# Chapter Ten

# MECHANICAL PROPERTIES OF FLUIDS



# MCQ I

**10.1** A tall cylinder is filled with viscous oil. A round pebble is dropped from the top with zero initial velocity. From the plot shown in Fig. 10.1, indicate the one that represents the velocity (v) of the pebble as a function of time (t).

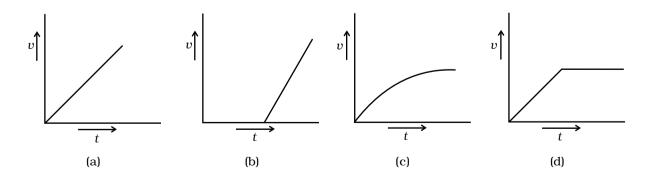
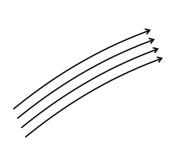
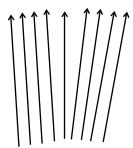
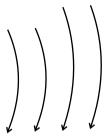


Fig. 10.1

**10.2** Which of the following diagrams (Fig. 10.2) does not represent a streamline flow?







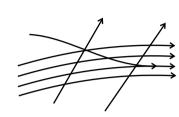


Fig. 10.2

- **10.3** Along a streamline
  - (a) the velocity of a fluid particle remains constant.
  - (b) the velocity of all fluid particles crossing a given position is constant.
  - (c) the velocity of all fluid particles at a given instant is constant.
  - (d) the speed of a fluid particle remains constant.
- **10.4** An ideal fluid flows through a pipe of circular cross-section made of two sections with diameters 2.5 cm and 3.75 cm. The ratio of the velocities in the two pipes is
  - (a) 9:4
  - (b) 3:2
  - (c)  $\sqrt{3}:\sqrt{2}$
  - (d)  $\sqrt{2}:\sqrt{3}$
- 10.5 The angle of contact at the interface of water-glass is  $0^{\circ}$ , Ethylalcohol-glass is  $0^{\circ}$ , Mercury-glass is  $140^{\circ}$  and Methyliodide-glass is  $30^{\circ}$ . A glass capillary is put in a trough containing one of these four liquids. It is observed that the meniscus is convex. The liquid in the trough is
  - (a) water
  - (b) ethylalcohol
  - (c) mercury
  - (d) methyliodide.

## MCQ II

- **10.6** For a surface molecule
  - (a) the net force on it is zero.
  - (b) there is a net downward force.

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### **Exemplar Problems-Physics**

- (c) the potential energy is less than that of a molecule inside.
- (d) the potential energy is more than that of a molecule inside.
- **10.7** Pressure is a scalar quantity because
  - (a) it is the ratio of force to area and both force and area are vectors.
  - (b) it is the ratio of the magnitude of the force to area.
  - (c) it is the ratio of the component of the force normal to the area.
  - (d) it does not depend on the size of the area chosen.
- **10.8** A wooden block with a coin placed on its top, floats in water as shown in Fig. 10.3.

The distance l and h are shown in the figure. After some time the coin falls into the water. Then

- (a) 1 decreases.
- (b) h decreases.
- (c) lincreases.
- (d) h increase.



Coin ی

- **10.9** With increase in temperature, the viscosity of
  - (a) gases decreases.
  - (b) liquids increases.
  - (c) gases increases.
  - (d) liquids decreases.
- 10.10 Streamline flow is more likely for liquids with
  - (a) high density.
  - (b) high viscosity.
  - (c) low density.
  - (d) low viscosity.

### **VSA**

- **10.11** Is viscosity a vector?
- **10.12** Is surface tension a vector?
- **10.13** Iceberg floats in water with part of it submerged. What is the fraction of the volume of iceberg submerged if the density of ice is  $\rho_i = 0.917 \text{ g cm}^{-3}$ ?
- **10.14** A vessel filled with water is kept on a weighing pan and the scale adjusted to zero. A block of mass M and density  $\rho$  is suspended by a massless spring of spring constant k. This block is submerged inside into the water in the vessel. What is the reading of the scale?

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### **Mechanical Properties of Fluids**

**10.15** A cubical block of density  $\rho$  is floating on the surface of water. Out of its height L, fraction x is submerged in water. The vessel is in an elevator accelerating upward with acceleration a. What is the fraction immersed?

### SA

- **10.16** The sap in trees, which consists mainly of water in summer, rises in a system of capillaries of radius  $r = 2.5 \times 10^{-5}$  m. The surface tension of sap is  $T = 7.28 \times 10^{-2}$  Nm<sup>-1</sup> and the angle of contact is 0°. Does surface tension alone account for the supply of water to the top of all trees?
- **10.17** The free surface of oil in a tanker, at rest, is horizontal. If the tanker starts accelerating the free surface will be titled by an angle  $\theta$ . If the acceleration is a m s<sup>-2</sup>, what will be the slope of the free surface?.
- **10.18** Two mercury droplets of radii 0.1 cm. and 0.2 cm. collapse into one single drop. What amount of energy is released? The surface tension of mercury  $T=435.5\times10^{-3}\,\mathrm{N}\;\mathrm{m}^{-1}$ .
- **10.19** If a drop of liquid breaks into smaller droplets, it results in lowering of temperature of the droplets. Let a drop of radius R, break into N small droplets each of radius r. Estimate the drop in temperature.
- **10.20** The sufrace tension and vapour pressure of water at  $20^{\circ}$ C is  $7.28 \times 10^{-2} \, \text{Nm}^{-1}$  and  $2.33 \times 10^{3} \, \text{Pa}$ , respectively. What is the radius of the smallest spherical water droplet which can form without evaporating at  $20^{\circ}$ C?

### LA

- **10.21** (a) Pressure decreases as one ascends the atmosphere. If the density of air is  $\rho$ , what is the change in pressure d*p* over a differential height d*h*?
  - (b) Considering the pressure p to be proportional to the density, find the pressure p at a height h if the pressure on the surface of the earth is  $p_0$ .
  - (c) If  $p_0 = 1.03 \times 10^5$  N m<sup>-2</sup>,  $\rho_0 = 1.29$  kg m<sup>-3</sup> and g = 9.8 m s<sup>-2</sup>, at what height will the pressure drop to (1/10) the value at the surface of the earth?
  - (d) This model of the atmosphere works for relatively small distances. Identify the underlying assumption that limits the model.
- **10.22** Surface tension is exhibited by liquids due to force of attraction between molecules of the liquid. The surface tension decreases

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### Exemplar Problems-Physics

with increase in temperature and vanishes at boiling point. Given that the latent heat of vaporisation for water  $L_{\nu}=540~\rm k$  cal kg<sup>-1</sup>, the mechanical equivalent of heat J = 4.2 J cal<sup>-1</sup>, density of water  $\rho_{\rm w}=10^3~\rm kg~\it t^{-1}$ , Avagadro's No  $N_{\rm A}=6.0\times10^{26}~\rm k$  mole <sup>-1</sup> and the molecular weight of water  $M_{\rm A}=18~\rm kg$  for 1 k mole.

- (a) estimate the energy required for one molecule of water to evaporate.
- (b) show that the inter-molecular distance for water is

$$d = \left[\frac{M_{\rm A}}{N_{\rm A}} \times \frac{1}{\rho_w}\right]^{1/3}$$
 and find its value.

- (c) 1 g of water in the vapor state at 1 atm occupies 1601cm<sup>3</sup>. Estimate the intermolecular distance at boiling point, in the vapour state.
- (d) During vaporisation a molecule overcomes a force F, assumed constant, to go from an inter-molecular distance d to d'. Estimate the value of F.
- (e) Calculate F/d, which is a measure of the surface tension.
- **10.23** A hot air balloon is a sphere of radius 8 m. The air inside is at a temperature of  $60^{\circ}$ C. How large a mass can the balloon lift when the outside temperature is  $20^{\circ}$ C? (Assume air is an ideal gas, R = 8.314 J mole<sup>-1</sup>K<sup>-1</sup>, 1 atm. =  $1.013 \times 10^{5}$  Pa; the membrane tension is  $5 \text{ N m}^{-1}$ .)