

# Universal Wave Equation Problems

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Potentially useful equations:

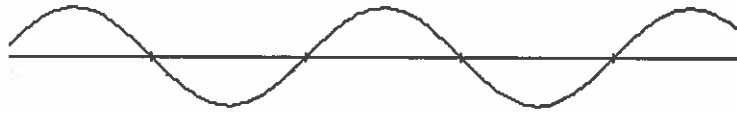
$$f = \frac{1}{T}$$

$$T = \frac{1}{f}$$

$$v = f\lambda$$

- Convert the following frequencies into periods
  - 340 Hz
  - 20 cycles/s
  - $0.33 \text{ s}^{-1}$
- A tuning fork's tines vibrate 250 times in 2.0 s. Find
  - the frequency of vibration
  - the period of vibration
- The frequency of a tuning fork is 1000 Hz. If the wavelength is 35 cm, find the speed of the sound wave in
  - m/s
  - km/h
- If  $\frac{\lambda}{4}$  is 0.85 m and the frequency is 125 Hz, find
  - the wavelength
  - the period of the wave
  - the velocity of the wave
- Find the period and velocity for the following frequencies if the wavelength was found to be 0.50 m:
  - 0.30 Hz
  - $400 \text{ s}^{-1}$
  - 102.1 MHz
- Find the frequency and velocity given that wavelength is 75 cm for the following periods:
  - 0.020 s
  - 15 ms
  - 0.6 h
- A source with a frequency of 20 Hz produces water waves that have a wavelength of 3.0 cm. What is the speed of the waves?
- A wave in a rope travels at a speed of 2.5 m/s. If the wavelength is 1.3 m, what is the period of the wave?
- An FM station broadcasts radio signals with a frequency of 92.6 MHz. If these radio waves travel at a speed of  $3 \times 10^8 \text{ m/s}$ , what is their wavelength?

10. You are shouting in a monotone voice with a frequency of 440 Hz. Your friend is 300 m away. If the speed of sound waves is 344 m/s, how many wavelengths occur between you and your friend?
11. This full scale diagram shows a series of wave crests. Successive crests pass a given point in 0.5 s.



- a) What is the amplitude of this wave? (measure this)  
 b) What is the wavelength in centimetres? (measure this)  
 c) What is the frequency?  
 d) What is the velocity of the waves?
12. A given crest of a water wave requires 5.2 s to travel between two points on a fishing pier located 19 m apart. It is noted in a series of waves that 20 crests pass the first point in 17s. What is the wavelength of the wave? (A diagram would help)
13. Two men are fishing from small boats located 30 m apart. Waves pass through the water, and each man's boat bobs up and down 15 times in 1.0 min. At a time when one boat is on a crest the other one is in a trough, and there is one crest between the two boats. Draw a well labelled diagram. What is the speed of the waves?

#### Numerical Answers:

1. a)  $2.9 \times 10^{-3} s$                       b)  $0.05 s$                       c)  $3 s$   
 2. a)  $125 \text{ Hz}$                               b)  $8.0 \times 10^{-3} s$   
 3. a)  $350 \text{ m/s}$                               b)  $1260 \text{ km/h}$   
 4. a)  $3.4 \text{ m}$                                 b)  $8 \times 10^{-3} s$                       c)  $425 \text{ m/s}$   
 5. a)  $3.3 s$ ;  $0.15 \text{ m/s}$                   b)  $2.5 \times 10^{-3} s$ ;  $200 \text{ m/s}$       c)  $9.8 \times 10^{-9} s$ ;  $5.1 \times 10^7 \text{ m/s}$   
 6. a)  $50 \text{ Hz}$ ;  $37.5 \text{ m/s}$                 b)  $67 \text{ Hz}$ ;  $50 \text{ m/s}$                 c)  $4.6 \times 10^{-4} \text{ Hz}$ ;  $3.5 \times 10^{-4} \text{ m/s}$   
 7.  $0.6 \text{ m/s}$   
 8.  $0.52 s$   
 9.  $3.24 \text{ m}$   
 10.  $385$   
 11. a)  $0.7 \text{ cm}$                               b)  $4.3 \text{ cm}$                       c)  $2 \text{ Hz}$  d)  $8.6 \times 10^{-2} \text{ m/s}$   
 12.  $3.1 \text{ m}$   
 13.  $5 \text{ m/s}$

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Date: WS # 3

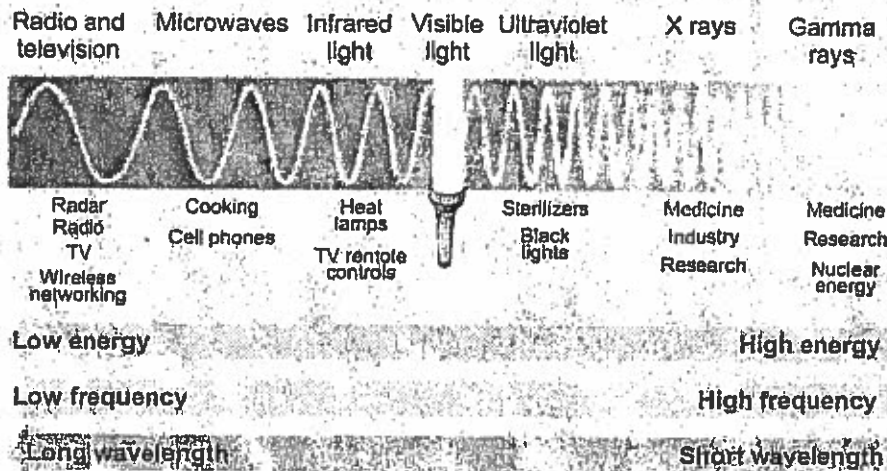


# The Electromagnetic Spectrum

READ

Radio waves, microwaves, visible light, and x-rays are familiar kinds of electromagnetic waves. All of these waves have characteristic wavelengths and frequencies. *Wavelength* is measured in meters. It describes the length of one complete oscillation. *Frequency* describes the number of complete oscillations per second. It is measured in hertz, which is another way of saying "cycles per second." The higher the wave's frequency, the more energy it carries.

## The Electromagnetic Spectrum



## Frequency, wavelength, and speed

In a vacuum, all electromagnetic waves travel at the same speed:  $3.0 \times 10^8$  m/sec. This quantity is often called "the speed of light" but it really refers to the speed of all electromagnetic waves, not just visible light. It is such an important quantity in physics that it has its own symbol, *c*.

The speed of light is related to frequency *f* and wavelength  $\lambda$  by the formula to the right.

The different colors of light that we see correspond to different frequencies. The frequency of red light is lower than the frequency of blue

light. Because the speed of both kinds of light is the same, a lower frequency wave has a longer wavelength. A higher frequency wave has a shorter wavelength. Therefore, red light's wavelength is longer than blue light's.

When we know the frequency of light, the wavelength is given by:  $\lambda = \frac{c}{f}$

When we know the wavelength of light, the frequency is given by:  $f = \frac{c}{\lambda}$

### THE SPEED OF LIGHT (relationship between frequency and wavelength)

$$\text{Speed of light } (3 \times 10^8 \text{ m/sec}) \rightarrow c = f \lambda$$

Wavelength (m)

Frequency (Hz)

PRACTICE 

Answer the following problems and show your work.

1. Yellow light has a longer wavelength than green light. Which color of light has the higher frequency?
2. Green light has a lower frequency than blue light. Which color of light has a longer wavelength?
3. Calculate the wavelength of violet light with a frequency of  $750 \times 10^{12}$  Hz.
4. Calculate the frequency of yellow light with a wavelength of  $580 \times 10^{-9}$  m.
5. Calculate the wavelength of red light with a frequency of  $460 \times 10^{12}$  Hz.
6. Calculate the frequency of green light with a wavelength of  $530 \times 10^{-9}$  m.
7. One light beam has wavelength,  $\lambda_1$ , and frequency,  $f_1$ . Another light beam has wavelength,  $\lambda_2$ , and frequency,  $f_2$ . Write a proportion that shows how the ratio of the wavelengths of these two light beams is related to the ratio of their frequencies.
8. The waves used by a microwave oven to cook food have a frequency of 2.45 gigahertz ( $2.45 \times 10^9$  Hz). Calculate the wavelength of this type of wave.
9. A radio station has a frequency of 90.9 megahertz ( $9.09 \times 10^7$  Hz). What is the wavelength of the radio waves the station emits from its radio tower?
10. An x-ray has a wavelength of 5 nanometers ( $5.0 \times 10^{-9}$  m). What is the frequency of x-rays?
11. The ultraviolet rays that cause sunburn are called UV-B rays. They have a wavelength of approximately 300 nanometers ( $3.0 \times 10^{-7}$  m). What is the frequency of a UV-B ray?
12. Infrared waves from the sun are what make our skin feel warm on a sunny day. If an infrared wave has a frequency of  $3.0 \times 10^{12}$  Hz, what is its wavelength?
13. Electromagnetic waves with the highest amount of energy are called gamma rays. Gamma rays have wavelengths of less than 10-trillionths of a meter ( $1.0 \times 10^{-11}$  m).
  - a. Determine the frequency that corresponds with this wavelength.
  - b. Is this the minimum or maximum frequency of a gamma ray?
14. Use the information from this sheet to order the following types of waves from lowest to highest frequency: visible light, gamma rays, x-rays, infrared waves, ultraviolet rays, microwaves, and radio waves.
15. Use the information from this sheet to order the following types of waves from shortest to longest wavelength: visible light, gamma rays, x-rays, infrared waves, ultraviolet rays, microwaves, and radio waves.

Name: \_\_\_\_\_

Date: \_\_\_\_\_

PHY504-\_\_

## Snell's Law Worksheet #4

### Part A

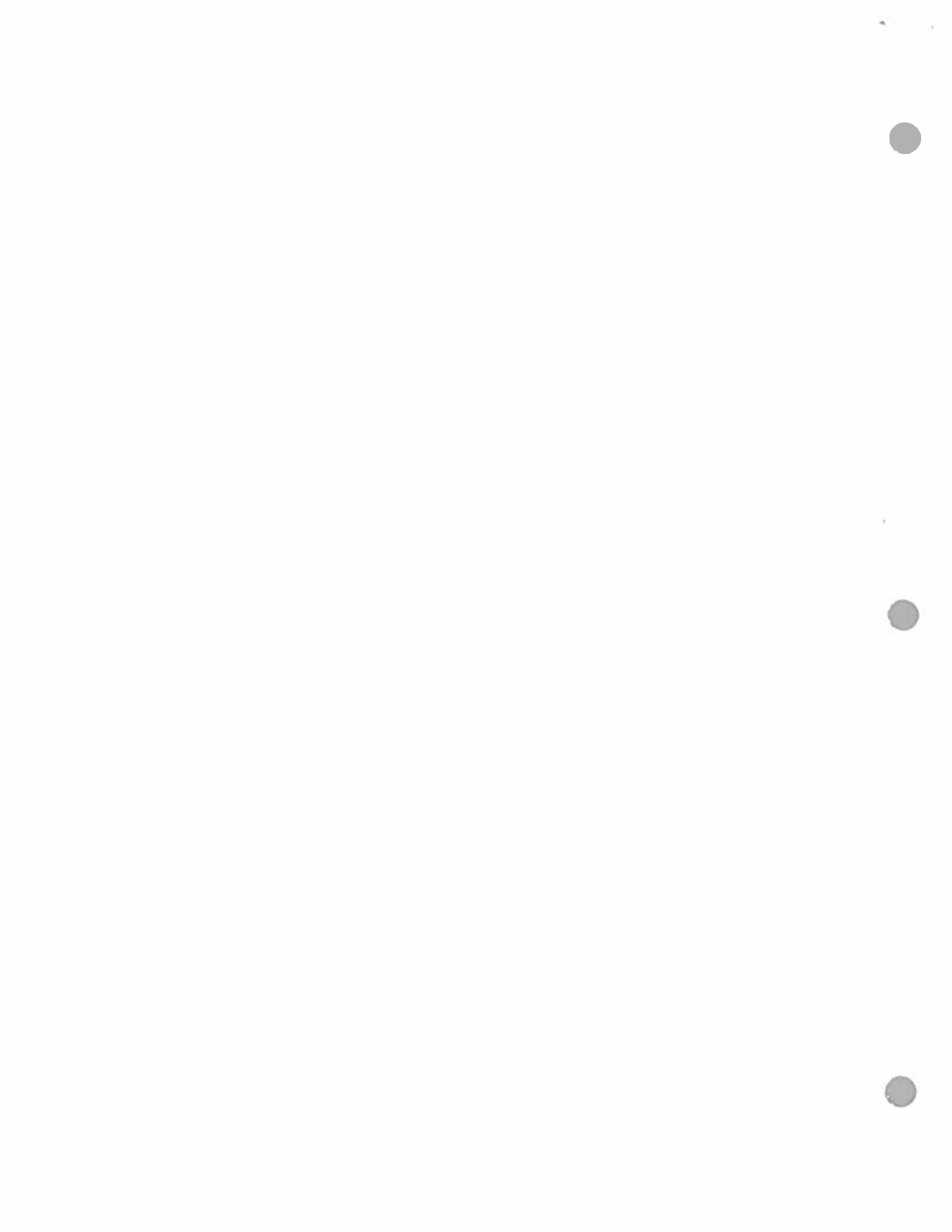
1. When light passes from air into water at an angle of  $60^\circ$  from the normal, what is the angle of refraction? (40.6°)
2. When light passes from air into water at an angle of  $30^\circ$  from the normal, what is the angle of refraction? (22.1°)
3. When light passes from water into diamond at an angle of  $45^\circ$  from the normal, what is the angle of refraction? (22.9°)
4. The refractive index of the lens of the human eye is 1.41. If a ray of light goes from the air into the lens at an angle of  $55^\circ$ , what is the angle of refraction? (35.5°)

### Part B

1. In an experiment, a block of cubic zirconia is placed in water. A laser beam is passed from the water through the cubic zirconia. The angle of incidence is  $50^\circ$ , and the angle of refraction is  $27^\circ$ . What is the index of refraction of this cubic zirconia? (2.24)
2. A ray of light approaches a jar of honey at an angle of  $30^\circ$ . If the angle of refraction is  $19.5^\circ$ , what is the refractive index of honey? (1.50)
3. A block of amber is placed in water and a laser beam travels from the water through the amber. The angle of incidence is  $35^\circ$  while the angle of refraction is  $24^\circ$ . What is the index of refraction of amber? (1.88)
4. A red laser beam travels from flint glass into lemon oil. The angle of incidence is  $40^\circ$  and the angle of reflection is  $44^\circ$ . What is the refractive index of lemon oil? (1.49)

**Table 1. Index of Refraction for Selected Media**

Media	Index of Refraction
Vacuum	1.00 (exactly)
Air	1.0003
Carbon dioxide gas	1.0005
Water	1.33
Alcohol	1.36
Pyrex glass	1.47
Plexiglas	1.49
Table salt	1.51
Flint glass	1.61
Sapphire	1.77
Cubic zirconia	2.16
Diamond	2.42
Gallium phosphide	3.50



Physics 2204

Worksheet

1. Define the following terms:

(a) Transverse wave: \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

(b) Reflection: \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

(c) Beam: \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_

(d) Period: \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

2. Define the following terms:

(a) Longitudinal wave: \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

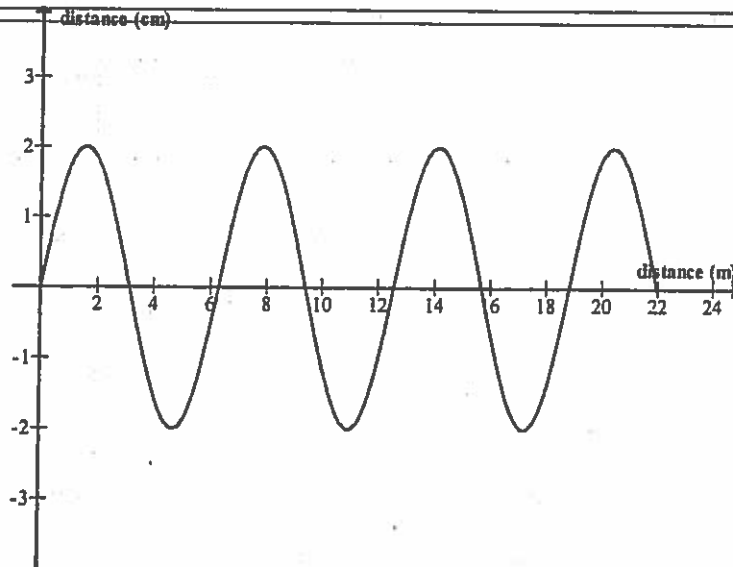
(b) Refraction: \_\_\_\_\_

(c) Ray: \_\_\_\_\_

(d) Cycle: \_\_\_\_\_

3. (a) What is the period and frequency of a person's heart if it beats 72 times in one minute?

(b) Consider the wave below. Find its (i) amplitude, (ii) wavelength, (iii) period, (iv) frequency, and (v) velocity. The elapsed time is 5.92 s.



4. (a) Calculate how long it would take light leaving Earth to reach the Moon,  $3.80 \times 10^8$  m away.

(b) Calculate the frequency of microwaves with a wavelength of 2.75 mm.



5. (a) State the characteristics of an image in a plane mirror.

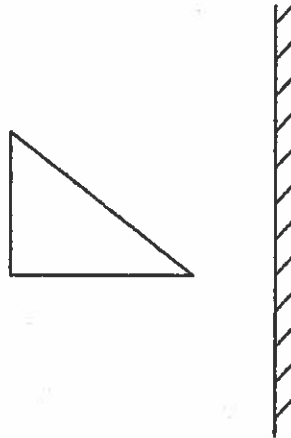
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- (b) Draw the image produced by the object in a plane mirror. (3 marks)



6. (a) Calculate the speed of light in diamond given that the index of refraction of diamond is 2.42.

- (b) How long does it take light to travel 0.500 mm in diamond?

- (c) Draw a picture of a light ray moving from a material with an index of refraction  $n_1$  to a material with an index of refraction  $n_2$  if  $n_1 > n_2$ .

7. (a) A light inside a fish tank passes from water to glass and then to the air outside. If the angle of incidence in water is  $35.0^\circ$ , find the refracted angle in air. The index of refraction of water is 1.33 and the index of refraction of glass is 1.50.

- (b) Find the critical angle for the glass-air boundary in (a).

8. A galaxy is moving toward Earth at a speed of  $2.80 \times 10^7$  m/s. What is the frequency of light observed if the wavelength of the emitted light is 522 nm?

light speed?

at its rest wavelength?

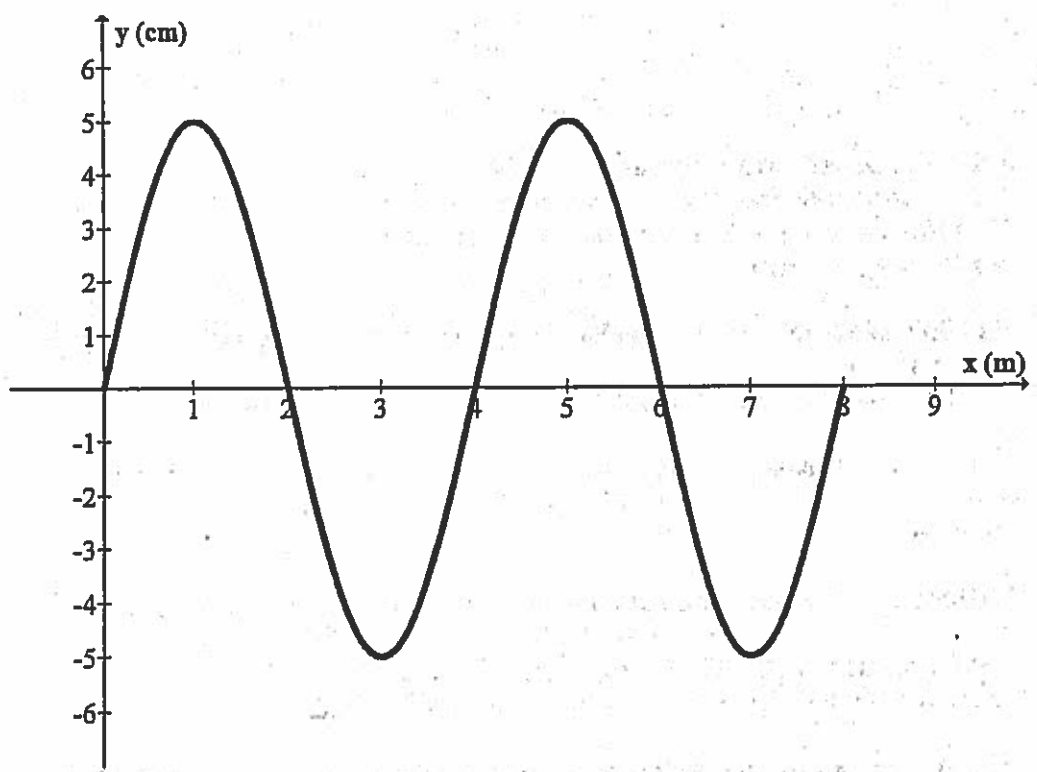
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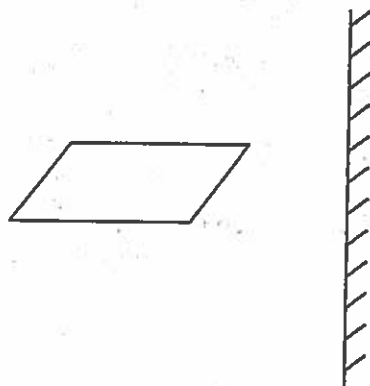
Physics 2204  
Chapter 10 Review

1. A tire rotates 13 times in 2.5 s. Calculate the period.
2. While standing on a beach, you observe 15 waves pass in 2.0 minutes. Calculate the frequency of the water waves.
3. (a) Given the period is 0.70 s, find the frequency.  
(b) Given the frequency is 262 Hz, find the period.
4. Distinguish between transverse and longitudinal waves.
5. For the transverse wave below, the elapsed time is 6.8 s. Find the (a) amplitude, (b) period, (c) frequency, (d) wavelength, and (e) speed of the wave.



6. (a) Using a slinky, you produce 48 cm long waves with a frequency of 2.0 Hz. Calculate the speed of the waves.  
(b) Find the wavelength of microwaves whose frequency is  $1.7 \times 10^{11}$  Hz.
7. Define: (a) reflection, (b) transmission, (c) refraction.
8. (a) If the reflected angle is  $25.0^\circ$  from a plane mirror, what is the angle of incidence as measured from the normal?  
(b) If  $30.0^\circ$  separated the incident and reflected rays, what is the measure of the refracted angle?

9. Distinguish between a ray and a beam.
10. (a) State the Laws of Reflection for Plane Mirrors.  
(b) What are the characteristics of images formed in a plane mirror?
11. Draw the reflection for the following object in a plane mirror.



12. What happened when light rays move from  
(a) a more dense medium to a less dense medium?  
(b) a less dense medium to a more dense medium?  
Explain why for each.
13. (a) Calculate the index of refraction for plastic if the speed of light in plastic is  $2.01 \times 10^8$  m/s.  
(b) How long does it take light to travel 4.0 cm into this material?
14. A ray of light traveling through water ( $n = 1.33$ ) enters air. If the angle of refraction is  $17.0^\circ$ , calculate the angle of incidence. Include a diagram with your solution.
15. Find the critical angle for a diamond-air interface ( $n = 2.42$  for diamond).
16. A known wavelength of 358 nm is observed to be 344 nm from a distant galaxy. What is the speed of this galaxy relative to Earth? It is receding or approaching?
17. A viewing screen is separated from a double slit source by 2.9 m. The distance between the two slits is 0.0055 mm. If the third order bright fringe is 3.8 cm from the central pattern,  
(a) determine the wavelength of light.  
(b) find the distance between the third and fifth order bright fringe.
18. Define diffraction.
19. If 560 nm light illuminates a single slit such that the angle of the second order minimum is  $32^\circ$ , calculate the slit width.