PHYSICS

BOOKS - ARIHANT PHYSICS (HINGLISH)

ELASTICITY

Level 1

1. Human bones remain elastic if strain is less than 0.5%. However, the young's modulus for compression (Y_c) and stretch (Y_s) are different. The typical values are $Y_c = 9.4 \times 10^9 Pa$ and $Y_s = 16 \times 10^9 Pa$. The shear modulus of elasticity for the bone is $h = 10^{10} Pa$ Answer following questions with regard to a leg bone of length $20cm$ and cross sectional area $3cm^2$

(a) Calculate the maximum stretching force that the bone can sustain and still remain elastic.

(b) A man of mass 60 kg jumps from a height of 10 m on a concrete floor. Half his momentum is absorbed by the impact of the floor on the particular bone we are talking about. The impact lasts for 0.02 s. Will the compressive stress exceed the elastic limit?

(c) How much shearing force will be needed to break the bone if breaking strain is $5^\circ C$.

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2. The elastic limit and ultimate strength for steel is $2.48 \times 10^8 Pa$ and $4.89 \times 10^8 Pa$ respectively. A steel wire of 10 m length and 2 mm cross sectional diameter is subjected to longitudinal tensile stress. Young's modulus of steel is $Y = 2 \times 10^{11} Pa$

(a) Calculate the maximum elongation that can be produced in the wire without permanently deforming it. How much force is needed to produce this extension?

(b) Calculate the maximum stretching force that can be applied without breaking the wire.

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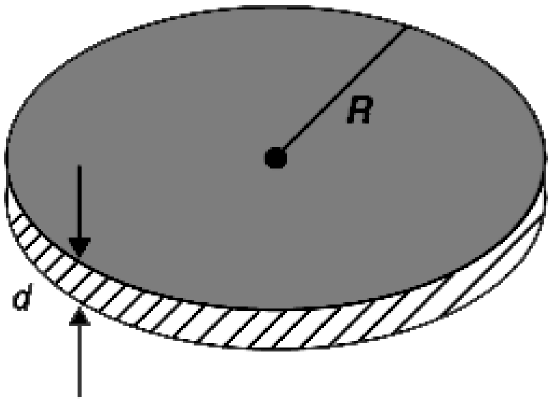
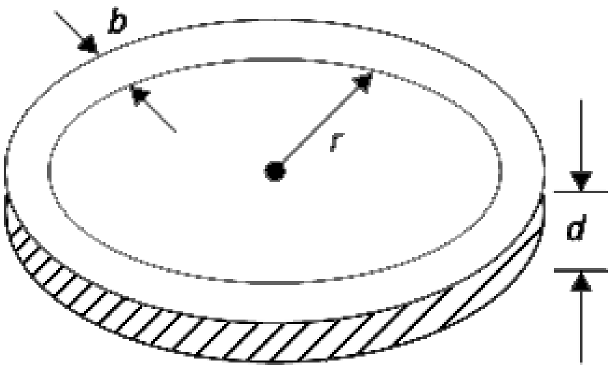
3. A steel ring is to be fitted on a wooden disc of radius R and thickness d. The inner radius of the ring is r which is slightly smaller than R. The outer radius of the ring is r + b and its thickness is d (same as the disc). There is no change in value of b and d after the ring is fitted over the disc, only the inner radius becomes R. If the Young's modulus of steel is Y, calculate the longitudinal stress developed in it. Also calculate the tension force developed in the ring.

[Take $b < \; < r$]





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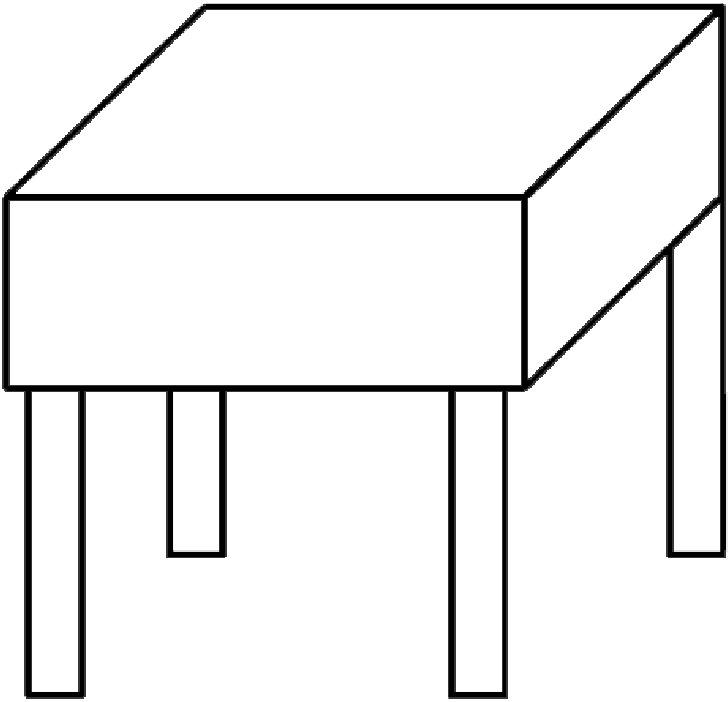
4. A water tank is supported by four pillars. The pillars are strong enough to sustain ten times the stress developed in them when the tank is completely full. An engineer decides to increase the every dimension of the tank and the pillars by hundred times so as to store more water. Do you think he has taken a right decision? Assume that material used in construction of the tank and pillars remain same.



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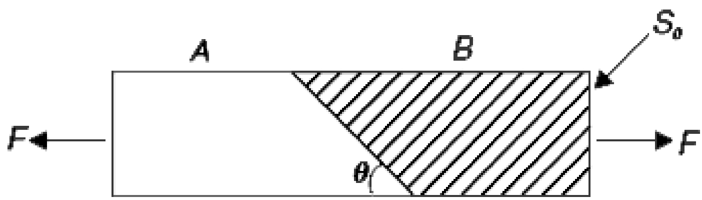
5. Two bars A and B are stuck using an adhesive. The contact surface of the bars make

an angle q with the length. Area of cross section of each bar is S_0. It is known that the adhesive yields if normal stress at the contact surface exceeds σ_0. Find the maximum pulling force F that can be applied without detaching the bars.



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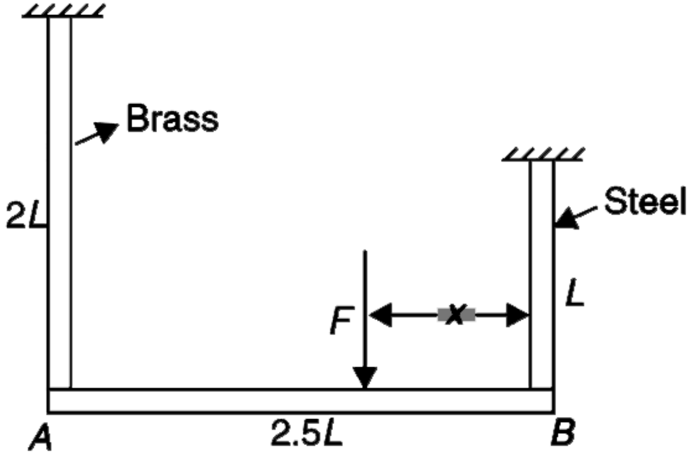
6. A very stiff bar (AB) of negligible mass is suspended horizontally by two vertical rods as shown in figure. Length of the bar is 2.5 L. The steel rod has length L and cross sectional radius of r and the brass rod has length 2L and cross sectional radius of 2r . A vertically downward force F is applied to the bar at a distance x from the steel rod and the bar remains horizontal. Find the value of x if it is given that ratio of Young's modulus of steel and brass is $\frac{Y_s}{Y_B} = 2.$



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7. A closed steel cylinder is completely filled with water at $0^\circ C$. The water is made to freeze at $0^\circ C$. Calculate the rise in pressure on the cylinder wall. It is known that density of water at $0^{\circ} C$ is $1000 kg / m^3$ and the density of ice at $0^{\circ} C$ is $910 kg / m^3$. Bulk modulus of ice at $0^{\circ} C$ is nearly $9 \times 10^9 Pa$. [Compare this pressure to the atmospheric pressure. Now you can easily understand why water pipelines burst in cold regions as the winter sets in.]

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8. (i) Two identical rods, one of steel, the other of copper, are stretched by an identical amount. On which operation more work is expended?

(ii) Two identical rods, one of steel, the other of copper, are stretched with equal force. On which operation is more work needed?

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Level 2

1. A thin ring of radius R is made of a wire of density ρ and Young's modulus Y. It is spun in its own plane, about an axis through its centre, with angular velocity w. Determine the amount (assumed small) by which its circumference increases.

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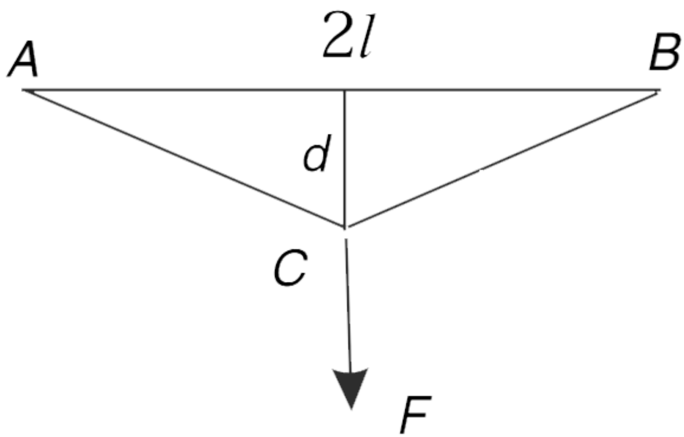
2. A steel wire of radius r is stretched without tension along a straight line with its ends fixed at A and B (figure). The wire is pulled into the shape ACB. Assume that d is very small compared to length of the wire. Young's modulus of steel is Y.

(a) What is the tension (T) in the wire?

(b) Determine the pulling force F. Is F larger than T?



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3. A uniform material rod of length L is rotated in a horizontal plane about a vertical axis

through one of its ends. The angular speed of rotation is w. Find increase in length of the rod. It is given that density and Young's modulus of the rod are r and Y respectively.

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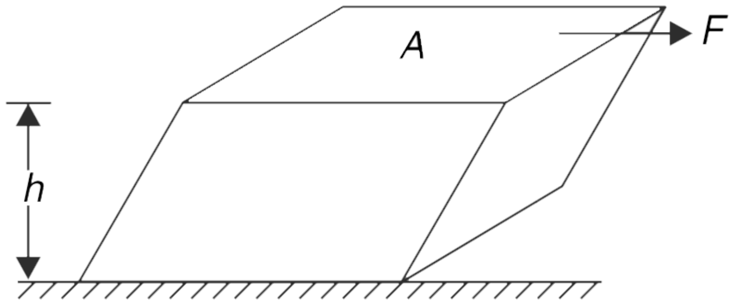
4. A rectangular bar is fixed to a hard floor. Height of the bar is h and its area in contact with the floor is A. A shearing force distorts the bar as shown. Prove that the work done by the shearing force is $W = \left(\frac{\sigma^2}{2\eta}\right) \times$ volume of the bar. Here σ is shear modulus of elasticity. Assume the deformation to be small.



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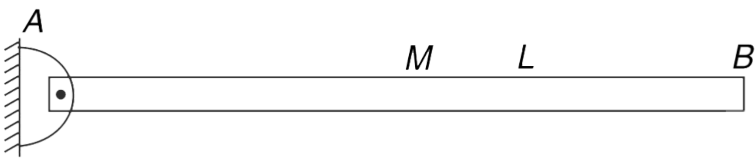
5. A thin uniform rod of mass M and length L is free to rotate in vertical plane about a horizontal axis passing through one of its ends. The rod is released from horizontal position shown in the figure. Calculate the shear stress developed at the centre of the rod immediately after it is released. Cross sectional area of the rod is A. [For calculation of moment of inertia you can treat it to very thin]



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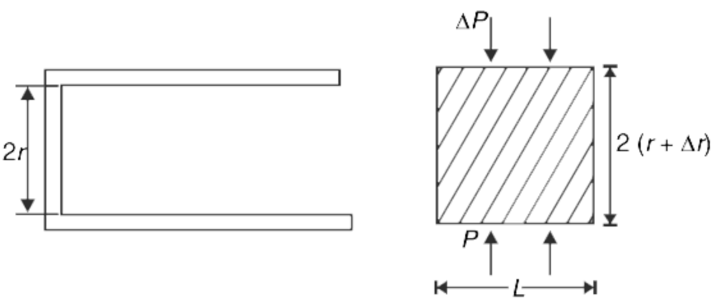
6. A rigid cylindrical container has inner radius r. A cork having radius $r + \Delta r$ and length L is to be fitted so as to close the container. Uniform pressure (ΔP) is needed on the curved cylindrical surface of the cork. Poisson's ratio of a cork is almost zero, and its bulk modulus is B.



(a) Calculate ΔP

(b) After the cork is fitted how much force will be needed to pull it out of the container? Coefficient of friction between the container and the cork is μ.

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7. Assume that the least load which would break a thread when simply suspended from it is M and that this load produces a strain of 1 percent at the moment of breaking. Also assume that Hooke's law applies to the thread right up to breakingpoint. A load of mass m is suspended from a thread of length λ. It is raised to a height and released. Find the least height to which the load must be raised so that it will will break the thread when allowed to fall.

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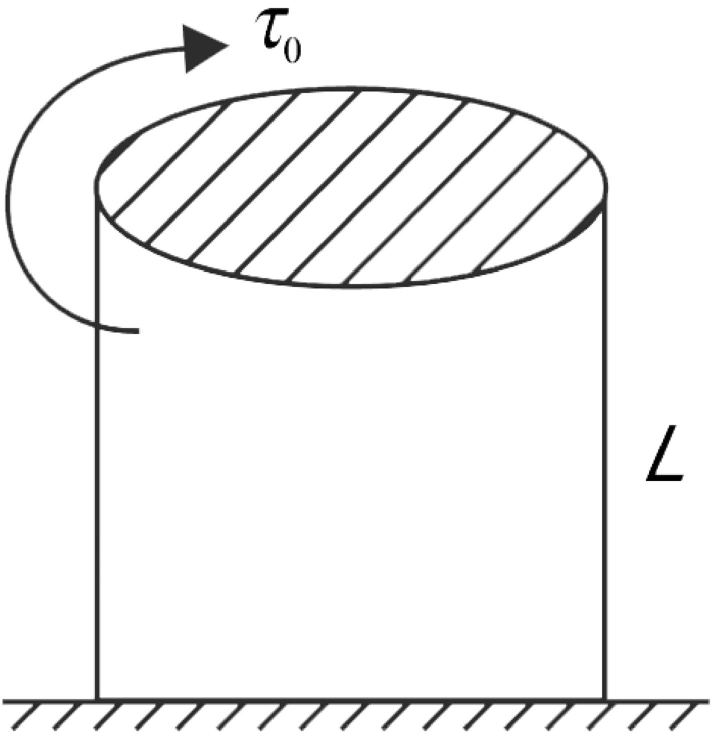
8. Atmospheric pressure is P_0 and density of water at the sea level is ρ_0. If the bulk modulus of water is B, calculate the pressure deep inside the sea at a depth h below the surface.

View Text Solution

Level 3

1. A metal cylinder of length L and radius R is fixed rigidly to ground with its axis vertical. A twisting torque τ_0 is applied along the circumference at the top of the cylinder. This causes an angular twist of θ_0 (rad) in the top surface. Calculate the shear modulus of elasticity (η) of the material of the cylinder.



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