
312

WAVES AND WAVE PROPERTIES
Lesson One (waves)

Energy can be **transferred** by **particles of matter or** by **waves**.

Early studies of waves lead scientists to believe that all waves were **MECHANICAL** (i.e. **required a medium** or substance in which to travel) **WAVES**.

James Clerk **MAXWELL** (1831-1879) developed a theory proposing the existence of **ELECTROMAGNETIC waves** that travel by vibrating ELECTRIC & MAGNETIC fields. Electromagnetic waves did not need to travel through a medium and therefore could travel through a **VACUUM**.

Types of Mechanical Waves:

1) **Longitudinal Wave**:
vibration of the **medium** is **parallel to** energy flow or **wave direction**.

Vibration ⟷
wave motion ⟶

2) **Transverse Wave**:
vibration of the **medium** is **perpendicular** to the energy flow or **wave direction.**

vibration ↕
wave motion ⟶

While **sound** travels as a **longitudinal wave,** the string on a stringed instrument vibrates as a transverse wave. Water travels mainly as transverse waves.
Surface waves are a **combination** of **longitudinal and transverse.** Water can have surface waves.

The **vibration** in **both longitudinal** and **transverse waves** is also **simple harmonic motion** .

Wave Definitions

A. LONGITUDINAL WAVES

1) **compression** - region of medium where longitudinal wave is **most compressed** due the to vibration of medium.

compression compression
I I I I I **IIII** I I I I I **IIII** I I I

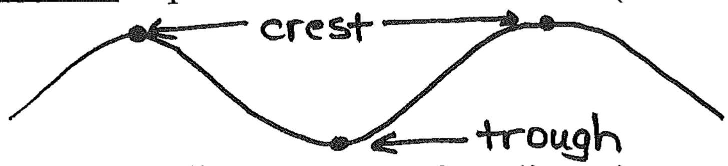
2) **rarefaction** - region of the medium that is **least compressed**.

rarefaction rarefaction
I I I I I IIII **I I I I I** IIII **I I I**

1λ (λ=wavelength) is the **distance from two like points in a wave** which could be from the beginning (middle or end) of a **rarefaction to beginning** (middle or end) of the **next rarefaction** or from the beginning (middle or end) of a **compression to** the beginning (middle or end) of the **next compression**.

B. **TRANSVERSE WAVES**

1) Crest - maximum displacement of the medium (due to a vibration).



2) Trough - maximum displacement of medium, in opposite direction of a crest.

For transverse waves, **1λ** (λ=wavelength) is still the **distance from two like points in a wave** which could be from the beginning (middle or end) of a **crest to** beginning (middle or end) of the **next crest** or from the beginning (middle or end) of a **trough to** the beginning (middle or end) of the **next trough**.

C. **GENERAL TERMS**

1) **Pulse** - a **single** disturbance (one **bump**) in a medium **whereas** a longitudinal or transverse **wave** consists of **several** adjacent **disturbances**. (2 or more bumps)

eg. When **one drop** of water or a pebble hits a pool of water a **pulse** is **created** but when a tap **drips** on a pool of water **waves** are **created**

2) **Wavelength** - the **shortest** **distance** between **two adjacent points** a wave that are **IN PHASE**. Often we use crest to crest. The Greek letter **lambda**, λ, is the **symbol** for **wavelength**.

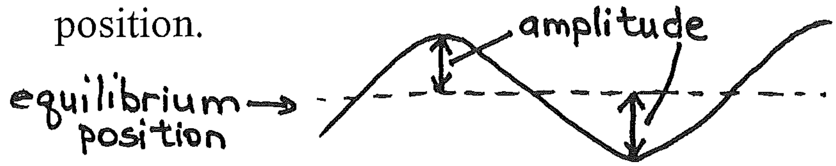
3) **<u>In Phase</u>** - two points in a medium vibrating in the **same direction**, together.

eg. Soldiers marching or points on two crests or two troughs etc.

4) **<u>Out of Phase</u>** - two points in a medium NOT vibrating together.

eg. A crowd walking or a point on a crest and one in a trough

5) **<u>Amplitude</u>** - **maximum displacement** from equilibrium position.



Definitions **1-5** apply to **BOTH types of waves.**

<u>Speed of a Wave</u>

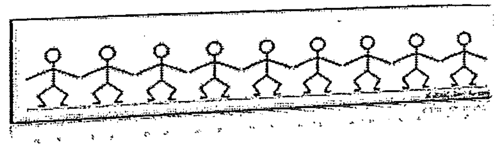
The **<u>speed</u>** <u>of mechanical</u> **<u>wave</u>** **depends** of the **nature** of the **medium** through which it is traveling AND can **ONLY** be **CHANGED** if the **<u>MEDIUM</u>** is **<u>changed</u>.** The speed of a wave is found from a special case of the v = d/t equation and is called the universal wave equation:

<u>Universal Wave Equation</u>

$v=\lambda f$ from $v=\frac{d}{t}$ and $t=\frac{1}{f}$

v → speed in (m/s) λ → (m) f → frequency in Hz (per second)

WAVE CHARACTERISTICS



Optics is the study of the nature of light.

One property of light that physicists in the field of optics are concerned with is how light moves.

Through scientific observation, it has been determined that:

- this is the reason that ________________________________form
- the paths that light travels can also be described through ________________ and ____________________.

WAVES:

Energy moves from one place to another through either **waves** or **particles.**

TYPES OF WAVES:

A. **Mechanical Waves**:

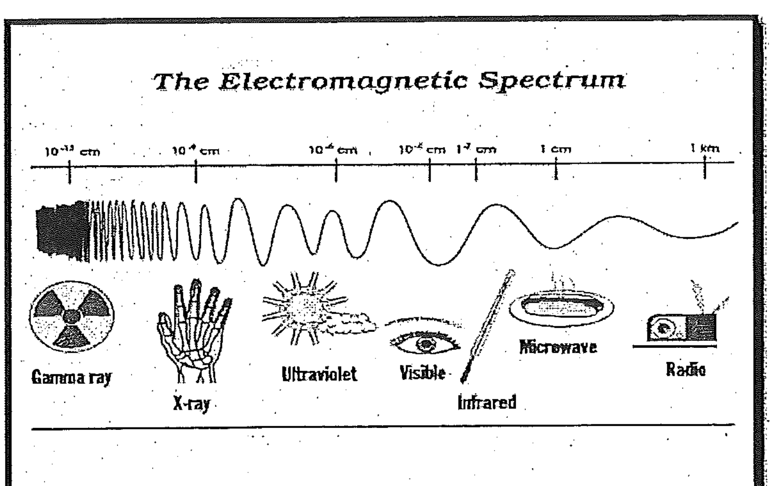
→ need something to travel through

→ they propagate (continue) through the vibration of particles of the material through which they are traveling.

B. **Electromagnetic Waves**

→ by their nature they **move on their own** with no need for a medium to carry them.

→ ex. Radiowaves, microwaves, light waves, x-rays



MECHANICAL WAVES

In **mechanical** waves, the medium is **vibrating**. This vibration can be either:

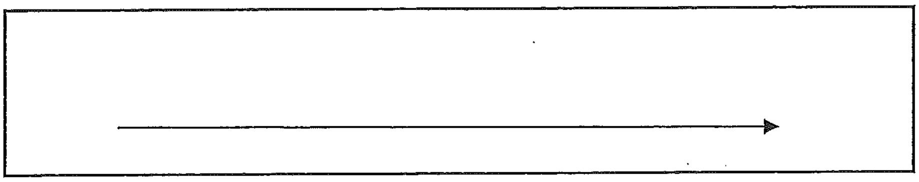
A. Longitudinal

B. Transverse

A. LONGITUDINAL WAVES-

The vibration of medium is ____________________to the energy flow.

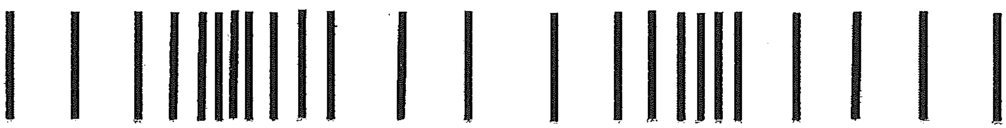
Diagram:



= this wave is composed of **compressions** or **rarefactions.**

Compressions -

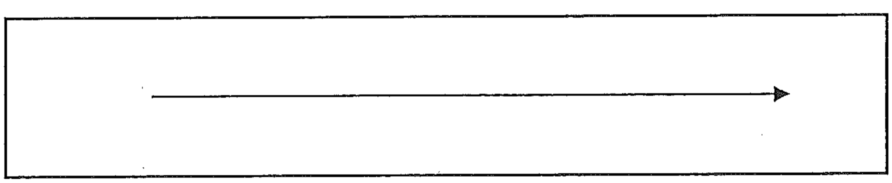
Rarefactions -



B. TRANSVERSE WAVES –

Vibration of medium is _________________________to energy flow.

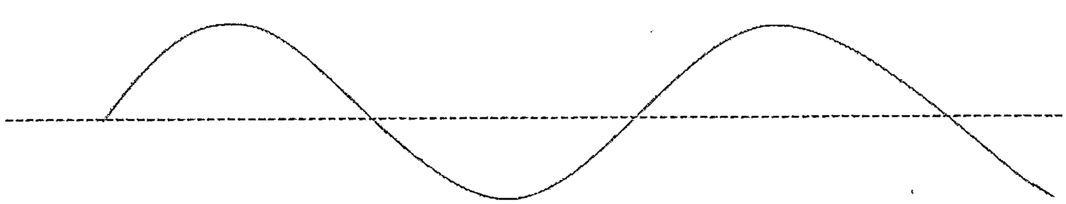
Diagram:



This wave is composed of **crests** and **troughs**.

Crests →

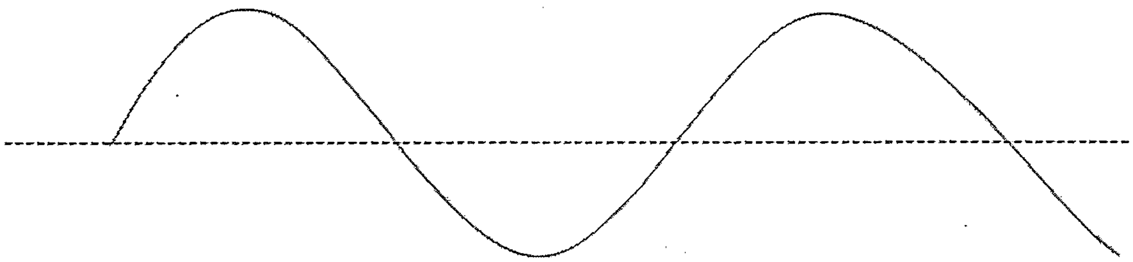
Troughs →



Both are measured from their equilibrium position.

TERMINOLOGY

Amplitude –

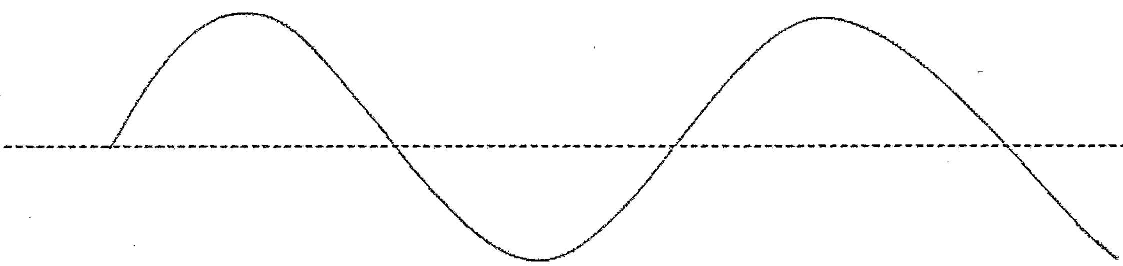


Frequency –

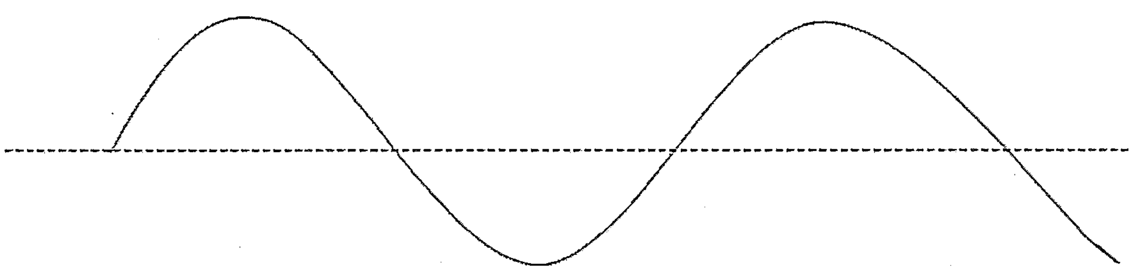
Period –

or

Phase –



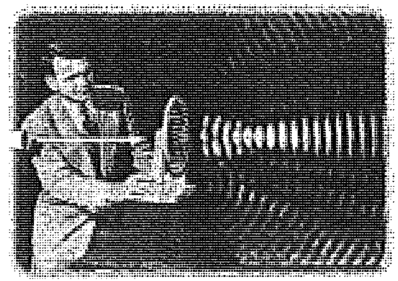
Wavelength –



SPEED OF A WAVE:

The speed of a wave depends on the nature (the make-up) of the medium through which it is traveling.

The speed relies on the density of the material. This is because the closer the particles (higher density), the less time it takes for the particles to excite the ones next to them.



UNIVERSAL WAVE CONTRACTION

Speed can also be determined from its wave characteristics (see terminology on previous page)

Formula:

Examples:

1. A wave has a frequency of 2.10 Hz and a wavelength of 5.30 m. What is its speed?

2. A wave has a speed of 5.0×10^{-1} m/s and a wavelength of 2.0 m. What is its period?

3. 25 crests are seen to pass a single point in 5.0 seconds. What is the frequency of the wave?

Lesson 1

Wave Characteristic Problems

1. A wave has a frequency of 5.0×10^{-1} Hz and a speed of 3.3×10^{-1} m/s. What is the wavelength of this wave? (0.66 m)

2. A form of energy travels as a wave 4.60 m in 2.00 s. What is the speed of the wave? (2.30 m/s)

3. A water wave has a wavelength of 5.0 m and a speed of 2.5 m/s. What is the period of this wave? (2.0 s)

4. 9.5 waves break on the beach in 1.0 min. What is the frequency in hertz of these waves? (0.16 Hz)

5. If sound waves travel at 335 m/s, what is the wavelength of sound that has a period of 1.00×10^{-2} s? (3.35m)

6. A radio station broadcasts at a frequency of 1.00×10^{6} Hz. If the speed of this wave is 3.00×10^{8} m/s, what is its wavelength? (3.00×10^{2} m)

7. While floating on an air mattress in a lake, you notice that you bob up and down 40 times in 5.0 min. You estimate the distance between crests 4.0 m. What is the estimated speed of the water waves? (0.53 m/s)

8. A light has a speed of 3.00×10^{8} m/s. If the length of this wave is 5.00×10^{-7} m, what is its period? (1.67×10^{-15}s)

Reflection of Light

Lesson TWO (waves)

The nature of light (wave versus particle) has produced much controversy. The study of light, in greater depth shows currently light has a **duality of nature**. This means light has some **wave characteristics** and **some particle characteristics**.

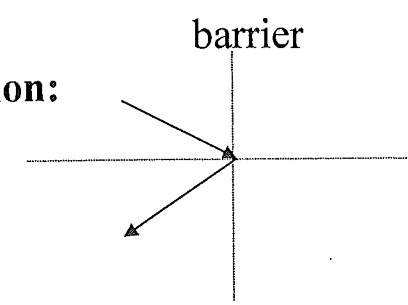
Light will be studied under the two general categories:

i. ray diagrams
ii. wave properties

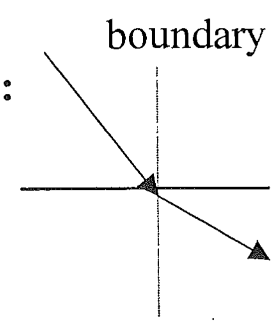
I) Ray Diagrams

Ray diagrams can be used to describe **reflection** and **refraction** and shed some "light" on the particle/wave nature of light.

reflection:



refraction:



II) Wave Properties

Constructive and destructive **interference**, **diffraction**, and **polarization** can **ONLY** occur with waves (not particles). These characteristics of light give support to the **wave nature of light**.

Reflection using Ray Diagrams

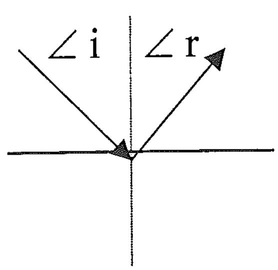
Having previously studied reflection it can be stated that:

- When a **wave** strikes a barrier or boundary, **some** or **all** of the wave is **reflected**.
- When a **particle** strikes a barrier it is also **reflected**.
- Therefore, the property of **reflection supports either wave** or **particle nature of light**

- **Law of Reflection** states:
  The angle of **incidence** = the angle of **reflection**

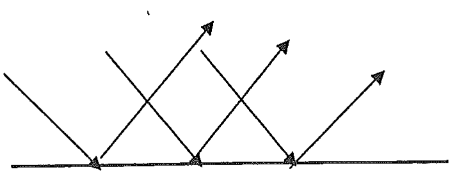
$$\angle i = \angle r$$

$\angle$'s are measured with respect to the **normal**



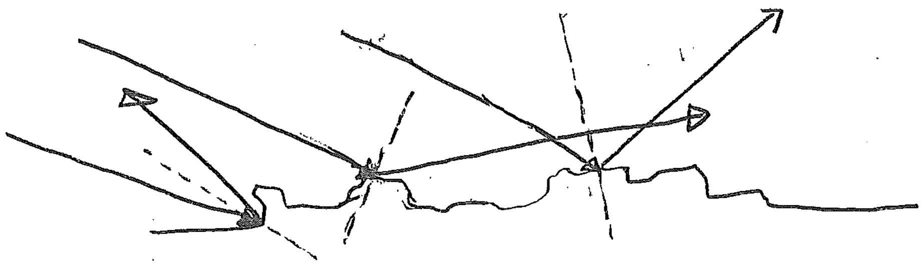
Types of Reflection

1) **Regular reflection**
   -occurs on a **smooth surface**
   -**parallel light rays** are **reflected parallel.**



2) **Diffuse Reflection**

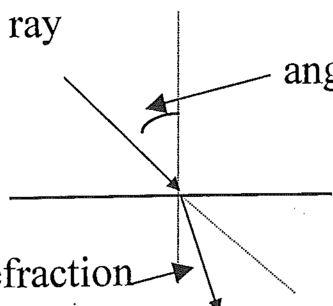
- occurs on a **rough surface.**
- light is **reflected** in **many directions**
- **law of reflection** still **applies.**



Additional Wave properties

Refraction

In addition to being reflected, light can also be refracted.

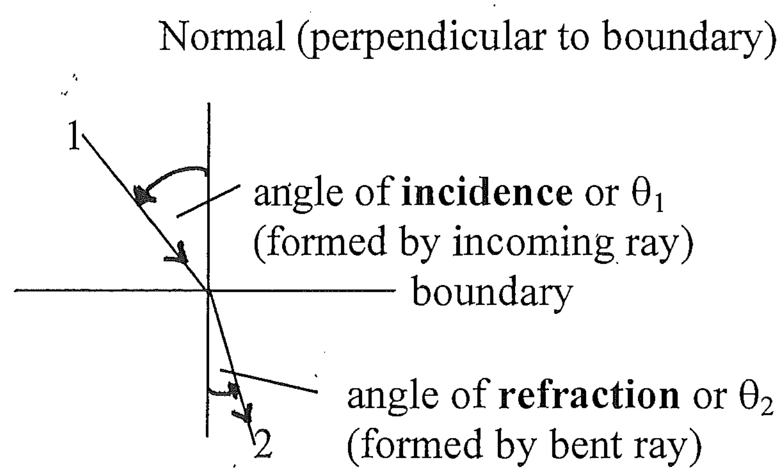


Refraction

When a wave strikes certain substances, it **passes into** the **new medium** rather than being reflected. Upon entering a new medium the wave **changes** its **speed and** the **direction** it was moving. The **change of the wave's direction** as the wave **passes from ONE MEDIUM** (substance) to **ANOTHER** is **called refraction.**

The "**Law of Refraction**" or **Snell's Law** states that:

$$\frac{\sin\theta_1}{\sin\theta_2} = n$$



where **1 = incident wave** and **2 = refracted wave**

angle of **incidence** and angle of **refraction** are also **measured** with respect **to** the **NORMAL**.

"n" is the **constant** called the "**index of refraction**" a **measures** the **extent of refraction** or **bending.**

Since **refraction** is caused by a **change in speed** (from a change in media), it can **also** be shown that:

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2} = \frac{n_2}{n_1}$$

and from $v=\lambda f$, **frequency does not change** because we are not changing the frequency of the source, so '**f**' is **constant even if the media change**.

thus, for frequency to remain constant when **speed changes**,

$$f = \frac{v\uparrow}{\lambda\uparrow} \text{ OR } \frac{\downarrow}{\downarrow}$$

wavelength must also change -speed and wavelength **both increase** or **both decrease, so:**

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2} = \frac{n_2}{n_1}$$

Laws of Refraction

Refraction: **change** in **wave direction** that occurs at the **boundaries** of two mediums.

$$\frac{\sin \varnothing_i}{\sin \varnothing_r} = n \leftarrow \text{index of refraction.} \qquad \frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2} = \frac{\sin\theta_1}{\sin\theta_2} = \frac{n_2}{n_1}$$

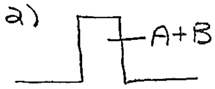
Principle of Superposition

If two or more waves pass a given point at the same time, the displacement is **resultant** (sum) of the displacement which would be produced by each of the waves if it acted separately.

1)

A B

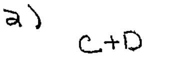
constructive interference: displacement = A + B

2)


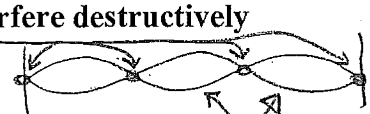
1)

C D

destructive interference: no displacement as C cancels D

2)


Standing waves result when **two waves** travel in **opposite directions, interfering constructively** at some points and **destructively** at others. (see fig 14-16, page 298)



NODE: two waves traveling in opposite directions always **interfere destructively** (**no displacement**)

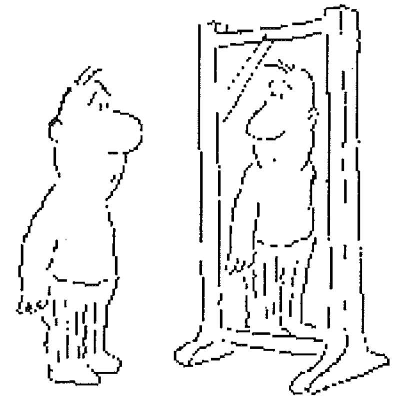
ANTINODE: points midway between nodes where **interfere constructively** (**maximum displacement** occurs here).

Electromagnetic Waves - no medium required
eg. Light, $v = c = 3.00\times10^{8}$ m/s

Mechanical Waves - need **medium**
eg. water, sound, waves in ropes

Pulse: **single disturbance** in a medium traveling wave

REFLECTION OF LIGHT

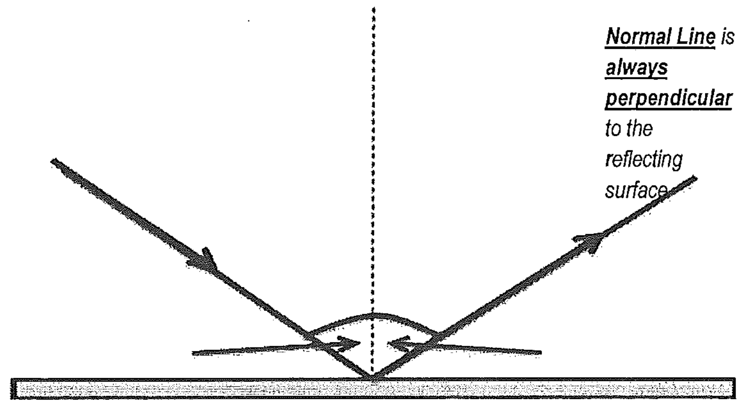


When a wave reaches a boundary, some or all, of the wave **reflects.**

THE LAW OF REFLECTION STATES THAT THE INCIDENCE ANGLE WILL **EQUAL** THE REFLECTED ANGLE.

Light obeys this law because it always travels in a straight line whether it travels in wave or particle form.

Both waves and particles will reflect according to the **law of reflection** –

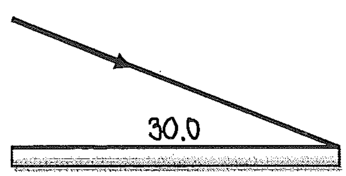


This only applies to **smooth** surfaces. Rough surfaces diffuse the reflection (makes it blurry).

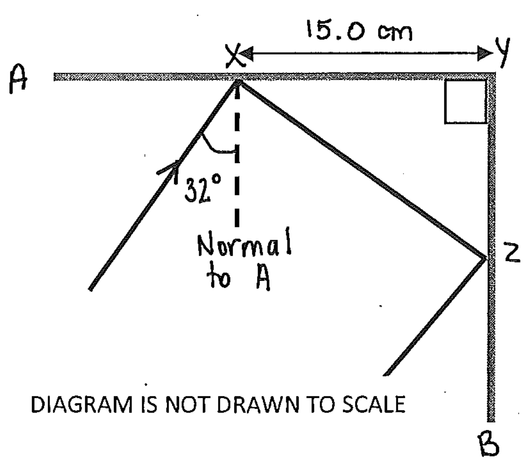
Examples:

1. If the angle of reflection from a mirror is 25.0°, what is the angle of incidence?

2. If a ray of light makes an angle of 30.0° with a mirror as shown in the diagram, what is the reflected angle?



3. A ray of light is reflected in series from two mirrors (A and B) as shown in the diagram. What is the angle of reflection from mirror B?



Waves Reflected from a Barrier or Boundary
Lesson 2 (waves)

- When a **wave** or **wave pulse** hits a **boundary** (between two substances or media) another, **some** of the **energy** carried in the original wave is **transmitted** into the new medium & **some** energy is **reflected.**

- The **pulse** that **passes into** the new medium (i.e. **TRANSMITTED**)is always **ERECT**. The **pulse** that **bounces off** the new medium (i.e. **REDFLECTED**) **depends** on the **media**.

I. **Two Densities & Unfixed end**

Suppose you attached a rope to a slinky and shook the rope while both were stretched out on the floor. A pulse would travel along the rope until it hits the slinky (new medium and a new and in this case greater density). Some of the pulse would be reflected and some of the pulse would be transmitted.

- the **transmitted** pulse is always **erect**

- the **REFLECTED** pulse that occurs when moving **FROM** a **LESS dense** medium **TO** a **MORE dense** medium always **INVERTED** (upside down).

Now, if you used the same rope and slinky, but you shook the other end (the slinky end) a pulse would travel along the slinky until it hit the rope (new medium and a new, and in this case lesser density).

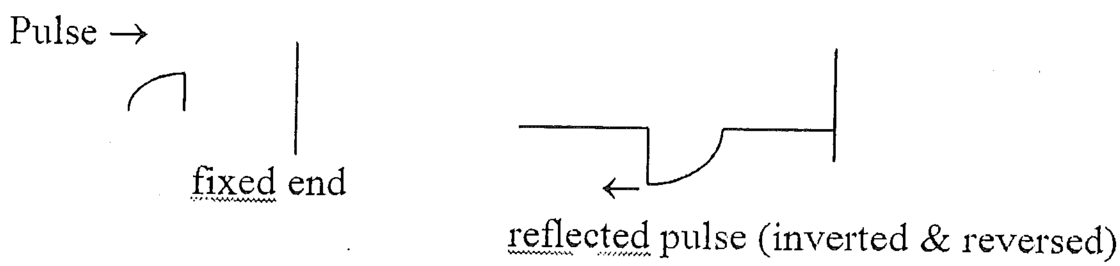
- the **transmitted** pulse is always **erect**

- the **REFLECTED** pulse that occurs when moving **FROM** a **MORE dense** medium **TO** a **LESS dense** medium, is always **ERECT** (in the same direction as the original pulse).

II. One Density and a Fixed End

Suppose you nail a rope to a wall so that the one end is fixed. Then you shake the other end of the rope. The pulse created will be reflected from the wall.

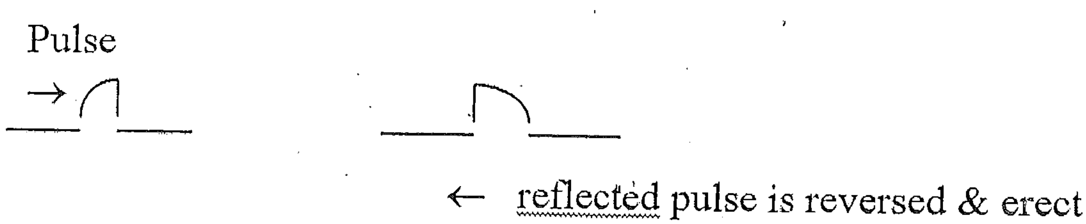
- the **REFLECTED** pulse that is produced from striking a **fixed boundary** is both **INVERTED & REVERSED**:



III. One density, end unfixed

Suppose you stretched a rope along the floor and shook one end. When the pulse reached the end of the rope some of it would be reflected back along the rope.

- The **REFLECTED** pulse produced from reaching and returning from an **UNFIXED end** is **REVERSED** and erect.



Lesson 2 (waves)

Practice Problems: Reflection

1. If the angle of incidence of a ray of light to a mirror is 50.0°, what is the angle of reflection from the mirror?

(50.0°)

2. If the angle of incidence of a ray of light to a mirror is 20.0°, what angle does the light ray make with the mirror when it reflects?

(70.0°)

3. If a ray of light makes an angle of 58° with a mirror, what is the angle between the incident ray and the reflected ray?

(64°)

4.

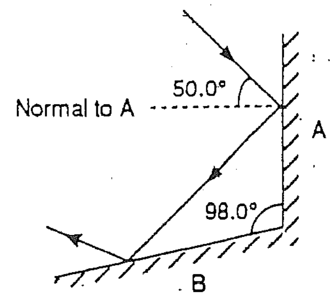


Diagram is not drawn to scale

A ray of light is reflected in series from two mirrors (A and B) as shown in the diagram. What is the angle of reflection from mirror B?

(48.0°)

5.

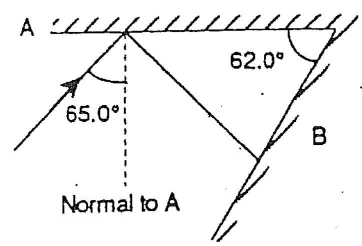


Diagram is not drawn to scale

A ray of light is reflected in series from two mirrors (A and B) as shown in the diagram. What is the angle of reflection from mirror B?

(3.0°)

20. If a string is vibrating in four parts, there are points it can be touched without disturbing its motion. Explain. How many points exist?
21. How does the pulse reflected from a rigid wall differ from the incident pulse?
22. Is interference a property of only some types of waves or all types of waves?

APPLYING CONCEPTS Lesson 4: 1–9, 15 (next page) PLUS Reviewing Concepts 17–22

1. George holds a 1-m metal bar in his hand and hits its end with a hammer; first, in a direction parallel to its length; second, in a direction at right angles to its length. Describe the waves George produces in the two cases.
2. You repeatedly dip your finger into a sink full of water to make circular waves. What happens to the wavelength as you move your finger faster?
3. What happens to the period of a wave as the frequency increases?
4. What happens to the wavelength of a wave as the frequency increases?
5. Joe makes a single pulse on a stretched spring. How much energy is required to make a pulse with twice the amplitude?
6. In each of the four waves in Figure 14–22, the pulse on the left is the original pulse moving toward the right. The center pulse is a reflected pulse; the pulse on the right is a transmitted pulse. Describe the boundaries at **A**, **B**, **C**, and **D**.

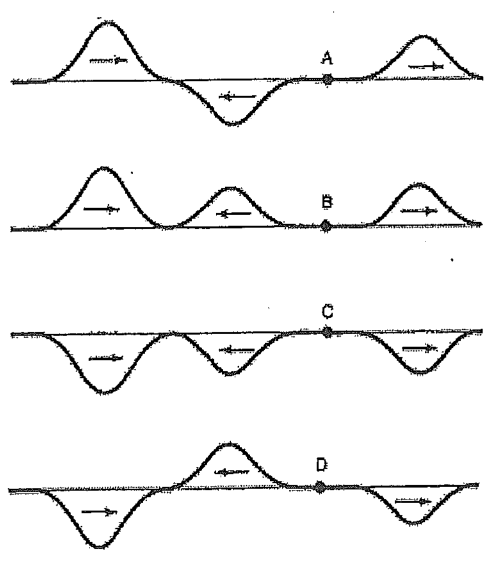


FIGURE 14-22. Use with Applying Concepts 6.

7. Sonar is the detection of sound waves reflected off boundaries in water. A region of warm water in a cold lake can produce a reflection, as can the bottom of the lake. Which would you expect to produce the stronger echo? Explain.
8. You can make water slosh back and forth in a shallow pan only if you shake the pan with the correct frequency. Explain.
9. AM radio signals have wavelengths between 600 m and 200 m, while FM signals have wavelengths about 3 m. Explain why AM signals can often be heard behind hills while FM signals cannot.

MORE PROBLEMS Lesson 2 (circled ones)

14.1 Wave Properties

1. The Sears Building in Chicago sways back and forth with a frequency of about 0.10 Hz. What is its period of vibration?
2. An ocean wave has a length of 10.0 m. A wave passes a fixed location every 2.0 s. What is the speed of the wave? (5.0 m/s)
3. Water waves in a shallow dish are 6.0 cm long. At one point, the water oscillates up and down at a rate of 4.8 oscillations per second.
   a. What is the speed of the water waves?
   b. What is the period of the water waves?
4. Water waves in a lake travel 4.4 m in 1.8 s. The period of oscillation is 1.2 s.
   a. What is the speed of the water waves? (2.4 m/s)
   b. What is their wavelength? (2.9 m)
5. The frequency of yellow light is 5.0×10^{14} Hz. Find its wavelength. (6.0×10^{-7} m)
6. A group of swimmers is resting in the sun on an off-shore raft. They estimate that 3.0 m separates a trough and an adjacent crest of surface waves on the lake. They count 14 crests that pass by the raft in 20 s. How fast are the waves moving?
7. AM radio signals are broadcast at frequencies between 550 kHz and 1600 kHz (kilohertz) and travel 3.0×10^{8} m/s.
   a. What is the range of wavelengths for these signals? (5.5×10^{2} m to 1.9×10^{2} m)
   b. FM frequencies range between 88 MHz and 108 MHz (megahertz) and travel at the same speed. What is the range of FM wavelengths? (3.4 m to 2.8 m)

(2)

8. A sonar signal of frequency 1.00×10^6 Hz has a wavelength of 1.50 mm in water.
   a. What is the speed of the signal in water?
   b. What is its period in water?
   c. What is its period in air?

(a) 1.5 m/s b) 1.00×10^{-6} s c) 1.00×10^{-6} s)

9. A sound wave of wavelength 0.70 m and velocity 330 m/s is produced for 0.50 s.
   a. What is the frequency of the wave?
   b. How many complete waves are emitted in this time interval?
   c. After 0.50 s, how far is the front wave from the source of the sound?

(a) 470 Hz b) 240 waves c) 170 m)

10. The speed of sound in water is 1498 m/s. A sonar signal is sent from a ship at a point just below the water surface and 1.80 s later the reflected signal is detected. How deep is the ocean beneath the ship?

(1350 m)

▸11. The velocity of the transverse waves produced by an earthquake is 8.9 km/s, while that of the longitudinal waves is 5.1 km/s. A seismograph records the arrival of the transverse waves 73 s before that of the longitudinal waves. How far away was the earthquake?

▸12. The velocity of a wave on a string depends on how hard the string is stretched, and on the mass per unit length of the string. If T is the force exerted on the string, and μ is the mass/unit length, then the velocity, v, is

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

A piece of string 5.30 m long has a mass of 15.0 g. What must the force on the string be to make the wavelength of a 125 Hz wave 120.0 cm?

13. The time needed for a water wave to change from the equilibrium level to the crest is 0.18 s.
   a. What fraction of a wavelength is this?
   b. What is the period of the wave?
   c. What is the frequency of the wave?

14.2 Wave Interference

▸14. The wave speed in a guitar string is 265 m/s. The length of the string is 63 cm. You pluck the center of the string by pulling it up and letting go. Pulses move in both directions and are reflected off the ends of the string.
   a. How long does it take for the pulse to move to the string end and return to the center?
   b. When the pulses return, is the string above or below its resting location?
   c. If you plucked the string 15 cm from one end of the string, where would the two pulses meet?

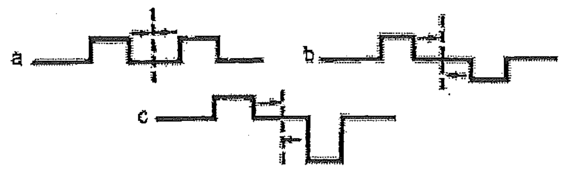


FIGURE 14-23. Use with Problem 15.

15. Sketch what happens, for each of the three cases shown in Figure 14–23, when centers of the two wave pulses lie on the dashed line so the pulses exactly overlap.

(more lesson 4)

16. If you slosh the water back and forth in a bathtub at the correct frequency, the water rises first at one end and then at the other. Suppose you can make a standing wave in a 150-cm long tub with a frequency of 0.30 Hz. What is the velocity of the water wave?

THINKING PHYSIC-LY

1. Why can animals such as bats, that have tiny, light-weight ear parts, hear sounds with much higher frequencies than humans can hear?
2. If you put one ear under water in a bath tub, you can hear sounds from other parts of the house or apartment building where you live. Why is this true?

Physics 11 WAVES

- When a wave moves from a less dense to a more dense medium, the reflected wave is inverted. When it moves from a more dense to a less dense medium, the reflected wave is erect.
- The principle of superposition states that the displacement of a medium due to two or more waves is the algebraic sum of the displacements caused by the individual waves.
- The result of the superposition of two or more waves on a medium is called interference. Interference does not affect the individual waves.
- Maximum destructive interference produces a node where there is no displacement. Maximum constructive interference results in an antinode, a location of the largest displacement.
- The nodes and antinodes of a standing wave are stationary.
- The law of reflection states that the angle of incidence is equal to the angle of reflection. Waves are reflected from a barrier at the same angle at which they approach it.
- The change in the direction of waves at the boundary between two different media is known as refraction.
- The spreading of waves around the edge of a barrier is called diffraction.

KEY TERMS

transverse wave	constructive interference
longitudinal wave	destructive interference
surface waves	node
wave pulse	antinode
traveling wave	standing wave
period	normal
frequency	angle of incidence
wavelength	angle of reflection
crests	law of reflection
troughs	refraction
amplitude	diffraction
principle of superposition	
interference	

REVIEWING CONCEPTS Lesson 3: 1-16

1. How many general methods of energy transfer are there? Give two examples of each.
2. What is the primary difference between a mechanical wave and an electromagnetic wave?
3. What is the difference among transverse, longitudinal, and surface waves?
4. Rhonda sends a pulse along a rope. How does the position of a point on the rope, before the pulse comes, compare to the position after the pulse has passed?
5. What is the difference between a pulse and a wave?
6. What is the difference between wave frequency and wave velocity?
7. Suppose you produce a transverse wave by shaking one end of a spring back and forth. How does the frequency of your hand compare with the frequency of the wave?
8. Waves are sent along a spring of fixed length.
   a. Can the speed of the waves in the spring be changed? Explain.
   b. Can the frequency of a wave in the spring be changed? Explain.
9. What is the difference between the speed of a transverse wave pulse down a spring and the motion of a point on the spring?
10. Sharon is lying on a raft in the wave pool. Describe to Sharon, in terms of the waves she is riding, each of the following: amplitude, period, wavelength, speed, frequency.
11. What is the amplitude of a wave and what does it represent?
12. What is the relationship between the amplitude of a wave and the energy carried?
13. When a wave reaches the boundary of a new medium, part of the wave is reflected and part is transmitted. What determines the amount of reflection?
14. A pulse reaches the boundary of a medium more dense than the one from which it came. Is the reflected pulse erect or inverted?
15. A pulse reaches the boundary of a medium less dense than the one from which it came. Is the reflected pulse erect or inverted?
16. When a wave crosses a boundary between thin and thick rope, its wavelength and velocity change, but its frequency does not. Explain why the frequency is constant.

more Lesson 4 17-22

17. When two waves interfere, is there a loss of energy in the system? Explain.
18. What happens to the spring at nodes of a standing wave?
19. A metal plate is held fixed in the center and sprinkled with sugar. Using a violin bow, the plate is stroked along one edge and made to vibrate. The sugar begins to collect in certain areas and move away from others. Describe these regions in terms of standing waves.

Lesson 3 (waves)

PHYSICS LAB : Waves on a Snakey

Purpose

To investigate properties of waves using a snakey as a model.

Materials

- a long coil spring (snakey)
- stopwatch
- meter stick

Procedure

1. You will need a clear path of about 6 meters for this activity.
2. Slowly stretch the snakey to the length suggested by your instructor.
3. Grip the snakey firmly with one hand for the entire activity.
4. It is easier to see the motion of the snakey if you are near one end. Don't watch from the side.
5. As the pulses die out, they can still be felt. Trust your feelings!
6. This activity is a sensual experience. Each student in the group should take some time on the end of the snakey.
7. Make a quick sideways snap with your wrist to produce a transverse pulse in the snakey.
8. Notice how many times the pulse will move back and forth on the snakey.
9. Look closely at the questions in the observation section. Try to design and conduct an experiment to answer each question.

Observations and Data

1. What happens to
   a. the amplitude of a wave as it travels?
   b. the speed of a wave as it travels?
2. Does the speed depend on the amplitude?
3. Put 2 quick pulses into the snakey. The distance between pulses is called λ. Does λ change as the pulses move?
4. What can you do to decrease the value of λ?
5. Do pulses bounce off each other or pass through?

Analysis

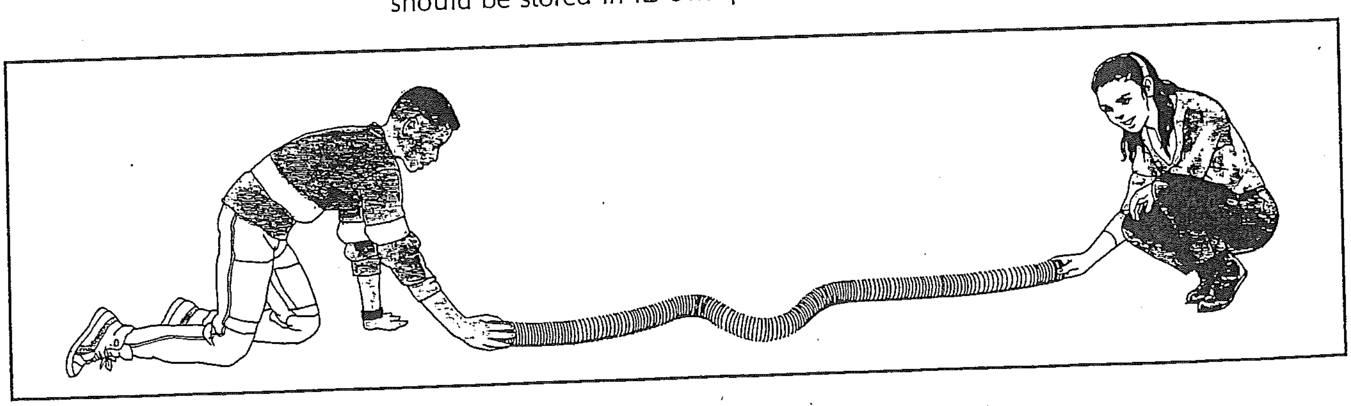
1. You probably used transverse waves for this activity. Should your answers be accurate for pressure (longitudinal) waves? Why?
2. Check your answers for steps 1-3 with *pressure* waves.
3. Use the snakey to find out if pressure waves go through each other. Describe your results.

Applications

Sound waves are pressure waves. Make your predictions consistent with your snakey results.

1. Does the speed of the sound depend on the loudness? (Do louder sounds travel *faster* than quiet sounds?)
2. Compare the speed of high frequency (short wavelength) sounds to low frequency (long wavelength) sounds.

* NOTE * Snakeys are *NOT SOCIAL*. Do not allow the snakeys to get tangled together! Each snakey should be stored in its own personal container!



Interference of Waves Lesson 4 (waves)

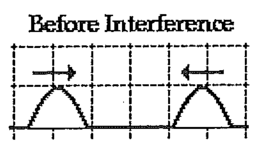
What happens when two waves meet while they travel through the same medium? What effect will the meeting of the waves have upon the appearance of the medium? Will the two waves bounce off each other upon meeting or will the two waves pass through each other?

Wave Interference occurs ______________________________________ ______________________________________. To begin our exploration of wave interference, consider two pulses of the same amplitude traveling in different directions along the same medium.

<u>PRINCIPLE OF SUPERPOSITION</u> – **states that when there are two or more sources of waves in a medium, these waves will combine to give a resultant wave that is the algebraic sum of all the waves.**

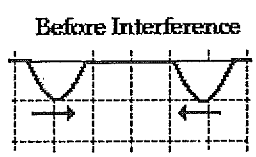
CONSTRUCTIVE INTERFERENCE:

Crest meets Crest:

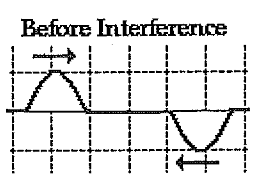


When a crest from one source meets a crest from another source, the energies ________________ to displace the medium (we add the energies together).

Trough meets Trough:



DESTRUCTIVE INTERFERENCE:

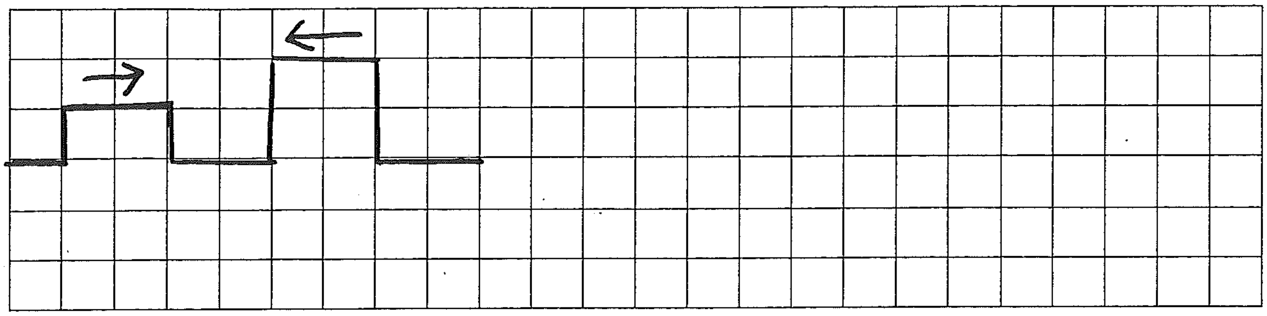


When a crest and a trough meet, the energies ________________________ ______________________ – they tend to cancel out.

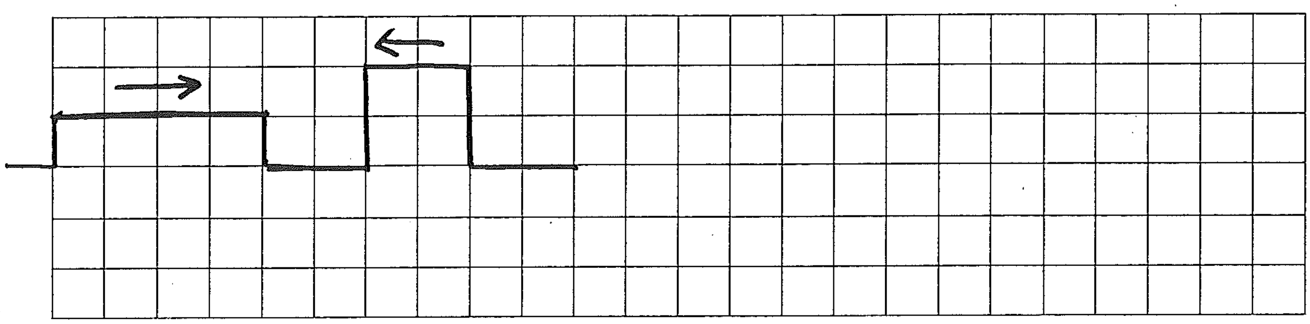
In both cases – constructive and destructive, the energies (crest and trough) pass through each other, only having an effect _____________________. .

Example: For simplicity, we will use square waves to illustrate interference.

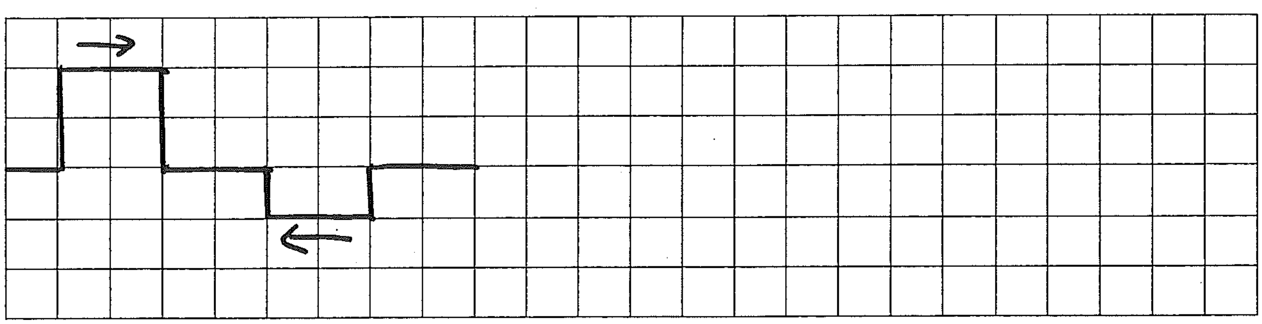
1. Two positive pulses of equal wavelength. What is the resultant?



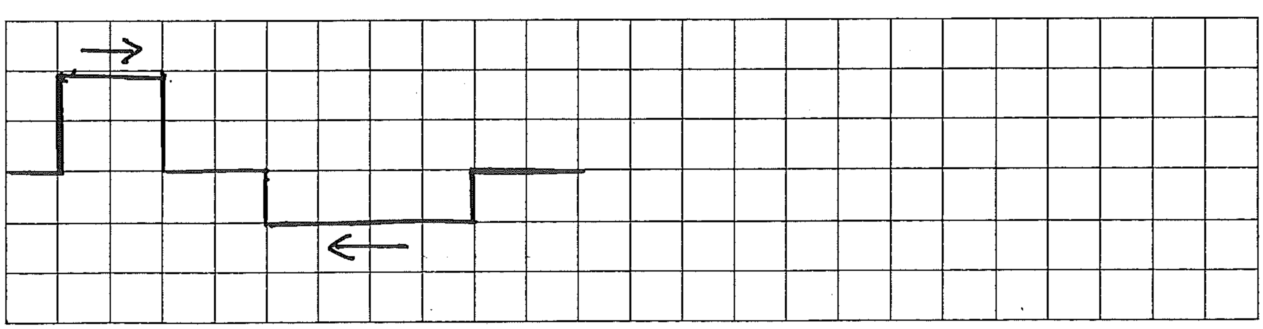
2. Two positive pulses of unequal wavelength. What is the resultant?



3. One positive and one negative pulse of equal wavelength. What is the resultant?



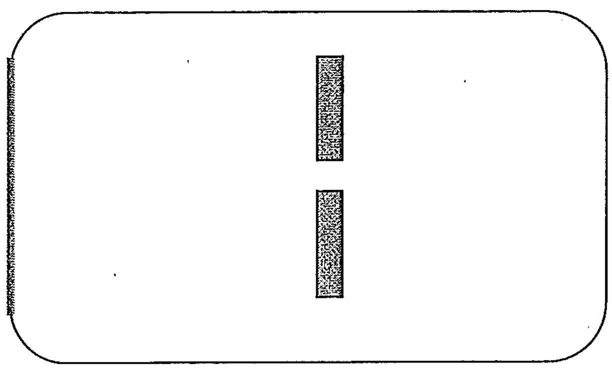
4. One positive and one negative pulse of unequal wavelength. What is the resultant?

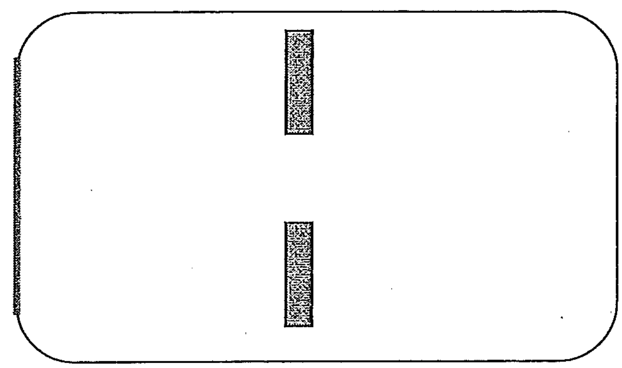


Diffraction

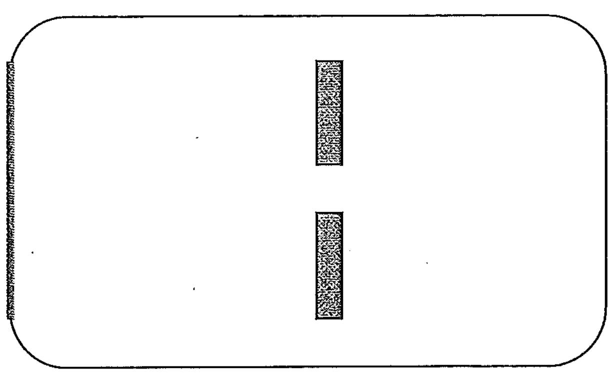
– the **spreading out of a wave** as it **passes through a small opening or around an obstacle.**
- **only waves refract**, <u>particles do not</u>.

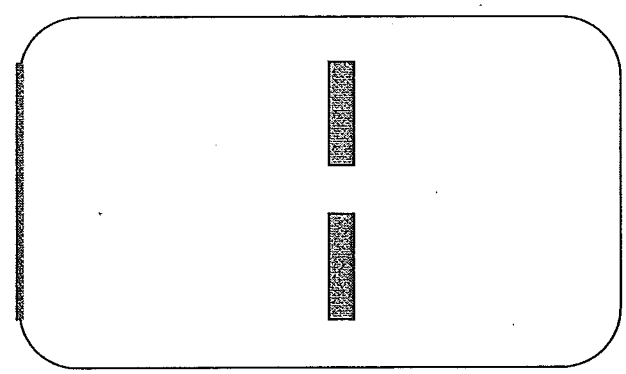
a) Size of the opening: the amount of diffraction (spreading out) depends on the size of the opening.





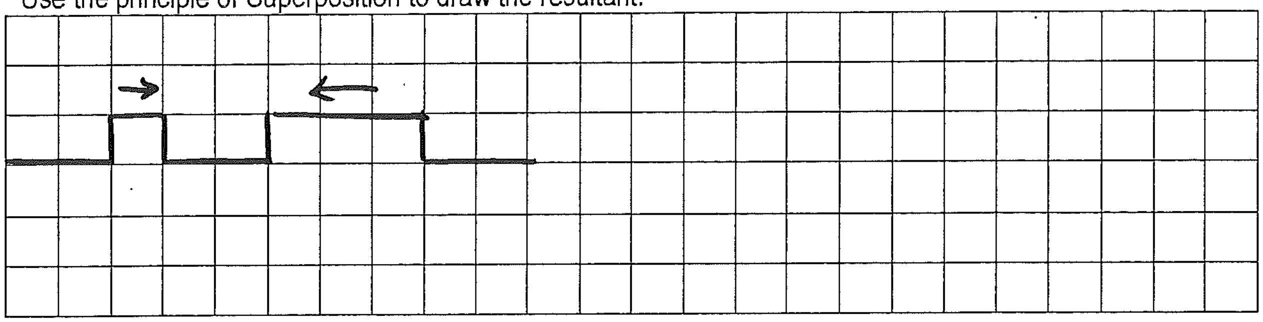
b) The wavelength

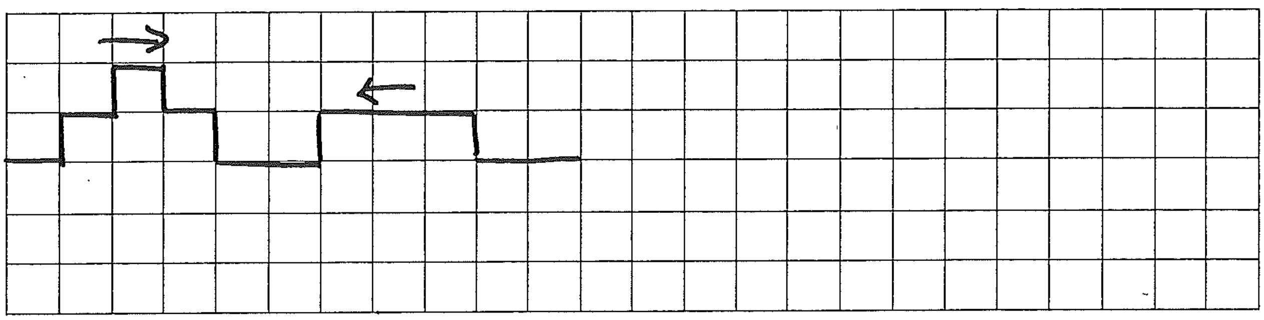


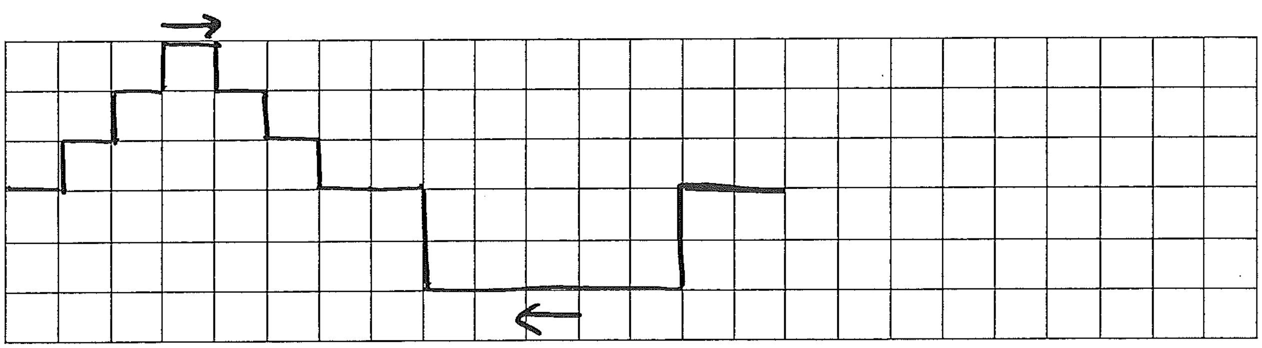


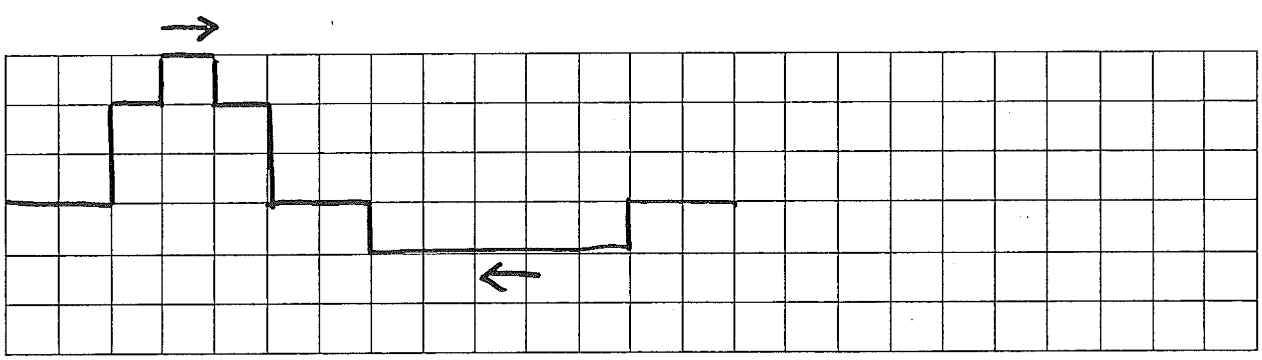
Constructive and Destructive Interference – Problems

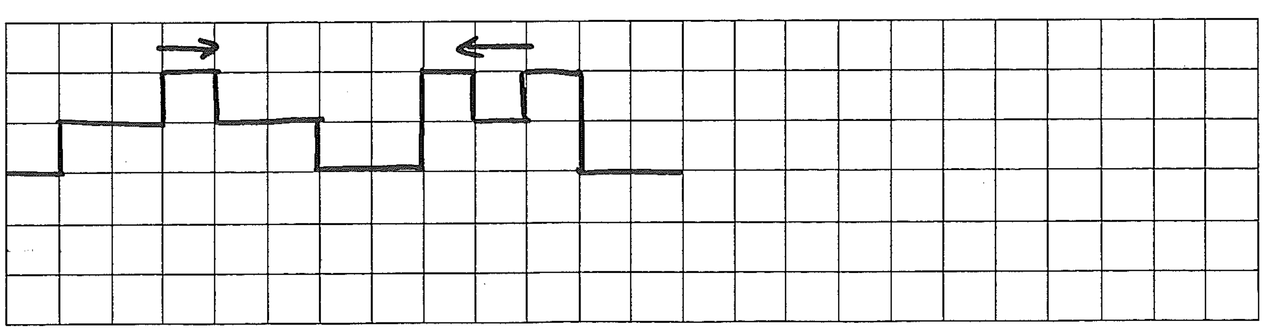
Use the principle of Superposition to draw the resultant.



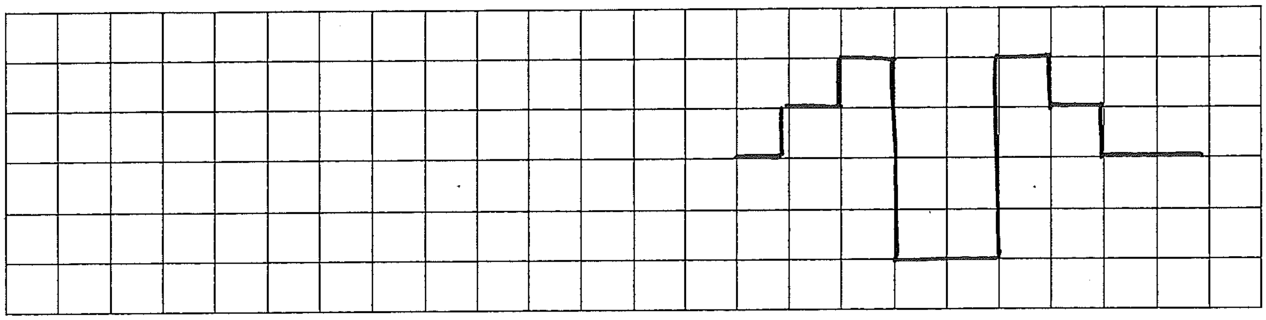




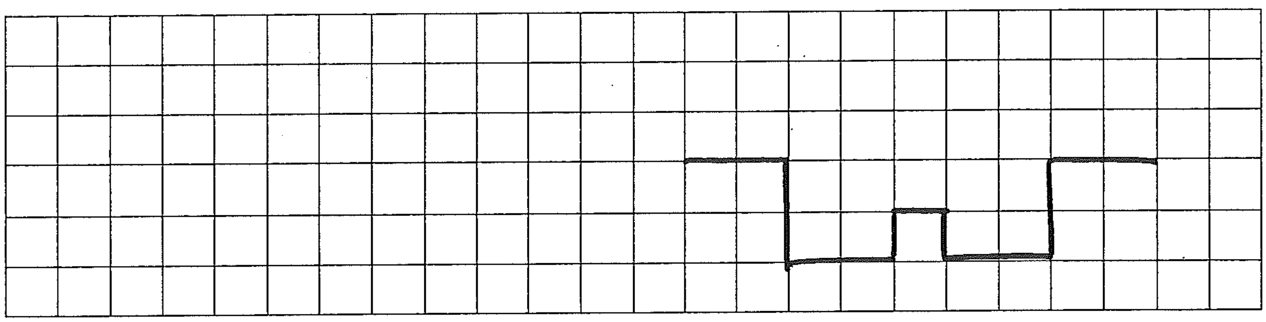




Draw two possible waves that could have formed this resultant. Answers will vary.

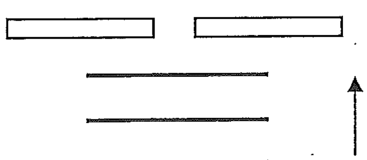


Draw two possible waves that could have formed this resultant. Answers will vary.

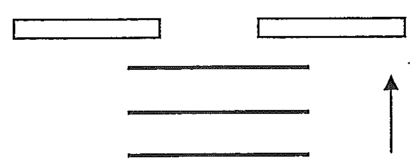


Draw the diffraction that will occur in each of the following cases.

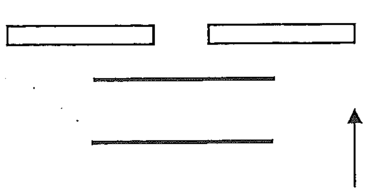
A. Opening Size



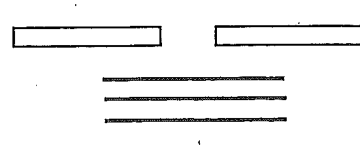
B. Opening Size



C. Wavelength



D. Wavelength



Lesson 5 (waves)

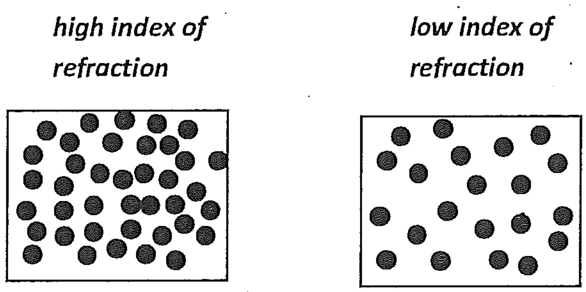
Refraction of Light – Snell's Law

When light strikes the interface between two transparent materials such as air and water, part of the incident light is reflected, and the remainder passes into the new material and experiences a change in speed due to the difference in density (optical density).

INDEX OF REFRACTION:

Every transparent medium will bend light and every medium refracts it differently. Therefore, <u>every transparent medium has its own characteristic index of refraction.</u>

As light moves from one medium to another and the index of refraction changes, the speed of the light will change. This is because the new material will have a different density (# of molecules in a certain space).



- The higher the index of refraction (n), the denser the material (more molecules closer together) and therefore the light will slow down (it is harder to move!)

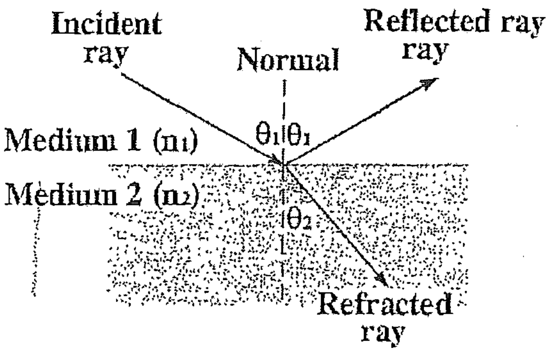
- The opposite is also true.

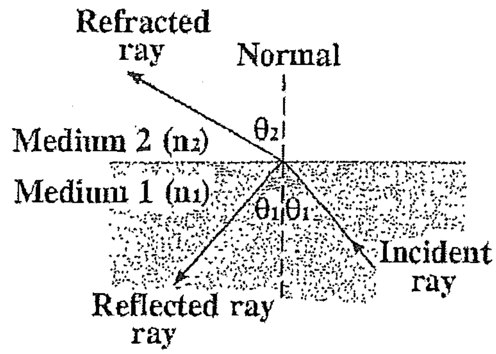
The speed of light in a material is different from that in a vacuum. The index of refraction of a material is the ratio of the speed of light in a vacuum to the speed of light in the material.

When light travels from one medium to another, **its speed and wavelength change**, but its **<u>frequency remains the same.</u>**

When light passes from one transparent medium into another, the ray is bent unless it enters perpendicular to the surface between the two media. <u>This bending is refraction</u>.

Refraction Diagrams:





Snell's Law –

A ratio (numerical relationship) between the mediums can be found by using the Law of Refraction – also known as Snell's Law

Snell's law states: that when light travels from one medium into another, the incident ray, the refracted ray, and the normal to the interface all lie in the same plane, and the angle of refraction depends on the angle of incidence and on the indices of refraction in the two media.

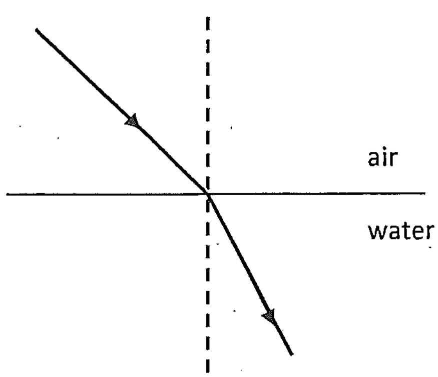
The numerical ratio is defined as- $n_1 \sin \theta_1 = n_2 \sin \theta_2$ or

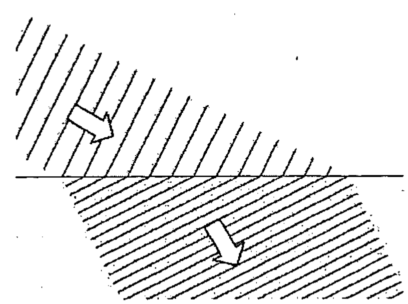
Refraction of Light:

If a ray of light enters denser medium of a greater index of refraction, its speed decreases and its path is bent toward the normal. If a ray of light enters a less dense medium of a smaller index of refraction, its speed increases and its path is bent away from the normal.

A. When light moves to a material with a higher index of refraction, the **light slows down**. This causes the light beam to **bend toward the normal line**.

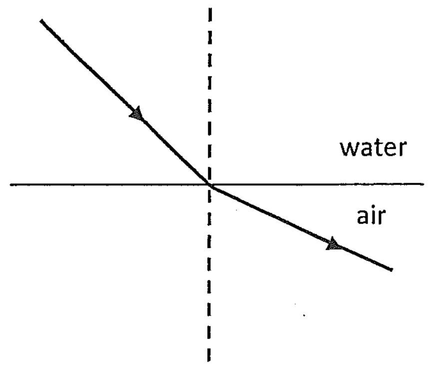
When light passes from one medium that has a low index of refraction (air) to a substance that has a higher index of refraction (water) – the light slows down and bends toward the normal.



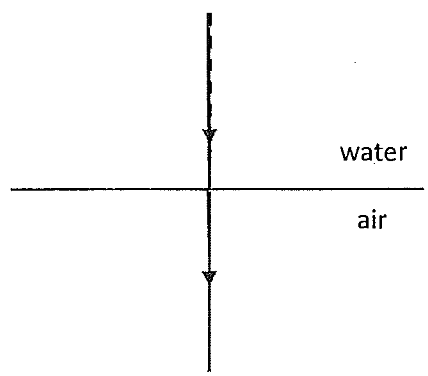


B. When light moves to a material with a lower index of refraction, the **light speeds up**. This causes the light beam to **bend away from the normal line.**

When light passes from one medium that has a high index of refraction (water), to a substance that has a lower index of refraction (air), – the light <u>speeds up</u> and bends <u>away from</u> the normal.



C. If a ray of light enters another medium along the normal, the ray is not refracted regardless of the index of refraction.



Formulas:

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2} = \frac{\gamma_1}{\gamma_2} = \frac{n_2}{n_1}$$

To solve problems that investigate refraction, you will need to remember the following:

1. The ONLY characteristics that **<u>change</u>** during refraction are the <u>speed (v) and the wavelength (γ).</u>

2. The **frequency** (*f*) does **<u>NOT</u>** change during refraction.

3. The **period** (T) does **<u>NOT</u>** change during refraction.

Lesson 5

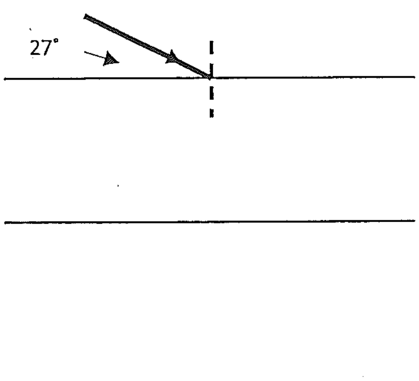
Examples:

1. A ray of light strikes the surface of a block of glass (n = 1.50) and has an incident angle of 72.0°. What is the angle of refraction?

2. The speed of light through water is 2.26×10^8 m/s. What is the index of refraction of water?

3. What is the index of refraction of a substance if the angle of incidence to this substance is 43.0° and the angle of refraction is 38.0°?

4. A ray of light travels from air into water (n=1.33) and then into glass (n=1.50) as shown in the diagram. Find the angle of refraction in the glass.



Refraction of Light Problems

1. What is the speed of light in a clear plastic whose index of refraction is 1.40? (2.14×10^8 m/s)

2. The speed of light in a clear liquid is 2.3×10^8 m/s. What is the index of refraction? (1.30)

3. A beam of light strikes the surface of a block of glass (n=1.50) and produces a refracted angle of 10.0^o. What is the incident angle? (15.1^o)

4. What is the wavelength of light in water (n=1.33) if its wavelength in air is 5.30×10^{-7} m? (3.98×10^{-7} m)

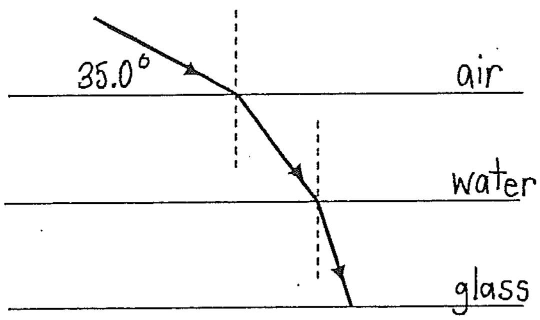
5. Monochromatic light has a wavelength of 6.0×10^{-7} m in air and 5.0×10^{-7} in a clear liquid. What is the index of refraction of the clear liquid? (1.2)

6. Monochromatic light has a wavelength of 5.75×10^{-7} m in air and 4.32×10^{-7} in a clear liquid. If a ray of light enters this clear liquid at an incident angle of 25.0^o, what is the angle of refraction? (18.5^o)

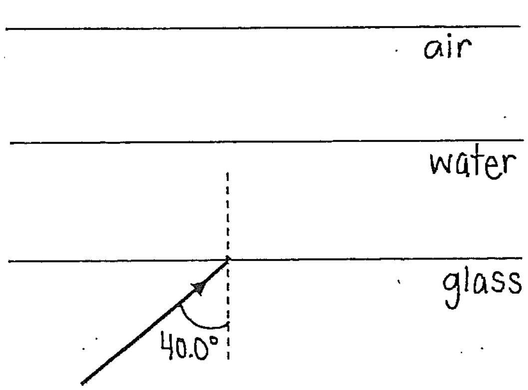
7. What is the index of refraction of a substance if the angle of incidence to this substance is 53.0^0 and the angle of refraction in this substance is 41.0^0? (1.22)

8. A ray of light strikes the surface of water (n=1.33) at an angle of 60.0^0 from the water surface. What is the angle of refraction? (22.1^0)

9. A ray of light travels from air into water (n=1.33) and then into glass (n=1.50) as shown in the diagram. Find the angle of refraction in the glass. (33.1^0)

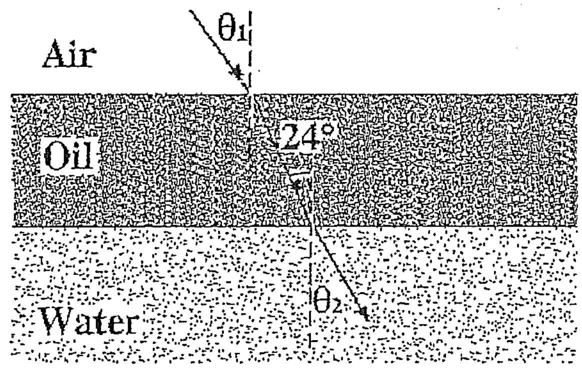


10. A ray of light travels from glass (n=1.50) into water (n=1.33) into air as shown in the diagram. Find the angle that the light leaves the water-air interface. (74.7^0)

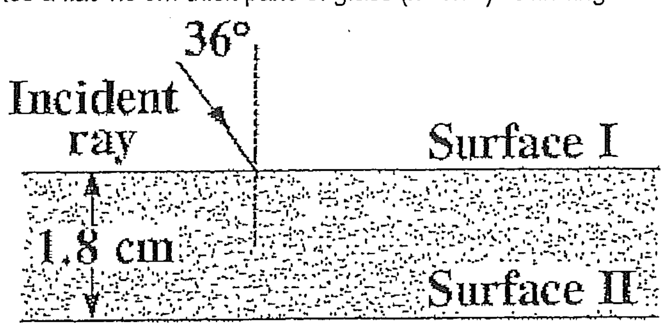


11. What is the frequency of light in diamond (n=2.42) if the frequency in air is 6.20 x 10^{14} Hz? (6.20x10^{14} Hz)

12. A layer of oil floats on water. A ray of light in air is incident an angle θ_1 on the surface of the oil. The light ray passes through the layer of oil and enters the water (n = 1.33) at an angle of 24° with the normal as shown in the diagram. The index of refraction of the oil is 1.45. Determine the angles θ_1 and θ_2. (36°, 26°)



13. A ray of light in air strikes a flat 1.8 cm thick pane of glass (n=1.52) at an angle of 36° with the normal as shown in the diagram.



a) Trace the ray of light through the glass pane and find the angles of incidence and refraction at the interface. (36°, 23°)

b) When the ray of light passes into the glass pane, the refracted ray is displaced laterally relative to incident ray by a distance d. Find the distance. (0.54cm)

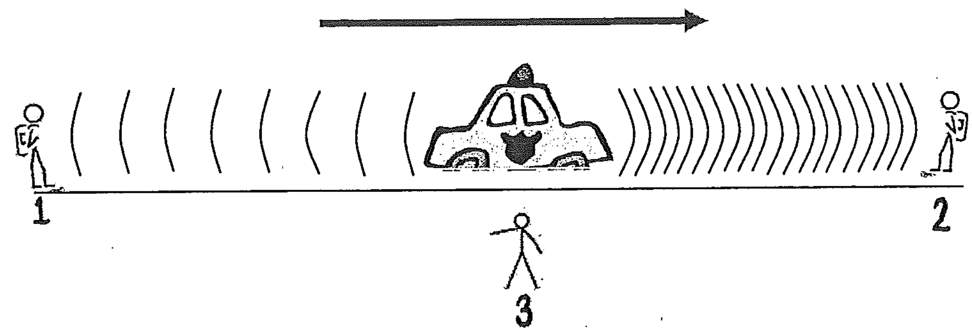
Lesson 6 (waves).

Physics 11 - **WAVE EFFECTS**

A. Doppler Effect

This effect is named after C.J. Doppler, an Australian physicist who first explained the phenomenon.

Example: A car sounds a horn as it drives away from observer 1 to observer 2.



Observer 2 will receive a **larger number of compressions** per second than observer 1. Therefore the **frequency** of the car's horn will seem relatively _______________ to observer 2 and relatively ___________ to observer 1.

For Observer 3, the frequency will ____________ when the car approaches him and ____________ as it moves away.

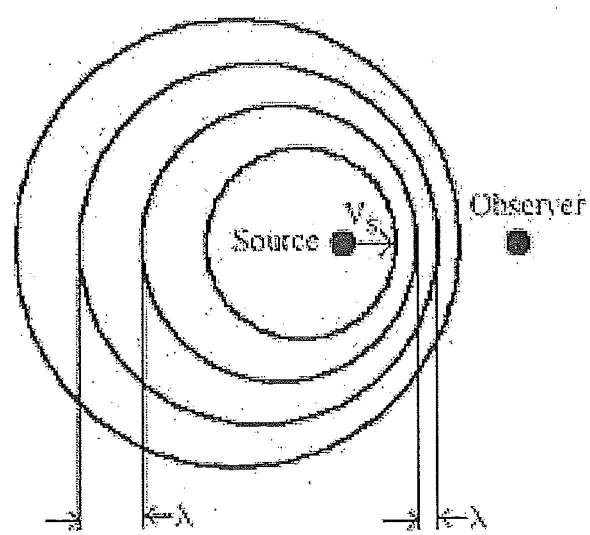
The frequency of a sound wave is what determines the pitch that our ears "hear". The higher the frequency, the higher the pitch heard.

From the driver's perspective, what happens to the frequency (or **pitch**) or the horn?

DOPPLER EFFECT (definition) - When a source that is generating waves moves toward an observer, the frequency of the waves relative to the observer increases. When a source that is generating waves moves away from an observer, the frequency of the waves relative to the observer decreses.

Applications: - Short-range radar devices, such as those used by the police to determine the speed of a car.

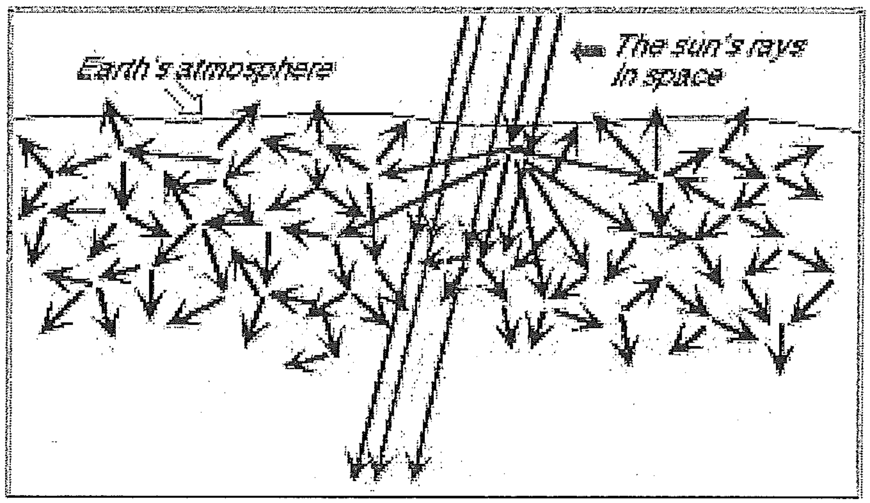
- Weather tracking (Doppler Radar)



B. Scattering

Scattering occurs when waves strike an obstacle that is smaller than the wavelength of the wave. When this occurs, waves are scattered from the obstacle in all directions.

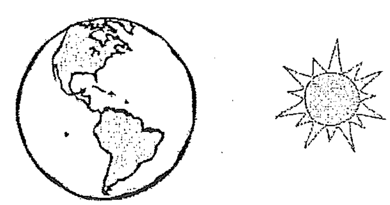
The amount of scattering depends on the wavelength of the incident waves. ***Shorter wavelengths are scattered MORE than the longer ones.***



WHY IS THE SKY BLUE?

a. Red/orange light both have **longer** wavelengths than blue/violet light.
b. The upper atmosphere contains many particles such as nitrogen (N_2) and oxygen (O_2).
   - These are ___________________ than the wavelengths of visible light and act as **obstacles** to sunlight
c. Blue light (___________________) is therefore scattered more than red light (___________________)
   - In the sky, you see the blue light that has been scattered in all directions by the particles in the atmosphere.

At sunset or sunrise, the light travels through ___________________ to reach an observer.



- `More of the _________________and ________________ wavelengths have been scattered out, leaving the wavelengths in the ___________ end of the spectrum.
- Sun appears orange or reddish as it rises or sets.

BENEFITS: Ozone (O_3) in the upper atmosphere scatters ultraviolet (UV) wavelengths that are harmful to cells and can cause cancer.

Lesson 6

Physics 11 Review: Waves

1. Energy can travel by which two methods?

2. a What is the major difference between longitudinal and transverse waves?

   b which type of wave can be polarized?

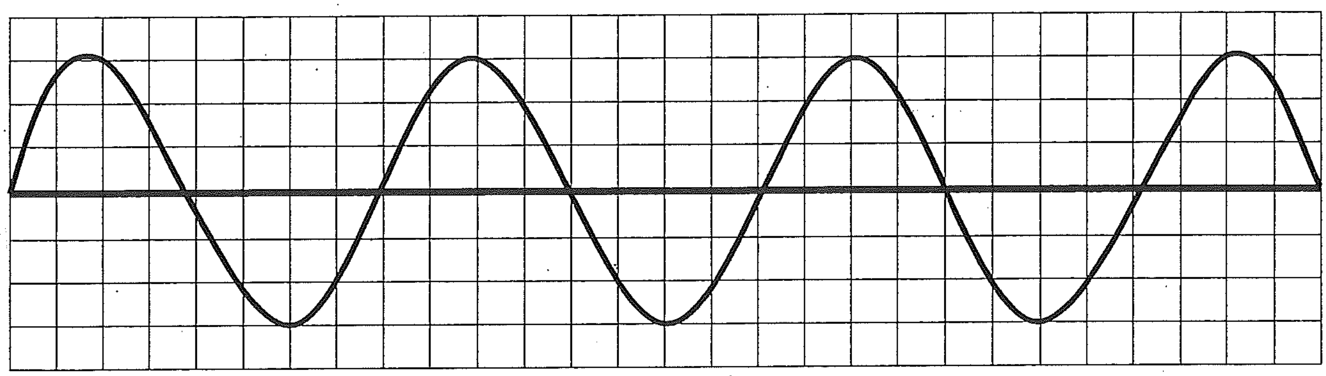
3. Which type of wave would best describe the motion of:

   a. Light

   b. Ocean waves

   c. An earth worm

4. For the following wave label: crest, trough, equilibrium position and show two points that are in phase



If each square represents one meter find the following characteristics:

Amplitude = ________________

Wavelength = ________________

5. While watching a duck on a lake you notice that the duck bobs up and down 32 times in 4.0 minutes. If you estimate the waves to be 3.0m between crests find:

   a. The frequency

   b. The period

   c. The speed

6. What is the wavelength of light that has a period of 3.42×10^{-4} s?

7. Explain the Doppler Effect in terms of an observer who watches a police car approach and then pass him. (use a diagram to help explain)

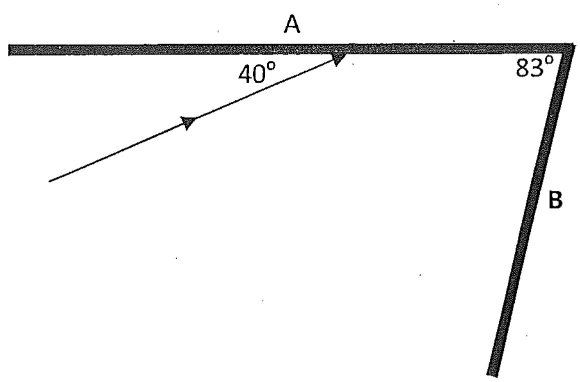
8. How does ozone (O_3) in the upper atmosphere help protect us? (name the effect and explain)

9. List 3 characteristics of an image produced by a pin-hole camera.

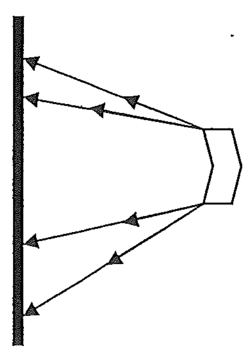
10. How far from the camera would a 13.2m tall object have to be if it produced an 11.0 cm image using a camera that is 15.0 cm long?

11. A 2.3 m tall person was standing 5.0 m from a campfire. How tall would their shadow be if it occurred on a tree 14 m behind the person?

12. What would be the angle of reflection from mirror B?



13. Complete the ray diagram.



PHYSICS II
Waves
Review

Questions

1. How many general methods of energy transfer are there? Give two examples of each.
2. Distinguish between a mechanical wave and an electromagnetic wave.
3. How do a transverse wave, a longitudinal wave, and a surface wave differ?
4. If a pulse is sent along a rope, how does the rope behave at any given point after the pulse has passed?
5. A pulse differs from a wave. How?
6. Distinguish among the wavelength, frequency, and period of a wave.
7. What is the equation used to find the velocity of a wave?
8. What is the amplitude of a wave and what does it measure?
9. Waves are sent along a spring of fixed length. Can the speed of the waves in the spring be changed? How can the frequency of a wave in the spring be changed?
10. When a wave reaches the boundary of a new medium, part of the wave is reflected and part is transmitted. What determines the amount of reflection?
11. A pulse reaches the boundary of a medium more rigid than the one from which it came. Is the reflected pulse erect or inverted?
12. A pulse reaches the boundary of a medium less rigid than the one from which it came. Is the reflected pulse erect or inverted?
13. When a wave passes into a new medium, what remains the same? What changes?
14. List three different means of changing the direction of a wave.
15. State the law of reflection.
16. What is diffraction?
17. Name two facts about the diffraction patterns produced by waves of different wavelengths as they pass through the same pair of openings.

Problems–A

1. An ocean wave has a wavelength of 10.0 m. A wave passes by every 2.0 s. What is the speed of the wave? — 1. 5.0 m/s
2. A sonar signal of frequency 1.00×10^6 Hz has a wavelength of 1.50 mm in water. — 2. a. 1.50×10^3 m/s b. 1.00×10^{-6} s c. 1.00×10^{-6} s
   a. What is the speed of the signal in water?
   b. What is its period in water?
   c. What is its period in air?
3. Waves of frequency 2.0 Hz are generated along a spring. The waves have a wavelength of 0.45 m. — 3. a. 0.90 m/s b. 0.15 m c. 2 m
   a. What is the speed of the waves along the spring?
   b. What is the wavelength of the waves along the spring if their frequency is increased to 6.0 Hz?
   c. If the frequency is decreased to 0.5 Hz, what is their wavelength?

Problems–B

1. The AM radio signals are broadcast at frequencies between 550 kHz and 1600 kHz (kilohertz) and travel at 3.0×10^8 m/s. — 1. a. 550 m, 190 m b. 3.4 m, 2.8 m
   a. What is the range of wavelengths for these signals?
   b. FM frequencies range between 88 MHz and 108 MHz (megahertz) and travel at the same speed. What is the range of FM wavelengths?
2. The speed of sound in water is 1498 m/s. A sonar signal is sent from a ship at a point just below the water surface and 1.80 s later the reflected signal is detected. How deep is the ocean beneath the ship? — 2. 1350 m

Waves and Light

Part 1

waves answers

Waves Lesson one answers

Wave Characteristic Problems

1. A wave has a frequency of 5.0 x 10^{-1} Hz and a speed of 3.3 x 10^{-1} m/s. What is the wavelength of this wave? (0.66 m)

$v = \lambda f$ $\quad 0.33 = \lambda(0.50) \quad \lambda = \underline{0.66 m}$

2. A form of energy travels as a wave 4.60 m in 2.00 s. What is the speed of the wave? (2.30 m/s)

$v = \frac{d}{t} = \frac{4.60}{2.00} \quad v = 2.30 m/s$

3. A water wave has a wavelength of 5.0 m and a speed of 2.5 m/s. What is the period of this wave? (2.0 s)

$T = \frac{1}{f} \quad T = \frac{1}{0.50} \quad T = \underline{2.0 s}$ $\quad v = \lambda f \quad 2.5 = 5.0 f \quad f = 0.50 Hz$

4. 9.5 waves break on the beach in 1.0 min. What is the frequency in hertz of these waves? (0.16 Hz)

$f = \frac{\#\text{of waves}}{sec} = \frac{9.5}{60} = \underline{0.16 Hz}$

5. If sound waves travel at 335 m/s, what is the wavelength of sound that has a period of 1.00 x 10^{-2} s? (3.35m)

$v = \lambda f \quad 335 = \lambda(100) = \underline{3.35 m}$ $\quad T = \frac{1}{f} \quad 0.01 = \frac{1}{f} \quad f = 100 Hz$

6. A radio station broadcasts at a frequency of 1.00 x 10^6 Hz. If the speed of this wave is 3.00 x 10^8 m/s, what is its wavelength? (3.00 x 10^2 m)

$v = \lambda f \quad 3.00 \times 10^8 = \lambda(1.00 \times 10^6) = \underline{3.00 \times 10^2 m}$

7. While floating on an air mattress in a lake, you notice that you bob up and down 40 times in 5.0 min. You estimate the distance between crests 4.0 m. What is the estimated speed of the water waves? (0.53 m/s)

$f = \frac{\#}{sec} = \frac{40}{(5.0)(60)} = 0.133 Hz$ $\quad v = \lambda f = (4.0)(0.133) = \underline{0.53 m/s}$

8. A light has a speed of 3.00 x 10^8 m/s. If the length of this wave is 5.00 x 10^{-7} m, what is its period? (1.67x10^{-15}s)

$T = \frac{1}{f} = \frac{1}{6.00 \times 10^{14}}$ $\quad v = \lambda f \quad 3.00 \times 10^8 = (5.00 \times 10^{-7}) f \quad f = 6.00 \times 10^{14} Hz$

$T = \underline{1.67 \times 10^{-15} s}$

Lesson 5 waves

Refraction of Light Problems

1. What is the speed of light in a clear plastic whose index of refraction is 1.40? (2.14×10^8 m/s)

air ↓ plastic

$V_a = 3.00 \times 10^8$ m/s
$V_p = ?$
$n_a = 1.00$
$n_p = 1.40$

$$\frac{V_a}{V_p} = \frac{n_p}{n_a} \qquad \frac{3.00 \times 10^8}{V_p} = \frac{1.40}{1.00}$$

$$V_p = 2.14 \times 10^8 \text{ m/s}$$

2. The speed of light in a clear liquid is 2.3×10^8 m/s. What is the index of refraction? (1.30)

air ↓ liquid

$V_a = 3.00 \times 10^8$
$V_p = 2.3 \times 10^8$
$n_a = 1.00$
$n_L = ?$

$$\frac{V_a}{V_p} = \frac{n_L}{n_a} \qquad \frac{3.00 \times 10^8}{2.3 \times 10^8} = \frac{n_L}{1.00}$$

$$n_L = 1.30$$

3. A beam of light strikes the surface of a block of glass (n=1.50) and produces a refracted angle of 10.0°. What is the incident angle? (15.1°)

air ↓ glass

$\angle i = ?$
$\angle R = 10.0$
$n_a = 1.00$
$n_g = 1.50$

$$\frac{\sin\angle i}{\sin\angle R} = \frac{n_g}{n_a} \qquad \frac{\sin\angle i}{\sin(10)} = \frac{1.50}{1.00}$$

$$\sin^{-1}(0.260) = 15.1^\circ$$

4. What is the wavelength of light in water (n=1.33) if its wavelength in air is 5.30×10^{-7} m? (3.98×10^{-7} m)

air ↓ water

$\lambda_a = 5.30 \times 10^{-7}$ m
$\lambda_w = ?$
$n_a = 1.00$
$n_w = 1.33$

$$\frac{\lambda_a}{\lambda_w} = \frac{n_w}{n_a} \qquad \frac{5.30 \times 10^{-7}}{\lambda_w} = \frac{1.33}{1.00}$$

$$\lambda_w = 3.98 \times 10^{-7} \text{ m}$$

5. Monochromatic light has a wavelength of 6.0×10^{-7} m in air and 5.0×10^{-7} in a clear liquid. What is the index of refraction of the clear liquid? (1.2)

air ↓ liquid

$$\frac{\lambda_a}{\lambda_w} = \frac{n_L}{n_a} \qquad \frac{6.0 \times 10^{-7}}{5.0 \times 10^{-7}} = \frac{n_L}{1.00} \qquad n_L = 1.2$$

6. Monochromatic light has a wavelength of 5.75×10^{-7} m in air and 4.32×10^{-7} in a clear liquid. If a ray of light enters this clear liquid at an incident angle of 25.0°, what is the angle of refraction? (18.5°)

air ↓ liquid

$$\frac{\sin\angle i}{\sin\angle R} = \frac{\lambda_a}{\lambda_L} \qquad \frac{\sin 25}{\sin\angle R} = \frac{5.75 \times 10^{-7}}{4.32 \times 10^{-7}}$$

$$\sin^{-1}(0.318) = 18.5^\circ$$

7. What is the index of refraction of a substance if the angle of incidence to this substance is 53.0° and the angle of refraction in this substance is 41.0°? (1.22)

air → substance

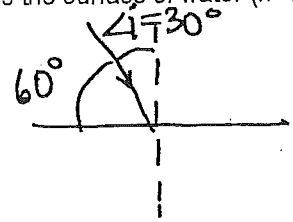
$$\frac{\sin\angle i}{\sin\angle R} = \frac{n_s}{n_a}$$

$$\frac{\sin 53}{\sin 41} = \frac{n_s}{1.00}$$

$n_s = 1.22$

8. A ray of light strikes the surface of water (n=1.33) at an angle of 60.0° from the water surface. What is the angle of refraction? (22.1°)

air → water

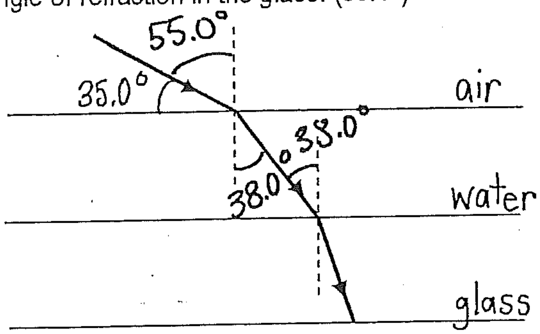


$$\frac{\sin\angle i}{\sin\angle R} = \frac{n_w}{n_a}$$

$$\frac{\sin 30}{\sin\angle R} = \frac{1.33}{1.00}$$

$\sin^{-1}(0.376) = 22.1°$

9. A ray of light travels from air into water (n=1.33) and then into glass (n=1.50) as shown in the diagram. Find the angle of refraction in the glass. (33.1°)



① air → water

$$\frac{\sin\angle i}{\sin\angle R} = \frac{n_w}{n_a}$$

$$\frac{\sin(55)}{\sin\angle R} = \frac{1.33}{1.00}$$

$\sin^{-1}(0.616) = 38.0°$

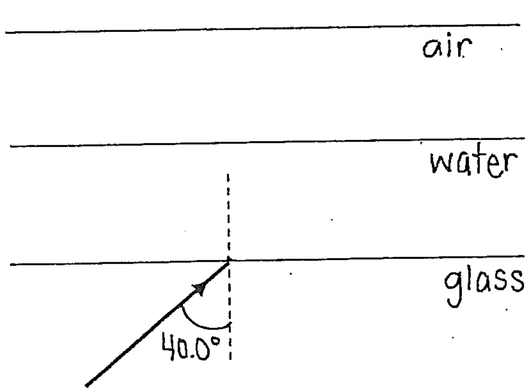
② water → glass

$$\frac{\sin\angle i}{\sin\angle R} = \frac{n_g}{n_w}$$

$$\frac{\sin(38)}{\sin\angle R} = \frac{1.50}{1.33}$$

$\sin^{-1}(0.546) = 33.1°$

10. A ray of light travels from glass (n=1.50) into water (n=1.33) into air as shown in the diagram. Find the angle that the light leaves the water-air interface. (74.7°)



① glass → water

$$\frac{\sin\angle i}{\sin\angle R} = \frac{n_w}{n_g}$$

$$\frac{\sin(40)}{\sin\angle R} = \frac{1.33}{1.50}$$

$\sin^{-1}(0.725) = 46.5°$

② water → air

$$\frac{\sin 46.5}{\sin\angle R} = \frac{1.00}{1.33}$$

$\sin^{-1}(0.965) = 74.7°$

11. What is the frequency of light in diamond (n=2.42) if the frequency in air is 6.20×10^{14} Hz? (6.20×10^{14} Hz)

Frequency does not change during refraction.

$f = 6.20 \times 10^{14}$ Hz

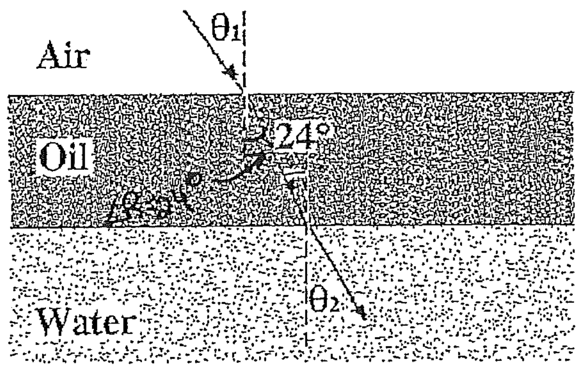
12. A layer of oil floats on water. A ray of light in air is incident an angle θ_1 on the surface of the oil. The light ray passes through the layer of oil and enters the water (n = 1.33) at an angle of 24° with the normal as shown in the diagram. The index of refraction of the oil is 1.45. Determine the angles θ_1 and θ_2. (36°, 26°)

air ($n_1 = 1.00$) ↓ oil ($n_2 = 1.45$)

$\frac{\sin\angle i}{\sin 24} = \frac{1.45}{1.00}$

$\sin^{-1}(0.589)$

$\angle i = 36° = \theta_1$



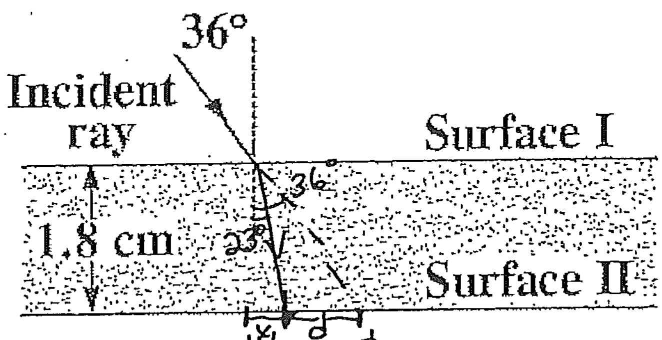
oil ($n_1 = 1.45$) ↓ water ($n_2 = 1.33$)

$\frac{\sin 24}{\sin\angle R} = \frac{1.33}{1.45}$

$\sin^{-1}(0.443)$ $\angle R = 26° = \theta_2$

13. A ray of light in air strikes a flat 1.8 cm thick pane of glass (n=1.52) at an angle of 36° with the normal as shown in the diagram.

air ($n_1 = 1.00$) ↓ glass ($n_2 = 1.52$)



a) Trace the ray of light through the glass pane and find the angles of incidence and refraction at the interface. (36°, 23°)

b) When the ray of light passes into the glass pane, the refracted ray is displaced laterally relative to incident ray by a distance d. Find the distance. (0.54cm)

a) $\frac{\sin 36}{\sin\angle R} = \frac{1.52}{1.00}$ $\sin^{-1}(0.386) = \angle R = 23°$ $\angle i = 36°$

b) $\tan 23 = \frac{x_1}{1.8}$ $\tan 36 = \frac{x_2}{1.8}$ $(d = x_2 - x_1)$

$x_1 = 0.764$ cm $x_2 = 1.31$ cm $\rightarrow 1.31 - 0.764 = 0.54$ cm

Lesson 6 waves

Physics 11 Review: Waves

1. Energy can travel by which two methods?

   particles and waves

2. a What is the major difference between longitudinal and transverse waves? direction of partical motion (parallel vs. perpendicula

   b which type of wave can be polarized? transverse

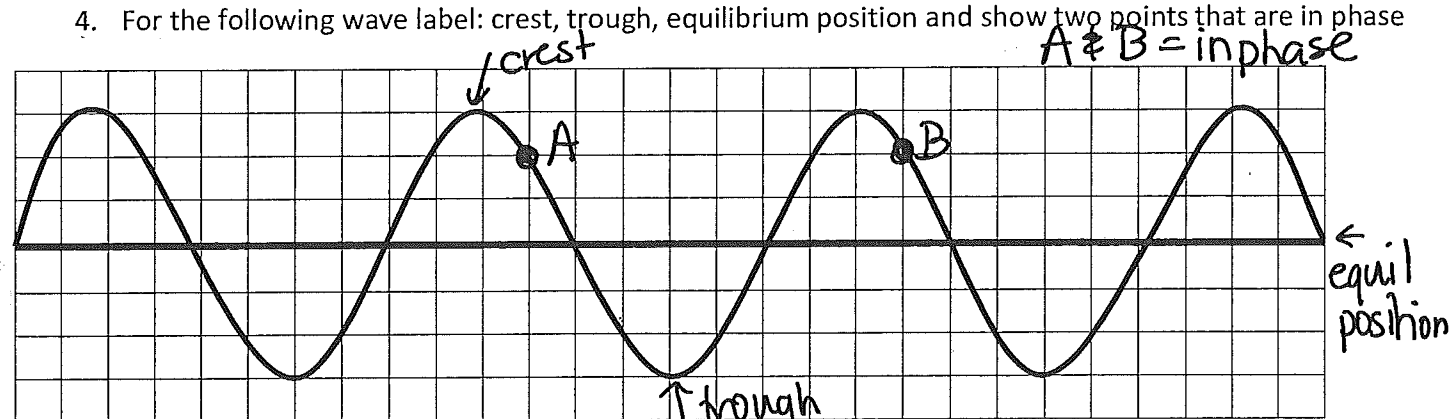
3. Which type of wave would best describe the motion of:

   a. Light transverse

   b. Ocean waves transverse

   c. An earth worm longitudinal

4. For the following wave label: crest, trough, equilibrium position and show two points that are in phase



If each square represents one meter find the following characteristics:

Amplitude = 3 m

Wavelength = 8 m

5. While watching a duck on a lake you notice that the duck bobs up and down 32 times in 4.0 minutes. If you estimate the waves to be 3.0m between crests find:

   a. The frequency $\frac{32}{4(60)} = 0.133\ Hz$

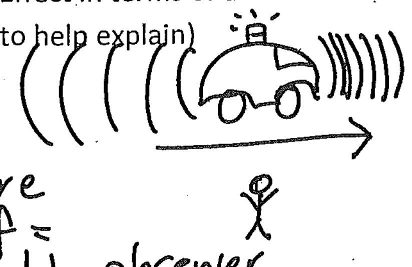
   b. The period $T = \frac{1}{0.133}$ $T = 7.5s$

   c. The speed $v = (3.0)(0.133)$ $= 0.40\ m/s$

6. What is the wavelength of light that has a period of 3.42×10^{-4} s?

$3.42 \times 10^{-4} = \frac{1}{f}$ $f = 2924\ Hz$ $3.0 \times 10^8 = \lambda(2924)$ $\lambda = 1.03 \times 10^5\ m$

7. Explain the Doppler Effect in terms of an observer who watches a police car approach and then pass him. (use a diagram to help explain)



→as the car passes him the soundwaves are further apart = ↓f = ↓pitch heard by observer

→as the car approaches, the sound waves will be compressed = ↑f = ↑pitch heard by observer

→when the car is right in front of him = normal/actual pitch

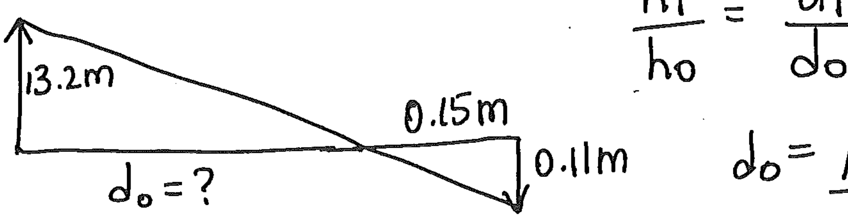
8. How does ozone (O_3) in the upper atmosphere help protect us? (name the effect and explain)

O_3 is the only particle smaller than the UV wavelength = scatter's UV rays & keeps most of them from making it to the surface.

9. List 3 characteristics of an image produced by a pin-hole camera.

- real
- inverted
- smaller

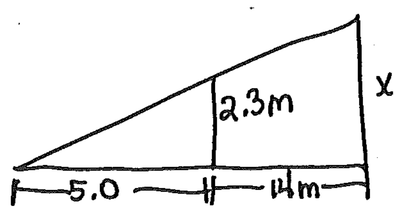
10. How far from the camera would a 13.2m tall object have to be if it produced an 11.0 cm image using a camera that is 15.0 cm long?



$$\frac{h_i}{h_o} = \frac{-d_i}{d_o} \quad \frac{-0.11}{13.2} = \frac{-(0.15)}{d_o}$$

d_o = 18 m

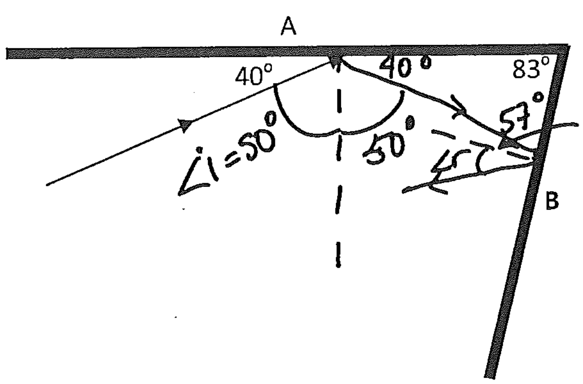
11. A 2.3 m tall person was standing 5.0 m from a campfire. How tall would their shadow be if it occurred on a tree 14 m behind the person?



$$\frac{x}{19.0} = \frac{2.3}{5.0}$$

x = 8.7m tall

12. What would be the angle of reflection from mirror B?



∠i=33° = ∠r = 33°

13. Complete the ray diagram.