CBSE Test Paper 02

Chapter 10 Mechanical Properties of Fluids

1. Which one of the following statements is correct for a fluid passing through the narrow part of non-uniform pipe? **1**
   a. its velocity decreases but its pressure increases
   b. its velocity and pressure both increase
   c. its velocity increases but its pressure decreases
   d. its velocity and pressure both decrease
2. Flow is said to be steady if **1**
   a. the flow rate decreases 10% every second
   b. the flow rate does not change with time
   c. the flow rate increases with time
   d. the flow rate decreases 20% every second
3. Gauge pressure at a point is **1**
   a. pressure at that point – atmospheric pressure
   b. pressure at that point + atmospheric pressure
   c. (pressure at that point – atmospheric pressure)/2
   d. (pressure at that point + atmospheric pressure)/2
4. Water drops are spherical because of **1**
   a. elasticity
   b. viscosity
   c. low shear strain
   d. surface tension
5. The unit of surface tension in S.I units is given by **1**
   a. dynes per cm
   b. dynes per cm^2

c. Newtons per meter^2
d. Newtons per meter

6. Hydrostatic pressure is a scalar quantity even though pressure is force divided by area, and force is a vector. Explain? **1**

7. Does Archimedes principle hold in a vessel in a free fall? **1**

8. The blood pressure in human is greater at the feet than at the brain. Why? **1**

9. What do you mean by velocity head, gravitational potential(elevation) head and pressure head? Write Bernoulli's equation in terms of pressure head, velocity head and elevation head. **2**

10. A body of mass 6 kg is floating in a liquid with 2/3 of its volume inside the liquid. Find ratio between the density of the body and density of liquid. Take g = 10m/s^2. **2**

11. A liquid drop of diameter D breaks up into 27 tiny drops. Find the resulting change in energy. Take surface tension of liquid as σ. **2**

12. If eight rain drops each of radius 1 mm are falling through air at a terminal velocity of 5 cm | s. If they coalesce to form a bigger drop, what is the terminal velocity of bigger drop? **3**

13. 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. **3**

14. What is Bernoulli’s theorem? Show that sum of pressure, potential and kinetic energy in the streamline flow is constant? **3**

15. Briefly explain the role of detergent in washing of clothes. **5**

Answer

1. c. its velocity increases but its pressure decreases

   Explanation: Consider two points A and B in the pipe at the same horizontal level. At point A,let a_1 be the area of cross-section of the pipe, v_1 the velocity of fuild flow and p_1 the fluid pressure. let a_2, v_2,p_2 be the corrospoding quantities at point B. then from Bernoulli's theorem we have,

   $p_1 + \frac{1}{2}\rho v_1^2 = p_2 + \frac{1}{2}\rho v_2^2$

   $\Rightarrow (p_1 - p_2) = \frac{1}{2}\rho(v_2^2 - v_1^2) \ldots .(1)$

   if $a_2 < a_1$, it following from continuity equation $a_1v_1 = a_2v_2$ that $v_1 > v_2$ from eq (1) it follows that $p_2 < p_1$, Hence at the narrow part of the pipe, the fluid velocity increase but its pressure decrease.

2. b. the flow rate does not change with time

   Explanation: The flow velocity u of a fluid is a vector field $u = u(x, t)$ which gives the velocity of an element of fluid at a position x and time t.
   The flow of a fluid is said to be steady if u does not vary with time. That is if $\frac{\delta u}{\delta t} = 0.$

3. a. pressure at that point – atmospheric pressure

   Explanation: Gauge pressure is zero-referenced against ambient air pressure, so it is equal to absolute pressure minus atmospheric pressure. Negative signs are usually omitted
   The difference between absolute pressure and atmospheric pressure is what we call gauge pressure (P_{gauge}). It can be calculated if we know the absolute and atmospheric pressures using this formula:

   $P_{gauge} = P_{abs} - P_{atm}$

4. d. surface tension

   Explanation: In fluids there are primarily 2 forces cohesive force and adhesive force. Cohesive force is the one which act between same molecules and

adhesive force is the one which acts between different molecules.
The cohesive force gives rise to a phenomenon called surface tension. In this phenomenon a fluid surface tends to pull itself inwards, causing reduction of exposed surface.
For a water droplet which is left alone, cohesive forces undoubtedly dominate, leading to surface tension . Surface tension makes all the molecules of water to stick with each other closely, this results in its spherical shape.

5. d. Newtons per meter
Explanation: surface tension is measured in force per unit length. The S.I unit is newton per meter but the CGS unit dyne per centimeter is also used.

6. According to principle of transmission of pressure in liquids When pressure is increased at a point in liquid which is at rest in a vessel , the pressure is transmitted equally and undiminished in all directions, inside the liquid. Since there is no fixed direction for the pressure due to liquid. Hence it is a scalar quantity.

7. Buoyant force acting on a body which is immersed in vessel and vessel is at rest F=mg , where m is mass of body. The apparent weight of system during free fall W=m(g-g)=0. As weight of an object become zero during free fall, the buoyant force also become zero. Thus, Archimedes principle does not hold during free fall.

8. The pressure "P" exerted by a liquid at a depth "h" is $P = h\rho g$. The height of the blood column is quite large at feet than at the brain, hence blood pressure at feet is greater.

9. **Velocity head**
Velocity head is defined as the ratio of kinetic energy per unit mass and acceleration due to gravity
Velocity head = $\frac{\text{K.E. per unit mass}}{g} = \frac{2}{g} = \frac{v^2}{2g}$
Pressure head = $\frac{\text{Pressure energy per unit mass}}{g} = \frac{PV}{mg} = \frac{P}{\rho g}$
Elevation (or potential) head = $\frac{\text{Gravitational P.E. per unit mass}}{g} = \frac{gh}{g} = h$
Bernoulli's equation may be expressed as
Pressure Head + Velocity Head + Elevation Head = constant
i.e, $\frac{P}{\rho g} + \frac{v^2}{2g} + h$= constant

10. For a floating body,

Buoyant force = Weight of liquid displaced

Suppose V be the volume of the body $\frac{2}{3} V \rho_l g = \rho_b g$

where ρ_b = density of the floating body

and ρ_l = density of the liquid

$\frac{\rho_b}{\rho_l} = \frac{2}{3}$

11. Radius of larger drop $= \frac{D}{2}$

Radius of each small drop = r

$\therefore \quad 27 \times \frac{4}{3}\pi r^3 = \frac{4}{3}\pi\left(\frac{D}{2}\right)^2 \Rightarrow r = \frac{D}{6}$

Initial surface area of large drop $4\pi\left(\frac{D}{2}\right)^2 = \pi D^2$

Final surface area of 27 small drop $27 \times 4\pi r^2 = 27 \times 4\pi \frac{D^2}{36} = 3\pi D^2$

$\therefore$ Change in energy = increase in area $\times \sigma$

$= 2\pi D^2 \sigma$

12. Let the radius of smaller drop = r

Let the radius of bigger drop = R

Volume of smaller drop $= \frac{4}{3}\pi r^3$

Volume of bigger drop $= \frac{4}{3}\pi R^3$

Now, according to the question,

Volume of bigger drop = Volume of 8 smaller drops.

$\frac{4}{3}\pi R^3 = 8 \times \frac{4}{3}\pi r^3$

$R^3 = 8r^3$

Taking cube – root

R = 2r

= 2 $\times$ 1 mm (r = 1mm (Given))

= 2mm

= 0.2 cm (1 cm = 10 mm)

Now, Terminal velocity of each small drop $N_T = \frac{2}{9} \times \frac{r^2}{\eta}(P - \sigma)g \rightarrow 1)$

Terminal velocity of bigger drop $V_T = \frac{2}{9} \times \frac{R^2}{\eta}(P - \sigma)g \rightarrow 2)$

η = Co-efficient of viscosity

P = Density of body

σ = Density of fluid

g = acceleration due to gravity

Dividing eq[4] 2) by 1)

$$\frac{V_T}{N_T} = \frac{R^2}{r^2}$$

$$V_T = N_T \times \frac{R^2}{r^2}$$

Given Terminal velocity of small drop = 5 cm/s

$$V_T = 5 \times \frac{(0.2)^2}{(0.1)^2}$$

$$= 5 \times \frac{0.04}{0.01}$$

V_T = 20 cm/s

13. change in temperature, $\Delta E = \sigma$ (final area - initial area) of surface

$$\Delta E = ms\Delta t,$$

By the law of conservation of mass, final volume = initial volume of one drop of radius R splited in N drops of radius r

$$\therefore \frac{4}{3}\pi R^3 = N \cdot \frac{4}{3}\pi r^3 \text{ or } R^3 = Nr^3$$

$$r = \frac{R}{(N)^{1/3}}$$

$\Delta E = \sigma \Delta A = \sigma$ [area of N drops of radius r – area of big drop]

$$ms\Delta t = \sigma\left[N.4\pi r^2 - 4\pi R^2\right]$$

$$V.\rho s\Delta t = 4\pi\sigma\left[Nr^2 - R^2\right]$$

$$N \cdot \left(\frac{4}{3}\pi r^3\right)\rho s\Delta t = 4\pi\sigma\left[Nr^2 - R^2\right]$$

M = mass of all smaller drops

ρ = density of liquid

S = specific heat of liquid

Δt = change in temperature (C^0 or Kelvin)

$$\Delta t = \frac{4\pi\sigma \times 3}{N \cdot 4\pi r^3 \rho}\left[Nr^2 - R^2\right] \ (\because R^3 = Nr^3)$$

$$\Delta t = \frac{3\sigma}{N\rho s}\left[\frac{Nr^2}{r^3} - \frac{R^2}{r^3}\right]\left(\therefore r^3 = \frac{R^3}{N}\right)$$

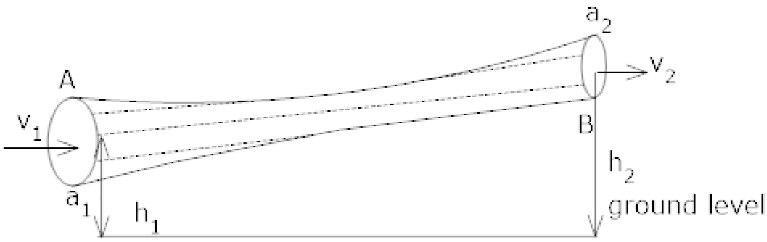
$$\Delta t = \frac{3\sigma}{N\rho s}\left[\frac{N}{r} - \frac{R^2 N}{R^3}\right] = \frac{3\sigma N}{\rho N s}\left[\frac{1}{r} - \frac{1}{R}\right]$$

$\Delta t = \frac{3\sigma}{\rho s}\left[\frac{1}{r} - \frac{1}{R}\right]$ as R > r

$\therefore \Delta t$ will be positive i.e., $\therefore \frac{1}{R} < \frac{1}{r}$

14. Acc. to Bernoulli 's theorem, for the streamline flow of an ideal liquid, the total energy that is sum of pressure energy, potential energy and kinetic energy per unit mass

remains constant at every cross-section throughout the flow. Consider a tube A B of varying cross-section.



p_1 = Pressure applied on liquid at A

p_2 = Pressure applied on liquid at B

a_1, a_2 = Area of cross - section at A & B

h_1 h_2 = height of section A and B from the ground.

v_1, v_2 = Normal velocity of liquid at A and B

s = Density of ideal liquid

Let $P_1 > P_2$

m = Mass of liquid crossing per second through any section of tube.

$a_1 v_1 s = a_2 v_2 s = m$

or $a_1 v_1 = a_2 v_2 = \frac{m}{s} = v$

As $a_1 > a_2 \therefore v_2 > v_1$

Force of on liquid at A = $p_1 a_1$

Force on liquid at B = $p_2 a_2$

Work done/second on liquid at A = $p_1 a_1` \times v_1 = p_1 V$

Work done/second on liquid at B = p_2 V

Net work done | second by pressure energy in moving the liquid from A to B = p_1 v - p_2 v $\rightarrow$ (1)

If 'm' mass of liquid flows in one second from A to B then Increases in potential energy per second from A to B = $mgh_2 - mgh_1 \rightarrow (2)$

Increase in kinetic energy/second of liquid from A to B = $\frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2 \rightarrow (3)$

From, work energy principle:-

Work done by pressure energy = Increase in P. E. /sec + Increase in K. E/sec

From equation 1, 2, & 3

P_1 v - p_2 v = (mgh_2 - mgh_1) + $\frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2$

P_1 v + mgh_1 + $\frac{1}{2}mv_1^2 = p_2v + \frac{1}{2}mv_2^2 + mgh_2$

Dividing throughout by m $\rightarrow$

$\frac{p_1v}{m} + gh_1 + \frac{1}{2v}v_1^2 \pm \frac{p_2v}{m} + \frac{1}{2}v_2^2 + gh_2$

$\frac{p_1}{s} + gh_1 + \frac{1}{2}v_1^2 = \frac{p_2}{s} + \frac{1}{2}v_2^2 + gh_2$

$s1 = \frac{m}{v}$ Density

Hence, $\rightarrow$ 4)

$\frac{p}{\rho} + gh + \frac{1}{2}v^2 =$ Constant

$\frac{p}{\rho} =$ Pressure energy per unit mass

gh = potential energy per unit mass

$\frac{1}{2}v^2$ = kinetic energy per unit mass

$\frac{p}{\rho} + gh + \frac{1}{2}v^2 =$ constant

15. The greasy stains on the dirty clothes cannot be cleaned only by washing them in water as water does not wet greasy dirt. Detergents are added to water, to remove the greasy dirt from the clothes. Following points describe the cleansing action of detergents:

    i. Detergent molecules reduce the surface tension of water. In other terms, they increase water grease oil interaction by attracting water at their one end and grease oil at the other end.
    ii. The detergent molecules have a hairpin-like shape. When detergent is added to water, heads of the hairpin-like detergent molecules gets attracted to the water surface.
    iii. When dirty clothes having greasy/oily stains are soaked in water containing detergents, the grease molecules get attached to the pointed ends of the hairpin-shaped detergent molecules. Hence, water comes in contact with the greasy stains. Thus, the water grease oil interfaces are formed and greasy dirt is held suspended.
    iv. When the clothes are rinsed in water, the greasy dirt is washed away by the running water.