ETOOS

THERMAL EXPANSION, CALORIMETRY, ELASTICITY & VISCOSITY

Contents

Syllabus

Thermal Expansion of Solid, Liquids and Gasses, Calorimetry, Elasticity, Viscosity, Stoke's law, Terminal Velocity, Streamline flow, Surface Tension, Surface Energy, Capiliatry rise.

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THERMAL EXPANSION

DEFINITION OF HEAT :

Heat is a form of energy which is transferred between a system and its surrounding as a result of temperature difference only.

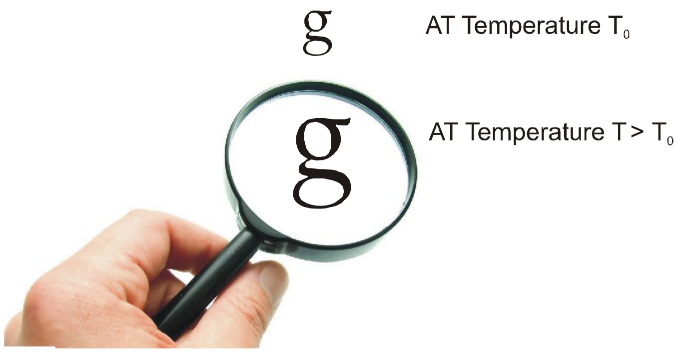
THERMAL EXPANSION : Expansion due to increase in temperature.

Atoms are in constant motion.

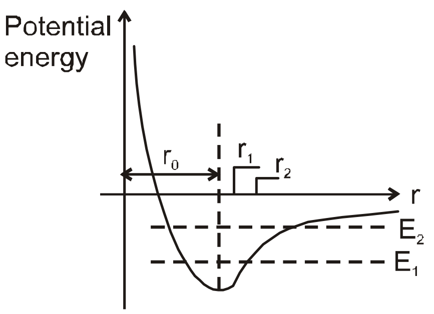
- Vibration increases with temperature
- Spacing increases with temperature

Most materials expand when their temperature is increased. When a homogeneous object expands, the distance between any two points on the object increases. Figure shows a block of metal with a hole in it. **The expanded object is like a photographic enlargement.** That in the hole expands in the same proportion as the metal, it does not get smaller

THERMAL EXPANSION AS PHOTOGRAPHIC MAGNIFICATION



At the atomic level, thermal expansion may be understood by considering how the potential energy of the atoms varies with distance. The equilibrium position of an atom will be at the minimum of the potential energy well if the well is symmetric. At a given temperature each atom vibrates about its equilibrium position and its average remains at the minimum point. If the shape of the well is not symmetrical the average position of an atom will not be at the minimum point. When the temperature is raised the amplitude of the vibrations increases and the average position is located at a greater inter atomic separation. This increased separation is manifested as expansion of thematerial.



Thermal expansion arises because the well is not symmetrical about the equilibrium position r_0.
As the temperature rise the energy of the atom increases.
The average position when the energy is E_2 is not the same as that when the energy is E_1.

(I) TYPES OF THERMAL EXPANSION :

	COEFFICIENT OF EXPANSION	FOR TEMPERATURE CHANGE Δt change in
(i) Linear	$\alpha = \lim_{\Delta t \to 0} \frac{1}{l_0}\frac{\Delta l}{\Delta t}$	length $\Delta l = l_0 \alpha \Delta t$
(ii) Superficial	$\beta = \lim_{\Delta t \to 0} \frac{1}{A_0}\frac{\Delta A}{\Delta t}$	Area $\Delta A = A_0 \beta \Delta t$
(iii) Volume	$\gamma = \lim_{\Delta t \to 0} \frac{1}{V_0}\frac{\Delta V}{\Delta t}$	volume $\Delta V = V_0 \gamma \Delta t$

The relation between α β γ :

(i) For isotropic solids $\alpha_1 = \alpha_2 = \alpha_3 = \alpha$ (let)

so $\beta = 2\alpha$ and $\gamma = 3\alpha$

(ii) For anisotropic solids $\beta = \alpha_1 + \alpha_2$ and $\gamma = \alpha_1 + \alpha_2 + \alpha_3$

Here α_1 , α_2 and α_3 are coefficient of linear expansion in X , Y and Z directions.

Variation of time period of pendulum clocks :

The time represented by the clock hands of a pendulum clock depends on the number of oscillation performed by pendulum every time it reaches to its extreme position the second hand of the clock advances by one second that means second hand moves by two seconds when one oscillation in complete

Let $T = 2\pi\sqrt{\frac{L_0}{g}}$ at temperature θ_0 and $T' = 2\pi\sqrt{\frac{L}{g}}$ at temperature θ.

$$\frac{T'}{T} = \sqrt{\frac{L'}{L}} = \sqrt{\frac{L[1+\alpha\Delta\theta]}{L}} = 1 + \frac{1}{2}\alpha\Delta\theta$$

Therefore change (loss or gain) in time per unit time lapsed is

$$\frac{T'-T}{T} = \frac{1}{2}\alpha\Delta\theta$$

gain or loss in time in duration of 't' in

$\boldsymbol{\Delta t = -\frac{1}{2}\alpha\Delta\theta\, t}$ **,** if T is the correct time and **Δt difference of time duration**

Δt positive implies gain in time

Δt negative implies loss in time

Measurement of length by metallic scale:

Case **(i)**

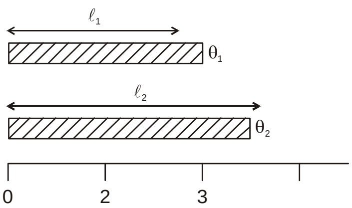
When object is expanded only

$\ell_2 = \ell_1\{1 + \alpha_0(\theta_2 - \theta_1)$

ℓ_1 = actual length of object at θ_1°C = measure length of object at θ_1°C.

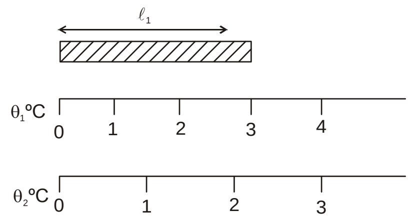
ℓ_2 = actual length of object at θ_2°C = measure length of object at θ_2°C.

α_0 = linear expansion coefficient of object.



Case (ii)

When only measurement instrument is expanded actual length of object will not change but measured value (MV) decreases.



$MV = \ell_1 \{1 - \alpha_S (\theta_2 - \theta_1)\}$

α_S = linear expansion coefficient of measuring instrument.

at θ_1 C MV = 3

at θ_2 C MV = 2.2

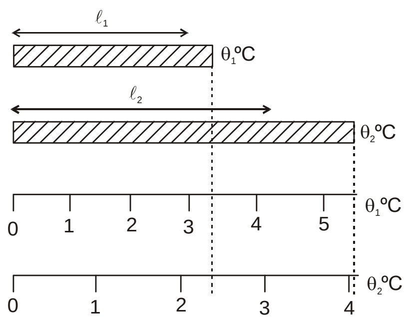
Case (iii)

If both expanded simultaneously

$MV = \{1 + (\alpha_0 - \alpha_s)(\theta_2 - \theta_1)$

(i) If $\alpha_0 > \alpha_s$, then measured value is more then the actual value at θ_1°C

(ii) If $\alpha_0 < \alpha_s$, then measured value is less then the actual value at θ_1°C



at θ_1°C MV = 3.4

θ_2°C MV = 4.1

Measured value = calibrated value × {1 + α Δ θ}

where $\alpha = \alpha_0 - \alpha_s$

α_o = coefficient of linear expansion of object material,

α_s = coefficient of linear expansion of scale material

$\Delta\theta = \theta - \theta_C$

θ = temperature at the time of measurement θ_C = temperature at the time of calibration.

For scale, **true measurement = scale reading $[1 + \alpha(\theta - \theta_0)]$**

If **$\theta > \theta_0$ true measurement > scale reading**

$\theta < \theta_0$ true measurement < scale reading

Variation of Density with Temperature :

As we known that mass = volume × density .

Mass of substance does not change with change in temperature so with increase of temperature, volume increases so density decreases and vice-versa.

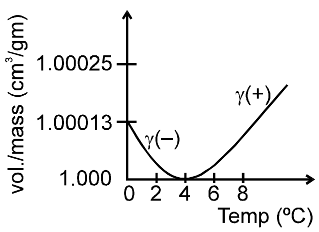
$$d = \frac{d_0}{(1+\gamma\Delta T)}.$$

For solids values of γ are generally small so we can write $d = d_0(1 - \gamma\Delta T)$ (using binomial expansion).

Note : **(i)** γ for liquids are in order of 10^{-3}.

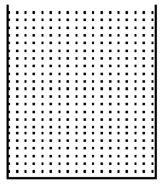
(ii) Anamolous expansion of water :

For water density increases from 0 °C to 4 °C so γ is negative and for 4 °C to higher temperature γ is positive. At 4 °C density is maximum. This anamolous behaviour of water is due to presence of three types of molecules i.e. H_2O, $(H_2O)_2$ and $(H_2O)_3$ having different volume/mass at different temperatures.



APPARENT EXPANSION OF A LIQUID IN A CONTAINER :

Initially container was full . When temperature change by ΔT,



volume of liquid $V_L = V_0 (1 + \gamma_L \Delta T)$

volume of container $V_C = V_0 (1 + \gamma_C \Delta T)$

So overflow volume of liquid relative to container

$\Delta V = V_L - V_C$ $\quad$ $\mathbf{\Delta V = V_0 (\gamma_L - \gamma_C) \Delta T}$

So, coefficient of apparent expansion of liquid w.r.t. container

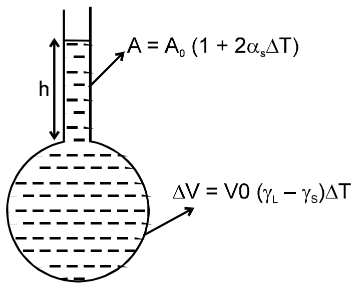
$\gamma_{apparent} = \gamma_L - \gamma_C$.

In case of expansion of liquid + container system:

if $\gamma_L > \gamma_C \longrightarrow$ level of liquid rise

if $\gamma_L < \gamma_C \longrightarrow$ level of liquid fall

Increase in height of liquid level in tube when bulb was initially not completely filled



$$h = \frac{\text{volume of liquid}}{\text{area of tube}} = \frac{V_0(1+\gamma_L \Delta T)}{A_0(1+2\alpha_S \Delta T)} = h_0 \{ 1 + (\gamma_L - 2\alpha_S) \Delta T\}$$

$$h = h_0 \{ 1 + (\gamma_L - 2\alpha_S) \Delta T\}$$

where h_0 = original height of liquid in container

α_S = linear coefficient of expansion of container.

Variation of force of Buoyancy with temperature :

If body is submerged completely inside the liquid

For solid, Buoyancy force $F_B = V_0 d_L g$

V_0 = Volume of the solid inside liquid,

d_L = density of liquid

Volume of body after increase its temperature $V = V_0 [1 + \gamma_S \Delta\theta]$,

Density of body after increase its temperature $d'_L = \dfrac{d_L}{[1+\gamma_L \Delta\theta]}$.

Buoyancy force of body after increase its temperature, $F'_B = V d'_L g$, $\dfrac{F'_B}{F_B} = \dfrac{[1+\gamma_S \Delta\theta]}{[1+\gamma_L \Delta\theta]}$,

if $\gamma_S < \gamma_L$ then $F'_B < F_B$

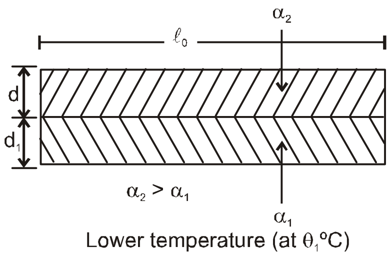
(Buoyant force decreases) or apparent weight of body in liquid gets increased

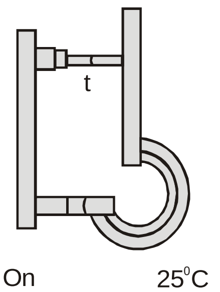
$[W - F'_B > W - F_B]$.

Bimetallic Strip :

It two strip of different metals are welded together to form a bimetallic strip, when heated uniformly it bends in form of an arc, the metal with greater coefficient of linear expansion lies on convex side. The radius of arc thus formed by bimetal is :

$$\ell_0 (1 + \alpha_1 \Delta\theta) = \left(R - \frac{d_1}{2}\right)\theta$$

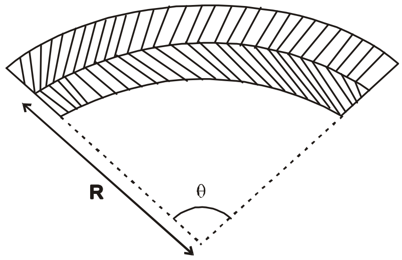


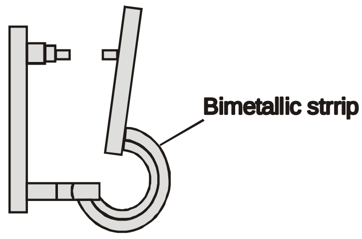


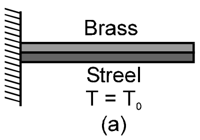
$$\ell_0 (1 + \alpha_2 \Delta\theta) = \left(R + \frac{d_2}{2}\right)\theta$$

$$\Rightarrow \frac{1+\alpha_2 \Delta\theta}{1+\alpha_1 \Delta\theta} = \frac{R + \frac{d_1}{2}}{R - \frac{d_2}{2}}$$

$$\Rightarrow R = \frac{d_1 + d_2/2}{(\alpha_2 - \alpha_1)\ \Delta\theta}$$

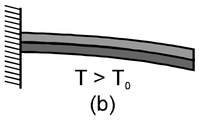




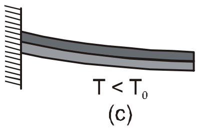


A bimetallic strips is made up of two strips of different

metals.Brass and iron are common metals used.



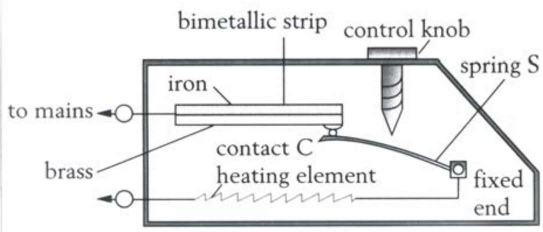
Brass expands more than iron when hot,



And contracts more too.

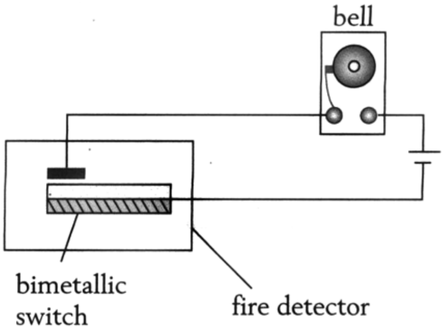
The strip bends as shown at temperatures above the reference temperature. Below the reference temperature the strip bends the other way. Many thermostats operate on this principle, making and breaking an electrical circuit as the temperature rises and falls.

SOME APPLICATION OF BIMETALLIC STRIP :

Appliance	Design of appliance	Role of the bimetallic thermostat
Electric iron	 Figure 6.27 Structure of an electric iron	1. As temperature increases, the bimetallic strip bends upwards. 2. Contact C is broken when the spring S is blocked by the tip of the control knob. 3. Bimetallic strip cools and as it straightens, contact C is made again. 4. For higher temperatures, turn the control knob further upwards.

FIRE ALARM

If the fire breaks out, the heat from the fire will cause the bimetallic strips to bend upwards and complete the circuit. The alarm bell then ring.



Zeroth Law of Thermodynamics :

If objects A and B are separately in thermal equilibrium with object C, then A and B are in thermal equilibrium with each other. If objects A and B are in thermal equilibrium, then they are at the same temperature.

Temperature :

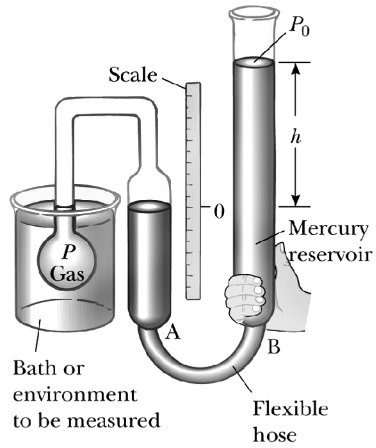
Temperature may be defined as the **degree of hotness or coldness** of a body. Heat energy flows from a body at higher temperature to that at lower temperature until their temperatures become equal. At this stage, the bodies are said to be in thermal equilibrium.

Measurement of Temperature :

The branch of thermodynamics which deals with the measurement of temperature is called thermometry. A thermometer is a device used to measure the temperature of a body. The substances like liquids and gases which are used in the thermometer are called thermometric substances.

The constant-volume gas thermometer :

The standard thermometer, against which all other thermometers are calibrated, is based on the pressure of a gas in a fixed volume. Figure shows such a constant volume gas thermometer; it consists of a gas-filled bulb con nected by a tube to a mercury monometer.



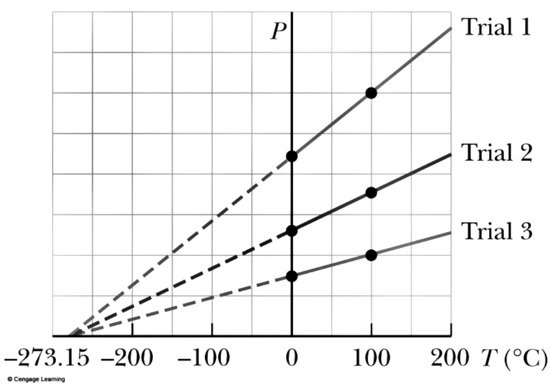
$$T = (273.16\ K)\left(\lim_{gas \to 0} \frac{P}{P_3}\right)$$

P = Pressure at the temperature being measured, P_3 = pressure when bulb in a triple point cell.

Reference Temperature :

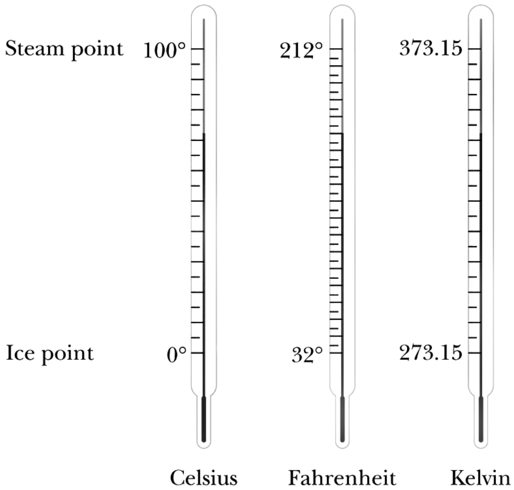
100°C for boiling water

0°C for freezing water



Extrapolate graph to zero pressure to find absolute zero temperature

TEMPERATURE SCALES :



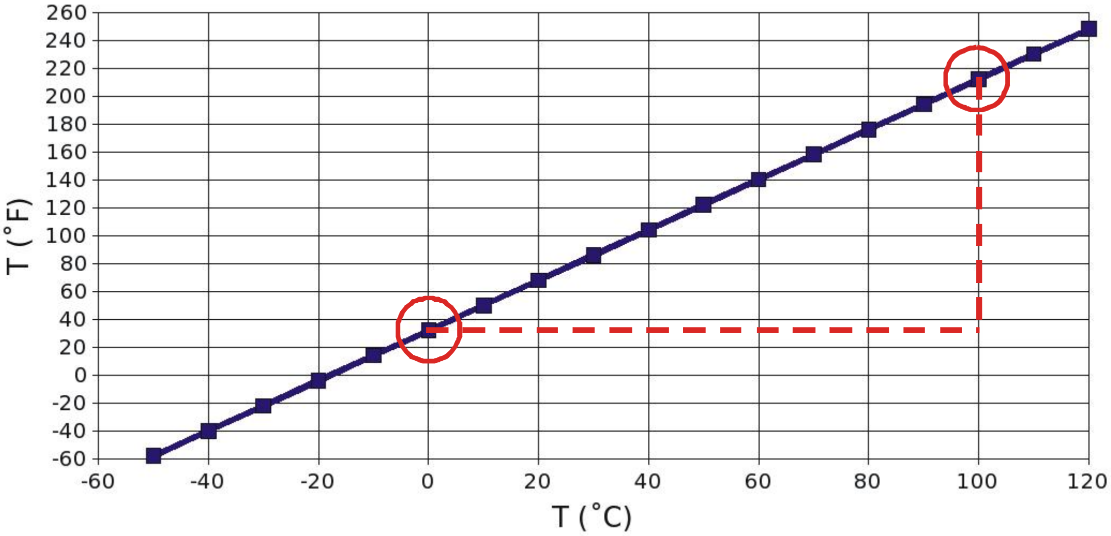
Column of fluid changes height in response to warmth or coolness of surroundings
Numbers assigned to the height establishes the *temperature scale.*
Each division in the scale is called a *degree*

DEFINED BY :

- Height of column when water freezes $(0°C = 32°F)$
- Height of column when water boils $(100°C = 212°F)$

CALORIMETRY

FAHRENHEIT AND CELSIUS SCALES



SLOPE: $\frac{\Delta T_F}{\Delta T_C} = \frac{212°F - 32°F}{100°C - 0°C} = \frac{180°F}{100°C} = \frac{9}{5}$ **Intercept** = 32°F

The formula for the conversion between different temperature scales is:

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

General formula for the conversion of temperature from one scale to another:

$$\frac{\text{Temp on one scale}(S_1) - \text{Lower fixed point}(S_1)}{\text{Upper fixed point}(S_2) - \text{Lower fixed point}(S_1)}$$

$$= \frac{\text{Temp. on other scale}(S_2) - \text{Lower fixed point}(S_2)}{\text{Upper fixed point}(S_2) - \text{Lower fixed point}(S_2)}$$

SPECIFIC HEAT :

Specific heat of substance is equal to heat gain or released by that substance to raise or fall its temperature by 1ºC for a unit mass of substance.

(a) the mass of the body $\Delta Q \propto m$

(b) rise or fall of temperature of the body $\Delta Q \propto \Delta T$

$\Delta Q \propto m \Delta T$ or $\mathbf{\Delta Q = m\, s\, \Delta T}$

or $dQ = m\, s\, dT$ or $Q = m \int s\, dT.$

where s is a constant and is known as the specific heat of the body $s = \frac{Q}{m \Delta T}$. S.I. unit of s is joule/kg-kelvin and C.G.S. unit is cal./gm °C.

Specific heat of water : S = 4200 J/kgºC = 1000 cal/kgºC = 1 Kcal/kgºC = 1 cal/gmºC

Specific heat of steam = half of specific heat of water = specific heat of ice

Heat capacity or Thermal capacity :

Heat capacity of a body is defined as the amount of heat required to raise the temperature of that body by 1°. If 'm' is the mass and 's' the specific heat of the body, then

Heat capacity = m s.

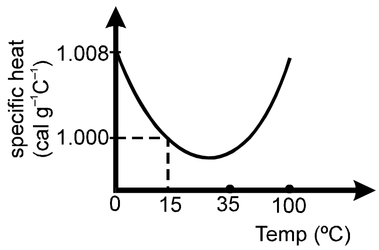
Units of heat capacity in: CGS system is, **cal ºC^{-1}**; SI unit is, **JK^{-1}**

• We know, $s = \frac{Q}{m\Delta T}$, if the substance undergoes the change of state which occurs at constant temperature ($\Delta T = 0$) , then $s = Q/0 = \infty$. Thus the specific heat of a substance when it melts or boils at constant temperature is infinite.

• If the temperature of the substance changes without the transfer of heat (Q = 0) then $s = \frac{Q}{m\Delta T} = 0$. Thus when liquid in the thermos flask is shaken, its temperature increases without the transfer of heat and hence the specific heat of liquid in the thermos flask is zero.

• To raise the temperature of saturated water vapours, heat (Q) is withdrawn. Hence, specific heat of saturated water vapours is negative. (This is for your information only and not in the course)

• The slight variation of specific heat of water with temperature is shown in the graph at 1 atmosphere pressure. Its variation is less than 1% over the interval form 0 to 100ºC.



Relation between Specific heat and Water equivalent :

It is the amount of water which requires the same amount of heat for the same temperature rise as that of the object

$ms\,\Delta T = m_W\, S_W\, \Delta T \quad \Rightarrow \quad m_W = \frac{ms}{s_W}$

In calorie $s_W = 1$

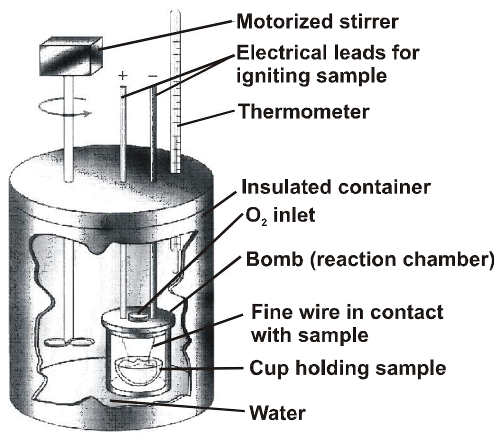
$\therefore \quad m_W = ms$

m_w is also represent by W

so $\quad W = ms$.

BOMB CALORIMETER :

A calorimeter is an insulated device used for measuring the amount of heat absorbed or released in a chemical reaction or physical process.



The Process of Measurement :

The temperature of the water is taken before the reaction takes place, and it is recorded as the initial temperature T_i.

- The final temperature of water is recorded at T_f.
- Heat changes in the calorimeter are denoted as q.
- Since the reaction takes place in water, water acts as the surrounding.
- Heat changes in the water are called q_{surr} while heat changes in the reaction are called q_{rxn}.
- The heat transferred between the reaction and the surrounding are opposite processes.
- Therefore $q_{rxn} = -q_{surr}$
- The amount of heat absorbed/ released in water is determined using the mass of water m, specific heat of water C, and change in water temperature.
- $q_{surr} = m \times C \times (T_f - T_i)$

Phase change :

Heat required for the change of phase or state,

Q = mL , L = latent heat.

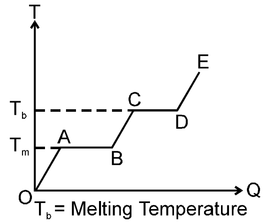
Latent heat (L): The heat supplied to a substance which changes its state at constant temperature is called latent heat of the body.

Latent heat of Fusion (L_f): The heat supplied to a substance which changes it from solid to liquid state at its melting point and 1 atm. pressure is called latent heat of fusion. Latent heat of fusion of ice is 80 kcal/kg

Latent heat of vaporization (L_v): The heat supplied to a substance which changes it from liquid to vapour state at its boiling point and 1 atm. pressure is called latent heat of vaporization. Latent heat of vaporization of water is 540 kcal kg^{-1}.

Latent heat of ice : L = 80 cal/gm = 80 Kcal/kg = 4200 × 80 J/kg

Latent heat of steam : L = 540 cal/gm = 540 Kcal/kg = 4200 × 540 J/kg



The given figure, represents the change of state by different lines

OA – solid state , AB – solid + liquid state (Phase change)

BC – liquid state , CD – liquid + vapour state (Phase change)

DE – vapour state

$\Delta Q = ms\Delta T$

slope $\frac{\Delta T}{\Delta Q} = \frac{1}{ms} \Rightarrow \frac{\Delta T}{\Delta Q} \propto \frac{1}{S}$

where mass (m) of substance constant slope of T – Q graph is inversely proportional to specific heat, if in given diagram

(slope) OA > (slope) DE

then $(s)_{OA} < (s)_{DE}$

when $\Delta Q = mL$

If (length of AB) > (length of CD)

then (latent heat of AB) > (latent heat of CD)

ELASTICITY

DEFINITION :

Elasticity is that property of the material of a body by virtue of which the body opposes any change in its shape or size when deforming forces are applied to it, and recovers its original state as soon as the deforming forces are removed.

Stress :

The internal restoring force acting per unit area of cross-section of the deformed body is called stress.

If an external force F is applied to the cross sectional area A of a body, then

Stress σ = F/A

Unit of stress : N/m^2

Dimension of stress : $M^1L^{-1}T^{-2}$

The effect of stress is to produce distortion or a change in size, volume and shape (i.e. configuration of the body).

Types of stress :

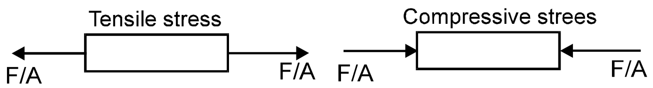
1. Longitudinal or Normal stress :

When object is one dimensional then force acting per unit area is called longitudinal stress.

It is of two types :

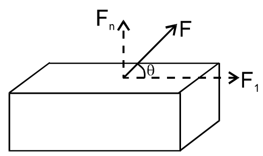
(a) compressive stress

(b) tensile stress



Consider a block of solid as shown in figure. Let a force F be applied to the face which has area A. Resolve $\vec{F}$ into two components :

$F_n = F \sin\theta$ called normal force and $F_t = F \cos\theta$ called tangential force.



$\therefore$ Normal (tensile) stress = $\frac{F_n}{A} = \frac{F\sin\theta}{A}$

2. Tangential or shear stress :

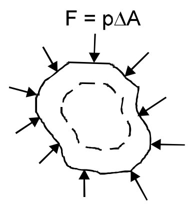
It is defined as the restoring force acting per unit area tangential to the surface of the body. Refer to shown in figure above.

Tangential (shear) stress = $\frac{F_t}{A} = \frac{F\cos\theta}{A}$

3. Bulk stress :

When force is acting all along the surface normal to the area, then force acting per unit area is known as pressure/bulk stress. The effect of pressure is to produce volume change.

The shape of the body may or may not change depending upon the homogeneity of body.



Strain :

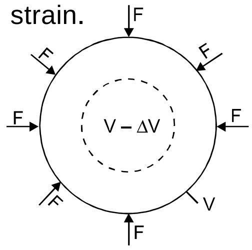
The change occurred in the unit size of the body is called strain.

Types of strain :

(A) Longitudinal Strain : Change in length per unit length is called linear strain

$$\text{Longitudinal Strain} = \frac{\text{Change in length}}{\text{Original length}} = \frac{\Delta L}{L}$$

(B) Volume Strain : Change in volume per unit volume is called volume strain.

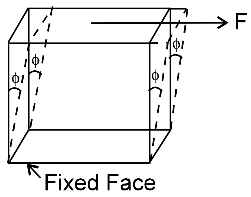


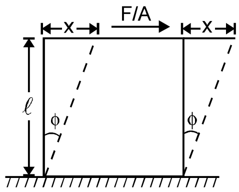
$$\text{Volume Strain} = \frac{\text{Change in volume}}{\text{Original volume}} = \frac{\Delta V}{V}$$

Shear Strain :

Angle through which a line originally normal to fixed surface is turned.

$$\text{Shear Strain} \quad \phi = \frac{x}{L}$$

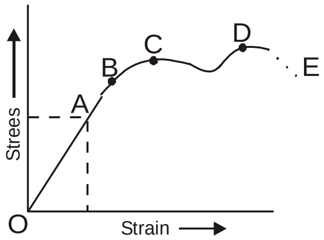




Note : Strain is unitless.

Stress-Stain Curve :

If we increase the load gradually on a vertical suspended metal wire, we obtain the following graph :



OA → Limit of Proportionality
OB → Elastic limit
C → Yield Point
CD → Plastic behaviour
D → Ultimate point
DE → Fracture

In Region OA : Strain is small (< 2%)

Stress $\propto$ Strain

Slope of line OA gives Young's modulus Y of the material.

In Region AB : Stress is not proportional to strain, but wire will still regain its original length after removing of stretching force.

In region BC : Wire yields $\Rightarrow$ strain increases rapidly with small change in stress. This behavior is shown up to point C known as yield point.

In region CD : Point D correspondes to maximum stress, which is called point of breaking or tensile strength.

In region DE : The wire literally flows. The maximum stress corresponding to D after which wire begin to flow.

In this region strain increase even if wire is unloaded and rupture at E.

- Breaking stress is independent of length of the wire ,it depwends on the material of the wire
- The breaking stress needed to break a wire is called tensile strength.

Hook's Law :

Stress is proportional to strain with in limit of proportionality for metal.

$$E = \text{Modulus of Elasticity} = \frac{\text{Stress}}{\text{Strain}} = \text{constant}$$

Young's Modulus (Y) :

$$Y = \frac{\text{Linear Stress}}{\text{Linear Strain}} = \frac{F/A}{\Delta L/L}$$

- Young's modulus Measures the resistance of a solid to a change in its length.

Bulk Modulus :

$$B = \frac{\text{Volume stress}}{\text{Volume strain}} = \frac{\Delta P}{-\frac{\Delta V}{V}} \Rightarrow B = -\frac{V\Delta P}{\Delta V}$$

- Bulk modulus measures the resistance of solids or liquids to changes in their volume.

Compressibility :

$$k = \frac{1}{B} = -\frac{1}{V}\left(\frac{\Delta V}{\Delta P}\right)$$

- $E_{solid} > E_{liquid} > E_{gas}$
- Isothermal Elasticity $E_\theta = P$
- Adiabatic Elasticity $E_\phi = \gamma P$

  $E_\phi > E_\theta$

Modulus of Rigidity :

$$\eta = \frac{\text{tangential stress}}{\text{tangential strain}}$$

$$\eta = \frac{F/A}{\phi}$$

Only solid can have shearing as these have definite shape.

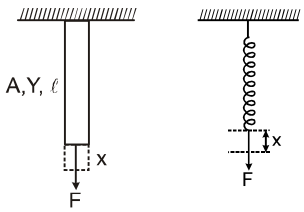
- Shear modulus measures the resistance to motion of the planes within a solid parallel to each other.
- Greater the value of Y, B, η, more elastic is material.
- Steel is more elastic than rubber.
- Elasticity increases on adding impurities and decreases on increasing temperature.
- Liquid and gases have only volume elasticity.
- With rise in temperature Y, B, η decreases because distance between atom increases.

Poission's Ratio :

$$\sigma = \frac{\text{Lateral strain}}{\text{Linear strain}} = \frac{d/D}{\Delta L/L} \qquad \sigma = \frac{dL}{\Delta LD}$$

Work done in Stretching a Wire :

ELASTIC POTENTIAL ENERGY STORED IN A STRETCHED WIRE OR IN A ROD :



Strain energy stored in equivalent spring

$$U = \frac{1}{2}kx^2$$

where $x = \frac{F\ell}{AY}$, $k = \frac{AY}{\ell}$ $\quad U = \frac{1}{2}\frac{AY}{\ell}\frac{F^2\ell^2}{A^2Y^2} = \frac{1}{2}\frac{F^2\ell}{AY}$.

equation can be re-arranged

$$U = \frac{1}{2}\frac{F^2}{A^2} \times \frac{\ell A}{Y}$$

[ℓA = volume of rod, F/A = stress]

$$U = \frac{1}{2}\frac{(\text{stress})^2}{Y} \times \text{volume}$$

again, $U = \frac{1}{2}\frac{F}{A} \times \frac{F}{AY} \times A\,\ell$ [Strain = $\frac{F}{AY}$]

$$U = \frac{1}{2}\ \text{stress} \times \text{strain} \times \text{volume}$$

- Due to tension intermolecular distance between atom is increase and therefore P.E. at the wire is increased and with removal of force interatomic distance is reduced and so is the P.E. This change in P.E. appears as heat in the wire and thus temperature of the wire increase.

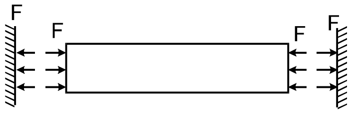
Thermal stress of a material:

If the rod is free to expand then there will be no stress and strain. Stress and strain is produced only when an object is restricted to expand or contract according to change in temperature. When the temperature of the rod is decreased or increased under constrained condition , compressive or tensile stresses are developed in the rod. These stresses are known as thermal stresses.

Strain = $\frac{\Delta L}{L_0}$ = $\frac{\text{final length} - \text{original length}}{\text{original length}} = \alpha\,\Delta T$,

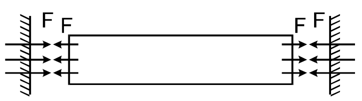
Note : Original and final length should be at same temperature.

Consider a rod of length ℓ_0 which is fixed between to rigid end separated at a distance ℓ_0 now if the temperature of the rod is increased by $\Delta\theta$ then the strain produced in the rod will be :



If ΔT = positive

thermal stress = Y strain = Y $\alpha\,\Delta T$



If ΔT = negative

$\frac{F}{A} = Y\alpha\Delta T$ $\quad$ $F = AY\,\alpha\,\Delta T$

$$\text{strain} = \frac{\text{length of the rod at new temperature} - \text{natural length of the rod at new temperature}}{\text{natural length of the rod at new temperature}}$$

$$= \frac{\ell_0 - \ell_0(1+\alpha\Delta\theta)}{\ell_0(1+\alpha\Delta\theta)} = \frac{-\ell_0\alpha\Delta\theta}{\ell_0(1+\alpha\Delta\theta)}$$

$\because$ α is very small so

strain = – $\alpha\,\Delta\,\theta$ (negative sign in the answer represents that the length of the rod is less than the natural length that means is compressed by the ends.)

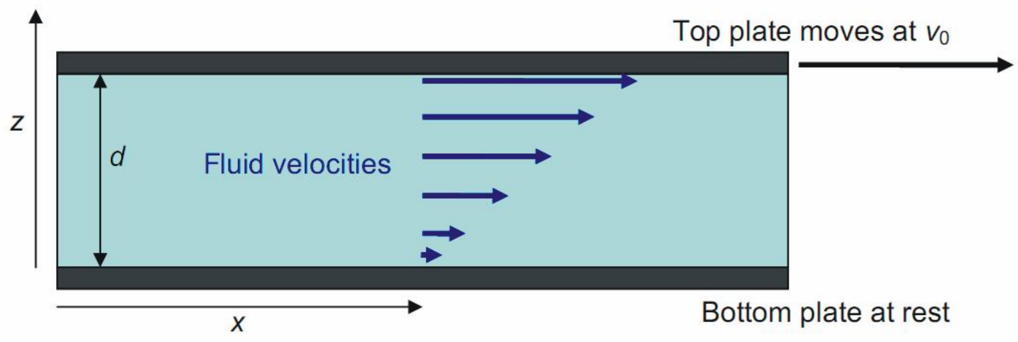
VISCOSITY

DEFINITION :

when a layer of a liquid slides over another layer of the same liquid, a frictional-force acts between them which opposes the relative motion between the layers. This force is called 'internal frictional-force'.

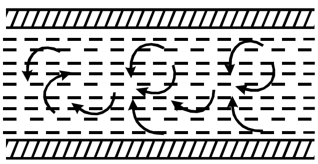
Suppose a liquid is flowing in streamlined motion on a fixed horizontal surfaceas shown (Fig.)below . each layer tends to decrease the velocity of the layer above it.. This means that in between any two layers of the liquid, internal tangential forces act which try to destroy the relative motion between the layers. These forces are called 'viscous forces'. If the flow of the liquid is to be maintained, an external force must be applied to overcome the dragging viscous forces. In the absence of the external force, the viscous forces would soon bring the liquid to rest. **The property of the liquid by virtue of which it opposes the relative motion between its adjacent layers is known as 'viscosity'.**

Newton assumed (and it has been amply confirmed by experiment) that at least for low speeds the fluid settles into the flow pattern shown below. The fluid in close contact with the bottom plate stays at rest, the fluid touching the top plate gains the same speed v_0 as that plate, and in the space between the plates the speed of the fluid increases linearly with height, so that, for example, the fluid halfway between the plates is moving at ½ v_0:



Viscosity comes into play only when there is a relative motion between the layers of the same material. This is why it does not act in solids.

Flow of Liquid In a Tube: Critical Velocity :



When a liquid flows in a tube, the viscous forces oppose the flow of the liquid, Hence a pressure difference is applied between the ends of the tube which maintains the flow of the liquid. If all particles of the liquid passing through a particular point in the tube move along the same path, the flow of the liquid is called 'stream-lined flow'. This occurs only when the velocity of flow of the liquid is below a certain limiting value called 'critical velocity'.

When the velocity of flow exceeds the critical velocity, the flow is no longer stream-lined but becomes turbulent. In this type of flow, the motion of the liquid becomes zig-zag and eddy-currents are developed in it.

Reynold's proved that the critical velocity for a liquid flowing in a tube is $v_c = k\eta/\rho r$. where ρ is density and η is viscosity of the liquid, r is radius of the tube and k is 'Reynold's number' (whose value for a narrow tube and for water is about 1000). When the velocity of flow of the liquid is less than the critical velocity, then the flow of the liquid is controlled by the viscosity, the density having no effect on it. But when the velocity of flow is larger than the critical velocity, then the flow is mainly governed by the density, the effect of viscosity becoming less important. It is because of this reason that when a volcano erupts, then the lava coming out of it flows speedily inspite of being very thick (of large viscosity).

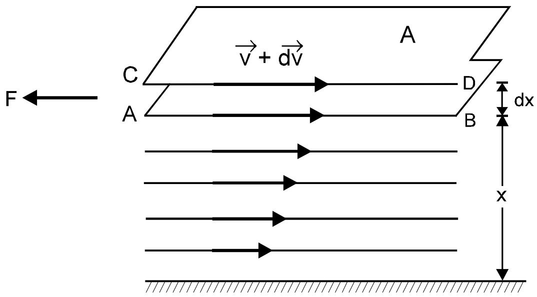
Velocity Gradient and Coefficient of Viscosity :

The property of a liquid by virtue of which an opposing force (internal friction) comes into play when ever there is a relative motion between the different layers of the liquid is called viscosity. Consider a flow of a liquid over the horizontal solid surface as shown in fig. Let us consider two layers AB and CD moving with velocities

$\vec{v}$ and $\vec{v} + d\vec{v}$ at a distance x and (x + dx) respectively from the fixed solid surface.

According to Newton, the viscous drag or back ward force (F) between these layers depends.

(i) directly proportional to the area (A) of the layer and (ii) directly proportional to the velocity gradient $\left(\frac{dv}{dx}\right)$ between the layers.



i.e. $F \propto A\frac{dv}{dx}$ or $F = -\eta A\frac{dv}{dx}$ ...(1)

η is called Coefficient of viscosity

Negative sign shows that the direction of viscous drag (F) is just opposite to the direction of the motion of the liquid.

Units of Coefficient of Viscosity :

From the above formula, we have $\eta = \frac{F}{A(\Delta v_x / \Delta z)}$

∴ dimensions of $\eta = [ML^{-1}T^{-1}]$

Its unit is kg/(meter-second)*

In C.G.S. system, the unit of coefficient of viscosity is dyne s cm^{-2} and is called poise. In SI the unit of coefficient of viscosity is N sm^{-2} and is called decapoise.

1 decapoise = 1 N sm^{-2} = (10^5 dyne) × s × (10^2 cm)$^{-2}$ = 10 dyne s cm^{-2} = 10 poise

Effect of Temperature on the Viscosity :

The viscosity of liquids decrease with increase in temperature and increase with the decrease in temperature. That is, $\eta \propto \frac{1}{\sqrt{T}}$. On the other hand, the value of viscosity of gases increases with the increase in temperature and vice-versa. That is, $\eta \propto \sqrt{T}$.

Stoke's Law :

Stokes proved that the viscous drag (F) on a spherical body of radius r moving with velocity v in a fluid of viscosity η is given by **F = 6 π η r v.** This is called Stokes' law.

Terminal Velocity :

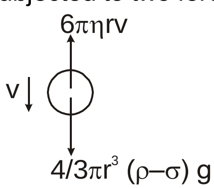
When a body is dropped in a viscous fluid, it is first accelerated and then its acceleration becomes zero and it attains a constant velocity called terminal velocity.

Calculation of Terminal Velocity :

Let us consider a small ball, whose radius is r and density is ρ, falling freely in a liquid (or gas), whose density is σ and coefficient of viscosity η. When it attains a terminal velocity v. It is subjected to two forces :

(i) effective force acting downward

$$= V(\rho - \sigma)g = \frac{4}{3}\pi r^3(\rho - \sigma)g,$$



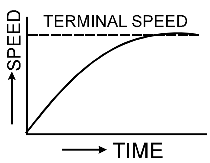
(ii) viscous force acting upward

$$= 6\pi\eta rv.$$

Since the ball is moving with a constant velocity v i.e., there is no acceleration in it, the net force acting on it must be zero. That is

$$6\pi\eta rv = \frac{4}{3} p r^3(\rho - \sigma)g$$

or $$v = \frac{2}{9}\frac{r^2(\rho - \sigma)g}{\eta}$$



Thus, terminal velocity of the ball is directly proportional to the square of its radius

In the beginning the soldier falls with gravity acceleration g, but soon the acceleration goes on decreasing rapidly until in parachute is fully opened. Therefore, in the beginning the speed of the falling soldier increases somewhat rapidly but then very slowly. Due to the viscosity of air the acceleration of the soldier becomes ultimately zero and the soldier then falls with a constant terminal speed. In Fig graph is shown between the speed of the falling soldier and time.

Air bubble in water always goes up. It is because density of air (ρ) is less than the density of water (σ). So the terminal velocity for air bubble is negative, which implies that the air bubble will go up. Positive terminal velocity means the body will fall down.

EXERCISE # 1

PART - I : OBJECTIVE QUESTIONS

*** Marked Questions are having more than one correct option.**

1. THERMAL EXPANSION

1.1 The temperature of a metal ball is raised. Arrange the percentage change in volume, surface area and radius in ascending order.

(A) %A < %R < %V (B) %R < %A < %V (C) %V < %A < %R (D) %A < %V < %R

1.2 We have a hollow sphere and a solid sphere of equal radii and of the same material. They are heated to raise their temperature by equal amounts. The change in their volumes, due to volume expansions, be $\Delta V_{\text{hollow sphere}}$ and $\Delta V_{\text{solid sphere}}$. Then :

(A) $\Delta V_{\text{hollow sphere}} > \Delta V_{\text{solid sphere}}$

(B) $\Delta V_{\text{hollow sphere}} < \Delta V_{\text{solid sphere}}$

(C) $\Delta V_{\text{hollow sphere}} = \Delta V_{\text{solid sphere}}$

(D) Any of the three options depending upon the material of the sphere

1.3 Now if the hollow sphere is filled with air then :

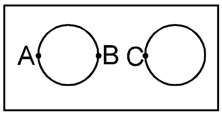
(A) $\Delta V_{\text{hollow sphere}} > \Delta V_{\text{solid sphere}}$

(B) $\Delta V_{\text{hollow sphere}} < \Delta V_{\text{solid sphere}}$

(C) $\Delta V_{\text{hollow sphere}} = \Delta V_{\text{solid sphere}}$

(D) Any of the three options depending upon the material of the sphere

1.4 Two large holes are cut in a metal sheet. If this is heated, distances AB and BC, (as shown)



(A) both will increase (B) both will decrease

(C) AB increases, BC decreases (D) AB decreases, BC increases

1.5 A steel scale is to be prepared such that the millimeter intervals are to be accurate within 6×10^{-5} mm. The maximum temperature variation from the temperature of calibration during the reading of the millimeter marks is ($\alpha = 12 \times 10^{-6}$ /ºC)

(A) 4.0°C (B) 4.5°C (C) 5.0°C (D) 5.5°C

1.6 Expansion during heating –

(A) occurs only in a solid (B) increases the density of the material

(C) decreases the density of the material (D) occurs at the same rate for all liquids and solids.

1.7 If a bimetallic strip is heated, it will

(A) bend towards the metal with lower thermal expansion coefficient.

(B) bend towards the metal with higher thermal expansion coefficient.

(C) twist itself into helix.

(D) have no bending.

1.8 A difference of temperature of 25º C is equivalent to a difference of :

(A) 45º F (B) 72º F (C) 32º F (D) 25º F

2. CALORIMETRY

2.1 A small quantity, mass m, of water at a temperature θ (in°C) is poured on to a large mass M of ice which is at its melting point. If c is the specific heat capacity of water and L the latent heat of fusion of ice, then the mass of ice melted is given by :

(A) $\frac{ML}{mc\theta}$ (B) $\frac{mc\theta}{ML}$ (C) $\frac{Mc\theta}{L}$ (D) $\frac{mc\theta}{L}$

2.2* When m gm of water at 10°C is mixed with m gm of ice at 0°C, which of the following statements are false?

(A) The temperature of the system will be given by the equation

$m \times 80 + m \times 1 \times (T - 0) = m \times 1 \times (10 - T)$

(B) Whole of ice will melt and temperature will be more than 0°C but lesser than 10°C

(C) Whole of ice will melt and temperature will be 0°C

(D) Whole of ice will not melt and temperature will be 0°C

2.3* Two identical beakers with negligible thermal expansion are filled with water to the same level at 4°C. If one says A is heated while the other says B is cooled, then :

(A) water level in A must rise (B) water level in B must rise

(C) water level in A must fall (D) water level in B must fall

2.4 A thermally isolated vessel contains 100 g of water at 0°C. When air above the water is pumped out, some of the water freezes and some evaporates at 0°C itself. The mass of the ice formed if no water is left in the vessel is : Latent heat of vaporization of water at 0°C = 2.10×10^6 J/kg and latent heat of fusion of ice = 3.36×10^5 J/kg.

(A) 80. 2 g (B) 76.2 g (C) 86.2 g (D) 90.2 g

2.5 A pitcher contains 20 kg of water. 0.5 gm of water comes out on the surface of the pitcher every second through the pores and gets evaporated taking energy from the remaining water. Calculate the approximate time in which temperature of the water decreases by 5°C .Neglect backward heat transfer from the atmosphere to the water.

Specific heat capacity of water = 4200J/Kg°C

Latent heat of vaporization of water 2.27×10^6 J/Kg

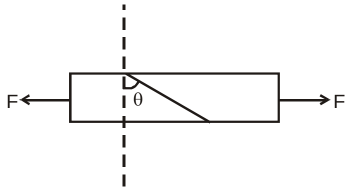
(A) 3.16 min (B) 4.16 min (C) 5.16 min (D) 6.16 min

3. ELASTICITY

3.1 The diameter of a brass rod is 4 mm and Young's modulus of brass is 9×10^{10} N/m^2. The force required to stretch it by 0.1% of its length is :

(A) $360\,\pi$ N (B) 36 N (C) $144\,\pi \times 10^3$ N (D) $36\,\pi \times 10^5$ N

3.2 A bar of cross-section A is subjected to equal and opposite tensile forces F at its ends. Consider a plane through the bar making an angle θ with a plane at right angles to the bar The tensile stress at this plane in terms of F, A and θ ?



(A) $\frac{F\cos^2\theta}{A}$ (B) $\frac{F\sin 2\theta}{2A}$ (C) $\frac{F\cos\theta}{A}$ (D) $\frac{F\sin\theta}{2A}$

3.3 In the above question the value of θ for which the shearing stress is maximum ?

(A) 0º (B) 45º (C) 60º (D) 90º

3.4 Four wires of the same material are stretched by the same load. The dimension of the wires are as given below. The one which has the maximum elongation is of

(A) diameter 1 mm and length 1 m (B) diameter 2 mm and length 2 m
(C) diameter 0.5 mm and length 0.5 m (D) diameter 3 mm and length 3 m

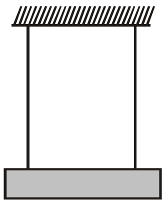
3.5 A steel wire is suspended vertically from a rigid support. When loaded with a weight in air, it expands by L_a and when the weight is immersed completely in water, the extension is reduced to L_w. Then relative density of the material of the weight is

(A) $\frac{L_a}{L_a - L_w}$ (B) $\frac{L_w}{L_a}$ (C) $\frac{L_a}{L_w}$ (D) $\frac{L_w}{L_a - L_w}$

3.6 A wire of cross-sectional area A is stretched horizontal between two clamps located at a distance 2ℓ meters from each other. A weight W N is suspended from the mid point of the wire. The strain produced in the wire, (if the vertical distance through which the mid point of the wire moves down $x << \ell$) will be

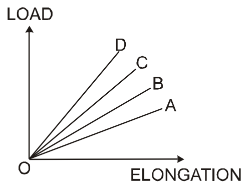
(A) x^2/ℓ^2 (B) $2x^2 / \ell^2$ (C) $x^2/2\ell^2$ (D) $x/2\ell$

3.7 Two wires of equal length and cross-section area suspended as shown in figure. Their Young's modulus are Y_1 and Y_2 respectively. The equivalent Young's modulus will be



(A) $Y_1 + Y_2$ (B) $\frac{Y_1 + Y_2}{2}$ (C) $\frac{Y_1 Y_2}{Y_1 + Y_2}$ (D) $\sqrt{Y_1 Y_2}$

3.8 The load versus elongation graph for four wires of the same materials is shown in the figure. The thinnest wire is represented by the line :



(A) OC (B) OD (C) OA (D) OB

3.9 A square brass plate of side 1.0 m and thickness 0.005 m is subjected to a force F on its smaller opposite edges, causing a displacement of 0.02 cm. If the shear modulus of brass is 0.4×10^{11} N/m^2, the value of the force F is

(A) 4×10^3 N (B) 400 N (C) 4×10^4 N (D) 1000 N

3.10 A metal block is experiencing an atmospheric pressure of 1×10^5 N/m^2, when the same block is placed in a vacuum chamber, the fractional change in its volume is (the bulk modulus of metal is 1.25×10^{11} N/m^2)

(A) 4×10^{-7} (B) 2×10^{-7} (C) 8×10^{-7} (D) 1×10^{-7}

3.11 A cube is subjected to a uniform volume compression. If the side of the cube decreases by 2%, the bulk strain is -

(A) 0.02 (B) 0.03 (C) 0.04 (D) 0.06

3.12 The isothermal bulk modulus of elasticity of a gas is equal to :
(A) Density (B) Volume (C) Pressure (D) Specific heat

3.13 The only elastic modulus that applies to fluids is :
(A) Young's modulus (B) Shear modulus (C) Modulus of rigidity (D) Bulk Modulus

3.14 The compressibility of water is 4×10^{-5} per unit atmospheric pressure. The decrease in volume of 100 cubic centimeter of water under a pressure of 100 atmosphere will be :
(A) 0.4 cc (B) 4×10^{-5} cc (C) 0.025 cc (D) 0.004 cc

3.15 One liter of a gas is maintained at pressure 72 cm of mercury. It is compressed isothermally so that its volume becomes 900 cm^3. The values of stress and strain will be respectively :
(A) 0.106 N m^{-2} and 0.1 (B) 95961.6 N m^{-2} and 0.1
(C) 106.62 N m^{-2} and 0.1 (D) 9596.16 N m^{-2} and 0.1

3.16 The mean density of sea water is ρ, and bulk modulus is B. The change in density of sea water in going from the surface of water to a depth h is :
(A) $\frac{\rho gh}{B}$ (B) $B\rho gh$ (C) $\frac{\rho^2 gh}{B}$ (D) $\frac{B\rho^2}{gh}$

3.17 If the potential energy of a spring is V on stretching it by 2 cm, then its potential energy when it is stretched by 10 cm will be :
(A) V/25 (B) 5 V (C) V/5 (D) 25 V

3.18 If work done in stretching a wire by 1mm is 2J, the work necessary for stretching another wire of same material, but with double the radius and half the length by 1mm in joule is -
(A) 1/4 (B) 4 (C) 8 (D) 16

3.19 The rubber cord catapult has a cross-sectional area 1 mm^2 and total unstretched length 10.0 cm. It is stretched to 12.0 cm and then released to project a missile of mass 5.0 g. Taking Young's modulus for rubber as 5.0×10^8 Nm^{-2}, the tension in the cord is -the velocity of projection of the missile is -
(A) 0.2 ms^{-1} (B) 2 ms^{-1} (C) 20 ms^{-1} (D) 200 ms^{-1}

3.20 A load of 31.4 kg is suspended from a wire of radius 10^{-3} m and density 9×10^3 kg/m^3. Calculate the change in temperature of wire if 75% of the work done is converted into heat will be : (The Young's modulus and specific heat capacity of the material of the wire are 9.8×10^{10} N/m^2 and 490 J/Kg K, respectively)
(A) $\frac{1}{12}$ ºC (B) $\frac{1}{120}$ ºC (C) $\frac{1}{90}$ ºC (D) $\frac{1}{9}$ ºC

3.21 Which of the following is not dimension less–
(A) Poisson ratio (B) Shearing strain (C) Longitudinal strain (D) Volume stress

3.22 The ratio of coefficient of isothermal and adiabatic elasticities of a gas is–
(A) γ (B) γ^2 (C) $1/\gamma$ (D) $1/\gamma^2$

3.23 A cylinder is of length ℓ and diameter d. On stretching the cylinder, an increment $\Delta\ell$ in length and decrease Δd in diameter are caused. The Poisson ratio is–
(A) $\sigma = -\frac{\Delta\ell}{\ell} \times \frac{d}{\Delta d}$ (B) $\sigma = -\frac{\ell}{d} \times \frac{\Delta d}{\Delta\ell}$ (C) $\sigma = -\frac{\Delta\ell}{\ell} \times \frac{\Delta d}{d}$ (D) $\sigma = -\frac{\ell}{\Delta\ell} \times \frac{d}{\Delta d}$

4. VISCOSITY

4.1 An oil drop falls through air with a terminal velocity of 5×10^{-4} m/s.

(i) the radius of the drop will be :

(A) 2.5×10^{-6} m (B) 2×10^{-6} m (C) 3×10^{-6} m (D) 4×10^{-6} m

(ii) the terminal velocity of a drop of half of this radius will be : (Viscosity of air = $\frac{18 \times 10^{-5}}{5}$ N-s/m^2, g = 10 m/s^2, density of oil = 900 Kg/m^3. Neglect density of air as compared to that of oil)

(A) 3.25×10^{-4} m/s (B) 2.10×10^{-4} m/s (C) 1.5×10^{-4} m/s (D) 1.25×10^{-4} m/s

4.2 The terminal velocity of a sphere moving through a viscous medium is :

(A) directly proportional to the radius of the sphere

(B) inversely proportional to the radius of the sphere

(C) directly proportional to the square of the radius of sphere

(D) inversely proportional to the square of the radius of sphere

4.3 A sphere is dropped gently into a medium of infinite extent. As the sphere falls, the force acting downwards on it

(A) remains constant throughout

(B) increases for sometime and then becomes constant

(C) decreases for sometime and then becomes zero

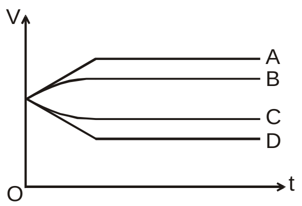
(D) increases for sometime and then decreases.

4.4 A solid sphere falls with a terminal velocity of 10 m/s in air. If it is allowed to fall in vacuum,

(A) terminal velocity will be more than 10 m/s (B) terminal velocity will be less than 10 m/s

(C) terminal velocity will be 10 m/s (D) there will be no terminal velocity

4.5 A small spherical solid ball is dropped from a great height in a viscous liquid. Its journey in the liquid is best described in the diagram given below (V = velocity and t = time) by the



(A) curve A (B) curve B (C) curve C (D) curve D.

4.6 A space ship entering the earth's atmosphere is likely to catch fire. This is due to

(A) the surface tension of air

(B) the viscosity of air

(C) the temperature of the upper atmosphere

(D) the greater proportion of oxygen in the atmosphere at high altitudes

5. SURFACE TENSION, SURFACE ENERGY AND CAPILLARY RISE

5.1 Two capillary tubes of same radius *r* but of lengths l_1 and l_2 are fitted in parallel to the bottom of vessel. The pressure head is P. What sould be the length *l* of the single tube that can replace the two tubes, so that the rate of flow is same as before.

(A) $l = l_1 + l_2$ (B) $l = \frac{l_1 l_2}{l_1 + l_2}$ (C) $l = \frac{1}{l_1} + \frac{1}{l_2}$ (D) $l = \frac{1}{l_1 + l_2}$

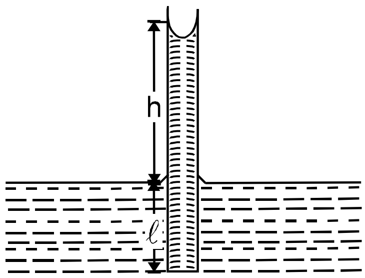
5.2 A container, whose bottom has round holes with diameter 0.1 mm is filled with water. The maximum height in cm upto which water can be filled without leakage will be what?
Surface tension = 75×10^{-3} N/m and g = 10 m/s^2:

(A) 20 cm (B) 40 cm (C) 30 cm (D) 60 cm

5.3 A liquid will not wet the surface of a solid if the angle of contact is :

(A) 0^0 (B) 45^0 (C) 60^0 (D) $> 90^0$

5.4 Water rises to a height h in a capillary tube lowered vertically into water to a depth ℓ as shown in the figure. The lower end of the tube is closed, the tube is then taken out of the water and opened again. The length of the water column remaining in the tube will be :



(A) 2h if $l \geq h$ and $l + h$ if $l \leq h$ (B) h if $l \geq h$ and $l + h$ if $l \leq h$
(C) 4h if $l \geq h$ and $l - h$ if $l \leq h$ (D) h/2 if $l \geq h$ and $l + h$ if $l \leq h$

5.5 Two parallel glass plates are dipped partly in the liquid of density 'd'. keeping them vertical. If the distance between the plates is 'x', Surface tension for liquid is T & angle of contact is θ then rise of liquid between the plates due to capillary will be :

(A) $\frac{T\cos\theta}{xd}$ (B) $\frac{2T\cos\theta}{xdg}$ (C) $\frac{2T}{xdg\cos\theta}$ (D) $\frac{T\cos\theta}{xdg}$

5.6* If for a liquid in a vessel, force of a cohesion is twice of adhesion :

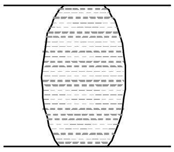
(A) the meniscus will be convex upwards
(B) the angle of contact will be obtuse
(C) the liquid will descend in the capillary tube
(D the liquid will wet the solid

5.7* The rise of liquid in a capillary tube depends on :

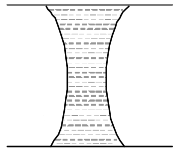
(A) the material of tube and nature of liquid (B) the length of tube
(C) the outer radius (D) the inner radius of the tube

6. EXCESS PRESSURE IN DROPS AND BUBBLE

6.1 If a water drop is kept between two glass plates, then its shape is


(A)


(B)


(C)

(D) None of these

6.2 A number of small drops of mercury adiabatically coalesce to form a single drop. The temperature of the drop will

(A) increase (B) remain same (C) decrease (D) depend on size.

6.3 Two spherical soap bubbles collapses. If V is the consequent change in volume of the contained air and S is the change in the total surface area and T is the surface tension of the soap solution, then (if P_0 is atmospheric pressure) : Assume temperature of the air remain same in all the bubbles

(A) $3P_0V + 4ST = 0$ (B) $4P_0V + 3ST = 0$ (C) $P_0V + 4TS = 0$ (D) $4P_0V + ST = 0$

6.4 When charge is given to a soap bubble, it shows :

(A) a decrease in size

(B) no change in size

(C) an increase in size

(D) sometimes an increase and sometimes a decreases in size

6.5 A soap bubble of radius r_1 is placed on another soap bubble of radius $r_2 (r_1 < r_2)$/ The radius R of the soapy film separating the two bubbles is :

(A) $r_1 + r_2$ (B) $\sqrt{r_1^2 + r_2^2}$ (C) $(r_1^3 + r_2^3)$ (D) $\frac{r_2 r_1}{r_2 - r_1}$

6.6 A water drop is divided into 8 equal droplets. The pressure difference between the inner and outer side of the big drop will be :

(A) same as for smaller droplet (B) 1/2 of that for smaller droplet

(C) 1/4 of that for smaller droplet (D) twice that for smaller droplet

6.7 An air bubble of radius r in water is at a depth h below the water surface at some instant. If P is atmospheric pressure, d and T are density and surface tension of water respectively, the pressure inside the bubble will be :

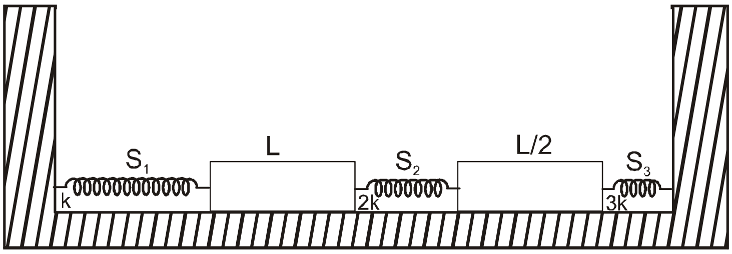
(A) $P + h\,dg - \frac{4T}{r}$ (B) $P + h\,dg + \frac{2T}{r}$ (C) $P + h\,dg - \frac{2T}{r}$ (D) $P + h\,dg + \frac{4T}{r}$

PART - II : MISCELLANEOUS OBJECTIVE QUESTIONS

Comprehensions Type :

Comprehension # 1

The system shown in figure consists of three springs and two rods as shown. The temperature of the rods is increased by ΔT. The spring are intially relaxed. There is no friction. The coefficient of linear expansion of the material of rods is equal to α.



1. The energy stored in spring S_1 is :

(A) $\frac{81}{484}\, k L^2 \alpha^2 (\Delta T)^2$ (B) $\frac{27}{242}\, k L^2 \alpha^2 (\Delta T)^2$ (C) $\frac{81}{242}\, k L^2 \alpha^2 (\Delta T)^2$ (D) $\frac{49}{484}\, k L^2 \alpha^2 (\Delta T)^2$

2. The energy stored in spring S_2 is :

(A) $\frac{81}{484}\, k L^2 \alpha^2 (\Delta T)^2$ (B) $\frac{27}{242}\, k L^2 \alpha^2 (\Delta T)^2$ (C) $\frac{81}{242}\, k L^2 \alpha^2 (\Delta T)^2$ (D) $\frac{49}{484}\, k L^2 \alpha^2 (\Delta T)^2$

3. The energy stored in spring S_3 is :

(A) $\frac{81}{484}\, k L^2 \alpha^2 (\Delta T)^2$ (B) $\frac{27}{242}\, k L^2 \alpha^2 (\Delta T)^2$ (C) $\frac{81}{242}\, k L^2 \alpha^2 (\Delta T)^2$ (D) $\frac{49}{484}\, k L^2 \alpha^2 (\Delta T)^2$

Comprehension # 2

A calorimeter of mass m contains an equal mass of water in it. The temperature of the water and calorimeter is t_2. A block of ice of mass m and temperature t_3 < 0ºC is gently dropped into the calorimeter. Let C_1,C_2 and C_3 be the specific heats of calorimeter, water and ice respectively and L be the latent heat of ice.

4. The whole mixture in the calorimeter becomes ice if :

(A) $(C_1t_2 + C_2t_2 + L + C_3t_3) > 0$ (B) $(C_1t_2 + C_2t_2 + L + C_3t_3) < 0$
(C) $(C_1t_2 + C_2t_2 - L - C_3t_3) > 0$ (D) $(C_1t_2 + C_2t_2 - L - C_3t_3) < 0$

5. The whole mixture in the calorimeter becomes water if

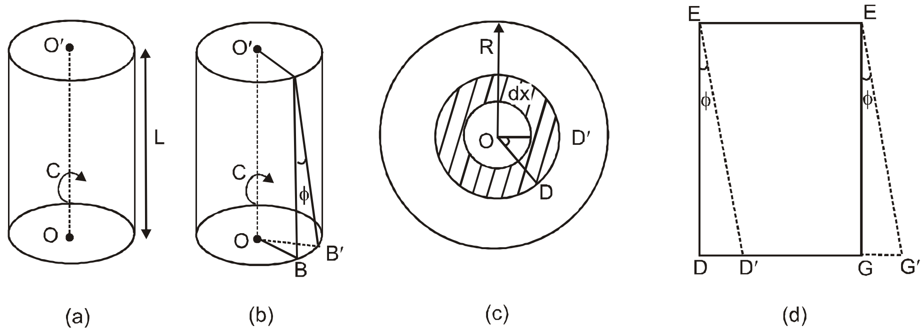
(A) $(C_1 + C_2)t_2 - + C_3t_3\, L > 0$ (B) $(C_1 + C_2)t_2 + C_3t_3 + L > 0$
(C) $(C_1 + C_2)t_2 - C_3t_3 - L > 0$ (D) $(C_1 + C_2)t_2 + C_3t_3 - L > 0$

6. Water equivalent of calorimeter is :

(A) mC_1 (B) $\frac{mC_1}{C_2}$ (C) $\frac{mC_2}{C_1}$ (D) none of these

Comprehension # 3

A solid cylinder of length L and radius R is fixed at its upper end and a couple C is applied to its lower end, which is applied in a plane perpendicular to its lengh (with its axis coinciding with that of the cylinder) as shown in the figure (a). As a result, the cylinder is twisted through an angle ϕ as shown in figure (b) Due to elastic properties, a resisting couple is produced in the cylinder which tends to oppose the twisting couple applied. At equilibrium, the two coules balance each other.



Coefficient of rigidity fo the material of the cylinder is G

To find out the value of this couple, the cylinder is assumed to consist of a large number of hollow, coaxial cylinders, one inside the other. Considering one such hollow cylinder of radius x and thickness dx. The cross-section of this hollow cylinder is shown in figure (c). This hollow cylinder also gets twisted by an angle θ due to application of couple C, (η is the coefficent of rigidity).

7. Give a suitable relation between x,θL and ϕ

(A) $\phi = x\ \theta/L$ (B) $\phi = x\ \phi/L$ (C) $\phi = (x^2/L^2)\ \phi$ (D) $\theta = \phi$

8. Now the hollow cylinder (of radius x) is cut along its length parallel to axis 00' before twisting. It is found as a rectangle DEFG. Due to the twisting couple, its deformed to a parallelogram D'EFG'.

Then find the shearing force on the face area of the cylinder:

(A) ηxL (B) $2\eta\pi x dx$ (C) $\frac{\eta\theta}{L}\ 2\pi x^2 dx$ (D) $\frac{\eta\theta}{L}\ \pi x^2 dx$

9. Find the restoring couple applied by the cylinder in equilibrium condition:

(A) $\frac{2\pi\eta R^4\theta}{2L}$ (B) $\frac{2}{3}\frac{\pi\eta R^3\theta}{3L}$ (C) $\frac{\pi\eta R^4\theta}{4L}$ (D) $\frac{2\pi G\eta^3\theta}{3L}$

Comprehension # 4

Questions refer to the table below. The Ultimate strength represents the maximum stress applied to a specimen without fracture.

Material	Density (kg/m^3)	Young's Modulus ($10^9\ N/m^2$)	Ultimate Strength ($10^6\ N/m^2$)
Steel	7860	200	400
Aluminum	2710	70	110
Glass	2190	65	50
Concrete	2320	30	40
Wood	525	13	50
Bone	1900	9	170

10. According to the table, which of the following can withstand the greatest amount of stress without breaking?

(A) A cylinder of glass 1 m long with a 10 cm radius

(B) A human femur 0.5 m long with a 10 cm radius

(C) A cylinder of concrete 10 m long with a 20 cm radius

(D) A cylinder of aluminium 0.5 m long with as cm radius

11. According to the table, what is the maximum per cent change in length withstood by a steel bar before it will break?

(A) 0.125 % (B) 0.2 % (C) 12.5 % (D) 125 %

12. According to the table, what is the maximum height to which a concrete column be made before it will collapse under its own weight?

(A) 10 m (B) 1.0×10^2 m (C) 1.7 x 10^2 m (D) 1.3×10^6 m

13. According to the table, which of the following is the most flexible? (expands the most without breaking)

(A) steel (B) glass (C) wood (D) bone

14. A woman with a mass of 65 kg puts all her weight on one heel of her high-heel shoe. The cross-sectional area of the heel is 1 cm^3. According to the table, if she is standing on a pane of glass that is flat against the ground, does the glass break:

(A) No, because the stress is less than the ratio for the ultimate strength to Young's modulus for glass

(B) No, because the stress is less than the ultimate strength of glass

(C) Yes, because the stress is greater than the ratio for the ultimate strength to Young's modulus for glass

(D) Yes, because the stress is greater than the ultimate strength of glass

15. A wooden beam 3m long has a cross-sectional area of 10 cm^2. If it is positioned vertically so that it supports 1.3×10^3 kg, what is its change in length ? (Ignore the weight of the beam)

(A) 3mm (B) 3cm (C) 33cm (D) 3m

16. A wooden beam 3m long has a cross-sectional area of 10 cm^2. If it is positioned vertically so that it supports 1.3 x 10^4 kg. If a 6 m beam were used instead, the change in length of the beam would:

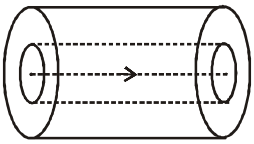
(A) decrease by a factor of 2 (B) remain the same

(C) increase by a factor of 2 (D) increase by a factor of 4

Comprehension # 5

When viscous liquid flows, adjacent layers oppose their relative motion by applying a viscous force given by

$$F = -\eta A \frac{dv}{dz}$$



When η = coefficient of viscosity, A = surface area of adjacent layers in contanct.

$$\frac{dv}{dz} = \text{velocity gradient}$$

Now, a viscous liquid having coefficient of viscosity η is flowing through a fixed tube of length ℓ and radius R under a pressure difference P between the two ends of the tube. Now, consider a cylindrical volume of liquid of radius r. Due to steady flow, net force on the liquid in cylindrical volume should be zero.

$$-\eta 2\pi r\ell \frac{dv}{dr} = P\pi r^2$$

$$-\int_v^0 dv = \frac{P}{2\eta\ell}\int_r^R r\,dr$$ ($\therefore$ layer in contact with the tube is stationary)

$$v = v_0\left(1-\frac{r^2}{R^2}\right), \text{ where } v_0 = \frac{PR^2}{4\eta\ell}$$

The volume of the liquid per second through the tube,

$$Q = \int_0^R v.2\pi r\,dr = \int_0^R v_0\left(1-\frac{r^2}{R^2}\right)2\pi r\ dr$$

$$= v_0 2\pi\left[\frac{r^2}{2}-\frac{r^4}{4R^2}\right]_0^R$$

$$= v_0 2\pi\left[\frac{R^2}{2}-\frac{R^4}{4}\right] = \frac{v_0\pi R^2}{2} = \frac{\pi P R^4}{8\eta\ell}$$

This is called poiseuile's equation

17. Force acting on the tube due to the liquid is :

(A) $\pi\,\eta\,\ell\,v_0$ (B) $2\pi\,\eta\,\ell\,v_0$ (C) $4\pi\,\eta\,\ell\,v_0$ (D) $6\pi\,\eta\,\ell\,v_0$ X

18. The viscous force on the cylindrical volume of the liquid varies as :

(A) $F \propto r^2$ (B) $F \propto r$ (C) $F \propto 1/r$ (D) $F \propto 1/r^2$

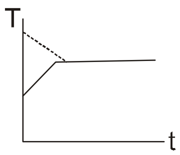
19. The momentum of the liquid confined in the tube is :

(A) $\rho\pi R^2\ell v_0$ (B) $\rho\pi R^2\ell v_0/2$ (C) $\rho\pi R^2\ell v_0/4$ (D) $2\rho\pi R^2\ell v_0$

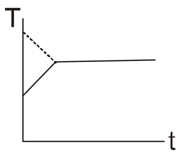
Match the Column :

20. In a vessel a liquid A is mixed with a block of ice B. The dotted line shows the temperature of A and dark line of B.

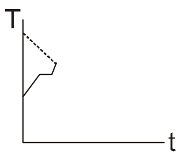
Column I **Column II**

(A) 

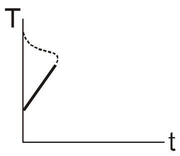
(P) The equillibrium temperature below freezing point of water

(B) 

(Q) At the equillibrium, the liquid partly freezes.

(C) 

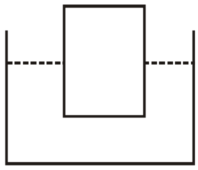
(R) The ice partly melts

(D) 

(S) The ice fully melt

(T) The equilibrium temperature is freezing point of water

21. A cylindrical isotropic solid of coefficient of thermal expansion α and density ρ floats in a liquid of coefficient of volume expansion γ and density d as shown in the diagram



Column I	Column II
(A) volume of cylinder inside the liquid remains constant	(p) $\gamma = 0$
(B) volume of cylinder outside the liquid remains constant	(q) $\gamma = 2\alpha$
(C) Height of cylinder outside the liquid remains constant	(r) $\gamma = 3\alpha \frac{d}{\rho}$
(D) Height of cylinder inside the liquid remain constant	(s) $\gamma = (2\alpha + \alpha \frac{d}{\rho})$

22. A metal wire of length L is suspended vertically from a rigid support. When a bob of mass M is attached to the lower end of wire, the elongation of the wire is ℓ :

Column - I	Column - II
(A) The loss in gravitational potential energy of mass M is equal to	(p) $Mg\ell$
(B) The elastic potential energy stored in the wire is equal to	(q) $\frac{1}{2}Mg\ell$
(C) The elastic constant of the wire is equal to	(r) Mg/ℓ
(D) Heat produced during extension is equal to	(s) $\frac{1}{4}Mg\ell$

EXERCISE # 2

PART - I : OBJECTIVE QUESTIONS

SINGLE CORRECT ANSWER TYPE

1. A force F is needed to break a copper wire having radius R. The force needed to break a copper wire of radius 2 R will be :

(A) F/2 (B) 2 F (C) 4 F (D) F/4

2. Two hail stones with radii in the ratio of 1 : 2 fall from a great height through the atmosphere. Then the ratio of their momentum after they have attained terminal velocity is

(A) 1 : 1 (B) 1 : 4 (C) 1 : 16 (D) 1 : 32

3. A 50 kg motor rests on four cylindrical rubber blocks. Each block has a height of 4 cm and a cross-sectional area of 16 cm^2. The shear modulus of rubber is 2×10^6 N/m^2. A sideways force of 500 N is applied to the motor. The distance that the motor moves sideways is

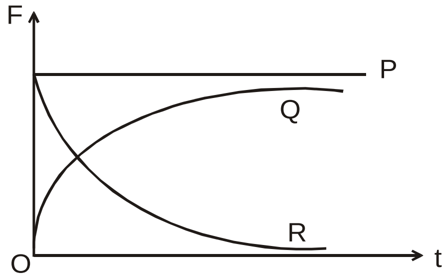
(A) 0.156 cm (B) 1.56 cm (C) 0.312 cm (D) 0.204 cm

4. A brass rod of length 2 m and cross-sectional area 2.0 cm^2 is attached end to end to a steel rod of length L and cross-sectional area 1.0 cm^2. The compound rod is subjected to equal and opposite pulls of magnitude 5×10^4 N at its ends. If the elongations of the two rods are equal, the length of the steel rod (L) is

($Y_{Brass} = 1.0 \times 10^{11}$ N/m^2 and $Y_{Steel} = 2.0 \times 10^{11}$ N/m^2)

(A) 1.5 m (B) 1.8 m (C) 1 m (D) 2 m

5. A spherical ball is dropped in a long column of viscous liquid. Which of the following graphs represent the variation of



(i) gravitational force with time

(ii) viscous force with time

(iii) net force acting on the ball with time

(A) Q, R, P (B) R, Q, P (C) P, Q, R (D) R, P, Q

6. The compressibility of water is 46.4×10^{-6}/atm. This means that

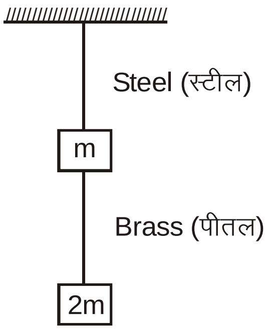
(A) the bulk modulus of water is 46.4×10^{6} atm

(B) volume of water decreases by 46.4 one-millionths of the original volume for each atmosphere increase in pressure

(C) when water is subjected to an additional pressure of one atmosphere, its volume decreases by 46.4%

(D) When water is subjected to an additional pressure of one atmosphere, its volume is reduced to 10^{-6} of its original volume.

7. If the ratio of lengths, radii and Young's modulii of steel and brass wires in the figure are a, b and c respectively. Then the corresponding ratio of increase in their lengths would be :



(A) $\frac{2ac}{b^2}$ (B) $\frac{3a}{2b^2c}$ (C) $\frac{3c}{2ab^2}$ (D) $\frac{2a^2c}{b}$

8. If a rubber ball is taken at the depth of 200 m in a pool its volume decreases by 0.1%. If the density of the water is 1×10^3 kg/m^3 and g = 10 m/s^2, then the volume elasticity in N/m^2 will be :

(A) 10^8 (B) 2×10^8 (C) 10^9 (D) 2×10^9

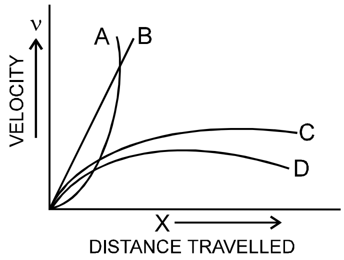
9. Two wires of the same material and length but diameter in the ratio 1 : 2 are stretched by the same force. The ratio of potential energy per unit volume for the two wires when stretched will be :

(A) 1 : 1 (B) 2 : 1 (C) 4 : 1 (D) 16 : 1

10. A small steel ball falls through a syrup at constant speed of 10 cm/s. If the steel ball is pulled upwards with a force equal to twice its effective weight, how fast will it move upwards ?

(A) 10 cm/s (B) 20 cm/s (C) 5 cm/s (D) – 5 cm/s

11. A small spherical solid ball is dropped in a viscous liquid. Its journey in the liquid is best described in the figure by –



(A) Curve A (B) Curve B (C) Curve C (D) Curve D

12. Two rods of lengths ℓ_1 and ℓ_2 are made of materials whose coefficients of linear expansion are α_1 and α_2. If the difference between two lengths is independent of temperature, then

(A) $\frac{\ell_1}{\ell_2}=\frac{\alpha_1}{\alpha_2}$ (B) $\frac{\ell_1}{\ell_2}=\frac{\alpha_2}{\alpha_1}$ (C) $\ell_2^2\alpha_1=\ell_1^2\alpha_2$ (D) $\frac{\alpha_1^2}{\ell_1}=\frac{\alpha_2^2}{\ell_2}$

13. Overall changes in volume and radii of a uniform cylindrical steel wire are 0.2% and 0.002% respectively when subjected to some suitable force. Longitudinal tensile stress acting on the wire is
($Y = 2.0 \times 10^{11}\ Nm^{-2}$)

(A) $3.2 \times 10^9\ Nm^{-2}$ (B) $3.2 \times 10^7\ Nm^{-2}$ (C) $3.6 \times 10^9\ Nm^{-2}$ (D) $4.08 \times 10^8\ Nm^{-2}$

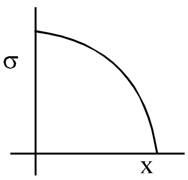
14. A solid sphere of radius R made of of material of bulk modulus K is surrounded by a liquid in a cylindrical container. A massless piston of area A floats on the surface of the liquid. When a mass m is placed on the piston to compress the liquid, the fractional change in the radius of the sphere $\delta R/R$ is

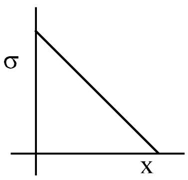
(A) mg/AK (B) mg/3AK (C) mg/A (D) mg/3AR

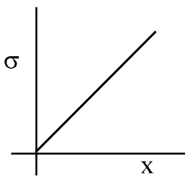
15. A cylindrical wire of radius 1 mm, length 1 m, Young's modulus = $2 \times 10^{11}\ N/m^2$, poisson's ratio $\mu = \pi/10$ is stretched by a force of 100 N. Its radius will become

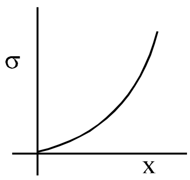
(A) 0.99998 mm (B) 0.99999 mm (C) 0.99997 mm (D) 0.99995 mm

16. A uniform rod rotating in gravity free region with certain constant angular velocity. The variation of tensile stress with distance x from axis of rotation is best represented by which of the following graphs.

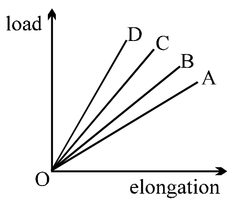
(A)


(B)


(C)


(D)


17. The load versus strain graph for four wires of the same material is shown in the figure. The thickest wire is represented by the line



(A) OB (B) OA (C) OD (D) OC

18. A thermally insulated vessel contains some water at 0^0C. The vessel is connected to a vacuum pump to pump out water vapour. This results in some water getting frozen. It is given Latent heat of vaporization of water at 0°C $=21 \times 10^5$ J/kg and latent heat of freezing of water $= 3.36 \times 10^5$ J/kg. The maximum percentage amount of water that will be solidified in this manner will be

(A) 86.2% (B) 33.6% (C) 21% (D) 24.36%

19. A block of mass 2.5 kg is heated to temperature of 500°C and placed on a large ice block. What is the maximum amount of ice that can melt (approx.). Specific heat for the body = 0.1 Cal/gm°C.
(A) 1 kg (B) 1.5 kg (C) 2 kg (D) 2.5 kg

20. 10 gm of ice at 0°C is kept in a calorimeter of water equivalent 10 gm. How much heat should be supplied to the apparatus to evaporate the water thus formed? (Neglect loss of heat)
(A) 6200 cal (B) 7200 cal (C) 13600 cal (D) 8200 cal

21. Heat is being supplied at a constant rate to a sphere of ice which is melting at the rate of 0.1 gm/sec. It melts completely in 100 sec. The rate of rise of temperature thereafter will be
(Assume no loss of heat.)
(A) 0.8 °C/sec (B) 5.4 °C/sec (C) 3.6 °C/sec (D) will change with time

22. 1 kg of ice at – 10°C is mixed with 4.4 kg of water at 30°C. The final temperature of mixture is :
(specific heat of ice is 2100 J/kg/k)
(A) 2.3°C (B) 4.4°C (C) 5.3°C (D) 8.7°C

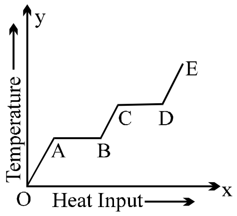
23. Steam at 100°C is added slowly to 1400 gm of water at 16°C until the temperature of water is raised to 80°C. The mass of steam required to do this is (L_V = 540 cal/gm) :
(A) 160 gm (B) 125 mg (C) 250 gm (D) 320 gm

24. Ice at 0°C is added to 200 g of water initially at 70°C in a vacuum flask. When 50 g of ice has been added and has all melted the temperature of the flask and contents is 40°C. When a further 80g of ice has been added and has all metled, the temperature of the whole is 10°C. Calculate the specific latent heat of fusion of ice.[Take S_w =1 cal /gm °C.]
(A) 3.8×10^5 J/ kg (B) 1.2×10^5 J/ kg (C) 2.4×10^5 J/ kg (D) 3.0×10^5 J/ kg

25. A 2100 W continuous flow geyser (instant geyser) has water inlet temperature = 10°C while the water flows out at the rate of 20 g/sec. The outlet temperature of water must be about
(A) 20°C (B) 30°C (C) 35°C (D) 40°C

26. A continuous flow water heater (geyser) has an electrical power rating = 2 kW and efficiency of conversion of electrical power into heat = 80%. If water is flowing through the device at the rate of 100 cc/sec, and the inlet temperature is 10°C, the outlet temperature will be
(A) 12.2°C (B) 13.8°C (C) 20°C (D) 16.5°C

27. A solid material is supplied with heat at a constant rate. The temperature of material is changing with heat input as shown in the figure. What does slope DE represent.



(A) latent heat of liquid (B) latent heat of vapour
(C) heat capacity of vapour (D) inverse of heat capacity of vapour

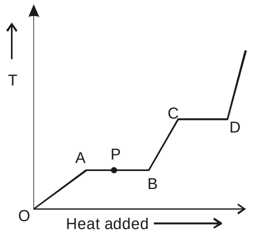
28. A block of ice with mass *m* falls into a lake. After impact, a mass of ice *m*/5 melts. Both the block of ice and the lake have a temperature of 0°C. If L represents the heat of fusion, the minimum distance the ice fell before striking the surface is

(A) $\frac{L}{5g}$ (B) $\frac{5L}{g}$ (C) $\frac{gL}{5m}$ (D) $\frac{mL}{5g}$

29. The specific heat of a metal at low temperatures varies according to $S = aT^3$ where a is a constant and T is the absolute temperature. The heat energy needed to raise unit mass of the metal from T = 1 K to T = 2 K is

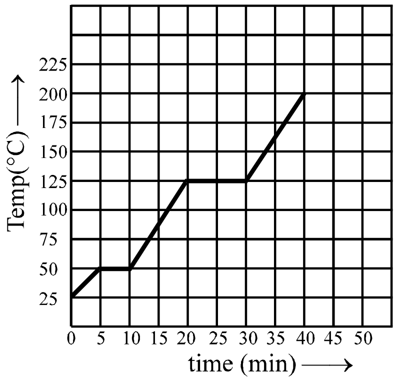
(A) 3 a (B) $\frac{15a}{4}$ (C) $\frac{2a}{3}$ (D) $\frac{12a}{5}$

30. The variation of temperature of material as heat is given to it at constant rate is shown in the figure. The material is in solid state at the point O. The state of the material at the point P is :



(A) partly solid and partly liquid. (B) partly liquid and partly gas.
(C) only solid (D) only liquid.

31. The graph shown in the figure represent change in the temperature of 5 kg of a substance as it abosrbs heat at a constant rate of 42 kJ min^{-1}. The latent heat of vapourazation of the substance is :



(A) 630 kJ kg^{-1} (B) 126 kJ kg^{-1} (C) 84 kJ kg^{-1} (D) 12.6 kJ kg^{-1}

32. The density of a material A is 1500 kg/m^3 and that of another material B is 2000 kg/m^3. It is found that the heat capacity of 8 volumes of A is equal to heat capacity of 12 volumes of B. The ratio of specific heats of A and B will be

(A) 1 : 2 (B) 3 : 1 (C) 3 : 2 (D) 2 : 1

33. Find the amount of heat supplied to decrease the volume of an ice water mixture by 1 cm^3 without any change in temperature. ($\rho_{ice} = 0.9\ \rho_{water}$, L_{ice} = 80 cal/gm).

(A) 360 cal (B) 500 cal (C) 720 cal (D) none of these

34. Some steam at 100°C is passed into 1.1 kg of water contained in a calorimeter of water equivalent 0.02 kg at 15°C so that the temperature of the calorimeter and its contents rises to 80°C. What is the mass of steam condensing. (in kg)

(A) 0.130 (B) 0.065 (C) 0.260 (D) 0.135

35. A rod of length 2m rests on smooth horizontal floor. If the rod is heated from 0°C to 20°C. Find the longitudinal strain developed? ($\alpha = 5 \times 10^{-5}$/°C)

(A) 10^{-3} (B) 2×10^{-3} (C) Zero (D) None of these

36. A steel tape gives correct measurement at 20°C. A piece of wood is being measured with the steel tape at 0°C. The reading is 25 cm on the tape, the real length of the given piece of wood must be:

(A) 25 cm (B) <25 cm (C) >25 cm (D) can not say

37. If two rods of length L and 2L having coefficients of linear expansion α and 2α respectively are connected so that total length becomes 3L, the average coefficient of linear expansion of the composition rod equals:

(A) $\frac{3}{2}\alpha$ (B) $\frac{5}{2}\alpha$ (C) $\frac{5}{3}\alpha$ (D) none of these

38. The bulk modulus of copper is 1.4×10^{11} Pa and the coefficient of linear expansion is 1.7×10^{-5} $(C°)^{-1}$. What hydrostatic pressure is necessary to prevent a copper block from expanding when its temperature is increased from 20°C to 30°C?

(A) 6.0×10^5 Pa (B) 7.1×10^7 Pa (C) 5.2×10^6 Pa (D) 40 atm

39. A thin copper wire of length L increase in length by 1% when heated from temperature T_1 to T_2. What is the percentage change in area when a thin copper plate having dimensions 2L × L is heated from T_1 to T_2?

(A) 1% (B) 2% (C) 3% (D) 4%

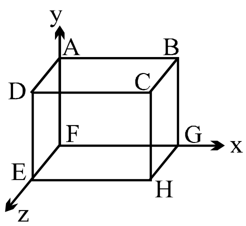
40. The coefficients of thermal expansion of steel and a metal X are respectively 12×10^{-6} and 2×10^{-6} per°C. At 40°C, the side of a cube of metal X was measured using a steel vernier callipers. The reading was 100 mm. Assuming that the calibration of the vernier was done at 0°C, then the actual length of the side of the cube at 0°C will be

(A) > 100 mm (B) < 100 mm (C) = 100 mm (D) data insufficient to conclude

41. A metallic rod l cm long with a square cross-section is heated through t°C. If Young's modulus of elasticity of the metal is E and the mean coefficient of linear expansion is α per degree Celsius, then the compressional force required to prevent the rod from expanding along its length is :(Neglect the change of cross-sectional area)

(A) $EA\alpha t$ (B) $EA\alpha t/(1 + \alpha t)$ (C) $EA\alpha t/(1-\alpha t)$ (D) $E/\alpha t$

42. A cuboid ABCDEFGH is anisotropic with $\alpha_x = 1 \times 10^{-5}$ /°C, $\alpha_y = 2 \times 10^{-5}$ /°C, $\alpha_z = 3 \times 10^{-5}$ /°C. Coefficient of superficial expansion of faces can be



(A) $\beta_{ABCD} = 5 \times 10^{-5}$ /°C (B) $\beta_{BCGH} = 4 \times 10^{-5}$ /°C

(C) $\beta_{CDEH} = 3 \times 10^{-5}$ /°C (D) $\beta_{EFGH} = 2 \times 10^{-5}$ /°C

43. The coefficient of apparent expansion of a liquid in a copper vessel is C and in a silver vessel is S. The coefficient of volume expansion of copper is γ_c. What is the coefficient of linear expansion of silver?

(A) $\frac{(C+\gamma_c+S)}{3}$ (B) $\frac{(C-\gamma_c+S)}{3}$ (C) $\frac{(C+\gamma_c-S)}{3}$ (D) $\frac{(C-\gamma_c-S)}{3}$

44. A sphere of diameter 7 cm and mass 266.5 gm floats in a bath of a liquid. As the temperature is raised, the sphere just begins to sink at a temperature 35°C. If the density of a liquid at 0°C is 1.527 gm/cc, then neglecting the expansion of the sphere, the coefficient of cubical expansion of the liquid is f :

(A) 8.486×10^{-4} per °C (B) 8.486×10^{-5} per °C

(C) 8.486×10^{-6} per °C (D) 8.486×10^{-3} per °C

45. The volume of the bulb of a mercury thermometer at 0°C is V_0 and cross section of the capillary is A_0. The coefficient of linear expansion of glass is α_g per °C and the cubical expansion of mercury γ_m per °C. If the mercury just fills the bulb at 0°C, what is the length of mercury column in capillary at T°C.

(A) $\frac{V_0T(\gamma_m+3\alpha_g)}{A_0(1+2\alpha_gT)}$ (B) $\frac{V_0T(\gamma_m-3\alpha_g)}{A_0(1+2\alpha_gT)}$ (C) $\frac{V_0T(\gamma_m+2\alpha_g)}{A_0(1+3\alpha_gT)}$ (D) $\frac{V_0T(\gamma_m-2\alpha_g)}{A_0(1+3\alpha_gT)}$

46. The loss in weight of a solid when immersed in a liquid at 0°C is W_0 and at t°C is W. If cubical coefficient of expansion of the solid and the liquid by γ_S and γ_1 respectively, then W is equal to :

(A) $W_0 [1 + (\gamma_s - \gamma_l) t]$
(B) $W_0 [1 - (\gamma_s - \gamma_l)t]$
(C) $W_0 [(\gamma_s - \gamma_l) t]$
(D) $W_0 t/(\gamma_s - \gamma_l)$

47. A thin walled cylindrical metal vessel of linear coefficient of expansion 10^{-3} °C^{-1} contains benzenr of volume expansion coefficient 10^{-3}°C^{-1}. If the vessel and its contents are now heated by 10°C, the pressure due to the liquid at the bottom.

(A) increases by 2%
(B) decreases by 1%
(C) decreases by 2%
(D) remains unchanged

48. An open vessel is filled completely with oil which has same coefficient of volume expansion as that of the vessel. On heating both oil and vessel,

(A) the vessel can contain more volume and more mass of oil
(B) the vessel can contain same volume and same mass of oil
(C) the vessel can contain same volume but more mass of oil
(D) the vessel can contain more volume but same mass of oil

49. A solid ball is completely immersed in a liquid. The coefficients of volume expansion of the ball and liquid are 3×10^{-6} and 8×10^{-6} per °C respectively. The percentage change in upthrust when the temperature is increased by 100 °C is

(A) 0.5 %
(B) 0.11 %
(C) 1.1 %
(D) 0.05 %

50. A rod of length 20 cm is made of metal. It expands by 0.075 cm when its temperature is raised from 0°C to 100°C. Another rod of a different metal B having the same length expands by 0.045 cm for the same change in temperature, a third rod of the same length is composed of two parts one of metal A and the other of metal B. Thus rod expand by 0.06 cm.for the same change in temperature. The portion made of metal A has the length :

(A) 20 cm
(B) 10 cm
(C) 15 cm
(D) 18 cm

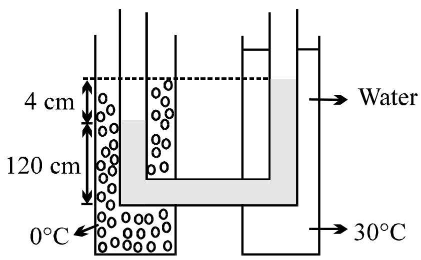
51. A rod of length 2m at 0°C and having expansion coefficient $\alpha = (3x + 2) \times 10^{-6}$ °C^{-1} where x is the distance (in cm) from one end of rod. The length of rod at 20°C is :

(A) 2.124 m
(B) 3.24 m
(C) 2.0120 m
(D) 3.124 m

52. A glass flask contains some mercury at room temperature. It is found that at different temperatures the volume of air inside the flask remains the same. If the volume of mercury in the flask is 300 cm^3, then volume of the flask is (given that coefficient of volume expansion of mercury and coefficient of linear expansion of glass are 1.8×10^{-4} (°C)$^{-1}$ and 9×10^{-6} (°C)$^{-1}$ respectively)

(A) 4500 cm^3
(B) 450 cm^3
(C) 2000 cm^3
(D) 6000 cm^3

53. Two vertical glass tubes filled with a liquid are connected by a capillary tube as shown in the figure. The tube on the left is put in an ice bath at 0°C while the tube on the right is kept at 30°C in a water bath. The difference in the levels of the liquid in the two tubes is 4 cm while the height of the liquid column at 0°C is 120 cm. The coefficient of volume expansion of liquid is (Ignore expansion of glass tube)



(A) 22×10^{-4}/°C
(B) 1.1×10^{-4}/°C
(C) 11×10^{-4}/°C
(D) 2.2×10^{-4}/°C

54. A metal ball of specific gravity 4.5 and specific heat 0.1 cal/gm-°C is placed on a large slab of ice at 0°C. Half of the ball sinks in the ice. The initial temperature of the ball is :-

(Latent heat capacity of ice = 80 cal/g, specific gravity of ice = 0.9)

(A) 100 °C (B) 90 °C (C) 80 °C (D) 70 °C

55. A steel rod 25 cm long has a cross-sectional area of 0.8 cm^2. Force required to stretch this rod by the same amount as the expansion produced by heating it through 10ºC is:

(Coefficient of linear expansion of steel is 10^{-5}/ºC and Young's modulus of steel is 2×10^{10} N/m^2.)

(A) 160 N (B) 360 N (C) 106 N (D) 260 N

56. If I is the moment of inertia of a solid body having α -coefficient of linear expansion then the change in I corresponding to a small change in temperature ΔT is

(A) $\alpha I \Delta T$ (B) $\frac{1}{2}\alpha I \Delta T$ (C) $2\alpha I \Delta T$ (D) $3\alpha I \Delta T$

57. A liquid with coefficient of volume expansion γ is filled in a container of a material having the coefficient of linear expansion α .If the liquid overflows on heating, then –

(A) $\gamma > 3\alpha$ (B) $\gamma < 3\alpha$ (C) $\gamma = 3\alpha$ (D) none of these

58. A metal ball immersed in water weighs w_1 at 5ºC and w_2 at 50ºC. The coefficient of cubical expansion of metal is less than that of water. Then

(A) $w_1 > w_2$ (B) $w_1 < w_2$ (C) $w_1 = w_2$ (D) data is insufficient

MULTIPLE CORRECT ANSWER(S) QUESTIONS

59. When two non reactive samples at different temperatures are mixed in an isolated container of negligible heat capacity the temperature of the mixture can be :

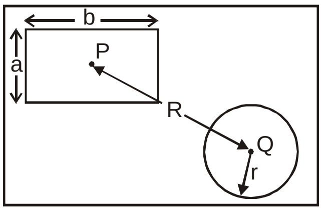
(A) lesser than lower or greater than higher temperature

(B) equal to lower or higher temperature

(C) greater than lower but lesser than higher temperature

(D) average of lower and higher temperatures

60. There is a rectangular metal plate in which two cavities in the shape of rectangle and circle are made, as shown with dimensions. P and Q are the centres of these cavities. On heating the plate, which of the following quantities increase ?



(A) πr^2 (B) ab (C) R (D) b

61. A composite rod consists of a steel rod of length 25 cm and area 2A and a copper rod of length 50cm and area A. The composite rod is subjected to an axial load F. If the Young's modulus of steel and copper are in the ratio 2 : 1.

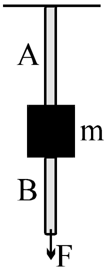
(A) the extension produced in copper rod will be more .

(B) the extension in copper and steel parts will be in the ratio 2 : 1.

(C) the stress applied to the copper rod will be more.

(D) no extension will be produced in the steel rod.

62. The wires A and B shown in the figure are made of the same material and have radii r_A and r_B respectively. The block between them has a mass m. When the force F is mg/3, one of the wires breaks.



(A) A breaks if $r_A = r_B$
(B) A breaks if $r_A < 2r_B$
(C) Either A or B may break if $r_A = 2r_B$
(D) The lengths of A and B must be known to predict which wire will break

63. A metal wire of length L area of cross-section A and Young's modulus Y is stretched by a variable force F such that F is always slightly greater than the elastic force of resistance in the wire. When the elongation of the wire is ℓ :

(A) the work done by F is $\frac{YA^2}{L}$

(B) the work done by F is $\frac{YA\ell^2}{2L}$

(C) the elastic potential energy stored in the wire is $\frac{YA\ell^2}{2L}$

(D) heat is produced during the elongation

64. Four rods A, B, C, D of same length and material but of different radii r, $r\sqrt{2}$, $r\sqrt{3}$ and 2r respectively are held between two rigid walls. The temperature of all rods is increased by same amount. If the rods donot bend, then
(A) the stress in the rods are in the ratio 1 : 2 : 3 : 4.
(B) the force on the rod exerted by the wall are in the ratio 1 : 2 : 3 : 4.
(C) the energy stored in the rods due to elasticity are in the ratio 1 : 2 : 3 : 4.
(D) the strains produced in the rods are in the ratio 1 : 2 : 3 : 4.

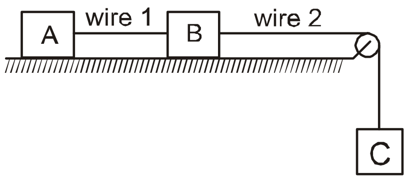
65. An experiment is perfomed to measure the specific heat of copper. A lump of copper is heated in an oven, then dropped into a beaker of water. To calculate the specific heat of copper, the experimenter must know or measure the value of all of the quantities below EXCEPT the
(A) heat capacity of water and beaker
(B) original temperature of the copper and the water
(C) final (equilibrium) temperature of the copper and the water
(D) time taken to achieve equilibrium after the copper is dropped into the water

66. When the temperature of a copper coin is raised by 80°C, its diameter increases by 0.2%.
(A) Percentage rise in the area of a face is 0.4 %
(B) Percentage rise in the thickness is 0.4 %
(C) Percentage rise in the volume is 0.6 %
(D) Coefficient of linear expansion of copper is 0.25×10^{-4} C°

PART - II : SUBJECTIVE QUESTIONS

1. Two exactly similar wires of steel and copper are stretched by equal force. If the difference in their elongation is 0.5 cm, find by how much each wire has elongated. (Given Young's modulus for steel = 2×10^{12} dyne cm^{-2} and for copper 12×10^{11} dyne cm^{-2}). The ratio of the elongation of copper wire to the elongation of steel wire in cm is $\frac{5}{x}$ then the value of x is :

2. Three blocks A, B and C each of mass 4 kg are attached as shown in figure. Both the wires has equal cross sectional area 5×10^{-7} m^2 . The surface is smooth. Find the ratio of longitudinal strain in the two wires if Young modulus of both the wires is 2×10^{11} N/m^2 (take g = 10 m/s^2)



3. A spherical ball contracts in volume by 0.001% when it is subjected to a pressure of 100 atmosphere. Its bulk modulus in atm is X × 10^7. Find the value of X

4. A substance of mass M = 1 kg requires a power input of P = 1watt to remain in the molten state at its melting point. When the power source is turned off, the sample completely solidifies in time t = 5 seconds. The latent heat of fusion of the substance in joule/kg is ....

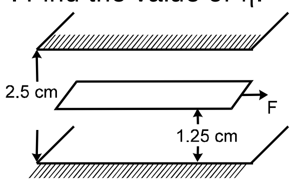
5. A solid sphere of radius R made of a material of bulk modulus K is surrounded by a liquid in a cylindrical container. A massless piston of area A floats on the surface of the liquid. When a mass M is placed on the pistonto compress the liquid, the fractional change in the radius of the sphere, $\delta R/R$ is $Mg/(\eta KA)$, then the find the value of η. ....

6. A metal rod of Young's modulus 2×10^{10} N m^{-2}, undergoes an elastic strain of 0.06%. The energy stored per unit volume is 600 X J/m^3. Find the value of X.

7. The bulk modulus of rubber is 9.8×10^8 N/m^2. When a rubber ball is taken at depth about 100 m in lake of water its volume is decreased by K × 10^{-1} %. Find the value of K. (Take g = 9.8 m/s^2)

8. The sum of lengths of an aluminium and a steel rod at 0°C is so that at all temperatures the difference in their lengths is 0.25m is 0.25 X. Find the value of X. (Take coefficient of linear expansion for aluminium and steel at 0°C as 22×10^{-6} / °C and 11×10^{-6} / °C respectively.)

9. A space 2.5 cm wide between two large plane surfaces is filled with oil. Force required to drag a very thin plate of area 0.5 m^2 just midway the surfaces at a speed of 0.5 m/sec is 1N. The coefficient of viscosity in kg–sec/m^2 is $5\eta \times 10^{-3}$. Find the value of η.

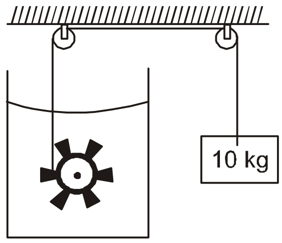


10. 1 kg steam at 200ºC = H + 1 kg water at 100ºC (S_{steam} = Constant = 0.5 Cal/gm°C)
In the above equation the value of H is (60 – X) × 10 k cal

11. The height from which a piece of ice (0°C) falls so that it melts completely is givenj as 130 + X km. Only one-quarter of the energy produced is absorbed by the ice as heat. (Latent heat of ice = 3.4×10^5 J kg^{-1}, g = 10 m/s^2) find the value of X.

12. A copper cube of mass 200g slides down on a rough inclined plane of inclination 37° at a constant speed. Assume that any loss in mechanical energy goes into the copper block as thermal energy. The increase in the temperature of the block as it slides down 60 cm is $\left(\frac{3}{7\times10X}\right)^{\circ}$. Find the value of X. (Specific heat capacity of

13. A paddle wheel is connected with a block of mass 10 kg as shown in figure. The wheel is completely immersed in liquid of heat capacity 4000 J/K. The container is adiabatic. For the time interval in which block goes down 1 m slowly, rise in the temperature of the liquid is $\left(\frac{1}{10X}\right)^{\circ}$ C. Find the value of X. (Neglect the heat capacity of the container and the paddle). ($g = 10\ m/s^2$)



14. The increase in energy of a brass bar of length 0.2 m and cross-sectional area 1 cm^2 when compressed with a load of 5 kg-weight along its length is $6x \times 10^{-6}$. Find the value of x.
(Young's modulus of brass = $1.0 \times 10^{11}\ N/m^2$ and $g = 9.8\ m/s^2$).

15. Two rods identical in geometry but of different materials having co-efficient of thermal expansion α_1 and α_2 and Young's modulii Y_1 and Y_2 respectively are fixed between two rigid massive walls. The rods are heated such that they undergo the same increase in temperature. There is no bending of the rods. If $\alpha_1 : \alpha_2 = 2 : 6$ the thermal stresses developed in the two rods are equal provided $Y_1 : Y_2$ is equal to :

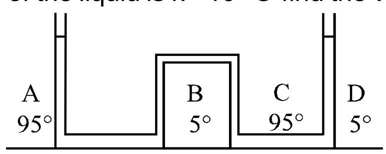
16. When the load on a wire increased slowly from 2 kg wt. to 4 kg wt., the elongation increases from 0.6 mm to 1.00 mm. The work done during the extension of the wire is $2x \times 10^{-3}$. Find the value of x. [$g = 9.8\ m/s^2$]

17. A spherical ball of radius 3.0×10^{-4} m and density $10^4\ kg/m^3$ falls freely under gravity through a distance h before entering a tank of water. If after entering the water the velocity of the ball does not change, the value of h. comes to be $2x^2$. Find the value of x. (Viscosity of water is 9.8×10^{-6} N-s/m^2). [$g = 10\ m/s^2$]

18. The time represented by the clock hands of a pendulum clock depends on the number of oscillations performed by pendulum. Every time it reaches to its extreme position the second hand of the clock advances by one second that means second hand moves by two second when one oscillation is completed. The number of oscillations completed by a pendulum of clock in 15 minutes at temperature of 40ºC if $\alpha = 2 \times 10^{-5}$ /ºC is 450 – x. Find the value of x :

19. In the above question time represented by the pendulum clock at 40ºC after 15 minutes if the initial time shown by the clock is 12 : 00 pm is 12 hr 14 min 60 – x sec. Find the value of x :

20. The apparatus shown in the figure consists of four glass columns connected by horizontal sections. The height of two central columns B & C are 49 cm each. The two outer columns A & D are open to the atmosphere. A & C are maintained at a temperature of 95° C while the columns B & D are maintained at 5° C. The height of the liquid in A & D measured from the base line are 52.8 cm & 51 cm respectively. the coefficient of thermal expansion of the liquid is $k\times 10^{-4}C^{-}$find the value of k = 2.



21. 20 gm ice at –10 ºC is mixed with m gm steam at 100 ºC. The minimum value of m so that finally all ice and steam converts into water is $\frac{85}{8x}$ gm. Find the value of x : (Use s_{ice}=0.5 cal/gmºC,s_{water}=1 cal/gmºC,L (melting) = 80 cal/gm and L (vaporization)=540 cal/gm)

22. A simple seconds pendulum is constructed out of a very thin string of thermal coefficient of linear expansion $\alpha = 20 \times 10^{-4}$ / °C and a heavy particle attached to one end. The free end of the string is suspended from the ceiling of an elevator at rest. The pendulum keeps correct time at 0°C. When the temperature rises to 50°C, the elevator operator of mass 60kg being a student of Physics accelerates the elevator vertically, to have the pendulum correct time. The apparent weight of the operator when the pendulum keeps correct time at 50 °C. (Take g = 10 m/s^2) is 110x. Find the value of x :

23. A metal piece weighing 15g is heated to 100ºC and then immersed in a mixture of ice and water at the thermal equilibrium. The volume of the mixture is found to be reduced by 0.15 cm^3 with the temperature of mixture remaining constant. The specific heat of the metal is 23x × 10^{-3} cal/gmºC. (given specific gravity of ice = 0.92, latent heat of fusion of ice = 80 cal/gm). Find the value of x :

24. A steel tape is correctly calibrated at 20 °C and is used to measure the length of a table at 30 °C. The percentage error in the measurement of length is (10+ x)10^{-3} [α_{steel}= 11 × 10^{-6}/ °C]. Find the value of x :

25. In a container of negligible heat capacity, 200 gm ice at 0°C and 100 gm steam at 100°C are added to 200 gm of water that has temperature 55°C. Assume no heat is lost to the surroundings and the pressure in the container is constant 1.0 atm. (Latent heat of fusion of ice = 80 cal/gm, Latent heat of vaporization of water = 540 cal/gm, Specific heat capacity of ice = 0.5 cal/gm-K, Specific heat capacity of water = 1 cal/gm-K) The final temperature of the system is (100 + x)ºC

26. In the above question the amount of the steam left in the system, is $\frac{100}{x}$ gm. Find the value of x :

27. 300 g of water at 25ºC is added to 100 g of ice at 0ºC. The final temperature of the mixture is in ºC.

EXERCISE # 3

PART-I IIT-JEE (PREVIOUS YEARS PROBLEMS)

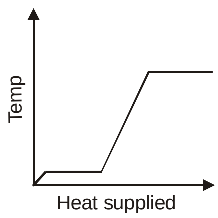
***Marked Questions are having more than one correct option.**

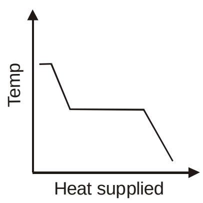
THERMAL EXPANSION & CALORIMETRY

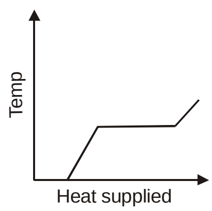
1*. A bimetallic strip is formed out of two identical strips, one of copper and the other of brass. The coefficients of linear expansion of the two metals are α_C and α_B .On heating, the temperature of the strips goes up by ΔT and the strip bends to form an arc of radius of curvature R. Then R is: **[JEE 1999, 2/200]**

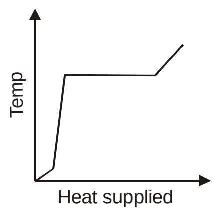
(A) Proportional to ΔT
(B) inversely proportional to ΔT
(C) proportional to $|\alpha_B - \alpha_C|$
(D) inversely proportional to $|\alpha_B - \alpha_C|$

2. A block of ice at -10ºC is slowly heated and converted to steam at 100ºC. Which of the following curves represents the phenomena qualitatively: **[JEE 2000, 1/35]**

(A) 

(B) 

(C) 

(D) 

3. When a block of iron floats in mercury at 0°C a fraction k_1 of its volume is submerged, while at the temperature 60ºC, a fraction k_2 is seen to be submerged. If the coefficient of volume expansion of iron is γ_{Fe} and that of mercury is γ_{Hg}, then the ratio $\frac{k_1}{k_2}$ can be expressed as: **[JEE '2001 (Scr.), 1/35]**

(A) $\frac{1+60\gamma_{Fe}}{1+60\gamma_{Hg}}$
(B) $\frac{1-60\gamma_{Fe}}{1+60\gamma_{Hg}}$
(C) $\frac{1+60\gamma_{Fe}}{1-60\gamma_{Hg}}$
(D) $\frac{1+60\gamma_{Hg}}{1+60\gamma_{Fe}}$

4. An ice cube of mass 0.1 kg at 0°C is placed in an isolated container which is at 227°C. The specific heat S of the container varies with temperature T according to the empirical relation S = A + BT, where A = 100 cal/kg-K and B = 2 x 10^{-2} cal/kg-K^2 . If the final temperature of the container is 27°C, Determine the mass of the container. (Latent heat of fusion of water = 8 x 10^4 cal/kg, sp. heat of water = 10^3 cal/kg-K). **[JEE '2002 (Scr.)]**

5. Two rods, one of aluminium and the other made of steel, having initial length ℓ_1 and ℓ_2 are connected together to form a single rod of length $\ell_1 + \ell_2$. The coefficients of linear expansion for aluminium and steel are α_a and α_s respectively. If the length of each rod increases by the same amount when their temperature are raised by t°C, then find the ratio $\frac{\ell_1}{(\ell_1 + \ell_2)}$. **[JEE-2003 (Scr.), 3/84,–1]**

(A) $\frac{\alpha_s}{\alpha_a}$ (B) $\frac{\alpha_a}{\alpha_s}$ (C) $\frac{\alpha_s}{(\alpha_a + \alpha_s)}$ (D) $\frac{\alpha_a}{(\alpha_a + \alpha_s)}$

6. 2 kg ice at – 20 ºC is mixed with 5 kg water at 20 ºC . Then final amount of water in the mixture will be : [Specific heat of ice = 0.5 cal/gm ºC, Specific heat of water = 1 cal/gm ºC, Latent heat of fusion of ice = 80 cal/gm] **[JEE-2003 (Scr.), 3/84,–1]**

(A) 6 kg (B) 7 kg (C) 3.5 kg (D) 5 kg

7. A cube of coefficient of linear expansion α_s is floating in a bath containing a liquid of coefficient of volume expansion γ_L . When the temperature is raised by ΔT, the depth upto which the cube is submerged in the liquid remains the same. Find the relation between α_s and γ_L showing all the steps.

[JEE-2004 (Mains), 2/60]

8. 2 liters water at 27°C is heated by a 1 kW heater in an open container. On an average heat is lost to surroundings at the rate 160 J/s. The time required for the temperature to reach 77°C is

[JEE-2005 (Scr.), 3/84, –1]

(A) 8 min 20 sec (B) 10 min (C) 7 min (D) 14 min

9. In an insulated vessel, 0.05 kg steam at 373 K and 0.45 kg of ice at 253 K are mixed. Find the final temperature of the mixture (in Kelvin). **[JEE 2006, 6/184, –1] [conducted by IIT Kharagpur]**

Given, L_{fusion} = 80 cal/gm = 336 J/gm, $L_{vaporization}$ = 540 cal/gm = 2268 J/gm,

S_{ice} = 2100 J/kg K = 0.5 cal/gm K and S_{water} = 4200 J/kg K = 1 cal/gmK

10. A piece of ice (heat capacity = 2100 J kg^{-1} ºC^{-1} and latent heat = 3.36×10^5 J kg^{-1}) of mass m grams is at –5 ºC at atmospheric pressure. It is given 420 J of heat so that the ice starts melting. Finally when the ice-water mixture is in equilibrium, it is found that 1 gm of ice has melted. Assuming there is no other heat exchange in the process, the value of m is : **[JEE 2010, 3/163] [conducted by IIT Madras]**

ELASTICITY & VISCOSITY

11. A thin rod of negligible mass and area of cross-section 4×10^{-6} m^2, suspended vertically from one end has a length of 0.5 m at 10°C. The rod is cooled at 0°C, but prevented from contracting by attaching a mass at the lower end. Find **[JEE - 97 – 5]**

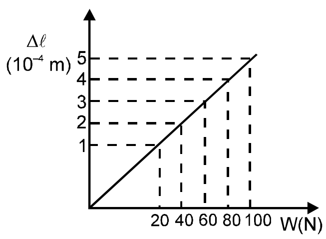
(i) This mass and

(ii) The energy stored in the rod.

Given for this rod, Y = 10^{11} Nm^{-2}, coefficient of linear expansion = 10^{-5} K^{-1} and g = 10ms^{-2}.

12. A 1m long metal wire of cross sectional area 10^{-6} m^2 is fixed at one end from a rigid support and a weight W is hanging at its other end. The graph shows the observed extension of length $\Delta\ell$ of the wire as a function of W. Young's modulus of material of the wire in SI units is

[JEE (Scr.), 2003, 3/84, –1]



(A) 5×10^4 (B) 2×10^5 (C) 2×10^{11} (D) 5×10^{11}

13. A small sphere falls from rest in a viscous liquid. Due to friction, heat is produced. Find the relation between the rate of production of heat and the radius of the sphere at terminal velocity. **[JEE 2004, 2/60]**

14. A 0.1 kg mass is suspended from a wire of negligible mass. The length of the wire is 1m and its cross-sectional area is 4.9×10^{-7} m^2. If the mass is pulled a little in the vertically downward direction and released, it performs simple harmonic motion of angular frequency 140 rad s^{-1}. If the Young's modulus of the material of the wire is n × 10^9 Nm^{-2}, the value of n is : **[JEE 2010, 3/252] [conducted by IIT Madras]**

15. A tiny spherical oil drop carrying a net charge q is balanced in still air with a vertical uniform electric field of strength $\frac{81\pi}{7} \times 10^5$ Vm^{-1}. When the field is switched off, the drop is observed to fall with terminal velocity 2×10^{-3} m s^{-1}. Given g = 9.8 m s^{-2}, viscosity of the air = 1.8×10^{-5} Ns m^{-2} and the density of oil = 900 kg m^{-3}, the magnitude of q is : **[JEE 2010, 5/237, –2] [conducted by IIT Madras]**

(A) 1.6×10^{-19} C (B) 3.2×10^{-19} C (C) 4.8×10^{-19} C (D) 8.0×10^{-19} C

16. Steel wire of length 'L' at 40°C is suspended from the ceiling and then a mass 'm' is hung from its free end. The wire is cooled down from 40°C to 30°C to regain its original length 'L'. The coefficient of linear thermal expansion of the steel is 10^{-5}/°C, Young's modulus of steel is 10^{11} N/m^2 and radius of the wire is 1 mm. Assume that L >> diameter of the wire. Then the value of 'm' in kg is nearly

[JEE 2011, 4/160] [conducted by IIT Kanpur]

PART-II AIEEE (PREVIOUS YEARS PROBLEMS)

1. Heat given to a body which raises its temperature by 1°C is : **[AIEEE 2002, 3/300]**

(1) water equivalent (2) thermal capacity
(3) specific heat (4) temperature gradient

2. If mass – energy equivalence is taken into account, when water is cooled to form ice, the mass of water should: **[AIEEE 2002, 3/300]**

(1) increase (2) remain unchanged
(3) decrease (4) first increase then decrease

3. The length of a simple pendulum executing simple harmonic motion is increased by 21%. The percentage increase in the time period of the pendulum of increased length is : **[AIEEE 2003, 3/300]**

(1) 11% (2) 21% (3) 42% (4) 10.5%

4. Time taken by a 836 W heater to heat one liter of water from 10ºC to 40ºC is : **[AIEEE 2004, 3/300]**

(1) 50 s (2) 100 s (3) 150 s (4) 200 s

5. 100 g of water is heated from 30° C to 50° C. Ignoring the slight expansion of the water, the change in its internal energy is (specific heat of water is 4148 J/kg/K) : **[AIEEE 2011, 4/120]**

(1) 4.2 kJ (2) 8.4 kJ (3) 84 kJ (4) 2.1 kJ

6. A wire suspended vertically from one of its ends is stretched by attaching a weight of 200 N to the lower end. The weight stretches the wire by 1 mm. The elastic energy stored in the wire is : **[AIEEE 2003, 4/300]**

(1) 0.2 J (2) 10 J (3) 20 J (4) 0.1 J

7. Spherical balls of radius R are falling in a viscous fluid of viscosity η with a velocity v. The retarding viscous force acting on the spherical ball is : **[AIEEE 2004, 4/300]**

(1) directly proportional to R but inversely proportional to v
(2) directly proportional to both radius R and velocity v
(3) inversely proportional to both radius R and velocity v
(4) inversely proportional to R but directly proportional to v

8. If 'S' is stress and 'Y' is Young's modulus of material of a wire, the energy stored in the wire per unit volume is : **[AIEEE-2005, 4/300]**

(1) $2S^2Y$ (2) $\frac{S^2}{2Y}$ (3) $\frac{2Y}{S^2}$ (4) $\frac{S}{2Y}$

9. If the terminal speed of a sphere of gold (density = 19.5 kg/m³) is 0.2 m/s in a viscous liquid then find the terminal speed of sphere of silver (density = 10.5 kg/m³) of the same size in the same liquid (density = 1.5 kg/m³). **[AIEEE 2006, 4½/180]**

(1) 0.4 m/s (2) 0.133 m/s (3) 0.1 m/s (4) 0.2 m/s

10. A wire elongates by ℓ mm when a load W is hanged from it. If the wire goes over a pulley and two weights W each are hung at the two ends, the elongation of the wire will be (in mm) **[AIEEE 2006, 4½/180]**

(1) ℓ (2) 2ℓ (3) zero शून्य (4) $\ell/2$

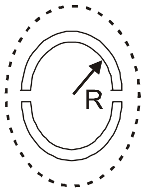
11. A spherical solid ball of volume V is made of a material of density ρ_1. It is falling through a liquid of density ρ_2 $(\rho_2 < \rho_1)$. Assume that the liquid applies a viscous force on the ball that is proportional to the square of its speed υ, i.e., $F_{viscous} = -k\rho^2$ $(k > 0)$. The terminal speed of the ball is **[AIEEE-2008, 3/105]**

(1) $\frac{Vg\rho_1}{k}$ (2) $\sqrt{\frac{Vg\rho_1}{k}}$ (3) $\frac{Vg(\rho_1 - \rho_2)}{k}$ (4) $\sqrt{\frac{Vg(\rho_1 - \rho_2)}{k}}$

12. Two wires are made of the same material and have the same volume. However wire 1 has cross-sectional area A and wire 2 has cross-sectional area 3A. If the length of wire 1 increases by Δx on applying force F, how much force is needed to stretch wire 2 by the same amount? **[AIEEE-2009, 4/144]**

(1) 4F (2) 6F (3) 9F (4) F

13. A wooden wheel of radius R is made of two semicircular parts (see figure). The two parts are held together by a ring made of a metal strip of cross sectional area S and length L. L is slightly less than $2\pi R$. To fit the ring on the wheel, it is heated so that its temperature rises by ΔT and it just steps over the wheel. As it cools down to surrounding temperature, it presses the semicircular parts together. If the cofficient of linear expansion of the metal is a, and its Young's modulus is Y, the force that one part of the wheel applies on the other part is : **[AIEEE-2012, 4/120]**



(1) $2SY\alpha\Delta T$ (2) $2\pi SY\alpha\Delta T$ (3) $SY\alpha\Delta T$ (4) $\pi SY\alpha\Delta T$

ANSWERS

Exercise # 1

PART-I

1.1	(B)	**1.2**	(C)	**1.3**	(A)	**1.4**	(A)	**1.5**	(C)	**1.6**	(C)	**1.7**	(A)
1.8	(A)	**2.1**	(D)	**2.2**	(ABC)	**2.3**	(AB)	**2.4**	(C)	**2.5**	(D)	**3.1**	(A)
3.2	(A)	**3.3**	(B)	**3.4**	(C)	**3.5**	(A)	**3.6**	(C)	**3.7**	(B)	**3.8**	(C)
3.9	(C)	**3.10**	(C)	**3.11**	(D)	**3.12**	(C)	**3.13**	(D)	**3.14**	(A)	**3.15**	(D)
3.16	(C)	**3.17**	(D)	**3.18**	(D)	**3.19**	(C)	**3.20**	(B)	**3.21**	(D)	**3.22**	(C)
3.22	(B)	**4.1**	**(i)**	(C)	**(ii)**	(D)	**4.2**	(C)	**4.3**	(C)	**4.4**	(D)	
4.5	(B)	**4.6**	(B)	**5.1**	(B)	**5.2**	(C)	**5.3**	(D)	**5.4**	(A)	**5.5**	(B)
5.6	(ABC)	**5.7**	(ABD)	**6.1**	(C)	**6.2**	(A)	**6.3**	(A)	**6.4**	(C)	**6.5**	(D)
6.6	(B)	**6.7**	(B)										

PART-II

1.	(C)	**2.**	(A)	**3.**	(B)	**4.**	(B)	**5.**	(D)	**6.**	(B)	**7.**	(A)
8.	(C)	**9.**	(A)	**10.**	(B)	**11.**	(B)	**12.**	(C)	**13.**	(D)	**14.**	(B)
15.	(B)	**16.**	(C)	**17.**	(C)	**18.**	(A)	**19.**	(B)				

20. (A) – R, T (B) R, T (C)- S (D)- P,Q

21. (A) – (p) ; (B) – (r) ; (C) – (s) ; (D) – (q)

22. (A) p (B) q ; (C) r ; (D) q

Exercise # 2

PART-I

1.	(C)	**2.**	(D)	**3.**	(A)	**4.**	(D)	**5.**	(C)	**6.**	(B)	**7.**	(B)
8.	(D)	**9.**	(D)	**10.**	(A)	**11.**	(C)	**12.**	(B)	**13.**	(D)	**14.**	(B)

15.	(D)	**16.**	(A)	**17.**	(C)	**18.**	(A)	**19.**	(B)	**20.**	(D)	**21.**	(A)
22.	(D)	**23.**	(A)	**24.**	(A)	**25.**	(C)	**26.**	(B)	**27.**	(D)	**28.**	(A)
29.	(B)	**30.**	(A)	**31.**	(C)	**32.**	(D)	**33.**	(C)	**34.**	(A)	**35.**	(C)
36.	(B)	**37.**	(C)	**38.**	(B)	**39.**	(B)	**40.**	(A)	**41.**	(B)	**42.**	(C)
43.	(C)	**44.**	(A)	**45.**	(B)	**46.**	(A)	**47.**	(C)	**48.**	(D)	**49.**	(D)
50.	(B)	**51.**	(C)	**52.**	(C)	**53.**	(C)	**54.**	(C)	**55.**	(A)	**56.**	(C)
57.	(A)	**58.**	(B)	**59.**	(BCD)	**60.**	(ABCD)	**61.**	(A C)	**62.**	(ABC)	**63.**	(BC)
64.	(BC)	**65.**	(ACD)	**66.**	(ACD)								

PART-II

1.	3	**2.**	2	**3.**	1	**4.**	5	**5.**	3	**6.**	6	**7.**	1
8.	3	**9.**	5	**10.**	1	**11.**	6	**12.**	5	**13.**	4	**14.**	4
15.	3	**16.**	7	**17.**	9	**18.**	1	**19.**	**1**	**20.**	2	**21.**	4
22.	6	**23.**	4	**24.**	1	**25.**	0	**26.**	**6**	**27.**	0		

Exercise # 3

PART- I IIT- JEE

1.	(B, D)	**2.**	(A)	**3.**	(A)	**4.**	$\frac{107}{216}$ kg @ 0.5 kg	**5.**	(C)
6.	(A)	**7.**	$g_L = 2a_s$.	**8.**	(A)	**9.**	273 K.	**10.**	8 gm
11.	(i) 4.0kg (ii) 0.001 J			**12.**	(C)	**13.**	$\frac{dQ}{dt} \propto r^5$	**14.**	**4**
15.	**(D)**	**16.**	3						

PART-II AIEEE

1.	(2)	**2.**	(1)	**3.**	(4)	**4.**	(3)	**5.**	(B)	**6.**	(4)	**7.**	(2)
8.	(2)	**9.**	(3)	**10.**	(1)	**11.**	(4)	**12.**	(3)	**13.**	(1)		