MECHANICS OF SOLID AND FLUID

- **Deforming force**:- A force acting on a body which produces change in its shape of body instead of its state of rest or uniform motion of the body.
- **Elasticity:**-The property of matter by virtue which it regains its original shape and size, when the deforming forces are removed is called elasticity.
- **Plasticity**:- The inability of a body to return to its original shape and size, when the deforming forces are removed is called plasticity.
- **Hooke's law**:- when a wire is loaded within elastic limit, the extension produced in wire is directly proportional to the load applied.

  OR

  Within elastic limit stress α strain

  $\frac{\text{Stress}}{\text{Strain}} = \text{Constant}$

- **Stress** :- Restoring force set up per unit area when deforming force acts on the body

  $$\text{Stress} = \frac{\text{Restoring force}}{\text{Area}}$$

  S.I Unit of stress = N/m^2 or Pascal (Pa)

  Dimensional formula = $M^a L^b T^c$

Types of stress:-

- Stress
  - Normal stress
    - Tensile stress(When there is an increase in dimension of the body along the direction of force)
    - Compression stress(when there is decrease in dimension)
  - Tangential stress (When deforming force acts tangential to the surface of body)

Strain:- The ratio of change in dimension to the original dimension is called strain

It has no unit

Types of strain:-

- Longitudinal strain= $\frac{\text{Change in Length}}{\text{Original Length}}$
- Volumetric strain = $\frac{\text{Change in Volume}}{\text{Original Volume}}$
- Sharing Strain = φ =$\frac{\Delta L}{L}$, Where ΔL =displacement of the face on which force is applied and L is the height of the face

Hooke's L aw:- Within elastic limit, stress α strain

$$\frac{\text{Strss}}{\text{Strain}} = \text{Constant (Modulus of Elasticity)}$$

Modulus of elasticity are of 3 types.

(1) **Young's Modulus (Y)** = $\frac{Normal\ stress}{Longitudinal\ Strain}$

(2) **Bulk Modulus (K)** = $\frac{Normal\ stress}{Volumetric\ Strain}$

(3) **Modulus of rigidity modulus (η)** =$\frac{Tangential\ stress}{Shearing\ \ Strain}$

- **Compressibility** : the reciprocal of bulk modulus of a material is called its compressibility

  Compressibility = 1/K

  Stress – Strain- diagram
- **Proportionality limit(P)** – The stress at the limit of proportionality point P is known as proportionality limit
- **Elastic limit** - the maximum stress which can be applied to a wire so that on unloading it return to its original length is called the elastic limit
- **Yield point(Y)-** The stress, beyond which the length of the wire increase virtually for no increase in the stress
- **Plastic region**- the region of stress- strain graph between the elastic limit and the breaking point is called the plastic region.

- **Fracture point or Breaking point(B)-** the value of stress corresponding to which the wire breaks is called breaking point
- **Work done in stretching a wire per unit volume/energy sored per unit volume of specimen**

  = ½ x stress x strain
- **Elastic after effect:-** The delay in regaining the original state by a body after the removal of the deforming force is called elastic after effect.
- **Elastic fatigue**:- the loss in strength of a material caused due to repeated alternating strains to which the material is subjected.
- **Poisson's ratio(ϭ)** :- The ratio of lateral strain to longitudinal strain is called

$$\text{Poisons ratio} = \frac{\text{Lateral Strain}}{\text{Longitudinal Strain}}$$

- Relation between Y,K,¶, ϭ
  1. Y=3K(1-2 ϭ)
  2. Y=2¶(1+ ϭ)
  3. $ϭ = \frac{3k-2¶}{2¶+6k}$
  4. $\frac{9}{\gamma}$ = 1/K +3/¶
- Applications of elasticity

1. Metallic part of machinery is never subjected to a stress beyond the elastic limit of material.
2. Metallic rope used in cranes to lift heavy weight are decided on the elastic limit of material
3. In designing beam to support load (in construction of roofs and bridges)
4. Preference of hollow shaft than solid shaft
5. Calculating the maximum height of a mountain

MECHANICS OF FLUID

- **Pressure** :The force/threat acting per unit area is called pressure

  S.I Unit of pressure is N/M^2 or pascal (Pa)

Dimensional formula ($ML^{-1}T^{-2}$)

- **Pascal's law:**- Pressure applied to an enclosed fluid is transmitted to all part of the fluid and to the wall of the container.
- **Application of Pascal's law:-**

  (1) Hydraulic lift, presses etc.

  (2) Hydraulic brakes
- **Pressure exerted by liquid column**:- $P = h\rho g$, where h= depth of liquid, ρ=density , g=acc$_n$. due to gravity.
- **Variation of pressure with depth**: $P = P_a + h\rho g$, where P_a =atmospheric pressure
- **Atmospheric pressure**:- The pressure exerted by atmosphere is called atmospheric pressure.

  At sea level, atmospheric pressure= 0.76m of Hg column

  Mathematically 1 atm = 1.013×10^5 Nm^{-2}
- **Archimedes' principle**:- It states that when a body is immersed completely or partly in a fluid, it loses in weight equal to the weight of the fluid displaced by it.

  Mathematically: Apparent weight = True weight – $V\rho g$

  Where V is volume of fluid displaced, ρ is its density.
- **Viscosity**:- It is the property of liquid (or gases) due to which a backward dragging force acts tangentially between two layers of liquid when there is relative motion between them.
- **Newton's formula for Viscous force**:- the viscous force between two liquid layer each of area A and having a velocity gradient dv/dx is

  $$F = \eta A (dv/dx)$$, where **η** is coefficient of viscosity
- **Coefficient of viscosity**:- It is define as the tangential viscous force which maintains a unit velocity gradient between two parallel layers each of unit area

  S.I unit of coefficient of viscosity is poiseuille or pascal-second

- **Poiseuille's equation**:- when a liquid of coefficient of viscosity flows through a tube of length 'l' and radius r, then the volume of liquid following out per second is given

  $$V = \pi P r^4 / 8 \eta l \ ,$$

  Where P is the difference of pressure between the two ends of the tube.
- **Stoke's law**: The backward dragging force acing on a small sphere of radius r falling with uniform velocity *v* through a medium of coefficient of viscosity is given by

  $$F = 6\pi \eta r v$$

- **Terminal velocity**:- It is the maximum constant velocity acquired by the body while falling freely in a viscous medium

  The terminal velocity v of a spherical body of radius r and density ϭ while falling freely in a viscous medium of viscosity ¶ , density is given by

  $$V = \frac{2}{q} \frac{r2}{\eta} (ϭ - \rho) g$$

- **Stream line**:- It is the path, straight or curved, the tangent at any point to which given the direction of the flow of liquid at that point
- **Tube of flow**:- A tube of flow is a bundle of stream lines having the same velocity of fluid elements over any cross section perpendicular to the direction of flow
- **Stream line flow**:- the flow of the liquid in which each molecule of the liquid passing through a point travels along the same path and with the some velocity as the preceeding molecule passing through the same point
- **Laminar flow**:- the flow of liquid, in which velocity of the layer varies from maximum at the axis to minimum for the layer in contact with the wall of the tube is called laminar flow.
- **Turbulent flow**:- It is the flow of liquid in which a liquid moves with a velocity greater than its critical velocity. The motion of the particles of liquid becomes disorderly or irregular.

- **Critical velocity**:- It is that velocity of liquid flow, upto which the flow of liquid is streamlined and above which its flow becomes turbulent. Critical velocity of a liquid (V_c) flowing through a tube is given by

$$\mathbf{V_c = K\eta / \rho\, r}$$

Where **ρ** is the density of liquid following through a tube of radius r and **η** the coefficient of viscosity of liquid

- **Reynold's umber**:- It is a pure number which determines the nature of flow of liquid through a pipe

Quantitatiively Renold's number N = $\boldsymbol{\rho} D V_c / \boldsymbol{\eta}$

Where **η** is coefficient of viscosity of liquid , **ρ** is density of liquid D is the diameter of the tube, V_c is critical velocity

For stream line flow, Reynold's number <2000

For turbulent flow, Reynold's number > 3000

For uncertain flow, 2000<Reynold's number<3000

- **Theorem of continuity** : If there is no source or sink of the fluid along the length of the pipe, the mass of the fluid crossing any section of the pipe per second is always constant

Mathematically $a_1 v_1 \rho_1 = a_2 v_2 \rho_2$

It is called the equation of continuity

For in compressible liquid $\rho_1 = \rho_2$ Therefore the equation continuity becomes

$$a_1 v_1 = a_2 v_2$$

Bernoulli's theorem:- It states that for an in compressible non-viscous liquid in steady flow, the total energy i.e. pressure energy, potential energy and kinetic energy remains constant its flow.

Mathematically $\frac{P}{\rho} + gh + \frac{1}{2} v^2$ = Constant

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

The term $\frac{P}{\rho g}$, h and $\frac{v2}{2g}$ are called pressure head, gravitational head and velocity head respectively.

- **Application of Bernoull's theorem**

  (i) Working of Bunsen burner

  (ii) Lift of an air foil

  (iii) Spinning of ball (Magnus effect)

  (iv) Sprayer

  (v) Ping pong ball in air jet.

- **Toricelli's theorem/speed of efflux**:-It states that the velocity of efflux i.e. the velocity with which the liquid flows out of an orifice (i.e. a narrow hole) is equal to that which is freely falling body would acquire in falling through a vertical distance equal to the depth of orifice below the free surface of liquid.

  Quantitatively velocity of efflus

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

  Venturimeter:- It is a device use to measure the rate of flow of liquid. Venturimeter consists of a wide tube having a constriction in the middle. If a_1 and a_2 are the areas of cross section of the wide end and the threat, p_1 and p_2 are the pressure of liquid, then velocity of the liquid entering at the wide end is given by $V_1=a_2 \quad \sqrt{} 2(P_1-P_2)\ \rho(a_1^2-a_2^2)$

- **Surface tension (T)** :- It is the property of a liquid by virtue of which, it behaves like an elastic stretched membrane with a tendency to contract so as to occupy a minimum surface area

  Mathematically $T = F/l$

  S.I Unit is : Nm^{-1} Dimensional formula : ML^0T^{-2}

  Surface Energy : The potential energy per unit area of the surface film is called the surface energy.

$$\text{Surface energy} = \frac{Work\ done\ in\ increasing\ the\ surface\ area}{Increase\ in\ area}$$

Surface tension is numerally equal to surface energy

- **Excess of pressure inside a drop and double**:- There is excess of pressure on concave side of a curved surface
  1. Excess of pressure inside a liquid drop = 2T/R
  2. Excess of pressure inside a liquid bubble = 4T/R
  3. Excess of pressure inside an air bubble = 2T/R, Where T is the surface tension , R = radius of liquid drop
- **Angle of contact**:- The angle which the tangent to the free surface of the liquid at the point of contact makes with the wall of the containing vessel, is called the angle of contact

  For liquid having convex meniscus, the angle of contact is obtuse and for having concave meniscus, the angle of contact is acute.
- **Capillary tube**:- A tube of very fine bore is called capillary tube
- **Capillarity**:-The rise or fall of liquid inside a capillary tube when it is dipped in it is called capillarity
- **Ascent formula**:- when a capillary tube of radius 'r' is dipped in a liquid of density *s* and surface tension T, the liquid rises or depresses through a height,

$$H= 2T\cos\theta \ /r \rho \ g$$

  There will be rise a liquid when angle of contact θ is acute. There will be fall in liquid when angle of contact θ is obtuse.

Thermal expansion and calorimetry

- Heat- it is a form of energy, which produce in us the sensation of warmth
- Temperature:- The degree of hotness or coldness of a body is called temperature
- Thermometer- It is a device used to measure the temperature of a body
- Scales of temperature:- there are four scales of temperature. Given below is scales of temp with lower and upper fixed point

  <u>Temperature scales</u> <u>Lower fixed point (Melting point office)</u> <u>Upper fixed point (Boiling point of water)</u>

1. Celsius	0^0C	100^0C
2. Fahrenheit	32^0F	212^0F
3. Reamur	0^0R	80^oR
4. Kelvin	273K	373K

- **Relation between the various temperature scales**

  If C,F, R and K are temperature of a body on Celsius, Fahrenheit , Reumer and Kelvin scale, then

  $$C/5 = F-32/9 = R/4 = K-273/5$$

- **Thermal expansion**:- all solid expands on heating. There are three types of expansion.

  (1) Liner expansion- When a solid rod of initial length 'l' is heated through a temperature ΔT then its new length $l' = l(1+\alpha\Delta T)$, where α is called coefficient of liner expansion

  (2) Superficial expansion- when a solid of initial surface area A is heated through temperature then its new Area is $A' = A(1 + \beta\Delta T)$, where β is coefficient of superficial expansion

  (3) Cubical expansion- when a solid of initial volume V is heated through a temperature ΔT then its new volume is $V' = V(1 + \Upsilon\Delta T)$,where ϒ is the coefficient of cubical expansion.

- Relation between α ,β and ϒ

  $$\alpha = \beta/2 = \Upsilon/3$$

- In case of liquid $\Upsilon_r = \Upsilon_a + \Upsilon_g$

  Where Υ_r=Coefficient of real expansion of a liquid

  Υ_a= Coefficient of apparent expansion of liquid

  Υ_g= Coefficient of cubical expansion of the vessel

  Thermal capacity = It is the amount of heat required to raise its temperature through one degree

- **Water equivalent** :- It is the mass of water which absorbs or emits the same amount of heat as is done by the body for the same rise or fall in temperature. It is represented by W = mc

- **Specific heat** :- It is the amount of heat required to raise the temperature of unit mass of substance through unit degree Celsius

$$C = \Delta Q / m\Delta T$$

- **Latent heat** :- It is define as the quantity of heat required to change the unit mass of the substance from its one state completely to another state at constant temperature

  Mathematically Q = ML

- *Types of Latent heat* → Latent heat of fusion (L_f)
  → Latent heat of vaporization (L_v)

- **Calorimeter** :- Device used for measuring heat
- **Principle of calorimetry** :- Heat loss by hot body = Heat gain by cold body
- **Transfer of heat** :- there are three modes by which heat transfer takes place

  (1) **Conduction**:- It is the process by which heat is transmitted from one point to another through a substance in the direction of fall of temperature without the actual motion of the particles of the substance. When two opposite faces of a slab, each of cross section A and separated by a distance d are maintained at temperature T_1 and T_2 ($T_1 > T_2$), then amount of heat that flows in time t

  $\mathbf{Q = K A (T_1 - T_2) t/d}$ Where K is coefficient of thermal conductivity of the mater

- **Coefficient of thermal conductivity**:- It may be defined as the quantity of heat energy that flows in unit time between the opposite faces of a cube of unit side, the faces being kept at one degree difference of temperature

  S.I unit of coefficient of thermal conductivity : $J\ S^{-1} m^{-1} K^{-1}$ or $W\ m^{-1} K^{-1}$

  (2) **Convection**:- It is the process by which heat is transmitted through a substance from one point to another due to the bodily motion of the heated particles of the substance.

  (3) **Radiation**:- It is the process by which heat is transmitted from one place to another without heating the intervening medium

- **Newton's laws of cooling**:- It states that the rate of loss of heat or rate of cooling of a body is directly proportional to the temperature difference between the body and the surrounding, provided the temperature difference is small

  Mathematically $-dQ/dt = K(T-T_0)$
- **Perfect black body**:- It is a body which absorbs heat radiations of all the wavelengths, which fall on it and emits the full radiation spectrum on being heated.
- **Stefan's law:-** It states that the total amount of heat energy radiated per unit area of a perfect black body is directly proportional to the fourth power of the absolute temperature of the substance of the body

  Mathematically $E \alpha T^4$

  $E = \Sigma T^4$ Where is called Stefan's constant

  It's value is 5.67×10^{-8} $JS^{-1}m^{-2}k^{-4}$

Wein's displacement law:- According to this law, the wavelength λ_m of maximum intensity of emission of black body radiation is inversel y proportional to absolute temperature (T) of black body.

$$\lambda_m \ \alpha \frac{1}{T}$$

$\boldsymbol{\lambda_m T = b}$ where b is wien's constant

Questions with **(mark) are HOTs Question

<u>1 MARK QUESTIONS</u>

Q.1 A wire is stretched by a force such that its length becomes double. How will the Young's modulus of the wire be affected?

Ans. Young's modulus remains the same.

Q.2 How does the Young's modulus change with rise in temperature?

Ans. Young's modulus of a material decreases with rise in temperature.

Q.3 Which of the three modulus of elasticity – Y, K and η is possible in all the three states of matter (solid, liquid and gas)?

Ans. Bulk modulus (K)

Q.4 The Young's modulus of steel is much more than that for rubber. For the same longitudinal strain, which one will have greater stress?

Ans. Stress= Y X longitudinal strain. So steel will have greater stress.

Q.5 Which of the two forces – deforming or restoring is responsible for elastic behavior of substance?

Ans. Restoring force.

Q.6. Which mode of transfer of heat is the quickest?

Ans. Radiation.

** Q. 7 A boat carrying a number of large stones is floating in a water tank. What will happen to the level of water if the stones are unloaded into the water?

Ans. The level of water will fall because the volume of the water displaced by stones in water will be less than the volume of water displaced when stones are in the boat.

Q.8. A rain drop of radius r falls in air with a terminal velocity v. What is the terminal velocity of a rain drop of radius 3r ?

Ans. $v = \frac{2r^2(\varsigma-\sigma)g}{9\eta}$ v α r^2

$\frac{v_2}{v_1} = \left(\frac{r_2}{r_1}\right)^2$ → $v_2 = \left(\frac{3r}{r}\right) v_1^2 = 9v_1$

**Q. 9 When air is blown in between two balls suspended close to each other , they are attracted towards each other. Why?

Ans. On blowing air between the two balls, the air velocity increases, decreasing pressure. The pressure on the outer side of the ball being more will exert forces on the balls, so they move towards each other.

Q.10. Why does air bubble in water goes up?

Ans. The terminal velocity , $v = \frac{2r^2(\varsigma-\sigma)g}{9\eta}$ As the density of air ς is less than density of water σ, the terminal velocity is negative. For this reason air bubbles moves upward.

2 MARKS QUESTIONS

Q.11 Steel is more elastic than rubber. Explain.

Ans. Consider two wire, one of steel and another of rubber having equal length L and cross sectional area A . When subjected to same deforming force F, the extension produce in steel is l_S and in rubber is l_R such that $l_R > l_S$.

Then $Y_s = \frac{FL}{Al_s}$ and $Y_r = \frac{FL}{Al_r}$

$\frac{Y_s}{Y_r} = \frac{l_r}{l_s}$

As $l_s < l_r \rightarrow Y_s > Y_r$

Hence steel is more elastic.

Q.12. A wire stretches by a certain amount under a load. If the load and radius are both increased to four times, find the stretch caused in the wire.

Ans. For a wire of radius r stretched under a force F,

$Y = \frac{FL}{\pi r^2 L}$ or $l = \frac{FL}{\pi r^2 Y}$

Let l' be the extension when both the load and the radius are increased to four times, Then, $l' = \frac{4F \ X \ L}{\pi(4r)^2 L} = \frac{FL}{4\pi r^2 Y} = \frac{l}{4}$

Q. 13. Calculate the percentage increase in the length of a wire of diameter 2mm stretched by a force of 1kg F. Young's modulus of the material of wire is 15 X $10^{10}Nm^{-2}$.

Ans. F = 1 Kg F = 9.8N Y = 15 X $10^{10}Nm^{-2}$ $r = \frac{2}{2}$ = 1mm = 10^{-3}m

Cross section of wire , $\pi r^2 = \pi \ X \ (10^{-3})^2 = \pi \ X \ 10^{-6} m^2$

Now $Y = \frac{FL}{al}$

$$\frac{l}{L} = \frac{F}{aY} = \frac{9.8}{\pi \ X \ 10^{-6} \ X \ 15 \ X \ 10^{10}} = 2.1 \ X \ 10^{-5}$$

Percentage increase = 2.1 X 10^{-5} X 100 = 0.0021%

Q. 14. The pressure of a medium is changed from 1.01 X 10^5 pa to 1.165 X 10^5 pa and changed in volume is 10% keeping temperature constant. Find the bulk modulus of the medium.

Ans. Here $\Delta p = 1.165 \ X \ 10^5 - 1.01 \ X \ 10^5 = 0.155 \ X \ 10^5$pa

$$\frac{\Delta V}{V} = 10 \% = 0.1$$

Now $K = \frac{\Delta P}{\frac{\Delta V}{V}} = \frac{0.155 \ X \ 10^5}{0.1} = 1.55 \ X \ 10^5$ pa

Q.15. 27 identical drops of water are falling down vertically in air each with a terminal velocity of 0.15m/s. If they combine to form a single bigger drop, what will be its terminal velocity?

Ans. Let r = radius of each drop, v = 0.15 m/s

Now $v = \frac{2r2(\varsigma - \sigma)g}{9\eta}$ -------------------------------------(1)

Let R be the radius of the big drop.

Volume of big drop = Volume of 27 small drops

$\frac{4}{3}\pi R^3$ = 27 X $\frac{4}{3}\pi r^3$

R = 3r

Let v_1 be the terminal velocity of bigger drop

$$v_1 = \frac{2R^2(\varsigma-\sigma)g}{9\eta} \text{ ------------------------------------(2)}$$

$$\frac{v_1}{v} = \frac{R^2}{r^2} = 9$$

v_1 = 9v = 9 X 0.15 = 1.35 m/s

Q.16. Water flows through a horizontal pipe line of varying cross section at the rate of $0.2m^3s^{-1}$. Calculate the velocity of water at a point where the area of cross section of the pipe is $0.02m^2$.

Ans. Rate of flow = av

$$v = \frac{Rate\ of\ flow}{a}$$

Rate of flow = $0.2m^3s^{-1}$ a = $0.02m^2$

$$v = \frac{0.2m^s s^{-1}}{0.02\text{m}^2} = 10 \text{ ms}^{-1}$$

Q. 17. A cylinder of height 20m is completely filled with water. Find the efflux water (in m s-1) through a small hole on the side wall of the cylinder near its bottom. Given g = 10m/s.

Ans Here h = 20m , g = 10 m/s

Velocity of efflux , v = $\sqrt{2gh}$ = $\sqrt{2\ X\ 10\ X\ 20}$ = 20m/s

**Q.18. At what common temperature would a block of wood and a block of metal appear equally cold or equally hot when touched?

Ans. When touched an object appear cold if heat flows from our hand to the object. On the other hand it appears hot, if heat flows from the object towards our hand. Therefore a block of wood and block of metal will appear equally cold or equally hot if there is no exchange of heat between hand and the block. So the two blocks will appear equally cold or equally hot if they are at the same temperature as that of our hands i.e. the temperature of our body.

Q.19. A piece of chalk immersed into water emits bubbles in all directions. Why?

Ans. A piece of chalk has extremely narrow capillaries. As it is immersed in water, water rises due to capillary action. The air present in the capillaries in the chalk is forced out by the rising water. As a result bubbles are emitted from the chalk in all the directions.

3 MARKS

Q. 20. Water at a pressure of 4×10^4 Nm-2 flows at $2ms^{-1}$ through a pipe of $0.02m^2$ cross sectional area which reduces to $0.01m^2$. What is the pressure in the smaller cross section of the pipe?

Ans.

$$a_1v_1 = a_2v_2$$

$$v_2 = \frac{a_1v_1}{v_2} = \frac{0.02 \times 2}{0.01} = 4m/s$$

Again $\frac{P_1}{\varsigma} + \frac{1}{2}v_1^2 = \frac{P_2}{\varsigma} + \frac{1}{2}v_2^2$

$$P_1 = P_2 - \frac{1}{2}\varsigma\,(v_1^2 - v_2^2)$$

$P_1 = 3.4 \times 10^4 Nm^{-2}$

Q.21. What is surface tension and surface energy? Derive the relation between surface tension and surface energy.

Q.22. Derive equation of continuity for steady and irrotational flow of a perfectly mobile and incompressible fluid. What conclusion is drawn from it?

Q.23 What is Stoke's law? Derive the relation by the method of dimension.

Q.24. A piece of iron of mass 0.1 kg is kept inside a furnace, till it attains the temperature of the furnace. The hot piece of iron is dropped into a calorimeter containing 0.24 Kg of water at 20℃. The mixture attains an equilibrium temperature of 60℃. Find the temperature of the furnace. Given water equivalent of calorimeter = 0.01 kg and specific heat of iron = 470 J Kg^{-1} $K^{-1.}$

Ans. Let θ_1 be the temperature of the furnace i.e of the piece of iron.

Heat lost by the piece of iron $Q = M_1C_1 (\theta_1 - \theta)$

Here M_1 = 0.1 Kg C_1 = 470 J Kg^{-1} K^{-1} $\theta = 60$℃

$Q = 0.1 \times 470 (\theta_1 - 60) = 47 (\theta_1 - 60)$ ------------------------- (1)

Heat gain by water and the calorimeter , $Q = (M_2 + w) C_2 (\theta - \theta_2)$

M_2 = 0.24 Kg w = 0.01 Kg θ_2 = 20℃ C_2 = Specific heat of water = 4200 J Kg^{-1} K^{-1}

$Q = (0.24 + 0.01) \times 4200 \times (60 – 20) = 42000$ -------------------------(2)

From (1) and (2) $47 (\theta_1 - 60) = 42000$

$\theta_1 = 953.62$ ℃

**Q. 25. Calculate the energy spent in spraying a drop of mercury of 1 cm radius into 10^6 droplets all of same size. Surface tension of mercury is 35×10^{-3} Nm^{-1}.

Ans. $T = 35 \times 10^{-3}$ Nm^{-1} R = 1 cm

Let r be the radius of each small drop, when the original drop is spitted into 10^6 small drops.

Then $10^6 \times \frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3$

$$r = 10^{-2} R$$

$$r = 10^{-2} \times 1 = 10^{-2} \text{ cm}$$

Initial surface area of the original drop $= 4\pi R^2 = 4\pi \times 1^2 = 4\pi cm^2$

Final surface area of the 10^6 small drops $= 10^6 \times 4\pi r^2 = 10^6 \times 4\pi \times (10^{-2})^2 = 400\,\pi\ cm^2$

Therefore increase in surface area $= 400\,\pi - 4\pi = 396\,\pi cm^2 = 396\pi \times 10^{-4} m^2$

Therefore energy spent = T X increase in surface area $= 35 \times 10^{-3} \times 396\pi \times 10^{-4} = 4.354 \times 10^{-3}$N

Q.26. A liquid takes 10 minutes to cool from 70℃ to 50℃. How much time will it take to cool from 60℃ to 40℃ ? The temperature of the surrounding is 20℃.

Ans. 1st case $\theta_1 = 70^0C$ $\theta_2 = 50^0C$ $\theta_0 = 20℃$ t = 10 minutes

Using $\frac{\theta_1 - \theta_2}{t} = k\,(\frac{\theta_1 + \theta_2}{2} - \theta_0)$, we get

$$\frac{20}{10} = k\,(60 - 20) = 40\,k$$

$$K = \frac{1}{20}$$

For 2nd case $\theta_1 = 60^0C$ $\theta_2 = 40^0C$ $\theta_0 = 20℃$ t = ?

Using $\frac{\theta_1 - \theta_2}{t} = k\,(\frac{\theta_1 + \theta_2}{2} - \theta_0)$, we get

$$\frac{20}{t} = \frac{1}{20}\,(50 - 20) = \frac{3}{2}$$

$$t = \frac{40}{3} = 13.33 \text{ minutes}$$

**Q. 28. A slab of stone of area $0.36m^2$ and thickness of 0.1m is exposed to the lower surface of steam at 100℃. A block of ice at 0℃ rest on the upper surface of the slab. In one hour 4.8 Kg of ice is melted. Calculate the thermal conductivity of stone.

Ans. Here A = $0.36m^2$, d = 0.1m , $T_1 - T_2$ = 100 – 0 = 100℃ t = 1hr = 3600 sec

Mass of ice melted M = 4.8 Kg

We know Latent heat of ice L = 336 X 10^3 J Kg^{-1}

Heat required to melt the ice Q = ML = 4.8 X 336 X10^3 = 1.613 X 10^6 K

Now $Q = \frac{KA(T_1 - T_2)t}{d}$

$$1.613 \times 10^6 = \frac{K \; X \; 0.36 \; X \; 100X \; 3600}{0.1}$$

K = 1.245 $wm^{-10}C^{-1}$

5 MARKS

Q. 28. Define capillarity and angle of contact. Derive an expression for the ascent of liquid inside a capillary tube where it is dipped in a liquid.

Q. 29. Show that there is always excess of pressure on the concave side of the meniscus of a liquid. Obtain the expression for the excess of pressure inside (i) a liquid drop (ii) liquid bubble.

Q. 30. State and prove the Bernoulli's principle. Give two practical application of it.

Q.31. Define terminal velocity. Show that the terminal velocity v of a sphere of radius r, density ς falling vertically through a viscous fluid of density **σ** and coefficient of viscosity η is given by

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

Q. 32. State and explain Hooke's law. A wire is fixed at one end and is subjected to increasing load at the other end. Draw a curve between stress and strain. With the help of the curve, explain the term elastic limit, yield point, breaking point and permanent set. How this curve does may be used to distinguish between ductile and brittle substances.