Mechanical properties of solids and fluid mechanics

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1. A steel wire having a radius of $2.0\ mm$, carrying a load of $4\ kg$, is hanging from a ceiling. Given that $g = 3.1\pi\ ms^{-2}$, what will be the tensile stress that would be developed in the wire?

   A. $4.8 \times 10^6\ Nm^{-2}$

   B. $5.2 \times 10^6\ Nm^{-2}$

   C. $6.2 \times 10^6\ Nm^{-2}$

   D. $3.1 \times 10^6\ Nm^{-2}$

2. A man grows into a giant such that his linear dimensions increase by a factor of 9. Assuming that his density remains same, the stress in the leg will change by a factor of

   A. $\dfrac{1}{81}$

   B. 9

   C. $\dfrac{1}{9}$

   D. 81

3. A pendulum made of a uniform wire of cross sectional area A has time period T. When an additional mass M is added to its bob, the time period changes to T_M. If the Young's modulus of the material of the wire is Y, then $1/Y$ is equal to

   A. $\left[\left(\dfrac{T_M}{T}\right) - 1\right]\dfrac{Mg}{A}$

   B. $\left[1 - \left(\dfrac{T_M}{T}\right)^2\right]\dfrac{A}{Mg}$

   C. $\left[1 - \left(\dfrac{T}{T_M}\right)^2\right]\dfrac{A}{Mg}$

   D. $\left[\left(\dfrac{T_M}{T}\right)^2 - 1\right]\dfrac{A}{Mg}$

4. Speed of transverse wave on a straight wire (mass $6.0\ g$, length $60\ cm$ and area of cross-section $1.0\ mm^2$) is $90\ m/s$. If the Young's modulus of wire is $16 \times 10^{11}\ Nm^{-2}$, the extension of wire over its natural length is

   A. $0.03\ mm$

   B. $0.02\ mm$

   C. $0.04\ mm$

   D. $0.01\ mm$

5. The normal density of a material is ρ and its bulk modulus of elasticity is K. The magnitude of increase in density of material, when a pressure P is applied uniformly on all sides, will be:

   A. $\dfrac{\rho K}{P}$

   B. $\dfrac{K}{\rho P}$

   C. $\dfrac{PK}{\rho}$

   D. $\dfrac{\rho P}{K}$

6. An object is located at 2 km beneath the surface of the water. If the fractional compression $\dfrac{\Delta V}{V}$ is 1.36%, the ratio of hydraulic stress to the corresponding hydraulic strain will be:
   [Given : density of water is 1000 kg m^{-3} and $g = 9.8 \text{ m s}^{-2}$]

   A. $2.26 \times 10^9 \text{ Nm}^{-2}$

   B. $1.96 \times 10^7 \text{ Nm}^{-2}$

   C. $1.44 \times 10^7 \text{ Nm}^{-2}$

   D. $1.44 \times 10^9 \text{ Nm}^{-2}$

7. A raindrop with radius $R = 0.2 \text{ mm}$ falls from a cloud at a height $h = 2000 \text{ m}$ above the ground. Assume that the drop is spherical throughout its fall and the force of buoyance may be neglected, then the terminal speed attained by the raindrop is :
   [Density of water $\rho_w = 1000 \text{ kg m}^{-3}$ and density of air
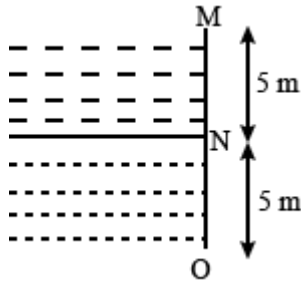 $\rho_a = 1.2 \text{ kg m}^{-3}, g = 10 \text{ m/s}^2$
   Coefficient of viscosity of air$= 1.8 \times 10^{-5} \text{ Nsm}^{-2}$

   A. 250.6 ms^{-1}

   B. 43.56 ms^{-1}

   C. 4.94 ms^{-1}

   D. 14.4 ms^{-1}

8.

Two liquids of densities ρ_1 and ρ_2 $(\rho_2 = 2\rho_1)$ are filled up behind a square wall of side 10 m as shown in figure. Each liquid has a height of 5 m. The ratio of the forces due to these liquids exerted on upper part MN to that at the lower part NO is (Assume that the liquids are not mixing)

   A. $1/3$

   B. $2/3$

   C. $1/2$

   D. $1/4$

9. An ideal fluid flows (laminar flow) through a pipe of non-uniform diameter. The maximum and minimum diameters of the pipes are 6.4 cm and 4.8 cm, respectively. The ratio of the minimum and maximum velocities of fluid in this pipe is:

   A. $\dfrac{9}{16}$

   B. $\dfrac{\sqrt{3}}{2}$

   C. $\dfrac{3}{4}$

   D. $\dfrac{81}{256}$

10. A leakproof cylinder of length 1 m, made of a metal which has very low coefficient of expansion, is floating vertically in water at $0°\text{C}$ such that its height above the water surface is 20 cm. When the temperature of water is increased to $4°\text{C}$, the height of the cylinder above the water surface becomes 21 cm. The density of water at $T = 4°C$, relative to the density at $T = 0°C$ is close to:

    A.   1.26

    B.   1.04

    C.   1.01

    D.   1.03

11. A hollow spherical shell at outer radius R floats just submerged under the water surface. The inner radius of the shell is r. If the specific gravity of the shell material is $\dfrac{27}{8}$ w.r.t water, the value of r is

    A. $\dfrac{8}{9}R$

    B. $\dfrac{4}{9}R$

    C. $\dfrac{2}{3}R$

    D. $\dfrac{1}{3}R$

12. In an experiment to verify Stokes law, a small spherical ball of radius r and density ρ falls under gravity through a distance h in air before entering a tank of water. If the terminal velocity of the ball inside water is same as its velocity just before entering the water surface, then the value of h is proportional to
(ignore viscosity of air)

   A. r^4

   B. r

   C. r^3

   D. r^2

13. An Object of mass m is suspended at the end of a massless wire of length L and area of cross-section A, Young modulus of the material of the wire is Y. If the mass is pulled down Slightly, its frequency of oscillation along the vertical direction is:

   A. $f = \dfrac{1}{2\pi}\sqrt{\dfrac{mL}{YA}}$

   B. $f = \dfrac{1}{2\pi}\sqrt{\dfrac{YA}{mL}}$

   C. $f = \dfrac{1}{2\pi}\sqrt{\dfrac{mA}{YL}}$

   D. $f = \dfrac{1}{2\pi}\sqrt{\dfrac{YL}{mA}}$

14. An air bubble of radius $1\ \text{cm}$ in water has an upward acceleration $9.8\ \text{cm/s}^2$. The density of water is $1\ \text{g/cm}^3$ and water offers negligible drag force on the bubble. The mass of the bubble is $(g = 980\ \text{cm/s}^2)$

   A. $4.51\ \text{gm}$

   B. $3.15\ \text{gm}$

   C. $4.15\ \text{gm}$

   D. $1.52\ \text{gm}$

15. A cylindrical plastic bottle of negligible mass is filled with 310 ml of water and left floating in a pond with still water. If pressed downward slightly and released, it starts performing simple harmonic motion at angular frequency ω. If the radius of the bottle is 2.5 cm then ω is close to: (density of water 10^3 kg/m^3)

    A. 3.75 rad s^{-1}

    B. 1.25 rad s^{-1}

    C. 2.50 rad s^{-1}

    D. $2.50\sqrt{10} \text{ rad s}^{-1}$

16. Two identical cylindrical vessels are kept on the ground and each contain the same liquid of density d. The area of the base of both vessels is S but the height of liquid in one vessel is x_1 and in the other, x_2. When both cylinders are connected through a pipe of negligible volume, very close to the bottom, the liquid flows from one vessel to the other until it comes to equilibrium at a new height. The change in energy of the system in the process is:

    A. $gdS(x_2^2 + x_1^2)$

    B. $gdS(x_2 + x_1)^2$

    C. $\dfrac{3}{4}gdS(x_2 - x_1)^2$

    D. $\dfrac{1}{4}gdS(x_2 - x_1)^2$

17. A cube of metal is subjected to a hydrostatic pressure of $4\,\mathrm{GPa}$. The percentage change in the length of the side of the cube is close to :(Given bulk modulus of metal, $B = 8 \times 10^{10}\,\mathrm{Pa}$)

   A. 5

   B. 0.6

   C. 20

   D. 1.67

18. A load of mass M is suspended from a steel wire of length 2 and radius $1.0\,\mathrm{mm}$ in Searle's apparatus experiment. The increase in length produced in the wire is $4.0\,\mathrm{mm}$. Now the load is fully immersed in a liquid of relative density 2. The relative density of the material of load is 8. The new value of increase in length of the steel wire is:

   A. $3.0\,\mathrm{mm}$

   B. $4.0\,\mathrm{mm}$

   C. $5.0\,\mathrm{mm}$

   D. Zero

19. The top of a water tank is open to air and its water level is maintained. It is giving out $0.74\,\mathrm{m}^3$ water per minute through a circular opening of $2\,\mathrm{cm}$ radius in its wall. The depth of the centre of the opening from the level of water in the tank is close to

   A. $6.0\,\mathrm{m}$

   B. $4.8\,\mathrm{m}$

   C. $9.6\,\mathrm{m}$

   D. $2.9\,\mathrm{m}$

20. A wooden block floating in a bucket of water has $\frac{4}{5}$ of its volume submerged. When a certain amount of an oil poured into the bucket, it is found that the block is just under the oil surface, with half of its volume underwater and half in oil. The density of oil relative to that of water is-

   A. 0.5

   B. 0.8

   C. 0.6

   D. 0.7

21. In an environment, brass and steel wires of length $1\ \mathrm{m}$ each with areas of cross section $1\ \mathrm{mm}^2$ are used. The wires are connected in series and one end of the combined wire is connected to a rigid support and other end is subjected to elongation. The stress required to produce a net elongation of $0.2\ \mathrm{mm}$ is

   [Given the Young's modulus for steel and brass are respectively $120 \times 10^9\ \mathrm{N/m^2}$ and $60 \times 10^9\ \mathrm{N/m^2}$]

   A. $1.2 \times 10^6\ \mathrm{N/m^2}$

   B. $4.0 \times 10^6\ \mathrm{N/m^2}$

   C. $1.8 \times 10^6\ \mathrm{N/m^2}$

   D. $0.2 \times 10^6\ \mathrm{N/m^2}$

   E. None of the above

22. A cubical block of side 0.5 m floats on water with 30% of its volume under water. What is the maximum weight that can be put on the block without fully submerging it under water? [Take, density of water $= 10^3$ kg/m^3]

   A. 46.3 kg

   B. 87.5 kg

   C. 65.4 kg

   D. 30.1 kg

23. A submarine experiences a pressure of 5.05×10^6 Pa at depth of d_1 in a sea. When it goes further to a depth of d_2, it experiences a pressure of 8.08×10^6 Pa. Then $d_2 - d_1$ is approximately

   (density of water $= 10^3$ kg/m^3 and acceleration due to gravity $= 10$ ms^{-2})

   A. 300 m

   B. 400 m

   C. 600 m

   D. 500 m

24. The elastic limit of brass is 379 MPa. What should be the minimum diameter of a brass rod, if it is to support a 400 N ?

   A. 1.0 mm

   B. 1.16 mm

   C. 0.90 mm

   D. 1.36 mm

25. Water from a tap emerges vertically downwards with an initial speed of 1.0 ms^{-1} . The cross-sectional area of the tap is 10^{-4} m^2. Assume that the pressure is constant throughout the stream of water and that the flow is streamlined. The cross-sectional area of the stream, 0.15 m below the tap would be :

    [Take $g = 10 \text{ ms}^{-2}$]

    A. $2 \times 10^{-5} \text{ m}^2$

    B. $5 \times 10^{-5} \text{ m}^2$

    C. $5 \times 10^{-4} \text{ m}^2$

    D. $1 \times 10^{-5} \text{ m}^2$

26. The value of tension in a long, thin metal wire has been changed from T_1 to T_2. The lengths of the metal wire at two different values of tension T_1 and T_2 are l_1 and l_2 respectively. The actual length of the metal wire is :

    A. $\dfrac{T_1 l_2 - T_2 l_1}{T_1 - T_2}$

    B. $\dfrac{T_1 l_1 - T_2 l_2}{T_1 - T_2}$

    C. $\dfrac{l_1 + l_2}{2}$

    D. $\sqrt{T_1 T_2 l_1 l_2}$

27. Two wires of same length and radius, are joined end to end and loaded. The Young's modulii of the materials of the two wires are Y_1 and Y_2. The combination behaves as a single wire whose Young's modulus is :

    A. $Y = \dfrac{2Y_1 Y_2}{3(Y_1 + Y_2)}$

    B. $Y = \dfrac{2Y_1 Y_2}{Y_1 + Y_2}$

    C. $Y = \dfrac{Y_1 Y_2}{2(Y_1 + Y_2)}$

    D. $Y = \dfrac{Y_1 Y_2}{Y_1 + Y_2}$

28. Two narrow bores of diameter 5.0 mm and 8.0 mm are joined together to form a U-shaped tube open at both ends. If this U-tube contains water, what is the difference in the level of two limbs of the tube.
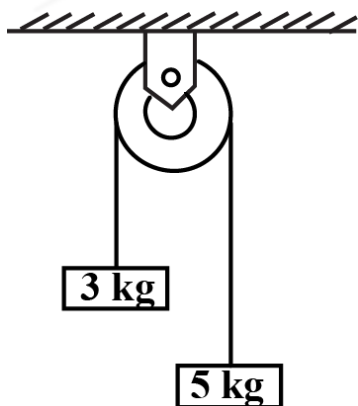
    Take surface tension of water, $T = 7.3 \times 10^{-2} \text{ Nm}^{-1}$
     angle of contact $= 0$
    $g = 10 \text{ ms}^{-2}$
    density of water $= 1.0 \times 10^3 \text{ kgm}^{-3}$

    A. 5.34 mm

    B. 3.62 mm

    C. 4.97 mm

    D. 2.19 mm

29. Two blocks of masses 3 kg and 5 kg are connected by a metal wire going over a smooth pulley. The breaking stress of the metal is $\dfrac{24}{\pi} \times 10^2 \text{ Nm}^{-2}$. What is the minimum radius of the wire?
    $(take \ g = 10 \text{ ms}^{-2})$

    A. 12.5 cm

    B. 125 cm

    C. 1250 cm

    D. 1.25 cm

30. Four identical hollow cylindrical columns of mild steel support a big structure of mass $50 \times 10^3 \ \mathrm{kg}$. The inner and outer radii of each column are $50 \ \mathrm{cm}$ and $100 \ \mathrm{cm}$ respectively. Assuming uniform local distribution, calculate the compression strain of each column. $\left[\text{use } Y = 2.0 \times 10^{11} \ \mathrm{Pa}, g = 9.8 \ \mathrm{m/s^2} \right]$

   A. 2.60×10^{-7}

   B. 3.60×10^{-8}

   C. 1.87×10^{-3}

   D. 7.07×10^{-4}