SOMANY INSTITUTE OF TECHNOLOGY AND MANAGEMNET, REWARI.

PRINTING TECHNOLOGY

BASIC SCIENCE FOR PRINTING

UNIT-4

A thermosetting plastic is a polymer that irreversibly becomes rigid when heated. Such a material is also known as a thermoset or thermosetting polymer. Initially, the polymer is a liquid or soft solid. Heat provides energy for chemical reactions that increase the cross-linking between polymer chains, curing the plastic. The rate of curing may be increasing in many cases by increasing pressure or by adding a catalyst.

Examples

Many common plastics are thermosets. They include:

- Vulcanized rubber
- Fiberglass (a fiber-reinforced polymer composite)
- Polyester resin
- Polyurethane
- Melamine
- Bakelite
- Silicone resin
- Epoxy resin

Thermoplastics are defined as polymers that can be melted and recast almost indefinitely. They are molten when heated and harden upon cooling. When frozen, however, a thermoplastic becomes glass-like and subject to fracture. These characteristics, which lend the material its name, are reversible, so the material can be reheated, reshaped, and frozen repeatedly. As a result, thermoplastics are mechanically recyclable. Some of the most common types of thermoplastic are polypropylene, polyethylene, polyvinylchloride, polystyrene, polyethylenetheraphthalate and polycarbonate.

Properties

Thermoplastics have a simple molecular structure comprising chemically independent macromolecules. Upon heating, they are softened or melted, then shaped, formed, welded, and solidified when cooled. Multiple cycles of heating and cooling can be repeated, allowing reprocessing and recycling.

Applications

Thermoplastics have been around for a long time and are an important component of everyday life today. For example:

- Acrylonitrile butadiene styrene (ABS) is a thermoplastic used to manufacture:
  - Sports equipment.
  - Toys (for example LEGO® blocks).
  - Various automobile parts

- Polycarbonate is used to make:
  - CDs and DVDs.
  - Drinking bottles
  - Food storage containers
  - Eyeglass lenses.

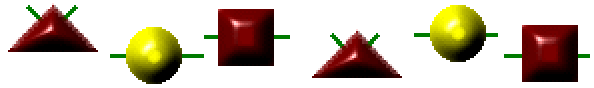
- Polyethylene is probably the most common thermoplastic and is used to make:
  - Shampoo bottles.
  - Plastic grocery bags.
  - Bullet-proof vests.

Lipids, Polysaccharides, Proteins and Polynucleotides are the major groups of **macromolecules** that are found in all living organisms. These giant molecules carry out all the vital functions needed by cells. Macromolecules are involved in processes such as food digestion, information storage, energy manipulation and metabolism. They are complex, huge associations of molecular subunits that appear impossibly difficult to understand. Fortunately they are all built using the same construction principle.

Monomers and Polymers

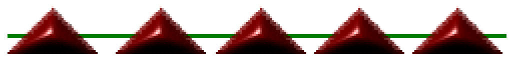
Monomers are small molecules, mostly organic, that can join with other similar molecules to form very large molecules, or polymers. All monomers have the capacity to form chemical bonds to at least two other monomer molecules.

monomers



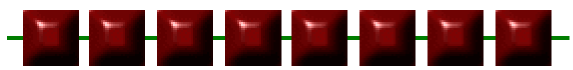
Polymers are a class of synthetic substances composed of multiples of simpler units called monomers. Polymers are chains with an unspecified number of monomeric units.

a polymer



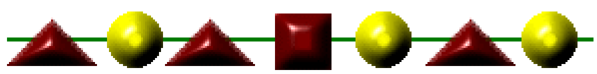
Homopolymers are polymers made by joining together monomers of the same chemical composition or structure.

a polymer consisting of all the same monomer



Heteropolymers are polymers composed of more than one kind of monomer.

a polymer consisting of more than one type of monomer

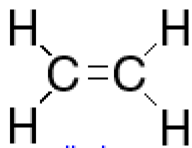


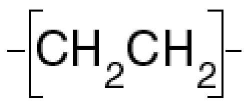
Artificial Polymers and Special Properties

One of the first humans to discover, and make, an artificial polymer, was the German chemist Hans von Pechmann. It was probably an accident. In 1899 he found a suspicious, sticky, white substance at the bottom of a flask in which he had been trying to decompose diazomethane. He had no idea what he had made, so he turned the analysis of the material over to Eugen Bamberger and Friedrich Tschirner, who found long chains of -CH_2-, which they called "polymethylene".

Some years later (1935) in England, Eric Fawcett and Reginald Gibson had a similar experience. They were trying very hard to make an explosive gas (ethylene) react with a much larger molecule (benzaldehyde), by forcing them together under high pressure. What they got was a useless, (so they thought!), white, waxy solid that couldn't be used for anything interesting or practical. How wrong they were, but nothing much more was done with this "polyethylene" until the start of the Second World War.

Suddenly there was a need for a flexible, non-reactive insulator to go around the cables of a new invention - radar. The British firm Imperial Chemical Industries re-discovered polyethylene and put it into production in 1939.

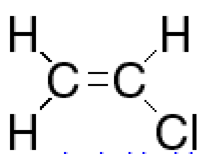

ethylene

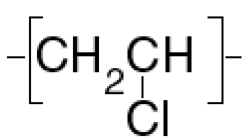

polyethylene

Small molecules of the odorless gas ethylene were then, and now, transformed into a polymer called polyethylene by uniting the ethylene monomers into a long chain. Some of these chains can be as long as 10,000 units. In some forms these chains branch, and they all coil and fold. Modern manufacturing methods start with ethylene gas which is heated under very high pressure until it becomes what is known as low-density polyethylene.

This material is a crystalline, transluscent thermoplastic which softens when heated. Today, consumers buy and use polyethylene in a huge number of ways, everything from packaging, garbage bags, soda bottles and containers, around wires (it's original use), and in almost every toy or house ware product on the market. Modern humans are very, very dependent on this particular artificial polymer.

polyvinylchloride


vinyl chloride

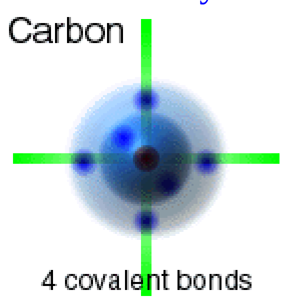

polyvinylchoride

The second most popular, and useful, artificial polymer is "polyvinyl chloride", PVC. In it's pure form PVC is quite rigid and will not easily catch fire, so it forms the basis of all kinds of pipes, and coverings for such things as siding, windows and doors. When other things, called plasticizers, are added to PVC, the material becomes much more flexible and can be used to produce everything from garden hose to shower curtains.

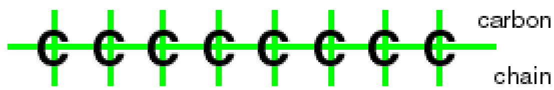
Such a universal, and safe, material has a dangerous start. The monomer used in it's synthesis is a deadly poisonous gas called vinyl chloride. This gas is made by passing oxygen, hydrogen chloride and ethylene over copper, which acts as a catalyst. After very careful storage and handling, the vinyl chloride is mixed with initiators that begin the polymerization process.

PVC is a homopolymer, which in its pure form is too stiff for most applications. However if a second momomer, vinyl acetate is also incorporated into the chain, a more flexible product is created that has many more uses. In 1930, the Union Carbide Corporation first began making this 'copolymer', called it "Vinylite", and pressed music into it to make phonograph records.

Carbon and Natural Bio-Polymers



The carbon atom has six electrons, four in the outermost energy level. Carbon can form four covalent bonds with other atoms and/or molecules. Carbon atoms can link to other carbon atoms to create long carbon strings that form the backbone of many natural organic molecules. It is this special property of carbon atoms that make them so important. Life is based on the chemistry of carbon.

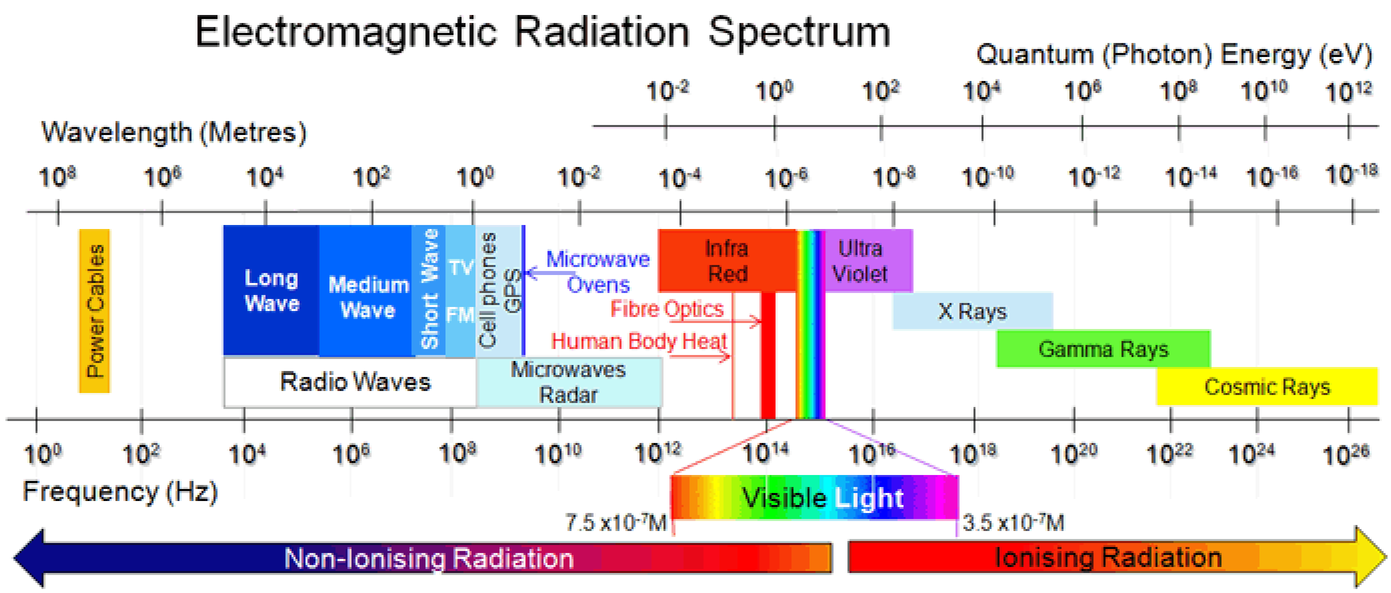


Electromagnetic Field

When a current flow through an object, it creates a physical field across it which is known as **Electromagnetic Field**. If the charges are stationary, then an electric field is created and if the charges are moving than a magnetic field is created. This electromagnetic field is mainly a combination of the electric and magnetic field which travels perpendicular to each other and spreads out infinitely throughout the space.

Electromagnetic Radiation

The Electromagnetic Field that propagates through space carries a radiant energy. This energy can be divided into 7 radiation namely radio Waves, Micro Waves, Infrared, Visible Lights, Ultraviolet, X-Ray and Gamma Rays based on their wavelength.



Light

The energy that is radiated within the wavelength of 400nm to 700nm and is a part of the visible light spectrum is visible to human eyes. It is due to the help of this light that human retina can perceive things around them. The naturally highest attainable speed in this world is that of light and it is equal to 3×10^{8} ms^{-1}.

Ray of Light

A Ray is defined as the path that a light traverse when it is travelling from one point to another.

Beam of Light

A bunch of ray of lights is known as **Beam of Lights**.

Optics

Optics is basically a branch of physics that deals with the study of the interactions of lights with matter and their behaviour.

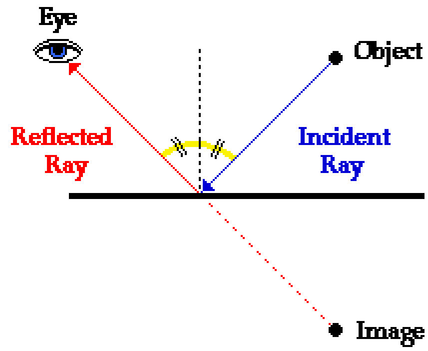
Reflection of Light

When a light travelling in air is incident on a reflecting surface material it gets reflected. The angle that the incident light makes with the normal of the surface is known as **Angle of Incidence** and the angle that the reflected light makes with the normal is known as Angle of Reflection.

Laws of Reflection:

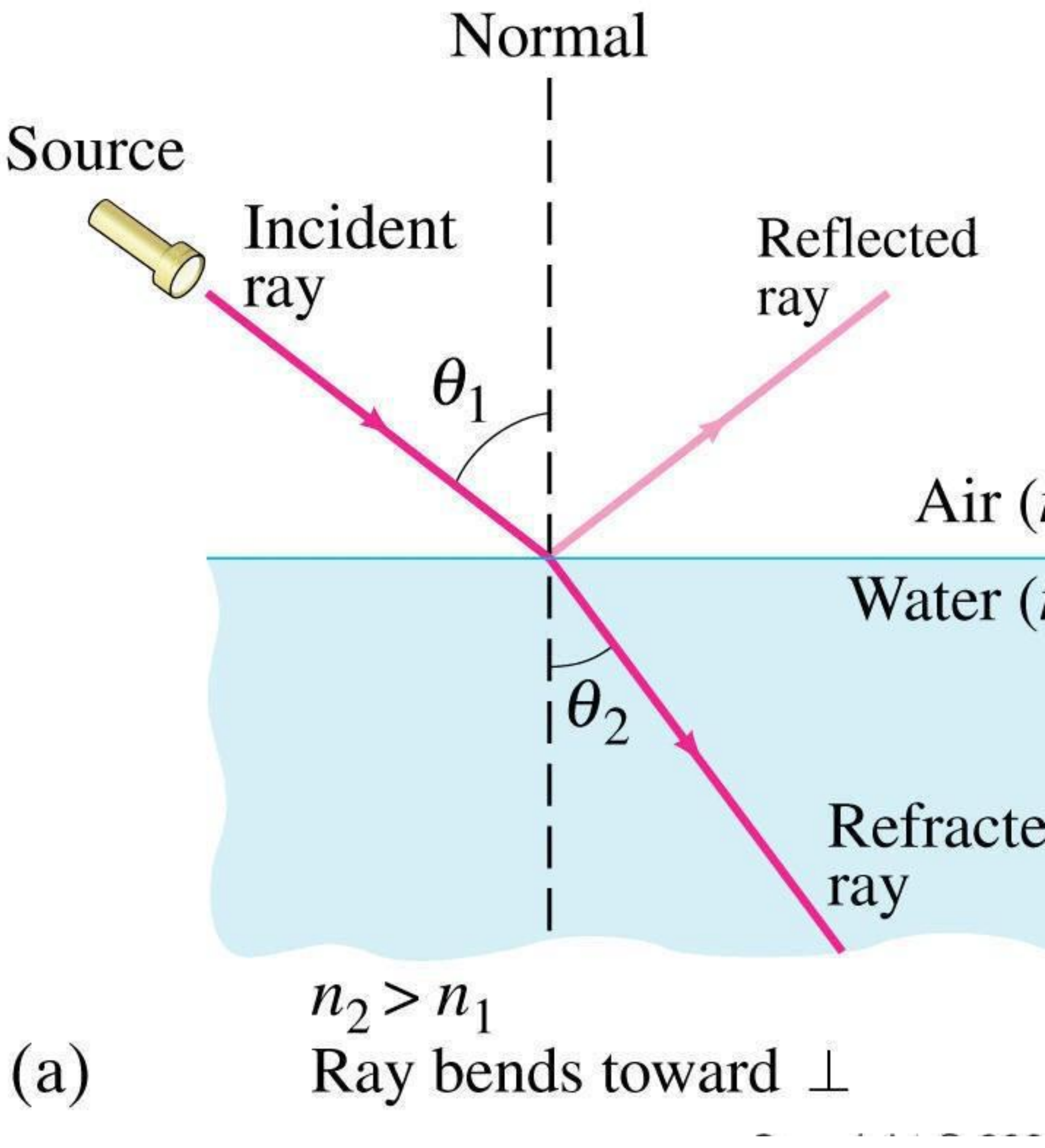
- The angle between the incident ray and normal that is, angle of incidence is always equal to the angle between normal and reflected ray that is, angle of reflection

- The ray which is incident on the surface, the normal and the ray which is reflected back lies on the same plane.



Refraction of Light

When a ray of light after travelling through air enters a different medium, it gets diffracted from the normal or bends towards the normal depending on the medium it is entering. When a ray of light travels from lighter medium to denser medium then the light bends towards the normal. Likewise, when a ray of light travels from denser medium to lighter medium, it deviates away from the normal.



Snell's Law or Laws of Refraction

- The incident ray, the refracted ray and the normal lie on the same plane of incidence.

- The ratio of the sine of angle of incidence to the angle of refraction is constant.

$$\frac{\sin i}{\sin r} = \frac{n_2}{n_1}$$

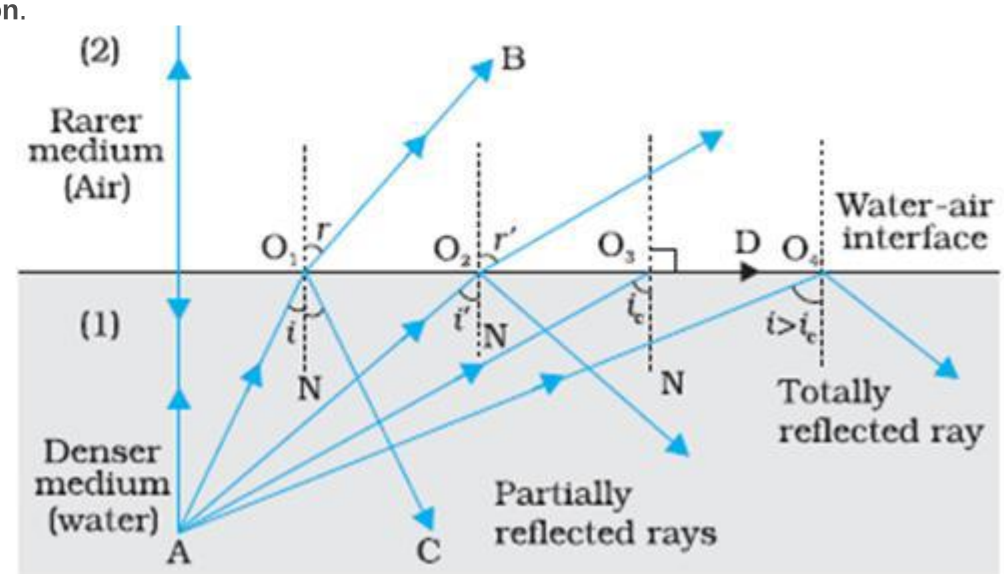
Where, n_2/n_1 is called the **Refractive Index**.

Total Internal Reflection

When a ray of light travels from a denser medium to a rarer medium, then a portion of it **gets reflected** back to the medium that it travelled and some portion enters the second medium and **gets refracted**. After some point, the incident ray gets totally reflected and does not suffer any further refraction. This reflection is known as **Total Internal Reflection**.

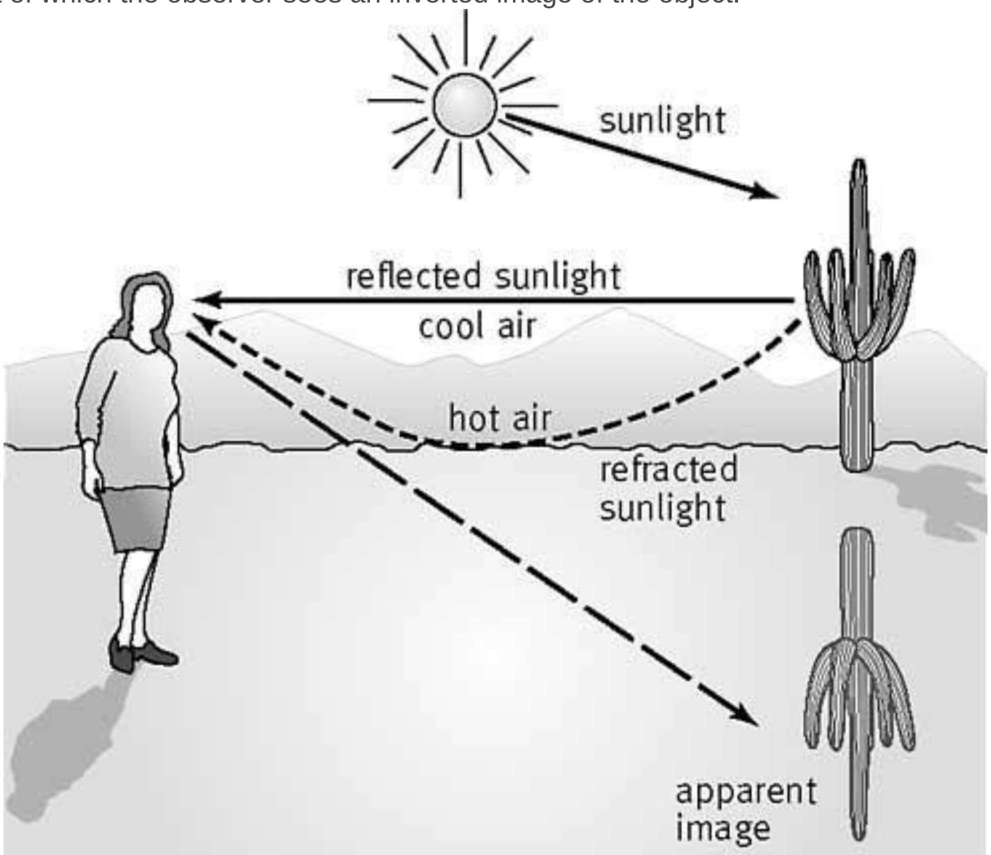
As we know that when a ray of light travels from a denser medium to rarer medium then it bends away from the normal.

Consider the example given below. A ray of light AO_1 while travelling from denser (water) to rarer medium (air), has some of its portion **reflected back** to the same medium (O_1C) forming an angle with the normal known as **Angle of Incidence (*i*)** while some of it portion gets refracted to the rarer medium creating a deviated angle with the normal which is known as **Angle of Refraction(*r*)**.
As seen from the diagram, there is an increase in the angle of refraction as the angle of incidence increases. A point comes when the angle of refraction is 90° (AO_3) and the incident ray (AO_4) gets totally reflected, after which there in no refraction possible even if the angle of incidence is increased further. This angle at which, the angle of refraction is perpendicular to normal that is, 90°, and there is no further refraction is known as **Critical Angle** and the Reflection is known as **Total Internal Reflection**.

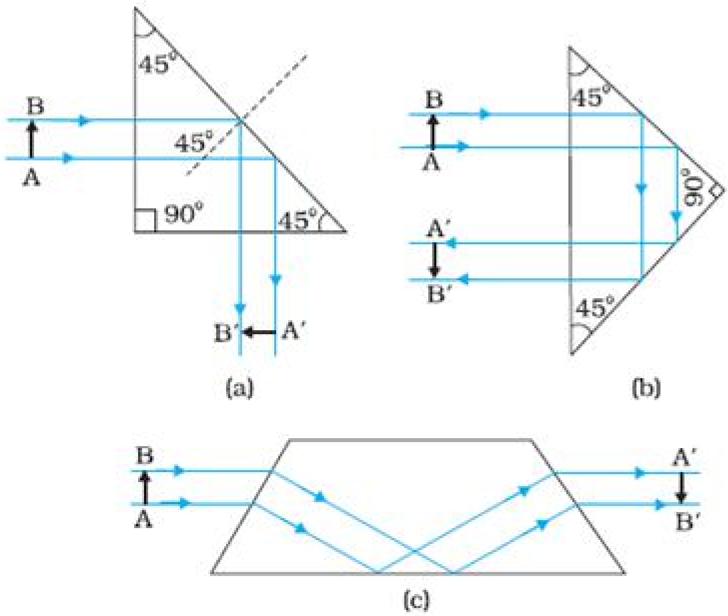


Applications of Total Internal Reflection:

- **Mirage**: Mirage is basically an optical illusion wherein the observer sees an inverted image of distant tall objects. During summer, the air near the ground is hotter compared to air at higher levels. The refractive index of hotter air is less than the cool air. So when light from a tall object travels from cool air (denser medium) to hot air (rarer medium), total internal reflection occurs, as a result of which the observer sees an inverted image of the object.



- **Diamond:** Diamonds are popular for their gloomy appearance. Naturally occurring diamonds does not have such property of shine. It is the technique of the diamond cutter who cuts and shapes diamond in such a way that, when light enters the diamond, it goes multiple total internal reflections. The refractive index of diamond is almost equal to 24.4° which is very small.
- **Prisms:** A prism is designed at such an angle that when light enters the prism, it undergoes total internal reflection at 90° or by 180°, which in returns produces an inverted image of the object without changing their size.

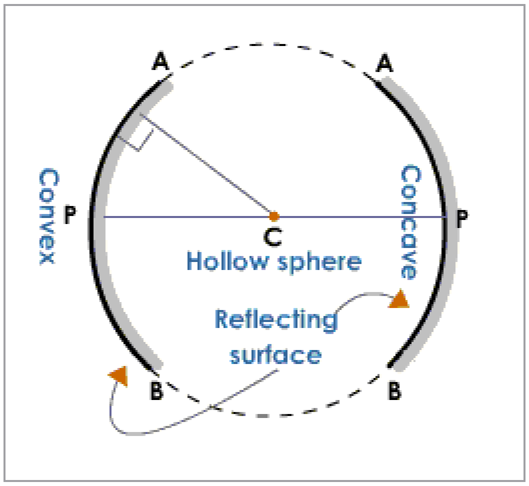


- **Optical Fibre:** Optical Fibres are made of glass/ quartz material. An optical fibre consists of two parts: a) core and b) cladding. The refractive index of the cladding is less than that of core. When data in the form of light is transmitted in optical fibre from one end than, it goes repeated **total internal reflection** and comes out from the other end without suffering any loss during the transmission. Optical fibres are most widely used for signal and video transmission. The most important advantage of optical fibre is that, even if the fibre is tweaked somewhere, there is no loss in data while transmission.

Spherical Mirrors and their types

Consider a glass with a hollow sphere and a reflecting surface. This reflecting hollow surface of the glass forms the spherical mirrors. Spherical mirrors are of two types:

a) Concave Mirror and b) Convex Mirror: Consider the diagram given below. The inward curved reflecting surface of the spherical mirror as seen in the figure below is known as **Concave Mirror** and the outward curved reflecting surface of the same spherical mirror is known a **Convex Mirror**.

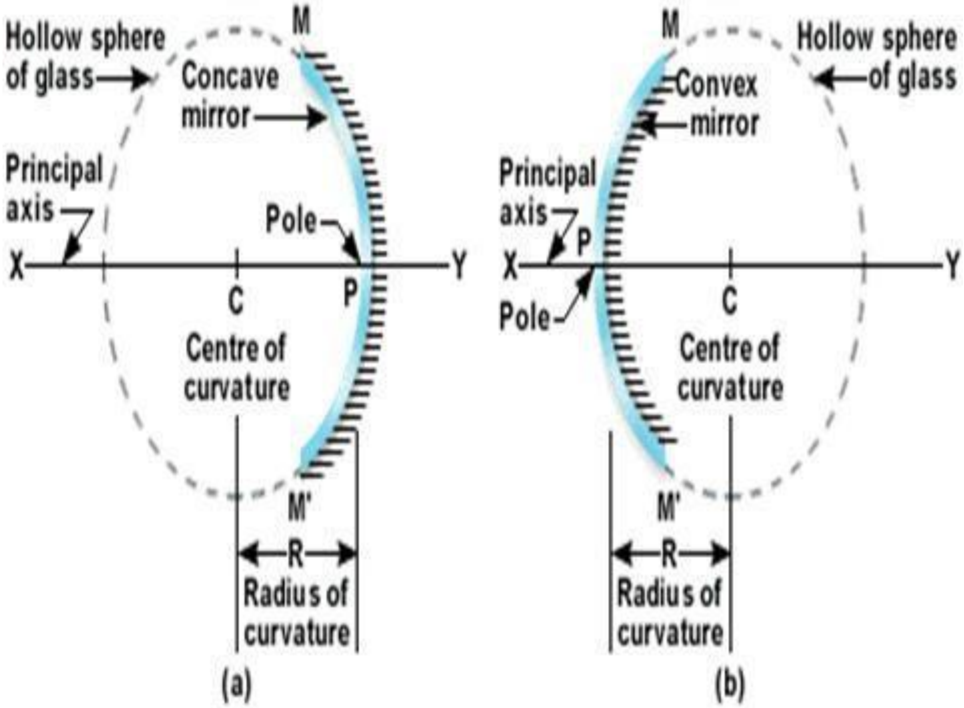


Centre of curvature of Spherical Mirrors

The centre of the hollow sphere which is a part of the spherical mirror is known as the centre of curvature. This is denoted by the letter **'C'**.

Pole of Spherical Mirrors

Pole of Spherical Mirror is the centre of the spherical mirror. It is denoted by the letter '**P'.** Kindly, note the difference between the centre of curvature and pole. Former is the centre of hollow sphere, whereas the latter is the centre of spherical mirror. For better understanding, consider the diagram given below:



Radius of curvature of Spherical Mirrors

The radius between the centre of curvature **'C'** and the Pole of the spherical mirror **'P'** is known as Radius of curvature.

Principal axis of a Spherical Mirror

It is a straight line joining the pole of the spherical mirror and the centre of the spherical mirror. In the above diagram XY is the principal axis.

Focal Length of a Mirror(*f*)

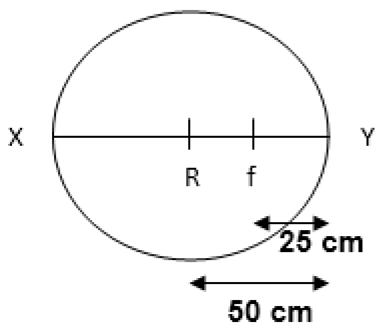
The focal length of a mirror is defined as the distance which is half of Radius of curvature, that is,

$$F = \frac{R}{2}$$

where f is the focal length and R is the radius of curvature.

Example of Numerical:

Q. If the radius of curvature of a spherical mirror is 50 cm, then find it focal length?



f = R/2

= 50/2

= 25 cm

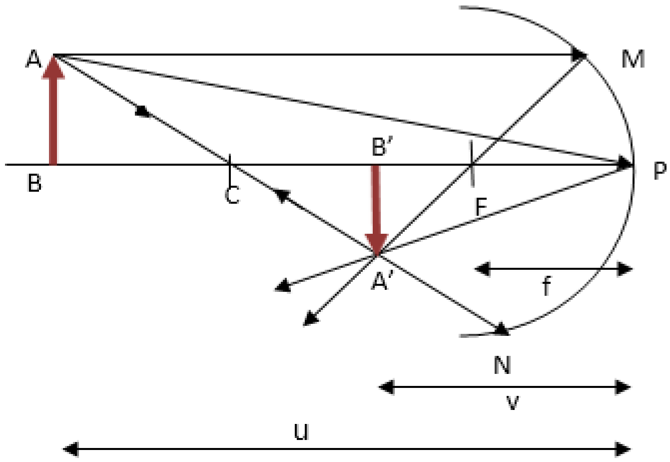
Sign Conventions

The Cartesian Sign Conventions that are considered while deriving the formulae for reflection and refraction by spherical mirror and lens respectively is given below:

- If the distance is measured in the direction same as that of the incident light, then the direction is taken to be positive while the distance measured in opposite direction is taken to be negative.
- The heights measured in upward direction normal to principal axis is considered positive while the height measured in downward direction normal to principal axis is considered negative.

Mirror Equation

Let us consider the diagram below to understand the process of image formation:



Let AB be an object and the distance of AB from the pole be ‘u’. ‘u’ is also known as **object distance**. An infinite number of rays travel from point A. But for time being let us consider only three rays that is, ray AM, AP and AN. The ray AN gets reflected back in the same direction that it travelled. As seen from the diagram the reflected rays of all the three rays intersect at a point where an inverted image of the object is formed. This is the real view of the original object. The distance at which the inverted image formed away from the pole is denoted by ‘v’. This distance is also known as **Image Distance**. **Then the mirror equation is given by**:

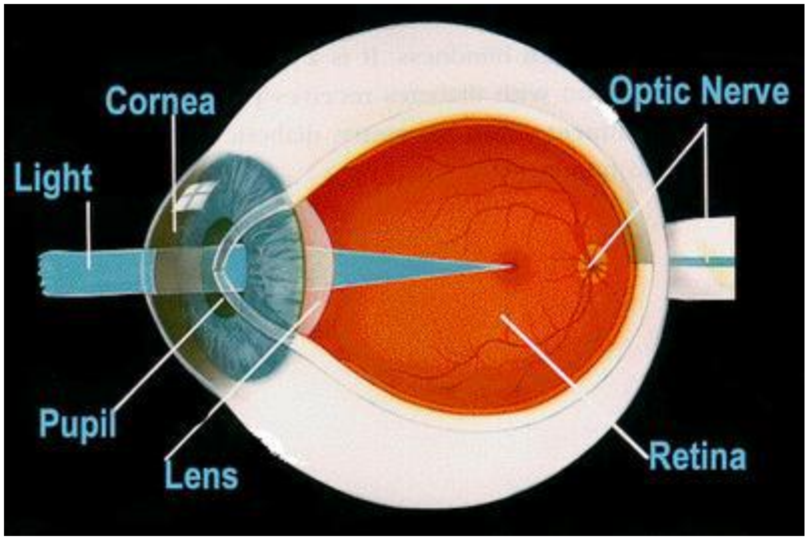
$$\frac{1}{f} = \frac{1}{u} = \frac{1}{v}$$

Introduction to optical instruments

Various optical instruments have been designed, using the property of reflection and refraction. Some of the important optical instruments are listed down below:

Eye

The Eye is the naturally designed optical instruments. Light enters the eye through cornea (which is the curved surface of eye) and enters the pupil through a hole in iris. The light further travels to the retina (which is covering the back of the curved surface of eye). The retina senses the intensity of light and its colour. The retina than further send electric signals to the brain via its optic nerve.



Microscope

The optical microscope makes use of the various properties of lights and enables the observer to view objects ranging from small to smallest, which is not even visible by naked eye by magnifying them to a larger size.

Telescope

An optical instrument which is used for angular magnification of distant objects like, celestial bodies, stars, etc is known as **Telescope**.

Colloids

A colloid is a mixture in which one substance of microscopically dispersed insoluble particles are suspended throughout another substance. Sometimes the dispersed substance alone is called the colloid. The colloid consists of a dispersed phase and a continuous phase.

Unlike solutions, colloids do not constitute a solute dissolved in the solvent phase. Rather, the solute phase is dispersed in the solvent phase. The dispersed-phase particles have a diameter between approximately 1 and 1000 nanometers. Such particles are normally easily visible in an optical microscope, although at the smaller size range ($r < 250$ nm), an ultramicroscope or an electron microscope may be required.

Some colloids are translucent because of the Tyndall effect, which is the scattering of light by particles in the colloid. Other colloids may be opaque or have a slight color.

Types of Colloids

- **Sol** – It is a suspension of minute solid particles in a liquid.
- **Emulsion** – It is a colloid between two or more liquid with one consisting a dispersion of another liquid.
- **Foam** – It consists of gas dispersed in solid or liquid.
- **Aerosol** – It consists of a minute liquid or solid particles in a gas.

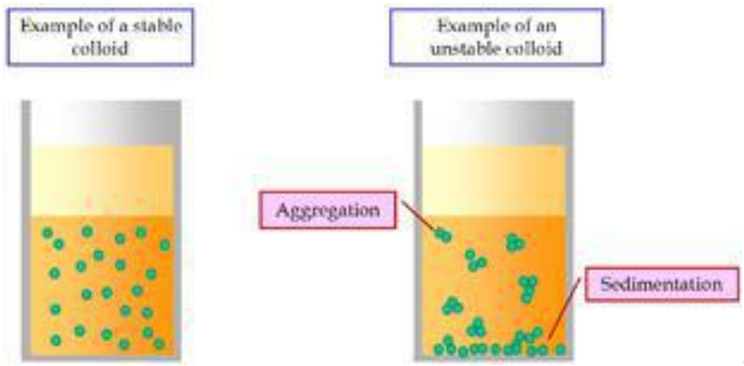
Methods of Preparation

There are two principal ways of preparation of colloids:

- Dispersion of large particles or droplets to the colloidal dimensions by milling, spraying, or application of shear (e.g., shaking, mixing, or high shear mixing).
- Condensation of small dissolved molecules into larger colloidal particles by precipitation, condensation, or redox reactions. Such processes are used in the preparation of colloidal silica or gold.

Stabilization of Colloids

The colloid is said to be stable when particles remain suspended in the solution without settling down i.e. the dispersed phase. Stability is hindered by aggregation and sedimentation phenomena, which are driven by the colloid’s tendency to reduce surface energy. In order to stabilize the colloidal system, we need to reduce the interfacial tension between the colloidal particles.



Source: Wikipedia

Aggregation is due to the sum of the interaction forces between particles. If attractive forces (such as van der Waals forces) prevail over the repulsive ones (such as the electrostatic ones) particles aggregate in clusters. Electrostatic stabilization and steric stabilization are the two main mechanisms for stabilization against aggregation.

- ***Electrostatic stabilization*** is based on the mutual repulsion of like electrical charges. In general, different phases have different charge affinities, so that an electrical double layer forms at any interface. Small particle sizes lead to enormous surface areas, and this effect is greatly amplified in colloids. In a stable colloid, the mass of a dispersed phase is so low that its buoyancy or kinetic energy is too weak to overcome the electrostatic repulsion between charged layers of the dispersing phase.
- ***Steric stabilization*** consists in covering the particles in polymers which prevents the particle to get close in the range of attractive forces.

Applications of Colloids

Colloids have varied applications. Some of them include:

- *Medicines*: Medicines in colloidal form are easily absorbed by the body tissues and hence are more effective.
- *Cleansing action of soap*: Soap solution is colloidal in nature. It removes the dirt particles either by adsorption or by emulsifying the greasy matter sticking to the cloth
- *Purification of water*: The precipitation of colloidal impurities present in water can be done by adding certain electrolytes like alum etc. The negatively charged colloidal particles of impurities get neutralized by the Al^{3+} ions and settle down and pure water can be decanted off.
- *Rubber industry:* Latex is a colloidal solution of negatively charged rubber particles. From latex, rubber can be obtained by coagulation. Rubber plated articles are prepared by depositing negatively charged rubber particles over the article to be rubber plated by making that article an anode in a rubber plating bath

What is fountain solution?

The dampening system on a lithographic sheetfed press applies a water-based dampening or fountain solution to the printing plate before it is inked. Dampening solutions keep the non-image areas of a plate moistened so that they will not accept ink, and are applied to the entire plate.

The non-image areas of the plate, which are made that way by adsorbing a thin film of gum arabic to them during platemaking, are hydrophilic (water loving) while the image areas are hydrophobic (water repellent). The desensitizing film on the non-image areas wears off gradually as the plate continues to run on press, so the chemicals in the dampening solution replenish the desensitizing film. Ink, plate, press speed, paper, temperature, and relative humidity are the principal factors that influence the need for various dampening solutions.

Fountain Solution

Fountain solution is a water-based mixture specially formulated to dampen lithographic printing plates before they are contacted by the inking rollers. In concentrated form, it is commonly referred to as fountain concentrate, fountain etch, or just etch. Most fountain concentrates today contain synthetic desensitizers. Very few manufacturers still use natural Sudanese gum arabic because of its cost. The term dampening solution is used for the diluted etch.

Fountain Solution Ingredients

Fountain solutions are usually sold as concentrated solutions that are diluted with water to the proper concentration. Most one-step concentrates already contain a natural or synthetic gum, an alcohol substitute, and other essential ingredients, and simply require being diluted with water. With two-step concentrates, the first step generally contains all of the ingredients except the alcohol substitute, with the alcohol substitute added as part of the second step. Although this extra step might be an inconvenience, it permits the press operator to control the alcohol substitute concentration better.

The proper mixture of chemicals in the solution is critical for quality printing. Though there may be many chemicals that make up a given manufacturer’s dampening solution concentrate, the general ingredients common to most are described below.

Composition of a Fountain solution

Fountain solution composition varies for a number of reasons. Most dampening solutions, however, are acidic, with a pH of 4.0-5.5 being typical. The dampening system itself also influences the composition of the dampening solution. For example, some dampening systems require a specific percentage of alcohol (or alcohol substitute) due to the method of applying the solution to the printing plate. Sometimes, in a conventional dampening system, the use of such an additive improves print quality although its presence in the dampening solution may not be essential.

In general, a dampening solution will consist of the following ingredients:

- Water, with minimal impurities.
- Acids or bases, depending to a large extent on the ink being used. Acids used include phosphoric acid, citric acid, and lactic acid.
- Gum, either natural (gum arabic) or synthetic, to desensitize non-image areas—that is, to make them prefer water to ink.
- Corrosion inhibitors, to prevent the dampening solution from reacting with the plate. Magnesium nitrate is sometimes used; it also acts as a scratch desensitizer and buffer (a substance capable of neutralizing acids and bases in solutions and thereby maintaining the acidity or alkalinity level of the solution).
- Wetting agents, such as isopropanol or an alcohol substitute, which decrease the surface tension of water and water-based solutions.
- Drying stimulator, a substance—such as cobalt chloride—that complements the drier in the ink. Drying stimulator is an additive that is used only if ink is not drying fast enough. Typical concentrations are 1-2 oz. of stimulator per gallon (8-16 ml per litre) of dampening solution.
- Fungicide, to prevent the formation of mildew and the growth of fungus and bacteria in the dampening system.
- Antifoaming agent, to prevent the build-up of foam. Foam can interfere with the even distribution of dampening solution on the dampening rollers.

What is pH?

- It measures the acidity or alkalinity in a solution
- The pH scale goes from 0 to 14, with 7 being neutral.
- A pH lower than 7 is acidic
- A pH higher than 7 is alkaline, or basic.
- Measured on a logarithmic scale, for example:

pH 5 solution = 10 X more acid than a pH 6 solution pH 4 solution = 100 X more acid than a pH 6 solution

What is conductivity?

- A solution's ability to transmit an electrical charge; to measure conductivity, one measures the number of ions in a solution. The higher the ion concentration, the higher the conductivity degree.

I hope this has given you a good overview of the necessary parts in a good fountain solution, and I leave you with some of the advantages of modern fountain solutions: prevention of printing plate surface oxidation; prevention of foaming in printing fountains and in dampening systems; curing of micro scratches on plate surfaces; lubrication of blanket surface; resistance to change of acidity in fountain; formation of protective film on plate surface; clean roll up; and minimum start up waste.