Hints & SOLUTIONS

1. (c)
2. (d)
3. (d)
4. (d) Scientific concept of work suggest that a work is said to be done if a force acts on an object and the object gets displaced.
5. (c)
6. (d)
7. (a) Work done is defined as the product of force and displacement.
8. (d)
9. (a)
10. (b)
11. (d) Unit of work done is Joule or Newton meter.
12. (d)
13. (a)
14. (d)
15. (b) Work done by a force can be both negative and positive.
16. (d)
17. (d)
18. (b)
19. (d) Negative value of work indicates that more than one force is acting on the object. The displacement and force are in opposite directions.
20. (c)
21. (a)
22. (a)
23. (b) Energy is the capacity of doing work.
24. (a)
25. (c)
26. (b)
27. (c) Unit of energy is same as the unit of work, i.e. Joule.
28. (c)
29. (a)
30. (a)
31. (b)
32. (a)
33. (a)
34. (b) 35. (d)

36. (d)
37. (a)
38. (b)
39. (c)
40. (d)
41. (c) The gravitational potential energy is not affected by the path followed provided the overall height is same.
42. (c) Mechanical energy = Potential energy + Kinetic energy.
43. (c) Rate of doing work is called power.
44. (d) 1 kilowatt = 1000 W = 1000 J s^{-1} = 1000 N m s^{-1}.
45. (d) 1 kW h = 3.6×10^6 J; 1 kW h is the energy consumed in one hour at the rate of 1000 Js^{-1}. 1 kW h is commonly referred to as a unit of electrical energy.
46. (c) Energy consumed = Work done = 0.5 kW × 5 hours × 30 days = 75 kW h.
47. (d) Solar energy can be transformed into chemical, electrical, heat or mechanical energy by using suitable equipments.
48. (d) Potential energy gets converted into kinetic energy progressively and the sum of potential energy and kinetic energy at any point during the free fall remains constant.
49. (c) The change in momentum on collision is likely to make the object rebound. The momentum of the object can cause a crater in the ground. The kinetic energy will be converted into heat energy.
50. (c) Kinetic energy = $\frac{1}{2}mv^2$ $\quad \therefore$ K.E. $\propto v^2$

    If velocity is doubled then kinetic energy will become four times.
51. (a) Let initial kinetic energy, $E_1 = E$

    Final kinetic energy, $E_2 = E + 300\%$ of $E = 4E$

    As $p \propto \sqrt{E} \Rightarrow \frac{p_2}{p_1} = \sqrt{\frac{E_2}{E_1}} = \sqrt{\frac{4E}{E}} = 2 \Rightarrow p_2 = 2p_1$

    $\Rightarrow p_2 = p_1 + 100\%$ of p_1

    i.e. momentum will increase by 100%.
52. (c) Kinetic energy = $\frac{1}{2}mv^2$

    As both balls are falling through same height therefore they possess same velocity.

But $KE \propto m$ (If v = constant)

$$\therefore \frac{(KE)_1}{(KE)_2} = \frac{m_1}{m_2} = \frac{2}{4} = \frac{1}{2}$$

53. **(b)** Efficiency

$$\eta = \frac{\text{useful work}}{\text{spent work}} = \frac{15gh}{(15+60)\,gh} = \frac{15}{75} = \frac{1}{5} = 20\%$$

Chapter 4 Sound, Oscillations, Heat & Thermodynamics

SOUND

Sound is a form of energy that we hear. A vibrating object i.e., anything that moves back and forth, to-and-fro from side to side, in and out and up and down produces sound, as the object (vibrating) has a certain amount of energy. Sound requires material medium-a solid, a liquid or a gas to travel.

If there is no medium to vibrate then no sound is possible, sound cannot travel in a vacuum. Air is a poor conductor of sound compared with solids and liquids.

Wave

Due to the vibratory motion of the particles of the medium a periodic disturbance is produced in a material medium. This is called a wave. In the absence of medium solid, liquid or gas sound wave is not being propagated but light (electromagnetic) waves travel through the vacuum.

Types of Waves

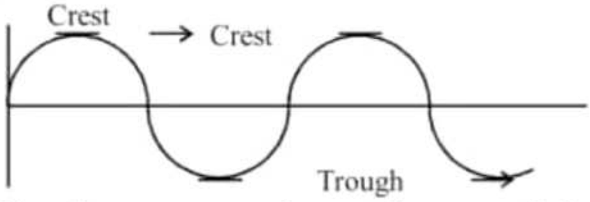
On the basis of the requirement of medium, waves are of two types

Mechanical Waves

A mechanical wave is a periodic disturbance which requires a material medium for its propagation. The properties of these waves depend on the medium so they are known as *elastic waves*, such as sound-waves, water waves, waves in stretched string etc. On the basis of motion of particles the mechanical waves are classified into two parts.

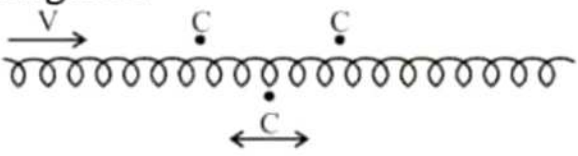
Transverse wave: When the particles of the medium vibrate in a direction perpendicular to the direction of propagation of the wave, the wave is known as the *transverse wave*. For example, waves produced in a stretched string, waves on the surface liquid.

These waves travel in the form of crests and troughs. These waves can travel in solids and liquids only.



Longitudinal wave: When the particles of the medium vibrate along the direction of propagation of the wave then the wave is known as the longitudinal wave. For example sound wave in air, waves in a solid rod produced by scrabbing etc.

These waves travel in the form of compressions and rarefactions. These waves can travel in solids, liquids and gases.



Electromagnetic Waves

The waves which do not require medium for their propagation are called electromagnetic waves. This means that these waves can travel through vacuum also. For example, light waves, X-rays, g-rays, infrared waves, radio waves, microwaves, etc. These waves are transverse in nature.

Difference between sound waves and electromagnetic waves

- Sound waves are longitudinal whereas electromagnetic waves are transverse.
- Sound waves travel at a speed of 340 m/s whereas electromagnetic waves travel at a speed of 3×10^8 m/s
- Sound waves do not pass through a vacuum but electromagnetic waves (light) do.

Basic Terms Related to Sound Waves

Time Period (T): Time taken in one complete vibration (full cycle) is called it's time period.
Frequency (n): Frequency is defined as the number of vibrations (or oscillations) completed by a particle in one second.

Frequency, $\nu = \frac{1}{T}$

Its SI unit is hertz
Wavelength (l): The distance travelled by the wave during the time in which any one particle of the medium completes one vibration about its mean position.
Amplitude: The maximum displacement of the wave particle from its mean position.
Wave Velocity: The distance i.e., wavelength (l) covered by a wave in one time period

Therefore, Wave velocity $= \frac{\text{wavelength}}{\text{time taken}}$

or $v = \lambda/T = \nu\lambda$

or Wave velocity = Frequency × Wavelength

Speed of sound is maximum in solids and minimum in gas.

Factors Affecting the Speed of Sound

Temperature: Speed of sound is directly proportional to the square root of absolute temperature i.e., .
Pressure: The speed of sound is independent of pressure.
Density: Speed of sound is inversely proportional to the square root of density of the gas.

$$v = \sqrt{\frac{\gamma P}{\rho}} \Rightarrow v \propto \frac{1}{\sqrt{\rho}} \text{ or, } \frac{v_1}{v_2} = \sqrt{\frac{\rho_2}{\rho_1}}$$

Humidity: Humid air is lighter than dry air that is why speed of sound increase as humidity increases.

Characteristics of Sound

Pitch

Pitch is the sensation (brain interpretation) of the frequency of an emitted sound and is the characteristic which distinguishes a shrill (or sharp) sound from a grave (or flat) sound. Faster the vibration of the source, higher is the frequency and higher is the pitch. Similarly low pitch sound corresponds to low frequency. A high pitch sound is called a shrill sound (humming of a bee, sound of guitar).

A low pitch sound is called a hoarse sound (roar of a lion, car horn, etc.)

The pitch of female voice is higher than the pitch of male voice.

Loudness

Loudness or softness of a sound wave is the sensation that depends upon its amplitude. The loudness of sound is a measure of the sound energy reaching the ear per second. When we strike a table top with more force, it vibrates and produces loud sound waves which have more amplitude.

The loudness depends on intensity as well as upon the sensitiveness of ear.

Loudness of sound is co-related with the sound level measured in **decible (dB)**,

Sound above 80dB is unpleasant for human ear.

Quality (Timbre)

Quality or timbre of a sound wave is that characteristic which helps us in distinguishing one sound from another having same pitch and loudness. We recognise a person (without seeing) by listening to his sound as it has a definite quality. *(A pure sound of single frequency is called a tone)*. An impure sound produced by mixture of many frequencies is called a **note**. It is pleasant to listen. Notes of the same pitch played upon different musical instruments are distinguished from each other by their quality. The quality of a note depends on the wave form. The waves produced by different instruments differ in their forms.

Reflection of Sound

It is a common experience that when we shout into a well or inside an empty hall, or inside a dome, we hear our own sound after a short time. It happens because our sound is reflected from the walls. When sound waves strike a surface, they return back into the same medium. This phenomenon is called reflection of sound.

Laws of Reflection of sound

- Angle of incidence Ði is equal the angle of reflection Ðr.
- The incident wave, the reflected wave and the normal all lie in the same plane.

Echo

The Phenomenon of hearing back our own sound is called an *echo*. It is due to successive reflection from the surfaces of obstacles.

Conditions for the formation of Echoes

- The minimum distance between the source of sound and the reflecting body should be 17.2 metres.
- The wavelength of sound should be less than the height of the reflecting body.
- The intensity of sound should be sufficient so that it can be heard after reflection.

Science in Action

- **Speaking tube or megaphone:** You must have seen in fairs or tourist spots, people using megaphones addressing a group of people. Megaphone is simply a horn-shaped tube. The sound waves are prevented from spreading out by successive reflections and are confined to the air in the tube. For the same reason, loud speakers also have horn-shaped.

Reverberation

Persistence of sound after its production is stopped, is called reverberation. When a sound is produced in a big hall, its waves reflect from the walls and travel back and forth. Due to this, energy does not reduce and the sound persist.

Range of Hearing

Normal human ears can hear the sound of frequency 20 Hz to 20,000 Hz. Sound of frequency less than 20 Hz is called **infrasonic**. Sound of frequency greater than 20,000 Hz is called **ultrasonic**. Children under the age of five and dogs, owls can hear upto 25 kHz. Whales and elephants produce sound in the infrasonic range. Rhinoceroes make communication between themselves by using a frequency as low as 5 Hz.

> ***Handy Facts***
> Supersonic refers to the speed greater than speed of sound

Ultrasound

Frequencies higher than 20,000 Hz are called ultrasound. Ultrasound can be produced by Galton's whistle. Some animals, such as dolphins can produce ultrasound. Bats can produce and hear ultrasound. On being high frequency waves, ultrasound possesses high intensity, and therefore can penetrate any solid or liquid medium.

SONAR

SONAR stands for **s**ound **n**avigation **a**nd **r**anging. SONAR is a device which is used to find depth of sea or to detect the position of submarine hidden inside water. Sonar consists of a transmitter and a detector.

Interference of Waves

When two waves of equal frequency and nearly equal amplitude travelling in same direction having same state of polarisation in medium superimpose, then intensity is different at different points. At some points intensity is large, whereas at other points it is nearly zero.

For Constructive Interference (Maximum Intensity)

Phase difference, $\phi = 2np$ or path difference = $n\lambda$ where n = 0, 1, 2, 3, ...

For Destructive Interference (Minimum Intensity)

Phase difference, $\phi = (2n + 1)\pi$, or path difference = $(2n-1)\frac{\lambda}{2}$; where n = 0, 1, 2, 3, ...

Stationary Longitudinal Waves and air columns

When two longitudinal waves of same frequency and amplitude travel in a medium in opposite directions then by superposition, standing waves are produced. These waves are produced in air columns in cylindrical tube of uniform diameter. These sound producing tubes are called **organ pipes.**

Vibration of Air Column in Closed Organ Pipe

The tube which is closed at one end and open at the other end is called closed organ pipe.

If λ is length of pipe and λ be the wavelength and v be the velocity of sound in organ pipe then,

Case (a), $L = \frac{\lambda}{4} \Rightarrow \lambda = 4L \Rightarrow n_1 = \frac{v}{\lambda} = \frac{v}{4L}$

Fundamental frequency or first harmonic.

Case (b), $L = \frac{3\lambda}{4} \Rightarrow \lambda = \frac{4L}{3} \Rightarrow n_2 = \frac{v}{\lambda} = \frac{3v}{4L}$

First overtone or third harmonic

Case (c), $L = \frac{5\lambda}{4} \Rightarrow \lambda = \frac{4L}{5} \Rightarrow n_3 = \frac{v}{\lambda} = \frac{5v}{4L}$

Second overtone or fifth harmonic.

Vibration of Air Column in Open Organ Pipe

The tube which is open at both ends is called an open organ pipe.

Case (a), $L = \frac{\lambda}{2} \Rightarrow \lambda = 2L \Rightarrow n_1 = \frac{v}{\lambda} = \frac{v}{2L}$

Fundamental frequency or first harmonic.

Case (b), $L = \frac{2\lambda}{2} \Rightarrow \lambda = \frac{2L}{2} \Rightarrow n_2 = \frac{v}{\lambda} = \frac{2v}{2L}$

First overtone or second harmonic.

Case (c), $L = \frac{3\lambda}{2} \Rightarrow \lambda = \frac{2L}{3} \Rightarrow n_3 = \frac{v}{\lambda} = \frac{3v}{2L}$

When open organ pipe vibrate in m^{th} overtone then

$$L = (m+1)\frac{\lambda}{4} \text{ so, } \lambda = \frac{4L}{m+1} \Rightarrow n = (m+1)\frac{v}{2L}$$

Second overtone or third harmonic.

Hence frequency of overtones i.e. of both odd and even harmonics and is given by the relation

$$n_1 : n_2 : n_3 \ldots\ldots\ldots\ldots = 1 : 2 : 3 \ldots\ldots$$

BEATS

When two sound waves of nearly same frequency are produced simultaneously, then the intensity of resultant sound wave increases and decreases with time. This change in the intensity of sound is called as the phenomenon of '*beats*'.

The time interval between two successive beats is called *beat period* and the number of beats per second is called the *beat frequency*.

If f_1 and f_2 are the frequencies ($f_1 > f_2$) of the two waves, then the beat frequency

$$b = f_1 - f_2$$

Important Features

- At frequency difference greater than about 6 or 7 Hz, we no longer hear individual beats.

SIMPLE HARMONIC MOTION (S.H.M.)

Oscillatory motion in which the acceleration of the particle is directly proportional to the displacement and directs towards a fixed point in a direction opposite to displacement is called simple harmonic motion abbreviated as S.H.M.

If a particle performs oscillatory motion such that its acceleration (a) and displacement (x) are related as below

$$a \propto -x,$$

then the motion of particle is simple harmonic.
The force (F) acting on the particle is obviously proportional to x and directs in opposite to it. i.e.,

$$F \propto -x$$

or $F = -kx$, where k is a constant force law
This force F is known as the restoring force as it always restore the position of the particle.

> ***Handy Facts***
>
> An oscillatory motion is always periodic i.e., the motion that repeats itself in equal intervals of time but a periodic motion may not be oscillatory.

Equation of S.H.M.

The equation of S.H.M. represents the displacement (x) of the particle at any time (t).
It is generally given by

$$x = A\sin(\omega t + \phi) \quad \text{or} \quad x = A\cos(\omega t + \phi)$$

Here, A = amplitude and ω = angular frequency

ϕ = phase constant or initial phase

Amplitude (A): It is the maximum distance on the either side of the mean position of oscillating particle. It is represented by A, its S.I. unit is metre (m).

Phase: Phase of a vibrating particle at any instant is the state of the vibrat ing particle regarding its displacement and direction of vibration at that particular instant.
The *cosine* in equation $x = A\cos(\omega t + \phi_0)$ gives the phase of oscillation at time t.

Velocity

The displacement of a particle executing S.H.M. is given by

$$x = A\sin(\omega t + \phi)$$

Time period: It is the time taken by the oscillating particle to complete one oscillation. It is represented by T.

Kinetic energy: A particle executing SHM possesses kinetic energy by virtue of its motion.

$$K.E = \frac{1}{2}mv^2 = \frac{1}{2}m\varpi^2(A^2 - x^2)\ (v = \omega\sqrt{A^2 - x^2})$$

Potential energy : A particle executing SHM possesses potential energy due to its displacement from its mean position.

$$P.E = \frac{1}{2}k\,x^2 \Rightarrow P.E = \frac{1}{2}m\omega^2x^2\ (k = m\omega^2)$$

At mean position, $x = 0 \Rightarrow$ P.E. = 0

At extreme position, $x = A$

- $(P.E)_{\max} = \frac{1}{2}m\omega^2A^2 = \frac{1}{2}k\omega^2$

Simple Pendulum

An ideal simple pendulum consists of a heavy point mass (bob) suspended by a weightless, inextensible and perfectly flexible string from a rigid support about which it is free to oscillate.

Time period of a simple pendulum,

$T = 2\pi\sqrt{\frac{l}{g}}$ where, l = length of pendulum

and g = acceleration due to gravity.

Time period of second pendulum is 2 seconds.

Resonance

The phenomenon of increase in amplitude when the driving force is close to the natural frequency of the oscillator.

Science in Action

- Resonance-while swinging in a swing to greater heights lies in the synchronisation of the rhythm of pushing against the ground with the natural frequency of the swing.

- Marching soldiers break steps while crossing a bridge.

HEAT AND THERMODYNAMICS

Heat is a form of energy which is responsible for the change in thermal condition of a body. It is also described as energy flow due to difference in temperature. The branch of science which deals with the conversion of heat into mechanical work and vice-versa is *Thermodynamics.*

Heat

Heat or thermal energy is the sum of all types of kinetic energies (translational, vibrational, rotational) of all the molecules of the body.

The SI unit of heat energy is joule (J), practical unit of heat energy is Calorie. "One calorie is the amount of heat required to raise temperature of one gram of water from 14.5°C to 15.5°C."

1 Calorie = 4.186 joule

Science in Action

The relative humidity during rainy season increases and the rate of vaporisation decreases. This is why clothes dry earlier in winter than in rainy season.

Temperature

Temperature is defined as the degree of hotness or coldness of a body. To measure temperature above 800°C, we use **Pyrometer**.

Absolute Temperature

The lowest temperature of –273.16°C at which a gas is supposed to have zero volume and zero pressure and at which entire molecular motion stops is called absolute zero temperature. A new scale of temperature starting with –273.16°C by Lord

Kelvin as zero. This is called Kelvin scale or absolute scale of temperature.

$$T(K) = t°C + 273.16$$

Temperature Scale

In order to measure the temperature, two-points are fixed, the lower fixed point is ice point and upper fixed point is boiling point of water.

Celsius Scale (°C): This scale was designed by Andre Celsius in 1710. In this scale the melting point of ice is taken as 0°C and the boiling point of water is taken as 100°C and the space between the two points is divided into 100 equal parts.

Fahrenheit Scale (°F): This scale was designed by Gabriel Fahrenheit in 1717. In this scale the melting point of ice is taken as 32°F and the boiling point of water is taken as 212°F and the space between the points is divided equally into 180 parts.

Kelvin Scale (K): This was designed by Kelvin. In this scale the melting point of ice is taken as 273K and boiling point of water is taken as 373K and the space between the points is divided equally into 100 parts.

Relation between various temperature scales

$$\left(\frac{C}{5} = \frac{F-32}{9} = \frac{K-273}{5}\right)$$

Handy Facts

- At –40° temperature, the celsius and fahrenheit scales read the same.
- At 574.25° temperature, the fahrenheit and kelvin scales read the same.

Triple Point of Water

The state at which three phases of water-ice, liquid water and water vapour are equally stable and coexist in equilibrium.

It is unique because it occurs at a specific temperature of 273.16 K and a specific pressure of 0.46 cm of Hg column.

Humidity

Absolute Humidity : It is the amount of water vapour present in a unit volume of air.

Relative humidity: It is defined as the ratio of the amount of water vapour present in a given volume of air at a given temperature to the amount of water vapour required to saturate the same volume of air at the same temperature.

> ***Science in Action***
>
> The relative humidity during rainy season increases and the rate of vaporisation decreases. This is why clothes dry earlier in winter than in rainy season.

Ideal-Gas Equation

The equation PV = nRT, where n = no. of moles in the sample of gas, R = Universal gas constant ($= 8.31\ J\ mol^{-1}\ K^{-1}$) is known as *ideal-gas equation.*

It is the combination of following three laws.

Boyle's Law: When temperature is held constant, the pressure is inversely proportional to volume.

i.e., $P\ ?\ \frac{1}{V}$ (at constant temperature)

Charle's Law: When the pressure is held constant, the volume of the gas is directly proportional to the absolute temperature.

i.e., $V \propto T$ (at constant pressure)

Avogadro's Law: When the pressure and temperature are kept constant, the volume is directly proportional to the number of moles of the ideal gas in the container.

i.e., $V \propto n$ (at constant pressure and temperature)

Thermal Expansion

When a body (almost all) is heated it expands. The expansion can take place in the length, area or volume of the body. Depending upon the expansion in length, area or volume we have three types of expansion.

Linear Expansion

Let l_1 be the length of a wire at temperature 'q$_1$' when temperature is increased to q$_2$, length increases to l_2 then

$$\alpha = \frac{\Delta l}{l_1 \Delta\theta} \text{ or } l_2 = l_1(1 + \alpha\Delta\theta)$$

($\Delta l = l_1 - l_2$ change in length & change in temperature

$\Delta\theta = \theta_1 - \theta_2$)

Where α is **coefficient of linear expansion**. Its unit is /°C or /K. It depends upon the nature of material. The value of 'a' also depends on temperature but very slightly.

Superficial or Areal Expansion:

Increase in surface area of a solid when temperature is increased. If A_1 and A_2 be the surface area at temperature q$_1$ and q$_2$ respectively then

$$\beta = \frac{\Delta A}{A_1 D\theta} \text{ or, } A_2 = A_1 (1 + \beta\Delta\theta)$$

'β' is **coefficient of superficial expansion** of a solid. Its unit is /°C and /K, it depends upon nature of material.

Cubical or Volume Expansion:

Increase in volume of a substance on heating. If V_1 and V_2 are volumes of a substance at temperature q$_1$ and q$_2$ respectively, then

$$y = \frac{\Delta V}{V_1 \Delta\theta} \text{ or, } V_2 = V_1(1 + gDq)$$

Where 'γ' is **coefficient of cubical expansion** of solid. Its unit is /°C or /K and it depends upon the nature of material.

The relation between (α, β and γ is $\alpha = \frac{\beta}{2} = \frac{\gamma}{3}$

$\Rightarrow$ α: β : γ = 1 : 2 : 3)

Science in Action

- A small gap is left between the iron nails of railway tracks.
- Space is left between the girders used for supporting bridges.
- Clock pendulums are made of invar. Invar has extremely small temperature coefficient of expansion, so the length of invar pendulum does not change with the change of season. i.e., temperature.

Expansion of Liquids

When we heat a liquid which is kept inside a container then liquid as well as the container both expand. In this case the observed expansion of liquid will be apparent expansion. But if the container were not expand then the expansion will be real expansion.

Coefficient of real expansion γ_r

$$= \frac{\text{real increase in volume}}{\text{originalvolume} \times \Delta\theta}$$

Coefficient of apparent expansion γ_a

$$= \frac{\text{apparent increase in volume}}{\text{originalvolume} \times \Delta\theta}$$

If γ_g is coefficient of volume expansion of material of container then

$$\gamma = \gamma_g + \gamma_a$$

Anomalous Expansion of Water

Almost all liquids expand on heating but water when heated from 0°C to 4°C its volume decreases and hence density increases until its temperature reaches 4°C as its density is maximum at 4°C and on further heating its density decreases. This behaviour of water is called anomalous behaviour of water.

This allows aquatic animals to remain alive and move freely near the bottom.

Calorimetry

We know that there is spontaneous transfer of heat from a hot body to colder body. If heat exchange with the surrounding is negligible then the total heat lost by a hot body is always equal to the heat gained by the cold body, this is the **principle of calorimetry or, law of mixture.**

Specific Heat Capacity

When we supply heat to a body, its temperature rises. If m is mass, Dq is temperature rise and Q is the heat supplied, then

$$Q \propto M \Rightarrow Q \propto \Delta\theta \text{ or } Q = Ms\Delta\theta \Rightarrow s = \frac{Q}{M\Delta\theta}$$

Where 's' is constant called *specific heat* which depends upon the nature of material and its surrounding.

Specific heat capacity of a material is equal to the heat required to raise temperature of unit mass from 14.5°C to 15.5°C.

Molar Heat Capacity and Heat Capacity

Molar heat capacity of a substance is the amount of heat required to raise the temperature of one mole of a substance by unit degree.

$$s_m = \frac{Q}{n\Delta\theta}$$

n = number of moles

Heat capacity of a substance is the amount of heat required to raise temperature of a body by unit degree. It is represented by C, its unit is J/°C or cal °C. Heat capacity depends upon nature of material and its mass.

$$\text{Heat capacity, } C = \frac{Q}{\Delta\theta} = \text{ms}$$

Water Equivalent and Latent Heat

Water Equivalent of a body is defined as the mass of water which has the same heat capacity as that of the body. It is represented by W.

Latent Heat or Hidden Heat: When state of a substance changes, change of state takes place at constant temperature (m.pt. or B. pt.) heat is released or absorbed and is given by

$Q = mL$ where L is latent heat. The S.I. unit of latent heat is J/kg.

Latent heat of fusion or melting (L_f): It is the amount of heat required to change unit mass of solid into liquid state at its melting point. It is represented by L_f. For ice its value is 80 cal g^{-1}.

$$Q = mL_f$$

Latent heat of vaporisation or boiling (L_v): It is the amount of heat required to change unit mass of liquid into its vapors at its boiling point. It is represented by L_v

For water L_v = 540 cal g^{-1}.

$$Q = mL_v$$

Sublimation: It is the conversion of a solid directly into vapours.

$$\text{Solid} \xrightarrow{\text{Heat}} \text{Vapour}$$

Regelation

The phenomenon in which ice melts when pressure is increased and again freezes when pressure is removed is called *regelation*.

Science in Action

- Skating is possible due to regelation. Water layer below the skates is formed due to the increase of pressure and it acts as a lubricant.
- By pressing snow in our hand, we can transform it into a snow-ball.

Heat Transfer

Heat energy can be transferred from a body at higher temperature to a body at lower temperature by three different ways viz. conduction, convection and radiation.

Conduction

Conduction is the process in which heat is transmitted from one point to the other through the substance without the actual motion of the particles. When one end of a metal is heated, the molecules at the hot end start vibrating with higher amplitudes (kinetic energy) and transmit this K.E. to the next molecule and so on. However, the molecules still remain in their mean positions of equilibrium. This process of conduction is prominent in the case of solids.

Convection

Convection is the process in which heat is transmitted from one place to the other by the actual movement of the vibrating particles. It is prominent in the case of liquids and gases.

Land and **sea breezes** and **trade winds** are formed due to convection. Convection plays an important part in ventilation, gas filled electric lamps and heating of buildings by hot water circulation. It is the process of transfer of heat in a fluid by the movement of the fluid itself.

Radiation

Radiation is the process in which heat is transmitted from one place to the other directly without the necessity of any intervening medium. We get heat radiations directly from the sun without affecting the intervening medium. Heat radiations can pass through vacuum. Heat radiations are a part of the electromagnetic spectrum.

Radiation has the following properties

- Radiant energy travels in straight line and when some object is placed in the path, it's shadow is formed at the detector.

- It is reflected and refracted or can be made to interfere. The reflection or refraction are exactly as in case of light.
- It can travel through vacuum.
- Intensity of radiation follows the law of inverse square.
- Thermal radiation can be polarised in the same way as light by transmission through a nicol prims.

Thermal Conductivity

It is the measure of ability of the solid to conduct heat through it. Examples: silver, copper, etc. are good conductors of heat and glass, wood are bad conductors of heat.

The coefficient of thermal conductivity (K) is defined as the amount of heat flowing in unit time across the opposite faces of a cube of side having unit length maintained at unit temperature difference.

Coefficient of thermal conductivity $K = \frac{(\Delta Q / \Delta t)}{(\Delta dT / \Delta x)}$

> ***Science in Action***
>
> - During the winter season, birds often swelt their feathers, this encloses the air between the body and feathers and thus stops the flow of heat from its body to the surroundings.
> - Metallic handles of doors during winter season appear colder as it is a good conductor, heat flows from the body to the handle.

Kirchhoff's Law

According to Kirchhoff's law the ratio of emissive power to absorptive power corresponding to the certain wavelength is the same for all bodies at a given temperature and is equal to the emissive power of a black body at that temperature.

Wien's Displacement Law

According to Wien's displacement law, wavelength corresponding to highest intensity (λ_m) is inversely proportional to the absolute temperature of the body.

Black Body

A black body absorbs the entire thermal radiation incident on it. Practically there is no body which absorbs 100% radiations incident on it. Ferry designed a black body which a spherical enclosure painted black from inside with a small hole in the wall.

Any radiation through this hole goes inside and get absorbed after multiple reflections. There is cone directly opposite to the hole due to which incident radiation is not reflected back through the hole.

Thermodynamic Processes

Thermodynamic process is said to take place if some change occurs in the state of a thermodynamic system, i.e. the thermodynamic variables of the system – pressure, volume, temperature and entropy change with time.

In practice, the following types of thermodynamic processes can take place :

Isothermal process: A thermodynamic process that takes place at constant temperature.

Isobaric process: A thermodynamic process that takes place at constant pressure.

Isochoric process: A thermodynamic process that takes place at constant volume.

Adiabatic process: A thermodynamic process in which no heat enters or leaves the system.

Cyclic process: A thermodynamic process in which the system returns to its original state.

Laws of Thermodynamics

Zeroth Law of Thermodynamics

If objects A and B are separately in thermal equilibrium with a third object C then objects A and B are in thermal equilibrium with each other.

First Law of Thermodynamics

If some quantity of heat is supplied to a system capable of doing external work, then the quantity of heat absorbed by the system is equal to the sum of the increase in the internal energy of the system and the external work done by the system.
i.e., $\Delta Q = \Delta U + \Delta W$

The first law of thermodynamics is essentially a re-statement of the law of conservation of energy i.e., energy can neither be created nor be destroyed but may be converted from one form to another.

Second Law of Thermodynamics

Kelvin-Planck statement : It is impossible for an engine working between a cyclic process to extract heat from a reservoir and convert completely into work. In other words, 100% conversion of heat into work is impossible.

Heat Engines

Heat engine is a device which converts heat energy into work. A heat engine, in general, consists of three parts :

- A source or high temperature reservoir at temperature T_1.
- A working substance.
- A sink or low temperature reservoir at temperature T_2.

The efficiency of internal combustion engine is approximately 40% to 60%.

Refrigerators and Heat Pumps

A **refrigerator** is the reverse of a heat engine. A heat pump is the same as a refrigerator.

Carnot Theorem

No irreversible engine (I) can have efficiency greater than Carnot reversible engine (R) working between same hot and cold reservoirs.

Exercise

DIRECTIONS: *This section contains multiple choice questions. Each question has choices (a), (2), (3) and (4) out of which only one is correct.*

1. Which of the following is carried by the waves from one place to another ?
   (a) Mass
   (b) Velocity
   (c) Wavelength
   (d) Energy
2. The velocity of sound is largest in
   (a) water
   (b) air
   (c) metal
   (d) vacuum
3. The ratio of the speed of a body to the speed of sound is called
   (a) Sonic index
   (b) Doppler ratio
   (c) Mach number
   (d) Refractive index
4. Sound is transmitted through a medium. The medium can be
   (a) Solid
   (b) Liquid
   (c) Gas
   (d) Solid, liquid or gas
5. The speed of sound of a wave of frequency 200 Hz in air is 340 m/s. The speed of sound of wave of frequency 400 Hz in same air is
   (a) 340 m/s
   (b) 680 m/s
   (c) 170 m/s
   (d) 3×10^8 m/s
6. Ultrasonic waves have frequency
   (a) below 20 Hz
   (b) between 20 and 20,000 Hz
   (c) only above 20,000 Hz
   (d) only above 20,000 MHz
7. One hertz is equivalent to
   (a) one cycle per second
   (b) one second

(c) one meter per second
(d) one second per meter

8. A particle of the medium in contact with the vibrating object is first displaced from its equilibrium position. It exerts a force on the adjacent particle and displaces it from rest. After displacing the adjacent particle the first particle
   (a) Comes back to its original position
   (b) Goes and displaces the other particle
   (c) Travels till the end of the medium
   (d) None of these
9. If you are at open-air concert and someone's head gets between you and the orchestra, you can still hear the orchestra because
   (a) sound waves pass easily through a head
   (b) a head is not very large compared with the wavelength of the sound
   (c) the sound is reflected from the head
   (d) the wavelength of the sound is much smaller than the head
10. An underwater explosion is caused near the sea-shore. There are two observers, X under water and Y on land, each at a distance of 1 km from the point of explosion
   (a) X will hear the sound earlier
   (b) Y will hear the sound earlier
   (c) Both will hear the sound at the same time.
   (d) Y will not hear the sound at all
11. In a long spring which of the following type of waves can be generated
   (a) longitudinal only
   (b) transverse only
   (c) both longitudinal and transverse
   (d) electromagnetic only
12. When a vibrating object moves forward, it pushes and compresses the air in front of it creating a region of high pressure called
   (a) rarefaction
   (b) compression
   (c) depression
   (d) hypertension
13. Human ears can sense sound waves travelling in air having wavelength of

(a) 10^{-3} m
(b) 10^{-2} m
(c) 1 m
(d) 10^{2} m

14. Which of the following statements is wrong?
(a) Sound travels in straight line
(b) Sound is form of energy
(c) Sound travels in the form of waves
(d) Sound travels faster in vacuum than in air

15. Voice of a friend is recognised by its
(a) pitch
(b) quality
(c) intensity
(d) velocity

16. When the vibrating object moves backwards, it create a region of low pressure called
(a) rarefaction
(b) compression
(c) depression
(d) hypertension

17. A sound wave travels from east to west in which direction do the particles of air move ?
(a) East-west
(b) North-south
(c) Up and down
(d) None of these

18. The unit of quantity on which loudness of sound depends is
(a) metre
(b) Hz
(c) metre/second
(d) second

19. The frequency of a wave travelling at a speed of 500 ms^{-1} is 25Hz. Its time period is
(a) 20 s
(b) 0.05 s
(c) 25 s
(d) 0.04 s

20. Pressure in the compression or rarefaction is related to the
(a) Number of particles of the medium in a given volume
(b) Density of particles in the medium
(c) Position of the particles

(d) Both (a) and (b)

21. Compression is a region of
(a) low pressure
(b) normal pressure
(c) high pressure
(d) no pressure

22. During summer, an echo is heard:
(a) sooner than during winter
(b) later than during winter
(c) after same time as in winter
(d) None of these

23. Echo is a type of
(a) reflected sound
(b) refracted sound
(c) polarised sound
(d) None of these

24. Sound is a
(a) mechanical wave
(b) electro-magnetic wave
(c) longitudinal waves
(d) Both (a) and (c)

25. Sitar is a
(a) wind instrument
(b) stringed instrument
(c) percussion instrument
(d) reed instrument

26. Sound cannot travel though –
(a) solids
(b) liquids
(c) gases
(d) vacuum

27. To hear a distinct echo, the minimum distance of a reflecting surface should be :
(a) 17 metres
(b) 34 metres
(c) 68 metres
(d) 340 metres

28. Sound can be characterized by its
(a) frequency only
(b) amplitude only
(c) speed only
(d) frequency, amplitude and speed

29. Which one of the following materials will reflect sound better?
    (a) Thermocole
    (b) Curtain made from cloth
    (c) Steel
    (d) Paper
30. A wave of frequency 1000 Hz travels between X and Y, a distance of 600 m in 2 sec. How many wavelengths are there in distance XY –
    (a) 3.3
    (b) 300
    (c) 180
    (d) 2000
31. The material used for making the seats in an auditorium has sound absorbing properties. Why?
    (a) It reduces reverberations.
    (b) It makes the quality of sound better
    (c) It makes the sound travel faster
    (d) All of the above
32. Select the irrelevant statement
    (a) Compressions are the regions where particles are crowded together
    (b) Compressions are represented by the upper portion of the curve in density-distance graph
    (c) Rarefactions are where particles are spread apart
    (d) Valleys are represented by the straight line
33. Bats can hunt at night
    (a) their eyesight is good
    (b) they can smell their prey
    (c) the high-pitched ultrasonic squeaks of the pat are reflected from the obstacles or prey and returned to bat's ear and thus the bat is able to detect.
    (d) All of the above
34. Which of the following statements is/are correct about sound?
    (i) Sound is produced by a vibrating body.
    (ii) Sound needs a medium for propagation.
    (iii) If 2 sounds are equally loud, then their pitch will also be equal.