# PHYSICS

# BOOKS - DHANPAT RAI & CO PHYSICS (HINGLISH)

# PROPERTIES OF SOLIDS

## Problem For Self Practice A Based On Young S Modulus

**1.** A weight of 1.0 kg is suspended form the lower end of a wire of cross- section $10mm^2$. What is the magnitude and direction of stress produced in it ? Take g=$9.8ms^{-2}$.

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## B Based On Bulk Modulus

**1.** A block of vloume 1 $m^3$ is subjected to a hydrostatic pressure of $1.3 \times 10^5 Nm^{-2}$. If the bulk modulus of the material of the block be $26 \times 10^{12} Nm^2$, what is the decrease in the volume of the block?

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## C Based On Modulus Of Rigidity

**1.** The upper face of a cube of edge 1 m moves through a distance of 1 mm relative to the lower fixed face under the action of a tangential force of $1.5 \times 10^8$ N. Calculate the tangential stress, shear strain and the modulus of rigidity.

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## D Based On Poisson S Ratio And Elastic Potential Energy

**1.** A steel wire of 4.0 m is stretched through 2.0 mm. The cross - sectional area of the wire is $2.0mm^2$. If young's modulus of steel is $2.0 \times 10^{11} Nm^{-2}$ find (i) the energy density of the wire, (ii) the elastic potential energy stored in the wire.

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## Others

**1.** A wire increases by $10^{-3}$ of its length when a stress of $1 \times 10^8 Nm^{-2}$ is applied to it. What is the Young's modulus of the material of the wire?

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2. The area of cross section of a steel wire $(Y = 2.0 \times 10^{11} N/m^2)$ is $0.1 cm^2$. The force required to double is length will be

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3. A uniform wire of steel of length 2.5m and density $8.0 gcm^{-3}$ weighs 50g. When stretched by a force of $10 kgf$, the length increases by 2mm. Calculate Young's modulus of steel.

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4. What load when suspended from an aluminium wire 2mm in diameter and 5m long will stretch it by 1mm ? Young's modulus $= 7 \times 10^{10} Nm^{-2}$

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**5.** A steel wire of length $4.5m$ and cross-sectional area $3 \times 10^{-5} m^2$ stretches by the same amount as a copper wire of length $3.5m$ and cross sectional area of $4 \times 10^{-5} m^2$ under a given load. The ratio of the Young's modulus of steel to that of copper is

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**6.** What is the percentage increase in length of a wire of diameter 2.5 mm, stretched by a force of 100 kg wt ? Young's modulus of elasticity of wire $= 12.5 \times 10^{11} dyne / cm^2$.

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**7.** Two long metallic strips are joined together by two rivets each of radius $2mm$. Each rivet can withstand a maximum shearing stress of $1.5 \times 10^9 N / m^2$. Assuming that each rivet shares the stretching load equally, the maximum tensile force the strip can exert without rupture is

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**8.** A cable is replaced by another cable of the same length and material but of double the diameter.

(i) Under a given load which cable will show greater extension?

(ii) How many times the second cable can support the maximum load without exceeding the elastic limit?

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**9.** The breaking stress of a material is $10^8 Nm^{-2}$ . Find the greatest length of a wire that could hang vertically without breaking. Density of material $= 3000 kgm^{-3}$

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**10.** A rubber string 10m long is suspended from a rigid support at its one end. Calculate the extension in the string due to its own weight. The density of rubber is $1.5 \times 10^3$ and Young's modulus for the rubber is $5 \times 10^6 Nm^{-2}$ Take $g = 10 Nkg^{-1}$ .

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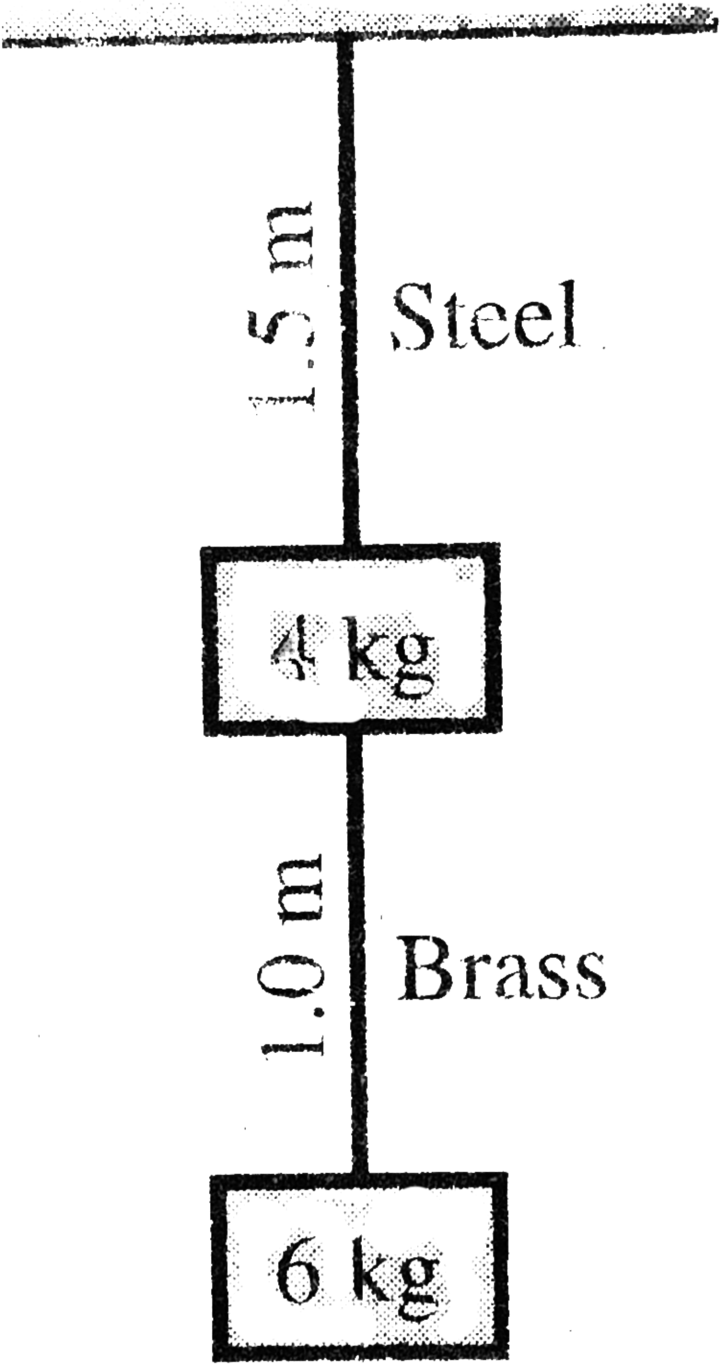
**11.** Two wires of diameter $0.25 cm$, one made of steel and other made of brass, are loaded as shown in the figure. The unloaded length of the steel wire is $1.5 m$ and that of brass is $1.0 m$.

Young's modulus of steel is $2.0 \times 10^{11}$Pa and that of brass is $1.0 \times 10^{11}$ Pa. Compute the ratio of elongations of steel and brass wires. $\frac{\triangle l_{\text{steel}}}{\triangle l_{\text{brass}}} = ?$



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12. Four identical hollow cylindrical cloumns of steel support a big structure of mass 50.000 kg. the inner and outer radii of each column are 30 cm and 60 cm respectively. Assume the load distribution to be uniform , calculate the compressional strain of each column. the Young's modulus of steel is $2.0 \times 10^{11} Pa.$

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13. A composite wire of uniform diameter 3.0 mm consisting of a copper wire of length 2.2m and a steel wire of length 1.6m stretches under a load by 0.7 mm. Calculate the load, given that the Young's modulus for copper is $1.1 \times 10^{11} Pa$ and for steel is $2.0 \times 10^{11} Pa.$

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**14.** If a compressive force of $3.0 \times 10^4 N$ is exerted on the end of a 20 cm long bone of cross-sectional area $3.6cm^2$ (i) will the bone break and (ii) if not by how much length does it shorten? Given compresive strength of bone $= 7.7 \times 10^8 N/m^2$ and young's modulus of bone $= 1.5 \times 10^{10} N/m^2$

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**15.** The maximum stress that can be applied to the material of a wire used to suspend an elevator is $\frac{3}{\pi} \times 10^8 N/m^2$ if the mass of elevator is 900 kg and it move up with an acceleration $2.2m/s^2$ than calculate the minimum radius of the wire.

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**16.** A mass of 100 grams is attached to the end of a rubber string 49 cm. long and having an area of cross section 20 sq. mm. The string is whirled round, horizontally at a constant speed of 40 r.p.s in a circle of radius 51 cm. Find Young's modulus of rubber.

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**17.** A uniform heavy rod of weight W, cross sectional area a and length L is hanging from fixed support. Young modulus of the material of the rod is Y. Neglect the lateral contraction. Find the elongation of the rod.

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**18.** A steel wire of uniform cross-section $1mm^2$ is heated to $70^\circ C$ and stretched by tying it two ends rigidly. Calculate the change in tension on the wire when temperature falls form $70^{\circ} C$ to $35^{\circ} C$

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**19.** Compute the bulk modulus of water from the following data : initial volume = 100.0 litre, pressure increase = 100.0 atmosphere. Final volume - 100.5 litre . (1 atmosphere = $1.013 \times 10^{5} Pa$). Compare the bulk modulus of water that of air (at constant temperature). explain in simple terms why the ratio is so large.

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**20.** A spherical ball contracts in volume by 0.01% when subjected to a normal uniform pressure of 100 atmospheres. Calculate the bulk modulus of the meterial.

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21. A solid sphere of radius 10cm is subjected to a uniform pressure $= 5 \times 10^8 Nm^2$ . Determine the consequnt change in volume. Bulk modulus of the material of the sphere is equal to $3.14 \times 10^{11} Nm^{-2}$

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22. Compressibility of water is $5 \times 10^{-10} m^2 / N$. Find the decrease in volume of $100mL$ of water when subjected to a pressure of $15MPa$.

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**23.** A sphere contracts in volume by $0.01\%$ when taken to the bottom of sea $1km$ keep. The bulk modulus of the material of the sphere is (Given density of sea water may be taken as $1.0 \times 10^3 kgm^{-3}$).

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**24.** What is the density of ocean water at a depth, where the pressure is 80.0 atm, given that its density at the surface is $1.03 \times 10^3 kgm^{-3}$? Compressibilty of water $= 45.8 \times 10^{-11} Pa^{-1}$. Given 1 atm. $=1.013 \times 10^5 Pa$.

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**25.** If the normal density of sea water is $1.00g/cm^3$, what will be its density at a depth of 4km? Given compressibility of water =

0.00005 per atmosphere. 1 atmospheric pressure $= 10^6 dyne / cm^2, g = 980cm / s^2$.

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26. Calculate the presure required to stop the increases in volume of a copper block when it is heated from $50^\circ$ to $70^\circ C$. Coefficient of linear expansion of copper $= 8.0 \times 10^{-6} .^\circ C^{-1}$ and bulk modulus of elasticity $3.6 \times 10^{11} Nm^{-2}$

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27. The bulk modulus of water is $2.3 \times 10^9 N / m^2$.

(a) Find its compressibility in the unit $atm^{-1}$.

(b) How much pressure in atmospheres is needed to compress a sample of water by $0.1\%$ ?

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**28.** A cube of aluminimum of each side 4 cn is subjected to a tangential (shearing) force. The top face of the cube is sheared through $0.012$ cm with respect to the bottom face. Find (i)shearing strain (ii) shearing stress and shearing force. Given $\eta = 2.08 \times 10^{11}$ dyne $cm^2$

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**29.** A square lead slab of side 50cm and thickness 5.0cm is subjected to a shearing force (on its narrow face) of magnitude $9.0 \times 10^4$ N. The lower edge is riveted to the floor. How much is the upper edge displaced, if the shear modulus of lead is $5.6 \times 10^{90}$ Pa?

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**30.** A 2.5 cm cube of gelatin placed on a table, is subjected to a shearing fornce a o $0.5gk$ . The upper surface of the of the cube is displaced by 0.5cm. Calculate the shear modulus of gelatin.

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**31.** A metallic cube whose each side is 10 cm is subjected to a shearing force of 100 kgf. The top face is displaced through 0.25 cm with respect to the bottom ? Calculate the shearing stress, strain and shear modulus.

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**32.** A 60 kg motor rests on four cylinderical rubber blocks. Each cylinder has a height of 3cm and a cross-sectional area of $15cm^2$

. The shear modulus for this rubber is $2 \times 10^6 Nm^{-2}$ . If a sideways force of 300N is applied to the motor, how far will it move sideways?

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**33.** A rubber block $1cm \times 3cm10cm$ is clamped at one end with its 10cm side vertical. A horizontal force of 30 N is applied to the free surface. What is the horizontal displacement of the top face ? Modulus of rigidity of rubber $1.4 \times 10^5 Nm^{-2}$

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**34.** Determine the Poisson's ratio of the material of a wire whose volume remains constant under an external normal stress.

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**35.** One end of a nylon rope of length 4.5 m and diameter 6 mmis fixed to a tree limb. A monkey weighing 100 N jumps to catch the free end and stays there. Find the elongation of the rope and the corresponding change in the diameter. Young modulus of nylon =0.2.

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**36.** A steel wire of 4.0 m in length is stretched through 2.00 mm. The cross-sectional area of the wire is $2.0mm^2$ if young's modulus of steel is $2.0 \times 10^{11} N/m^2$ find (i) the energy density of wire (ii) the elastic potential energy stored in the wire.

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**37.** A brass rod of cross sectional area $1cm^2$ and length $0.2m$ is compressed lengthwise by a weight of $5kg$. If Young's modulus of elasticity of brass is $1 \times 10^{11} \frac{N}{m^2}$ and $g = 10 \frac{m}{\sec^2}$ Then increase in the energy of the ro will be

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**38.** When the load on a wire is increases from 0.61mm to 1.02mm. How much work is done during the extension of the wire ?

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**39.** A 40 kg boy whose leg are $4cm^2$ in area and $50cm$ long falls through a height of $2m$ without breaking his leg bones. If the bones can stand a stress of $1.0 \times 10^8 \frac{N}{m^2}$, calculate the Young's modulus for the material of the bone.

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**40.** A metallic wire is stretched by suspending weight to it. If $\alpha$ is the longitudinal strain and Y its Young's modulus of elasticity, shown that the elastic potential energy per unit volume is given by $Y\alpha^2/2$

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**41.** A material has Poisson's ratio $0.50$. If a uniform rod of it suffers a longitudinal strain of $2 \times 10^{-3}$, then the percentage change in volume is

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**42.** A copper wire of negligible mass, $1m$ length and cross-sectional area $10^{-6}m^2$ is kept on a smooth horizontal table with one end fixed. A ball of mass $1kg$ is attached to the other end. The wire and the ball are rotating with an angular velocity of $20rad/s$. If the elongation in the wire is $10^{-3}m$.

a. Find the Young's modulus of the wire (in terms of $\times 10^{11}N/m^2$).

b. If for the same wire as stated above, the angular velocity is increased to $100rad/s$ and the wire breaks down, find the breaking stress (in terms of $\times 10^{10}N/m^2$).

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**43.** A load of 31.4 kg is suspended from a wire of radius $10^{-3}$ m and density $9 \times 10^3 kg/m^3$ Calculate the change is temperature of the wire if 75% of the work done is converted into heat. The

Young's modulus and the specific heat capactiy of the meterial of the wire are $9.8 \times 10^{10} N/m^2$ and $490 J/kg/K$ respectively.

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**44.** Alight rod of length 2 m is suspended horizontlly from the ceiling bty means of two vertical wirs of equal length tied to its ends One wire is mode of steel and is of cross - section 0.1 sq cm and the other is of brass of cross -section 0.2 sq cm Find the postion along the rod at which a wight may be hung to produce (i) equal stress in both wirs (ii) equal strain in both wires (Y for brass $= 10 \times 10^{10} Nm^{-2}$ and $Y$ for steel $= 20 \times 10^{10} Nm^{-2}$)

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**45.** A thin rod of negligible mass and area of cross-section $4 \times 10^{-6} m^2$, suspended vertically from one end has a length of $0.5m$ at $10^{\circ} C$. The rod is cooled art $0^{\circ} C$, but prevented from contracting by attaching a mass at the loose end. Find

$(i)$ This mass and

$(ii)$ The energy stored in the rod.

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

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**46.** A wire of cross section $A$ is stretched horizontally between two clamps located $2lm$ 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

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**47.** A wire of cross -sectional area $4 \times 10^{-4} m^2$ , modulus of elasticity $2 \times 10^{11} Nm^{-2}$ and length 1 m is stretched between two rigid poles . A mass of 1 kg is suspended at its middle . Calculate the angle it makes with horizontal . Take g = $10 ms^{-2}$

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**48.** A rod AD consisting of three segments AB, BC and CD joined together is hanging vertically from a fixed support at A. The lengths of the segments are respectively : 1 m, 0.2 m and 0.15 m. The cross section of the rod is uniformly $10^{-4} m^2$. A weight of 10 kg is hung from D. Calculate the displacements of point of B, C and D using the data of Young's moduli given below (neglect the weight of the rod).

$Y_{AB} = 2.5 \times 10^{10} N / m^2$,

$Y_{BC} = 4.0 \times 10^{10} N/m^2,$

$Y_{CD} = 1.0 \times 10^{10} N/m^2$

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**49.** A stone of 0.5 kg mass is attached to one end of a $0.8$ m long aluminium wire of $0.7$ mm diameter and suspended vertically. The stone is now rotated in a horizontal plane at a rate such that the wire makes an angle of $85^\circ$ with the vertical. find the increase in the length of the wire. The Young's modulus of aluminium = $7 \times 10^{10} Nm^{-2}$, $\sin 85^\circ = 0.9962$, $\cos 85^\circ = 0.0872$

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**50.** A sphere of radius $0.1m$ and mass $8\pi\ kg$ is attached to the lower end of a steel wire of length $5.0m$ 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 position . Young's modulus of steel is $(1.994 \times 10^{11} N/m^2)$.

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**51.** A thin uniform metallic rod of length 0.5 m and radius 0.1 m rotates with an angular velocity 400rad/s is a horizontal plane about a vertical axis passing through one of its ends. Calculate (a) tenstion in the rod and (b) the elogation of te rod. The density of material of the rod is $10^4 kg/m^3$ and the young's modulus is $2 \times 10^{11} N/m^2$

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**52.** A body of mass $3.14kg$ is suspended from one end of a wire of length $10m$. The radius of cross-section of the wire is changing uniformly from $5 \times 10^{-4}m$ at the top (i.e. point of suspension) to $9.8 \times 10^{-4}m$ at the bottom . Young's modulus of elasticity is $2 \times 10^{11}N/m^2$. The change in length of the wire is

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**53.** Two rods of equal cross-sections, one of copper and the other of steel are joined to from a composite rod of length $2.0m$ at $20^\circ C$ the length of the copper rod is $0.5m$. When the temperature is raised to $120^\circ C$, the length of composite rod increases to $2.002m$. If the composite rod is fixed between two rigid walls and thus not allowed to expand, it is found that the length of the component rod also do not change with increase in temperature. Calculate the Young's modulus of steel. Given Young's modulus of copper $= 1.3 \times 10^{11} N/m^2$ the coefficient of linear expansion of copper $\alpha_C = 1.6 \times 10^{-5} / .^\circ c$

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**54.** Two rods of equal cross-sections, one of copper and the other of steel are joined to from a composite rod of length $2.0m$ at $20^\circ C$ the length of the copper rod is $0.5m$. When the temperature is raised to $120^\circ C$, the length of composite rod increases to $2.002m$. If the composite rod is fixed between two rigid walls and thus not allowed to expand, it is found that the length of the component rod also do not change with increase in temperature. Calculate the Young's modulus of steel. Given Young's modulus of copper $= 1.3 \times 10^{11} N/m^2$ the coefficient of linear expansion of copper $\alpha_C = 1.6 \times 10^{-5} / .^\circ c$

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**55.** In order to produce a longitudinal strain of $2 \times 10^{-4}$, a stress of $2.4 \times 10^{7} Nm^{-2}$ is produced in a wire. Calculate the Young's modulus of the material of the wire.

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**56.** A load of 2 kg produces an extension of 1 mm in a wire 3 m in length and 1 mm in diameter.l Calculate Young's modulus of elesticity of wire.

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**57.** A 4m long aluminium wire whose diameter is 3 mm is used to support a mass of 50 kg. What will be elongation of the wire ? Y for aluminium is $7 \times 10^{10} Nm6( - 2)$

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**58.** How much will a 30 m steel tape 1 cm wide and 0.05 cm thick stretch under a pull of force of 300 N , if Young's modulus of steel is $2 \times 10^{11} Nm^{-2}$?

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**59.** Find the stress to be applied to a steel wire to stretch it by 0.025% of its original length. Y for steel is $9 \times 10^{10} Nm^{-2}$

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**60.** A uniform wire 6 m long weighing 40 g elongates by 0.8 mm when stretched by a load of 1 kg. If its density is 8.9 g $cm^{-3}$, Find young's modulus of the material.

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**61.** Two wires made of the same material are subjected to forces in the ratio of $1:4$. Their lengths are in the ratio $8:1$ and diameter in the ration 2:1. Find the ratio of their extensions.

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**62.** A wire elongates by 9 mm when a load of 10 kg is suspended from it. What is the elongation when its radius is doubled, if all other quantities are same as before?

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**63.** The breaking stress of aluminium is $7.5 \times 10^7 Nm^{-2}$ Find the greatest length of aluminum wire that can hang vertically without breaking Density of aluminium is $2.7 \times 10^3 kgm^{-3}$

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**64.** A steel wire of length 5.0 m and cross-section $3.0 \times 10^{-5} m^2$ stretches by the same amount as a copper wire of length 3.0 m and cross -section $4.0 \times 10^{-5} m^2$ under a given load. What is the ratio of Young's modulus of steel to that of copper?

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**65.** A mass of 5 kg is hung from a copper wire of 5 mm diameter and 2 m in length. Calculate the extension produced. What should be the minimum diameter of the wire so that its elastic limit is not exceeded ? Elastic limit for copper $= 1.5 \times 10^9$ dyne $cm^{-2}$ and Y for copper $= 1.1 \times 10^{12}$ dyne $cm^{-2}$

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**66.** A stress of 1 kg $mm^{-2}$ is applied to a wire of which Young's modulus is $10^{11} Nm^{-2}$ and $1.1 \times 10^{11} Nm^{-2}$. Find the percentage increase in length.

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**67.** Two exactly similar wires of steel and copper are stretched by equal forces. If the total elogation is 1cm. Find by how much is each wire elongated ? Given Y for steel $= 20 \times 10^{11} dyne / cm^2$ and $Y f$ or $copper = 12 \times 10^{11} dyne / cm^2$

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**68.** $Na$ से $Na^+$ ................ होगा|

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**69.** Two parallel wires A and B of same material are fixed to rigid support at the upper ends and subjected to same load at the lower ends. The lengths of the wire are in the ration 4 : 5 and their radii are in the ratio 4 : 3 the increase in the length of wire A is 1 mm. Calculate the increase in the length of the wire B.

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**70.** Two wires of equal cross section but one made of steel and the other of copper, are joined end to end. When the combination is kept under tension, the elongations in the two wires are found to be equal. Find the ratio of the lengths of the two wires. Young modulus of steel $= 2.0 \times 10^{11} Nm^{-2}$ and that of copper $= 1.1 \times 10^{1} Nm^{-2}$

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**71.** A lift is tied with thick iron wire and its mass is $1000kg$. If the maximum acceleration of the lift is $1.2ms^2$ and the maximum stress of the wire is $1.4 \times 10^8 Nm^2$ what should be the minimum diameter of the wire?

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72. The length of a metal wire is $l_1$ when the tension in it is $T_1$ and is $l_2$ when the tension is $T_2$. Then natural length of the wire is

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73. A metal bar of length $L$ and area of cross-section A is clamped between two rigid supports. For the material of the rod. It Young's modulus is Y and Coefficient if linear expansion is $\alpha$. If the temperature of the rod is increased by $\Delta t^{\circ} C$, the force exerted by the rod on the supports is

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74. A steel wire 2mm in diameter is stretched between two clamps, when its temperature is $40^{\circ} C$ Calculate the tension in

the wire, when its temperature falls to $30^\circ C$ Given, coefficient Y for steel $= 21 \times 10^{11} dyne/cm^2$, coefficient for steel= 11 x 10^(-6).

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**75.** Find the change in volume which 1c.c. of water at the surface will undergo, when it is taken to the bottom of the lake 100 m deep, given that volume elasticity is 22000 atmosphere.

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**76.** A solid ball 300 cm in diameter is submerged in a lake a such a depth that the pressure exerted by water is 1.00 kgf $cm^{-2}$. Find the change in volume of the ball at this depth k for material of the ball $= 1.00 \times 10^{13} dy \ne cm^{-2}$

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77. A spherical ball contracts in volume by 0.0098% when subjected to a pressure of 100 atm. Calculate its bulk modulus. Given 1 atm $= 1.01 \times 10^5 Nm^{-2}$.

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78. What increases in pressure will be needed to decrease the volume of $1.0m^3$ of water by 10c.c. ? The bulk modulus of water is $0.21 \times 10^{10} Nm^{-2}$

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79. Determine the fractional change in volume as the pressure of the atmosphere $(1.0 \times 10^5$Pa) around a metal block is reduced

to zero by placing the block in vacuum. The bulk modulus for the block is $1.25 \times 10^{11} Nm^{-2}$.

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**80.** Find the density of the metal under a pressure of 20,000 N $cm^{-2}$. Given density of the metal=11 g $cm^{-3}$, bulk modulus of the metal $= 8 \times 10^{9} Nm^{-2}$

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**81.** Calculate the volume change of a solid copper cube, 40 mm on each edge, when subjected to a pressure of $2 \times 10^{7}$ Pa. The bulk modulus for copper is $1.25 \times 10^{11} Nm^{-2}$.

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**82.** Find the depth of a lake at which density of water will be 10% higher than the density at the surface. Compresssibility of water is $0.00005$ per atmosphere. Given average density of sea-water $= 1100 kgm^{-3}$

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**83.** The compressibility of water is $4 \times 10^{-5}$ per unit atmospheric pressure. The decrease in volume of 100 cubic centimetre of water under a pressure of 100 atmosphere will be

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**84.** In taking a solid ball of rubber from the surface to the bottom of a lake of $180 m$ depth, reduction in the volume of the ball is $0.01 \%$. The density of water of the lake is $1 \times 10^3 kg/m^3$.

Determine the value of the bulk modulus of elasticity of rubber .

$(g = 9.8m/s^2)$

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**85.** A uniform pressure P is exerted by an external agent on all sides of a solid cube at temperature $t^\circ C$. By what amount should the temperature of the cube be raised in order to bring its volume back to its original volume before the pressure was applied if the bulk modulus is B and co-efficient of volumetric expansion is $\gamma$?

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

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**87.** An Indian rubber cube of side 7 cm has one side fixed, while a tengential force equal to the weight of 200 kilogram is applied to the opposite face. Find the shearing strain produced and distance through which th strained side moves. Modulus of rigidity for rubber is $2 \times 10^7$ dyne $cm^{-2}$

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**88.** A box shaped piece of gelatine desert has a top area of 15 $cm^2$ and a height of 3 cm. when a shearing force of 0.50 N is applied to the upper surface, the upper surface is displaced 4mm relative to the bottom surface. What are the shearing stress, shearing strain and shear modulus for the gelatin ?

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**89.** The metal cube of side 10 cm is subjected to a shearing stress of $10^4 Nm^{-2}$. The modulus of rigidiy if the top of the cube is displaced by 0.05 cm with respect to its bottom is

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**90.** Two parallel and opposite forces, each of magnitude $4000N$, are applied tangentially to the upper and lower faces of a cubical metal block $25cm$ on a side. Find the angle of shear and the displacement of the upper surface relative to the lower surface. The shear modulus for the metal is $80 GPa$.

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**91.** If the Young's modulus of steel is $2 \times 10^{11} Nm^{-2}$, calculate the work done in stretching a steel wire 100 cm in length and of cross-sectional area $0.03 cm^3$ when a load of 20 kg is slowly applied without the elastic limit being reached.

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**92.** A wire of area of cross section $3.0 mm^2$ and natural length 50 cm is fixed at one end and a mas of 2.1 kg is hung from the other end. Find the elastic potential energy stored in the wire in steady state. Young modulus of the material of the wire $= 1.9 \times 10^{11} Nm^{-2}. Take g = 10 ms^{-2}$

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**93.** The limiting stress for a typical human bone is $0.9 \times 10^{8} Nm^{-2}$ while Young's modulus is $1.4 \times 10^{10} Nm^{-2}$. How much energy can be absorbed by two legs ( without breaking ) if each has typical length of 50 cm and an average cross-sectional area of $5 cm^{2}$ ?

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