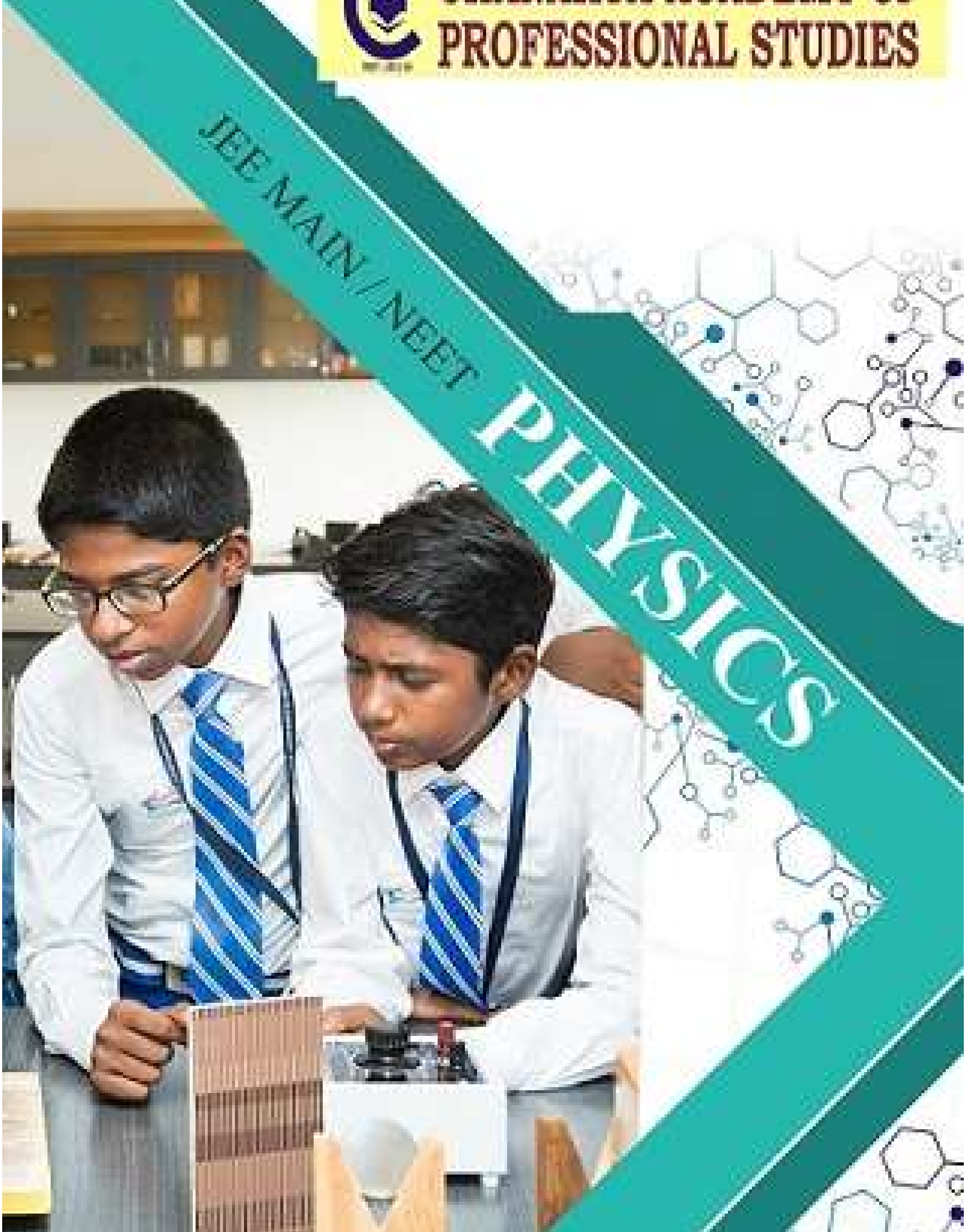
CHANAKYA ACADEMY OF PROFESSIONAL STUDIES

JEE MAIN / NEET

PHYSICS



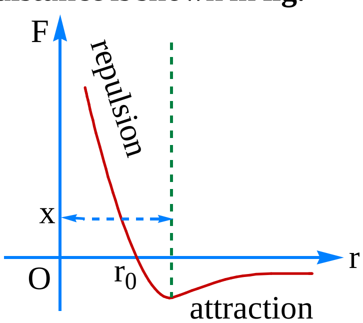
MECHANICAL PROPERTIES OF SOLIDS

- Elasticity deals with property of a material , such as its strength and ability to withstand against external forces which are acting on it.

Inter Molecular Forces :

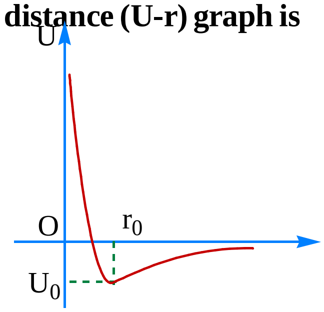
- The forces between the molecules due to electrostatic interaction between the charges of the molecules are called intermolecular forces. Thus intermolecular forces are also electromagnetic in nature. These forces are active if the separation between two molecules is of the order of molecular size $\left(\approx 10^{-9} m\right)$.

The variation of intermolecular forces with distance is shown in fig.



- For large distance r, the intermolecular force is negligible.
- As the distance decreases, the force of attraction increases.
- At a particular distance x, the force of attraction becomes maximum. After this distance, the force of attraction decreases and becomes zero at a distance r_0.
- Interatomic force is the force between two atoms or molecules due to electrostatic force of attraction between charges.

The variation of potential energy versus distance (U-r) graph is



r_0=Equilibrium distance

- Generally $U = \frac{a}{r^p} - \frac{b}{r^q}$, also $F = \frac{-dU}{dr}$

$$\therefore F = -\frac{d}{dr}\left[\frac{a}{r^p} - \frac{b}{r^q}\right] = \frac{pa}{r^{p+1}} - \frac{qb}{r^{q+1}}$$

where q, p are powers and a, b are constants.

- The positive term with constant 'a' indicates positive potential energy, the negative term with constant 'b' indicates negative potential energy.

EX-1: The potential energy function for the force between two atoms in a diatomic molecule is approximately given by $U(r) = \frac{a}{r^{12}} - \frac{b}{r^6}$, where a and b are constants and r is the distance between the atoms. If the dissociation energy of the molecule is $D = \left[U(r=\infty) - U_{at\ equilibrium}\right]$, D is

Sol. $U(r) = \frac{a}{r^{12}} - \frac{b}{r^6}, U(r=\infty) = 0$

as, $F=-\frac{dU}{dr}=-\left[\frac{-12a}{r^{13}}+\frac{6b}{r^{7}}\right]$

At equilibrium, $F=0, r^{6}=\frac{2a}{b}$

$$U_{at\ \ equilibrium}=\frac{a}{\left(\frac{2a}{b}\right)^{2}}-\frac{b}{\left(\frac{2a}{b}\right)}=\frac{-b^{2}}{4a}$$

$$\therefore D=\left[U(r-\infty)-U_{at\ \ equilibrium}\right]=\frac{b^{2}}{4a}$$

Rigid Body: A body whose size and shape cannot be changed, however large the applied force may be is called rigid body.

There is no perfectly rigid body in nature. The nearest approach to a perfect rigid body is **diamond.**

Deformation force :

The external force which changes the size or shape or both of a body without moving it as a whole is called deformation force.

Restoring force :

The internal force which restores the size and shape of the body when deformation force is removed is called restoring force.

- Magnitude of restoring force is equal to the deformation force.
- The restoring forces at a point do not form action, reaction pair with applied force. This force is responsible for the elastic nature of the body.

Elastic Behaviour of Solids

- In a solid, each atom or molecules are bonded together by interatomic or intermolecular forces and stay in a stable equilibrium position.
- When a solid is deformed, the atoms or molecules are displaced from their equilibrium positions causing a change in the interatomic distances. When the deforming force is removed, the inter-atomic forces tend to drive them back to their original positions. Thus the body regains its original shape and size.

Elasticity :

The property of a material by virtue of which it regains its original size and shape when deformation force is removed is called elasticity.

Ex : Quartz, Diamond, Steel, Rubber etc...

There is no perfectly elastic material exist in nature, but quartz is the nearest perfectly elastic material. Elasticity is molecular property of matter.

Plasticity :

The property of a material by virtue of which it does not regain its original size and shape after the deforming force is removed is called Plasticity.

Ex : Putty dough, Chewing gum, Soldering lead

- No material is perfectly plastic but putty is nearest approach for perfect plastic material.

Stress

- The restoring force acting per unit area is called stress.

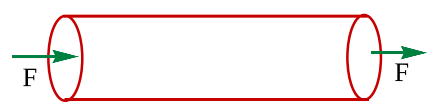
$$\text{Stress}=\frac{\text{restoring force}}{\text{area of cross section}}=\frac{F}{A}$$

SI Unit : N/m^2 (or) Pascal.

Dimensional formula : $M^1L^{-1}T^{-2}$

- Logitudinal stress is called tensile stress when there is an increase in length and compressive stress when there is a decrease in length.
- The normal stress developed due to elongation is called tensile stress.

- The normal stress developed due to compression is called compressive stress.

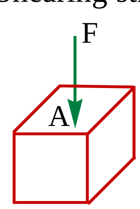


- If the force is normal to the surface, then the stress is called normal stress.

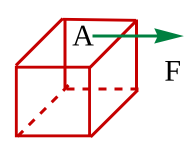
$$\text{Normal stress}=\frac{\text{Normal restoring force}}{\text{Area of cross section}}$$

- If the force is tangential to the surface, it is called tangential stress.
- The stress which changes the shape of the body is called shearing stress

$$\text{Shearing stress}=\frac{\text{Tangential restoring force}}{\text{Area of cross section}}$$



Fixed
Normal stress
(A)

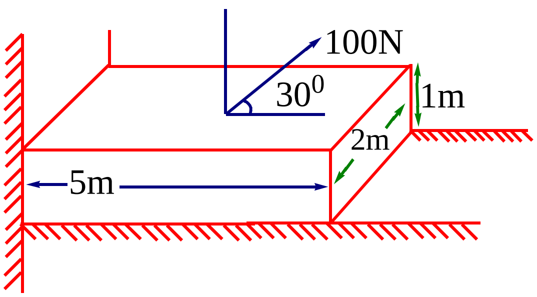


Fixed
Tangential stress
(B)

- Shearing stress is a tangential stress which produce change in shape.
- When normal stress changes the volume of the body then it is called volume stress (or) bulk stress. It is denoted by 'B'.
- Longitudinal stress, bulk stress are kinds of normal stresses which produce change in size.
- A hollow cylinder of inner and outer radii r_1 and r_2 respectively is placed vertically on the horizontal surface, stress at the bottom of the cylinder is

$$\frac{mg}{\pi\left(r_2^2 - r_1^2\right)}$$

EX-1a: A uniform rope of mass M and length L, on which a force F is applied at one end, then find stress in the rope at a distacne x from the end where force is applied?



Sol. Longitudinal or normal stress

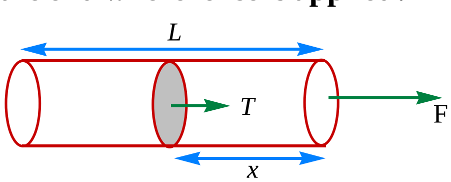
$$\Rightarrow \sigma_1 = \frac{100\sin 30^0}{5\times 2} = 5\mathrm{N/m^2}$$

Tangential stress

$$\Rightarrow \sigma_1 = \frac{100\cos 30^0}{5\times 2} = 5\sqrt{3}\mathrm{N/m^2}$$

EX-2: A uniform rope of mass M and length L, on which a force F is applied at one end, then find stress in the rope at a distacne x from the end where force is applied?

Sol.



$\frac{M}{L}$ = mass per unit length

From $F = Ma \Rightarrow a = \frac{F}{M}$

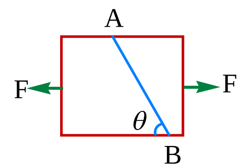
Tension, $T = \frac{M}{L}(L-x)a$

$$T = \frac{M}{L}(L-x) = \frac{F}{M} = \frac{F}{L}(L-x)$$

$$\text{Stress} = \frac{T}{A} = \frac{A}{A}\left(1-\frac{x}{L}\right)$$

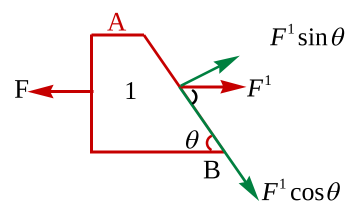
Where tension T and are A must be perpendicular for tensile stress.

EX-3: Two equal and opposite forces F and -F act on a rod of uniform cross-sectional area A, as shown in the figure. Find the (i) shearing (ii) longitudinal stress on the section AB.



Sol. (i) As the force acting on the rod is zero, it is in equilibrium. Let the tension in the segment AB be F^1. Applying Newton's 2nd law for the segment 1

$$F_{net} = F^1 - F = ma,$$



Where, a=0; this gives, F^1=F

Resolving the force F^1 parallel and perpendicular to the given area AB(=A^1, say),

we have $F_{tan} = F^1\cos\theta; F_{long} = F^1\sin\theta$

Then, $P_{shearing} = \frac{F_{tan}}{A^1} = \frac{F^1\cos\theta}{A^1}$

where, $A^1 = \frac{A}{\sin\theta}$ *and* $F^1 = F$

This gives, $P_{shearing} = \frac{F\sin\theta\cos\theta}{A}$

ii) Similarly, $P_{long} = \frac{F_{long}}{A^1}$

$= \frac{F^1\sin\theta}{A^1}$ where $A^1 = \frac{A}{\sin\theta}$ and $F^1 = F$

This gives, $P_{long} = \frac{F}{A}\sin^2\theta$

can withstand a stress of $0.9\times10^8 N/m^2$. Calculate

the Young's modulus of material of the bone.

Sol. Mass=40Kg, area of each leg=4cm^2=4x10^{-4}m^2
breaking stress = 0.9 x 10^8 N/m^2,
length of each leg = 50 cm = 50 x 10^{-2} m.

From $E = \frac{1}{2} \times \frac{(stress)^2}{Y} \times A \times L$

Where elastic energy of bone in the form of potential energy, E=mgh; For two legs.

$$mgh = 2\left(\frac{1}{2} \times \frac{stress^2}{Y} \times volume\right),$$

$$Y = \frac{(0.9\times10^8)^2 \times 4\times10^{-4} \times 50\times10^{-2}}{40\times9.8\times2}$$

$= 2.05\times10^9\ N/m^2$

EX-29: A copper wire 2m long is stretched by 1mm. If the energy stores in the stretched wire is converted into heat, then calculate the rise in temperature of the wire.

$(Y = 12.5\times10^{10}\ N/m^2;$

$\rho = 9\times10^3 kg/m^3; s = 385 J/Kg-K)$

Sol. $ms\Delta t = \frac{1}{2}Y(strain)^2 \times \frac{m}{\rho}$

$$\Delta t = \frac{1}{2} \times \frac{Y}{s\rho} \times \left(\frac{e}{\ell}\right)^2$$

$$\Delta t = \frac{1}{2} \times \frac{12.5\times10^{10}}{9\times10^3\times385} \times \left[\frac{1}{1000\times2}\right]^2 = 0.0045^0 C$$

So the rise in temperature of the wire is 0.0045^{0}C

EX-30: A catapult consists of two parallel rubber cords each of length 20 cm and cross-sectional are 5 cm^2. When stretched by 8 cm, it can throw a stone of mass 4gm to a vertical height 5 m, the Young's modulus of elasticity of rubber is $\left[g = 10 m/\sec^2\right]$

Sol. The total elastic potential energy is converted into gravitational potential energy

$$\frac{1}{2} \times \frac{YAe^2}{L} = mgh \Rightarrow Y = \frac{2mghL}{Ae^2}$$

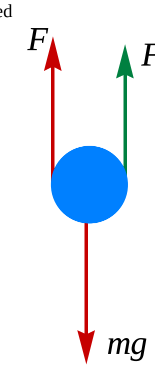
for a single string, $Y = \frac{mghL}{Ae^2}$

$$= \frac{4\times10^{-3}\times10\times5\times20\times10^{-2}}{5\times10^{-4}\times(8\times10^{-2})^2} = \frac{4\times10^{-2}}{5\times64\times10^{-8}}$$

$= 1.25\times10^4\ N/m^2$

EX-31: A uniform cylinder of length L and mass m having cross-sectional area A is suspended with its length vertical from a fixed point by a mass less spring, such that it is half submerged in a liquid of density at equilibrium position, the extension x_0 of the spring when it is in equilibrium is [AIEEE-13]

Sol. $F = Kx_0$ [restoring force in spring]
F_B=buoyant force = $(mg)_{\text{liq displaced}}$
$= \frac{AL}{2}\sigma g$, at equilibrium F_{net}=0



From free body diagram,

$$Kx_0 + \frac{AL}{2}\sigma g = mg$$

$$\Rightarrow Kx_0 = mg - \frac{AL}{2}\sigma g$$

$$x_0 = \frac{mg}{K}\left[1 - \frac{AL\sigma}{2m}\right]$$

Spring :

- For a given spring $F \propto x$; $F = kx$; $k = \frac{F}{x}$

k is called spring constant (or) force constant (or) stiffness constant.
Spring constant interms of Young's modulus area of cross section and length $k = \frac{yA}{\ell}$.

- P.E. of a streched spring

$$E = \frac{1}{2}Kx^2 = \frac{1}{2}Fx = \frac{F^2}{2K}$$

- Springs in series, $K_{eff} = \frac{K_1K_2}{K_1+K_2}$
- Springs in parallel , $K_{eff} = K_1 + K_2$
- Two springs having force constants K_1 & K_2 (K_1>K_2) are stretched by same amount then more work is done on the first spring $W \propto K$.
- Two springs having force constants K_1,K_2(K_1>K_2) are stretched by same force then

THEORY BITS

Elastic behaviour

1. **Reason for the deformation of a regular body is**
   1) bulk strain 2) shearing strain
   3) linear strain 4) lateral strain

2. **For a gas elastic limit**
   1) Exists 2) Does not exist
   3) Exists only at absolute zero
   4) Exists for a perfect gas

3. **Which of the following effect the elasticity of a substance**
   1) hammering and annealing
   2) change in temperature
   3) impurity in substance 4) all of these

Stress & Strain

4. **A spiral spring is stretched by a force, the resultant strain produced in the spring is**
   1) Volume strain 2) Longitudinal strain
   3) Shearing strain 4) All the above

5. **Three wires A, B, C made of different materials elongated by 1.5,2.5,3.5 mm, under a load of 5kg. If the diameters of the wires are the same, the most elastic material is that of**
   1) A 2) B 3) C 4) A, B & C are correct

6. **The modulus of elasticity is dimensionally equivalent to**
   1) Sress 2) Surface tension
   3) Strain 4) Coefficient of viscosity

7. **Modulus of elasticity for a perfectly elastic body is**
   1) Zero 2) infinity 3) 1 4) 2

8. **The only elastic modulus that applies to fluids is**
   1) young's modulus 2) bulk modulus
   3) modulus of rigidity 4) all the above

9. **As temperature increases the Young's modulus , the material of a wire**
   1) increases 2) decreases
   3) remains the same 4) becomes infinite

10. **If stress is numerically equal to young's modulus, the elongation will be**
    1)1/4 the original length
    2)1/2 the original length
    3)equal to the original length
    4)Twice the original length

11. **A wire elongates by1 mm when a load W is hung from it. If the wire goes over a pulley and the elongation of the wire will be**
    1) 0.5mm 2) 1 mm 3) 2mm 4) 4mm

12. **An iron bar of length L. cross-ssection A and Young's modulus Y is pulled by a force F from ends so as to produce and elongation l. Which of the following statements is correct?**
    1) $l\alpha\frac{1}{L}$ 2) $l\alpha A$ 3) $l\alpha\frac{1}{A}$ 4) $l\alpha Y$

13. **The bulk modulus for an incompressible liquid is**
    1) infinity 2) unity 3) zero 4) between 0 and 1

14. **Shearing strain is expressed by**
    1) angle of twist 2) angle of shear
    3) decrease in volume 4) increase in volume

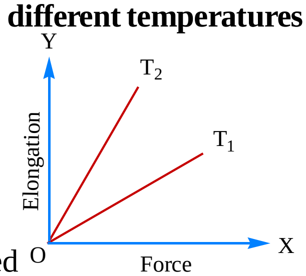
15. **Breaking force per unit area of cross section of a wire is called**
    1) Yield point 2) Tensile stress
    3) Ductility 4) Breaking stress

16. **The property of metals whereby they could be drawn into thin wires beyond their elastic limit without breaking is**
    1) Ductility 2) Malleability 3) Elasticity 4) Hardness

17. **The breaking stress of a wire depends upon**
    1)material of the wire 2)length of the wire
    3)radius of the wire 4)shape of the cross section

18. **A wire can sustain the weight of 40kg before breaking. If the wire is cut into 4 equal parts, each part can sustain a weight of....kg**
    1) 40 2) 160 3) 10 4) 20

19. **Force vs elongation graph of a wire is shown in the figure. At two different temperatures T_1 & T_2 then**



    1) $T_1 = T_2$
    2) $T_1 < T_2$
    3) $T_1 > T_2$
    4) cannot be predicted

20. **If the length of the wire is doubled the strain produced is**
    1) 0.5 2) 1 3) 0.25 4) 2

21. **A copper and steel wire of same diameter and length are connected end to end and a force is applied which stretches their combined length by 1cm, the two wires will have**
    1)The same stress and strain
    2)The same strain but different stresses
    3)The same stress but different strains
    4)different stress and strains

THEORY BITS-KEY

01) 2	02) 2	03) 4	04) 3	05) 1	06) 1
07) 2	08) 2	09) 2	10) 3	11) 2	12) 3
13) 1	14) 2	15) 4	16) 1	17) 1	18) 1
19) 2	20) 2	21) 3			

MODULE-1
(CLASS WORK)

Stress & Strain

1. A 20 Kg load is suspended by a wire of cross section 0.4 mm². The stress produced in N/m² is
1) 4.9×10^{-6} 2) 4.9×10^{8} 3) 49×10^{8} 4) 2.45×10^{-6}

2. The length of a wire is 4m. Its length is increased by 2mm when a force acts on it. The strain is
1) 0.5×10^{-3} 2) 5×10^{-3} 3) 2×10^{-3} 4) 0.05

3. An air filled balloon is at a depth of 1 km below the water level in an ocean. Determine the normal stress of the balloon (atmospheric pressure = 10^5 pa)
1) $98\times10^{5}\,N/m^2$ 2) $99\times10^{5}\,N/m^2$
3) $98\times10^{3}\,N/m^2$ 4) $99\times10^{3}\,N/m^2$

Elastic Moduli and young's modulus

4. In the Searle's method to determine the Young's modulus of a wire, a steel wire of length 156 cm and diameter 0.054 cm is taken as experimental wire. The average increase in length for $1\frac{1}{2}$ kg wt is found to be 0.050cm. Then the Young's modulus of the wire.
1) 3.002×10^{11}N/m² 2) 1.002×10^{11}N/m²
3) 2.002×10^{11}N/m² 4) 2.5×10^{11}N/m²

5. An elongation of 0.1% in a wire of cross-section 10^{-6}m² causes a tension of 100N. Y for the wire is
1) 10^{12}N/m² 2) 10^{11}N/m²
3) 10^{10}N/m² 4) 100 N/m²

6. The length of two wires are in the ratio 3 : 4. Ratio of the diameters is 1:2; young's modulus of the wires are in the ratio 3:2; If they are subjected to same tensile force, the ratio of the elongation produced is
1) 1 : 1 2) 1 : 2 3) 2 : 3 4) 2 : 1

7. The ratio of diameters of two wires of same material is n:1 The length of each wire is 4m. On applying the same load, increase in length of thin wire will be(n>1)
1) n^2 times 2) n times 3) 2n times 4) (2n+1) times

8. An aluminium rod has a breaking strain 0.2%. The minimum cross-sectional area of the rod in m² in order to support a load of 10^4N is (Youngs modulus is 7×10^9Nm^{-2})
1) 1.7×10^{-4} 2) 1.7×10^{-3}
3) 7.1×10^{-4} 4) 1.4×10^{-4}

9. A metallic ring of radius 2cm and cross sectional area 4cm² is fitted into a wooden circular disc of radius 4cm. If the Young's modulus of the material of the ring is 2×10^{11} N/m², the force with which the metal ring expands is:
1) 2×10^7N 2) 8×10^7 N
3) 4×10^7 N 4) 6×10^7 N

10. The length of a metal wire is 10cm when the tension in it is 20N and 12cm when the tension is 40N. Then natural length of the wire is in cm
1) 6 2) 4 3) 8 4) 9

11. A solid sphere hung at the lower end of a wire is suspended from a fixed point so as to give an elongation of 0.4mm. When the first solid sphere is replaced by another one made of same material but twice the radius, the new elongation is
1) 0.8mm 2)1.6mm 3) 3.2mm 4)1.2mm

12. The extension of a wire by application of load is 0.3cm. The extension in a wire of same material but of double the length and half the radius of cross section by the same load will be in (cm)
1) 0.3 2) 0.6 3) 0.2 4) 2.4

13. Two steel wires have equal volumes. Their diameters are in the ratio 2 : 1. When same force is applied on them, the elongation produced will be in the ratio of
1) 1:8 2) 8:1 3) 1:16 4) 16:1

14. An iron wire and copper wire having same length and cross-section are suspended from same roof Young's modulus of copper is 1/3rd that of iron. Then the ratio of the weights to be added at their ends so that their ends are at the same level is
1) 1:3 2) 1:9 3) 3:1 4) 9:1

MODULE-1 KEY
(CLASS WORK)

01) 2 02) 1 03) 2 04) 3 05) 2 06) 4
07) 1 08) 3 09) 2 10) 3 11) 3 12) 4
13) 3 14) 3

MODULE-1 HINTS
(CLASS WORK)

1) Stress = F / A, F=Mg 2) Strain = $\Delta l / l$

3) Net pressure = Pressure due to atmosphere + pressure due to water column = $P_0 + h\rho g$

4) $Y = \frac{F\ell}{Ae}, F = Mg$ 5) $Y = \frac{F}{A\left(\frac{\Delta\ell}{\ell}\right)}$

6) $e = \frac{F\ell}{\pi r^2 Y}, e\alpha \frac{\ell}{Yr^2}$ 7) $e = \frac{F\ell}{\pi r^2 Y}, F \alpha r^2$

8) $Y = \frac{F}{A\left(\frac{\Delta\ell}{\ell}\right)}$

9) Length to be double $e = \ell, F = \frac{YAe}{\ell}$

10) Stress = Y Strain 11) $e = \frac{F\ell^2}{VY} e\alpha V\alpha r^3$

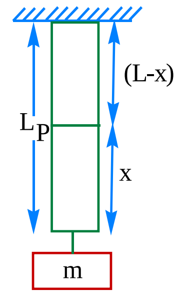
12) $e = \frac{F\ell}{\pi r^2 Y}, e\alpha \frac{\ell}{r^2}$ 13) $e = \frac{FV}{YA^2} e\alpha \frac{\ell}{r^4}$

14) $F = \frac{YAe}{\ell}, F \alpha Y$ 15) $F = YA\alpha\Delta t$

MODULE-2
(CLASS WORK)

Stress & Strain

1. One end of a uniform wire of length 'L' and mass 'M' is attached rigidly to a point in the roof and a load of mass 'm' is suspended from its lower end. If A is the area of cross-section of the wire then the stress in the wire at height 'x' from its lower end (x<L) is



1) $\frac{Mg}{A} + \frac{mxg}{AL}$ 2) $\frac{mg}{A} - \frac{Mxg}{AL}$
3) $\frac{mg}{A} + \frac{Mxg}{AL}$ 4) $\frac{mg}{AL} + \frac{Mxg}{A}$

Elastic Moduli and Poison's ratio

2. A load of 4.0 kg is suspended from a ceiling through a steel wire of length 20m and radius 2.0mm. It is found that the length of the wire increases by 0.031 mm. as equilibrium is achieved. If g=3.1 x π ms^{-2} , the value of young's modulus in Nm^{-2} is

1) 2.0 x 10^{12} 2) 4.0 x 10^{11}
3) 2.0 x 10^{11} 4) 0.02 x 10^{9}

3. Two wires of equal cross section, but one made up of steel and the other copper are joined end to end. When the combination is kept under tension, the elongations in the two wires are found to be equal. If Y_{steel} = 2.0 x 10^{11} Nm^{-2} and Y_{copper} = 1.1 x 10^{11} Nm^{-2}, the ratio of the lengths of the two wires is

1) 20 : 11 2) 11:20 3) 5 : 4 4) 4 : 5

4. If Young's modulus of iron be 2 x 10^{11} N/m^{-2} and interatomic distance be 3 x 10^{-10}m^{-2}, the interatomic force constant will be (in N/m)

1) 60 2) 120 3) 30 4) 180

5. Two wires A and B of the same dimensions are under loads of 4kg and 5.5kg respectively. The ratio of Young's moduli of the materials of the wires for the same elongation is

1) 64 : 121 2) $\sqrt{11}:\sqrt{8}$ 3) 11:8 4) 8 : 11

6. A load of 1kg weight is attached to one end of a steel wire of cross sectional area 3 mm^2 and Young's modulus 10^{11} N/m^2. The other end is suspended vertically from a hook on a wall, then the load is pulled horizontally and released. When the load passes through its lowest position the fractional change in length is (g=10m/s^2)

1) 10^{-4} 2) 10^{-3} 3) 10^{3} 4) 10^{4}

7. The radii and young's modulus of two uniform wires A & B are in the ratio 2:1 and 1:2 respectively. Both the wires are subjected to the same longitudinal force. If increase in the length of wire A is 1% . Then the percentage increase in length of wire B is

1) 1 2) 1.5 3) 2 4) 3

8. Four identical hollow cylindrical columns of steel support a big structure of mass 50,000 kg. The inner and outer radii of each column are 30 cm and 40 cm respectively, Assuming the load distribution to be uniform. Calculate the compressional strain of each column, the young's modulus of steel is 2 x 10^{11} Pa

1) 2.78 x 10^{-6} 2) 3.78 x 10^{-6}
3) 2.78 x 10^{-4} 4) 3.78 x 10^{-4}

9. A wire of length 1m and radius 1mm is subjected to a load. The extension is 'x'. The wire is melted and then drawn into a wire of square cross-section of side 1mm. What is its extension under the same load?

1) $\pi^2 x$ 2) πx^2 3) πx 4) π / x

10. An aluminium wire and steel wire of the same length and cross section are joined end to end. The composite wire is hung from a rigid support and a load is suspended from the free end. The young's modulus of steel is 20/7 times the aluminium. The ratio of increase of length of steel and aluminium is

1) 20/7 2) 400/49 3) 7/20 4) 49/400

11. What percent of length of a wire will increase by applying a stress of 1 kg. wt/mm^2 on it. [Y=1x10^{11}Nm^{-2} and 1 kg wt = 9.8N]

1) 0.0078% 2) 0.0088%
3) 0.0098% 4) 0.0067%

12. A lift is tied with thick iron wire and its mass is 1000kg. If the maximum acceleration of the lift is 1.2 ms^{-2} and the maximum stress of the wire is 1.4 x 10^8 Nm^{-2} what should be the minimum diameter of the wire?

1) 10^{-2}m 2) 10^{-4}m 3) 10^{-6}m 4) 0.5 x10^{-2}m

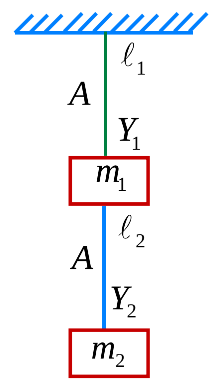
13. Two wires are made of the same material & have the same volume. However wire 1 has cross-section area A and wire 2 has cross-section area 3A. If the length of the wire 1 increased by Δx on appling force F how much force is needed to stretch wire 2 by the same amount

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

14. An aluminium wire and a steel wire of the same length and cross-section are joined end to end. The composite wire is hung from a rigid support and a load is suspended from the free end. If the increase in the length of the composite wire is 2.7 mm, then the increase in the length of each wire is (in mm).
(Y_{Al}= 2x10^{11}Nm^{-2}, Y_{steel}= 7x10^{11} Nm^{-2})

1) 1.7,1 2) 1.3,1.4 3) 1.5,1.2 4) 2.1,0.6

15. Two wires are arranged as shown in the figure. The elongations in upper and lower wires are respectively



1) $\frac{(m_1+m_2)g\ell_1}{Ay_1}, \frac{m_2 g\ell_2}{Ay_2}$

2) $\frac{(m_1-m_2)g\ell_1}{Ay_1}, \frac{m_2 g\ell_2}{Ay_2}$

3) $\frac{\left(\frac{m_1}{m_2}+1\right)g\ell_1}{Ay_1}, \frac{m_2 g\ell_2}{Ay_2}$

4) $\frac{\left(\frac{m_1}{m_2}-1\right)g\ell_1}{Ay_1}, \frac{m_2 g\ell_2}{Ay_2}$

MODULE-2 KEY
(CLASS WORK)

01) 3	02) 1	03) 1	04) 1	05) 4	06) 1
07) 3	08) 1	09) 1	10) 3	11) 3	12) 1
13) 4	14) 4	15) 1			

MODULE-2 HINTS
(CLASS WORK)

1) Tension in the string at point 'P' is
T=wt of load + wt of wire of length 'x'

$$T = mg + \frac{M}{L}xg; Stress\ at\ P = \frac{T}{A} = \frac{mg}{A} + \frac{Mxg}{AL}$$

2) $Y = \frac{mgl}{Ae}$

3) $\frac{l_S}{l_C} = \frac{Y_S}{Y_C}$, in series, stress=constant, $e = \frac{FL}{AY}$

4) $K = Yr_0$; K=interatomic force constant
r_0=interatomic distance

5) $e = \frac{W}{A}\frac{\ell}{Y}, W = mg$

6) $e = \frac{T}{A}\frac{\ell}{Y}, mg\ell = \frac{1}{2}mv^2, T = \frac{mv^2}{\ell} + mg$

7) $\frac{\Delta\ell}{\ell} = \frac{F}{AY}, \frac{S_{tB}}{S_{tA}} = \frac{r_A^2}{r_B^2}\frac{Y_A}{Y_B}$

8) The resisting area is each column $\pi\left(R^2 - r^2\right)$

Compressional strain = $\frac{F}{AY}$

9) Volume=constant, $\pi r^2\ell = a^2\ell^1$

10) $e = \frac{FL}{AY}, Y_S e_S = Y_{Al}e_{Al}$;11) $\frac{e}{l}\times 100 = \frac{F}{AY}\times 100$

12) Breaking stress = $\frac{m(g+a)}{\pi r^2}$

13) Volume=constant, $a_1 l_2 = a_2 l_2; \Delta x_1 = \Delta x_2$

14) $e = \frac{FL}{AY}, e\alpha\frac{1}{Y}, \frac{e_1}{e_2} = \frac{Y_2}{Y_1}$;

substituting in $e_1 + e_2 = e$

15) For lower wire $F=m_2g$

$$F = \frac{F\ell_2}{AY_2} \Rightarrow e_2 = \frac{m_2 g\ell_2}{AY_2}$$

For upper wire $F=(m_1+m_2)g$

$$e_1 = \frac{F\ell_1}{AY_1} = \frac{(m_1+m_2)g\ell_1}{AY_1}$$

MODULE-3

Young's modulusElasticity

1. A wire of length 1m fixed at one end has a sphere attached to it at the other end. The sphere is projected horizontally with a velocity of $\sqrt{9g}$. When it describes a vertical circle, the ratio of elongations of the wire when the sphere is at the top and bottom of the circle is

1) 2:5 2) 5:2 3) 3:5 4) 5:3

2. A body of mass 10kg is attached to a wire 0.3m long. Its breaking stress is 4.8 x 10^7 N/m². The area of cross section of the wire is 10^{-6}m². The maximum angular velocity with which it can be rotated in a horizontal circle without breaking is

1) 2 rad/s 2) 4 rad/s 3) 6 rad/s 4) 8 rad/s

3. A mass 'm' kg is whirled in a vertical plane by tying it at the end of a flexible wire of length 'L' and area of cross-section 'A' such that it just completes the vertical circle. When the mass is at its lowest position, the strain produced in the wire is (Young's modulus of the wire is 'Y')

1) AY/6 mg2) 6mg/AY 3) 5mg/AY 4) AY/5mg

4. When a mass is suspended from the end of a wire the top end of which is attached to the roof of the lift, the extension is 'e' when the lift is stationary. If the lift moves up with a constant acceleration g/2, the extension of the wire would be

1) 2e/3 2) 3e/2 3) $2e$ 4) $3e$

5. A block of mass 1 Kg is fastened to one end of wire of cross-sectional area of 2 mm² and is rotated in vertical circle of radius 20cm. The speed of the block at the bottom of the circle is 3.5 ms⁻¹. The elongation of the wire when the block is at top of the circle is

1) 0.6125×10^{-5}m 2) 0.6125×10^{-4}m
3) 0.6125×10^{-3}m 4) 0.6125×10^{-2}m

6. As shown in adjacent figure if a load of mass (m) is attached at lower end of wire. Then find the displacement of the points B, C and D as shown in figure,

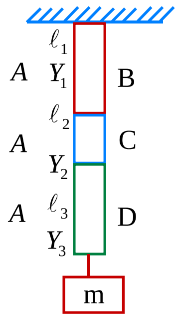
i) elongation of first wire $e_1 = \frac{(mg)\ell_1}{AY_1}$

ii) elongation of 2nd wire

$$e_2 = \frac{(mg)\ell_2}{AY_2} + \frac{(mg)\ell_1}{AY_1}$$

iii) elongation of 3rd wire

$$e_3 = \frac{(mg)\ell_3}{AY_3} + \frac{(mg)\ell_2}{AY_2} + \frac{(mg)\ell_1}{AY_1}$$



1) (i) is correct

2) (i) & (ii) are correct

3) (iii) is correct

4) All are correct

7. **A copper wire of negligible mass, length (ℓ) and cross-sectional area (A) is kept on a smooth horizontal table with one end fixed, a ball of mass 'm' is attached at the other end. The wire and the ball are rotated with angular velocity 'ω'. If wire elongates by $\Delta\ell$, then the Young's modulus of wire and if on increasing the angular velocity from ω to ω^1, when the wire breaks-down, then the breaking stress ($\Delta\ell << \ell$) are respectively.**

1) $\frac{(m\ell\omega^2)}{A\Delta\ell}, \frac{m\omega^{1^2}}{A}$ 2) $\frac{m\ell}{A\Delta\ell\omega^2}, \frac{M\ell\omega^2}{A}$

3) $\frac{m\ell\omega^2}{A\Delta\ell}, \frac{M\omega^{1^2}}{A\ell}$ 4) $\frac{m\ell\omega^2}{A\Delta\ell}, \frac{m\ell\omega^1}{A}$

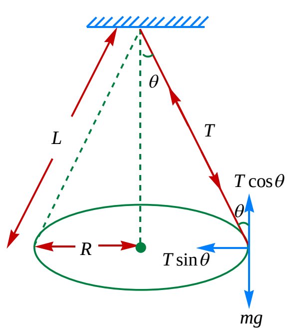
8. **A stone of mass (m) is attached to one end of a small wire of length (ℓ) and cross sectional area (A) suspended vertically. The stone is now rotated in horizontal plane such that the wire makes an angle 'θ' with vertical. If Y is its Young's modulus, then the increase in length of wire is**

1) $\frac{mg\ell\cos\theta}{AY}$

2) $\frac{mg\ell}{AY\cos\theta}$

3) $\frac{mg\ell Y}{A\cos\theta}$

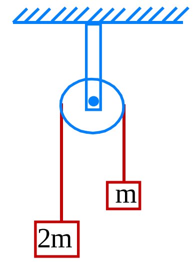
4) $\frac{mg\ell A}{Y\cos\theta}$



9. **Two blocks of masses m and 2m are connected through a wire of breaking stress S passing over a frictionless pulley. The maximum radius of the wire to be used so that the wire may not break is**

1) $\sqrt{\frac{3}{4}\frac{mg}{\pi S}}$ 2) $\sqrt{\frac{4}{3}\frac{mg}{S}}$

3) $\sqrt{\frac{4}{3}\frac{mg}{\pi S}}$ 4) $\sqrt{\frac{1}{2}\frac{mg}{\pi S}}$



10. **One end of a long metallic wire of length L, area of cross-section A and Young's modulus Y is tied to the ceiling. The other end is tied to a massless spring of force constant K. A mass m hangs freely from the free end of the spring. It is slightly pulled down and released. Its time period is given by**

1) $2\pi\sqrt{\frac{m}{K}}$ 2) $2\pi\sqrt{\frac{mYA}{KL}}$

3) $2\pi\sqrt{\frac{mK}{KL}}$ 4) $2\pi\sqrt{\frac{m(KL+YA)}{KYA}}$

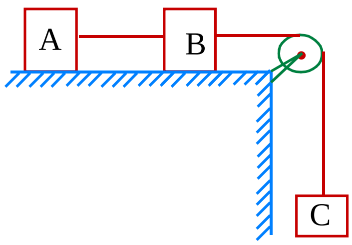
11. **A wire of cross section A is stretched horizontally between two clamps located '$2l$'m apart. A weight W kg is suspended from the mid-point of the wire. If the mid-point sags vertically through a distance $x << l$ the strain produced is**

1) $\frac{2x^2}{l^2}$ 2) $\frac{x^2}{l^2}$ 3) $\frac{x^2}{2l^2}$ 4) $\frac{x}{2l^2}$

12. **If in the above question the Young's modulus of the material is Y, the value of extension x is**

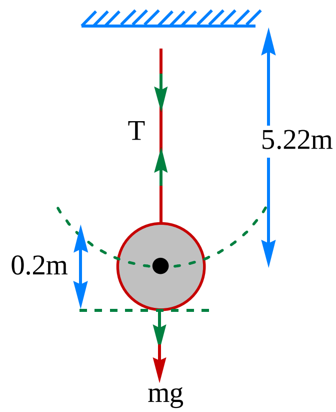
1) $\left(\frac{Wl}{YA}\right)^{1/3}$ 2) $\left(\frac{YA}{Wl}\right)^{1/3}$ 3) $\frac{1}{l}\left(\frac{WA}{Y}\right)^{1/3}$ 4) $l\left(\frac{W}{YA}\right)^{1/3}$

13. **Each of three blocks shown in figure has a mass 3kg. The wire connecting blocks A and B has area of cross-section 0.005 cm^2 and Young's modulus of elasticity Y=2x10^{11} N/m^2. Neglect friction. Find the elastic potential energy stored per unit volume in wire connecting blocks A and B in steady state (in j/m^3 (Take g=10 m/s^2))**



1) 500 2) 1000 3) 2000 4) 3000

14. A sphere of radius 0.1 m and mass 8π kg is attached to the lower end of a steel wire of length 5.0 m and diameter 10^{-3}m. The wire is suspended from 5.22m high ceiling of a room. When the sphere is made to swing as a simple pendulum, it just grazes the floor at its lowest point. Calculate the velocity of the sphere at the lowest point.
(Y for steel = 1.994×10^{11} N/m^2)



1) 7.5 ms^{-1} 2) 8.2 ms^{-1} 3) 8.8 ms^{-1} 4) 6.5 ms^{-1}

15. A thin uniform metallic rod of mass M and length L is rotated with a angular velocity ω in a horizontal plane about a vertical axis passing through one of its ends. The tension in the middle of the rod is

1) $\frac{1}{2}ML\omega^2$ 2) $\frac{1}{4}ML\omega^2$ 3) $\frac{1}{8}ML\omega^2$ 4) $\frac{3}{8}ML\omega^2$

MODULE-3 KEY

01) 1	02) 2	03) 2	04) 2	05) 1	06) 4
07) 1	08) 2	09) 3	10) 4	11) 3	12) 4
13) 2	14) 3	15) 4			

MODULE-3 HINTS

1) $V_{top} = \sqrt{xrg}; V_{bottom} = \sqrt{(x+4)rg}$

$V_{top} = \sqrt{5g}; v = \sqrt{9gr}$

$T_{bottom} = \frac{mv_b^2}{r} + mg = 10mg$

$T_{top} = \frac{mv_t^2}{r} - mg = 4mg; \frac{e_1}{e_b} = \frac{4mg}{10mg}$

2) $mr\omega^2$ = Breaking stress x A

3) $F = 6mg, strain = \frac{F}{AY}$ 4) $e_2 = e_1\left[1 + \frac{a}{g}\right]$

5) i) Tension at the bottom of the circle,

$T = \frac{mv^2}{r} + mg; = e = \frac{F\ell}{AY}$

ii) Tension at the top of the circle,
T=Tension at the bottom-6mg

The increase in length $e = \frac{Fl}{AY}$

6) displacement of B is e_1, displacement of C is e_1+e_2 displacement of D is $e_1+e_2+e_3$

7) a) $r = \ell + \Delta\ell; F = T = mr\omega^2 = m(\ell + \Delta\ell)\omega^2$

as $\Delta\ell$ in small; $F \approx m\ell\omega^2; Y = \frac{(m\ell\omega^2)}{A\Delta\ell}$

b) We know Breaking stress

$= \frac{Breaking\ \ force}{Area\ of\ \ cross\ section} = \frac{m\ell\omega^{1^2}}{A}$

8) From fig. $T\cos\theta = mg \Rightarrow T = \frac{mg}{\cos\theta}$

$T\sin\theta = mR\omega^2;$

$e = \frac{F\ell}{AY} = \frac{T\ell}{AY}; e = \frac{mg\ell}{AY\cos\theta}$

9) Stress, $S = \frac{T}{\pi r^2}$, here T-mg = ma....(i)

2mg-T=2ma.......(ii)

on solving $T = \frac{4}{3}mg$ then $S = \frac{4mg}{3\pi r^2}$

10) $K_{eq} = \frac{K_1K_2}{K_1 + K_2} = \frac{K.\frac{YA}{L}}{K + \frac{YA}{L}} = \frac{KYA}{KL + YA}$

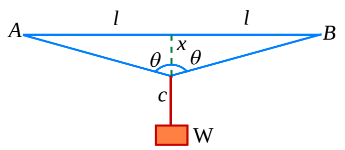
$T = 2\pi\sqrt{\frac{m}{K_{eq}}} = 2\pi\sqrt{\frac{m(KL + YA)}{KYA}}$

($\therefore$ string & spring in series)

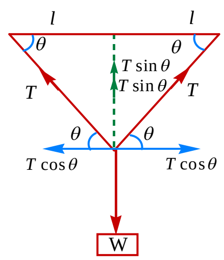
11) Here change in length is

$$\Delta l = [AC + BC] - 2l = 2\left(l^2 + x^2\right)^{1/2} - 2l$$

$$= 2l\left(1 + \frac{x^2}{l^2}\right)^{1/2} = 2l\left(1 + \frac{1}{2}\frac{x^2}{l^2}\right) - 2l = \frac{x^2}{l}$$



$$\therefore strain = \frac{\Delta \ell}{2\ell} = \frac{x^2}{2\ell^2}$$

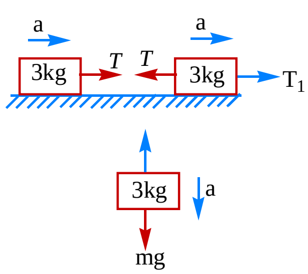
12) 

$$2T\sin\theta = W\,(\text{for small angles } \sin\theta = \tan\theta)$$

$$2T\tan\theta = W; \quad \tan\theta = \frac{x}{\sqrt{x^2 + l^2}} = \frac{x}{l}$$

$$2T\frac{x}{l} = W; T = \frac{Wl}{2x}; Stress = \frac{T}{A} = \frac{Wl}{2xA}$$

$$Y = \frac{stress}{strain} = \frac{Wl}{2Ax} \times \frac{2l^2}{x^2}, Y = \frac{Wl^3}{Ax^3} or x = \left(\frac{W}{AY}\right)^{1/3} \times l$$

13) 

From force diagram, T=3a.....(i);

$$T_1 - T = 3a.....(ii) \qquad 3g - T_1 = 3a.....(iii)$$

After solving eqs. (i), (ii)

$$\therefore stress = \frac{T}{A} = \frac{10}{0.005 \times 10^{-4}}$$

$\therefore$ The elastic energy stored per unit volume

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

$$= \frac{1}{2} \times stress \times \frac{stress}{Y}\left(\because Y = \frac{stress}{strain}\right)$$

$$= \frac{stress^2}{2Y} = \frac{\left(\dfrac{10}{0.005 \times 10^{-4}}\right)^2}{2 \times 2 \times 10^{11}} = 1000\,J/m^3$$

14) As the length of the wire is 5m and diameter 2x0.1=0.2m and at lowest point it grazes the floor which is at a distance 5.22 m from the roof, the increase in the wire at the lowest point

$$\Delta L = 5.22 - (5 + 0.2) = 0.02m$$

So tension in the wire (due to elasticity)

$$T = \frac{YA}{L}\Delta L = \frac{1.994 \times 10^{11} \times \pi\left(5 \times 10^{-4}\right)^2 \times 0.02}{5} = 199.4\pi N$$

and as equation of circular motion of a mass 'm' tied to a string in a vertical plane is

$$\left(mv^2/r\right) = T - mg\cos\theta$$

So at lowest point

$$\left(mv^2/r\right) = T - mg\,[as\ \theta = 0]$$

But here $r = 5 + 0.02 + 0.1 = 5.12m$

So $\left(8\pi^2/5.12\right) = \left(1.99.4\pi - 8\pi \times 9.8\right)$

$v^2 = \left(121 \times 5.12/8\right) = 77.44$, So $v = 8.8m/s$

15) Let m be the mass per unit length of the rod. Then M=mL

Consider a small element of length dx located at C at a distance x from A

The mass of element of length dx=mdx.

The centripetal force at C is

$$dF = (mdx)x\omega^2$$

$$F = \int_{x=x}^{x=L}(mdx)x\omega^2 = \frac{1}{2}m\omega^2\left(L^2 - x^2\right)$$

Now, $m = \frac{M}{L}; F = \frac{1}{2}ML\omega^2\left(1 - \frac{x^2}{L^2}\right)$

$$F = \frac{1}{2}\pi r^2 \rho L^2 \omega^2\left(1 - \frac{x^2}{L^2}\right)$$

Tension in the middle put $x = L/2$

MODULE-4

Single correct answer type

1. Modulus of rigidity of ideal liquids is
a) infinity b) zero c) unity
d) some finite small non-zero constant value

2. The maximum load a wire can withstand without breaking, when its length is reduced to half of its original length, will
a) be double b) be half
c) be four times d) remain same

3. The temperature of a wire is doubled. The Young's modulus of elasticity
a) will also double b) will become four times
c) will remain same d) will decrease

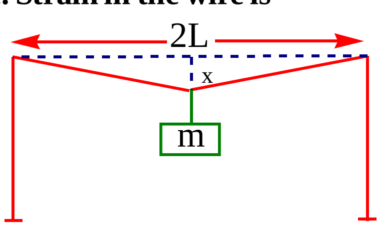
4. A spring is stretched by applying a load to its free end. The strain produced in the spring is
a) volumetric b) shear
c) longitudinal and shear d) longitudinal

5. A rigid bar of mass M is supported symmetrically by three wires each of length l . Those at each end are of copper and the middle one is of iron. The ratio of their diameters, if each is to have the same tension, is equal to

1) Y_{copper}/Y_{iron} 2) $\sqrt{\dfrac{Y_{iron}}{Y_{copper}}}$

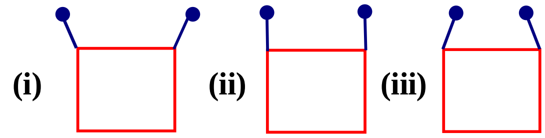
3) $\dfrac{Y_{iron}^2}{Y_{copper}^2}$ 4) $\dfrac{Y_{iron}}{Y_{copper}}$

6. A mild steel wire of length 2L and cross-sectional area A is stretched, well within elastic limit, horizontally between two pillars (figure). A mass m is suspended from the mid point of the wire. Strain in the wire is



a) $x^2 / 2L^2$ b) x / L c) x^2 / L d) $x^2 / 2L$

7. A rectangular frame is to be suspended symmetrically by two strings of equal length on two supports (figure). It can be done in one of the following three ways;



The tension in the strings will be
a) the same in all cases b) least in (i)
c) least in (ii) d) least in (iii)

8. Consider two cylindrical rods of identical dimensions, one of rubber and the other of steel. Both the rods are fixed rigidly at one end to the roof. A mass M is attached to each of the free ends at the centre of the rods.
a) Both the rods will elongate but there shall be no perceptible change in shape.
b) The steel rod will elongate and change shape but the rubber rod will only elongate.
c) The steel rod will elongate without any perceptible change in shape, but the rubber rod will elongate and the shape of the bottom edge will change to an ellipse.
d) The steel rod will elongate, without any perceptible change in shape, but the rubber rod will elongate with the shape of the bottom edge tapered to a tip at the centre.

9. A truck is pulling a car out of a ditch by means of a steel cable that is 9.1 m long and has a radius of 5 mm. When the car just beings to move, the tension in the cable is 800 N. If Young's modulus for steel is 2×10^{11} N / m^2 then the stretch in the cable is (nearly)
a) 5×10^{-3}m b) 0.5×10^{-3}m
c) 3×10^{-3} m d) 0.3×10^{-3}m

10. A wire of length L and radius r is clamped rigidly at one end. When the other end of the wire is pulled by a force f, its length increases by l. Another wire of the same material of length 2L and radius 2r, pulled by a force 2f. Then the increase in length of this wire is
a) l/2 b) l c) 21 d) 4l

11. A steel rod ($Y = 2.0 \times 10^{11}$ N/m^2 and $\alpha = 10^{-50}$ $^0C^{-1}$) of length lm and area of cross-section 1cm^2 is heated from 0^0C to 200^0C, without being allowed to extend or bend. Then the tension produced in the rod is
a) 4×10^4 N b) 3×10^4 N
c) 2×10^4N d) 1×10^4N

12. To what depth must a rubber ball be taken in deep sea so that its volume is decreased by 0.1%.

(The bulk modulus of rubber is $9.8 \times 10^8 N/m^2$; and the density of sea water is $10^3 kg/m^3$)

a) 0.1 b) 1m c) 10m 4) 100m

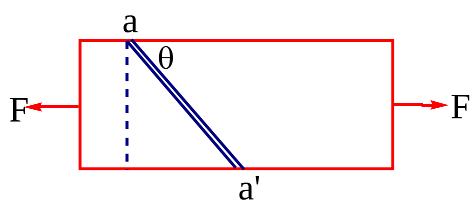
13. A steel wire of mass μ per unit length with a circular cross-section has a radius of 0.1cm. The wire is of length 10m when measured lying horizontal, and hangs from a hook on the wall. A mass of 25kg is hung from the free end of the wire. Assume the wire to be uniform and lateral strain <<longitudinal strain. If density of steel is 7860 kgm^{-3} and Young's modulus is $2 \times 10^{11} N/m^2$ then the extension in the length of the wire is

a) 1×10^{-3} m b) 2×10^{-3} m
c) 3×10^{-3} m d) 4×10^{-3} m

14. In the above problem if the yield strength of steel is $2.5 \times 10^8 N/m^2$, then the maximum mass that can be hung at the lower end of the wire is

a) 785 kg b) 78.75 kg 3) 78.25 kg 4) 78.50 kg

15. Consider a long steel bar under a tensile due to force F acting at the edges along the length of the bar (figure). Consider a plane making an angle with the length. For what anlge is the tensile stress a maximum?



a) 30^0 b) 45^0 c) 60^0 d) 90^0

MODULE-4 KEY

Single correct anser type

1) b	2) d	3) d	4) c	5) b	6) a
7) c	8) d	9) b	10) b	11) a	12) d
13) d	14) c	15) d			

MODULE-4 HINTS

1. The frictional (viscous) force cannot exist in case of ideal fluid

2. Breaking froce A
Breaking stress is a constant for a given material and it does ot depending upon length or thickness of wire.

3. $$Y = \frac{FL_0}{A\ \Delta L} = \frac{FL_0}{AL_0 \alpha \Delta T} = \frac{F}{A\alpha\Delta T}$$

$$\Rightarrow Y \propto \frac{1}{\Delta T}$$

when temperature increases ΔT increase Y decreases

4. The length and shape of the spring changes and the weight of the load behaves as a deforming force. The change in length corresponds to shearing strain.

5. As the bar is supported symmetrically by the three wires, therefore extension in each wire is same.

$$Y = \frac{\text{stress}}{\text{strain}} = \frac{F/A}{\Delta L/L} = \frac{F}{A} \times \frac{L}{\Delta L}$$

$$= \frac{F}{\pi (D/2)^2} \times \frac{L}{\Delta L} = \frac{4FL}{\pi D^2 \Delta L}$$

$$\Rightarrow D^2 = \frac{4FL}{\pi \Delta L Y} \Rightarrow D = \sqrt{\frac{4FL}{\pi \Delta L Y}}$$

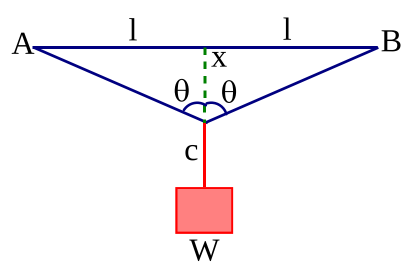
$D = \frac{K}{\sqrt{Y}}$ (K is proportionality constant)

$$\frac{D_{copper}}{D_{iron}} = \sqrt{\frac{Y_{iron}}{Y_{copper}}}$$

6. Here change in length is

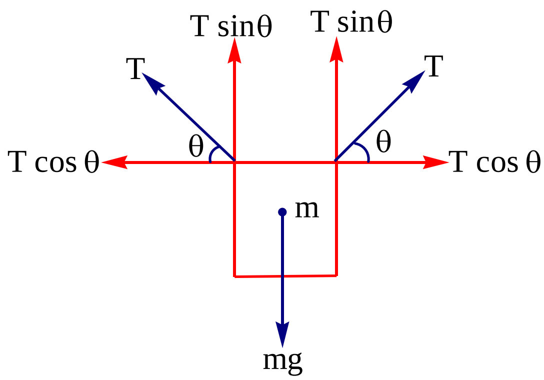
$$\Delta l = [AC + BC] - 2l = 2(l^2 + x^2)^{1/2} - 2l$$

$$= 2l\left(1 + \frac{x^2}{l^2}\right)^{1/2} - 2l = 2l\left(1 + \frac{1}{2}\frac{x^2}{l^2}\right) - 2l = \frac{x^2}{l}$$



$$\therefore \text{strain} = \frac{\Delta l}{2l} = \frac{x^2}{2l^2}$$

7.



$2T\sin\theta - mg = 0$ [T is tension in string]

$\Rightarrow 2T\sin\theta = mg$

$$T = \frac{mg}{2\sin\theta}$$

$$\Rightarrow T \propto \frac{1}{\sin\theta}$$

$$T_{min} = \frac{mg}{2\sin\theta_{max}} \text{(since, } \sin\theta_{max} = 1)$$

$\sin\theta_{max} = 1 \Rightarrow \theta = 90^0$

8. Steel rod will elongate without making any perceptible change in shape, but the rubber rod will elongate with the shape of the bottom edge tapered to a tip at the centre.

9. $$Y = \frac{F/A}{\Delta L/L} \Rightarrow \Delta L = \frac{Fl}{Y(\pi r^2)}$$

$$\Delta L = \frac{800\times 9.1}{(2\times 10^{11})(3.14\times 25\times 10^{-6})}$$

$= 4.64 \times 10^{-4}$m $\approx 5 \times 10^{-4}$m $= 0.5 \times 10^{-3}$ m

10. Both the wires are of same material, so Young's modulus will be same

$$Y = \frac{f}{\pi r^2}\times\frac{L}{l} = \frac{2f}{\pi(2r^2)}\times\frac{2L}{x}$$

$x = l$

11. $$T = Y\frac{\Delta L}{L}\times A$$

$$T = 2\times 10^{11}\times\frac{2\times 10^{-3}}{1}\times 10^{-4} = 4\times 10^4 N$$

12. $$B = \frac{\Delta P}{(\Delta V/V)} \Rightarrow \Delta P = B\times\frac{\Delta V}{V}$$

$\Rightarrow \Delta P = 9.8\times 10^8 \times 10^{-3} = 9.8\times 10^5 Nm^{-2}$

$\Delta P = \rho g h$

$$h = \frac{\Delta P}{\rho g} = \frac{9.8\times 10^5}{10^3\times 9.8} \Rightarrow h = 10^2 m = 100m$$

13. Suppose ΔL_1 is the extension in the wire of length L due to its mass. Then,

$$\Delta L_1 = \frac{(mg)(L/2)}{YA} = \frac{mgL}{2YA}$$

where $m = \pi r^2 L\rho$

Suppose ΔL_2 is the extention in the wire due to hanged mass M.

$$\Delta L_2 = \frac{(Mg)L}{YA} = \frac{MgL}{YA}$$

Hence, total extension in the wire,

$$\Delta L = \Delta L_1 + \Delta L_2 = \frac{mgL}{2YA} = \frac{MgL}{YA}$$

$$\Delta L = \frac{gL}{YA}\left(\frac{m}{2} + M\right)$$

$$\Delta L = \frac{10\times 10}{2\times 10^{11}\times 3.14\times 10^{-6}}(0.125 + 25)$$

$= 4 \times 10^{-3}$ m

14. Yield force = (Yield strength Y) x area

$$= 250\times 10^6 \pi\times(10^{-3})^2 = 250\times\pi N = 785N$$

At the yield point, $(m+M_{max})g = 785$

$0.25 + M_{max} = 78.5 \Rightarrow M_{max} = 78.25$kg

15. Tensile stress $\frac{F_\perp}{A'} = \frac{F\sin\theta}{A/\sin\theta} = \frac{F}{A}\sin^2\theta$

For tensile stress to be maximum,

$$\sin^2\theta = 1 \Rightarrow \sin\theta = 1 \Rightarrow \theta = \frac{\pi}{2} \text{ or } \theta = 90^0$$

MODULE-1
(HOME WORK)

Stress & Strain

1. A steel wire of 2mm in diameter is stretched by applying a force of 72N. Stress in the wire is

1) $2.29\times 10^7 N/m^2$ 2) $1.7\times 10^7 N/m^2$

3) $3.6\times 10^7 N/m^2$ 4) $0.8\times 10^7 N/m^2$

2. The length of a wire under stress changes by 0.01%. The strain produced is

1) 1×10^{-4} 2) 0.01 3) 1 4) 10^4

3. An air filled balloon is at a depth of 2 km below the water level in an ocean. Determine the

normal stress on the balloon [atmospheric pressure = 10^5 pa]

1) 190 x 10^5 pa 2) 196 x 10^5 Pa
3) 190 x 10^7 pa 4) 196 x 10^7 pa

Elastic Moduli and Poison's ratio

4. A wire of 10m long and $1mm^2$ area of cross section is stretched by a force of 20N. If the elongation is 2mm, the young's modulus of the material of the wire (in Pa) is

1) $1x10^9$ 2) $2x10^{-9}$ 3) $1x10^{11}$ 4) $1x10^{12}$

5. The area of cross-section of a wire is $10^{-5}m^2$ when its length is increased by 0.1% a tension of 1000N is produced. The Young's modulus of the wire will be (in Nm^{-2})

1) 10^{12} 2) 10^{11} 3) 10^9 4) 10^{10}

6. There are two wires of same material. Their radii and lengths are both in the ratio 1:2. If the extensions produced are equal, the ratio of the loads is

1) 1:2 2) 2:1 3) 1:4 4) 4:1

7. If stress is numerically equal to young's modulus the elongation will be

1) ¼ th original length 2) ½ the original length
3) Equal to the original length
4) Twice the original length

8. Two wires of same material and length but radii in the ratio 1:2 are stretched by two forces to produce equal elongation. The ratio of two forces is

1) 1:1 2) 1:2 3) 1:3 4) 1:4

9. A steel wire of length 5m and cross sectional area $2x10^{-6}m^2$ stretches by the same amount as a copper wire of length 4 m and cross sectional area of $3x10^{-6}m^2$ under a given load. The ratio of Young's modulus of steel to that of copper is

1) 8:15 2) 15:8 3) 5:3 4) 3:5

**10. A metal ring of inner radius r_1 and cross-sectional area 'A' is fitted on to a wooden disc of radius r_2
$r_2 > r_1$. If Y is the young's modulus of the metal then the tension in the ring is**

1) $\frac{AYr_2}{r_1}$ 2) $\frac{AY(r_2-r_1)}{r_1}$ 3) $\frac{Y(r_2-r_1)}{Ar_1}$ 4) $\frac{Yr_1}{Ar_2}$

11. When the tension on a wire is 4N its length is ℓ_1. When the tension on the wire is 5N its length is ℓ_2. Find its natural length.

1) $5\ell_1 - 4\ell_2$ 2) $4\ell_1 - 5\ell_2$
3) $10\ell_1 - 8\ell_2$ 4) $8\ell_1 - 10\ell_2$

12. A wire whose cross-sectional area is 4 mm^2 is stretched by 0.1 mm by a certain load. If a similar wire of double the area of cross section is under the same load, then the elongation would be

1) 0.5mm 2) 0.05mm 3) 0.005mm 4) 5mm

13. Two wires A and 13 have Young's moduli in the ratio 1:2 and ratio of lengths is 1:1. Under the application of same stress the ratio of elongations is

1) 1:1 2) 1:2 3) 2:1 4) 1:4

14. A wire is stretched by 0.01m by a certain force 'F' another wire of same material whose diameter and lengths are double to original wire is stretched by the same force then its elongation will be

1) 0.005m 2) 0.01 m 3) 0.02 m 4) 0.04 m

15. A brass wire of length 300 cm when subjected to a force F produces an elongation "a". Another wire of twice the diameter and of same length and material, when subjected to the force F produces an elongation b. Then the value of a/b is

1)1:1 2)4:1 3) 2:1 4)1:2

MODULE-1 KEY
(HOME WORK)

01) 1	02) 1	03) 2	04) 3	05) 2	06) 1
07) 3	08) 4	09) 2	10) 2	11) 1	12) 2
13) 3	14) 1	15) 2			

MODULE-1 HINTS
(HOME WORK)

1) Stress $= \frac{F}{A} = \frac{F}{\pi r^2}$ 2) Strain $= \frac{\Delta l}{l}$

3) $P = P_0 + hdg$ 4) $Y = \frac{Fl}{Ae}$

5) $Y = \frac{Fl}{Ae}, \frac{\Delta\ell}{\ell} = 0.1\%$ 6) $F = \frac{YAe}{\ell}, \frac{F_1}{F_2} = \frac{r_1^2}{r_2^2} \times \frac{l_2}{l_1}$

7) $\frac{F}{A} = Y, Y = \frac{\left(\frac{F}{A}\right)}{\left(\frac{\Delta l}{l}\right)}$ 8) $e = \frac{F \times l}{\pi r^2 \times Y}, F \; \alpha \; r^2$

9) $Y=\frac{Fl}{Ae}, \frac{Y_1}{Y_2}=\frac{A_1}{A_2}\frac{\ell_1}{\ell_2}$ 10) $F=\frac{YAe}{l}, e=r_2-r_1, \ell=r_1$

11) $\frac{l_1-l}{l_2-l}=\frac{T_1}{T_2}$ 12) $e=\frac{Fl}{AY}-\frac{Mgl}{AY}, e\alpha\frac{1}{A}$

13) $e=\frac{Fl}{AY}, \frac{e_1}{e_2}=\frac{\ell_1}{\ell_2}\frac{Y_2}{Y_1}$ 14) $e=\frac{Fl}{AY}$

15) $e=\frac{Fl}{AY}, e=\frac{F\times l}{\pi r^2\times Y}$ 16) $e=\frac{FV}{YA^2}, V=volume$

MODULE-2
(HOME WORK)

Stress & Strain

1. One end of uniform wire of length L and weight W is attached to rigid point in the roof and a weight w_1 is suspended from its lower end. If S is the area of cross-section of the wire the stress in the wire at a height (3L/4) from its lower end is

1) $\frac{w_1}{S}$ 2) $\frac{\left(w_1+\frac{w}{4}\right)}{S}$ 3) $\frac{\left(w_1+\frac{3w}{4}\right)}{S}$ 4) $\frac{(w_1+w)}{S}$

Young's Modulus

2. A 20 kg load is suspended from the lower end of a wire 10cm long and 1mm² in cross sectional area. The upper half of the wire is made of iron and the lower half with aluminium. The total elongation in the wire is(Y_{iron}=20 x 10^{10} N/m²,Y_{Al}= 7 x 10^{10} N/m²)

1) 18.9 x 10^{-3}m 2) 17.8 x 10^{-3} m
3) 1.78 x 10^{-3} m 3) 1.89 x 10^{-4} m

3. A steel wire is 1m long and 1mm² in area of cross-section. If it takes 200 N to stretch this wire by 1mm, the force that will be required to stretch the wire of the same same materialand cross sectional area from a length of 10m to 1002 cm

1) 100 N 2) 200 N 3) 400 N 4) 2000 N

4. A wire of length 1m and radius 1mm is subjected to a load. The extension is 'x'. The wire is melted and then drawn into a wire of square cross-section of side 2mm. What is its extension under the same load?

1) $\frac{\pi^2 x}{16}$ 2) πx^2 3) $\frac{\pi^2 x}{3}$ 4) $\frac{\pi}{x}$

5. A stress of 10^6 N/m² is required for breaking a material. If the density of the material is 3 x 10^3 kg/m³, then what should be the minimum length of the wire made of the same material so that it breaks by its own weight? (g=10m/s²)

1) 33.4 m 2) 3.4 m 3) 34 cm 4) 3.4 cm

6. A wire can be broken by 400kg.wt. The load required to break the wire of double the thickness of the same material will be

1) 800 kg.wt 2) 1600 kg.wt.
3) 3200 kg. wt 4) 6400 kg. wt

7. A copper wire and an aluminium wire has lengths in the ratio 3:2 diameter in the ratio 2:3 and force applied in the ratio 4:5 find the ratio of the increase in length of the two wires

$Y_{At}=7\times10^{10}N/m^2, Y_{Cu}=11\times10^{10}N/m^2$

1) 110:89 2) 180:110 3) 189:110 4) 80:11

8. There are two wires of same material their radii and lengths are both in the ratio 1:2. If the extensions produced are equal, what is the ratio of the loads?

1) 1:2 2) 2:1 3) 1:4 4) 4:1

9. Two rods of different materials having coefficient of linear expansion α_1 and α_2 and Young's moduli Y_1 and Y_2 respectively are fixed between two rigid massive walls, the rods are heated such that they under go the same increase in temp. there is no bending of rods. If $\alpha_1:\alpha_2=2:3$, then the thermal stresses developed in the two rods are equal if $Y_1:Y_2$ is equal to

1) 4:9 2) 3:2 3) 9:4 4) 2:2

10. A piece of copper wire has twice the radius of steel wire, which are connected in series, so that both of them can be subjected to the same longitudinal force. Y for steel is twice that of copper. When the length of copper wire is increased by 1%, the steel wire will be stretched by

1) 2% of its original length
2) 1% of its original length
3) 4% of its original length
4) 0.5 % of its original length

Rigidity Modulus

11. A tangential force of 2100N is applied on a surface area 3x10^{-6}m² which is 0.1m from fixed surface. The force produces a shift of 7mm of

upper surface with respect to bottom. Calculate the modulus of rigidity of the material.

1) 2 x 10^{10} N/m^2 2) 1 x 10^{10} N/m^2
3) 3 x 10^{10} N/m^2 4) 4 x 10^{10} N/m^2

Bulk Modulus

12. A uniform pressure 'P' is exerted on all sides of a solid cube at temperature 0^0C. In order to bring the volume of the cube to the original volume, the temperature of the cube must be increased by t^0c. If α is the linear coefficient and K be the bulk modulus of the material of the cube, then t is equal to

1) $\frac{3P}{K\alpha}$ 2) $\frac{P}{2\alpha K}$ 3) $\frac{P}{3\alpha K}$ 4) $\frac{P}{\alpha K}$

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

1) $\frac{mg}{AK}$ 2) $\frac{mg}{3AK}$ 3) $\frac{mg}{A}$ 4) $\frac{3mg}{AK}$

14. Find the change in density of water in ocean at depth of 700 m below the surface. The density of water at the surface is 1000 kg/m^3 and the bulk modulus of water is 4.9 x 10^9 Nm^{-2}.

1) 2.4 kg/m^3 2) 3.4 kg/m^3 3) 1.4 kg/m^3 4) 4.4 kg/m^3

15. When a rubber ball of volume v, bulk modulus K is at a depth h in water then decrease in its volume is

1) $\frac{h\rho gv}{K}$ 2) $\frac{h\rho gv}{2K}$ 3) $\frac{h\rho gv}{3K}$ 4) $\frac{h\rho gv}{4K}$

MODULE-2 KEY
(HOME WORK)

01) 3	02) 4	03) 3	04) 1	05) 1
06) 2	07) 3	08) 1	09) 2	10) 1
11) 2	12) 3	13) 2	14) 3	15) 1

MODULE-2 HINTS
(HOME WORK)

1) Force acting at 3/4 length from bottom

$$F = \left(\frac{3}{4}W\right) + W_1$$

2) $e = e_1 + e_2, e = \frac{F\ell}{AY}, \frac{e_1}{e_2} = \frac{Y_2}{Y_1}$

3) $F = \frac{YAe}{\ell}, \frac{F_1}{F_2} = \frac{\ell_2}{\ell_1}\frac{e_2}{e_1}$

4) Volume = constant, $\pi r^2 \ell = a^2 \ell^1, e = \frac{F\ell}{YV}$

5) $e = \frac{\ell^2 dg}{2Y}$ 6) $B.S = \frac{F}{A}, F\alpha r^2$

7) $Y = \frac{F\ell}{Ae}; \frac{e_1}{e_2} = \frac{F_1\ell_1 r_2^2 Y_2}{F_2\ell_2 r_1^2 Y_1}$;8) $F = \frac{YAe}{\ell}, F\alpha\frac{r^2}{\ell}$

9) Thermal stress = $\gamma\alpha\Delta t, Y_1\alpha_1 = Y_2\alpha_2$

10) $F = AY\left(\frac{e}{\ell}\right) = cons\tan t; A_S Y_S\left(\frac{e}{\ell}\right)_S = A_C Y_C\left(\frac{e}{\ell}\right)_c$

11) $\eta = \frac{F}{A}\frac{L}{\Delta x}$; 12) $K = \frac{P}{\frac{\Delta V}{V}}; \frac{\Delta V}{V} = \gamma t = 3\alpha t$

13) $\frac{\Delta V}{V} = \frac{F}{AK} = \frac{mg}{AK}; \frac{\Delta R}{R} = \frac{1}{3}\frac{\Delta V}{V}$

14) $\Delta\rho = \frac{P\rho}{K}, P = hdg$ 15) $K = -\frac{\Delta pV}{\Delta V}$

122) $\frac{E}{V} = \frac{(stress)^2}{2Y} = \frac{S^2}{2Y}$

23) $T_1 = 2\pi\sqrt{\frac{\ell + \Delta\ell_1}{g}}$ and $T_2 = 2\pi\sqrt{\frac{\ell + \Delta\ell_2}{g}}; \Delta T = T_2 - T_1$

24) $\frac{E}{V} = \frac{1}{2} \times \frac{(stress)^2}{Y}$