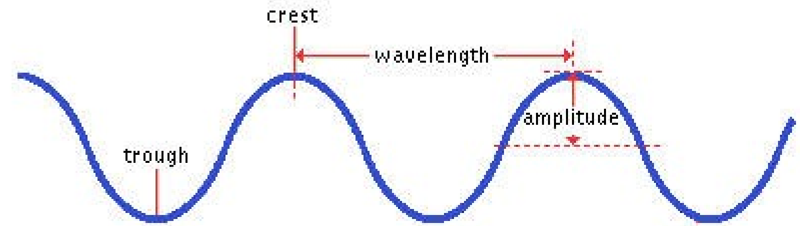


Figure 2: Transverse Wave

Light Passing Through Crossed Polarizers

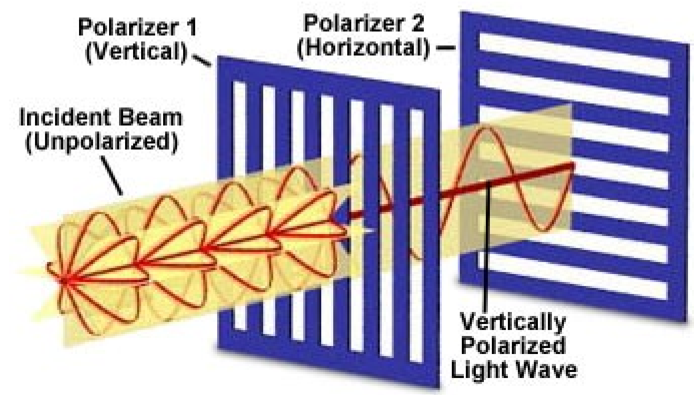
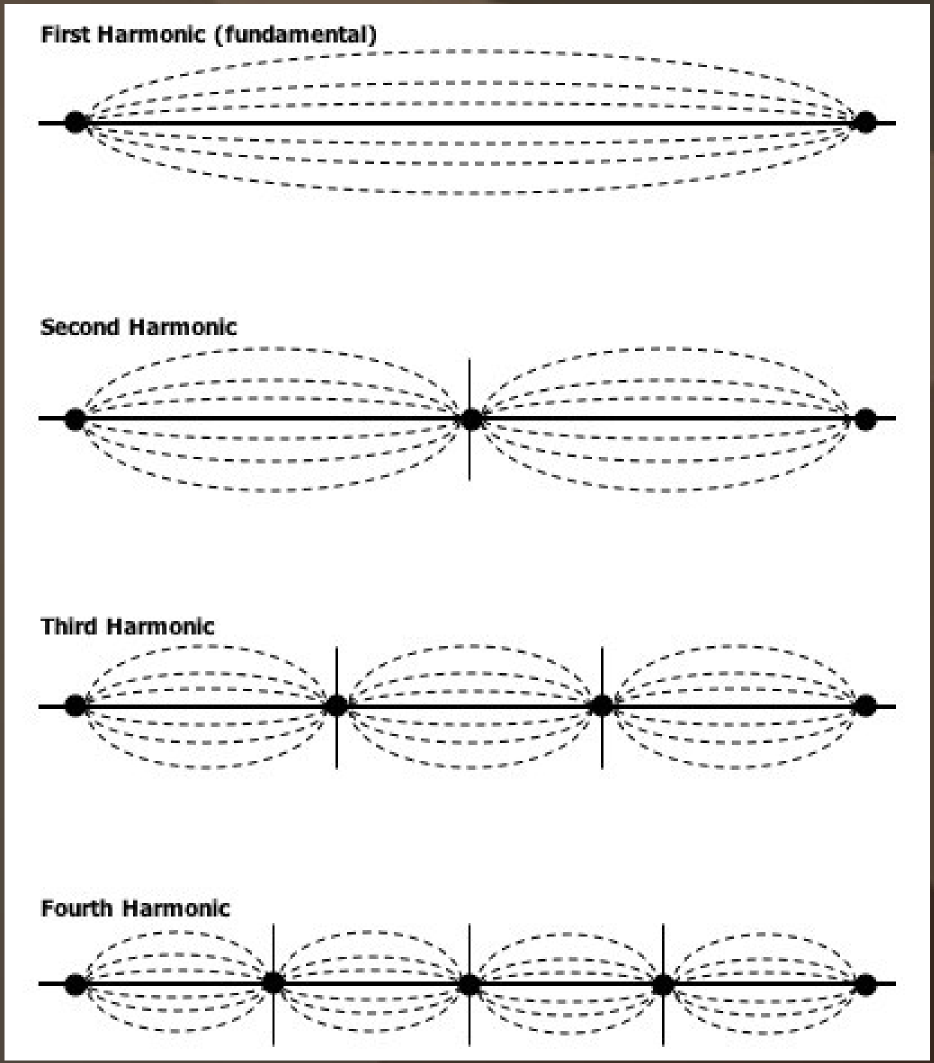


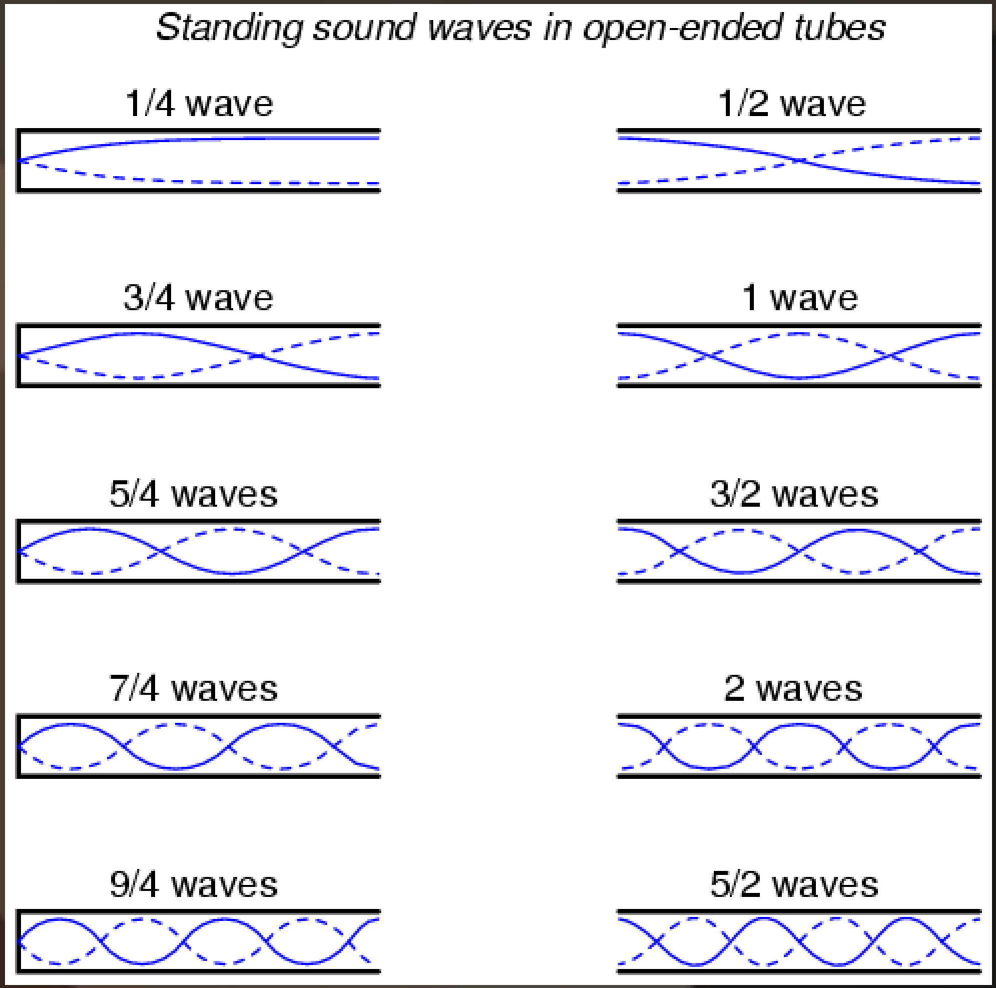
Figure 1

3. Standing Waves

a) Sketch possible standing wave modes for a stretched string that is fixed at both ends, and determine the amplitude, wavelength, and frequency of such standing waves.

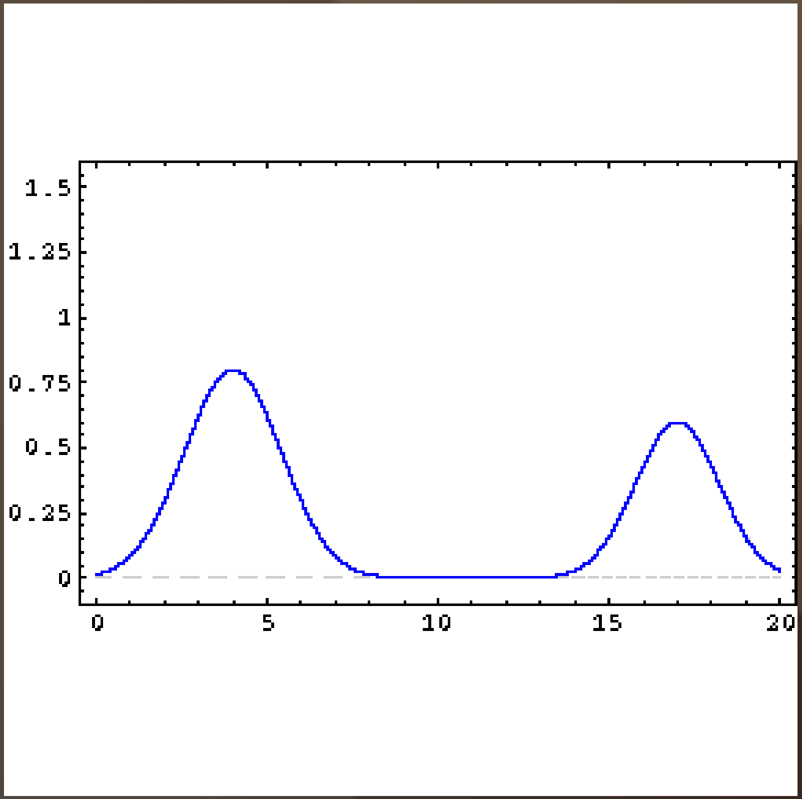
b) Describe possible standing sound waves in a pipe that has either open or closed ends, and determine the wavelength and frequency of such standing waves.

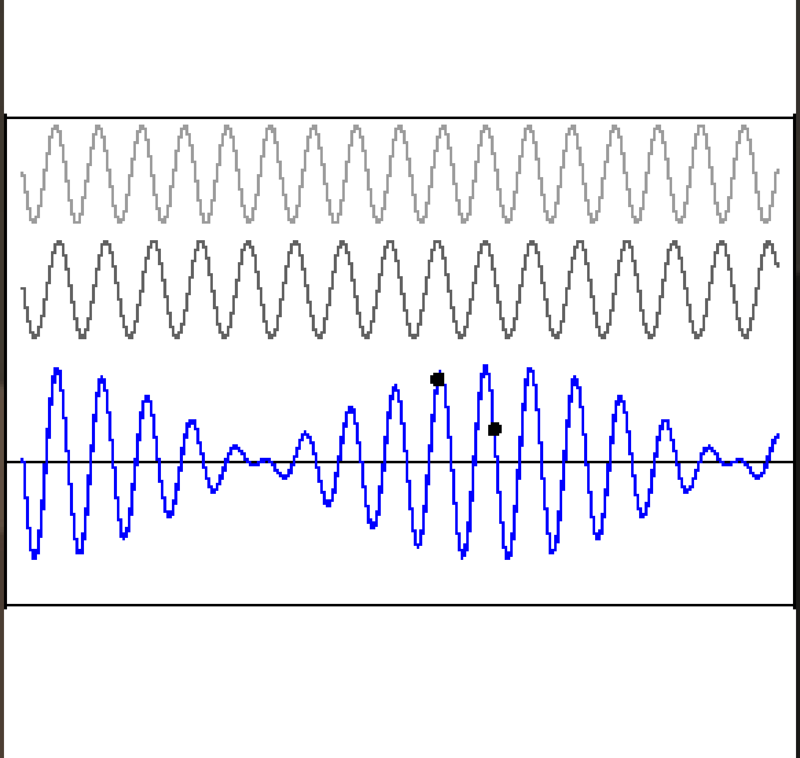

First Harmonic (fundamental)
Second Harmonic
Third Harmonic
Fourth Harmonic

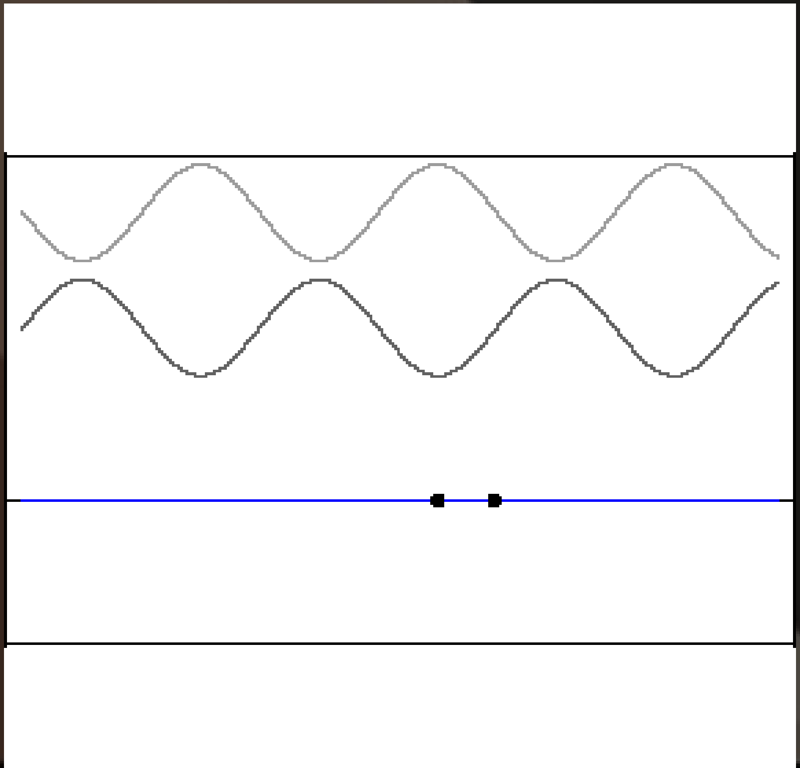

Standing sound waves in open-ended tubes
1/4 wave
1/2 wave
3/4 wave
1 wave
5/4 waves
3/2 waves
7/4 waves
2 waves
9/4 waves
5/2 waves

4. Superposition

- Students should understand the principle of superposition, so they can apply it to traveling waves moving in opposite directions, and describe how a standing wave may be formed by superposition.


1.5
1.25
1
0.75
0.5
0.25
0
0
5
10
15
20





B. Physical Optics

1. Interference and Diffraction
2. Dispersion of Light and the Electromagnetic Spectrum

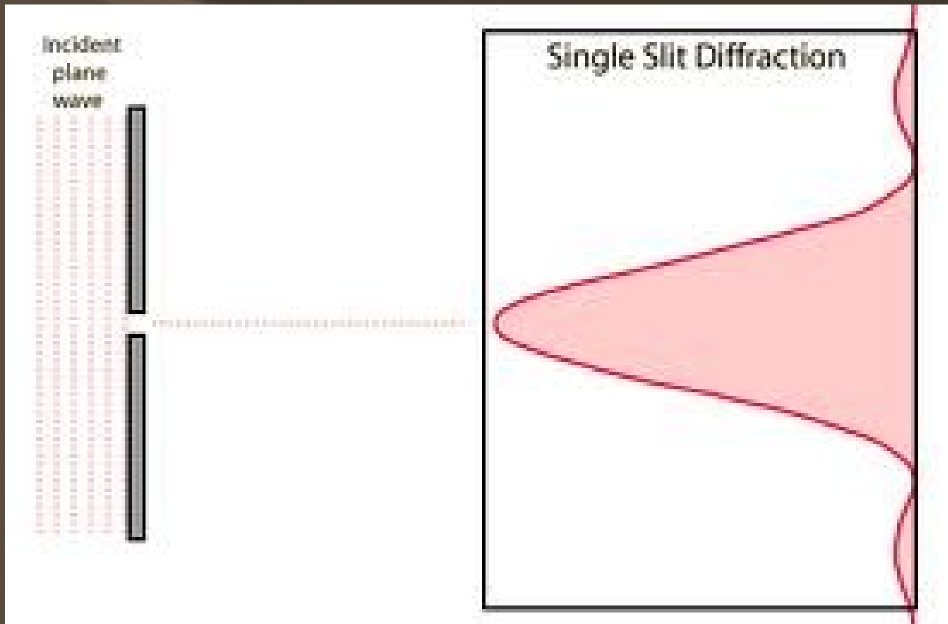
1. Interference and Diffraction

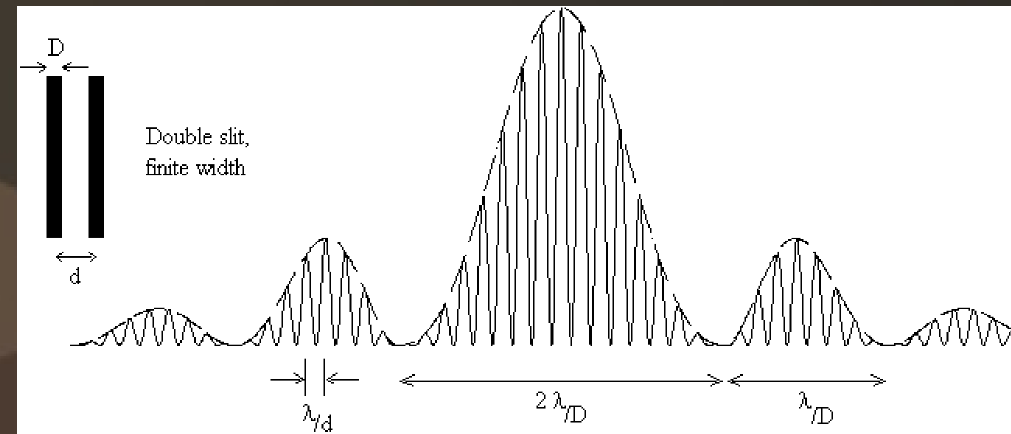
a) Apply the principles of interference to coherent sources in order to:

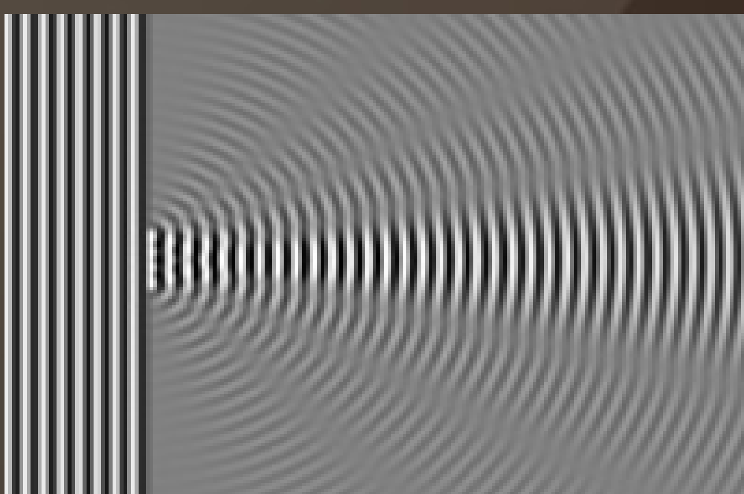
(1) Describe the conditions under which the waves reaching an observation point from two or more sources will all interfere constructively, or under which the waves from two sources will interfere destructively.

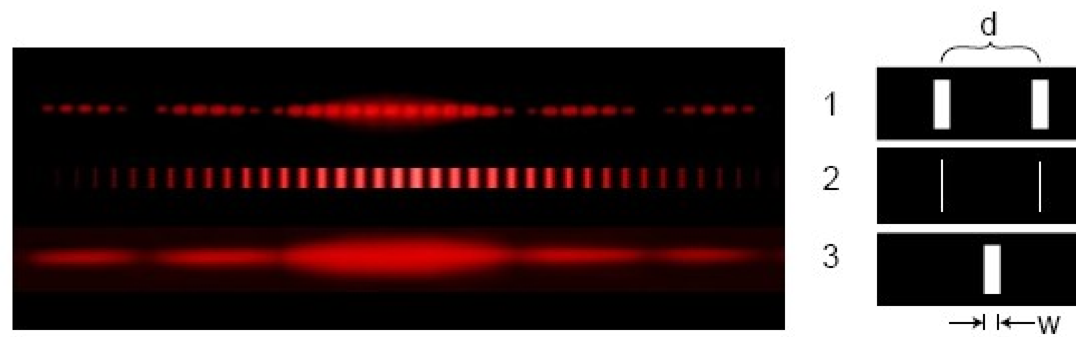
(2) Determine locations of interference maxima or minima for two sources or determine the frequencies or wavelengths that can lead to constructive or destructive interference at a certain point.

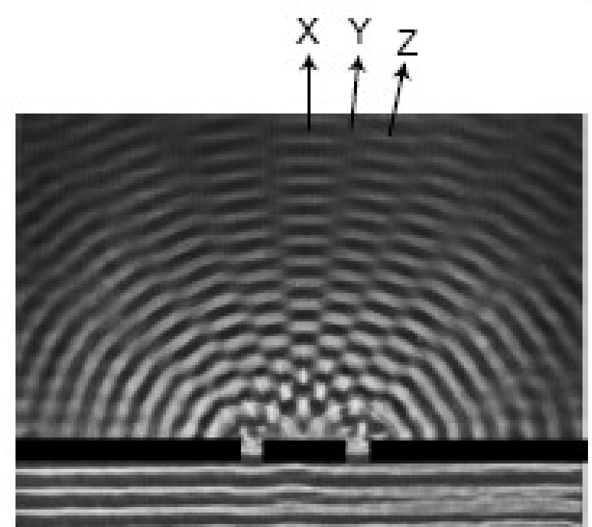
(3) Relate the amplitude produced by two or more sources that interfere constructively to the amplitude and intensity produced by a single source.


Incident
plane
wave
Single Slit Diffraction


D
d
Double slit,
finite width
λ/d
2 λ/D
λ/D




d
1
2
3
w


X
Y
Z

1. Interference and Diffraction

b) Apply the principles of interference and diffraction to waves that pass through a single or double slit or through a diffraction grating, so they can:

(1) Sketch or identify the intensity pattern that results when monochromatic waves pass through a single slit and fall on a distant screen, and describe how this pattern will change if the slit width or the wavelength of the waves is changed.

(2) Calculate, for a single-slit pattern, the angles or the positions on a distant screen where the intensity is zero.

(3) Sketch or identify the intensity pattern that results when monochromatic waves pass through a double slit, and identify which features of the pattern result from single-slit diffraction and which from two-slit interference.

(4) Calculate, for a two-slit interference pattern, the angles or the positions on a distant screen at which intensity maxima or minima occur.

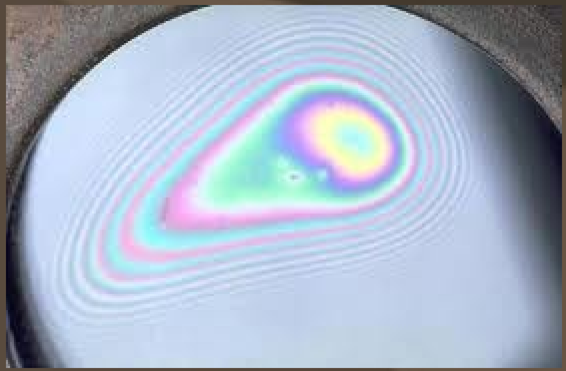
(5) Describe or identify the interference pattern formed by a diffraction grating, calculate the location of intensity maxima, and explain qualitatively why a multiple-slit grating is better than a two-slit grating for making accurate determinations of wavelength.

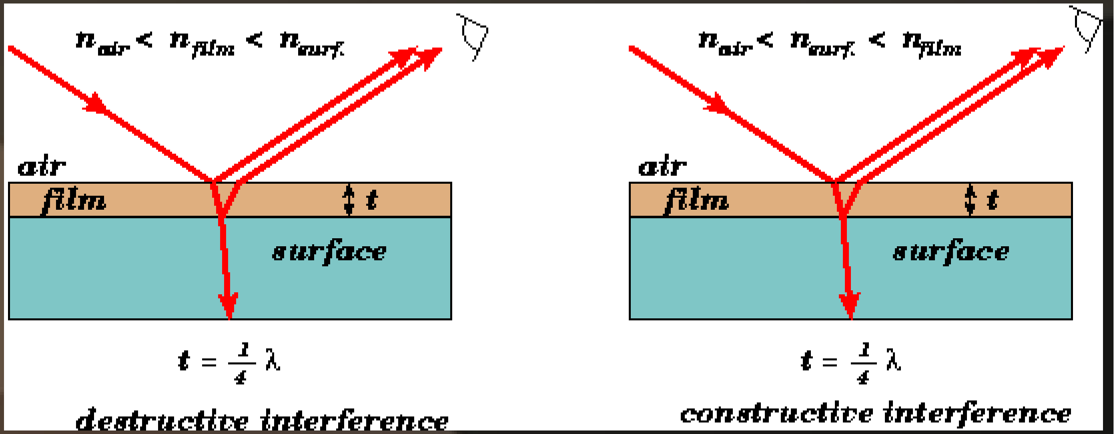
1. Interference and Diffraction

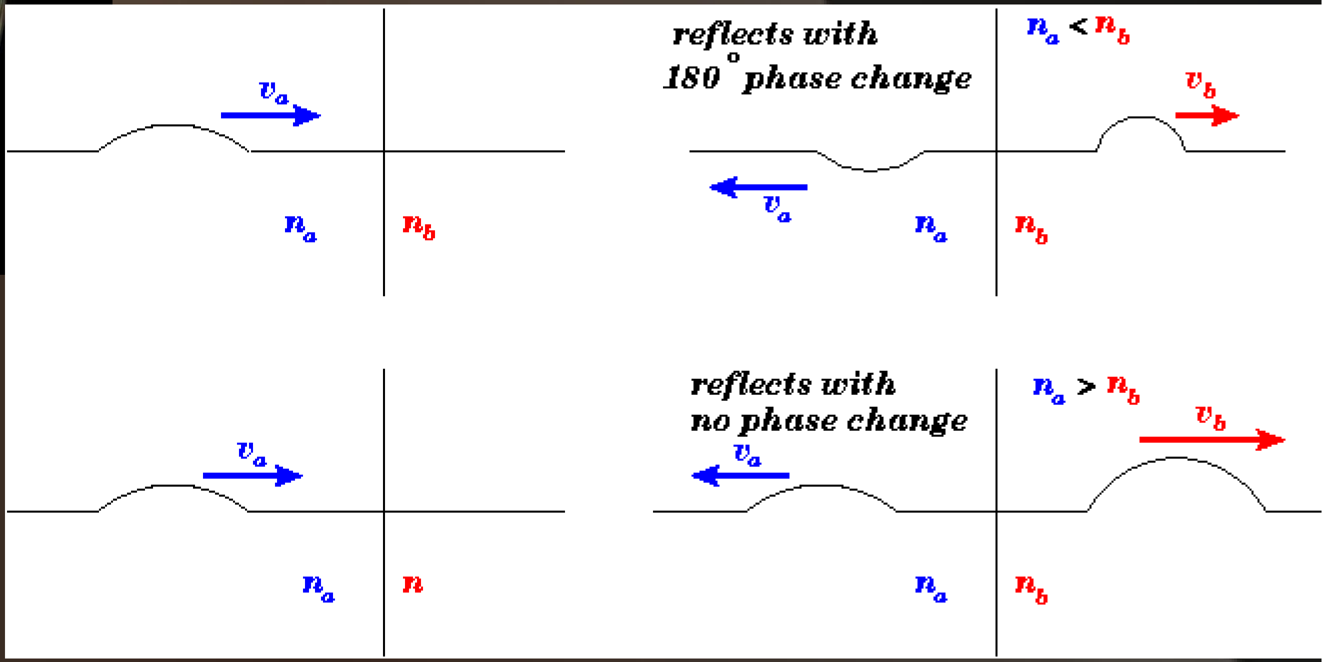
c) Apply the principles of interference to light reflected by thin films, so they can:

(1) State under what conditions a phase reversal occurs when light is reflected from the interface between two media of different indices of refraction.

(2) Determine whether rays of monochromatic light reflected perpendicularly from two such interfaces will interfere constructively or destructively, and thereby account for Newton's rings and similar phenomena, and explain how glass may be coated to minimize reflection of visible light.



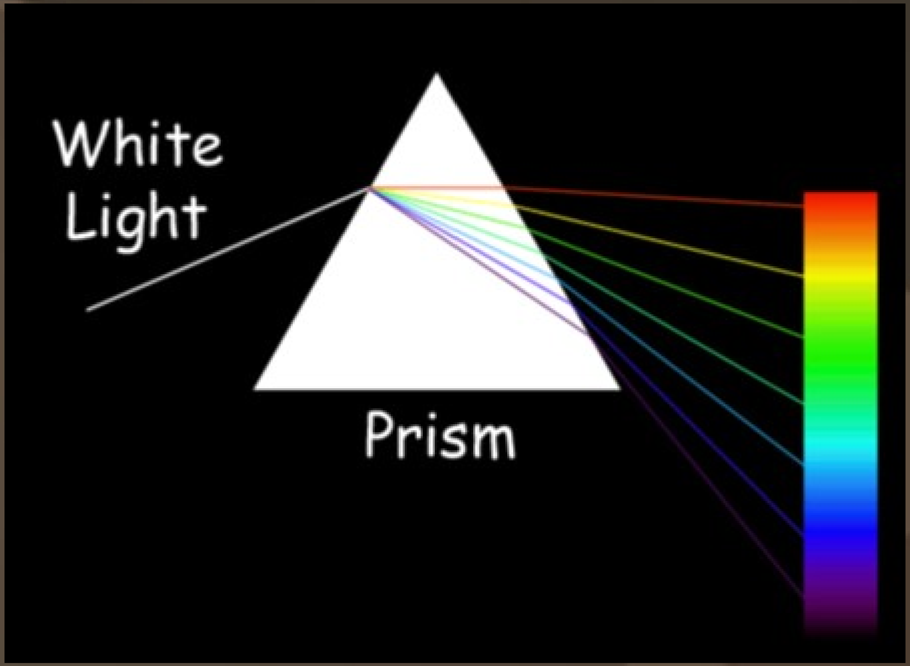

$n_{air} < n_{film} < n_{surf.}$
air
film
t
surface
$t = \frac{1}{4}\lambda$
destructive interference
$n_{air} < n_{surf.} < n_{film}$
air
film
t
surface
$t = \frac{1}{4}\lambda$
constructive interference

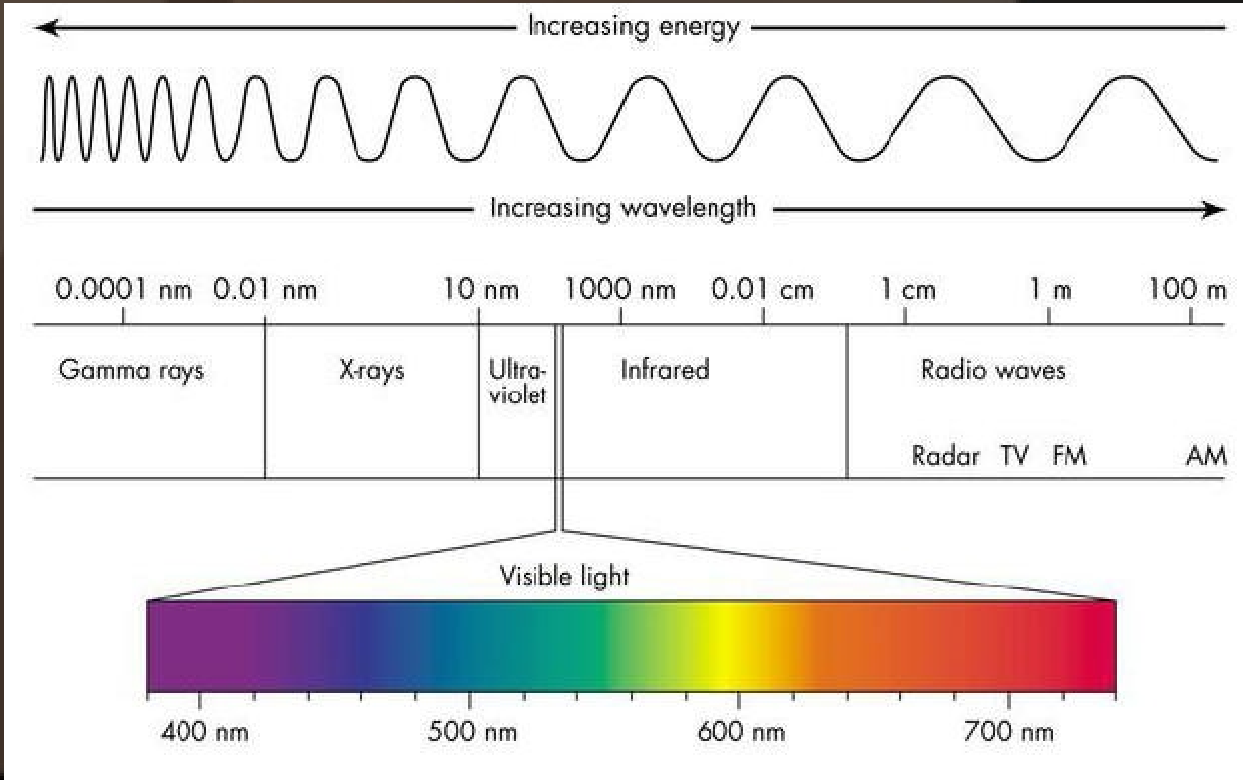

v_a
n_a
n_b
reflects with
180° phase change
$n_a < n_b$
v_b
v_a
n_a
n_b
v_a
n_a
n
reflects with
no phase change
$n_a > n_b$
v_b
v_a
n_a
n_b

2. dispersion of light and the electromagnetic spectrum

a) Relate a variation of index of refraction with frequency to a variation in refraction.

b) Know the names associated with electromagnetic radiation and be able to arrange in order of increasing wavelength the following: visible light of various colors, ultraviolet light, infrared light, radio waves, x-rays, and gamma rays.


White Light
Prism


Increasing energy
Increasing wavelength
0.0001 nm
0.01 nm
10 nm
1000 nm
0.01 cm
1 cm
1 m
100 m
Gamma rays
X-rays
Ultra-violet
Infrared
Radio waves
Radar
TV
FM
AM
Visible light
400 nm
500 nm
600 nm
700 nm