

## LIGHT NOTES

The corpuscular (**particle**) theory of *Newton* states that light is composed of particles.

The **wave** theory of *Huygens* states that light is composed of waves. Light waves are transverse waves composed of crests and troughs. (Sound waves are longitudinal).

We need both theories to explain all the phenomenon of light. Whenever a tiny particle moves at high speed, it assumes wave properties.

**Photons** are the particles (with wave properties) of light. Each photon is a quantum of energy.

The electromagnetic theory states that light photons are waves with two components at right angles to each other. The electric field and the magnetic field are the components.

### PROPERTIES OF LIGHT:

**RECTILINEAR PROPAGATION** . Like all waves, the wave front spreads out in straight lines from the origin.

**REFLECTION**. The angle of incidence equals the angle of reflection. The angles are measured from the **NORMAL** to the surface.

**REFRACTION** is the bending of light as it changes media at an angle. It is due to the fact that light travels more slowly in denser media.

**DIFFRACTION** is the spreading out of light waves as they pass around objects.

**THE PHOTOELECTRIC EFFECT**. When light strikes a substances with sufficient energy, electrons are emitted by the substance. An example is the photoelectric cell or the "electric eye".

**THE QUANTUM THEORY** explains the photoelectric effect. The energy of the emitted electrons depends on the frequency of the light photon. The number of electrons emitted depends on the intensity of the light.

**PLANK'S EQUATION** is  $E = hf$  where E is the energy of the emitted electron, f is the frequency of the light waves, and h is Plank's Constant,  $6 \times 10^{-34}$  js (the quantum of energy).

**THE QUANTIZED ATOM**. The above quantum effects coupled with the discrete spectral lines emitted by stimulated atoms, led to the orbital model of the atom with electrons spreading out to fill quantum energy levels about the nucleus of the atom. Whenever an electron changes energy levels (orbitals), photons of light are absorbed or emitted. This gives the special spectral lines associated with each element.

**THE LASER** (Light Amplification by Stimulated Emission of Radiation), is the result of raising electrons to higher energy levels by applying a burst of energy (say by intense light,

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electrical charge, or chemical reaction). The energetic electrons drop back to their lower energy levels simultaneously when stimulated by photons reflecting back and forth between mirrors. This gives a coherent burst of pure light (the waves are in phase to give massive constructive interference).

**PRESSURE OF LIGHT.** Light exerts a force per area which is equal to  $4 \times 10^{-11}$  atmospheres. It is sufficient to push forth the tails of comets (along with other solar radiation).

### ILLUMINATION --

Luminous is the property of a substance to emit light by virtue of accelerated particles. Particles are accelerated by electric stimulation or by high temperature. Examples are stars, heated objects, and electric discharges. Illumination is the receiving of light from another source. An object which can be both luminous and illuminated is a light bulb. Intensity is the strength of light emitted. It is measured in candles, cd.

Illumination depends upon both intensity and distance (the inverse square law). Its unit is the lumen. One lumen is the amount of light received on the interior surface of sphere one meter in area at a distance of one meter from a one candle source. The formula for illumination is  $E = I/r^2$  where  $E$  is in lumens,  $I$  is in candles, and  $r$  is in meters. The Seasons on Earth are caused by the variation of the angle of incidence of the sun's rays due to the tilt of the earth's axis (23.5 deg).

The Speed of Light is 300,000 Km/s,  $3 \times 10^8$  m/s. From Michelson's method using a rotating mirror and the formula  $d = rt$ .

The Umbra is the total dark shadow of the earth and the moon.

The Moon is eclipsed when it is in the Earth's umbra.

The Sun is eclipsed when we are in the Moon's umbra.

The Penumbra is the partial shadow of the earth or the moon.

Partial eclipses involve the penumbra. See text for diagrams.

The Inverse Square Law applies to all forms of energy that radiate such as light, sound, gravity, magnetism, and electric fields.

### REFLECTION:

Regular reflection is caused by smooth surfaces so that the reflected rays are parallel.

Diffuse reflection is caused by irregular surfaces such that the reflected rays are not parallel.

Law of reflection-- The angle in incidence is equal to the angle of reflection. The angles are measured from the line drawn normal to the surface at the point of contact. These three parts are all in the same plane.

### MIRRORS--

Plane mirrors are flat and images appear as far behind them as the objects are in front of them.

Concave curves inward. It is a converging reflector as parallel rays come to a focus.

Convex curves outward (like the middle of the Boom). It will cause parallel rays to diverge.

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### REFRACTION:

Refraction is the bending of light as it passes from one medium into another due to its change in speed. The Index of Refraction is the ratio of the speed of light in vacuum to the speed of light in the medium.

Snell's Law states that the index of refraction is also equal to the ratio of the sine of the angle of incidence to the sine of the angle of refraction. The angles are measured from the normal drawn to the surface.

$$n = \sin i / \sin r \text{ where } n \text{ is the index of refraction.}$$

### LENS OPTICS:

Converging lenses are thicker (avoid the term fatter) in the center. They cause parallel rays to pass through a focal point.

Diverging lenses are thinner in the middle. They cause parallel rays to spread out. Rules and diagrams for constructing and calculating lens situations are important.

### DISPERSION:

Dispersion is the spreading of white light into its spectrum of colors. ROY G BIV. It is caused by the fact that light of different wave lengths is refracted by different amounts. The red end of the spectrum bends the least.

Primary Colors of Light are red, green, and blue. These three join to make white light. The primaries of light ADD to make resultant colors.

Complementary Colors are two colors that join to make white light. One of the complements already contains two primaries.

Primary Colors of Pigment (paint) are cyan, magenta, and yellow. They SUBTRACT light by absorption. The three primaries of pigment produce black when mixed as they absorb all the light.

Chromatic Aberration is the distortion and separation of colors by the fact that different colors are refracted differently by uncorrected lenses.

### DIFFRACTION:

Diffraction is the spreading out of light as passes around sharp objects or through narrow slits.

Interference is the interreaction of light waves.

Constructive interference is the adding of light waves crest to crest and trough to trough.

Destructive interference is the adding of light waves crest to trough so that there is cancellation.

Two interacting light waves out of phase will give interference patterns. Thin Film interference explains soap bubble and oil slick colors. Also bird feathers are colored by this method.

The Diffraction Grating is a transparent surface having several thousand lines per centimeter etched thereon. It will produce spectra of white light or line spectra for stimulated gases. (The prism does this by refraction). Spectra are produced because different wavelengths are diffracted different amounts.

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**THE DOPPLER EFFECT** for light is the change in frequency (color) of light due to relative motion between the source and observer. Approaching gives blue shifts, and receding gives redshifts. Remember that higher frequency is bluer light, and approaching sources crowd waves more closely together to increase the frequency.

The relative velocity of stars and galaxies can be determined by the blue or red shifts of their light. The shift is a comparison of spectral lines of the star to the lines of the same elements in the laboratory.

**POLARIZATION** is the process of the light waves vibrating in the same plane. This is accomplished by certain crystals or by reflection of light at certain angles.

**SCATTERING OF LIGHT** is caused by small particles such as molecules or very tiny dust particles. The particles are a size about the same as the wavelength of the light being scattered.

**BLUE SKY AND DEEP WATER** are colored by the scattering of the blue light which has a short wave length. The longer red waves diffract around the particles in the atmosphere and travel a long distance.

Hence, during the day when the sun is high in the sky, the rays travel a short distance down through the atmosphere (a few hundred kilometers) and so not much blue light is scattered out.

**RED SUNSETS AND SUNRISES** are caused by the scattering of the short wave length blue light. This leaves the longer red waves to traverse the atmosphere to the observer over the horizon.

Hence, at sunrise and sunset, the rays are traveling a great distance through the atmosphere (thousands of kilometers) so most of the blue is scattered out and mainly the red remains.