Mechanical Properties of Fluids: NCERT Solutions

Question 10. 3. Fill in the blanks using the words from the list appended with each statement:

(a) Surface tension of liquids generally……………with temperature. (increases/decreases)

(b) Viscosity of gases……………..with temperature, whereas viscosity of liquids…………..with temperature. (increases/decreases)

(c) For solids with elastic modulus of rigidity, the shearing force is proportional to…………………..while for fluids it is proportional to………… (shear strain/rate of shear strain)
(d) For a fluid in steady flow, the increases inflow speed at a constriction follows from…………………………. while the decrease of pressure there follows from………………….(conservation of mass/Bernoulli's principle)
(e) For the model of a plane in a wind tunnel, turbulence occurs at a…………….speed than the critical speed for turbulence for an actual plane. (greater/smaller)
Answer: (a), decreases
(b) increases; decreases
(c) shear strain; rate of shear strain
(d) conservation of mass; Bernoulli's principle
(e) greater.
Question 10. 4. Explain why

(a) To keep a piece of paper horizontal, you should blow over, not under, it.

(b) When we try to close a water tap with our fingers, fast jets of water gush through the openings between our fingers.

(c) The size of a needle of a syringe controls flow rate better than the thumb pressure exerted by a doctor while administering an injection.
(d) A fluid flowing out of a small hole in a vessel results in a backward thurst on the vessel.
(e) A spinning cricket ball in air does not follow a parabolic trajectory.

Answer: (a) When we blow over the piece of paper, the velocity of air increases. As a result, the pressure on it decreases in accordance with the Bernoulli's theorem whereas the pressure below remains the same (atmospheric pressure). Thus, the paper remains horizontal.
(b) By doing so the area of outlet of water jet is reduced, so velocity of water increases according to equation of continuity av = constant.

(c) For a constant height, Bernoulli's theorem is expressed as $P + 1/2\ \rho\ v^2$ = Constant
In this equation, the pressure P occurs with a single power whereas the velocity occurs with a square power. Therefore, the velocity has more effect compared to the pressure. It is for this reason that needle of the syringe controls flow rate better than the thumb pressure exerted by the doctor.
(d) This is because of principle of conservation of momentum. While the flowing fluid carries forward momentum, the vessel gets a backward momentum.
(e) A spinning cricket ball would have followed a parabolic trajectory has there been no air. But because of air the Magnus effect takes place. Due to the Magnus effect the spinning cricket ball deviates from its parabolic trajectory.

Question 10. 5. A 50 kg girl wearing high heel shoes balances on a single heel. The heel is circular with a diameter 1.0 cm. What is the pressure exerted by the heel on the horizontal floor?

Answer:

Mass of girl, $m = 50$ kg.

$\therefore$ Force on the heel, $F = mg = 50 \times 9.8 = 490$ N

Diameter, $D = 1.0 \text{ cm} = 1 \times 10^{-2}$ m

$$\therefore \quad \text{Area, } A = \frac{\pi D^2}{4} = \frac{3.14 \times (1 \times 10^{-2})^2}{4} = 7.85 \times 10^{-5} \text{ m}^2$$

$$\therefore \quad \text{Pressure, } P = \frac{F}{A} = \frac{490}{7.85 \times 10^{-5}} = 6.24 \times 10^6 \text{ Pa.}$$

Question 10. 6. Toricelli's barometer used mercury. Pascal duplicated it using French wine of density 984 kg m^{-3}. Determine the height of the wine column for normal atmospheric pressure.

Answer:

We know that atmospheric pressure, $P = 1.01 \times 10^5$ Pa.

If we use French wine of density, $\rho = 984$ kg m^{-3}, then height of wine column should be h_m, such that $P = h\rho g$

$$\Rightarrow \quad h_m = \frac{P}{\rho g} = \frac{1.01 \times 10^5}{984 \times 9.8} = 10.47\text{m} \simeq 10.5 \text{ m}$$

Question 10. 7. A vertical off-shore structure is built to withstand a maximum stress of 10^9 Pa. Is the structure suitable for putting up on top of an oil well in the ocean? Take the depth of the ocean to be roughly 3 km, and ignore ocean currents.

Answer: Here, Maximum stress = 10^9 Pa, h = 3 km = 3×10^3 m;

p (water) = 10^3 kg/m^3 and g = 9.8 m/s^2.

The structure will be suitable for putting upon top of an oil well provided the pressure exerted by sea water is less than the maximum stress it can bear.

Pressure due to sea water, $P = h\rho g = 3 \times 10^3 \times 10^3 \times 9.8$ Pa $= 2.94 \times 10^7$ Pa

Since the pressure of sea water is less than the maximum

Question 10. 8. A hydraulic automobile lift is designed to lift cars with a maximum mass of 3000 kg. The area of cross-section of the piston carrying the load is 425 cm^2. What maximum pressure would the smaller piston have to bear?

Answer:

Pressure on the piston due to car

$$= \frac{\text{Weight of car}}{\text{Area of piston}}$$

$$P = \frac{3000 \times 9.8}{425 \times 10^{-4}} \text{ Nm}^{-2} = \mathbf{6.92 \times 10^5 \text{ Pa}}$$

This is also the maximum pressure that the smaller piston would have to bear.

Question 10. 9. A U tube contains water and methylated spirit separated by mercury. The mercury columns in the two arms are in level with 10.0 cm of water in one arm and 12.5 cm of spirit in the other. What is the relative density of spirit?

Answer: For water column in one arm of U tube, h_1 = 10.0 cm; ρ_1 (density) = 1 g cm^{-3}

For spirit column in other arm of U tube, h_2 = 12.5 cm; ρ_2 =?

As the mercury columns in the two arms of U tube are in level, therefore pressure exerted by each is equal.

Hence $h_1\rho_1 g = h_2\rho_2 g$ or $\rho_2 = h_1\rho_1/h_2$ =10 x 1/12.5 = 0.8 g cm^{-3}

Therefore, relative density of spirit = ρ_2/ρ_1 = 0.8/1 = 0.8

Question 10. 10. In Q.9, if 15.0 cm of water and spirit each are further poured into the respective arms of the tube, what is the difference in the levels of mercury in the two arms? (Relative density of mercury = 13.6)

Answer:

Height of the water column, h_1 = 10 + 15 = 25 cm

Height of the spirit column, h_2 = 12.5 + 15 = 27.5 cm

Density of water, ρ_1 = 1 g cm^{-3}

Density of spirit, ρ_2 = 0.8 g cm^{-3}

Density of mercury = 13.6 g cm^{-3}

Let h be the difference between the levels of mercury in the two arms.

Pressure exerted by height h, of the mercury column:

= $h\rho g$

$= h \times 13.6g$ … **(i)**

Difference between the pressures exerted by water and spirit:

$= \rho_1 h_1 g - \rho_2 h_2 g$

$= g(25 \times 1 - 27.5 \times 0.8)$

$= 3g$ … **(ii)**

Equating equations **(i)** and **(ii)**, we get:

$13.6\ hg = 3g$

$h = 0.220588 \approx 0.221$ cm

Hence, the difference between the levels of mercury in the two arms is 0.221 cm.

Question 10. 11. Can Bernoulli's equation be used to describe the flow of water through a rapid motion in a river? Explain.

Answer: Bernoulli's theorem is applicable only for there it ideal fluids in streamlined motion. Since the flow of water in a river is rapid, way cannot be treated as streamlined motion, the theorem cannot be used.

Question 10. 12. Does it matter if one uses gauge instead of absolute pressures in applying Bernoulli's equation? Explain.

Answer: No, it does not matter if one uses gauge instead of absolute pressures in applying Bernoulli's equation, provided the atmospheric pressure at the two points where Bernoulli's equation is applied are significantly different.

Question 10. 13. Glycerine flows steadily through a horizontal tube of length 1.5 m and radius 1.0 cm. If the amount of glycerine collected per second at one end is 4.0 x 10^{-3} kg s^{-1}, what is the pressure difference between the two ends of the tube? (Density

of glycerine = 1.3 x 10^3 kg m^{-3} and viscosity of glycerine = 0.83 Pa s). [You may also like to check if the assumption of laminar flow in the tube is correct],

Answer:

$$l = 1.5 \text{ m}, \quad r = 1 \times 10^{-2} \text{m},$$

Volume/s, $$V = \frac{\text{Mass / s}}{\text{Density}} = \frac{4 \times 10^{-3}}{1.3 \times 10^{3}} \text{m}^3 \text{ s}^{-1}$$

$$= \frac{4}{1.3} \times 10^{-6} \text{m}^3 \text{s}^{-1}$$

$$\eta = 0.83 \text{ Pa s}$$

Now, $$V = \frac{\pi p r^4}{8 \eta l},$$

where p is the pressure difference across the capillary.

or $$p = \frac{8 V \eta l}{\pi r^4}$$

Substituting values,

$$p = 8 \times \frac{4}{1.3} \times 10^{-6} \times 0.83 \times 1.5 \times \frac{7}{22} \times \frac{1}{10^{-8}} \, Pa$$

$$= \mathbf{9.75 \times 10^2 \ Pa}$$

The Reynolds number is 0.3. So, the flow is **laminar.**

Question 10. 14.

In a test experiment on a model aeroplane in a wind tunnel, the flow speeds on the upper and lower surfaces of the wing are 70 ms^{-1} and 63 ms^{-1} respectively. What is the lift on the wing if its area is 2.5 m^2? Take the density of air to be 1.3 kg m^{-3}.

Answer:

Let v_1, v_2 be the speeds on the upper and lower surfaces of the wing of aeroplane, and P_1 and P_2 be the pressures on upper and lower surfaces of the wing respectively.

Then $v_1 = 70\ \text{ms}^{-1}$; $v_2 = 63\ \text{ms}^{-1}$; $\rho = 1.3\ \text{kg m}^{-3}$.

From Bernoulli's theorem

$$\frac{P_1}{\rho} + gh + \frac{1}{2}v_1^2 = \frac{P_2}{\rho} + gh + \frac{1}{2}v_2^2$$

$$\therefore \qquad \frac{P_1}{\rho} - \frac{P_2}{\rho} = \frac{1}{2}(v_2^2 - v_1^2)$$

or

$$P_1 - P_2 = \frac{1}{2}\rho(v_2^2 - v_1^2) = \frac{1}{2} \times 1.3\,[(70)^2 - (63)^2]\ \text{Pa} = 605.15\ \text{Pa}.$$

This difference of pressure provides the lift to the aeroplane. So, lift on the aeroplane = pressure difference × area of wings

$$= 605.15 \times 2.5\ \text{N} = 1512.875\ \text{N}$$

$$= 1.51 \times 10^3\ \text{N}.$$