SCIENCE 1210

CONTENTS

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II. WAVE MOTION

In this section you will review wave phenomena in general, sound, and light. The emphasis will be on the behavior of waves and on developing a model for light.

SECTION OBJECTIVES

Read these objectives. When you have completed this section, you should be able:

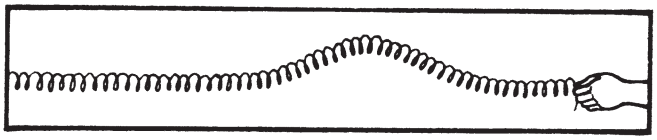
6. To describe transverse and longitudinal waves.
7. To calculate velocity problems for sound and light.
8. To calculate index of refraction problems for light.
9. To draw lens and mirror diagrams.
10. To calculate lens and mirror problems.
11. To describe refraction, diffraction, interference, and polarization.
12. To identify the phenomena that support the particle model and the wave model of light.

WAVES

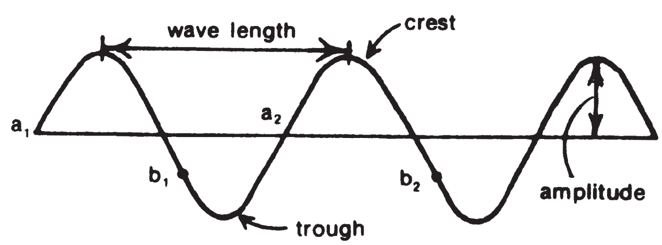
You may wish to review LIGHTUNIT 1204: vocabulary words, types of waves, and wave phenomena.

Water waves and waves on a coil spring can be used to demonstrate frequency, wave length, velocity in a medium, interference, diffraction, refraction at a boundary, reflection, polarization, and dispersion—all the characteristics of light. By analogy, light must have a wave nature. The wave nature of light, however, cannot explain the photoelectric effect, which the particle (quantum) model can explain. The conclusion that must be reached is that light demonstrates different natures under different conditions, but never both natures at once. This set of circumstances is unlike anything else in physics.

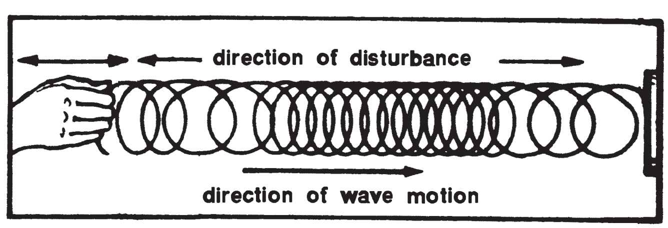
Wave types. A transverse wave oscillates perpendicular to the direction of wave travel. An example of a transverse wave is the motion of water waves (although water waves, in fact, are more complex than simple transverse waves).



Light demonstrates the properties of a transverse wave generated on a taut rope or a stretched spring. The crest is the highest part of the wave and the lowest part is called the trough.



A longitudinal wave oscillates parallel to the direction of the wave travel. Longitudinal waves are also called *compressional* or *pressure*, waves. Sound waves are longitudinal waves like the motion on a stretched spring whose loops have been gathered and then released. Regions



of compression are called *condensations*, and regions of spread are termed *rarefactions*.

Both types of waves transmit energy although the material that carries the wave (the wave medium) moves only about the equilibrium position. Frequency (f) is the number of waves that pass a given point per unit time. The *period* of a wave (T) is the time during which a complete wave passes a fixed point; it is the inverse of frequency ($T = \frac{1}{f}$). Wave length (λ) is the distance between indentical parts of two successive waves. The speed at which the wave travels is defined as the frequency times the wave length ($v = f\lambda$).

Write the letter of the correct choice.

2.1 If light travels at $3 \cdot 10^8 \frac{m}{sec.}$ and its frequency is $6 \cdot 10^{15}$ Hz, then its wave length is _____ .

a. $10 \cdot 10^7$ m
b. $5 \cdot 10^{-7}$ m
c. $0.5 \cdot 10^{-7}$ m
d. $10 \cdot 10^{-7}$ m

2.2 When an earthquake occurs, the fastest wave is called a *primary* wave, or pressure wave (P wave). This wave produces _____ on the surface of the earth.

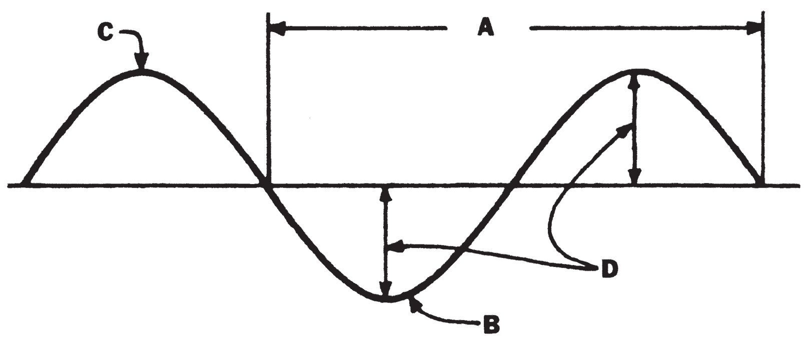
a. a back-and-forth motion
b. an up-and-down motion

2.3 The second type of wave produced by an earthquake is an S wave (secondary wave) which is a transverse wave. It produces _____ on the surface of the earth.

a. a back-and-forth motion
b. an up-and-down motion

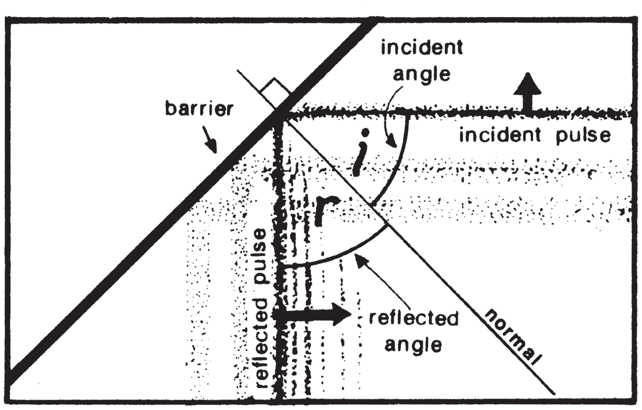
2.4 Refer to the sketch to identify parts of the wave and to answer the question.

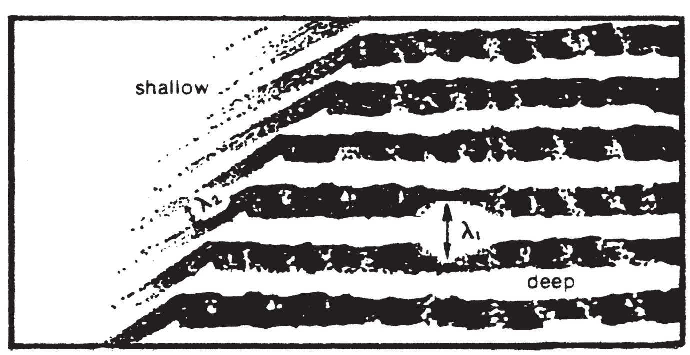
a. crest _____
b. trough _____
c. wave length _____



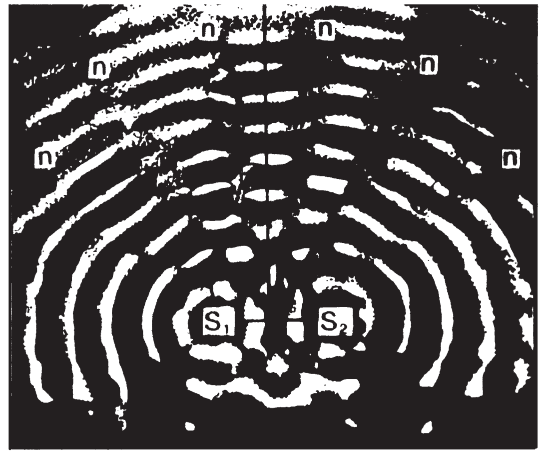
d. Is this a sketch of a transverse wave or a longitudinal wave? __________

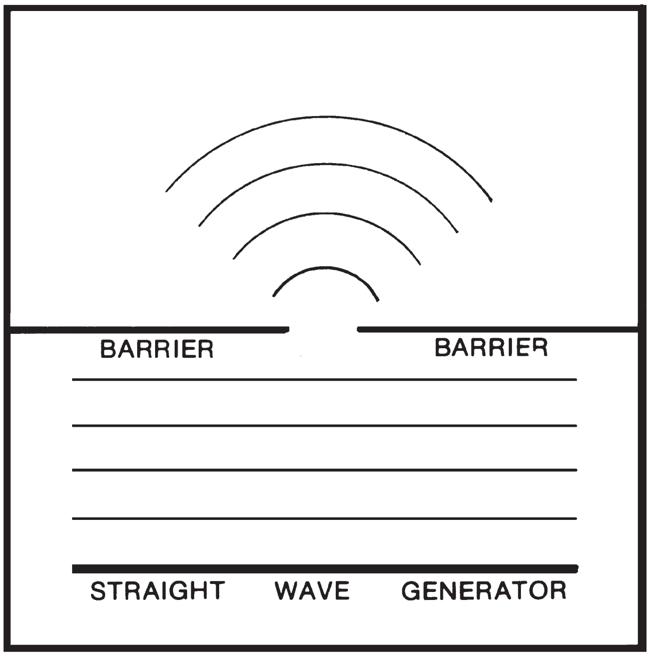
Wave phenomena. Waves exhibit various phenomena. When a wave reaches a boundary and bounces off (*reflects*), the angle of incidence equals the angle of reflection. In addition, when the wave passes into a second medium of a different density or through a nonuniform medium, the wave bends (*refracts*). The angle of refraction is less in the medium of greater density.



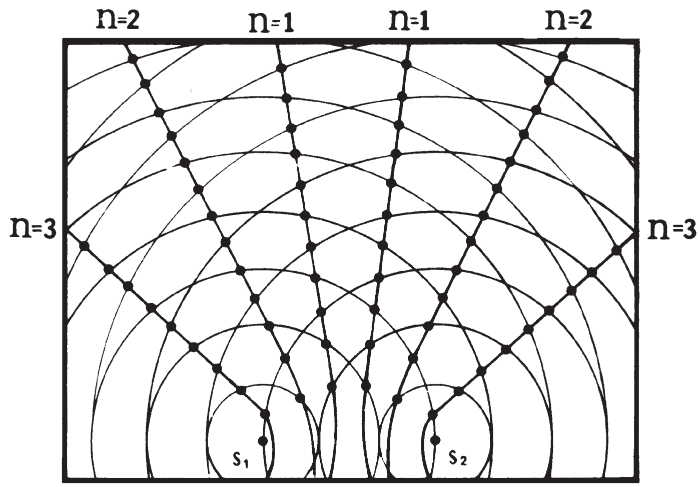


The phenomenon of *diffraction* occurs when waves in a uniform medium bend around the edges of objects or when passing through narrow openings, as when sea waves curve around a breakwater or when sound comes from around a corner.





The areas marked *n* are nodal lines, the locations of destructive interference. Between the nodal lines are antinodes, locations of maximum wave motion (constructive interference).



Interference of waves is the superposition of two periodic waves producing regions of constructive and destructive interference.

Complete these sentences.

2.5 When two waves are superimposed, the result is ______________ .

2.6 A line or region of calm water where waves should be is explained by ____ .

2.7 The pattern of nodes and antinodes is called a(n) ______________ pattern.

2.8 Waves that spread out after passing through a hole in a barrier display ______________ .

2.9 The bending of waves upon entering a different medium is ______________ .

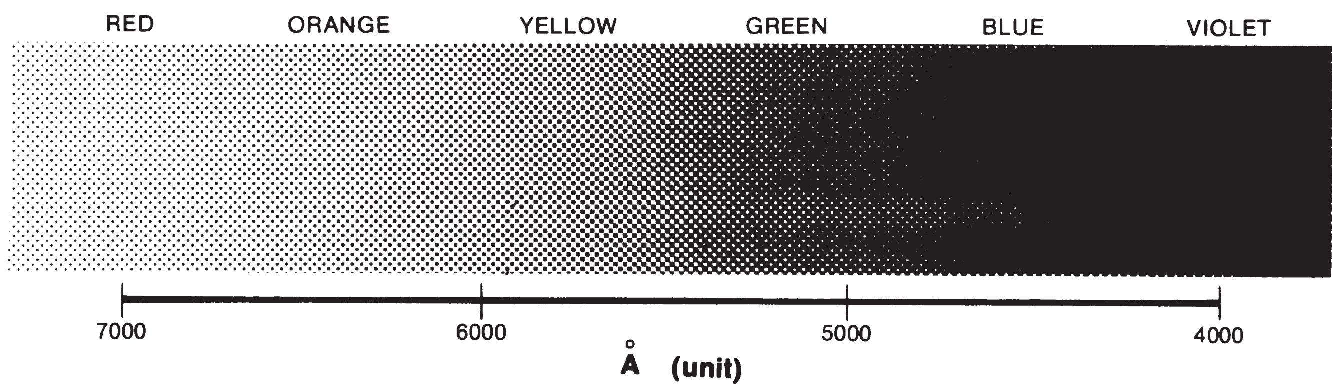
2.10 When waves enter a more dense medium, they bend ______________ (toward, away from) the normal.

LIGHT

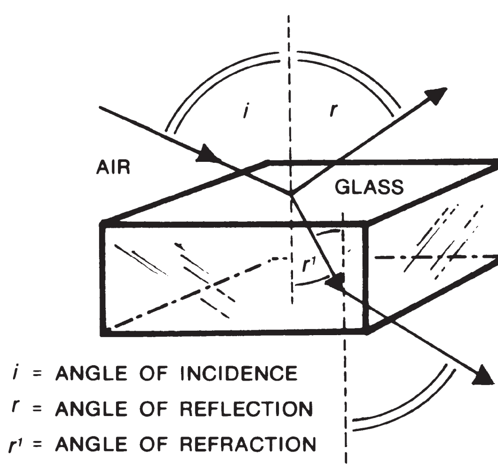
You may wish to review LIGHTUNIT 1205: the vocabulary words and the sections on the properties of light, mirrors and lenses, and models for light.

The traditional approach to light is the construction of ray diagrams. Practical application of this approach is severely limited, and the treatment misses the significance of light behavior. No single description of light explains its behavior under all circumstances. Consequently, the wave/particle duality is presently employed to describe light in place of a full explanation.

Properties of light. The speed of light in a vacuum (c) is a constant equal to $3 \cdot 10^8 \frac{m}{sec.}$. In the conventional system the value of c is $1.86 \cdot 10^5 \frac{mi}{sec.}$. Red light and blue light travel at the same speed. Blue light has the smaller wave length and higher frequency; red light has the longer wave length and lower frequency.



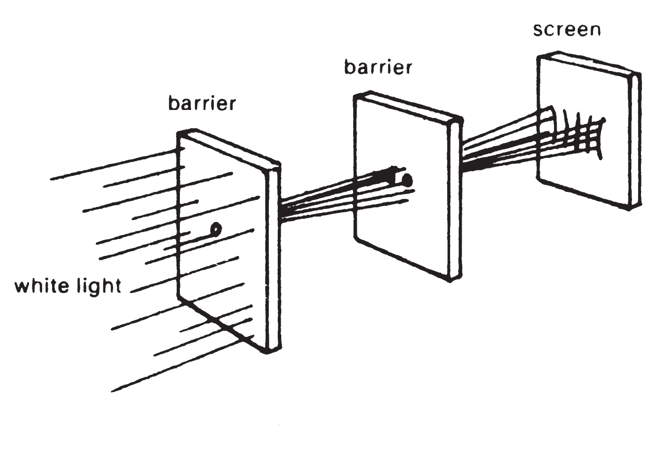
In reflection of light, the angle of incidence equals the angle of reflection. In refraction the angle of refraction is smaller in the denser



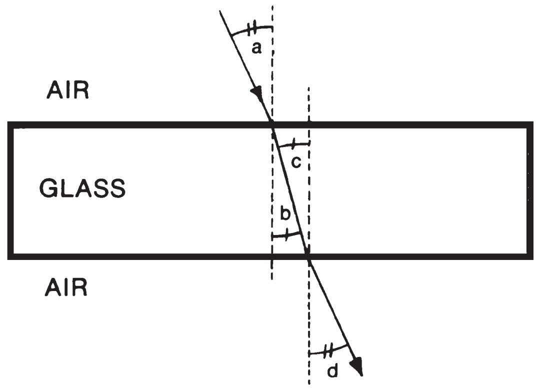
medium. The ratio of the speed of light in a vacuum (c) to the speed in the medium (v) is called the *index refraction (n)*:

$$n = \frac{c}{v}$$

Light passing through narrow slits or pinholes displays a diffraction pattern that can be produced only by interference. Furthermore, light can be polarized.



Write the letter of the correct choice. Refer to the illustration to answer Activities 2.11, 2.12, and 2.13.



2.11 If Angle a is 25°, Angle b is ______.

a. equal to 25°

b. less than 25°

c. greater than 25°

2.12 Angle b is ______ Angle c.

a. equal to

b. less than

c. greater than

2.13 Angle d is ______.

a. equal to 25°

b. greater than 25°

c. less than 25°

Solve this problem.

2.14 If the wave length of orange light is $6 \cdot 10^{-7}$ m, calculate its frequency.