# PHYSICS 534

ANSWERS

EXERCISE-45 Intro to Optics Part-1 /2

Ernest Lawrence was awarded the Nobel prize for physics in 1939 for his invention of the cyclotron.

**LAWRENCE**

- **LIGHT**

Light is a form of energy. In many ways light is is unique in that it has both particle properties and wave properties. For this reason, light is said to have a ***dual nature***. Indeed, the study of light, called optics, is divided into two parts:

**OPTICS** (the study of light)

① Geometrical Optics (the study of light as particles)

② Physical Optics (the study of light as waves)

The properties of light can be summarized into ***two*** groups. Specifically, in accordance with its dual nature, light possesses three "particle" properties and three "wave" properties".

Particle properties of light: (difficult to explain using the wave theory)

① Rectilinear propagation (travels in straight lines)
② Reflection (changes direction)
③ Refraction (bends in going from one material to another)

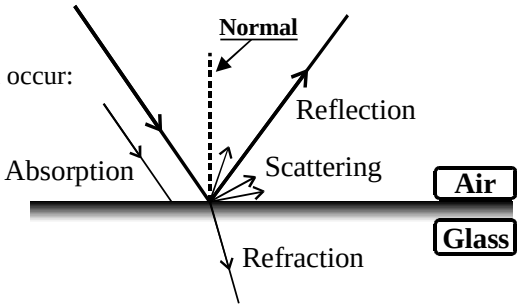
Wave properties of light: (difficult to explain using the particle theory)

① Interference (waves "superpose" and pass right through each other)
② Diffraction (waves "spill over" the edges of their obstructions)
③ Polarization (eliminating one of light's "fields")

The particles of light are called ***photons*** which are packages of energy. Each different photon posseses a different amount of energy and is seen by the eye as a different color. Red photons have the least amount of energy while violet photons have the highest amount of energy.

Note that when light strikes a surface, the following four phenomena occur:

- **Reflection** (light beam changes direction)
- **Refraction** (light beam bends)
- **Scattering** (light beam breaks into many tiny beams going in all directions)
- **Absorption** (light is absorbed by a material)




While these four phenomena always take place, usually only one of them is predominant. That is, there is either more reflection or more scattering or more refraction or more absorption.

- **THE SPEED OF LIGHT**

The speed of light is one of the most important constants in physics. The measurement of the speed of light represents one of the most precise measurements made by science. The standard value for the speed of light is $3.00 \times 10^8$ m/s and is designated using the lower case letter "c".

- **RAY OF LIGHT**

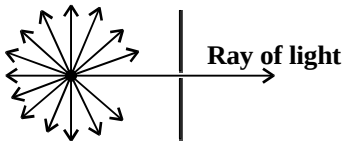
In Geometrical Optics, a ray of light consists of a stream of particles (photons) coming from a light source. A ray of light is also called a "pencil of light". Note that light rays ***cannot*** be seen while in transit.

- **POINT SOURCE OF LIGHT**

A point source of light is an imaginary source of light whose dimensions are a point. In reality, sources of light are larger than points.

↳ **NOTE**: In order to obtain (simulate) a ray of light, a screen with a tiny opening is used as illustrated below.

A screen with a tiny opening (a "pin" hole) can be used to produce a ray of light. As we make the opening smaller and smaller, the ray of light becomes narrower and narrower. However, we cannot continue making the opening smaller and smaller indefinetely because as we do, the wave properties of light become more and more pronounced. As a result, begining at some point, the ray of light becomes wider and wider as the opening becomes smaller and smaller. Indeed, this is one of the consequences of the dual nature of light.




- **LIGHT POSTULATES**

The geometrical properties of light are based on four assumptions known as ***postulates:***

① Rectilinear propagation (light travels in a straight line)
② Law of Reflection (light changes direction within the same medium)
③ Law of Refraction (light bends in going from one medium into another medium)
④ Principle of reversibility (source-to-object path equals object-to-source path)

- **FERMAT'S PRINCIPLE**

The French mathematician Pierre Fermat, considered by some historians as the inventor of integral calculus, was the first to record that light takes the ***shortest*** possible distance when traveling from one point to another. As Fermat put it, "nature is economical".

⇨ Fermat's principle: The path taken by a light ray in going from one point to another is that path which takes the ***least*** possible time.

↳ ***Note***: Fermat was unaware that there are circumstances in nature where light takes the ***longest*** possible path and thus the ***longest*** possible time to travel from one point to another.

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**1.** Define light and explain what is meant by the phrase "the dual nature of light".

**Light is a form of energy. It has a dual nature in that it possesses both particle properties and wave properties.**

**2.** Define: a) Geometrical optics

b) Physical optics

**3.** State the three ***particle*** properties of light:

❶ Rectilinear propagation
❷ Reflection
❸ Refraction

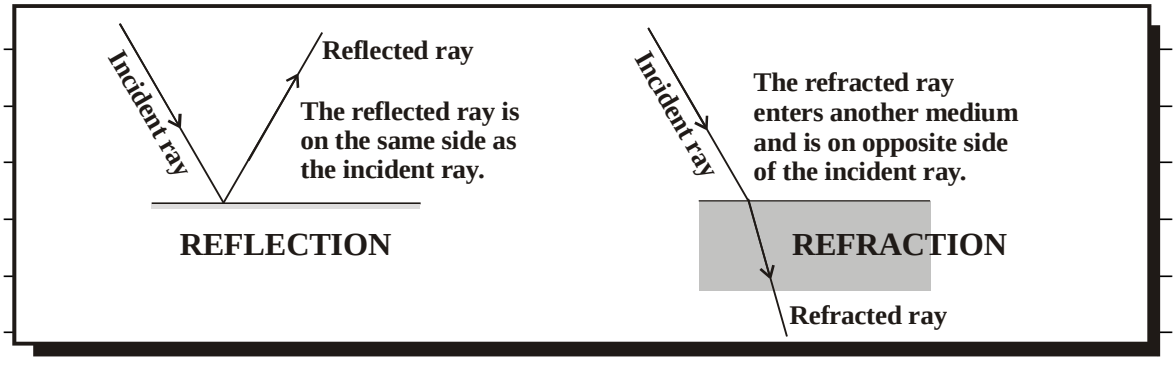
**4.** State the three ***wave*** properties of light:

❶ Interference
❷ Diffraction
❸ Polarization

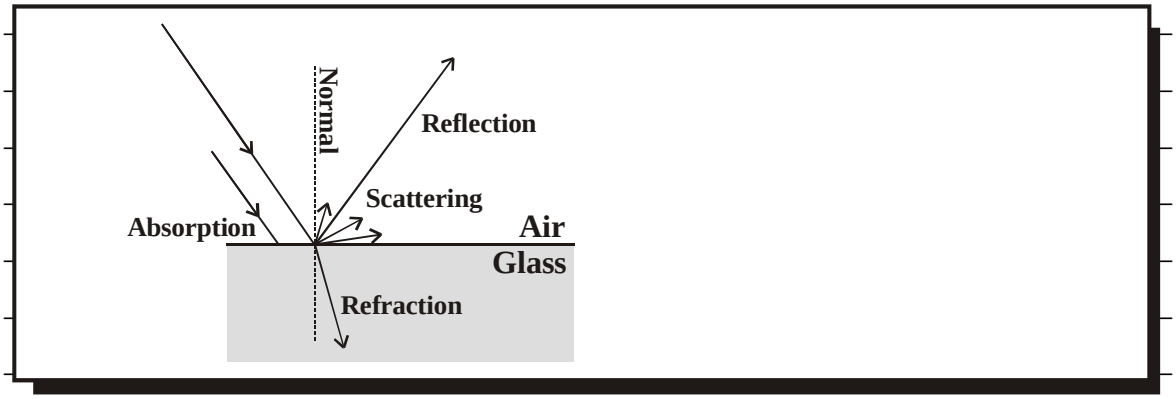
**5.** State the four postulates (assumptions) of light:

① Rectilinear propagation
② Law of reflection
③ Law of refraction
④ Principle of reversibility

**6.** With the aid of a diagram, explain the difference between ***reflection*** and ***refraction***.



**7.** Explain the four phenomena which occur when a light beam strikes a surface.




**8.** State Fermat's Principle

**The path taken by a light ray in going from one point to another is that path which takes the least possible time.**

**9.** In your own words, define a photon.

**A photon is a packet of light energy traveling at the speed of 3 x $10^8$ m/s.**

**Each different color is a photon containing a different amount of energy.**

**10.** What distance will light travel in:

a) One second

$$d = c\,t$$
$$= (3\times10^{8}\ \text{m/s})(1\ \text{s})$$
$$= 3\times10^{8}\ \text{m}$$

b) One hour

$$d = c\,t$$
$$= (3\times10^{8}\ \text{m/s})(3600\ \text{s})$$
$$= 1.1\times10^{12}\ \text{m}$$

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