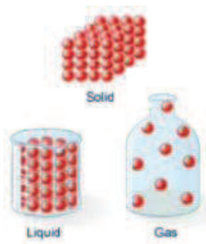


Unit - 7

Properties Of Matter

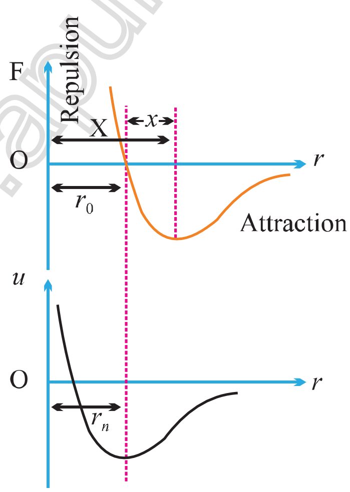
7.1 Interatomic Forces

The forces between the atoms due to electrostatic interaction between the charges of the atoms are called interatomic forces.

(1) When two atoms are brought close to each other to a distance of the order of 10^{-10} *m,* attractive interatomic force is produced between two atoms.

(2) This attractive force increases continuously with decrease in r and becomes maximum for one value of r called critical distance, represented by x (as shown in the figure).

(3) When the distance between the two atoms becomes r_0, the interatomic force will be zero. This distance r_0 is called normal or equilibrium distance.



(4) When the distance between the two atoms further decreased, the interatomic force becomes repulsive in nature and increases very rapidly.

(5) The potential energy U is related with the interatomic force F by the following relation.

$$F = \frac{-dU}{dr}$$

When the distance between the two atoms becomes r_0, the potential energy of the system of two atoms becomes minimum (*i.e.,* attains maximum negative value hence the two atoms at separation r_0 will be in a state of equilibrium.

7.2 Intermolecular Forces

The forces between the molecules due to electrostatic interaction between the charges of the molecules are called intermolecular forces. These forces are also called Vander Waal forces and are quite weak as compared to inter-atomic forces.

7.3 Solids

A solid is that state of matter in which its constituent atoms or molecules are held strongly at the position of minimum potential energy and it has a definite shape and volume.

7.4 Elastic Property of Matter

(1) Elasticity : The property of matter by virtue of which a body tends to regain its original shape and size after the removal of deforming force is called elasticity.

(2) Plasticity : The property of matter by virtue of which it does not regain its original shape and size after the removal of deforming force is called plasticity.

(3) Perfectly elastic body : If on the removal of deforming forces the body regain its original configuration completely it is said to be perfectly elastic.

A quartz fibre and phosphor is the nearest approach to the perfectly elastic body.

(4) Perfectly plastic body : If the body does not have any tendency to recover its original configuration on the removal of deforming force, it is said to be perfectly plastic.

Paraffin wax, wet clay are the nearest approch to the perfectly plastic body. Practically there is no material which is either perfectly elastic or perfectly plastic.

(5) Reason of elasticity : On applying the deforming forces, restoring forces are developed.When the deforming force is removed, these restoring forces bring the molecules of the solid to their respective equilibrium position ($r = r_0$) and hence the body regains its original form.

(6) Elastic limit : The maximum deforming force upto which a body retains its property of elasticity is called elastic limit of the material of body.

Elastic limit is the property of a body whereas elasticity is the property of material of the body.

(7) Elastic fatigue : The temporary loss of elastic properties because of the action of repeated alternating deforming force is called elastic fatigue.

It is due to this reason :

(i) Bridges are declared unsafe after a long time of their use.

(ii) Spring balances show wrong readings after they have been used for a long time.

(iii) We are able to break the wire by repeated bending.

(8) Ealstic after effect : The time delay in which the substance regains its original condition after the removal of deforming force is called elastic after effect. It is negligible for perfectly elastic substance, like quartz, phosphor bronze and large for glass fibre.

7.5 Stress

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

$$\text{Stress} = \frac{\text{Force}}{\text{Area}} = \frac{F}{A}$$

Unit : N/m^2 (S.I.), $dyne/cm^2$ (C.G.S.)

Stress developed in a body depends upon how the external forces are applied over it.

On this basis there are two types of stresses : Normal and Shear or tangential stress

(1) Normal stress : Here the force is applied normal to the surface.

It is again of two types : Longitudinal and Bulk or volume stress.

(i) Longitudinal stress

(a) Deforming force is applied parallel to the length and causes increase in length.

(b) Area taken for calculation of stress is area of cross section.

(c) Longitudinal stress produced due to increase in length of a body under a deforming force is called tensile stress.

(d) Longitudinal stress produced due to decrease in length of a body under a deforming force is called compressional stress.

(ii) Bulk or Volume stress

(a) It occurs in solids, liquids or gases.

(b) Deforming force is applied normal to surface at all points.

(c) It is equal to change in pressure because change in pressure is responsible for change in volume.

(2) Shear or tangential stress : It comes in picture when successive layers of solid move on each other *i.e.,* when there is a relative displacement between various layers of solid.

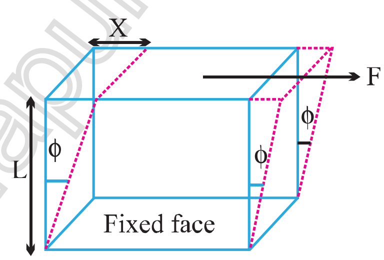
(i) Here deforming force is applied tangential to one of the faces.

(ii) Area for calculation is the area of the face on which force is applied.

(iii) It produces change in shape, volume remaining the same.

7.6 Strain

The ratio of change in configuration to the original configuration is called strain. It has no dimensions and units. Strain are of three types :



(1) Linear strain : Linear strain $= \dfrac{\text{Change in length}}{\text{Original length}} = \dfrac{l}{L}$

Linear strain in the direction of deforming force is called longitudinal strain and in a direction perpendicular to force is called lateral strain.

(2) Volumetric strain : Volumetric strain $= \dfrac{\text{Change in volume } (\Delta V)}{\text{Original volume} (V)}$

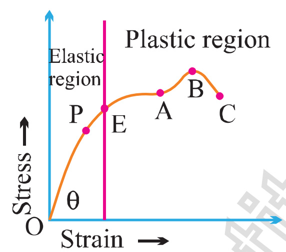
(3) Shearing strain : It is defined as angle in radians through which a plane perpendicular to the fixed surface of the cubical body gets turned under the effect of tangential force.

$$\phi = \frac{x}{L}$$

- When a beam is bent both compression strain as well as an extension strain is produced.

7.7 Stress-strain Curve

(1) When the strain is small (region OP) stress is proportional to strain. This is the region where the so called Hooke's law is obeyed. The point P is called limit of proportionality and slope of line OP gives the Young's modulus Y of the material of the wire. Y = tan θ.

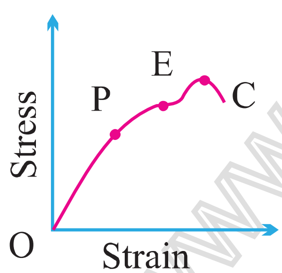
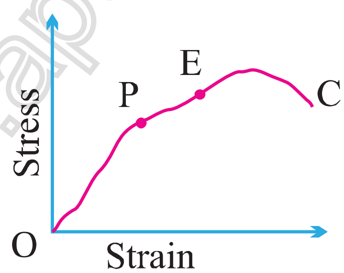
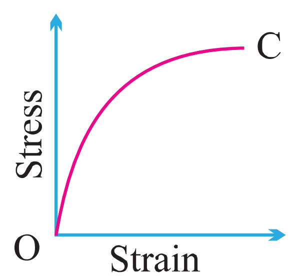


(2) Point E known as elastic limit or yield-point.

(3) Between EA, the strain increases much more.

(4) The region EABC represents the plastic behaviour of the material of wire.

(5) Stress-strain curve for different materials, are shown in following figure.

Brittle material	Ductile material	Elastomers
		
The plastic region between E and C is small for brittle material and it will break soon after the elastic limit is crossed.	The material on this type have a good plastic range and such materials can be easily changed into different shapes and can be drawn into thin wires.	For ealstomers the strain produced is much larger than the stress applied. Such materials have no plastic range and the breaking point lies very close to elastic limit. Example : rubber.

7.8 Hooke's law and Modulus of Elasticity

According to this law, within the elastic limit, stress is proportional to the strain.

i.e., stress α strain or $\alpha = \frac{\text{stress}}{\text{strain}}$ = constant = E

The constant E is called modulus of elasticity.

(1) It's value depends upon the nature of material of the body and the manner in which the body is deformed.

(2) It's value depends upon the temperature of the body.

(3) It's value is independent of the dimensions of the body.

There are three modulii of elasticity namely Young's modulus (Y), Bulk modulus (K) and modulus of rigidity (η) corresponding to three types of the strain.

7.9 Young's Modulus (Y)

It is defined as the ratio of normal stress to longitudinal strain within limit of proportionality.

$$Y = \frac{\text{Normal stress}}{\text{Longitudinal strain}} = \frac{F/A}{l\,F} = \frac{FL}{A\,l}$$

Thermal stress : If a rod is fixed between two rigid supports, due to change in temperature its length will change and so it will exert a normal stress. This stress is called thermal stress. Thermal stress = Y α $\Delta\theta$. Force produced in the body = YA $\alpha\Delta\theta$.

7.10 Work Done in Stretching a Wire

In stretching a wire work is done against internal restoring forces. This work is stored in the wire as elastic potential energy or strain energy.

$\therefore$ Energy stroed in wire $U = \frac{1}{2}\frac{YAl^2}{L} = \frac{1}{2}Fl$ (l = change in length)

Energy stored in per unit volume of wire

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

7.11 Breaking of Wire

When the wire is loaded beyond the elastic limit, then strain increases much more rapidly. The maximum stress corresponding to B (see stress-strain curve) after which the wire begin to flow and breaks, is called breaking stress or tensile strength and the force by application of which the wire breaks is called the breaking force.

(i) Breaking force depends upon the area of cross-section of the wire.

(ii) Breaking stress is a constant for a given material.

(iii) Breaking force is independent of the length of wire.

(iv) Breaking force α πr^2.

(v) Length of wire if it breaks by its own weight

$$L = \frac{P}{dg}$$

7.12 Bulk Modulus

The ratio of normal stress to the volumetric strain within the elastic limits is called as Bulk modulus.

This is denoted by K.

$$K = \frac{\text{Normal stress}}{\text{Volumetric strain}};$$

$$K = \frac{F/A}{-\Delta V/V} = \frac{-pV}{\Delta V}$$

where p = increase in pressure; V = original volume; ΔV = change in volume

The reciprocal of bulk modulus is called compressibility

$$C = \text{compressibility} = \frac{1}{K} = \frac{\Delta V}{pV}$$

S.I. unit of compressibility is $N^{-1}m^2$ and C.G.S. unit is $\text{dyne}^{-1}\ \text{cm}^2$.

Gases have two bulk modulii, namely isothermal elasticity E_θ and adiabatic elasticity E_ϕ.

7.13 Modulus of Rigidity

Within limits of proportionality, the ratio of tangential stress to the shearing strain is called modulus of rigidity of the material of the body and is denoted by η, *i.e.,*

$$\eta = \frac{\text{Shear Stress}}{\text{Shear strain}} = \frac{F/A}{\phi} = \frac{F}{A\phi}$$

Only solids can exhibit a shearing as these have definite shape.

7.14 Poisson's Ratio

Lateral strain : The ratio of change in radius to the original radius is called lateral strain.

Longitudinal strain : The ratio of change in length to the original length is called longitudinal strain. The ratio of lateral strain to longitudinal strain is called Poisson's ratio (σ).

i.e.,

$$\sigma = \frac{\text{Lateral strain}}{\text{Longitudinal strain}}$$

7.15 Factors Affecting Elasticity

(1) Hammering and rolling : This result is increase in the elaticity of material.

(2) Annealing : Annealing results is decrease in the ealsticity of material.

(3) Temperature : Elasticity decreases with rise in temperature but the elasticity of invar steel (alloy) does not change with change of temperature.

(4) Impurities : The type of effect depends upon the nature of impurities present in the material.

7.16 Practical Applications of Elasticity

(i) The thickness of the metallic rope used in the crane is decided from the knowledge of elasticity.

(ii) Maximum height of a mountain on earth can be estimated.

(iii) A hollow shaft is stronger than a solid shaft made of same mass, length and material.

7.17 Intermolecular Force

The force of attraction or repulsion acting between the molecules are known as intermolecular force. The nature of intermolecular force is electromagnetic.

The intermolecular forces of attraction may be classified into two types.

Cohessive force	Adhesive force
The force of attraction between molecules of same substance is called the force of cohesion. This force is lesser in liquids and least in gases.	The force of attraction between the molecules of the different substances is called the force of adhesion.

7.18 Surface Tension

The property of a liquid due to which its free surface tries to have minimum surface area is called surface tension. A small liquid drop has spherical shape due to surface tension. Surface tension of a liquid is measured by the force acting per unit length on either side of an imaginary line drawn on the free surface of liquid, then T = (F/L).

(1) It depends only on the nature of liquid and is independent of the area of surface or length of line considered.

(2) It is a scalar as it has a unique direction which is not to be specified.

(3) Dimension : $[MT^{-2}]$. (Similar to force constant)

(4) Units : N/m (S.I.) and Dyne/cm [C.G.S.]

7.19 Factors Affecting Surface Tension

(1) Temperature : The surface tension of liquid decreases with rise of temperature

$$T_t = T_0 (1 - \alpha t)$$

where T_t, T_0 are the surface tensions at t^0C and 0^0C respectively and α is the temperature coefficient of surface tension.

(2) Impurities : A highly soluble substance like sodium chloride when dissolved in water, increases the surface tension of water. But the springly soluble substances like phenol when dissolved in water, decreases the surface tension of water.

7.20 Surface Energy

The potential energy of surface molecules per unit area of the surface is called surface energy.

Unit : Joule/m^2 (S.I.) erg/cm^2 (C.G.S.)

Dimension : $[MT^{-2}]$

$\therefore$ W = T × ΔA [ΔA = Total increases in area of the film from both the sides] *i.e.,* surface tension may be defined as the amount of work done in increasing the area of the liquid surface by unity against the force of surface tension at constant temperature.

7.21 Splitting of Bigger Drop

When a drop of radius R splits into n smaller drops, (each of radius r) then surface area of liquid increases.

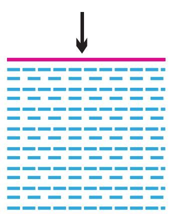
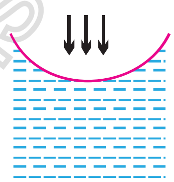
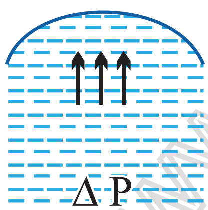
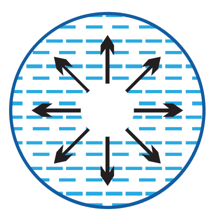
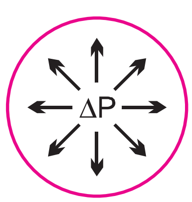
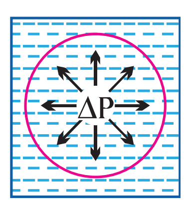
$$R^3 = nr^3$$

$$\text{Work done} = T \times \Delta A = T\,[\text{Total final surface area of } n \text{ drops}$$

$$- \text{surface area of big drop}] = T[n\pi r^2 - 4\pi R^2].$$

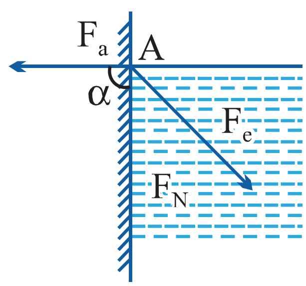
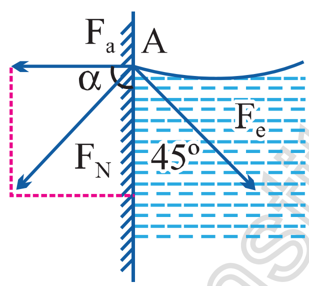
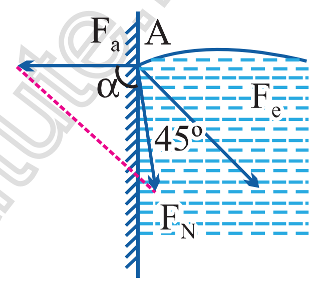
7.22 Excess Pressure

Excess pressure in different cases is given in the following table :

Plane surface	**Concave surface**
$\Delta P = o$  $\Delta P = o$	ΔP  $\Delta P = \frac{2T}{R}$
Convex surface	**Drop**
 $\Delta P = \frac{2T}{R}$	 $\Delta P = \frac{2T}{R}$
Bubble air	**Bubble in liquid**
 $\Delta P = \frac{4T}{R}$	 $\Delta P = \frac{2T}{R}$

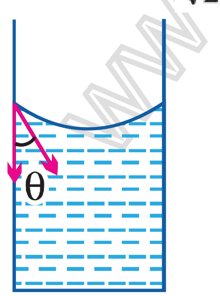
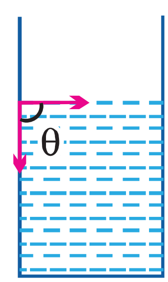
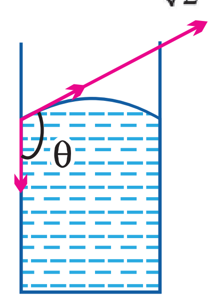
7.23 Shape of Liquid Meniscus

The curved surface of the liquid is called meniscus of the liquid.

If $F_c = \sqrt{2F_a}$	$F_c < \sqrt{2F_a}$	$F_c > \sqrt{2F_a}$
$\tan\alpha = \infty \therefore \alpha = 90^o$ *i.e.,* the resultant force acts vertically downwards. Hence the liquid meniscus must be horizontal.	$\tan a$ = positive $\therefore \alpha$ is acute angle *i.e.,* the resultant force directed outside the liquid. Hence the liquid meniscus must be concave upward.	$\tan\alpha$ = negative $\therefore \alpha$ is obtuse angle *i.e.,* the resultant force directed inside the liquid. Hence the liquid meniscus must be convex upward.
		
Example : Pure water in silver coated capillary tube.	**Example :** Water in glass capillary tube.	**Example :** Mercury in glass capillary tube.

7.24 Angle of Contact

Angle of contact between a liquid and a solid is defined as the angle enclosed between the tangents to the liquid surface and the solid surface inside the liquid, both the tangents being drawn at the point of contact of the liquid with the solid.

$\theta < 90^o; F_a > \frac{F}{\sqrt{2}}$	$\theta < 90^o; F_a > \frac{F}{\sqrt{2}}$	$\theta < 90^o; F_a > \frac{F}{\sqrt{2}}$
		
concave meniscus. Liquid wets the solid surface.	plane meniscus. Liquid does not wet the solid surface.	convex meniscus, wet the solid surface.

(i) Its value lies between 0º and 180º.

$\theta = 0^\circ$ for pure water and glass, $\theta = 90^\circ$ for water and silver.

(ii) On increasing the temperature, angle of contact decreases.

(iii) Soluble impurities increases the angle of contact.

(iv) Partially soluble impurities decreases the angle of contact.

7.25 Capillarity

If a tube of very narrow bore (called capillary) is dipped in a liquid, it is found that the liquid in the capillary either ascends or descends relative to the surrounding liquid. This phenomenon is called capillarity.

The cause of capillarity is the difference in pressures on two sides curved surface of liquid.

7.26 Ascent Formula

When one end of capillary tube of radius r is immersed into a liquid of density d which wets the sides of the capillary and R = radius of curvature of liquid meniscus.

T = surface tension of liquid

P = atmospheric pressure

$$\therefore \qquad h = \frac{2T\cos\theta}{rdg}$$

Important points

(i) The capillary rise depends on the nature of liquid and solid both *i.e.,* on T. d, θ and R.

(ii) Capillary action for various liquid-solid pair.

Meniscus	Angle of contact	Level
Concave	$\theta < 90^\circ$	Rises
Plane	$\theta = 90^\circ$	No rise no fall
Convex	$\theta > 90^\circ$	Fall

7.27 Pressure

The normal force exerted by liquid at rest on a given surface in contact with it is called thrust of liquid on that surface.

If F be the normal force acting on a surface of area A in contact with liquid, then pressure exerted by liquid on this surface is P = F/A

(1) **Units :** N/m^2 or Pascal (S.I.) and $Dyne/cm^2$ (C.G.S.)

(2) **Dimension :** $[P] = \frac{[F]}{[A]} = \frac{[MLT^{-2}]}{[L^2]} = [ML^{-1}T^{-2}]$

(3) Pressure is a tensor quantity.

(4) **Atmospheric pressure :** atm = 1.01×10^5 Pa = 1.01bar = 1 torr.

(5) If P_0 is the atmospheric pressure then for a point at depth h below the surface of a liquid of density ρ, hydrostatic pressure P is given by $P = P_0 + h\rho g$.

(6) **Gauge pressure :** The pressure difference between hydrostatic pressure P and atmospheric pressure P_0 is called gauge pressure. $P - P_0 + h\rho g$.

7.28 Pascal's Law

The increase in pressure at one point of the enclosed liquid in equilibrium of rest is transmitted equally to all other points of the liquid and also to the walls of the container, provided the effect of gravity is neglected.

Example : Hydraulic lift, hydraulic press and hydraulic brakes.

7.29 Archimedes Principle

When a body is immersed partly or wholly in a fluid, in rest it is buoyed up with a force equal to the weight of the fluid displaced by the body. This principle is called Archimedes principle. Apparent weight of the body of density (ρ) when immersed in a liquid of density (σ).

$$\begin{aligned} \text{Apparent weight} &= \text{Actual weight} - \text{Upthrust} \\ &= W - F_{up} = V\rho g - V\sigma g = V(\rho - \sigma)g \\ &= V\rho g\left(1 - \frac{\sigma}{\rho}\right) \end{aligned}$$

$$\therefore \quad W_{app} = W\left(1 - \frac{\sigma}{\rho}\right)$$

(1) Relative density of a body (R.D.)

$$= \frac{\text{Weight of body in air}}{\text{Weight in air} - \text{weight in water}}$$

$$= \frac{w_1}{w_1 - w_2}$$

(2) If the loss of weight of a body in water is 'a' while in liquid is 'b'

$$\therefore \quad \frac{\sigma_L}{\sigma_w} = \frac{\text{Upthrust on body in liquid}}{\text{Upthrust on body in water}}$$

$$= \frac{\text{Loss of weight in liquid}}{\text{Loss of weight in water}}$$

$$= \frac{a}{b} = \frac{W_{air} - W_{liquid}}{W_{air} - W_{water}}$$

7.30 Streamline, Laminar and Turbulent Flow

(1) Stream line flow : Stream line flow of a liquid is that flow in which each element of the liquid passing through a point travels along the same path and with the same velocity as the preceding element passes through that point.

The two streamlines cannot cross each other and the greater is the crowding of streamlines at a place, the greater is the velocity of liquid particles at that place.

(2) Laminar flow : If a liquid is flowing a horizontal surface with a steady flow and moves in the form of layers of different velocities which do not mix with each other, then the flow of liquid is called laminar flow.

In this flow the velocity of liquid flow is always less than the critical velocity of the liquid.

(3) Turbulent flow : When a liquid moves with a velocity greater than its critical velocity, the motion of the particles of liquid becomes disordered or irregular. Such a flow is called a turbulent flow.

7.31 Critical Velocity

The critical velocity is that velocity of liquid flow upto which its flow is streamlined and above which its flow becomes turbulent.

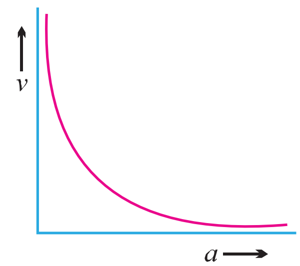
7.32 Equation of Continuity

The equation of continuity is derived from the principle of conservation of mass.

For an incompressible, streamlined and non-viscous liquid product of area of cross section of tube and velocity of liquid remains constant.

i.e., $$a_1 v_1 = a_2 v_2$$

or $$av = \text{constant}; \text{ or } a \propto \frac{1}{v}$$



When water falls from a tap, the velocity of falling water under the action of gravity will increase with distance from the tap (*i.e.,* $v_2 > v_1$). So in accordance with continuity equation the cross section of the water stream will decrease (*i.e.,* $A_2 < A_1$), *i.e.,* the falling stream of water becomes narrower.

7.33 Energy of a Flowing Fluid

Pressure Energy	Potential energy	Kinetic energy
It is the energy possessed by a liquid by virtue of its pressure. It is the measure of work done in pushing the liquid against pressure without imparting any velocity to it.	It is the energy possessed by liquid by virtue of its height or position above the surface of earth or any reference level taken as zero level.	It is the energy possessed by a liquid by virtue of its motion or velocity.
Pressure energy of the liquid PV Pressure energy per unit mass of the liquid $\frac{P}{\rho}$ Pressure energy per unit volume of the liquid P	Potential energy of the liquid mgh Potential energy per unit mass of the liquid gh Potential energy per unit volume of the liquid pgh	Kinetic energy of the liquid $\frac{1}{2}mv^2$ Kinetic energy per unit mass of the liquid $\frac{1}{2}v^2$ Kinetic energy per unit volume of the liquid $\frac{1}{2}\rho v^2$

7.34 Bernoulli's Theorem

According to this theorem the total energy (pressure energy, potential energy and kinetic energy) per unit volume or mass of an incompressible and non-viscous fluid in steady flow through a pipe remains constant throughout the flow.

$$P + \rho g h + \frac{1}{2}\rho v^2 = \text{constant}$$

(i) Bernoulli's theorem for unit mass of :

$$\frac{P}{\rho} + gh + \frac{1}{2}v^2 = \text{constant}$$

(ii) Dividing above equation by g, we get

$$\frac{P}{\rho g} + h + \frac{v^2}{2g} = \text{constant}$$

Here $\frac{P}{\rho g}$ is called pressure head, h is called gravitational head and $\frac{v^2}{2g}$ is called velocity head.

7.35 Applications of Bernoulli's Theorem

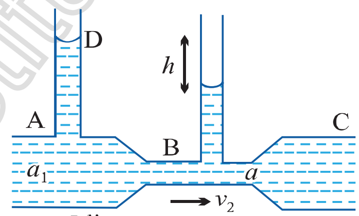
(i) Attraction between two closely parallel moving boats.

(ii) Working of an aeroplane : 'dynamic lift' (= pressure difference × area of wing)

(iii) Action of atomiser :

(iv) Blowing off roofs by wind storms

(v) Magnus effect : When a spinning ball is thrown, it deviates from its usual path in flight. This effect is called Magnus effect.



(VENTURIMETER)

(vi) Venturimeter : It is a device used for measuring the rate of flow of liquid through pipes.

$$\text{Rate of flow of liquid V} = a_1 a_2 \sqrt{\frac{2hg}{a_1^2 - a_2^2}}.$$

7.36 Velocity of Efflux

Velocity of efflux from a hole made at a depth h below the free surface of the liquid (of depth H) is given by $v = \sqrt{2gh}$.

Which is same as the final speed of a free falling object from rest through a height h. This result is known as Torricelli's theorem.

7.37 Viscosity and Newton's law of Viscous Force

The property of a fluid due to which it opposes the relative motion between its different layers is called viscosity (or fluid friction or internal friction) and the force between the layers opposing the relative motion is called viscous force.

Viscous force F is proportional to the area of the plane A and the velocity gradient $\frac{dv}{dx}$ in a direction normal to the layer,

i.e., $$F = -\eta A \frac{dv}{dx}$$

Where η is a constant called the coefficient of viscosity. Negative sign is employed because viscous force acts in a direction opposite to the flow of liquid.

(1) Units : dyne-s-cm^{-2} or Poise (C.G.S. system);

Newton-s-m^{-2} or Poiseuille or decapoise (S.I. system)

1 Poiseuille = 1 decapoise = 10 Poise

(2) Dimension : $[ML^{-1}T^{-1}]$

(3) With increase in pressure, the viscosity of liquids (except water) increases while that of gases is independent of pressure. The viscosity of water decreases with increase in pressure.

(4) Solid friction is independent of the area of surfaces in contact and the relative velocity between them.

(5) Viscosity represents transport of momentum, while diffusion and conduction represents transport of mass and energy respectively.

(6) The viscosity of gases increases with increase of temperature.

(7) The viscosity of liquid decreases with increase of temperature.

7.38 Stoke's Law and Terminal Velocity

Stokes established that if a sphere of radius r moves with velocity v through a fluid of viscosity η, the viscous force opposing the motion of the sphere is $F = 6\pi\eta r v$ (stokes law)

If a spherical body of radius r is dropped in a viscous fluid, it is first accelerated and then it's acceleration becomes zero and it attains a constant velocity called terminal velocity.

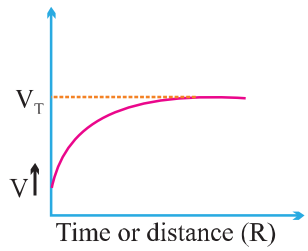
$$\text{Terminal velocity } v = \frac{2}{9}\frac{r^2(\rho-\sigma)g}{\eta}$$

(i) If $\rho > \sigma$ then body will attain constant velocity in downward direction.

(ii) If $\rho < \sigma$ then body will attain constant velocity in upward direction.

Example : Air bubble in a liquid and clouds in sky.

(iii) Terminal velocity graph :



7.39 Poiseuille's Formula

Poiseuille studied the stream–line flow of liquid in capillary tubes. He found that if a pressure difference (P) is maintained across the two ends of a capillary tube of length '*l*' and radius *r*, then the volume of liquid coming out of the tube per second is

$$V = \frac{\pi P r^4}{8\eta l} \quad \text{(Poiseuille's equation)}$$

This equation also can be written as, $V = \frac{P}{R}$ where $R = \frac{8\eta l}{\pi r^4}$

R is called as liquid resistance.

3.40 Stefan's Law

According to it the radiant energy emitted by a perfectly black body per unit area per sec (*i.e.,* emissive power of black body) is directly proportional to the fourth power of its absolute temperature.

i.e., $E \propto T^4$ or $E = \sigma T^4$

where σ = Stefan's constant having dimension $[MT^{-3}\theta^{-4}]$ and value 5.67×10^{-8} W/m^{2}K^4.

(i) If e is the emissivity of the body then $E = e\,\sigma\,T^4$

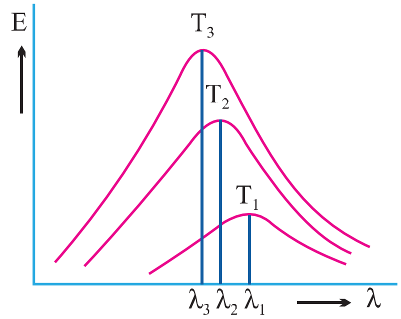
(ii) If Q is the total energy radiated by the body then $Q = AtesT^4$

(iii) If a body at temperature T is surrounded by a body at temperature T_0, then $E = e\,\sigma\,(T^4 - T_0^4)$.

Nature of thermal Radiation

- Radiation emitted by a black body is a mixture of waves of different wavelengths and only a small range of wavelength has significant contribution in the total radiation.

- A body is heated at different temperature and Energy of radiation is plotted against wavelength is plotted for different temperature we get following curves.



- These curves show

  (i) Energy is not uniformly distributed in the radiation spectrum of black body.

  (ii) At a given temperature the intensity of radiations increases with increase in wavelength, becomes maximum at particular wavelength and further increase in wavelength leads to decrease in intensity of heat radiation.

  (iii) Increase in temperature causes increase in energy emission for all wavelengths.

  (iv) Increase in temperature causes decrease in λ_m, where λ_m is wavelength corresponding to highest intensity. This wavelength λ_m is inversely preoperational to the absolute temperature of the emitter. $\lambda_m \text{ T} = b$

  where b is a constant and this equation is known as Wein's displacement law. $b = 0.2896 \times 10^{-2}$ *mk* for black body and is known as Wien's constant.

Very Short Answer Questions (1 Mark)

1. Why do spring balances show wrong readings after they have been used for a long time ?

2. Why do we prefer steel to copper in the manufacture of spring ?

3. Draw stress-strain curve for elastomers (elastic tissue of Aorta)

4. How are we able to break a wire by repeated bending ?

5. What is the value of bulk modulus for an incompressible liquid ?

6. Define Poisson's ratio ? Does it have any unit ?
7. What is elastic fatigue ?
8. Why is it easier to swim in sea water than in the river water ?
9. Railway tracks are laid on large sized wooden sleepers. Why ?
10. The dams of water reservoir are made thick near the bottom. Why ?
11. Why is it difficult to stop bleeding from a cut in human body at high altitude ?
12. The blood pressure in human is greater at the feet than at the brain. Why ?
13. Define coefficient of viscosity and write its SI unit.
14. Why machine parts get jammed in winter ?
15. Why do the clouds float in the sky ?
16. Antiseptics have low surface tension. Why ?
17. What will be the effect of increasing temperature on (i) angle of contact (ii) surface tension ?
18. For solids with elastic modulus of rigidity, the shearing force is proportional to shear strain. On what factor does it depend in case of fluids ?
19. How does rise in temperature effect (i) viscosity of gases (ii) viscosity of liquids ?
20. Explain why detergents should have small angle of contact ?
21. Write the dimensions of coefficient of viscosity and surface tension.
22. Obtain a relation between SI unit and cgs unit of coefficient of viscosity.
23. Explain, how the use of parachute helps a person jumping from an aeroplane.
24. Why two ships moving in parallel directions close to each other get attracted ?
25. Why the molecules of a liquid lying near the free surface possess extra energy ?
26. Why is it easier to wash clothes in hot water soap solution ?

27. Why does mercury not wet glass ?

28. Why ends of a glass tube become rounded on heating ?

29. What makes rain coats water proof ?

30. What happens when a capillary tube of insufficient length is dipped in a liquid ?

31. Does it matter if one uses gauge pressure instead of absolute pressure in applying Bernoulli's equation ?

32. State Wein's displacement law for black body radiation.

33. State Stefan Boltzmann law.

34. Name two physical changes that occur on heating a body.

35. Distinguish between heat and temperature.

36. Which thermometer is more sensitive a mercury or gas thermometer ?

37. Metal disc has a hole in it. What happens to the size of the hole when disc is heated ?

38. Name a substance that contracts on heating.

39. A gas is free to expand what will be its specific heat ?

40. Is the bulb of a thermometer made of diathermic or adiabatic wall ?

41. What is the absorptive power of a perfectly black body ?

42. At what temperature does a body stop radiating ?

43. If Kelvin temperature of an ideal black body is doubled, what will be the effect on energy radiated by it ?

44. In which method of heat transfer does gravity not play any part ?

45. Give a plot of Fahrenheit temperature versus Celsius temperature.

46. Why birds are often seen to swell their feather in winter ?

47. A brass disc fits snugly in a hole in a steel plate. Should we heat or cool the system to loosen the disc from the hole.

Short Answer Type Questions (2 Marks)

48. State Hooke's law. Deduce expression for young's modulus of material of a wire of length 'l', radius of cross-section 'r' loaded with a body of mass M producing an extension Δl in it.

49. A wire of length l area of crossection A and young's modulus Y is stretched by an amount x. What is the work done ?

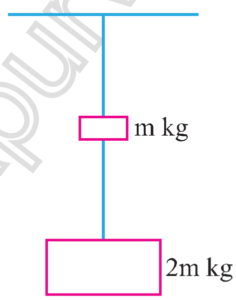
50. Prove that the elastic potential energy per unit volume is equal to $\frac{1}{2} \times$ stress $\times$ strain.

51. Define the term bulk modulus. Give its SI unit. Give the relation between bulk modulus and compressibility.

52. Define shear modulus. With the help of a diagram explain how shear modulus can be calculated.

53. Which is more elastic steel or rubber. Explain.

54. Two wires P and Q of same diameter are loaded as shown in the figure. The length of wire P is L *m* and its young's modulus is Y N/m^2 while length of wire *a* is twice that of P and its material has young's modulus half that of P. Compute the ratio of their elongation.



55. In case of emergency, a vaccum brake is used to stop the train. How does this brake works ?

56. Define surface tension and surface energy. Obtain a relation between them.

57. State and prove Torricelli's theorem for velocity of efflux.

58. Using dimensional method obtain, Stoke's law expression for viscous force $F = 6\pi \eta a v$.

59. The fig (a) & (b) refer to the steady flow of a non-viscous liquid which of the two figures is incorrect ? Why ?

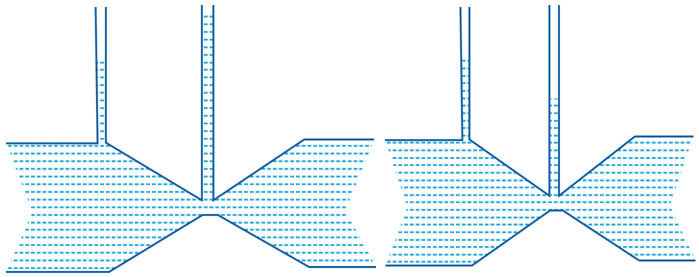
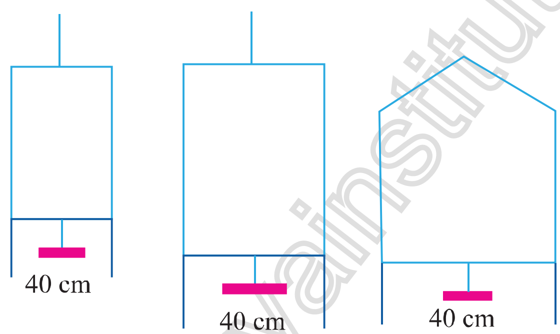


fig (a) fig (b)

60. The fig. below shows a thin liquid supporting a small weight 4.5×10^{-2} N. What is the weight supported by a film of same liquid at the same temperature in fig. (b) & (c). Explain your answer.



(a) (b) (c)

61. Two soap bubbles of different diameter are in contact with a certain portion common to both the bubbles. What will be the shape of the common boundary as seen from inside the smaller bubble ? Support your answer with a neat diagram and justify your answer.

62. During blood transfusion the needle is inserted in a vein where gauge pressure is p_g and atmospheric pressure is p. At what height must the blood container be placed so that blood may just enter the vein. Given density of blood is p.

63. Why we cannot remove a filter paper from a funnel by blowing air into narrow end.

64. On a hot day, a car is left in sunlight with all windows closed. Explain why it is considerably warmer than outside, after some time ?

65. A capillary tube is dipped first in cold water and then in hot water. Comment on the capillary rise in the second case.

66. If a drop of water falls on a very hot iron, it does not evaporate for a long time. Why ?

67. The earth without its atmosphere would be inhospitably cold. Why ?

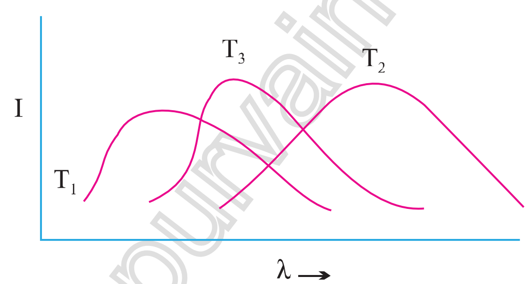
68. The coolant used in chemical or in a nuclear plant should have high specific heat. Why ?

69. A sphere, a cube and a disc made of same material and of equal masses heated to same temperature of 200ºC. These bodies are then kept at same lower temperature in the surrounding, which of these will cool (i) fastest, (ii) slowest, explain.

70. (a) Why pendulum clocks generally go faster in winter and slow in summer.

(b) Why the brake drums of a car are heated when it moves down a hill at constant speed.

71. The plots of intensity versus wavelength for three black bodies at temperature T_1, T_2 and T_3 respectively are shown.



Arrange the temperature in decreasing order. Justify your answer.

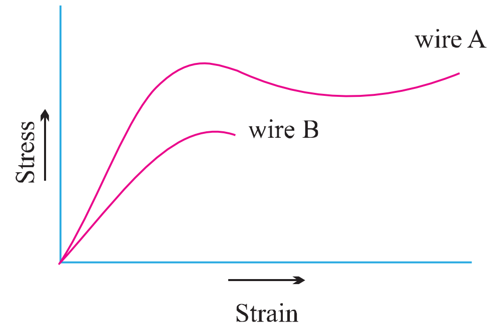
72. The triple point of water is a standard fixed point in modern thermometry. Why ? Why melting point of ice or boiling point of water not used as standard fixed points.

Short Answer Type Questions (3 Marks)

73. The knowledge of elasticity useful in selecting metal ropes show its use, in cranes for lifting heavy loads, when rope of steel is used (Elastic limit 30×10^7 Nm^{-2}) if load of 10^5 kg is to be lifted.

What should be the radius of steel rope ? What should we do to increase flexibility of such wire ?

74. Stress-strain curve for two wires of material A and B are as shown in Fig.



(a) which material in more ductile ?

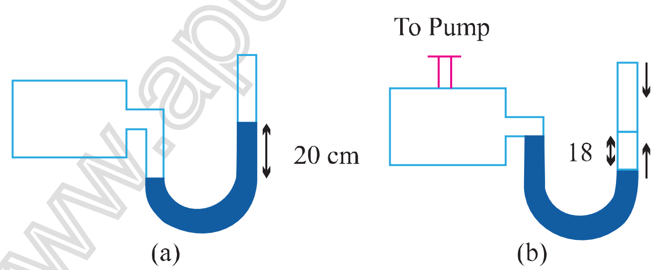
(b) which material has greater value of young modulus ?

(c) which of the two is stronger material ?

(d) which material is more brittle ?

75. State Pascal's law for fluids with the help of a neat labelled diagram explain the principle and working of hydraulic brakes.

76. A manometer reads the pressure of a gas in an enclosure as shown in the fig. (a) when some of the gas is removed by a pump, the manometer reads as in fig (b). The liquid used in manometer is mercury and the atmospheric pressure is 76 cm of mercury, (i) Give absolute and gauge pressure of the gas in the enclosure for cases (a) and (b).



77. How would the levels change in (b) if 13.6 cm of H_2O (immensible with mercury) are poured into the right limb of the manometer in the above numerical.

78. Define Capillarity and angle of contact. Derive an expression for the ascent of a liquid in a capillary tube.

79. The terminal velocity of a tiny droplet is *v*. N number of such identical droplets combine together forming a bigger drop. Find the terminal velocity of the bigger drop.

80. Two spherical soap bubble coalesce. If v be the change in volume of the contained air, A is the change in total surface area then show that 3PV + 4AT = 0 where T is the surface tension and P is atmospheric pressure.

81. Give the principle of working of venturimeter. Obtain an expression for volume of liquid flowing through the tube per second.

82. A big size balloon of mass M is held stationary in air with the help of a small block of mass M/2 tied to it by light string such that both float in mid air. Describe the motion of the balloon and the block when the string is cut. Support your answer with calculations.

83. Two vessels have the same base area but different shapes. The first vessels takes twice the volume of water that the second vessel requires to fill upto a particular common height. Is the force exerted by the water on the base of the vessel the same ? Why do the vessels filled to same height give different reading on weighing scale.

84. A liquid drop of diameter D breaks up into 27 tiny drops. Find the resulting change in energy. Take surface tension of liquid as σ.

85. Define the coefficients of linear expansion. Deduce relation between it and coefficient of superficial expansion and volume expansion.

86. Describe the different types of thermometers commonly used. Used the relation between temperature on different scales. Give four reasons for using mercury in a thermometer.

87. Two rods of different metals of coefficient of linear expansion α_1 and α_2 and initial length l_1 and l_2 respectively are heated to the same temperature. Find relation in α_1, α_2, l_1 and l_2 such that difference between their lengths remain constant.

88. Explain why :

(a) a body with large reflectivity is a poor emitter.

(b) a brass tumbler feels much colder than a wooden tray on a chilly day.

89. Draw a graph to show the anomalous behaviour of water. Explain its importance for sustaining life under water.

90. A brass wire 1.8 *m* long at 27ºC is held taut with little tension between two rigid supports. If the wire is cooled to a temperature of – 39ºC, what is the tension developed in the wire, if its diameter is 2.0 mm ? Coefficient of linear expansion of brass = $2.0 \times 10^{-5}\,{}^{\circ}C^{-1}$, Young's modulus of brass = 0.91×10^{11} Pa.

91. Define (i) Specific heat capacity (ii) Heat capacity (iii) Molar specific heat capacity at constant pressure and at constant volume and write their units.

92. What is latent heat ? Give its units. With the help of a suitable graph, explain the terms latent heat of fusion and latent heat of vaporisation.

93. What is the effect of pressure on melting point of a substance ? What is regelation. Give a practical application of it.

94. What is the effect of pressure on the boiling point of a liquid. Describe a simple experiment to demonstrate the boiling of H_2O at a temperature much lower than 100ºC. Give a practical application of this phenomenon.

95. State and explains the three modes of transfer of heat. Explains how the loss of heat due to these three modes is minimised in a thermos flask.

96. Define coefficient of thermal conductivity. Two metal slabs of same area of cross-section, thickness d_1 and d_2 having thermal conductivities K_1 and K_2 respectively are kept in contact. Deduce expression for equivalent thermal conductivity.

Long Answer Type Questions (5 Marks)

97. Draw and discuss stress versus strain graph, explaining clearly the terms elastic limit, permanent set, proportionality limit, elastic hysteresis, tensible strength.

98. Show that there is always an excess pressure on the concave side of the meniscus of a liquid. Obtain an expression for the excess pressure inside (i) a liquid drop (ii) soap bubble (iii) air bubble inside a liquid.

99. State and prove Bernoullis theorem. Give its limitation. Name any two application of the principle.

100. Define terminal velocity. Obtain an expression for terminal velocity of a sphere falling through a viscous liquid. Use the formula to explain the observed rise of air bubbles in a liquid.

101. On what factors does the rate of heat conduction in a metallic rod in the steady state depend. Write the necessary expression and hence define the coefficient of thermal conductivity. Write its unit and dimensions.

102. Show graphically how the energy emitted from a hot body varies with the wavelength of radiation. Give some of salient points of the graph.

103. What is meant by a block body. Explain how a black body may be achieved in practice. State and explain Stefan's law ?

104. State and prove Pascal's law of transmission of fluid pressure. Explain how is Pascal's law applied in a hydraulic lift.

105. Discuss energy distribution of black body radiation spectrum and explain Wein's displacement law of radiation and Stefan's law of heat radiation.

NUMERICALS

106. An aluminium wire 1 m in length and radius 1 mm is loaded with a mass of 40 kg hanging vertically. Young's modulus of Al is 7.0×10^{10} N/m^2. Calculate (a) tensile stress (b) change in length (c) tensile strain and (d) the force constant of such a wire.

107. The average depth of ocean is 2500 m. Calculate the fractional compression $\left(\frac{\Delta V}{V}\right)$ of water at the bottom of ocean, given that the bulk modulus of water is 2.3×10^9 N/m^2.

108. A force of 5×10^3 N is applied tangentially to the upper face of a cubical block of steel of side 30 cm. Find the displacement of the upper face relative to the lower one, and the angle of shear. The shear modulus of steel is 8.3×10^{10} pa.

109. How much should the pressure on one litre of water be changed to compress it by 0.10%.

110. Calculate the pressure at a depth of 10 m in an Ocean. The density of sea water is 1030 kg/m^3. The atmospheric pressure is 1.01×10^5 pa.

111. In a hydraulic lift air exerts a force F on a small piston of radius 5 cm. The pressure is transmitted to the second piston of radius 15 cm. If a car of mass 1350 kg is to be lifted, calculate force F that is to be applied.

112. How much pressure will a man of weight 80 kg *f* exert on the ground when (i) he is lying and (2) he is standing on his feet. Given area of the body of the man is 0.6 m^2 and that of his feet is 80 cm^2.

113. The manual of a car instructs the owner to inflate the tyres to a pressure of 200 *k* pa. (a) What is the recommended gauge pressure ? (b) What is the recommended absolute pressure (c) if, after the required inflation of the tyres, the car is driven to a mountain peak where the atmospheric pressure is 10% below that at sea level, what will the tyre gauge read ?

114. Calculate excess pressure in an air bubble of radius 6 mm. Surface tension of liquid is 0.58 N/m.

115. Terminal velocity of a copper ball of radius 2 mm through a tank of oil at 20ºC is 6.0 cm/s. Compare coefficient of viscosity of oil. Given $p_{cu} = 8.9 \times 10^3$ kg/m^3, $\rho_{oil} = 1.5 \times 10^3$ kg/m^3.

116. Calculate the velocity with which a liquid emerges from a small hole in the side of a tank of large cross-sectional area if the hole is 0.2 m below the surface liquid ($g = 10$ ms^{-2}).

117. A soap bubble of radius 1 cm expands into a bubble of radius 2 cm. Calculate the increase in surface energy if the surface tension for soap is 25 dyne/cm.

118. A glass plate of 0.2 m^2 in area is pulled with a velocity of 0.1 m/s over a larger glass plate that is at rest. What force is necessary to pull the upper plate if the space between them is 0.003 m and is filled with oil of η 0.01 Ns/m^2.

119. The area of cross-section of a water pipe entering the basement of a house is 4×10^{-4} m^2. The pressure of water at this point is 3×10^5 N/m^2, and speed of water is 2 m/s. The pipe tapers to an area of cross section of 2×10^{-4} m^2, when it reaches the second floor 8 m above the basement. Calculate the speed and pressure of water flow at the second floor.

120. A large bottle is fitted with a siphon made of capillary glass tubing. Compare the times taken to empty the bottle when it is filled (i) with water (ii) with petrol of density 0.8 cgs units. The viscosity of water and petrol are 0.01 and 0.02 cgs units respectively.

121. The breaking stress for a metal is 7.8×10^9 Nm^{-2}. Calculate the maximum length of the wire made of this metal which may be suspended without breaking. The density of the metal = 7.8×10^{-3} kg m^{-3}. Take $g = 10$ N kg^{-1}.

122. Two stars radiate maximum energy at wavelength, 3.6×10^{-7} m and 4.8×10^{-7} n respectively. What is the ratio of their temperatures ?

123. Find the temperature of 149ºF on kelvin scale.

124. A metal piece of 50 g specific heat 0.6 cal/gºC initially at 120ºC is dropped in 1.6 kg of water at 25ºC. Find the final temperature or mixture.

125. A iron ring of diameter 5.231 m is to be fixed on a wooden rim of diameter

5.243 m both initially at 27ºC. To what temperature should the iron ring be heated so as to fit the rim (Coefficient of linear expansion of iron is $1.2 \times 10^5\ k^{-1}$?

126. 100 g of ice at 0ºC is mixed with 100 g of water at 80ºC. The resulting temperature is 6ºC. Calculate heat of fusion of ice.

127. Calculate heat required to convert 3 kg of water at 0ºC to steam at 100ºC. Given specific heat capacity of $H_2O = 4186\ J\ kg^{-1}k^{-1}$ and latent heat of steam $= 2.256 \times 10^6$ J/kg.

128. Calculate the stress developed inside a tooth cavity that filled with copper. When hot tea at temperature 57ºC is drunk. You can take body (tooth) temperature to be 37ºC and $\alpha = 1.7 \times 10^{-5}$/ºC bulk modules for copper $= 140 \times 10^9\ Nm^{-2}$.

129. A body at temperature 94ºC cools to 86ºC in 2 min. What time will it take to cool from 82ºC to 78°C. The temperature of surrounding is 20ºC.

130. A body re-emits all the radiation it receives. Find surface temperature of the body. Energy received per unit area per unit time is 2.835 watt/m^2 and $\alpha = 5.67 \times 10^{-8}\ W\ m^{-2}\ k^{-4}$.

ANSWERS

VERY SHORT ANSWERS (1 MARK)

1. This is due to elastic fatigue.

2. Because steel is more elastic than copper as its Young's modulus is more than that of copper.

4. Repeated bending of wire decreases elastic strength and therefore it can be broken easily.

5. $K = \frac{\text{stress}}{\text{strain}} = \frac{\text{stress}}{\text{o}} = \infty$ (Infinity)

6. Poisson's ratio is the ratio of lateral strain to the longitudinal strain. It has no units.

7. It is the loss in strength of a material caused due to repeated alternating strains to which the material is subjected.

8. The density of sea water is more than the density of river water, hence sea water gives more up thrust for the same volume of water displaced.

9. This spreads force due to the weight of the train on a larger area and hence reduces the pressure considerably and in turn prevents yielding of the ground under the weight of the train.

10. Pressure exerted by liquid column = *hpg* so as '*h*' increases *p* increases so to with stand high pressure dams are made thick near the bottom.

11. The atmospheric pressure is low at high altitudes. Due to greater pressure difference in blood pressure and the atmospheric pressure, it is difficult to stop bleeding from a cut in the body.

12. The height of blood column is quite large at feet than at the brain, hence blood pressure at feet is greater.

14. In winter *i.e.,* at low temperature the viscosity of lubricants increases.

15. Due to zero terminal velocity.

16. They have to spread over a large area.

17. Angle of contact increases with increase of temperature while surface tension generally decreases with increase of temperature.

18. Rate of Shear Strain.

19. Viscosity of gases increases while viscosity of liquid decreases.

20. Detergents should have small angle of contact so that they have low surface tension and greater ability to wet a surface. Further as $h = \frac{2T\cos\theta}{rpg}$ *i.e.,* θ is small $\cos\theta$ will be large so *h i.e.,* penetration will be high.

21. $[\eta] = [M^1L^{-1}T^{-1}]$

$[T] = [M^1L^{-2}L^0]$

22.

$$\begin{aligned} \text{c.g.s unit of } \eta &= \text{poise} \\ \text{S.I. Unit of } \eta &= \text{poiseuille or deca poise} \\ 1 \text{ poise} &= 1 \text{ g cm}^{-1} \text{ s}^{-2} = 10^{-1} \text{ kg m}^{-1} \text{ s}^{-1} \\ &= 0.1 \text{ poiseuille} \end{aligned}$$

23. Viscous force on the parachute is large as $F = 6\pi \eta r v$, $F \alpha r$, so its terminal velocity becomes small so the person hits the ground with this small velocity and does not get injured.

24. According to Bernoulli's theorem for horizontal flow $P + \frac{1}{2}pv^2$ = constant.

As speed of water between the ships is more than outside them pressure between them gets reduced & pressure outside is more so the excess pressure pushes the ships close to each other therefore they get attracted.

25. The molecules in a liquid surface have a net downward force (cohesion) on them, so work done in bringing them from within the body of liquid to the surface increases surface energy.

26. Hot water soap solution has small surface tension therefore can remove the dirt from clothes by wetting them effectively.

27. Mercury does not wet glass because of larger cohesive force between Hg-Hg molecules than the adhesive forces between mercury-glass molecules.

28. When glass is heated, it melts. The surface of this liquid tends to have a minimum area. For a given volume, the surface area is minimum for a sphere. This is why the ends of a glass tube become rounded on heating.

29. The angle of contact between water and the material of the rain coat is obtuse. So the rain water does not wet the rain coat.

30. When a capillary tube of insufficient length is dipped in a liquid, the radius of curvature of the meniscus increase so that *hr* = constant. That is pressure on concave side becomes equal to pressure exerted by liquid column so liquid does not overflow.

31. No. Unless the atmospheric pressures at the two points where Bernoulli's equation is applied, are significantly different.

34. Volume and electrical resistance.

36. Gas thermometer is more sensitive as coefficient of expansion of Gas is more than mercury.

37. Expansion is always outward, therefore the hole size increased on heating.

38. Ice

39. Infinity

40. The temperature above which molar heat capacity of a solid substance becomes constant.

41. One.

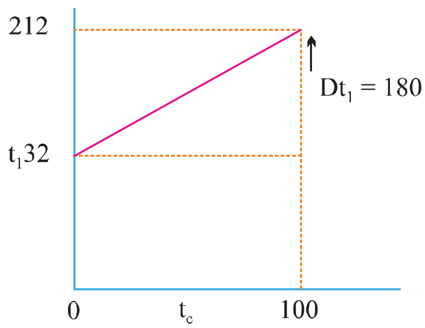
42. At oK.

43. $E \propto T^4 \therefore \dfrac{E_2}{E_1} = \left(\dfrac{T_2}{T_1}\right)^4 = \left(\dfrac{2T_1}{T_1}\right)^4 = 16$

$\therefore E_2 = 16\,E_1$

44. In conduction and radiation.

45.



46. When birds swell their feathers, they trap air in the feather. Air being a poor conductor prevents loss of heat and keeps the bird warm.

47. The temp, coefficient of linear expansion for brass is greater than that for steel. On cooling the disc shrinks to a greater extent than the hole, and hence brass disc gets lossened.

SHORT ANSWERS (2 MARKS)

49. Restoring force in extension $x = F = \dfrac{AYx}{L}$

Work done in stretching it by $dx = dw = F.dx$

Work done in stretching it from zero to $x = W = \int dw = \int_0^x F dx$

$$W = \int_0^x \frac{AYx}{L} dx = \frac{1}{2}\frac{AYx^2}{L}$$

50.

$$\text{Energy Density} = \frac{\text{Energy}}{\text{Volume}} = \frac{\frac{1}{2}\frac{AY}{L}x^2}{AL}$$

$$= \frac{1}{2}\left(\frac{AYx}{L}\right)\frac{x}{L}$$

$$= \frac{1}{2}\frac{F}{A} \times \frac{x}{L} \qquad \left[\because Y = \frac{FL}{Ax}\right]$$

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

53. $$Y_s = \frac{F}{A}\frac{I}{\Delta I_s}$$

$$Y_r = \frac{F}{A}\frac{I}{\Delta I_r}$$

For same force applied to wires made of steel & rubber of same length and same area of cross section

$$\Delta I_s < \Delta I_r$$

$$\frac{Y_s}{Y_r} = \frac{\Delta I_r}{\Delta I_s} > 1$$

$\therefore$ $$Y_s > Y_r$$

54. $$\Delta I_p = \frac{3mg}{A} \times \frac{L}{Y}$$

$$\Delta I_Q = \frac{2mg}{A} \cdot \frac{2L}{Y/2} = \frac{8mg}{A}\frac{L}{Y}$$

$\therefore$ $$\frac{\Delta I_p}{\Delta I_q} = \frac{3}{8}$$

55. Steam at high pressure is made to enter the cylinder of vacuum brake. Due to high velocity, pressure decreases in accordance with Bernoulli's principle. Due to this decrease in pressure, the piston gets lifted. Consequently brake gets lifted.

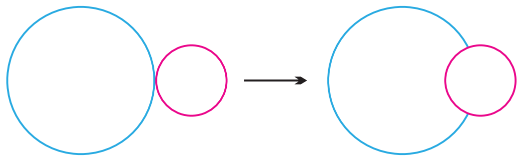
59. Fig. (a) is correct.

At the constriction, the area of cross section is small so liquid velocity is large, consequently pressure must be small so height of liquid must be less.

60. The weight supported by (b) and (c) are same as that in (a) and is equal to 4.5×10^{-2} N.

The weight supported = 2 σ *l*, where σ is surface tension and *l* is the length which is same in all the three cases, hence weight supported is same.

61.



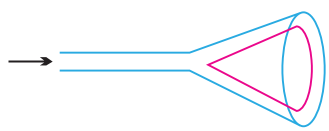
When seen from inside the smaller bubble the common surface will appear 2T concave as (1) the pressure (excess) = $\frac{2T}{R}$ will be greater for concave surface & as R is small for the smaller bubble, the pressure will be greater.

62.

$$P_g = pgh$$

$$h = \frac{P_g}{pg}$$

63.



When air is blown into the narrow end its velocity in the region between filter paper and glass increases. This decreases the pressure. The filter paper gets more firmly held with the wall of the tunnel.

64. Glass transmits 50% of heat radiation coming from a hot source like sun but does not allow the radiation from moderately hot bodies to pass through it.

65. We know that $h = \frac{2S\cos\theta}{r\rho g}$

Surface tension of hot water is less than the surface tension of cold water. Moreover, due to thermal expansion the radius of the capillary tube will increase in hot water. Due to both reasons, the height of capillary rise will be less in hot water as compared to cold water.

66. A vapour film is formed between water drop and the hot iron. Vapour being a poor conductor of heat makes the water droplet to evaporate slowly.

67. Due to green house effect, the presence of atmosphere prevents heat radiations received by earth to go back. In the absence of atmosphere radiation will go back at night making the temperature very low and inhospitable.

68. So, that it absorbs more heat with comparatively small change in temperature and extracts large amount of heat.

69. Rate of energy emission is directly proportional to area of surface for a given mass of material. Surface area of sphere is least and that of disc is largest.

Therefore cooling of (i) disc is fastest and (ii) sphere is slowest.

70. (a) Time period of pendulum = T = $2\pi\sqrt{\frac{l}{g}}$ or $T \times \sqrt{l}$

In winter I becomes shorter so its time period reduces so it goes faster. In summer I increases resulting in increase in time period so the clock goes slower.

(b) When the car moves down hill, the decrease in gravitational potential energy is converted into work against force of friction between brake shoe and drum which appears as heat.

71. According to wein's displacement law, λmt = Constant

$\lambda_1 < \lambda_3 < \lambda_2$

$T_1 > T_3 > T_2$

72. The melting point of ice as well as the boiling point of water changes with change in pressure. The presence of impurities also changes the melting and boiling points. However the triple point of water has a unique temperature and is independent of external factors. It is that temperatures at which water, ice & water vapour co-exist that is 273. 16 K and pressure 0.46 cm of Hg.

ANSWERS FOR SHORT QUESTIONS (3 MARKS)

73. The ultimate stress should not exceed elastic limit of steel (30×10^7 N/m^2)

$$U = \frac{F}{A} = \frac{Mg}{\pi r^2} = \frac{10^5 \times 9.8}{\pi r^2} = 30 \times 10^7$$

$\therefore r = 3.2$ cm

So to lift a bad of 10^4 kg, crane is designed to withstand 10^5 kg. To impart flexibility the rope is made of large number of thin wires braided.

74. (a) Wire with larger plastic region is more ductile material A.

(b) Young's modulus is $\frac{\text{Stress}}{\text{Strain}}$

$\therefore Y_A > Y_B$

(c) For given strain, larger stress is required for A than that for B.

$\therefore$ A is stronger than B.

(d) Material with smaller plastic region is more brittle, therefore B is more brittle than A.

76. (i) In case (a) Pressure head, $h = +20$ cm of Hg

$$\text{Absolute Pressure} = P + h = 76 + 20 = 96 \text{ cm of Hg.}$$

$$\text{Gauge Pressure} = h = 20 \text{ cm of Hg.}$$

In case (b) Pressure Head $h = -18$ cm of Hg

$$\text{Absolute Pressure} = 76 - 18 = 58 \text{ cm of Hg}$$

$$\text{Gauge Pressure} = h = -18 \text{ cm of Hg}$$

77. as

$$h_1 p_1 g = h_2 p_2 g$$

$$h_1 \times 13.6 \times g = 13.6 \times 1 \times g$$

$$h_1 = 1 \text{ cm}$$

Therefore as 13.6 cm of H_2O is poured in right limb it will displace Hg level by 1 cm in the left limb, so that difference of levels in the two limbs will become 19 cm.

79.

$$v = \frac{2}{9}\left[\frac{g(\sigma-\rho)r^2}{\eta}\right]$$

$$\Rightarrow \quad \frac{v}{r^2} = \frac{2g}{9\eta}(\sigma-\rho) \qquad ...(1)$$

Similarly,

$$\frac{v'}{R^2} = \frac{2g}{9\eta}(\sigma-\rho) \qquad ...(2)$$

Divididng 1 by 2,

$$\frac{v}{v'} = \frac{r^2}{R^2} \Rightarrow v' = v\left(\frac{R}{r}\right)^2$$

If N drops coalesce, then

$$\text{Volume of one big drop} = \text{Volume of N droplets}$$

$$\frac{4}{3}\pi R^3 = N\left(\frac{4}{3}\pi r^3\right)$$

$$R = N^{1/3} r$$

$\therefore$ Terminal velocity of bigger drop

$$= \left(\frac{R}{r}\right)^2 \times v \text{ from equation (1)}$$

$=N^{2/3}\,v$ from equation (2)

80. Let P_1 & P_2 be the pressures inside the two bubbles, then

$$P_1 - P = \frac{4T}{r_1} \Rightarrow P_1 = P + \frac{4T}{r_1}$$

$$P_2 - P = \frac{4T}{r_2} \Rightarrow P_2 = P + \frac{4T}{r_2}$$

When bubbles coalesce

$$P_1V_1 + P_2V_2 = PV \qquad ...(1)$$

$\therefore$ The pressure inside the new bubble

$$P = P + \frac{4T}{r}$$

Substituting for P, P_1 & P_2 in equation (1)

$$\left(P + \frac{4T}{r_1}\right)\frac{4}{3}\pi r_1^3 + \left(P + \frac{4T}{r_2}\right)\frac{4}{3}\pi r_2^3 = \left(P + \frac{4T}{r}\right)\frac{4}{3}\pi r^3$$

or $$\frac{4}{3}\pi P(r_1^3 + r_2^3 - r^3) + \frac{16\pi T}{3}[r_1^2 + r_2^2 - r^2] = 0$$

Given change in volume,

$$V = \frac{4}{3}\varpi r_1^3 + \frac{4}{3}\varpi r_2^3 - \frac{4}{3}\varpi r^3 \qquad ...(3)$$

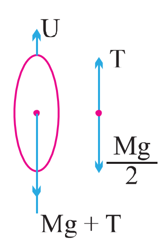
Change in Area

$$4\pi r_1^2 + 4\pi r_2^2 - 4\pi r^2 \qquad ...(4)$$

Using equation (3) and (4) in (2), we get

$$PV + \frac{4T}{3}A = 3\,PV + 4TA = 0$$

82. Free block diagram of balloon and block shown below :



When the balloon is held stationary in air, the forces acting on it get balance

$$Up \text{ thrust} = \text{Wt. of Balloon + Tension in string}$$

$$U = Mg + T$$

M for the small block of mass $\frac{M}{2}$ floating stationary in air

$$T = \frac{M}{2}g$$

$$\therefore \quad U = Mg + \frac{M}{2}g = \frac{3}{2}Mg$$

When the string is cut T = 0, the small block begins to fall freely, the balloon rises up with an acceleration 'a' such that

$$U - Mg = Ma$$

$$\frac{3}{2}Mg - Mg = Ma$$

$$a = \frac{g}{2} \text{ in the upward direction.}$$

83. (i) As the two vessels have liquid to same height and the vessels have same base area, the force exerted = pressure × base area will be same as pressure

$$= h\,p\,g.$$

(ii) Since the volume of water in vessel 1 is greater than in vessel (2) the weight of water = volume × density × h, so weight of first vessel will be greater than the water in second vessel.

84. Radius of larger drop $= \frac{D}{2}$

Radius of each small drop= r

$$27 \times \frac{4}{3}\pi r^3 = \frac{4}{3}\pi\left(\frac{D}{2}\right)^2 \Rightarrow r = \frac{D}{6}$$

Initial surface area of large drop $4\pi\left(\frac{D}{2}\right)^2 = \pi D^2$

Final surface area of 27 small drop

$$= 27 \times 4\pi r^2 = 27 \times 4\pi\frac{D^2}{36} = 3\pi D^2$$

$$\therefore \quad \text{Change in energy} = \text{Increase in area} \times \sigma$$

$$= 2\pi D^2\sigma$$

87. $$I_1^1 = I_1\,[1+ \alpha_1\,(t_2 - t_1)]$$

$$I_2^1 = I^1\,[1+ \alpha_2\,(t_2 - t_1)]$$

Given that the difference in their length remain constant

$\therefore$ $$I_2^1 - I_1^1 = I_2 - I_1$$

$$I_2\,[1+ \alpha_2\,(t_1 - t_1)] - I_1\,[1 + \alpha_1\,(t_2 - t_1)] = I_2 - I_1$$

$\therefore$ $$I_2\alpha_2 = I_1\alpha_1$$

90. Here $$I = 1.8 \text{ m},\ t_1 = 27^{\circ}\text{C},\ t_2 = -39^{\circ}\text{C}$$

$$r = \frac{2.0}{2} = 1.0 \text{ mm} = 1.0 \times 10^{-3} \text{ m}$$

$$r = 2.0 \times 10^{-5}\ {}^{\circ}\text{C}^{-1}, Y = 0.91 \times 10^{11} \text{ Pa}$$

As $$\Delta I = I\,\alpha\,(t_2 - t_1)$$

$\therefore$ Strain, $$\frac{\Delta I}{I} = \alpha\,(t_2 - t_1)$$

Stress = Strain × Young's modulus = $\alpha\,(t_2 - t_1) \times Y$

$= 2.0 \times 10^{-5} \times (-39 - 27) \times 0.91 \times 10^{11} = 1.2 \times 10^8 \text{ Nm}^{-2}$

[Numerically]

Tension developed in the wire = Stress × Area of cross-section

= Stress × $pr^2 = 1.2 \times 10^8 \times 3.14 \times (1.0 \times 10^{-3})^2 = 3.77 \times 10^2$ N .

96. Definition of coefficient of thermal conductivity.

In steady state the heat passing in unit time through the rod remain same that is

$$\frac{Q}{t} = \frac{K_1A(T_1 - T)}{d_1} = \frac{K_2A(T - T_2)}{d_2} = \frac{KA(T_1 - T_2)}{d_1 + d_2}$$

where k is the coefficient of thermal conductivity

Also $$T_1 - T_2 = (T_1 - T) + (T - T_2)$$

$\therefore$ $$\frac{d_1 + d_2}{kA} = \frac{d_1}{K_1A} + \frac{d_2}{K_2A}$$

$\therefore$ $$\frac{d_1 + d_2}{kA} = \frac{d_1}{K_1} + \frac{d_2}{K_2} = \frac{K_2d_1 + K_1d_2}{K_1K_2}$$

$$\therefore \qquad K = \frac{K_1K_2(d_1+d_2)}{K_2d_1+K_1d_2}$$

ANSWERS FOR NUMERICALS

106. (a) Stress $= \frac{F}{A} = \frac{mg}{\pi r^2} = \frac{40\times 10}{\pi\times(1\times10^{-3})^2} = 1.27\times10^8\ \text{N/m}^2$

(b) $\Delta L = \frac{FL}{AY} = \frac{40\times10\times1}{\pi\times(1\times10^{-3})^2\times7\times10^{10}} = 1.8\times10^{-3}$ **m**

(c) Strain $= \frac{\Delta L}{L} = \frac{1.8\times10^{-3}}{1} = 1.8\times10^{-3}$

(d) $F = Kx = K\Delta L$, K = Force constant

$$K = \frac{\Delta F}{L} = \frac{40\times10}{1.8\times10^{-3}} = 2.2\times10^5\ \text{N/m}$$

107. Pressure exerted at the bottom layer by water column of height h is

$$P = h\rho g = 2500 \times 1000 \times 10$$

$$= 2.5 \times 10^7\ \text{N/m}^{-2}$$

$$= \text{Stress}$$

Bulk modulus $\qquad K = \frac{\text{Stress}}{\text{Strain}} = \frac{P}{\Delta V/V}$

$$\frac{\Delta V}{V} = \frac{P}{K} = \frac{2.5\times10^7}{2.3\times10^9} = 1.08\times10^{-2}$$

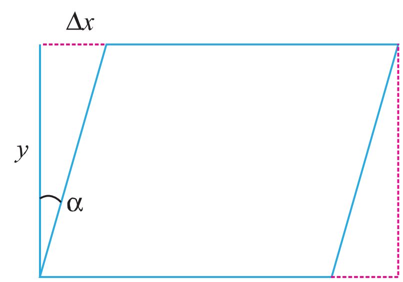
$$= 1.08\%$$

108. Area A of the upper face $= (0.30)^2\ \text{m}^2$

The displacement Δx of the upper face relative to the lower one is given by

$$\Delta x = \frac{yF}{\eta A}, \quad \therefore \eta = \frac{F/A}{\Delta x / y}$$

$$\frac{0.30\times5\times10^3}{8.3\times10^{10}\times(0.30)^2} = 2\times10^{-7}\ \text{m}$$



∴ Angle of shear α is given by

$$\tan\alpha = \frac{\Delta x}{y}$$

$$\alpha = \tan^{-1}\left(\frac{\Delta x}{y}\right)$$

$$= \tan^{-1}\left(\frac{2\times10^{-7}}{0.30}\right) = \tan^{-1}(0.67\times10^{-6})$$

109. $$V = 1 \text{ litre} = 10^{-3}\ m^3$$

$$\frac{\Delta V}{V} = 0.10\% = \frac{0.10}{100} = 0.001$$

$$K = \frac{P}{\Delta V/V} \Rightarrow P = \frac{K\Delta V}{V} = 2.2\times10^9\times0.001$$

$$P = 2.2\times10^6\ Nm^{-2}$$

110. Pressure at a depth of 10 m $= h\rho g$

$= 10\times1030\times10 = 1.03\times10^5\ N/m^2$

ATM. pressure $= 1.01\times10^5$ pa.

Total pressure at a depth of 10 m $= 1.03\times10^5 + 1.01\times10^5$

$= 2.04\times10^5$ pa

111. $$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

$$F_1 = F_2\frac{A_1}{A_2} = F_2\left(\frac{\pi r_1^2}{\pi r_2^2}\right)$$

$$F_1 = 1350\times9.8\left(\frac{5\times10^{-2}}{15\times10^{-2}}\right)^2$$

$$= 1470 \text{ N.}$$

112. (i) When man is lying $P = \frac{F}{A} = \frac{80\times9.8}{0.6} = 1.307\times10^3 \text{ N/m}^{-2}$

(ii) When man is standing then $A = 2 \times 80 \text{ cm}^2 = 160 \times 10^{-4} \text{ m}^2$

$$P = \frac{80\times9.8}{160\times10^{-4}} = 4.9\times10^4 \text{ Nm}^{-2}$$

113. (a) Pressure Instructed by manual = P_g = 200 K P_a

(b) Absolute Pressure = 101 k P_a + 200 k P_a = 301 k P_a

(c) At mountain Peak Pa' is 10% less

$$P_a' = 90\ k\ P_a$$

If we assume absolute pressure in tyre does not change during driving then

$$P_g = P - P_a' = 301 - 30 = 211\ k\ P_a$$

So the tyre will read 211 k P_a, pressure.

114. Excess pressure in soap bubble = $p = \frac{4T}{r} = \left(\frac{4\times0.58}{6\times10^{-3}}\right)$

$$= 387 \text{ Nm}^{-2}$$

115.

$$v_t = \frac{2}{9}\left[\frac{g(\sigma-\rho)r^2}{\eta}\right]$$

$$\eta = \frac{2}{9}\left[\frac{9.8\times(8.9\times10^3-1.5\times10^3)(2\times10^{-3})^2}{6\times10^{-2}}\right]$$

$$= 1.08 \text{ kg m}^{-1}\text{ s}^{-1}$$

116. From Torricelli theorem, velocity of efflux

$$\upsilon = \sqrt{2gh}$$

$$= \sqrt{2\times10\times0.2}$$

$$= 2 \text{ m/s}$$

117. Surface energy per unit area is equal to surface tension.

$$E = \text{increase in surface area} \times ST$$
$$= 4\pi (2^2 - 1^2) \times 2.5$$
$$= 4\pi \times 3 \times 2.5$$
$$= 1.02 \times 10^3 \text{ erg}$$

118.
$$F = \eta A \frac{dv}{dy}$$
$$= 0.01 \times 0.2 \times \frac{0.1}{0.003} = 66.7 \times 10^{-3} \text{ N}$$

119. Since $A_1 v_1 = A_2 v_2$

$$v_2 = \frac{2 \times 4 \times 10^{-4}}{2 \times 10^{-4}} = 4 \text{ m/s}$$

Using Bernoulli's Theorem

$$P_2 = P_1 + \frac{1}{2}\rho(\upsilon_1^2 - \upsilon_2^2) + \rho g(h_1 - h_2)$$

$\therefore$ $v_2 > v_1$

$h_2 > h_1$

$$= 3 \times 10^5 + \frac{1}{2}(1000)[(2)^2 - (4)^2] - 1000 \times 9.8 \times 8$$
$$= 2.16 \times 10^5 \text{ N/m}^2$$

120. The volume of liquid flowing in time t through a capillary tube is given by

$$V = Qt = \frac{\pi P r^4 t}{8\eta l} = \frac{\pi h \rho g r^4 t}{8\eta l}$$

$\therefore$ For Water, $$V_1 = \frac{\pi h \rho_1 g r^4 t_1}{8 l \eta_1}$$

For Petrol, $$V_2 = \frac{\pi h \rho_2 g r^4 t_2}{8 l \eta_2}$$

But $V_1 = V_2$

$\therefore$ $$\frac{\pi h \rho_1 g r^4 t_1}{8 l \eta_1} = \frac{\pi h \rho_2 g r^4 t_2}{8 l \eta_2}$$

or $$\frac{t_1}{t_2} = \frac{\eta_1}{\eta_2} \times \frac{\rho_1}{\rho_2} = \frac{0.01}{0.02} \times \frac{0.8}{0.02} = 0.4$$

121. Breaking stress = Maximum stress that the wire can withstand

$$= 7.8 \times 10^9 \text{ Nm}^{-2}$$

When the wire is suspended vertically, it tends to break under its own weight.

Let its length be I and cross-sectional area A.

$$\text{Weight of wire} = mg = \text{volume} \times \text{density} \times g = Al\rho g$$

$$\text{Stress} = \frac{\text{Weight}}{A} = Al\rho g/A = l\rho g$$

For the wire not to break, $l\rho g$ = Breaking stress = 7.8×10^9 Nm^{-2}

$$\therefore \quad l = \frac{7.8 \times 10^9}{\rho g} = \frac{7.8 \times 10^9}{7.8 \times 10^3 \times 10} = 10^5 \text{ m.}$$

122. By Wein's Displacement Law

$$\lambda_m T = \lambda'_m T'$$

$$\frac{T}{T'} = \frac{\lambda'_m}{\lambda_m} = \frac{4.8 \times 10^{-7}}{3.6 \times 10^{-7}}$$

$$= \frac{4}{3}$$

123. $$\frac{F-32}{180} = \frac{T-273}{100}$$

$$\frac{149-32}{180} = \frac{T-273}{100} \Rightarrow \frac{117}{9} = T - 273$$

$$T = 286\ k$$

124. $$m_1 c_1 (\theta_1 - \theta) = m_2 c_2 (\theta - \theta_2)$$

$$\therefore \quad c_2 = 1 \text{ cal/gm}^\circ\text{C}$$

$$\therefore \quad 50 \times 0.6 \times (120 - \theta) = 1.6 \times 10^3 \times 1 \times (\theta - 25)$$

$$\theta = 26.8^\circ\text{C}$$

125. $$d_2 = d_1 [1 + \alpha \Delta t]$$

$$5.243 = 5.231 [1 + 1.2 \times 10^{-5} (T - 30)]$$

$$\left[\frac{5243}{5231}-1\right] = 1.2 \times 10^{-5}(T-300)$$

$$T = 191 + 300 = 491\ k = 218^{\circ}C$$

126. ice at 0° C → water at 0° C → water at 6° C

$$m_1c_1\,(80-6) = m_2L + m_2c_2\,(6-0)$$

$$100 \times 1 \times 74 = 100\ L + 100 \times 1 \times 6$$

$$L = (1 \times 74) - 6$$

$$= 68\ cal/g.$$

127. Heat required to convert H_2O at 0° to H_2O at 100° = m_1c_1t

$$= 30 \times 4186 \times 100$$

$$= 1255800\ J$$

Heat required to convert H_2O at 100°C to steam at 100°C is = mL

$$= 3 \times 2.256 \times 10^6$$

$$= 6768000\ J$$

$$\text{Total heat} = 8023800\ J$$

128. $$\text{Thermal stress} = K x\ \text{strain} = \frac{K\Delta V}{V}$$

Now, $$\gamma = \frac{\Delta V}{V\Delta T} \text{ or } \frac{\Delta V}{V} = \gamma\Delta T$$

$$\text{Thermal stress} = K\gamma\Delta T = 3K\alpha\Delta T \qquad [\because \gamma = 3\alpha]$$

$$= 3 \times 140 \times 10^9 \times 1.7 \times 10^{-5} \times 20$$

$$= 1.428 \times 10^8\ Nm^2$$

❑❑