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Class: 11
Subject: Physics
Topic: Mechanical properties of fluids
No. of Questions: 30

Q1. Bernoulli's principle is based on the law of conservation of ________

a. energy

b. mass

c. momentum

d. none of these

Sol. A

Bernoulli's principle is based on the law of conservation of energy.

Q2. Radius of an air bubble at the bottom of a lake is r and it becomes 2r when the air bubble rises to the surface of the lake. If P is the atmospheric pressure of water, then the depth (in cm) of the lake is

a. 2P

b. 8P

c. 4P

d. 7P

Sol. D

Let depth of lake is x cm.

$$\therefore \quad P_1V_1 = P_2V_2$$

$$(Pdg + xdg)\left(\frac{4}{3}\pi r^3\right) = Pdg\left[\frac{4}{3}\pi(2r)^3\right]$$

$$(P + x)r^3 = P(8r^3)$$

$$x = 8P - P$$

$$\Rightarrow \quad x = 7P$$

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Q3. Radius of one arm of a hydraulic lift is four times the radius of the other arm. What force should be applied on the narrow arm to lift 100 kg?

a. 26.5 N

b. 62.5 N

c. 6.25 N

d. 8.3 N

Sol. B

$A_1x_1 = A_2x_2$ ---- eq 1 as volume of fluid displaced is same.
A_1 is cross-sectional area of cylinder 1 and x_1 is the distance moved by piston 1 and the same for A_2 and x_2.
Now,
$A_1 = \pi r^2 = A$
Let $r_1 = r$; $r_2 = 4r$
$A_2 = \pi (4r)^2 = 16\pi r^2 = 16A$
Let $x_1 = x$
Putting values of A_1 and A_2 in eq. 1
$Ax = 16\ Ax_2$
$x = 16\ x_2$
As W is same so $F_1x_1 = F_2x_2$
$F_2 = 100 * 10$
Where, $F_1 = F_2x_2 / x1 = 100 * 10 * x_2 / 16\ x2 = 1000 / 16 = 62.5$ N

Q4. A liquid drop of radius 'R' breaks into 64 tiny drops each of radius 'r'. If the surface tension of the liquid is 'T', then the gain in energy is

a. $48\pi R^2T$

b. $12\pi r^2 T$

c. $96\pi R^2T$

d. $192\pi r^2T$

Sol. D

As volume is the same; $\frac{4}{3}\pi R^3 = 64 \times \frac{4}{3}\pi r^3$ or $R^3 = 64r^3$ or $R = 4r$

$A_1 = 4\pi R^2 = 4\pi(4r)^2 = 4\pi \times 16r^2 = 64\pi r^2$; $A_2 = 4\pi \times 64 \times r^2 = 256\pi r^2$

$\Delta A = A_2 - A_1 = 192\pi r^2$; $T = \frac{W}{\Delta A}$; $W = T\Delta A = T \times 192\pi r^2 = 192\pi r^2 T$

Q4. A liquid drop of radius 'R' breaks into 64 tiny drops each of radius 'r'. If the surface tension of the liquid is 'T', then the gain in energy is

a. 2.012×10^5 N/m^2

b. 2.012×10^4 N/m^2

c. 1.027×10^5 N/m^2

d. 1.027×10^4 N/m^2

Sol. C

The excess pressure inside the air bubble is given by

$$P_2 - P_1 = \frac{2T}{R}$$

$\therefore$ Pressure inside the air bubble

$$P_2 = P_1 + \frac{2T}{R}$$

Substituting the values, we have

$$P_2 = 1.013 \times 10^5 + \frac{2 \times 7.2 \times 10^{-2}}{10^{-4}}$$

$$= 1.027 \times 10^5 \text{ N/m}^2$$

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Q6. The increase in pressure (in k Pa) required to decrease 200 litres volume of a liquid by 0.004% is (Bulk modulus of the liquid = 2100 MPa)

a. 8.4

b. 84

c. 92.4

d. 168

Sol. b

Bulk modulus of elasticity is defined as the ratio of normal stress to the volumetric strain, within the elastic limit.

Thus,

$$B = \frac{\text{normal stress}}{\text{volumetric strain}}$$

$$B = \frac{\Delta p}{-\Delta V/V}$$

Here, negative sign shows that volume is decreased, when pressure is increased.

Here, $B = 2100 \times 10^6$ Pa

$V = 200$ L

$$\Delta V = 200 \times \frac{0.004}{100} = 0.008 \text{ L}$$

$$\therefore \ 2100 \times 10^6 = \frac{\Delta p}{\left(\frac{0.008}{200}\right)}$$

$$\therefore \quad \Delta p = 84 \text{ kPa}$$

Note Compressibility (C) of a material is the reciprocal of its bulk modulus of elasticity (B) *ie,*

$$C = \frac{1}{B}$$

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Q7. A spinner swings a cricket ball due to

a. Boyle's law
b. Magnus effect
c. Viscosity
d. Surface tension

Sol. B

A spinner swings a cricket ball due to Magnus effect.

Q8 If the radius of a soap bubble is four times that of another, then the ratio of their excess pressure will be

a. 1 : 4
b. 8 : 1
c. 16 : 1
d. 5 : 1

Sol. A

$$\Delta P = \frac{4T}{r} \frac{\Delta P_1}{\Delta P_2} = \frac{r_2}{r_1} = 1:4$$

Q9. In streamline flow of liquid, the total energy of liquid is constant at

a. all points
b. inner points
c. outer points
d. none of these

Sol. A

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In streamline flow of liquid, the total energy of liquid is constant at all the points.

Q10. The radii of the two columns in a U-tube are 'r_1' and 'r_2' ($r_1 > r_2$). When a liquid of density 'ρ' (angle of contact is 0^o) is filled in it, the level difference of the liquid in the two arms is 'h'. The surface tension of the liquid is
(g = acceleration due to gravity)

a. $\frac{\rho g h r_1 r_2}{2(r_1 - r_2)}$

b. $\frac{\rho g h (r_1 - r_2)}{r_1 r_2}$

c. $\frac{2(r_1 - r_2)}{\rho g h r_1 r_2}$

d. $\frac{\rho g h}{2(r_2) - r_1}$

Sol. A

Let h_1 be the height of column 1 and h_2 be the height of column 2 $h_1 = \frac{2Tcos\Theta}{r_1 \rho g}$ $h_2 = \frac{2Tcos\theta}{r_2 \rho g}$ $now \theta = 0, so cos 0 = 1$

$h_2 - h_1 = \frac{2T}{r_2 \rho g} - \frac{2T}{r_1 \rho g}$ $h = 2T(\frac{r_1 - r_2}{r_1 r_2 \rho g})$ $T = \frac{hg\rho r_1 r_2}{2(r_1 - r_2})$

Q11. A horizontal pipe of cross-sectional diameter 5 cm carries water at a velocity of 4 m/s. The pipe is connected to a smaller pipe with a cross-sectional diameter 4 cm. What is the velocity of water through the smaller pipe?

a. 6.25 m/s

b. 5.0 m/s

c. 3.2 m/s

d. 2.56 m/s

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Sol. A

From equation of continuity, $a_1v_1 = a_2v_2$ $\pi\,(2.5)^2 * 4 = \pi\,(2)^2 * v_2$ $v_2 = 6.25$ m/s

Q12. At a given place where acceleration due to gravity is 'g' m/s2, a sphere of lead of density 'd' kg/m3 is gently released in a column of liquid of density '' kg/m3. If d > , The sphere will

a. fall vertically with an acceleration 'g' m/s^2

b. fall vertically with no acceleration

c. fall vertically with an acceleration g(d – ρ)/d

d. fall vertically with an acceleration g(ρ/d)

Sol. C

Apparent weight = actual weight – upthrust

$$Vdg' = Vdg - V\rho g$$

$$\Rightarrow \quad g' = \left(\frac{d-\rho}{d}\right)g$$

Q13. When a drop of radius R splits into n number of smaller drops, then

a. surface area of liquid increases

b. volume of liquid increases

c. surface area of liquid decreases

d. nothing can be said

Sol. A

When a drop of radius R splits into n number of smaller drops, then surface area of liquid increases.

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Q14. The pressures inside two soap bubbles are 1.01 and 1.02 atm. The ratio of their volumes is

a. 16 : 1

b. 8 : 1

c. 4 : 1

d. 2 : 1

Sol. B

The pressure inside a soap bubble is the sum of excess pressure and atmospheric pressure *i.e.*, $(P + p)$.

Here, For first soap bubble $P + p_1 = 1.01$ atm

For second soap bubble $= P + p_2 = 1.02$ atm

$\therefore P + p_1 = 1.01P \Rightarrow p_1 = 1.01P - P$

$p_1 = 0.01P$

and $P + p_2 = 1.02P \Rightarrow p_2 = 1.02P - P$

$\therefore \quad p_2 = 0.02P$

For I soap bubble excess of pressure

$$p_1 = \frac{4T}{R_1}$$

For II soap bubble excess of pressure

$$p_2 = \frac{4T}{R_2}$$

Where R_1 and R_2 are the radius of soap bubbles. So,

$R_1 = 4T/p_1$ and $R_2 = 4T/p_2$

$$\therefore \quad \frac{\text{Volume I soap bubble}}{\text{Volume of II soap bubble}}$$

$$= \frac{V_1}{V_2} = \frac{\frac{4}{3}\pi R_1^3}{\frac{4}{3}\pi R_2^3} = \left(\frac{R_1}{R_2}\right)^3$$

$$\Rightarrow \frac{V_1}{V_2} = \left(\frac{4T/p_1}{4T/p_2}\right)^3 = \left(\frac{p_2}{p_1}\right)^3 = \left(\frac{0.02}{0.01}\right)^3$$

$$= \left(\frac{2}{1}\right)^3 = \frac{8}{1}$$

$$V_1 : V_2 = 8 : 1$$

Q15. A square wire frame of size L is dipped in a liquid. On taking out, a membrane is formed. If the surface tension of the liquid is T, then the force acting on the frame will be

a. 2 TL

b. 4 TL

c. 8 TL

d. 10 TL

Sol. c

Membrane has two free surfaces.

The surface tension of a liquid is defined as the force per unit length in the plane of the liquid surface, acting at right angles on either side of an imaginary line drawn on that surface. Thus,

$$T = \frac{F}{L}$$

Since, membrane has two free surfaces, total force acting is given by

$$F = 2 \times T \times \text{ boundary of frame}$$

$$F = 2T \times 4L$$

$$F = 8\,TL$$

Q16. Two small drops of mercury each of radius 'r' form a single large drop. The ratio of surface energy before and after this change will be

a. $1 : 2^{1/3}$

b. $2^{1/3} : 1$

c. 2 : 1

d. 1 : 2

Sol. b

Surface energy = T * A

T = Surface tension

A = Surface area

$$\frac{E_1}{E_2} = \frac{T_1 * A_1}{T_2 * A_2}$$

But $T_1 = T_2 = T$

$$\frac{E_1}{E_2} = \frac{S_1}{S_2}$$

$$\frac{S_1}{S_2} = \frac{2^{\frac{1}{3}}}{1}$$

$$\frac{E_1}{E_2} = \frac{2^{\frac{1}{3}}}{1}$$

Q17. In a stationary lift, a man is standing with a bucket full of water, having a hole at its bottom. The rate of flow of water through this hole is R_0. If the lift starts to move up and down with the same acceleration such that the water flows at the rate of R_u and R_d, then

a. $R_0 > R_u > R_d$

b. $R_u > R_0 > R_d$

c. $R_d > R_0 > R_u$

d. $R_u > R_d > R_0$

Sol. b

Bernoulli principle

Q18. If a liquid does not wet a glass, then its angle of contact is

a. zero

b. acute

c. obtuse

d. right angle

Sol. c

For the liquids, which do not wet a glass, the liquid meniscus is convex upward, so angle of contact is obtuse.

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Q19. Two small drops of mercury each of radius 'r' form a single large drop. The ratio of surface energy before and after this change will be

a. $1 : 2^{1/3}$

b. $2^{1/3} : 1$

c. $2 : 1$

d. $1 : 2$

Sol b

Surface energy = T * A

T = Surface tension

A = Surface area

$$\frac{E_1}{E_2} = \frac{T_1 * A_1}{T_2 * A_2}$$

But $T_1 = T_2 = T$

$$\frac{E_1}{E_2} = \frac{S_1}{S_2}$$

$$\frac{S_1}{S_2} = \frac{2^{\frac{1}{3}}}{1}$$

$$\frac{E_1}{E_2} = \frac{2^{\frac{1}{3}}}{1}$$

Q20. A liquid drop of radius 'R' breaks into 64 tiny drops each of radius 'r'. If the surface tension of the liquid is 'T', then the gain in energy is

a. $48\pi R^2 T$

b. $12\pi r^2 T$

c. $96\pi R^2 T$

d. $192\pi r^2 T$

Sol. d

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As volume is the same; $\frac{4}{3}\pi R^3 = 64 \times \frac{4}{3}\pi r^3$ or $R^3 = 64r^3$ or $R = 4r$

$A_1 = 4\pi R^2 = 4\pi(4r)^2 = 4\pi \times 16r^2 = 64\pi r^2$; $A_2 = 4\pi \times 64 \times r^2 = 256\pi r^2$

$\Delta A = A_2 - A_1 = 192\pi r^2$; $T = \frac{W}{\Delta A}; W = T\Delta A = T \times 192\pi r^2 = 192\pi r^2 T$

Q21. How does rise in temperature effect (i) viscosity of gases (ii) viscosity of liquids.

Sol. Viscosity of gases increases while viscosity of liquid decreases.

Q22. A wire of length l, area of crossection A and young's modulus Y is stretched

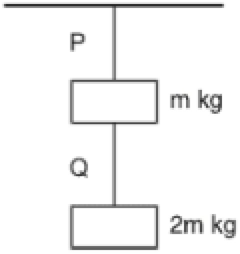
Sol. Restoring force in extension x = F $= \frac{AYx}{L}$

Work done in stretching it by dx = dw = F. dx

Work done in stretching it from zero to x = W = $\int dw = \int_o^x F\, dx$

W = $\int_o^x \frac{AYx}{L}\, dx = \frac{1}{2}\frac{AYx^2}{L}$

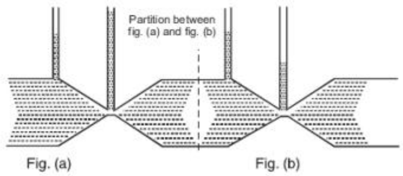
Q23. Two wires P and Q of same diameters are loaded as shown in the figure. The length of wire P is L m and its young's modulus is Y N/m^2 While length of wire Q is twice that of P and its material has young's half that of P. Computer the ratio of their elongation.



Sol. $\Delta l_p = \frac{3mg}{A} \times \frac{L}{Y}$ $\Delta l_Q = \frac{2mg}{A} \cdot \frac{2L}{Y/2} = \frac{8mg}{A}\frac{L}{Y}$

$\therefore \frac{\Delta_p}{\Delta_Q} = \frac{3}{8}$

Q24. The fig (a) & (b) refer to the steady flow of a non viscous liquid. Which one of the two figures is incorrect? Why?



Sol. Fig. (a) is correct.
A the constriction, the area of cross section is small so liquid velocity is large, consequently pressure must be small so height of liquid must be less.

Q25. An aluminium wire 1m in length and radius 1mm is loaded with a mass of 40 kg hanging vertically. Young's modulus of Al is 7.0×10^{-10} N/m^2 Calculate (a) tensile stress (b) change in length (c) tensile strain and (d) the force constant of such a wire.

Sol.

(a) Strees $= \frac{F}{A} = \frac{mg}{\pi^2} = \frac{40\times10}{\pi\times(1\times10^{-3})^2} = 1.27\times10^8 N\ /\ m^2$

(b) $\Delta L = \frac{FL}{AY} = \frac{40\times1\times1}{\pi\times(1\times10^{-3})^2\times7\times10^{10}} = 1.8\times10^{-3}$

(c) Strain $\frac{\Delta L}{L} = \frac{1.8\times10^{-3}}{1} = 1.8\times10^{-3}$

(d) F = Kx = k ΔL k = Force constant

$K = \frac{F}{\Delta L} = \frac{40\times10}{1.8\times10^{-3}} = 2.2\times10^5 N\ /\ m$

Q26. The average depth of ocean is 2500 m. Calculate the fractional compression $\left[\frac{\Delta V}{V}\right]$ of water at the bottom of ocean, given that the bulk modulus of water is 2.3×10^9 N/m^2.

Sol. Pressure exerted at the bottom layer by water column of height h is

$P = h\rho g = 2500\times1000\times10$

$= 2.5\times10^7\ N\ m^{-2}$

= Strees

Bulk modulus $K = \frac{Strees}{Strain} = \frac{P}{\Delta V\ /V}$

$\therefore \quad \frac{\Delta V}{V} = \frac{P}{K} = \frac{2.5\times10^7}{2.3\times10^9} = 1.08\times10^{-2}$

1.08%

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Q27. Terminal velocity of a copper ball of radius 2 mm through a tank of oil at 20°C is 6.0 cm/s. Compare coefficient of viscosity of oil. Given $P_{cu} = 8.9 \times \frac{10^3 kg}{m^3} . P^{oil} = 1.5 \times 10^3 kg/m^3$

Sol. $V_t = \frac{2}{9}\left|\frac{g(\sigma-\rho)r^2}{\eta}\right|$

$\eta = \frac{2}{9}\left|\frac{9.8(8.9\times10^3-1.5\times10^3)(2\times10^{-3})^2}{6\times10^{-2}}\right|$

$= 1.08 \text{ kg } m^{-1}\, s^{-1}$

Q28. The torque required to produce unit twist in a solid shaft of radius r, length | and made of material of modulus of rigidity η is given by

$$\tau = \frac{\pi\, \eta r^4}{2\,|}$$

Explain why hollow shafts are preferred to solid shafts for transmitting torque?

Sol. Torque required to produce unit twist in hollow shaft of internal radius r_1 and external radius r_2 is

$$\tau' = \frac{\pi\eta\left(r_2^4 - r_1^4\right)}{2l}$$

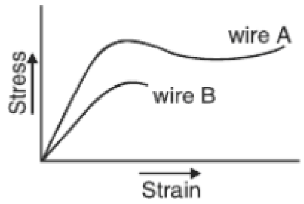
$$\therefore \quad \frac{\tau'}{\tau} = \frac{r_2^4 - r_1^4}{r^4} = \frac{\left(r_2^2 + r_1^2\right)\left(r_2^2 - r_1^2\right)}{r^4}$$

If the shafts are made of material of equal volume.

$$\pi r^2 l = \pi\left(r_2^2 - r_1^2\right)l \text{ or } r_2^2 - r_1^2 = r^2$$

$$\therefore \quad \text{Since } r_2^2 + r_1^2 > r^2 \quad \tau' > \tau$$

Q29. Stress strain curve for two wires of material A and B are as shown in Fig.



(a) Which material is more ductile?
(b) Which material has greater value of young's modulus?
(c) Which of the two is stronger material?
(d) Which material is more brittle?

Sol.

(a) Wire with larger plastic region is more ductile material A
(b) Young's modulus is $\frac{Stress}{Strain}$
$\therefore Y_A > Y_B$
(c) For given strain, larger stress is required for A than that for B.
$\therefore$ A is stronger than B.
(d) Material with smaller plastic region is more brittle, therefore, B is more brittle than A.

Q30. The terminal velocity of a tiny droplet is v. N number of such identical droplets combine together forming a bigger drop. Find the terminal velocity of the bigger drop.

Sol.

$$\upsilon = \frac{2}{9}\left[\frac{g(\sigma-\rho)r^2}{\eta}\right]$$

$$\upsilon \times r^2$$

If N drops coalesce, then

Volume of one big drop = volume of N droplets

$$\frac{4}{3}\pi R^3 = N\left(\frac{4}{3}\pi r^3\right)$$

$$R = N^{1/3} r$$

$\therefore$ Terminal velocity of bigger drop $= \left(\frac{R}{r}\right)^2 \times \upsilon$ from eq.(1)

$= N^{2/3}$ v from eq. (2)