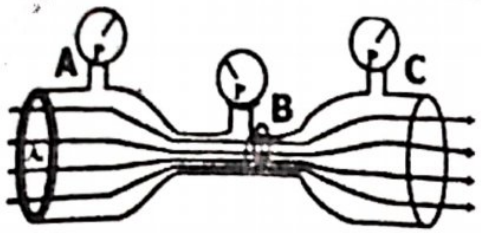


Chapter 6

FLUID DYNAMICS

KEY POINTS

Viscous Drag and Stokes Law:

- An object moving through a fluid experiences a retarding force known as drag force. It increases as the speed of the object increases.

  $F_d = 6\pi\eta rv$

  where η is the coefficient of viscosity of the fluid.

Viscosity:

- Viscosity is the measure of the force required to slide one layer of a liquid over another.
- SI unit of coefficient of viscosity is $Kgm^{-1}s^{-1}$ and dimension $ML^{-1}T^{-1}$

Stokes law:

A sphere of radius r moving with a speed v through a fluid of viscosity η experiences a viscous drag force F. and is given by $F_D = 6\pi\eta rv$.

Terminal Velocity:

The maximum and constant velocity of an object falling vertically downward is called terminal velocity.

$$V_t = \frac{F_d}{6\eta rv} \quad and \quad v_t \alpha r^2$$

Fluid Flow:

- **Streamline or Laminar Flow:** If every particle that passes a particular point, moves along exactly the same path as followed by particles which passed that point earlier then flow is called ***streamline or laminar***
- **Turbulent Flow:** Irregular or unsteady flow of the fluid is called *turbulent flow*
- **Conditions for ideal fluid**

(i) The fluid is non viscous

(ii) The fluid is incompressible

(iii) The fluid motion is steady

CamScanner

Equation of Continuity:

- The product of cross sectional area of the pipe and the fluid speed at any point along the pipe is constant.

  $A_1V_1 = A_2V_2 = \text{constant}$

- It obey law of conservation of mass

Flow Rate:

Volume flow per second of the fluid is called flow rate

- Its unit is m^3s^{-1}
- Its dimension is $[L^3T^{-1}]$

Bernoulli's Equation

- Bernoulli's equation is expressed as. $P + \frac{1}{2}\rho V^2 + \rho gh = \text{constant}$
- It obeys law of conservation of energy

Applications of Bernoulli's Equation:

- Speed of efflux is determined by Torricelli's theorem

  $V = \sqrt{2g(h_1-h_2)}$

- Pressure of fluid increases if the speed of fluid decreases.
- The effect of the decrease in pressure with the increase in speed of the fluid in a horizontal pipe is known as Venture relation.
- Venturimeter is a device used to measure the speed of liquid flow
- Venture relation is expressed as

  $P_1 - P_2 = \frac{1}{2}\rho v_2^2$

Blood Pressure:

- Blood is incompressible.
- Instrument used to measure blood pressure is called sphygmomanometer. It measures blood pressure dynamically.
- Blood pressure is measured in the unit torr. 1 torr = 133.3 Nm^{-2}
- For normal healthy person the systolic pressure is 120 and diastolic pressure is 75 to 80 torr.

Topic 6.1: TOPICAL MULTIPLE CHOICE QUESTIONS

Viscous Drag and Stokes Law

(1) **An object moving through a fluid experience a retarding force known as**
(a) external force (b) terminal force
(c) drag force (d) gravitational force

(2) **η is denoted for**
(a) coefficient of viscosity (b) coefficient of kinetic friction
(c) coefficient of static friction (d) coefficient of volume expansion

(3) **Stokes law is applicable on**
(a) Spherical shape (b) For small velocites
(c) For ideal fluids (d) All

(4) **Drag force is expressed by**
(a) $3\pi\eta rv$ (b) $6\pi\eta rv$
(c) $\frac{2}{9\eta}\rho rv$ (d) $6\eta\rho rv$

(5) **Substances which can not flow easily have**
(a) large viscosity (b) zero viscosity
(c) small viscosity (d) none of these

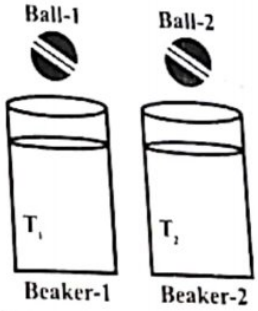
(6) **Which of the following has the highest viscosity**
(a) air (b) water
(c) methanol (d) glycerin

(7) **With increases in temperature, the viscosity of the liquid**
(a) increases (b) decreases
(c) may increase or decrease (d) no change

(8) **As the speed of the object increases the drag force**
(a) increases (b) decreases
(c) remain same (d) none of these

(9) **With increase in temperature viscosity of gases**
(a) increases (b) decreases
(c) may increase or decrease (d) no change

(10) **Two beakers having same liquid of same height are at different temperatures T_1 and T_2 such that $T_1 > T_2$. Now if two identical balls are allowed to fall freely there what is true?**



(a) Ball-1 will attain leis terminal velocity
(b) Ball-2 will reach the bottom first
(c) Ball-1 will have greater terminal velocity and will reach bottom sooner
(d) Ball-2 will reach bottom late yet will have more terminal velocity.

(11) **The frictional effect between different layers of flowing fluids is described in terms of**
(a) viscosity of fluid (b) velocity of fluid
(c) pressure of fluids (d) acceleration of fluids

(12) **Honey was initially at temperature T_1 and then it is heated to a temperature T_2. If the viscosity of honey at T_1 was η_1 and at T_2 was η_2 then**
(a) $\eta_1 > \eta_2$ (b) $\eta_1 < \eta_2$
(c) $\eta_1 = \eta_2$ (d) Cant be predicted

(13) The dimension of co-efficient of viscosity is
(a) $[MLT^{-1}]$ (b) $[M^{-1}T]$
(c) $[ML^{-1}T^{-1}]$ (d) $[MT^{-1}]$

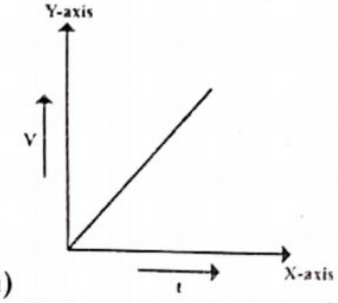
Topic 6.2:

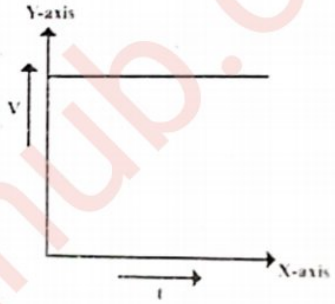
Terminal Velocity

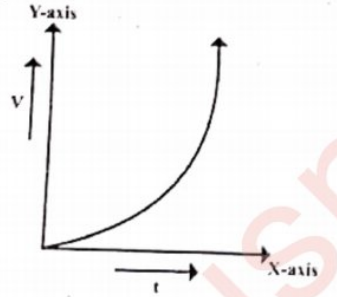
(14) The maximum constant velocity of an object moving through the fluid is called
(a) escape velocity (b) drag velocity
(c) terminal velocity (d) fluid velocity

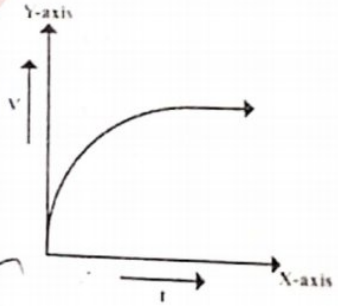
(15) Two fog droplets have radius 2:3 their terminal velocities are in ratio of
(a) 4:6 (b) 4:9
(c) 2:3 (d) 4:3

(16) A spherical droplet falls through air such that it finally attains terminal velocity. Which of the following v-t curves best represent the curve for this motion?

(a)


(b)


(c)


(d)


(17) The net force acting on a body falling through the fluid is given by
(a) net force = drag force - weight (b) net force = drag force + weight
(c) net force = drag force / weight (d) net force = weight- drag force

(18) The unit of terminal velocity is
(a) ms^{-1} (b) ms
(c) Ns^{-1} (d) ms^{-2}

(19) A fog droplet falls vertically through air with an acceleration
(a) equal to g (b) greater than g
(c) less than g (d) equal to zero

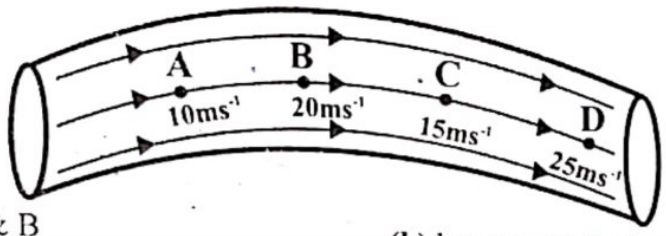
(20) The terminal velocity of spherical body of radius 'r' is proportional to
(a) r^2 (b) r
(c) r^{-2} (d) r^{-1}

(21) If the radius of droplet is doubled then terminal velocity would be
(a) half (b) doubled
(c) quadrupled (d) one fourth

Topic 6.3:

Fluid Flow

(22) **A pipe of non-uniform thickness is shown in the figure. A particle of fluid passes through points A, B, C & D and respective velocities are shown in the figure. Is the flow streamlined at any point?**



(a) between A & B
(b) between B & C
(c) between C & D
(d) can't be predicted

(23) **The formula one cars have a**
(a) steady flow designed
(b) streamlined designed
(c) Turbulent designed
(d) Unsteady flow designed

(24) **The incompressible and non viscous fluid is called**
(a) viscous fluid
(b) non ideal fluid
(c) fluid
(d) ideal fluid

(25) **The dolphins have**
(a) Streamlined bodies
(b) turbulent bodies
(c) Unsteady bodies
(d) none of these

(26) **A fluid is said to be ideal when it appears**
(a) non-viscous
(b) incompressible
(c) to move with uniform speed
(d) all of these

Topic 6.4:

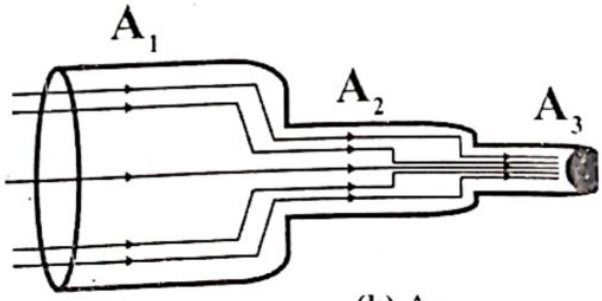
Equation of Continuity

(27) **Equation of continuity is given by the relation**
(a) $A_1P_2=A_2P_1$
(b) $A_2V_2=A_1V_1$
(c) $A_2D_2=A_1D_1$
(d) $P_1V_1=P_2V_2$

(28) **The rate of flow of liquid through pipes**
(a) A/V
(b) V/A
(c) AV
(d) 1/AV

(29) **The product of cross-sectional area of pipe and fluid speed is equal to**
(a) pressure
(b) volume
(c) flow rate
(d) work done

(30) **If area of cross-section is decreased then fluid pressure**



(a) A_1
(b) A_2
(c) A_3
(d) flow rate remains same

31) **SI unit of flow rate is**
(a) ms^{-2}
(c) m^3s^{-1}
(b) m^3s^{-2}
(d) m^2s^{-1}

32) **The law of conservation of mass gives us**
(a) Bernoulli's equation
(b) equation of continuity
(c) Van-derwall's equation
(d) Einstein's equation

33) **The radius at two ends of a pipe is in the ratio of 2:3, then the speed of fluid at the two ends is in the ratio of**
(a) 3:2
(b) 2:3
(c) 9:4
(d) 4:9

Topic 6.5

Bernoulli's Equation

34) **The law of conservation of energy is basis on the**
(a) equation of continuity
(b) Bernoulli's equation
(c) Einstein's equation
(d) Van-derwall's equation

35) **Which of the following cannot be explained on the basis of Bernoulli's effect**
(a) lift of an aero plane
(b) lift of rocket
(c) swing of cricket ball
(d) working of carburetor

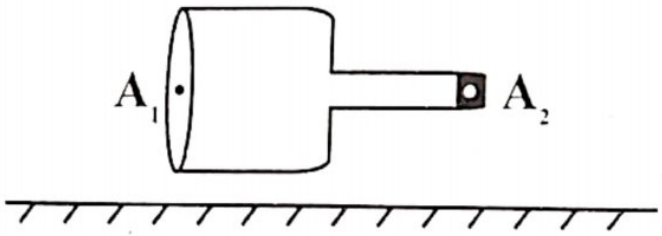
36) **Bernoulli's equation is not applicable for**
(a) swing of a cricket ball
(b) lift of an aeroplane
(c) working of spray
(d) all of these

37) **According to Bernoulli's principle, velocity and pressure are**
(a) inversely proportional
(b) directly proportional
(c) have no relation
(d) none of these

38) **Bernoulli's equation is expressed as**
(a) $P-\frac{1}{2}\rho v^2 = \text{constant}$
(b) $P+\frac{1}{2}\rho v^2+\rho gh = \text{constant}$
(c) $P+\frac{1}{2}\rho v^2-\rho gh = \text{constant}$
(d) $P-\frac{1}{2}\rho v^2-\rho gh = \text{constant}$

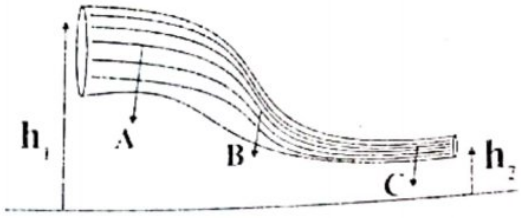
39) **The effect used in perfume bottles and paint sprays is based upon.**
(a) Bernoulli's theorem
(b) equation of continuity
(c) Einstein's mass energy equation
(d) Archimedes principle

40) **A horizontal pipe of non-uniform cross-sectional area is shown in the figure. What form bernoulli's equation aquires in this case if ideal fluid passes through it?**



(a) $P+\frac{1}{2}\rho v^2+\rho gh=\text{constant}$
(b) $P+\rho gh=\text{constant}$
(c) $P+\frac{1}{2}\rho v^2=\text{constant}$
(d) none of these

(41) **According to bernoulli's theorem $P+\frac{1}{2}\rho v^2+\rho gh$=constant considering the figure shown at which point "P" has maximum but $\frac{1}{2}\rho v^2$ has minimum value?**



(a) at point "B" "P" is maximum but $\frac{1}{2}\rho v^2$ is minimum

(b) at point "A" "P" is maximum but $\frac{1}{2}\rho v^2$ is minimum

(c) at point "C"

(d) remains same at every where

(42) **In Bernoulli's equation the unit of expression 'ρgh' is same as that of**

(a) force (b) work

(c) density (d) pressure

(43) **In a pipe, water is flowing through the region in the pipe where streamlines are forced close together**

(a) speed is low and pressure is low (b) speed is high and pressure is high

(c) speed is high and pressure is low (d) none of these

(44) **If a pipe placed horizontally on ground then Bernoulli's equation can be expressed as**

(a) P (b) $\frac{1}{2}\rho v^2$

(c) ρgh (d) all

Topic 6.6:

Application of Bernoulli's equation

(45) **Speed of efflux depends_____on the height below the orifice.**

(a) directly (b) inversly

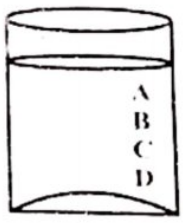
(c) does not depned (d) can't be predicted

(46) **Venturi meter is used to measure**

(a) fluid pressure (b) fluid density

(c) Fluid viscosity (d) fluid speed

(47) **A container is shown in the figure filled up with water. At which point pressure is maximum?**



(a) A (b) B

(c) C (d) D

(48) **1 torr =**

(a) 133.3 Nm^{-2} (b) 1333 Nm^{-2}

(c) 13.33 Nm^{-2} (d) 1.333 Nm^{-2}

(49) **The density of blood is**

(a) 3 to 5 times of water (b) 2 to 3 times of water

(c) 2 to 5 times of water (d) equal to that of water

CamScanner

50) 1 torr equal to
(a) 1mm of Hg
(b) 133.3mm of Hg
(c) 1cm of Hg
(d) 1m of Hg

51) In the above figure of Q.47 if an orifice is developed at the points shown such that an efflux of water comes out. At which point efflux can be maximum?
(a) A
(b) B
(c) C
(d) D

2) The instrument use to measure the blood pressure is
(a) barometer
(b) sphygmomanometer
(c) venture meter
(d) stethoscope

3) The high concentration of red blood cells increases its viscosity from
(a) equal to that of water
(b) 3 to 5 times of water
(c) 2 to 3 times of water
(d) 2 to 5 times of water

4) The venturi relation is given by
(a) $P_1 - P_2 = \frac{1}{2}\rho v_2^2$
(b) $P_2 - P_1 = \frac{1}{2}\rho v_2^2$
(c) $P_2 + P_1 = \frac{1}{2}\rho v_1^2$
(d) $P_2 - P_1 = \frac{1}{3}\rho v_2^2$

5) Human blood pressure measured in
(a) Nm^{-1}
(b) torr
(c) Nm^{-2}
(d) Nm^{-3}

6) A very strong wind blows above the house as shown in the figure. The pressure on the ceiling is.

(a) inward
(b) upward
(c) along ceiling
(d) no pressure

7) The systolic pressure is about
(a) 120 torr
(b) 115 torr
(c) 125 torr
(d) 80 torr

8) The blood pressure varies from high systolic pressure to low diastolic pressure of about
(a) 80-90 torr
(b) 75-85 torr
(c) 75-80 torr
(d) 85-95 torr

9) Sphygmo means
(a) kidney
(b) heart
(c) liver
(d) pulse

60) Torricelli's expression is written as
(a) $V = \sqrt{2g(h_1 - h_2)}$
(b) $V = \sqrt{2g(h_1 + h_2)}$
(c) $V = \sqrt{2g(h_2 - h_1)}$
(d) $V = \sqrt{2\rho g(h_1 - h_2)}$

61) A 2 meter high tank is full of water. If a hole appears at it middle then the speed of efflux is
(a) 4.42m/s
(b) 42.4m/s
(c) 5.42m/s
(d) 424m/s

62) For which position will be the maximum blood pressure in the body have the smallest value
(a) sitting position
(b) standing position
(c) lying position

MULTIPLE CHOICE QUESTIONS

(From Past Papers 2012-2017)

(Federal Board)

(1) The expression for terminal velocity is _____ (FDR 2012)

(a) $v_t = \frac{2r^2\rho}{9\eta g}$ (b) $v_t = \frac{2gr^2}{9\eta\rho}$

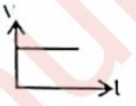
(c) $v_t = \frac{2gr^2\rho}{9\eta}$ (d) $v_t = \frac{2g\eta r^2}{9\rho}$

(2) Which of the following curves represents the motion of water droplet? (FDR 2014)

(a) 

(b) 

(c) 

(d) 

(3) For which position will the maximum blood pressure in the body have the smallest value? (FDR 2015)

(a) standing upright (b) sitting

(c) lying horizontally (d) lying inclined

(4) The SI unit of co-efficient of viscosity is: (FDR 2017)

(a) $kgm^{-1}s^{-1}$ (b) $kgm^{-1}s^{-2}$

(c) $kgm^{-2}s^{-1}$ (d) $kgm^{-3}s^{-2}$

(5) The property of fluid by which its own molecules are attracted is said to be: (FDR 2017)

(a) Adhesion (b) Cohesion

(c) Viscosity (d) Surface Tension

CamScanner

SHORT QUESTIONS
(From Textbook Exercise)

6.1. Explain what do you understand by the term viscosity?

Ans: Definition:

"The frictional effect between different layers of a flowing fluid is described in terms of viscosity of fluid." Viscosity measures how much force is required to slide one layer of fluid over the other layer. e.g: glycerin, honey and thick tar has highest viscosity.

Unit: kg $m^{-1}s^{-1}$

6.2. What is meant by drag force? What are the factors upon which drag force acting upon a small sphere of radius r, moving down through a liquid, depend?

Ans: Definition:

"When the body moves through a viscous medium, its motion is opposed by a force known as drag force." OR

An object moving through a fluid experience a retarding force known as drag force.

According to Stoke's law, drag force is given by the relation:

$F_d = 6\pi\eta rv$

This relation shows that drag force depends upon.

- Radius of sphere (r)
- Velocity of sphere (v)
- Co-efficient of viscosity of fluid (η)

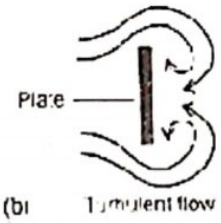
6.3. Why fog droplets appear to be suspended in air?

Ans: We know that as the terminal velocity of a body is directly proportional to the square of radius of a body. i.e. $V_t \propto r^2$

As, the size of the fog droplet is very small, therefore, their terminal velocity is very small and consequently, the fog droplet appears to be suspended in air.

6.4. Explain the difference between laminar flow and turbulent flow.

Ans:

LAMINAR FLOW	TURBULENT FLOW
• The flow is said to be stream line or laminar if every particle that passes a particular point, moves along exactly the same path, as following by the particle which passed that point earlier  (a) Streamlines (laminar flow) • In this case each particle of fluid moves along a smooth path called streamlined or laminar. • **For examples** • Flow of water in wide and smooth river • Flow of gentle breeze. • Flow of wind around streamlined designed car. • Flow of water around dolphins.	• The irregular or unsteady flow of the fluid is called turbulent flow.  (b) Turbulent flow • In turbulent flow, there is great disorder and a constantly changing flow pattern • **For examples** • Flow of water from the top of mountains. • Flow of water in the form of water fall. • Very strongly flowing wind • Water flow at sea shores.

State Bernoulli's relation for a liquid in motion and describe some of it applications.

Bernoulli's Equation

It states that the sum of pressure, kinetic and potential energies per unit volume in a steady flow of an incompressible and non viscous fluid remains constant at every point of its path

Mathematically, $P + \frac{1}{2}\rho v^2 + \rho gh = \text{constant}$.

Applications

(i) Lift in an aero plane.
(ii) Swing of a cricket or a Tennis ball.
(iii) Working of a carburetor of a car.
(iv) Operation of a chimney for smoke exhaust.
(v) Measurement of speed of a liquid.

A person is standing near a fast moving train. Is there any danger that he will fall towards it?

ns: Yes, there is a danger that he will fall towards the train. When a fast moving train passes near a person then the speed of air between the train and the person is greater than the speed of air on the other side of the person.

According to the result of Bernoulli's equation $P + \frac{1}{2}\rho v^2 + \rho gh = \text{constant}$

"Where the speed is high, pressure will be low".
Therefore, the pressure between the train and person is less than the pressure on the other side. Therefore, there is a danger that the person will fall towards the train.

.7. Identify the correct answer. What do you infer from Bernoulli's theorem?
(i) Where the speed of the fluid is high the pressure will be low.
(ii) Where the speed of the fluid is high the pressure is also high.
(iii) This theorem is valid only for turbulent flow of the liquid.

ns: The correct answer is (i)

.8. Two row boats moving parallel in the same direction are pulled towards each other. Explain.

ns: When the two row boats moving parallel in the same direction then the speed of water between the boats is greater than the speed of water on the other sides of the boats.

According to result of Bernoulli's equation: $P + \frac{1}{2}\rho v^2 + \rho gh = \text{constant}$

"Where the speed of the fluid is high the pressure will be low."
Therefore, the pressure between the boats is decreased and they are pulled towards each other.

6.9. Explain how the swing is produced in a fast moving cricket ball.

Ans: One side of the cricket ball is rough and the other side is shining. When the ball is delivered. then the speed of air on the shining is greater then the speed of air on the rough side.

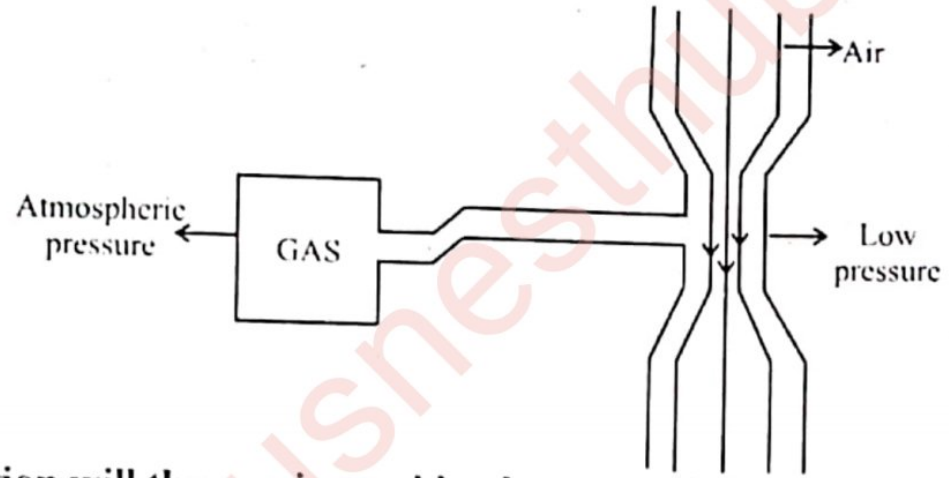
According to result of Bernoulli's equation: $[P + \frac{1}{2}\rho v^2 + \rho gh = \text{constant}\ .]$

"Where the speed is high, pressure will be low."
Therefore, the pressure on shiny side decreases and the ball swings towards the shiny side

CamScanner

6.10. Explain the working of carburetor of a motorcar using by Bernoulli's principle.

Ans: The carburetor of a car engine uses a Venturi duct to feed the correct mixture of air and fuel (petrol) to the cylinders. Air is drawn through the duct and along the pipe to the cylinders. A tiny inlet at the side of duct is fed with petrol. the air through the duct moves very fast. creating low pressure in the duct. which draws petrol vapours into the air stream.



6.11. For which position will the maximum blood pressure in the body have the smallest value.
(a) Standing up right (b) Sitting (c) Lying horizontally (d) Standing on one's head

Ans: Correct answer is (c)

6.12. In an orbiting space station, would the blood pressure in major arteries in the leg ever be greater than the blood pressure in major arteries in the neck?

Ans: In an orbiting space station. there is weightlessness inside the space station. Therefore. the pressure in major arteries in the legs will be equal to the blood pressure in the major arteries in the neck.

(From past papers 2012-2017)
(Federal Board)

(1) Explain how the swing is produced in a fast moving cricket ball. **(FDR 2012)**

(2) Define torr. **(FDR 2013)**

(3) Certain globular particle has a density of 1246 kgm^{-3} it falls through pure water $\left(\eta = 8.0 \times 10^{-4} Nm^{-2}s\right)$ with a terminal speed of 3.0 cm h^{-1}. Find the radius of the particle. **(FDR 2013)**

(4) Explain the working of a carburetor of a motor-car using Bernoulli's principle. **(FDR 2014)**

(5) What is torr? How is it related with Pascal? **(FDR 2014)**

(6) How is the aeroplane lifted upward? **(FDR 2015)**

(7) Using Bernoulli's law briefly describe the working of a carburetor of a motor car? **(FDR 2015)**

(8) Water flows through a hose, whose internal diameter is 1.0 cm with a speed of 2.0 ms^{-1}. What should be the diameter of the nozzle, if the water is to emerge at 20 ms^{-1}? **(FDR 2016)**

(9) Why fog droplets appear to be suspended in air? Explain. **(FDR 2016)**

(10) Water flows downhill through a closed vertical funnel. The flow speed at the top is 12 cm/s, the flows speed at the bottom is twice the speed at the top. If the funnel is 40 cm long and the pressure at the top is $1x10^3$ N/m^2, what is the pressure at the bottom? **(FDR 2017)**