CHAPTER

7 Properties of Solids and Liquids

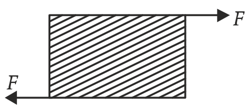
1. A solid sphere of radius r made of a soft material of bulk modulus K is surrounded by a liquid in a cylindrical container. A massless piston of area a floats on the surface of the liquid, covering entire cross section of cylindrical container. When a mass m is placed on the surface of the piston to compress the liquid, the fractional decrement in the radius of the sphere, $\left(\frac{dr}{r}\right)$, is
(a) $\frac{Ka}{mg}$ (b) $\frac{Ka}{3mg}$ (c) $\frac{mg}{3Ka}$ (d) $\frac{mg}{Ka}$
(2018)

2. A thin uniform tube is bent into a circle of radius r in the vertical plane. Equal volumes of two immiscible liquids, whose densities are ρ_1 and ρ_2 ($\rho_1 > \rho_2$), fill half the circle. The angle θ between the radius vector passing through the common interface and the vertical is
(a) $\theta = \tan^{-1}\frac{\pi}{2}\left(\frac{\rho_1+\rho_2}{\rho_1-\rho_2}\right)$ (b) $\theta = \tan^{-1}\frac{\pi}{2}\left(\frac{\rho_2}{\rho_1}\right)$
(c) $\theta = \tan^{-1}\pi\left(\frac{\rho_1}{\rho_2}\right)$ (d) $\theta = \tan^{-1}\left[\frac{\pi}{2}\left(\frac{\rho_1-\rho_2}{\rho_1+\rho_2}\right)\right]$
(Online 2018)

3. A body takes 10 minutes to cool from 60°C to 50°C. The temperature of surroundings is constant at 25°C. Then, the temperature of the body after next 10 minutes will be approximately
(a) 47°C (b) 43°C (c) 41°C (d) 45°C
(Online 2018)

4. When an air bubble of radius r rises from the bottom to the surface of a lake, its radius becomes $\frac{5r}{4}$. Taking the atmospheric pressure to be equal to 10 m height of water column, the depth of the lake would approximately be (ignore the surface tension and the effect of temperature)
(a) 11.2 m (b) 10.5 m (c) 9.5 m (d) 8.7 m
(Online 2018)

5. As shown in the figure, forces of 10^5 N each are applied in opposite directions, on the upper and lower faces of a cube of side 10 cm, shifting the upper face parallel to itself by 0.5 cm. If the side of another cube of the same material is 20 cm, then under similar conditions as above, the displacement will be
(a) 0.25 cm
(b) 0.37 cm
(c) 1.00 cm
(d) 0.75 cm



(Online 2018)

6. A small soap bubble of radius 4 cm is trapped inside another bubble of radius 6 cm without any contact. Let P_2 be the pressure inside the inner bubble and P_0, the pressure outside the outer bubble. Radius of another bubble with pressure difference $P_2 - P_0$ between its inside and outside would be
(a) 12 cm (b) 4.8 cm (c) 2.4 cm (d) 6 cm
(Online 2018)

7. 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) 9 (b) $\frac{1}{9}$
(c) 81 (d) $\frac{1}{81}$
(2017)

8. A copper ball of mass 100 g is at a temperature T. It is dropped in a copper calorimeter of mass 100 g, filled with 170 g of water at room temperature. Subsequently, the temperature of the system is found to be 75°C. T is given by
(Given : room temperature = 30°C, specific heat of copper = 0.1 cal g^{-1} °C^{-1})
(a) 800°C (b) 885°C
(c) 1250°C (d) 825°C
(2017)

9. An external pressure P is applied on a cube at 0°C so that it is equally compressed from all sides. K is the bulk modulus of the material of the cube and α is its coefficient of linear expansion. Suppose we want to bring the cube to its original size by heating. The temperature should be raised by
(a) $\frac{P}{3\alpha K}$ (b) $\frac{P}{\alpha K}$ (c) $\frac{3\alpha}{PK}$ (d) $3PK\alpha$
(2017)

10. A compressive force, F is applied at the two ends of a long thin steel rod. It is heated, simultaneously, such that its temperature increases by ΔT. The net change in its length is zero. Let l be the length of the rod, A its area of cross-section, Y its Young's modulus, and α its coefficient of linear expansion. Then, F is equal to
(a) $l^2 Y\alpha\Delta T$ (b) $\frac{AY}{\alpha\Delta T}$
(c) $AY\alpha\Delta T$ (d) $lAY\alpha\Delta T$
(Online 2017)

11. Two tubes of radii r_1 and r_2, and lengths l_1 and l_2, respectively, are connected in series and a liquid flows through each of them in streamline conditions. P_1 and P_2 are pressure differences across the two tubes. If P_2 is $4P_1$ and l_2 is $\frac{l_1}{4}$, then the radius r_2 will be equal to

(a) $2r_1$ (b) $\frac{r_1}{2}$ (c) $4r_1$ (d) r_1

(Online 2017)

12. A steel rail of length 5 m and area of cross section 40 cm^2 is prevented from expanding along its length while the temperature rises by 10 °C. If coefficient of linear expansion and Young's modulus of steel are 1.2×10^{-5} K^{-1} and 2×10^{11} N m^{-2} respectively, the forced developed in the rail is approximately

(a) 2×10^9 N (b) 3×10^{-5} N

(c) 2×10^7 N (d) 1×10^5 N *(Online 2017)*

13. A pendulum clock loses 12 s a day if the temperature is 40°C and gains 4 s a day if the temperature is 20°C. The temperature at which the clock will show correct time, and the co-efficient of linear expansion (α) of the metal of the pendulum shaft are respectively

(a) 25°C; $\alpha = 1.85 \times 10^{-5}$/°C

(b) 60°C; $\alpha = 1.85 \times 10^{-4}$/°C

(c) 30°C; $\alpha = 1.85 \times 10^{-3}$/°C

(d) 55°C; $\alpha = 1.85 \times 10^{-2}$/°C *(2016)*

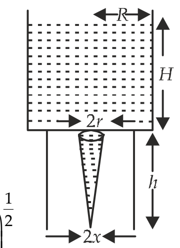
14. A uniformly tapering conical wire is made from a material of Young's modulus Y and has a normal, unextended length L. The radii, at the upper and lower ends of this conical wire, have values R and $3R$, respectively. The upper end of the wire is fixed to a rigid support and a mass M is suspended from its lower end. The equilibrium extended length, of this wire, would equal

(a) $L\left(1+\frac{2}{9}\frac{Mg}{\pi YR^2}\right)$ (b) $L\left(1+\frac{1}{9}\frac{Mg}{\pi YR^2}\right)$

(c) $L\left(1+\frac{1}{3}\frac{Mg}{\pi YR^2}\right)$ (d) $L\left(1+\frac{2}{3}\frac{Mg}{\pi YR^2}\right)$

(Online 2016)

15. Consider a water jar of radius R that has water filled up to height H and is kept on a stand of height h (see figure). Through a hole of radius r(r <<R) at its bottom, the water leaks out and the stream of water coming down towards the ground has a shape like a funnel as shown in the figure. If the radius of the cross-section of water stream when it hits the ground is x. Then



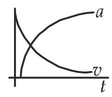
(a) $x = r\left(\frac{H}{H+h}\right)^{\frac{1}{4}}$

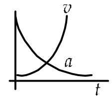
(b) $x = r\left(\frac{H}{H+h}\right)$

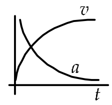
(c) $x = r\left(\frac{H}{H+h}\right)^2$ (d) $x = r\left(\frac{H}{H+h}\right)^{\frac{1}{2}}$

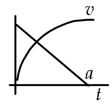
(Online 2016)

16. Which of the following option correctly describes the variation of the speed v and acceleration a of a point mass falling vertically in a viscous medium that applies a force $F = -kv$, where k is a constant, on the body? (Graphs are schematic and not drawn to scale)

(a) 

(b) 

(c) 

(d) 

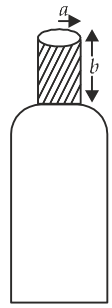
(Online 2016)

17. A simple pendulum made of a bob of mass m and a metallic wire of negligible mass has time period 2 s at T = 0°C. If the temperature of the wire is increased and the corresponding change in its time period is plotted against its temperature, the resulting graph is a line of slope S. If the coefficient of linear expansion of metal is α then the value of S is

(a) $\frac{\alpha}{2}$ (b) 2α (c) α (d) $\frac{1}{\alpha}$

(Online 2016)

18. A bottle has an opening of radius a and length b. A cork of length b and radius $(a + \Delta a)$ where ($\Delta a << a$) is compressed to fit into the opening completely (see figure). If the bulk modulus of cork is B and frictional coefficient between the bottle and cork is μ then the force needed to push the cork into the bottle is



(a) $(\pi\mu Bb)a$

(b) $(2\pi\mu Bb)\Delta a$

(c) $(\pi\mu Bb)\Delta a$

(d) $(4\pi\mu Bb)\Delta a$

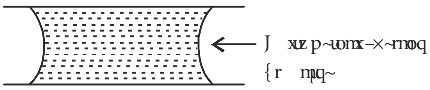
(Online 2016)

19. If it takes 5 minutes to fill a 15 litre bucket from a water tap of diameter $\frac{7}{\sqrt{\pi}}$ oy then the Reynolds number for the flow is (density of water = 10^3 kg/m^3 and viscosity of water = 10^{-3} Pa.s) close to

(a) 5500 (b) 11,000 (c) 550 (d) 1100

(Online 2015)

20. If two glass plates have water between them and are separated by very small distance (see figure), it is very difficult to pull them apart. It is because the water in between forms cylindrical surface on the side that gives rise to lower pressure in the water in comparison to atmosphere. If the radius of the cylindrical surface is R and surface tension of water is T then the pressure in water between the plates is lower by



(a) $\frac{q}{9o}$ (b) $\frac{q}{7o}$ (c) $\frac{9q}{o}$ (d) $\frac{7q}{o}$

(Online 2015)

21. An experiment takes 10 minutes to raise the temperature of water in a container from 0°C to 100°C and another 55 minutes to convert it totally into steam by a heater supplying heat at a uniform rate. Neglecting the specific heat of the container and taking specific heat of water to be 1 cal/g °C, the heat of vapourization according to this experiment will come out to be

(a) 530 cal/g (b) 540 cal/g
(c) 550 cal/g (d) 560 cal/g

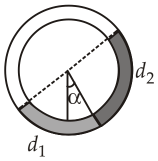
(Online 2015)

22. An open glass tube is immersed in mercury in such a way that a length of 8 cm extends above the mercury level. The open end of the tube is then closed and sealed and the tube is raised vertically up by additional 46 cm. What will be length of the air column above mercury in the tube now? (Atmospheric pressure = 76 cm of Hg)

(a) 6 cm (b) 16 cm (c) 22 cm (d) 38 cm

(2014)

23. There is a circular tube in avertical plane. Two liquids which do not mix and of densities d_1 and d_2 are filled in the tube. Each liquid subtends 90° angle at centre. Radius joining their interface makes an angle α with vertical. Ratio $\frac{d_1}{d_2}$ is



(a) $\frac{1+\sin\alpha}{1-\cos\alpha}$ (b) $\frac{1+\sin\alpha}{1-\sin\alpha}$
(c) $\frac{1+\cos\alpha}{1-\cos\alpha}$ (d) $\frac{1+\tan\alpha}{1-\tan\alpha}$

(2014)

24. The pressure that has to be applied to the ends of a steel wire of length 10 cm to keep its length constant when its temperature is raised by 100°C is (For steel Young's modulus is 2×10^{11} N m^{-2} and coefficient of thermal expansion is 1.1×10^{-5} K^{-1})

(a) 2.2×10^6 Pa (b) 2.2×10^8 Pa
(c) 2.2×10^9 Pa (d) 2.2×10^7 Pa

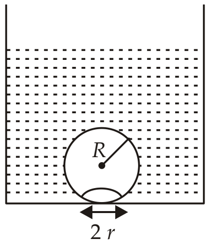
(2014)

25. Three rods of Copper, Brass and Steel are welded together to form a Y-shaped structure. Area of cross-section of each rod = 4 cm^2. End of copper rod is maintained at 100°C where as ends of brass and steel are kept at 0°C. Lengths of the copper, brass and steel rods are 46, 13 and 12 cm respectively. The rods are thermally insulated from surroundings except at ends. Thermal conductivities of copper, brass and steel are 0.92, 0.26 and 0.12 CGS units respectively. Rate of heat flow through copper rod is

(a) 6.0 cal/s (b) 1.2 cal/s
(c) 2.4 cal/s (d) 4.8 cal/s

(2014)

26. On heating water, bubbles being formed at the bottom of the vessel detatch and rise. Take the bubbles to be spheres of radius R and making a circular contact of radius r with the bottom of the vessel. If $r << R$, and the surface tension of water is T, value of r just before bubbles detatch is (density of water is ρ_W)



(a) $R^2\sqrt{\frac{3\rho_W g}{T}}$

(b) $R^2\sqrt{\frac{\rho_W g}{3T}}$

(c) $R^2\sqrt{\frac{\rho_W g}{6T}}$

(d) $R^2\sqrt{\frac{\rho_W g}{T}}$

(2014)

27. Assume that a drop of liquid evaporates by decrease in its surface energy, so that its temperature remains unchanged. What should be the minimum radius of the drop for this to be possible? The surface tension is T, density of liquid is ρ and L is its latent heat of vaporization.

(a) $\frac{2T}{\rho L}$ (b) $\frac{\rho L}{T}$ (c) $\sqrt{\frac{T}{\rho L}}$ (d) $\frac{T}{\rho L}$

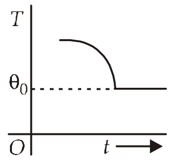
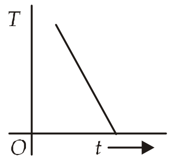
(2013)

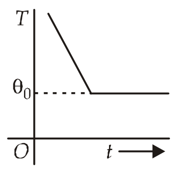
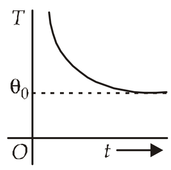
28. A uniform cylinder of length L and mass M having cross-sectional area A is suspended, with its length vertical, from a fixed point by a massless spring, such that it is half submerged in a liquid of density σ at equilibrium position. The extension x_0 of the spring when it is in equilibrium is

(a) $\frac{Mg}{k}\left(1+\frac{LA\sigma}{M}\right)$ (b) $\frac{Mg}{k}$
(c) $\frac{Mg}{k}\left(1-\frac{LA\sigma}{M}\right)$ (d) $\frac{Mg}{k}\left(1-\frac{LA\sigma}{2M}\right)$

(2013)

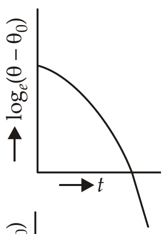
29. If a piece of metal is heated to temperature θ and then allowed to cool in a room which is at temperature θ_0, the graph between the temperature T of the metal and time t will be closed to

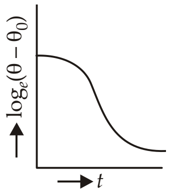
(a)  (b) 

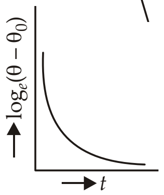
(c)  (d) 

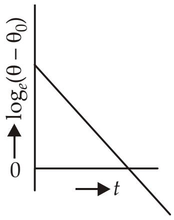
(2013)

30. A liquid in a beaker has temperature $\theta(t)$ at time t and θ_0 is temperature of surroundings, then according to Newton's law of cooling the correct graph between $\log_e(\theta - \theta_0)$ and t is

(a) 

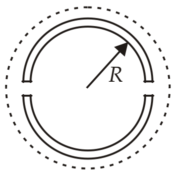
(b) 

(c) 

(d) 

(2012)

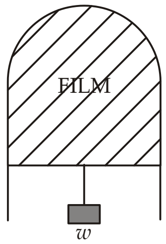
31. A wooden wheel of radius R is made of two semicircular parts (see figure). The two parts are held together by a ring made of a metal strip of cross sectional area S and length L. L is slightly less than $2\pi R$.



To fit the ring on the wheel, it is heated so that its temperature rises by ΔT and it just steps over the wheel. As it cools down to surrounding temperature, it presses the semicircular parts together. If the coefficient of linear expansion of the metal is α, and its Young's modulus is Y, the force that one part of the wheel applies on the other part is

(a) $SY\alpha\Delta T$ (b) $\pi SY\alpha\Delta T$
(c) $2SY\alpha\Delta T$ (d) $2\pi SY\alpha\Delta T$ *(2012)*

32. A thin liquid film formed between a U-shaped wire and a light slider supports a weight of 1.5×10^{-2} N (see figure). The length of the slider is 30 cm and its weight negligible. The surface tension of the liquid film is



(a) 0.1 Nm^{-1}
(b) 0.05 Nm^{-1}
(c) 0.025 Nm^{-1}
(d) 0.0125 Nm^{-1} *(2012)*

33. Water is flowing continuously from a tap having an internal diameter 8×10^{-3} m. The water velocity as it leaves the tap is 0.4 m s^{-1}. The diameter of the water stream at a distance 2×10^{-1} m below the tap is close to

(a) 5.0×10^{-3} m (b) 7.5×10^{-3} m
(c) 9.6×10^{-3} m (d) 3.6×10^{-3} m *(2011)*

34. Work done in increasing the size of a soap bubble from a radius of 3 cm to 5 cm is nearly (Surface tension of soap solution = 0.03 N m^{-1})

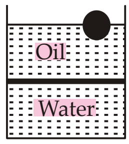
(a) 4π mJ (b) 0.2π mJ (c) 2π mJ (d) 0.4π mJ *(2011)*

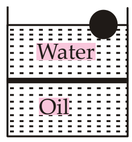
35. The potential energy function for the force between two atoms in a diatomic molecule is approximately given by $U(x) = \frac{a}{x^{12}} - \frac{b}{x^6}$, where a and b are constants and x is the distance between the atoms. If the dissociation energy of the molecule is $D = [U(x = \infty) - U_{\text{at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

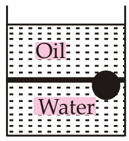
(a) $\frac{b^2}{6a}$ (b) $\frac{b^2}{2a}$ (c) $\frac{b^2}{12a}$ (d) $\frac{b^2}{4a}$

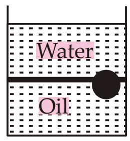
(2010)

36. A ball is made of a material of density ρ where $\rho_{oil} < \rho < \rho_{water}$ with ρ_{oil} and ρ_{water} representing the densities of oil and water, respectively. The oil and water are immiscible. If the above ball is in equilibrium in a mixture of this oil and water, which of the following pictures represents its equilibrium position?

(a) 

(b) 

(c) 

(d) 

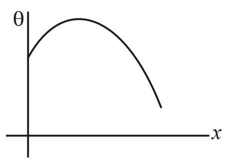
(2010)

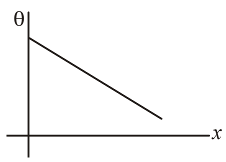
37. Two wires are made of the same material and have the same volume. However wire 1 has cross-sectional area A and wire 2 has cross-sectional area $3A$. If the length of wire 1 increases by Δx on applying force F, how much force is needed to stretch wire 2 by the same amount?

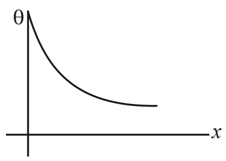
(a) F (b) $4F$ (c) $6F$ (d) $9F$

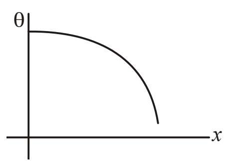
(2009)

38. A long metallic bar is carrying heat from one of its ends to the other end under steady-state. The variation of temperature θ along the length x of the bar from its hot end is best described by which of the following figures?

(a) 

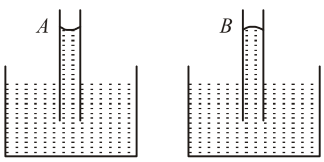
(b) 

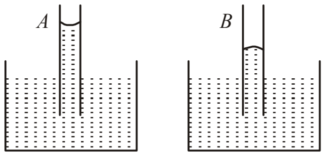
(c) 

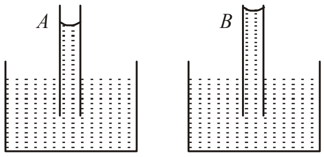
(d) 

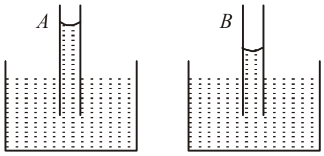
(2009)

39. A capillary tube (A) is dipped in water. Another identical tube (B) is dipped in a soap-water solution. Which of the following shows the relative nature of the liquid columns in the two tubes?

(a) 

(b) 

(c) 

(d) 

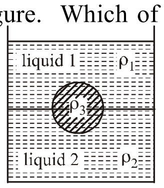
(2008)

40. A spherical solid ball of volume V is made of a material of density ρ_1. It is falling through a liquid of density ρ_2 ($\rho_2 < \rho_1$). Assume that the liquid applies a viscous force on the ball that is proportional to the square of its speed v, *i.e.*, $F_{\text{viscous}} = -kv^2$ ($k > 0$). The terminal speed of the ball is

(a) $\dfrac{Vg(\rho_1 - \rho_2)}{k}$ (b) $\sqrt{\dfrac{Vg(\rho_1 - \rho_2)}{k}}$

(c) $\dfrac{Vg\rho_1}{k}$ (d) $\sqrt{\dfrac{Vg\rho_1}{k}}$ *(2008)*

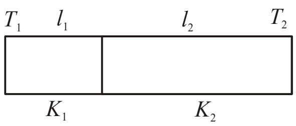
41. A jar is filled with two non-mixing liquids 1 and 2 having densities ρ_1 and ρ_2 respectively. A solid ball, made of a material of density ρ_3, is dropped in the jar. It comes to equilibrium in the position shown in the figure. Which of the following is true for ρ_1, ρ_2 and ρ_3?



(a) $\rho_1 < \rho_3 < \rho_2$
(b) $\rho_3 < \rho_1 < \rho_2$
(c) $\rho_1 > \rho_3 > \rho_2$
(d) $\rho_1 < \rho_2 < \rho_3$

(2008)

42. One end of a thermally insulated rod is kept at a temperature T_1 and the other at T_2. The rod is composed of two sections of lengths l_1 and l_2 and thermal conductivities K_1 and K_2 respectively. The temperature at the interface of the two sections is



(a) $\dfrac{(K_1l_1T_1 + K_2l_2T_2)}{(K_1l_1 + K_2l_2)}$ (b) $\dfrac{(K_2l_2T_1 + K_1l_1T_2)}{(K_1l_1 + K_2l_2)}$

(c) $\dfrac{(K_2l_1T_1 + K_1l_2T_2)}{(K_2l_1 + K_1l_2)}$ (d) $\dfrac{(K_1l_2T_1 + K_2l_1T_2)}{(K_1l_2 + K_2l_1)}$ *(2007)*

43. A wire elongates by l mm when a load W is hanged from it. If the wire goes over a pulley and two weights W each are hung at the two ends, the elongation of the wire will be (in mm)

(a) $l/2$ (b) l (c) $2l$ (d) zero.

(2006)

44. If the terminal speed of a sphere of gold (density = 19.5 kg/m^3) is 0.2 m/s in a viscous liquid (density = 1.5 kg/m^3) find the terminal speed of a sphere of silver (density 10.5 kg/m^3) of the same size in the same liquid

(a) 0.2 m/s (b) 0.4 m/s
(c) 0.133 m/s (d) 0.1 m/s. *(2006)*

45. Assuming the sun to be a spherical body of radius R at a temperature of T K, evaluate the total radiant power, incident on earth, at a distance r from the sun.

(a) $\dfrac{R^2\sigma T^4}{r^2}$ (b) $\dfrac{4\pi r_0^2 R^2\sigma T^4}{r^2}$

(c) $\dfrac{\pi r_0^2 R^2\sigma T^4}{r^2}$ (d) $\dfrac{r_0^2 R^2\sigma T^4}{4\pi r^2}$.

where r_0 is the radius of the earth and σ is Stefan's constant.

(2006)

46. If S is stress and Y is Young's modulus of material of a wire, the energy stored in the wire per unit volume is

(a) $2Y/S$ (b) $S/2Y$ (c) $2S^2Y$ (d) $\dfrac{S^2}{2Y}$

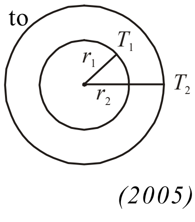
(2005)

47. A 20 cm long capillary tube is dipped in water. The water rises up to 8 cm. If the entire arrangement is put in a freely falling elevator the length of water column in the capillary tube will be

(a) 4 cm (b) 20 cm (c) 8 cm (d) 10 cm

(2005)

48. The figure shows a system of two concentric spheres of radii r_1 and r_2 and kept at temperatures T_1 and T_2, respectively. The radial rate of flow of heat in a substance between the two concentric spheres is proportional to



(a) $\dfrac{r_1r_2}{(r_2 - r_1)}$

(b) $(r_2 - r_1)$

(c) $\dfrac{(r_2 - r_1)}{r_1r_2}$ (d) $\ln\left(\dfrac{r_2}{r_1}\right)$ *(2005)*

49. If two soap bubbles of different radii are connected by a tube,

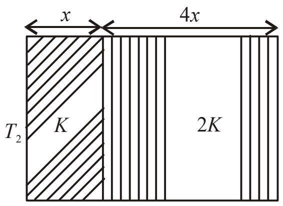
(a) air flows from the bigger bubble to the smaller bubble till the sizes become equal
(b) air flows from the bigger bubble to the smaller bubble till the sizes are interchanged
(c) air flows from the smaller bubble to the bigger
(d) there is no flow of air. *(2004)*

50. Spherical balls of radius R are falling in a viscous fluid of viscosity η with a velocity v. The retarding viscous force acting on the spherical ball is

(a) directly proportional to R but inversely proportional to v
(b) directly proportional to both radius R and velocity v
(c) inversely proportional to both radius R and velocity v
(d) inversely proportional to R but directly proportional to velocity v. *(2004)*

51. A wire fixed at the upper end stretches by length l by applying a force F. The work done in stretching is
(a) $F/2l$ (b) Fl (c) $2Fl$ (d) $Fl/2$. *(2004)*

52. The temperature of the two outer surfaces of a composite slab, consisting of two materials having coefficients of thermal conductivity K and $2K$ and thickness x and $4x$, respectively are T_2 and T_1 ($T_2 > T_1$). The rate of heat transfer through the slab, in a steady state is $\left(\frac{A(T_2 - T_1)K}{x}\right)f$, with f equal to



(a) 1 (b) 1/2
(c) 2/3 (d) 1/3. *(2004)*

53. A radiation of energy E falls normally on a perfectly reflecting surface. The momentum transferred to the surface is
(a) E/c (b) $2E/c$
(c) Ec (d) E/c^2. *(2004)*

54. If the temperature of the sun were to increase from T to $2T$ and its radius from R to $2R$, then the ratio of the radiant energy received on earth to what it was previously will be
(a) 4 (b) 16
(c) 32 (d) 64. *(2004)*

55. A wire suspended vertically from one of its ends is stretched by attaching a weight of 200 N to the lower end. The weight stretches the wire by 1 mm. Then the elastic energy stored in the wire is
(a) 0.2 J (b) 10 J (c) 20 J (d) 0.1 J. *(2003)*

56. According to Newton's law of cooling, the rate of cooling of a body is proportional to $(\Delta\theta)^n$, where $\Delta\theta$ is the difference of the temperature of the body and the surroundings, and n is equal to
(a) two (b) three
(c) four (d) one. *(2003)*

57. The earth radiates in the infra-red region of the spectrum. The wavelength of the maximum intensity of the spectrum is correctly given by
(a) Rayleigh Jeans law (b) Planck's law of radiation
(c) Stefan's law of radiation (d) Wien's law. *(2003)*

58. A cylinder of height 20 m is completely filled with water. The velocity of efflux of water (in m s^{-1}) through a small hole on the side wall of the cylinder near its bottom is
(a) 10 (b) 20 (c) 25.5 (d) 5. *(2002)*

59. Two spheres of the same material have radii 1 m and 4 m and temperatures 4000 K and 2000 K respectively. The ratio of the energy radiated per second by the first sphere to that by the second is
(a) 1 : 1 (b) 16 : 1 (c) 4 : 1 (d) 1 : 9. *(2002)*

60. Which of the following is more close to a black body?
(a) Black board paint (b) Green leaves
(c) Black holes (d) Red roses. *(2002)*

ANSWER KEY

1. (c)	**2.** (*)	**3.** (b)	**4.** (c)	**5.** (a)	**6.** (c)	**7.** (a)	**8.** (b)	**9.** (a)	**10.** (c)	**11.** (b)	**12.** (d)
13. (a)	**14.** (c)	**15.** (a)	**16.** (c)	**17.** (c)	**18.** (d)	**19.** (a)	**20.** (*)	**21.** (c)	**22.** (b)	**23.** (d)	**24.** (b)
25. (d)	**26.** (*)	**27.** (a)	**28.** (d)	**29.** (d)	**30.** (d)	**31.** (c)	**32.** (c)	**33.** (d)	**34.** (d)	**35.** (d)	**36.** (c)
37. (d)	**38.** (b)	**39.** (d)	**40.** (b)	**41.** (a)	**42.** (d)	**43.** (b)	**44.** (d)	**45.** (c)	**46.** (d)	**47.** (b)	**48.** (a)
49. (c)	**50.** (b)	**51.** (d)	**52.** (d)	**53.** (b)	**54.** (d)	**55.** (d)	**56.** (d)	**57.** (d)	**58.** (b)	**59.** (a)	**60.** (a)

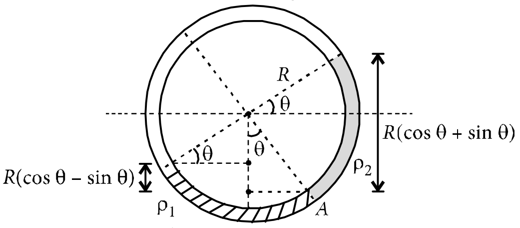
Explanations

1. (c) : Bulk modulus $= \dfrac{\text{Volumetric stress}}{\text{Volumetric strain}}$

$$K = \left|\frac{\Delta P}{\Delta V/V}\right| = \frac{F/a}{dV/V}$$

Here, $F = mg, \dfrac{dV}{V} = 3\dfrac{dr}{r}$ $\therefore$ $K = \dfrac{mg/a}{3\dfrac{dr}{r}}$ or, $\dfrac{dr}{r} = \dfrac{mg}{3Ka}$

2. (*) :



Equating pressure at point A

$\rho_1 gR(\cos\theta - \sin\theta) = \rho_2 gR(\sin\theta + \cos\theta)$

$$\frac{\rho_1}{\rho_2} = \frac{\sin\theta + \cos\theta}{\cos\theta - \sin\theta} = \frac{\tan\theta + 1}{1 - \tan\theta}$$

$\rho_1 - \rho_1 \tan\theta = \rho_2 + \rho_2 \tan\theta$; $(\rho_1 + \rho_2)\tan\theta = \rho_1 - \rho_2$

$$\theta = \tan^{-1}\left(\frac{\rho_1 - \rho_2}{\rho_1 + \rho_2}\right)$$

* None of the given option is correct.

3. (b) : As, $\dfrac{d\theta}{dt} = k\left(\dfrac{\theta_1 + \theta_2}{2} - \theta_0\right)$

According to question, $\dfrac{10}{10} = k\left(\dfrac{50+60}{2} - 25\right) = 30k$

$$k = \frac{1}{30}\ \text{min}^{-1}$$

Again, $\dfrac{50-\theta}{10} = \dfrac{1}{30}\left(\dfrac{50+\theta}{2} - 25\right)$

$50 - \theta = \dfrac{50}{6} + \dfrac{\theta}{6} - \dfrac{25}{3}$ or, $7\theta = 300$ or $\theta = 42.85 \approx 43°\text{C}$

4. (c) : At depth h, $\Delta P = \dfrac{4T}{r}$ or $P_1 = P_0 + \rho gh + \dfrac{4T}{r}$

At the surface of lake, $\Delta P' = \dfrac{4T}{(5r/4)} = \dfrac{16T}{5r}$; $P_2 = P_0 + \dfrac{16T}{5r}$

Also, $P_1V_1 = P_2V_2$ or $\dfrac{P_1}{P_2} = \dfrac{r_2^3}{r_1^3}$

$$\frac{P_0 + \rho gh + \frac{4T}{r}}{P_0 + 16T/(5r)} = \frac{(5r/4)^3}{r^3} \Rightarrow \frac{125}{64} = \frac{10+h}{10} \therefore h = 9.5 \text{ cm}$$

(Excess pressure is very small so we can neglect it.)

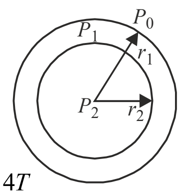
5. (a) : For a given material, shear modulus is constant

$$\frac{F}{A_1} \times \frac{L_1}{\Delta x_1} = \frac{F}{A_2} \times \frac{L_2}{\Delta x_2}$$

Here, $L_2 = 2L_1$; $A_2 = L_2^2 = 4L_1^2 = 4A_1$, $\Delta x_1 = 0.5$ cm

$$\frac{1}{A_1} \times \frac{L_1}{0.5} = \frac{1}{4A_1} \times \frac{2L_1}{\Delta x_2} \quad \therefore \quad \Delta x_2 = 0.25 \text{ cm}$$

6. (c) : Excess pressure inside the inner bubble,



$P_2 - P_1 = \dfrac{4T}{r_2}$ ...(i)

Excess pressure inside the outer bubble,

$P_1 - P_0 = \dfrac{4T}{r_1}$ ...(ii)

From eqn (i) and (ii), $P_2 - P_0 = 4T\left(\dfrac{1}{r_2} + \dfrac{1}{r_1}\right) = \dfrac{4T}{r}$

Here r is required radius of a soap bubble,

$$\therefore \ r = \frac{r_2 r_1}{r_1 + r_2} = \frac{4 \times 6}{4+6} = \frac{24}{10} = 2.4 \text{ cm}$$

7. (a) : We know stress is given by

$$\text{Stress} = \frac{\text{Force}}{\text{Area}} = \frac{mg}{A} = \frac{\rho Vg}{A} \qquad \left(\because \rho = \frac{m}{V}\right)$$

i.e., stress $\propto \dfrac{L^3}{L^2}$ (L is the linear dimension.)

$\Rightarrow$ Stress $\propto L$

Since linear dimension increases by a factor of 9, stress also increases by a factor of 9.

8. (b) : Heat lost by the copper ball,

$Q = ms\Delta T = 100(0.1)(T - 75)$ cal

Heat gained by the water, $Q_1 = 170(1)(75 - 30) = 7650$ cal

Heat gained by the copper calorimeter, $Q_2 = 100(0.1)45 = 450$ cal

Now, $Q = Q_1 + Q_2$

$100(0.1)(T - 75) = 7650 + 450$

$10(T - 75) = 8100 \Rightarrow T = 885°\text{C}$

9. (a) : Bulk modulus of the gas is given by $K = \dfrac{-P}{\left(\dfrac{\Delta V}{V_0}\right)}$

(Here negative sign indicates the decrease in volume with pressure)

or $\dfrac{\Delta V}{V_0} = \dfrac{P}{K}$ ...(i)

Also, $V = V_0(1 + \gamma\Delta T)$ or $\dfrac{\Delta V}{V_0} = \gamma\Delta T$ ...(ii)

Comparing eq. (i) and (ii), we get $\dfrac{P}{K} = \gamma\Delta T \Rightarrow \Delta T = \dfrac{P}{K\gamma}$

$\Rightarrow \Delta T = \dfrac{P}{3\alpha K}$ $(\because \gamma = 3\alpha)$

10. (c) : Thermal expansion, $\Delta l = l\,\alpha\,\Delta T$ ...(i)

Compression $\Delta l'$ produced by applied force is given by,

$Y = \dfrac{Fl}{A\Delta l'}$ or $F = YA\dfrac{\Delta l'}{l}$ ...(ii)

Net change in length = 0 $\Rightarrow \Delta l' = \Delta l$ ...(iii)

Solving eqns. (i), (ii) and (iii),

or $F = YA \times \dfrac{l\,\alpha\,\Delta T}{l} = YA\,\alpha\,\Delta T$

11. (b): Rate of flow of liquid through narrow tube,

$$\frac{dv}{dt} = \frac{\pi P r^4}{8\eta l}$$

As both the given tubes are connected in series so rate of flow of liquid is same.

$$\therefore \quad \frac{\pi P_1 r_1^4}{8\eta l_1} = \frac{\pi P_2 r_2^4}{8\eta l_2} \Rightarrow r_2^4 = \left(\frac{P_1}{P_2}\right)\left(\frac{l_2}{l_1}\right) r_1^4$$

Here, $P_2 = 4P_1$, $l_2 = l_1/4$ So, $r_2^4 = \left(\dfrac{P_1}{4P_1}\right)\left(\dfrac{l_1}{4l_1}\right) r_1^4$

$$r_2^4 = \frac{r_1^4}{16} = \left(\frac{r_1}{2}\right)^4 \quad \therefore \quad r_2 = \frac{r_1}{2}$$

12. (d): Here, $A = 40\ \text{cm}^2 = 4 \times 10^{-3}\ \text{m}^2$

$\Delta\theta = 10°\text{C}$, $Y = 2 \times 10^{11}\ \text{N m}^{-2}$,

$\alpha = 1.2 \times 10^{-5}\ \text{K}^{-1}$, $F = ?$

As $F = YA\,\alpha\,\Delta\theta = 2 \times 10^{11} \times 4 \times 10^{-3} \times 1.2 \times 10^{-5} \times 10$

$= 9.6 \times 10^4\ \text{N} \approx 1 \times 10^5\ \text{N}$

13. (a): Time period of the pendulum clock at temperature θ is given by

$$q_\theta = 7\pi\sqrt{\frac{\theta}{}} = 7\pi\sqrt{\frac{5\text{-}6+\alpha\theta.}{}} = 7\pi\sqrt{\frac{5}{}}\,\text{-}6+\alpha\theta.^{\frac{6}{7}}$$

$$q_\theta \approx q_5\left(6+\frac{6}{7}\alpha\theta\right) \quad \text{...(i)}$$

Assume pendulum clock gives correct time at temperature θ_0

$$\therefore\ q_{\theta_5} = q_5\left(6+\frac{6}{7}\alpha\theta_5\right) \quad \text{...(ii)}$$

At θ = 40 °C > θ_0 as clock loses time.

$$q_{95} = q_5\left(6+\frac{6}{7}\alpha\times 95\right) \quad \text{...(iii)}$$

At θ = 20°C < θ_0 as clock gains time.

$$q_{75} = q_5\left(6+\frac{6}{7}\alpha\times 75\right) \quad \text{...(iv)}$$

From equations (ii) and (iii), we get

$$\frac{q_{95}-q_{\theta_5}}{q_5} = \frac{6}{7}\alpha\text{-}95-\theta_5.$$

or 12 s = $\alpha(40 - \theta_0)$ (12 h) ...(v)

From equations (ii) and (iv), we get

$$\frac{q_{\theta_5}-q_{75}}{q_5} = \frac{6}{7}\alpha\text{-}\theta_5-75.$$

or, 4 s = $\alpha(\theta_0 - 20)$(12 h) ...(vi)

From equations (v) and (vi), we get $3(\theta_0 - 20) = (40 - \theta_0)$

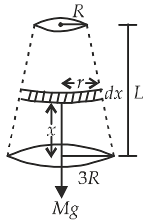
$3\theta_0 + \theta_0 = 40 + 60$

$$\theta_5 = \frac{655}{9} = 7\text{: °J}$$

From equation (vi), 4 s = α(25 – 20)(12 × 3600 s)

$$\alpha = \frac{9}{:\times 67\times 8;\ 55} = 63\text{=:}\times 65^{-:}\ \text{°J}^{-6}$$

14. (c): Consider a uniform cross-section of wire of length dx and radius r at a vertical distance of x from the lower end.



Here, $r = 3R - \dfrac{2R}{L}x$

$\therefore$ Extension in wire of length dx

$$dl = \frac{Fdx}{AY} = \frac{Mgdx}{\pi\left(3R - \frac{2R}{L}x\right)^2 Y}$$

Hence, extension in wire

$$l = \int dl = \int_0^L \frac{Mgdx}{\pi\left(3R-\frac{2R}{L}x\right)^2 Y} = \frac{Mg}{\pi Y}\int_0^L \frac{dx}{\left(3R-\frac{2R}{L}x\right)^2} = \frac{MgL}{3\pi R^2 Y}$$

$\therefore$ Extended length of wire $= L + \dfrac{MgL}{3\pi R^2 Y} = L\left(1+\dfrac{Mg}{3\pi R^2 Y}\right)$

15. (a): Let v_1 and v_2 be the velocities of water when it leaks out through the hole and when it hits the ground respectively. Then, as per Bernoulli's principle, $v_1^2 + 2gh = v_2^2$

Now, according to Torricelli's law, $v_1 = \sqrt{2gH}$ ...(i)

$\therefore$ $2gH + 2gh = v_2^2$ ...(ii)

According to continuity equation, $a_1 v_1 = a_2 v_2$

or $\pi r^2 \cdot \sqrt{2gH} = \pi x^2 \cdot \sqrt{2g(H+h)}$ [Using (i) and (ii)]

$x^2 = r^2\sqrt{\dfrac{H}{H+h}}$ or $x = r\left(\dfrac{H}{H+h}\right)^{1/4}$

16. (c): Equation of motion for the point mass

$ma = mg - kv$ ...(i)

or $\dfrac{dv}{dt} = \dfrac{mg-kv}{m} \Rightarrow \dfrac{dv}{mg-kv} = \dfrac{dt}{m}$

Integrating $\displaystyle\int_0^v \frac{dv}{mg-kv} = \frac{1}{m}\int_0^t dt$

$$\Rightarrow -\frac{1}{k}[\ln(mg-kv)]_0^v = \frac{t}{m} \Rightarrow \ln\left(\frac{mg-kv}{mg}\right) = \frac{-k}{m}t$$

$$\Rightarrow 1 - \frac{kv}{mg} = e^{\frac{-kt}{m}} \Rightarrow \frac{kv}{mg} = 1 - e^{\frac{-kt}{m}}$$

$$\Rightarrow v = \frac{mg}{k}\left(1 - e^{\frac{-kt}{m}}\right) \quad \text{...(ii)}$$

Putting (ii) in (i), we get

$ma = mg - k \times \dfrac{mg}{k}\left(1 - e^{\frac{-kt}{m}}\right)$ or $a = ge^{\frac{-kt}{m}}$

Hence option (c) represents the correct variation.

17. (c): Variation of length of wire with temperature,

$\Delta l = \alpha l \Delta\theta$ …(i)

Now, time period of simple pendulum

$$T_\theta = 2\pi\sqrt{\frac{l+\Delta l}{g}} = 2\pi\sqrt{\frac{l}{g}}\left(1+\frac{\Delta l}{l}\right)^{1/2} \approx T_0\left(1+\frac{\Delta l}{2l}\right)$$

Variation in time period

$$\Delta T = T_\theta - T_0 = \frac{T_0 \Delta l}{2l} = \frac{\alpha l \Delta\theta T_0}{2l} \quad \text{(using (i))}$$

$\Rightarrow \quad \frac{\Delta T}{\Delta\theta} = \frac{\alpha T_0}{2} = \alpha \times \frac{2}{2} = \alpha \quad \therefore \quad S = \alpha$

18. (d): Bulk modulus, $B = \frac{\text{Normal stress}}{\text{Volumetric strain}}$

$P = \frac{N}{A} = \frac{N}{(2\pi a)b}$

Volumetric strain $= \frac{2\pi a\, \Delta a \times b}{\pi a^2 \times b} = \frac{2\Delta a}{a} \quad \therefore \quad B = \frac{N}{2\pi ab} \times \frac{a}{2\Delta a}$

$N = 4\pi b\ \Delta a \times B$

$\therefore$ Required force = Frictional force = $\mu N = (4\pi\mu Bb)\Delta a$

19. (a): Here, Time t = 5 min = 300 s

Volume, V = 15 ltr = 15 × 10^{-3} m^3

Diameter, $d = \frac{7}{\sqrt{\pi}}$ oy

Cross sectional area of tap= $\pi\left(\frac{6}{\sqrt{\pi}} \times 65^{-7}\right)^7 = 65^{-9}$ y ^{7}

Velocity of water, $v = \frac{s}{W} = \frac{6: \times 65^{-8}}{6 \times 65^{-9} \times 855} = 53$ y $^{-6}$

$o = \frac{\rho}{\eta} = \frac{65^8 \times 53 \times \frac{7}{\sqrt{\pi}} \times 65^{-7}}{65^{-8}} = 5642 \approx 5500$

20. (*): For cylindrical shape, excess pressure is given by

$\Delta P = \frac{q}{o}$

*None of the given options is correct.

21. (c): Heat supplied to raise the temperature of water

$\Delta Q = m\ C\ \Delta T \Rightarrow P\ \Delta t = m\ C\Delta T$ ...(i)

Heat supplied to vaporize the same amount of water.

$\Delta Q' = mL \Rightarrow P\ \Delta t' = m\ L$ ...(ii)

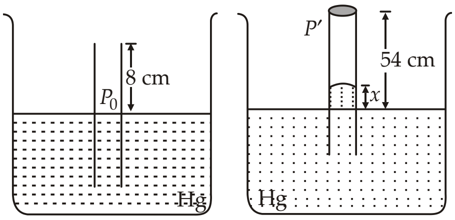
From eqn. (i) and (ii), $\frac{\Delta}{\Delta\ '} = \frac{Y\Delta q}{i}$

Here C = 1 cal g^{-1} °C^{-1}, ΔT = 100 °C

Δt = 10 min, $\Delta t'$ = 55 min

$\therefore \quad \frac{65}{::} = \frac{6 \times 655}{i}$ or, L = 550 cal g^{-1}.

22. (b):



When glass tube is open, pressure inside it = P_0

When the open end of glass tube is closed then pressure inside it = P'

$P' = P_0 - \rho g x$ ...(i)

Work done in case I = Work done in case II

Now, $P_0A(8) = P'A(54 - x)$

$\Rightarrow P_0(8) = (P_0 - \rho g x)(54 - x)$ [using (i)]

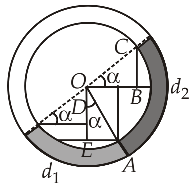
$\Rightarrow \rho g(76)(8) = \rho g(76 - x)(54 - x)$

$\Rightarrow 76(8) = (76 - x)(54 - x)$

On solving x = 38 cm

Therefore, air column = 54 – 38 = 16 cm

23. (d): $OA = R$



$BC = R\sin\alpha$

$OE = R\cos\alpha$

$OD = R\sin\alpha$

Pressure exerted due to liquid of density d_1 at the point A

$P_1 = P_0 + d_1g(DE) = P_0 + d_1g(OE - OD)$

$= P_0 + d_1gR(\cos\alpha - \sin\alpha)$

Pressure exerted due to liquid of density d_2 at the point A

$P_2 = P_0 + d_2g(AC) = P_0 + d_2g(BC + OE)$

$= P_0 + d_2gR\ (\sin\alpha + \cos\alpha)$.

As system is in equilibrium, $P_1 = P_2$.

$\Rightarrow P_0 + d_1gR(\cos\alpha - \sin\alpha) = P_0 + d_2g(\sin\alpha + \cos\alpha)$

$\Rightarrow d_1(\cos\alpha - \sin\alpha) = d_2(\sin\alpha + \cos\alpha)$

$\Rightarrow \quad \frac{d_1}{d_2} = \frac{\sin\alpha + \cos\alpha}{\cos\alpha - \sin\alpha} = \frac{1 + \tan\alpha}{1 - \tan\alpha}$.

24. (b): Given, ΔT = 100°C, $Y = 2 \times 10^{11}$ N m^{-2}

$\alpha = 1.1 \times 10^{-5}$ K^{-1}

Thermal strain in the wire = $\alpha\Delta T$ [As $l = l_0(1 + \alpha\ \Delta T)$]

Thermal stress in rod is the pressure due to the thermal strain.

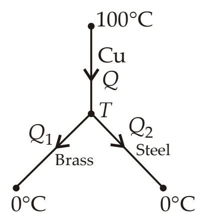
Required pressure = $Y\ \alpha\Delta T = 2 \times 10^{11} \times 1.1 \times 10^{-5} \times 100$

$= 2.2 \times 10^8$ Pa.

25. (d): Here, heat flow per second through the copper rod is divided into two parts at the junction and that flow in two different rods made up of brass and steel as shown in figure.

$Q = Q_1 + Q_2$

$\Rightarrow \quad \frac{100 - T}{R_C} = \frac{T - 0}{R_B} + \frac{T - 0}{R_S}$



where $R = \frac{l}{KA}$, A is equal in each case

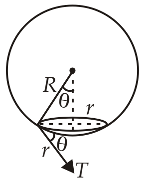
$\Rightarrow \quad (100 - T)\frac{K_C}{l_C} = T\left(\frac{K_B}{l_B} + \frac{K_S}{l_S}\right)$

$\Rightarrow \quad (100 - T)\frac{0.92}{46} = T\left(\frac{0.26}{13} + \frac{0.12}{12}\right) \Rightarrow T = 40°\text{C}$

$\therefore \quad Q = \frac{(100 - 40)}{l_C}K_CA$

$Q = \frac{60 \times 0.92 \times 4}{46} = 4.8 \text{ cal s}^{-1}$

26. (*): Force due to surface tension



$= \int T dl \sin\theta$

$= (T\sin\theta)\int dl = T\left(\frac{r}{R}\right)(2\pi r)$

This force will balance the force of buoyancy.

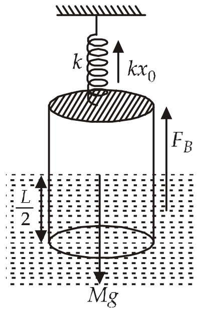
So, $T(2\pi r)\left(\frac{r}{R}\right) = \rho_W\left(\frac{4}{3}\pi R^3\right)g$

$\Rightarrow \quad r^2 = \frac{2}{3}\frac{\rho_W g}{T}R^4 \Rightarrow r = R^2\sqrt{\frac{2\rho_W g}{3T}}$.

* None of given option is correct.

27. (a)

28. (d) : Let k be the spring constant of spring and it gets extended by length x_0 in equilibrium position.



In equilibrium,

$kx_0 + F_B = Mg$

$$kx_0 + \sigma\frac{L}{2}Ag = Mg$$

$$x_0 = \frac{Mg - \frac{\sigma LAg}{2}}{k}$$

$$= \frac{Mg}{k}\left(1 - \frac{\sigma LA}{2M}\right)$$

29. (d) : According to Newton's law of cooling the option (d) represents the correct graph.

30. (d) : According to Newton's law of cooling

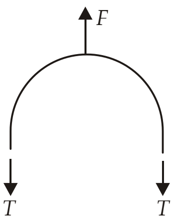
$\frac{d\theta}{dt} = -k(\theta - \theta_0)$ or $\frac{d\theta}{\theta - \theta_0} = -kdt$

Integrating both sides, we get $\int\frac{d\theta}{\theta - \theta_0} = \int -kdt$

$\log_e(\theta - \theta_0) = -kt + C$ where C is a constant of integration.

So, the graph between $\log_e(\theta - \theta_0)$ and t is a straight line with a negative slope. Option (d) represents the correct graph.

31. (c) : Increase in length, $\Delta L = L\alpha\Delta T$



$\therefore \quad \frac{\Delta L}{L} = \alpha\Delta T$

The thermal stress developed is

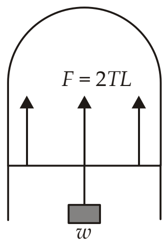
$\frac{T}{S} = Y\frac{\Delta L}{L} = Y\alpha\Delta T$

or $\quad T = SY\alpha\Delta T$

From FBD of one part of the wheel, or $\quad F = 2T$

Where, F is the force that one part of the wheel applies on the other part. $\therefore \quad F = 2SY\alpha\Delta T$

32. (c) : The force due to the surface tension will balance the weight.



$F = w$

$2TL = w$

$T = \frac{w}{2L}$

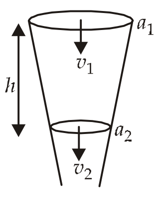
Substituting the given values, we get

$$T = \frac{1.5 \times 10^{-2}\ \text{N}}{2 \times 30 \times 10^{-2}\ \text{m}} = 0.025\ \text{N m}^{-1}$$

33. (d) : Here, $d_1 = 8 \times 10^{-3}$ m

$v_1 = 0.4$ m s^{-1}, $h = 0.2$ m

According to equation of motion,



$v_2 = \sqrt{v_1^2 + 2gh} = \sqrt{(0.4)^2 + 2 \times 10 \times 0.2}$

≈ 2 m s^{-1}

$\therefore \quad$ According to equation of continuity

$$a_1v_1 = a_2v_2$$

$$\pi \times \left(\frac{8 \times 10^{-3}}{2}\right)^2 \times 0.4 = \pi \times \left(\frac{d_2}{2}\right)^2 \times 2$$

$d_2 = 3.6 \times 10^{-3}$ m

34. (d) : Here, surface tension, $S = 0.03$ N m^{-1}

$r_1 = 3$ cm $= 3 \times 10^{-2}$ m, $r_2 = 5$ cm $= 5 \times 10^{-2}$ m

Since bubble has two surfaces,

Initial surface area of the bubble

$= 2 \times 4\pi r_1^2 = 2 \times 4\pi \times (3 \times 10^{-2})^2 = 72\pi \times 10^{-4}$ m^2

Final surface area of the bubble

$= 2 \times 4\pi r_2^2 = 2 \times 4\pi(5 \times 10^{-2})^2 = 200\pi \times 10^{-4}$ m^2

Increase in surface energy

$= 200\pi \times 10^{-4} - 72\pi \times 10^{-4} = 128\pi \times 10^{-4}$

$\therefore \quad$ Work done $= S \times$ increase in surface energy

$= 0.03 \times 128 \times \pi \times 10^{-4} = 3.84\pi \times 10^{-4} = 4\pi \times 10^{-4}$ J $= 0.4\pi$ mJ

35. (d) : $U = \frac{a}{x^{12}} - \frac{b}{x^6}$

Force, $F = -\frac{dU}{dx} = -\frac{d}{dx}\left(\frac{a}{x^{12}} - \frac{b}{x^6}\right)$

$$= -\left[\frac{-12a}{x^{13}} + \frac{6b}{x^7}\right] = \left[\frac{12a}{x^{13}} - \frac{6b}{x^7}\right]$$

At equilibrium $F = 0$

$\therefore \quad \frac{12a}{x^{13}} - \frac{6b}{x^7} = 0$ or $\quad x^6 = \frac{2a}{b}$

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

$U(x = \infty) = 0$

$$D = [U(x = \infty) - U_{\text{at equilibrium}}] = \left[0 - \left(-\frac{b^2}{4a}\right)\right] = \frac{b^2}{4a}$$

36. (c) : As $\rho_{oil} < \rho_{water}$, so oil should be over the water. As $\rho > \rho_{oil}$, so the ball will sink in the oil but $\rho < \rho_{water}$ so it will float in the water.

Hence option (c) is correct.

37. (d) : For the same material, Young's modulus is the same and it is given that the volume is the same and the area of cross-section for the wire l_1 is A and that of l_2 is $3A$.

$V = V_1 = V_2$

$V = A \times l_1 = 3A \times l_2 \quad \Rightarrow \quad l_2 = l_1/3$

$Y = \frac{F/A}{\Delta l/l} \quad \Rightarrow \quad F_1 = YA\frac{\Delta l_1}{l_1}$

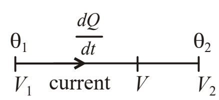
$F_2 = Y3A\frac{\Delta l_2}{l_2}$

Given $\Delta l_1 = \Delta l_2 = \Delta x$ (for the same extension)

$\therefore \quad F_2 = Y \cdot 3A \cdot \frac{\Delta x}{l_1/3} = 9 \cdot \left(\frac{YA\Delta x}{l_1}\right) = 9F_1$ or $9F$.

38. (b) : Heat flow can be compared to charges flowing in a conductor.

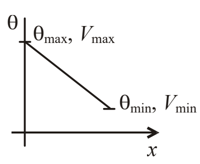
Current is the same.



The potential difference $V_1 - V$ at any point $= I \times$ Resistance $= I \times \frac{\rho l}{A}$

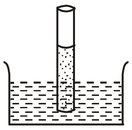
Potential difference is $\propto l$ but negative.

As l increases, potential decreases (temperature decreases) but it is a straight line function.



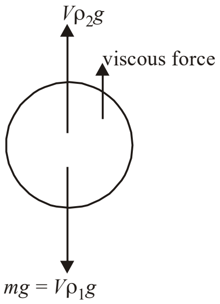
Potential difference is proportional to resistance (thermal as well as electric).

39. (d) : The force acting upwards $2\pi rT \simeq h\pi r^2 \rho g$, the force acting down or $T \propto h$ without making finer corrections. Soap reduces the surface tension of water. The height of liquid supported decreases.
But it is also a wetting agent.
Therefore the meniscus will not be convex as in mercury. Therefore (d).

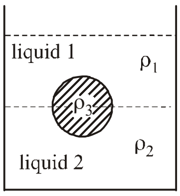


40. (b) : The forces acting on the solid ball when it is falling through a liquid are mg downwards, thrust by Archimedes principle upwards and the force due to the force of friction also acting upwards. The viscous force rapidly increases with velocity, attaining a maximum when the ball reaches the terminal velocity.
Then the acceleration is zero.
$mg - V\rho_2 g - kv^2 = ma$ where V is volume, v is the terminal velocity.
When the ball is moving with terminal velocity $a = 0$.
Therefore $V\rho_1 g - V\rho_2 g - kv^2 = 0$.

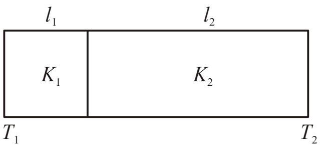
$$\Rightarrow v = \sqrt{\frac{Vg(\rho_1 - \rho_2)}{k}}.$$



41. (a) : The liquid 1 is over liquid 2.
Therefore $\rho_1 < \rho_2$. If ρ_3 had been greater than ρ_2, it will not be partially inside but anywhere inside liquid 2 if $\rho_3 = \rho_2$ or it would have sunk totally if ρ_3 had been greater than ρ_2.
$\therefore \quad \rho_1 < \rho_3 < \rho_2$.



42. (d) : Let T be the temperature of the interface.



Since two section of rod are in series, rate of flow of heat in them will be equal

$$\therefore \quad \frac{K_1 A [T_1 - T]}{l_1} = \frac{K_2 A [T - T_2]}{l_2} \text{ or } K_1 l_2 (T_1 - T) = K_2 l_1 (T - T_2)$$

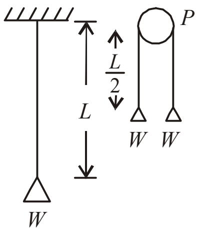
or $\quad T(K_1 l_2 + K_2 l_1) = K_1 l_2 T_1 + K_2 l_1 T_2$

or $\quad T = \dfrac{K_1 l_2 T_1 + K_2 l_1 T_2}{K_1 l_2 + K_2 l_1}$.

43. (b) : $Y = \dfrac{\text{Force} \times L}{A \times l} = \dfrac{WL}{Al}$

$\therefore \quad l = \dfrac{WL}{AY}$

Due to pulley arrangement, the length of wire is $L/2$ on each side and so the elongation will be $l/2$. For both sides, elongation $= l$.



44. (d) : Terminal velocity $= v$
viscous force upwards = weight of sphere downwards

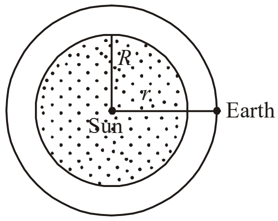
or $\quad 6\pi\eta rv = \left(\dfrac{4}{3}\pi r^3\right)(\rho - \sigma)g$

For gold and silver spheres falling in viscous liquid,

$$\therefore \quad \frac{v_g}{v_s} = \frac{\rho_g - \sigma}{\rho_s - \sigma} = \frac{19.5 - 1.5}{10.5 - 1.5} = \frac{18}{9} = \frac{2}{1}$$

or $\quad v_s = \dfrac{v_g}{2} = \dfrac{0.2}{2} = 0.1 \text{ m/s}.$

45. (c) : Energy radiated by sun, according to Stefan's law, $E = \sigma T^4 \times$ (area $4\pi R^2$) (time)
This energy is spread around sun in space, in a sphere of radius r. Earth (E) in space receives part of this energy.



$$\frac{\text{Energy}}{\text{Area of envelope}} = \frac{\sigma T^4 \times 4\pi R^2 \times \text{time}}{4\pi r^2}$$

Energy incident per unit area on earth $= \dfrac{\sigma T^4 R^2 \times \text{time}}{r^2}$

$\therefore \quad$ Power incident per unit area on earth $= \left(\dfrac{R^2 \sigma T^4}{r^2}\right)$

$\therefore \quad$ Power incident on earth $= \pi r_0^2 \times \dfrac{R^2 \sigma T^4}{r^2}$

46. (d) : Energy stored per unit volume $= \dfrac{1}{2} \times \text{stress} \times \text{strain}$

$$= \frac{\text{Stress} \times \text{stress}}{2Y} = \frac{S^2}{2Y}.$$

47. (b) : In a freely falling elevator $g = 0$
Water will rise to the full length i.e., 20 cm to tube.

48. (a) : For conduction from inner sphere to outer one,

$$dQ = -KA\frac{dT}{dr} \times (\text{time } dt) \text{ or } \frac{dQ}{dt} = -K \times (4\pi r^2)\frac{dT}{dr}$$

$\therefore \quad$ Radial rate of flow $Q = -4\pi K r^2 \dfrac{dT}{dr}$

$$\therefore \quad Q\int_{r_1}^{r_2} \frac{dr}{r^2} = -4\pi K \int_{T_1}^{T_2} dT \text{ or } Q\left[\frac{r_1 - r_2}{r_1 r_2}\right] = 4\pi K [T_2 - T_1]$$

or $\quad Q = \dfrac{4\pi K (T_1 - T_2) r_1 r_2}{(r_2 - r_1)}$

$\therefore \quad Q$ is proportional to $\left(\dfrac{r_1 r_2}{r_2 - r_1}\right)$.

49. (c) : Pressure inside the bubble $= P_0 + \dfrac{4T}{r}$
Smaller the radius, greater will be the pressure. Air flows from higher pressure to lower pressure. Hence air flows from the smaller bubble to the bigger.

50. (b) : Retarding viscous force $= 6\pi\eta Rv$
obviously option (b) holds goods.

51. (d) : Young's modulus $Y = \dfrac{FL}{Al}$ ...(i)

$\therefore \quad F = \dfrac{YAl}{L}$

or $\quad dW = F\,dl = \frac{YAl(dl)}{L} \quad$ or $\quad \int dW = \frac{YA}{L}\int_0^l l\,dl = \frac{YAl^2}{2L}$

or Work done $= \frac{YAl^2}{2L}$ ...(ii)

From (i) and (ii)

Work done $= \frac{Fl}{2}$.

52. (d) : From first surface, $Q_1 = \frac{KA(T_2 - T)t}{x}$

From second surface, $Q_2 = \frac{(2K)A(T - T_1)t}{(4x)}$

At steady state, $Q_1 = Q_2 \Rightarrow \frac{KA(T_2 - T)t}{x} = \frac{2KA(T - T_1)t}{4x}$

or $2(T_2 - T) = (T - T_1)$

or $T = \frac{2T_2 + T_1}{3}$ $\therefore$ $Q_1 = \frac{KA}{x}\left[T_2 - \frac{2T_2 + T_1}{3}\right]t$

or $\left[\frac{A(T_2 - T_1)K}{x}\right]f = \frac{KA}{x}\left[\frac{T_2 - T_1}{3}\right] \times 1$ or $f = \frac{1}{3}$

53. (b) : Initial momentum = E/c
Final momentum = $-E/c$

$\therefore$ Change of momentum = $\frac{E}{c} - \left(-\frac{E}{c}\right) = \frac{2E}{c}$

$\therefore$ Momentum transferred to surface = $\frac{2E}{c}$.

54. (d) : According to Stefan's law,
Radiant energy $E = (\sigma T^4) \times$ area $\times$ time

$\therefore \frac{E_2}{E_1} = \frac{\sigma(2T)^4 \times 4\pi(2R)^2 \times t}{\sigma T^4 \times (4\pi R)^2 \times t} = 16 \times 4 \quad \therefore \frac{E_2}{E_1} = 64.$

55. (d) : Elastic energy per unit volume $= \frac{1}{2} \times \text{stress} \times \text{strain}$

$\therefore$ Elastic energy $= \frac{1}{2} \times \text{stress} \times \text{strain} \times \text{volume}$

$= \frac{1}{2} \times \frac{F}{A} \times \frac{\Delta L}{L} \times (AL) = \frac{1}{2} F\Delta L = \frac{1}{2} \times 200 \times 10^{-3} = 0.1 \text{ J}$.

56. (d) : According to Newton's law of cooling, rate of cooling is proportional to $\Delta\theta$. $\therefore (\Delta\theta)^n = (\Delta\theta)$ or $n = 1$.

57. (d) : Wien's law

58. (b) : $v = \sqrt{2gh} = \sqrt{2 \times 10 \times 20} = 20$ m/s.

59. (a) : Energy radiated
$E = \sigma T^4 \times$ (area $4\pi R^2$) $\times$ time $\times$ e

$\frac{E_1}{E_2} = \frac{(4000)^4 \times (1)^2 \times 1 \times 4\pi\sigma e}{(2000)^4 \times (4)^2 \times 1 \times 4\pi\sigma e} = \frac{1}{1}$.

60. (a) : A good absorber is a good emitter but black holes do not emit all radiations.