**Government of Tamil Nadu**

**Department of Employment and Training**

Course : TNPSC Combined Civil Services Examination - IV(Group IV / VAO)

Subject : Physics

Topic : Heat, Light and Sound



**Commissioner,**

**Department of Employment and Training.**

# HEAT, LIGHT AND SOUND

## Heat

Molecules in objects are constantly vibrating or moving inside objects. We cannot see that movement with our naked eye. When we heat the object this vibration and movement of molecules increases and temperature of the object also increases.

**Heat is an energy that raises the temperature of a thing by causing the molecules in that thing to move faster.**

Heat is not a matter. It does not occupy space. It has no weight. Like light, sound and electricity, heat is a form of energy.

**SI Unit of Heat is joule**. The unit calorie is also used.

## Temperature

The measurement of warmness or coldness of a substance is known as its Temperature.SI unit of temperature is kelvin.

## Heat and Temperature

Heat and temperature are not the same thing, they in fact mean two different things.

- Temperature is related to how fast the atoms or molecules move or vibrate within the substance.
- Heat not only depends on the temperature of the substance but also depends on how many molecules are there in the object.
- Temperature measures the average kinetic energy of molecules.
- Heat measures the total kinetic energy of the molecules in the substance.

## Transfer of heat

Heat transfer takes place in three ways:

i. Conduction, ii. Convection, iii. Radiation

**Conduction**

The process of transfer of heat in solids from a region of higher temperature to a region of lower temperature without the actual movement of molecules is called conduction.

e.g. Mercury is used in thermometers because it is a good conductor of heat.

**Convection**

Convection is the flow of heat through a fluid from places of higher temperature to places of lower temperature by movement of the fluid itself.

eg. Sea breeze and Land Breeze

**Radiation**

Radiation is the flow of heat from one place to another by means of electromagnetic waves.

e.g. Base of cooking utensils is blackened because black surface absorb more heat from the surrounding

**Sublimation**

The process in which a solid is converted to gaseous state is called sublimation.

**Specific Heat Capacity**

Specific Heat Capacity of a substance is defined as the amount of heat required to raise the temperature of 1 kg of the substance by 10C or 1 K. The SI unit of specific heat capacity is $Jkg^{-1}\ K^{-1}$. The most commonly used units of specific heat capacity are $J/kg^0C$ and $J/g^0C$.

**Heat capacity or Thermal capacity**

Heat Capacity is the heat required to raise the temperature of a entire mass of the body by 10C. Thus, heat capacity or thermal capacity is defined as the amount of heat energy required to raise the temperature of a body by 10C. It is denoted by C'.

**Change of state**

The process of changing of a substance from one physical state to another at a definite temperature is defined as change of state.

**Melting – Freezing**

The process in which a solid is converted to liquid by absorbing heat is called melting or fusion.

The temperature at which a solid changes its state to liquid is called melting point.

The reverse of melting is freezing. The process in which a liquid is converted to solid by releasing heat is called freezing.

The temperature at which a liquid changes its state to solid is called freezing point. In the case of water, melting and boiling occur at $0^0$C.

**Boiling-Condensation**

The process in which a liquid is converted to vapor by absorbing heat is called boiling or vaporization.

The temperature at which a liquid changes its state to gas is called boiling point.

The process in which a vapor is converted to liquid by releasing heat is called condensation.

The temperature at which a vapour changes its state to liquid is called condensation point.

Boiling point as well as condensation point of water is $100^0$C.

**Thermal contact**

Two objects are said to be in thermal contact if they can exchange heat energy.

**Thermal equilibrium**

Thermal equilibrium exists when two objects in thermal contact no longer affect each others temperature.

**Thermal Expansion**

The expansion of a substance on heating is called, the thermal expansion of that substance.

The expansion in length is called linear expansion and the expansion in volume is called cubical expansion.

Glassware used in kitchen and laboratory are generally made up of borosilicate glass (pyrex glass). The reason is that the borosilicate glass do not expand much on being heated and therefore they do not crack.

**Latent heat**

When a substance changes from one state to another, a considerable amount of heat energy is absorbed or liberated. This energy is called latent heat. Thus, latent heat is the amount of heat energy absorbed or released by a substance during a change in its physical sates without any change in its temperature.

Heat energy is absorbed by a solid during melting and an equal amount of heat energy is liberated by the liquid during freezing, without any temperature change. It is called latent heat of fusion.

**Specific Latent Heat**

Specific Latent Heat is the amount of heat energy absorbed or liberated by unit mass of a substance during change of state without causing any change in temperature.

The SI unit of specific latent heat is J/kg.

## LIGHT

Light is a form of energy which travels in the form of waves. The path of light is called ray of light and group of these rays are called as beam of light.

Any object which gives out light are termed as source of light. Some of the sources emit their own light and they are called as luminous objects.

## PROPERTIES OF LIGHT

- Light is a form of energy.
- Light always travels along a straight line.
- Light does not need any medium for its propagation. It can even travel through vacuum.
- The speed of light in vacuum or air is, $c = 3 \times 10^8\ ms^{-1}$.
- Since, light is in the form of waves, it is characterized by a wavelength ($\lambda$) and a frequency ($\nu$), which are related by the following equation: $c = \nu \lambda$ (c - velocity of light).
- Different coloured light has different wavelength and frequency.
- Among the visible light, violet light has the lowest wavelength and red light has the highest wavelength.
- When light is incident on the interface between two media, it is partly reflected and partly refracted.

## REFRACTION OF LIGHT

When a ray of light travels from one transparent medium into another obliquely, the path of the light undergoes deviation. This deviation of ray of light is called refraction.

Refraction takes place due to the difference in the velocity of light in different media.

## SCATTERING OF LIGHT

When sunlight enters the Earth's atmosphere, the atoms and molecules of different gases present in the atmosphere refract the light in all possible directions. This is called as 'Scattering of light'.

In this phenomenon, the beam of light is redirected in all directions when it interacts with a particle of medium.

The interacting particle of the medium is called as 'scatterer'.

**Types of scattering**

When a beam of light, interacts with a constituent particle of the medium, it undergoes many kinds of scattering.

Based on initial and final energy of the light beam, scattering can be classified as,

1)Elastic scattering 2) Inelastic scattering

**1)Elastic scattering**

If the energy of the incident beam of light and the scattered beam of light are same, then it is called as 'elastic scattering'.

**2)Inelastic scattering**

If the energy of the incident beam of light and the scattered beam of light are not same, then it is called as 'inelastic scattering'. The nature and size of the scatterer results in different types of scattering. They are

- Rayleigh scattering
- Mie scattering
- Tyndall scattering
- Raman scattering

**Rayleigh scattering**

The scattering of sunlight by the atoms or molecules of the gases in the earth's atmosphere is known as Rayleigh scattering.

**Rayleigh's scattering law**

Rayleigh's scattering law states that, "The amount of scattering of light is inversely proportional to the fourth power of its wavelength".

Amount of scattering 'S' $\propto \frac{1}{\lambda 4}$

According to this law, the shorter wavelength colours are scattered much more than the longer wavelength colours.

When sunlight passes through the atmosphere, the blue colour (shorter wavelength) is scattered to a greater extent than the red colour (longer wavelength). This scattering causes the sky to appear in blue colour.

At sunrise and sunset, the light rays from the Sun have to travel a larger distance in the atmosphere than at noon. Hence, most of the blue lights are scattered away and only the red light which gets least scattered reaches us. Therefore, the colour of the Sun is red at sunrise and sunset.

**Mie scattering**

Mie scattering takes place when the diameter of the scatterer is similar to or larger than the wavelength of the incident light.

It is also an elastic scattering. The amount of scattering is independent of wave length.

Mie scattering is caused by pollen, dust, smoke, water droplets, and other particles in the lower portion of the atmosphere.

Mie scattering is responsible for the white appearance of the clouds. When white light falls on the water drop, all the colours are equally scattered which together form the white light.

**Tyndall Scattering**

When a beam of sunlight, enters into a dusty room through a window, then its path becomes visible to us. This is because, the tiny dust particles present in the air of the room scatter the beam of light. This is an example of Tyndall Scattering.

The scattering of light rays by the colloidal particles in the colloidal solution is called Tyndall Scattering or Tyndall Effect.

**Colloid** is a microscopically small substance that is equally dispersed throughout another material. Example: Milk, Ice cream, muddy water, smoke

**Raman scattering**

When a parallel beam of monochromatic (single coloured ) light passes through a gas or liquid or transparent solid, a part of light rays are scattered.

The scattered light contains some additional frequencies (or wavelengths) other than that of incident frequency (or wavelength). This is known as Raman scattering or Raman Effect.

Raman Scattering is defined as *"The interaction of light ray with the particles of pure liquids or transparent solids, which leads to a change in wavelength or frequency."*

The spectral lines having frequency equal to the incident ray frequency is called 'Rayleigh line' and the spectral lines which are having frequencies other than the incident ray frequency are called 'Raman lines'.

The lines having frequencies lower than the incident frequency is called stokes lines and the lines having frequencies higher than the incident frequency are called Anti-stokes lines.

**LENSES**

A lens is an optically transparent medium bounded by two spherical refracting surfaces or one plane and one spherical surface.

Lens is basically classified into two types.

They are: (i) Convex Lens (ii) Concave Lens

**(i)Convex or bi-convex lens:**

It is a lens bounded by two spherical surfaces such that it is thicker at the centre than at the edges. A beam of light passing through it, is converged to a point. So, a convex lens is also called as converging lens.

**(ii) Concave or bi-concave Lens:**

It is a lens bounded by two spherical surfaces such that it is thinner at the centre than at the edges. A parallel beam of light passing through it, is diverged or spread out. So, a concave lens is also called as diverging lens.

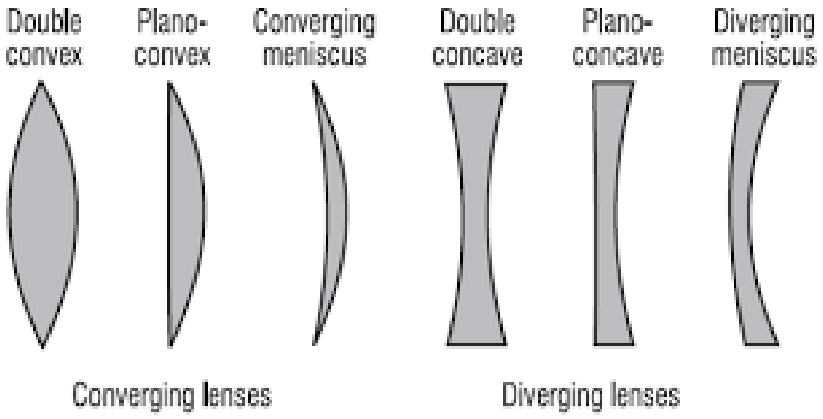
**Other types of Lenses**

**Plano-convex lens:**

If one of the faces of a bi-convex lens is plane, it is known as a plano-convex lens.

**Plano-concave lens:**

If one of the faces of a bi-concave lens is plane, it is known as a plano-concave lens.




**Lens Formula :**

The lens formula gives the relationship among distance of the object (u), distance of the image (v) and the focal length (f) of the lens.

It is expressed as

$$1/f = 1/v - 1/u$$

**Differences between a Convex Lens and a Concave Lens**

| S.No | Convex Lens | Concave Lens |
|---|---|---|
| 1 | A convex lens is thicker in the middle than at edges. | A concave lens is thinner in the middle than at edges. |
| 2 | It is a converging lens. | It is a diverging lens. |
| 3 | It produces mostly real images. | It produces virtual images. |
| 4 | It is used to treat hypermeteropia. | It is used to treat myopia. |

**APPLICATIONS OF CONCAVE LENSES**

1. Concave lenses are used as eye lens of 'Galilean Telescope'
2. They are used in wide angle spy hole indoors.

3. They are used to correct the defect of vision called ‘myopia’

**Persistence of vision**

If the time interval between two consecutive light pulses is less than 0.1 second, human eye cannot distinguish them separately. It is called persistence of vision.

**Myopia**

Myopia, also known as short sightedness, occurs due to the lengthening of eye ball. With this defect, nearby objects can be seen clearly but distant objects cannot be seen clearly. This defect can be corrected using a concave lens.

**Hypermeteropia**

Hypermeteropia, also known as long sightedness, occurs due to the shortening of eye ball. With this defect, distant objects can be seen clearly but nearby objects cannot be seen clearly. This defect can be corrected using a convex lens.

**Presbyopia**

Due to ageing, ciliary muscles become weak and the eye-lens become rigid (infl exible) andso the eye loses its power of accommodation. Because of this, an aged person cannot see the nearby objects clearly. So, it is also called as ‘old age hypermetropia’.

Some persons may have both the defects of vision - myopia as well as hypermetropia. This can be corrected by ‘bifocal lenses’. In which, upper part consists of concave lens (to correct myopia) used for distant vision and the lower part consists of convex lens (to correct hypermetropia) used for reading purposes.

**Astigmatism**

In this defect, eye cannot see parallel and horizontal lines clearly. It may be inherited or acquired. It is due to the imperfect structure of eye lens because of the development of cataract on the lens, ulceration of cornea, injury to the refracting surfaces, etc. Astigmatism can be corrected by using cylindrical lenses (Torrid lenses).

**Telescope**

Telescope is an optical instrument to see the distant objects. The first telescope was invented by Johann Lippershey in 1608.

**Types of Telescope**

According to optical property, it is classified into two groups:

i)refracting telescope ii) reflecting telescope

**Refracting Telescopes :**

In refracting telescope lenses are used. Galilean telescope, Keplerian telescope, Achromatic refractors, are some refracting telescopes.

**Reflecting Telescopes :**

In reflecting telescope parabolic mirrors are used Gregorian, Newtonian, Cassegrain telescope are some reflecting telescopes.

According to the things which are observed, Astronomical Telescope and Terrestrial Telescopes are the two major types of telescope.

**Advantages of Telescopes**

- Elaborate view of the Galaxies, Planets, starsand other heavenly bodies is possible.
- Camera can be attached for taking photograph for the celestial objects.
- Telescope can be viewed even with the low intensity of light.

**Disadvantages**

- Frequent maintenances needed.
- It is not easily portable one.

# SOUND

Sound is a form of energy which produces sensation of hearing in our ears. Human ear can hear only a particular range of frequency of sound that too with a certain range of energy.

**Properties :**

- Sound needs a medium for Propagation
- A sound wave is an example of a longitudinal mechanical wave.
- Sound can travel only when there are particles which can be compressed and rarefied.
- Compressions are the regions where particles are crowded together.
- Rarefactions are the regions of low pressure where particles are spread apart.

**Characteristics of a sound wave**

A sound wave can be described completely by five characteristics namely amplitude, frequency, time period, wavelength and velocity or speed.

**Amplitude (A)**

The maximum displacement of the particles of the medium from their original undisturbed positions, when a wave passes through the medium is called amplitude of the wave.

If the vibration of a particle has large amplitude, the sound will be loud and if the vibration has small amplitude, the sound will be soft.

Amplitude is denoted as A. Its SI unit is meter (m).

**Frequency (n)**

The number of vibrations (complete waves or cycles) produced in one second is called frequency of the wave.

It is denoted as n. The SI unit of frequency is s–1 (or) hertz (Hz).

Human ear can hear sound of frequency from 20 Hz to 20,000 Hz.

Sound with frequency less than 20 Hz is called infrasonic sound.

Sound with frequency greater than 20,000 Hz is called ultrasonic sound.

Human beings cannot hear infrasonic and ultrasonic sounds.

**Time period (T)**

The time required to produce one complete vibration (wave or cycle) is called time period of the wave. It is denoted as T. The SI unit of time period is second (s). Frequency and time period are reciprocal to each other.

**Wavelength (λ)**

The minimum distance in which a sound wave repeats itself is called its wavelength.

In a sound wave, the distance between the centers of two consecutive compressions or two consecutive rarefactions is also called wavelength. The wavelength is usually denoted as λ (Greek letter lambda). The SI unit of wavelength is metre (m).

**Velocity or speed (v)**

The distance travelled by the sound wave in one second is called velocity of the sound. The SI unit of velocity of sound is $m\ s^{-1}$.

## REFLECTION OF SOUND

When you speak in an empty room, you hear a soft repetition of your voice. This is nothing but the reflection of the sound waves that you produce.

When sound waves travel in a given medium and strike the surface of another medium, they can be bounced back into the first medium. This phenomenon is known as reflection.

**Laws of reflection**

The incident wave, the normal to the reflecting surface and the reflected wave at the point of incidence lie in the same plane.

The angle of incidence ∠i is equal to the angle of reflection ∠r.

## ECHOES

An echo is the sound reproduced due to the reflection of the original sound from various rigid surfaces such as walls, ceilings, surfaces of mountains, etc.

### Applications of echo

- Some animals communicate with each other over long distances and also locate objects by sending the sound signals and receiving the echo as reflected from the targets.
- The principle of echo is used in obstetric ultrasonography, which is used to create real-time visual images of the developing embryo or fetus in the mother's uterus. This is a safe testing tool, as it does not use any harmful radiations.
- Echo is used to determine the velocity of sound waves in any medium.

### Reverberation

A sound created in a big hall will persist by repeated reflection from the walls until it is reduced to a value where it is no longer audible. The repeated reflection that results in this persistence of sound is called reverberation.

### Whispering Gallery

One of the famous whispering galleries is in St. Paul's cathedral church in London. It is built with elliptically shaped walls. When a person is talking at one focus, his voice can be heard distinctly at the other focus. It is due to the multiple reflections of sound waves from the curved walls.

## APPLICATIONS REFLECTION OF SOUND

### Sound board

These are basically curved surfaces (concave), which are used in auditoria and halls to improve the quality of sound. This board is placed such that the speaker is at the focus of the concave surface. The sound of the speaker is reflected towards the audience thus improving the quality of sound heard by the audience.

**Ear trumpet**

Ear trumpet is a hearing aid, which is useful by people who have difficulty in hearing. In this device, one end is wide and the other end is narrow. The sound from the sources fall into the wide end and are reflected by its walls into the narrow part of the device. This helps in concentrating the sound and the sound enters the ear drum with more intensity. This enables a person to hear the sound better.

**Mega phone**

A megaphone is a horn-shaped device used to address a small gathering of people. Its one end is wide and the other end is narrow. When a person speaks at the narrow end, the sound of his speech is concentrated by the multiple reflections from the walls of the tube. Thus, his voice can be heard loudly over a long distance.

**DOPPLER EFFECT**

When ever there is a relative motion between a source and a listener, the frequency of the sound heard by the listener is different from the original frequency of sound emitted by the source. This is known as “Doppler effect”.

**Applications of Doppler effect**

**(a) To measure the speed of an automobile**

An electromagnetic wave is emitted by a source attached to a police car. The wave is reflected by a moving vehicle, which acts as a moving source. There is a shift in the frequency of the reflected wave. From the frequency shift, the speed of the car can be determined. This helps to track the over speeding vehicles.

**(b) Tracking a satellite**

The frequency of radio waves emitted by a satellite decreases as the satellite passes away from the Earth. By measuring the change in the frequency of the radio waves, the location of the satellites is studied.

**(c) RADAR (RAdio Detection And Ranging)**

In RADAR, radio waves are sent, and the reflected waves are detected by the receiver of the RADAR station. From the frequency change, the speed and location of the aeroplanes and aircrafts are tracked.

**(d) SONAR**

In SONAR, by measuring the change in the frequency between the sent signal and received signal, the speed of marine animals and submarines can be determined.

**(e) Ultrasonic sound or Ultrasound**

Ultrasonic sound is the term used for sound waves with frequencies greater than 20,000 Hz. These waves cannot be heard by the human ear, but the audible frequency range for other animals includes ultrasound frequencies. For example dogs can hear ultrasonic sound. Ultrasonic whistles are used on cars to alert deer to oncoming traffic so that they will not leap across the road in front of cars.

An important use of ultrasound is in examining inner parts of the body. Thus ultrasound is an alternative to X-rays. The ultrasonic waves allow different tissues such as organs and bones to be 'seen' or distinguished by bouncing of ultrasonic waves by the objects examined.

The waves are detected, analysed and stored in a computer. An echogram is an image obtained by the use of reflected ultrasonic waves. It is used as a medical diagnostic tool. Ultrasonic sound is having application in marine surveying also.

**Applications of ultrasonic waves**

Ultra sound can be used in cleaning technology. Minute foreign particles can be removed from objects placed in a liquid bath through which ultrasound is passed.

Ultrasounds can also be used to detect cracks and flaws in metal blocks.

Ultrasonic waves are made to reflect from various parts of the heart and form the image of the heart. This technique is called ‘echo cardiography’.

Ultrasound may be employed to break small ‘stones’ formed in the kidney into fine grains. These grains later get flushed out with urine.

**(f) Hearing Aid**

A hearing aid is an electronic, battery operated device. The hearing aid receives sound through a microphone. The microphone converts the sound waves into electrical signals. These electrical signals are amplified by an amplifier.

The amplified electrical signals are given to a speaker of the hearing aid. The speaker converts the amplified electrical signals to sound and sends to the ear for clear hearing.

**Points to Remember**

- Wave velocity is the velocity with which the wave travels through the medium.
- Velocity of a sound wave is maximum in solids because they are more elastic in nature than liquids and gases. Since gases are least elastic in nature.
- Infrasonic waves are sound wave with a frequency below 20 Hz. A human ear cannot hear these waves.
- Ultrasonic waves are sound waves with frequency greater than 20 kHz, A human ear cannot detect these waves.
- The minimum distance between the source and the reflecting surface should be 17.2 m to hear an echo clearly.
- The deviation in the path of light ray is called refraction.
- The ratio of speed of light in vacuum to the speed of light in a medium is defined as refractive index ‘μ’ of that medium.

- The ability of the eye to focus nearby as well as the distant objects is called power of accommodation of the eye.
- A microscope is an optical instrument which helps us to see the objects which are very small in dimension.
- Telescope is an optical instrument used to see the distant objects clearly.
- Sound cannot travel through vacuum.
- All the molecules have kinetic energy as well as potential energy.
- Expansion, change in temperature and change in state are the effects of heat.
- Heat is transferred from hot region to cold region.