Physics Notes Class 11 CHAPTER 9 MECHANICAL PROPERTIES OF SOLIDS

Deforming Force

A force which produces a change in configuration of the object on applying it, is called a deforming force.

Elasticity

Elasticity is that property of the object by virtue of which it regain its original configuration after the removal of the deforming force.

Elastic Limit

Elastic limit is the upper limit of deforming force upto which, if deforming force is removed, the body regains its original form completely and beyond which if deforming force is increased the body loses its property of elasticity and get permanently deformed.

Perfectly Elastic Bodies

Those bodies which regain its original configuration immediately and completely after the removal of deforming force are called perfectly elastic bodies. e.g., quartz and phosphor bronze etc.

Perfectly Plastic Bodies

Those bodies which does not regain its original configuration at all on the removal of deforming force are called perfectly plastic bodies, e.g., putty, paraffin, wax etc.

Stress

The internal restoring force acting per unit area of a deformed body is called stress.

Stress = Restoring force / Area

Its unit is N/m^2 or Pascal and dimensional formula is $[ML^{-12}T^{-2}]$.

Stress is a tensor quantity.

Stress is of Two Types

(i) Normal Stress If deforming force is applied normal to the area, then the stress is called normal stress.

If there is an increase in length, then stress is called **tensile stress**.

If there is a decrease in length, then stress is called **compression stress**.

(ii) **Tangential Stress** If deforming force is applied tangentially, then the stress is called tangential stress.

Strain

The fractional change in configuration is called strain.

Strain = Change in the configuration / Original configuration

It has no unit and it is a dimensionless quantity.

According to the change in configuration, the strain is of three types

(1) Longitudinal strain= Change in length / Original length

(2) Volumetric strain = Change in volume / Original volume

(iii) Shearing strain = Angular displacement of the plane perpendicular to the fixed surface.

Hooke’s Law

Within the limit of elasticity, the stress is proportional to the strain.

Stress &infi; Strain

or Stress = E * Strain

where, E is the **modulus of elasticity** of the material of the body.

Types of Modulus of Elasticity

1. Young’s Modulus of Elasticity

It is defined as the ratio of normal stress to the longitudinal strain Within the elastic limit.

y = Normal stress / Longitudinal strain

$y = F\Delta l / Al = Mg\ \Delta l / \pi r^2 l$

Its unit is N/m^2 or Pascal and its dimensional formula is $[ML^{-1}T^{-2}]$.

2. Bulk Modulus of Elasticity

It is defined as the ratio of normal stress to the volumetric strain within the elastic limit.

K = Normal stress / Volumetric strain

K = FV / A ΔV = &DElta;p V / Δ V

where, Δp = F / A = Change in pressure.

Its unit is N/m^2 or Pascal and its dimensional formula is $[ML^{-1}T^{-2}]$.

3. **Modulus of Rigidity** (η)

It is defined as the ratio of tangential stress to the shearing strain, within the elastic limit.

η = Tangential stress / Shearing strain

Its urut is N/m^2 or Pascal and its dimensional formula is $[ML^{-1}T^{-2}]$.

Compressibility

Compressibility of a material is the reciprocal of its bulk modulus of elasticity.

Compressibility (C) = 1 / k

Its SI unit is $N^{-1}m^2$ and CGS unit is $dyne^{-1}\ cm^2$.

Steel is more elastic than rubber. Solids are more elastic and gases are least elastic.

For liquids. modulus of rigidity is zero.
Young's modulus (Y) and modulus of rigidity (η) are possessed by solid materials only.

Limit of Elasticity

The maximum value of deforming force for which elasticity is present in the body is called its limit of elasticity.

Breaking Stress

The minimum value of stress required to break a wire, is called breaking stress.

Breaking stress is fixed for a material but breaking force varies with area of cross-section of the wire.

Safety factor = Breaking stress / Working stress

Elastic Relaxation Time

The time delay in restoring the original configuration after removal of deforming force is called elastic relaxation time.

For quartz and phosphor bronze this time is negligible.

Elastic After Effect

The temporary delay in regaining the original configuration by the elastic body after the removal of deforming force, is called elastic after effect.

Elastic Fatigue

The property of an elastic body by virtue of which its behaviour becomes less elastic under the action of repeated alternating deforming force is called elastic fatigue.

Ductile Materials

The materials which show large plastic range beyond elastic limit are called ductile materials, e.g., copper, silver, iron, aluminum, etc.

Ductile materials are used for making springs and sheets.

Brittle Materials

The materials which show very small plastic range beyond elastic limit are called brittle materials, e.g., glass, cast iron, etc.

Elastomers

The materials for which strain produced is much larger than the stress applied, with in the limit of elasticity are called elastomers, e.g., rubber, the elastic tissue of aorta, the large vessel carrying blood from heart. etc.

Elastomers have no plastic range.

Elastic Potential Energy in a Stretched Wire

The work done in stretching a wire is stored in form of potential energy of the wire.

Potential energy U = Average force * Increase in length

$= 1 / 2 F\Delta l$

= 1 / 2 Stress * Strain * Volume of the wire

Elastic potential energy per unit volume

U = 1 / 2 * Stress * Strain

= 1 / 2 (Young's modulus) * $(Strain)^2$

Elastic potential energy of a stretched spring = 1 / 2 kx^2

where, k = Force constant of spring and x = Change in length.

Thermal Stress

When temperature of a rod fixed at its both ends is changed, then the produced stress is called thermal stress.

Thermal stress = F / A = $y\alpha\Delta\theta$

where, α = coefficient of linear expansion of the material of the rod.

When temperature of a gas enclosed in a vessel is changed, then the thermal stress produced is equal to change in pressure (Δp)of the gas.

Thermal stress = Δ p = Ky Δ θ

where, K = bulk modulus of elasticity and

γ = coefficient of cubical expansion of the gas.

Interatomic force constant

$K = Yr_o$

where, r_o = interatomic distance.

Poisson's Ratio

When a deforming force is applied at the free end of a suspended wire of length 1 and radius R, then its length increases by dl but its radius decreases by dR. Now two types of strains are produced by a single force.

(i) Longitudinal strain = &DElta;U l

(ii) Lateral strain = – Δ R/ R

∴ Poisson's Ratio (σ) = Lateral strain / Longitudinal strain = – Δ R/ R / ΔU l

The theoretical value of Poisson's ratio lies between – 1 and 0.5. Its practical value lies between 0 and 0.5.

Relation Between Y, K, η and σ

(i) $Y = 3K(1 - 2\sigma)$

(ii) $Y = 2\eta(1 + \sigma)$

(iii) $\sigma = 3K - 2\eta / 2\eta + 6K$

(iv) $9 / Y = 1 / K + 3 / \eta$ or $Y = 9K\eta / \eta + 3K$

Important Points

- Coefficient of elasticity depends upon the material, its temperature and purity but not on stress or strain.
- For the same material, the three coefficients of elasticity γ, η and K have different magnitudes.
- Isothermal elasticity of a gas $E_T = \rho$ where, ρ = pressure of the gas.
- Adiabatic elasticity of a gas $E_s = \gamma\rho$

where, $\gamma = C_p / C_v$ ratio of specific heats at constant pressure and at constant volume.

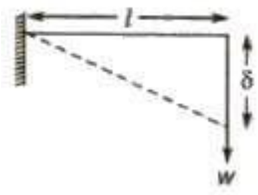
- Ratio between isothermal elasticity and adiabatic elasticity $E_s / E_T = \gamma = C_p / C_v$

Cantilever

A beam clamped at one end and loaded at free end is called a cantilever.

Depression at the free end of a cantilever is given by

$\delta = wl^3 / 3YI_G$



where, w = load, 1 = length of the cantilever,

y = Young's modulus of elasticity, and I_G = geometrical moment of inertia.

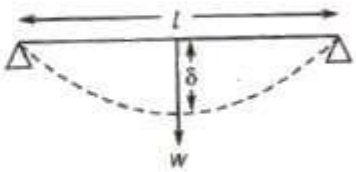
For a beam of rectangular cross-section having breadth b and thickness d.

$I_G = bd^3 / 12$

For a beam of circular cross-section area having radius r,

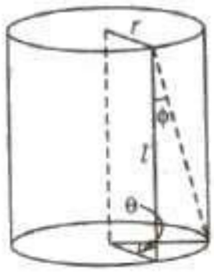
$I_G = \pi r^4 / 4$

Beam Supported at Two Ends and Loaded at the Middle



Depression at middle $\delta = wl^3 / 48YI_G$

Torsion of a Cylinder



Couple per unit twist $C = \frac{\pi \eta r^4}{2l}$

where, η = modulus of rigidity of the material of cylinder,

r = radius of cylinder,

and 1 = length of cylinder,

Work done in twisting the cylinder through an angle θ

$W = 1 / 2\ C\theta^2$

Relation between angle of twist (θ) and angle of shear (φ)

$r\theta = l\varphi$ or $\varphi = r / l = \theta$

Physics Notes Class 11 CHAPTER MECHANICAL PROPERTIES OF FLUIDS

Fluids

Fluids are those substances which can flow when an external force is applied on it.

Liquids and gases are fluids.

Fluids do not have finite shape but takes the shape of the containing vessel,

The total normal force exerted by liquid at rest on a given surface is called thrust of liquid.

The SI unit of thrust is newton.

In fluid mechanics the following properties of fluid would be considered

(i) When the fluid is at rest **- hydrostatics**

(ii) When the fluid is in motion **- hydrodynamics**

Pressure Exerted by the Liquid

The normal force exerted by a liquid per unit area of the surface in contact is called **pressure of liquid** or**hydrostatic pressure**.

Pressure exerted by a liquid column

$p = h\rho g$

Where, h = height of liquid column, ρ = density of liquid

and g = acceleration due to gravity

Mean pressure on the walls of a vessel containing liquid upto height h is ($h\rho g / 2$).

Pascal's Law

The increase in pressure at a point in the enclosed liquid in equilibrium is transmitted equally in all directions in liquid and to the Walls of the container.

The working of hydraulic lift, hydraulic press and hydraulic brakes are based on Pascal's law.

Atmospheric Pressure

The pressure exerted by the atmosphere on earth is **atmospheric pressure**.

It is about 100000 N/m^2.

It is equivalent to a weight of 10 tones on 1 m^2.

At sea level, atmospheric pressure is equal to 76 cm of mercury column. Then, atmospheric pressure

$= hdg = 76 \times 13.6 \times 980$ $dyne/cm^2$

[The atmospheric pressure does not crush our body because the pressure of the blood flowing through our circulatory system] balanced this pressure.]

Atmospheric pressure is also measured in torr and bar.

1 torr = 1 mm of mercury column

1 bar = $l0^5$ Pa

Aneroid barometer is used to measure atmospheric pressure.

Buoyancy

When a body is partially or fully immersed in a fluid an upward force acts on it, which is called buoyant force or simply buoyancy.

The buoyant force acts at the centre of gravity of the liquid displaced] by the immersed part of the body and this point is called the centre buoyancy.

Archimedes' Principle

When a body is partially or fully immersed in a liquid, it loses some of its weight. and it is equal to the weight of the liquid displaced by the immersed part of the body.

If T is the observed weight of a body of density σ when it is fully immersed in a liquid of density p, then real weight of the body

$w = T / (1 – p / \sigma)$

Laws of Floatation

A body will float in a liquid, if the weight of the body is equal to the weight of the liquid displaced by the immersed part of the body.

If W is the weight of the body and w is the buoyant force, then

(a) If W > w, then body will sink to the bottom of the liquid.

(b) IfW < w, then body will float partially submerged in the liquid.
(c) If W = w, then body will float in liquid if its whole volume is just immersed in the liquid,

The floating body will be in stable equilibrium if meta-centre (centre of buoyancy) lies vertically above the centre of gravity of the body.

The floating body will be in unstable equilibrium if meta-centre (centre of buoyancy) lies vertically below the centre of gravity of the body.

The floating body will be in neutral equilibrium if meta-centre (centre of buoyancy) coincides with the centre of gravity of the body.

Density and Relative Density

Density of a substance is defined as the ratio of its mass to its volume.

Density of a liquid = Mass / Volume

Density of water = 1 g/cm^3 or l0^3 kg/m^3

It is scalar quantity and its dimensional formula is [ML^{-3}].

Relative density of a substance is defined as the ratio of its density to the density of water at 4°C,

Relative density = Density of substance / Density of water at 4°C

= Weight of substance in air / Loss of weight in water

Relative density also known as specific gravity has no unit, no dimensions.

For a solid body, density of body = density of substance

While for a hollow body, density of body is lesser than that of Substance.

When immiscible liquids of different densities are poured in a container, the liquid of highest density will be at the bottom while, that of lowest density at the top and interfaces will be plane.

Density of a Mixture of Substances

When two liquids of mass m_1 and m_2 having density p_1 and p_2 are mixed together then density of mixture is

$p = m_1 + m_2 / (m_1 / p_1) + (m_2 + p_2)$

$= p_1 p_2 (m_1 + m_2) / (m_1 p_2 + m_2 p_1)$

When two liquids of same mass m but of different densities p_1 and p_2 are mixed together then density of mixture is

$p = 2p_1 p_2 / p_1 + p_2$

When two liquids of same volume V but of different densities p_1 and p_2 are mixed together then density of mixture is

$p = p_1 + p_2 / 2$

Density of a liquid varies with pressure

$p = p_o [1 + \Delta p / K]$

where, p_o = initial density of the liquid, K = bulk modulus of elasticity of the liquid and Δp = change in pressure

Physics Notes Class 11 CHAPTER 11 THERMAL PROPERTIES OF MATTER

The branch dealing with measurement of temperature is called thremometry and the devices used to measure temperature are called thermometers.

Heat

Heat is a form of energy called thermal energy which flows from a higher temperature body to a lower temperature body when they are placed in contact.

Heat or thermal energy of a body is the sum of kinetic energies of all its constituent particles, on account of translational, vibrational and rotational motion.

The SI unit of heat energy is joule (J).

The practical unit of heat energy is calorie.

1 cal = 4.18 J

1 calorie is the quantity of heat required to raise the temperature of 1 g of water by 1°C.

Mechanical energy or work (W) can be converted into heat (Q) by 1 W = JQ

where J = Joule’s mechanical equivalent of heat.

J is a conversion factor (not a physical quantity) and its value is 4.186 J/cal.

Temperature

Temperature of a body is the degree of hotness or coldness of the body. A device which is used to measure the temperature, is called a thermometer.

Highest possible temperature achieved in laboratory is about 108 while lowest possible temperature attained is 10-8 K.

Branch of Physics dealing with production and measurement temperature close to 0 K is known as cryagenics, while that deaf with the measurement of very high temperature is called pyromet Temperature of the core of the sun is 107 K while that of its surface 6000 K.

NTP or STP implies 273.15 K (0°C = 32°F).

Different Scale of Temperature

1. **Celsius Scale** In this scale of temperature, the melting point ice is taken as 0°C and the boiling point of water as 100°C and space between these two points is divided into 100 equal parts
2. **Fahrenheit Scale** In this scale of temperature, the melt point of ice is taken as 32°F and the boiling point of water as 211 and the space between these two points is divided into 180 equal parts.
3. **Kelvin Scale** In this scale of temperature, the melting pouxl ice is taken as 273 K and the boiling point of water as 373 K the space between these two points is divided into 100 equal pss

Relation between Different Scales of Temperatures

$$\frac{C}{100} = \frac{F-32}{180} = \frac{K-273}{100} = \frac{R}{80}$$

Thermometric Property

The property of an object which changes with temperature, is call thermometric property. Different thermometric properties thermometers have been given below

(i) Pressure of a Gas at Constant Volume

$$\frac{p_1}{T_1} = \frac{p_2}{T_2}$$

and

$$p_t = p_0\left(1 + \frac{t}{273}\right)$$

$$t = \left(\frac{p_t - p_0}{p_{100} - p_0} \times 100\right) ^\circ C$$

where p, p_{100}. and p_t, are pressure of a gas at constant volume 0°C, 100°C and t°C.

A constant volume gas thermometer can measure tempera from – 200°C to 500°C.

(ii) Electrical Resistance of Metals

$R_t = R_0(1 + \alpha t + \beta t^2)$

where α and β are constants for a metal.

As β is too small therefore we can take

$R_t = R_0(1 + \alpha t)$

where, α = temperature coefficient of resistance and
R_0 and R_t, are electrical resistances at 0°C and t°C.

$$\alpha = \frac{R_2 - R_1}{R_1 t_2 - R_2 t_1}$$

where R_1 and R_2 are electrical resistances at temperatures t_1 and t_2.

$$t = \frac{R_t - R_0}{R_{100} - R_0} \times 100°C$$

where R_{100} is the resistance at 100°C.

Platinum resistance thermometer can measure temperature from —200°C to 1200°C.

(iii) Length of Mercury Column in a Capillary Tube

$l_t = l_0(1 + \alpha t)$

where α = coefficient of linear expansion and l_0, l_t are lengths of mercury column at 0°C and t°C.

Thermo Electro Motive Force

When two junctions of a thermocouple are kept at different temperatures, then a thermo-emf is produced between the junctions, which changes with temperature difference between the junctions. Thermo-emf

$E = at + bt^2$

where a and b are constants for the pair of metals.

Unknown temperature of hot junction when cold junction is at 0°C.

$$t = \left(\frac{E_t}{E_{100}} \times 100\right)°C$$

Where E_{100} is the thermo-emf when hot junction is at 100°C.

A thermo-couple thermometer can measure temperature from —200°C to 1600°C.

Thermal Equilibrium

When there is no transfer of heat between two bodies in contact, the the bodies are called in thermal equilibrium.

Zeroth Law of Thermodynamics

If two bodies A and B are separately in thermal equilibrium with thirtli body C, then bodies A and B will be in thermal equilibrium with each other.

Triple Point of Water

The values of pressure and temperature at which water coexists inequilibrium in all three states of matter, i.e., ice, water and vapour
called triple point of water.

Triple point of water is 273 K temperature and 0.46 cm of mere pressure.

Specific Heat

The amount of heat required to raise the temperature of unit mass the substance through 1°C is called its specific heat.

It is denoted by c or s.

Its SI unit is joule/kilogram-°C'(J/kg-°C). Its dimensions is $[L^2T^{-2}\theta^{-1}]$.

The specific heat of water is 4200 J $kg^{-1}°C^{-1}$ or 1 cal g^{-1} C^{-1}, which high compared with most other substances.

Gases have two types of specific heat

1. The specific heat capacity at constant volume (C_v).
2. The specific heat capacity at constant pressure (C_r).

Specific heat at constant pressure (C_p) is greater than specific heat constant volume (C_V), i.e., $C_p > C_V$.

For molar specific heats $C_p - C_V = R$
where R = gas constant and this relation is called Mayer’s formula.

The ratio of two principal sepecific heats of a gas is represented by γ.

$$\gamma = \frac{C_p}{C_V}$$

The value of y depends on atomicity of the gas.

Amount of heat energy required to change the temperature of any substance is given by

$Q = mc\Delta t$

- where, m = mass of the substance,
- c = specific heat of the substance and
- Δt = change in temperature.

Thermal (Heat) Capacity

Heat capacity of any body is equal to the amount of heat energy required to increase its temperature through 1°C.

Heat capacity = me

where c = specific heat of the substance of the body and m = mass of the body.

Its SI unit is joule/kelvin (J/K).

Water Equivalent

It is the quantity of water whose thermal capacity is same as the heat capacity of the body. It is denoted by W.

W = ms = heat capacity of the body.

Latent Heat

The heat energy absorbed or released at constant temperature per unit mass for change of state is called latent heat.

Heat energy absorbed or released during change of state is given by

Q = mL

where m = mass of the substance and L = latent heat.

Its unit is cal/g or J/kg and its dimension is $[L^2T^{-2}]$.

For water at its normal boiling point or condensation temperature (100°C), the latent heat of vaporisation is

L = 540 cal/g
= 40.8 kJ/ mol
= 2260 kJ/kg

For water at its normal freezing temperature or melting point (0°C), the latent heat of fusion is

L = 80 cal/ g = 60 kJ/mol
= 336 kJ/kg

It is more painful to get burnt by steam rather than by boiling was 100°C gets converted to water at 100°C, then it gives out 536 heat. So, it is clear that steam at 100°C has more heat than wat 100°C (i.e., boiling of water).

After snow falls, the temperature of the atmosphere becomes very This is because the snow absorbs the heat from the atmosphere to down. So, in the mountains, when snow falls, one does not feel too but when ice melts, he feels too cold.

There is more shivering effect of ice cream on teeth as compare that of water (obtained from ice). This is because when ice cream down, it absorbs large amount of heat from teeth.

Melting

Conversion of solid into liquid state at constant temperature is melting.

Evaporation

Conversion of liquid into vapour at all temperatures (even below boiling point) is called evaporation.

Boiling

When a liquid is heated gradually, at a particular temperature saturated vapour pressure of the liquid becomes equal to atmospheric pressure, now bubbles of vapour rise to the surface d liquid. This process is called boiling of the liquid.

The temperature at which a liquid boils, is called boiling point The boiling point of water increases with increase in pre sure decreases with decrease in pressure.

Sublimation

The conversion of a solid into vapour state is called sublimation.

Hoar Frost

The conversion of vapours into solid state is called hoar fr..

Calorimetry

This is the branch of heat transfer that deals with the measorette heat. The heat is usually measured in calories or kilo calories.

Principle of Calorimetry

When a hot body is mixed with a cold body, then heat lost by ha is equal to the heat gained by cold body.

Heat lost = Heat gain

Thermal Expansion

Increase in size on heating is called thermal expansion. There are three types of thermal expansion.

1. Expansion of solids
2. Expansion of liquids
3. Expansion of gases

Expansion of Solids

Three types of expansion -takes place in solid.

Linear Expansion Expansion in length on heating is called linear expansion.

Increase in length

$l_2 = l_1(1 + \alpha \Delta t)$

where, l_l and l_2 are initial and final lengths,Δt = change in temperature and α = coefficient of linear expansion.

Coefficient of linear expansion

$\alpha = (\Delta l/l * \Delta t)$

where 1= real length and Δl = change in length and

Δt= change in temperature.

Superficial Expansion Expansion in area on heating is called superficial expansion.

Increase in area $A_2 = A_1(1 + \beta \Delta t)$

where, A_1 and A_2 are initial and final areas and β is a coefficient of superficial expansion.

Coefficient of superficial expansion

$\beta = (\Delta A/A * \Delta t)$

where. A = area, AA = change in area and At = change in temperature.

Cubical Expansion Expansion in volume on heating is called cubical expansion.

Increase in volume $V_2 = V_1(1 + \gamma\Delta t)$

where V_1 and V_2 are initial and final volumes and γ is a coefficient of cubical expansion.

Coefficient of cubical expansion

$$\gamma = \frac{\Delta V}{V \times \Delta t}$$

where V = real volume, AV =change in volume and Δt = change in temperature.
Relation between coefficients of linear, superficial and cubical expansions
$\beta = 2\alpha$ and $\gamma = 3\alpha$
Or $\alpha:\beta:\gamma = 1:2:3$

2. Expansion of Liquids

In liquids only expansion in volume takes place on heating.

(i) Apparent Expansion of Liquids When expansion of th container containing liquid, on heating is not taken into accoun then observed expansion is called apparent expansion of liquids.

Coefficient of apparent expansion of a liquid

$$(\gamma_a) = \frac{\text{apparent increase in volume}}{\text{original volume} \times \text{rise in temperature}}$$

(ii) Real Expansion of Liquids When expansion of the container, containing liquid, onheating is also taken into account, then observed expansion is called real expansion of liquids.

Coefficient of real expansion of a liquid

$$(\gamma_r) = \frac{\text{real increase in volume}}{\text{original volume} \times \text{rise in temperature}}$$

Both, y_r, and y_a are measured in °C^{-1}.

We can show that $y_r = y_a + y_g$

where, y_r, and y_a are coefficient of real and apparent expansion of liquids and y_g is coefficient of cubical expansion of the container.

Anamalous Expansion of Water

When temperature of water is increased from 0°C, then its vol decreases upto 4°C, becomes minimum at 4°C and then increases. behaviour of water around 4°C is called, anamalous expansion water.

3. Expansion of Gases

There are two types of coefficient of expansion in gases

(i) Volume Coefficient (γv) At constant pressure, the change in volume per unit volume per degree celsius is called volume coefficient.

$$\gamma_V = \frac{V_2 - V_1}{V_0 (t_2 - t_1)}$$

where V_0, V_1, and V_2 are volumes of the gas at 0°C, t_1°C and t_2°C.

(ii) Pressure Coefficient (γ_p) At constant volume, the change in pressure per unit pressure per degree celsius is called pressure coefficient.

$$\gamma_p = \frac{p_2 - p_1}{p_0 (t_2 - t_1)}$$

where p_0, p_1 and p_2 are pressure of the gas at 0°C, t_1° C and t_2° C.

Practical Applications of Expansion

1. When rails are laid down on the ground, space is left between the end of two rails.
2. The transmission cables are not tightly fixed to the poles.
3. The iron rim to be put on a cart wheel is always of slightly smaller diameter than that of wheel.
4. A glass stopper jammed in the neck of a glass bottle can be taken out by warming the neck of the bottles.

Important Points

- Due to increment in its time period a pendulum clock becomes slow in summer and will lose time.
- Loss of time in a time period $\Delta T = (1/2)\alpha\, \Delta\theta T$
  ∴ Loss of time in any given time interval t can be given by
  $\Delta T = (1/2)\alpha\, \Delta\theta t$
- At some higher temperature a scale will expand and scale reading will be lesser than true values, so that
  true value = scale reading $(1 + \alpha\, \Delta t)$
  Here, Δt is the temperature difference.
- However, at lower temperature scale reading will be more or true value will be less.