PHYSICS CLASS XI
CHAPTER-10 MECHANICAL PROPERTIES OF FLUIDS

Q.1. Can Bernoulli's equation be used to describe the flow of water through a rapid in a river? Explain.

Ans. No, Bernoulli's equation cannot be used to describe the flow of water through a rapid in a river because Bernoulli's equation can be utilised only for streamline flow.

Q.2. Does it matter if ones uses gauge instead of absolute pressures in applying Bernoulli's equation? Explain.

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

Q.3. A hot liquid moves faster than a cold liquid. Why?

Ans. The viscosity of liquid decreases with the increase in temperature. Therefore, viscosity of hot liquid is less than that of cold liquid. Due to this liquid moves faster than the cold liquid.

Q.4. The flow of blood in a large artery of an anesthetized dog is diverted through a venturimeter. The wider part of the meter has a cross-sextional area equal to that of the artery. A = 8mm^2.

Address: Plot No 420, Behind Shopprix Mall, Vaishali Sector 5, Ghaziabad – 201010
M: 9999907099, 9818932244 O: 0120-4130999
Website: www.vaishalieducationpoint.com , www.educationsolution.co

The narrower part has an area a = 4 mm^2. The pressure drop in the artery is 24 Pa. What is the speed of the blood in the artery?

Ans. We know that density of blood = 1.06×10^3 kg/m^3

Ratio of the area = $\frac{A}{a} = \frac{8}{4} = 2$

i.e., Velocity

v = $\sqrt{\frac{2\Delta p}{\rho(r^2-1)}} = \sqrt{\frac{2\times 24}{1060\times(2^2-1)}} = 0.125\, m/s$

Q.5. The height of water level in a tank is H = 96 cm. Find the range of water stream coming out of a hole at depth H/4 from upper surface of water.

Ans. The depth of hole below the upper surface of water is h = $\frac{H}{4} = \frac{96}{4} = 24cm$

The height of hole from ground is, h' = 96 – 24 = 72 cm

Horizontal range = $2\sqrt{hh'}$ = $2\sqrt{24 \times 72}$ = $48\sqrt{3}$ cm

Q.6. Can two streamlines cross each other, why?

Ans. Two streamlines can never cross each other because if they cross at a point then at the point of intersection there will be two possible direction of flow of fluid which is impossible.

Q.7. On what factors does the critical speed of fluid flow depend?

Ans. The critical speed of a fluid depends (a) diameter of tube, (b) density of fluid, (c) coefficient of viscosity of the fluid.

Q.8. 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.

Address: Plot No 420, Behind Shopprix Mall, Vaishali Sector 5, Ghaziabad – 201010
M: 9999907099, 9818932244 O: 0120-4130999
Website: www.vaishalieducationpoint.com , www.educationsolution.co

Ans. Given, depth of ocean (h) = 3 km = 3000 m

Density of water (ρ) = 10^3 kg/m^3

Pressure exerted by water column

$$p = h\rho g$$

$$= 3000 \times 10^3 \times 9.8$$

$$= 2.94 \times 10^6 \text{ Pa}$$

$$= 2.94 \times 10^7 \text{ Pa}$$

Maximum stress which can be withstand by the vertical off – shore structure = 10^9 Pa

As, 10^9Pa > 2.9×10^7 Pa

Therefore, the vertical structure is suitable for putting up on top of an oil well in the ocean.

Q.9. At what speed will the velocity head of stream of water be 40 cm?

Ans. Given, h = 40 cm

g = 980 cm/s^2

We know that velocity head, h = $\frac{v^2}{2g}$

$$v = \sqrt{2gh} = \sqrt{2 \times 980 \times 40}$$

$$= 280 \text{ cms}^{-1}$$

Q.10. The velocity of water in a river is 18 kmh^{-1} near the surface. If the river is 5 m deep, find the shearing stress between horizontal layers of water. The coefficient of viscosity of water 10^{-2} poise.

Address: Plot No 420, Behind Shopprix Mall, Vaishali Sector 5, Ghaziabad – 201010
M: 9999907099, 9818932244 O: 0120-4130999
Website: www.vaishalieducationpoint.com , www.educationsolution.co

Ans. As the velocity of water at the bottom of the river is zero.

$$dv = 18 \text{ kmh}^{-1} = 18 \times \frac{5}{18} = 5 \text{ ms}^{-1}$$

Also $dx = 5$ m, $\eta = 10^{-2}$ poise $= 10^{-3}$ Pa –s

Force of viscosity, $F = \eta A \frac{dv}{dx}$

We know that shearing stress $= \frac{F}{A}$

$$\Rightarrow \quad \frac{F}{A} = \eta \frac{dv}{dx} = \frac{10^{-3} \times 5}{5} = 10^{-3} \text{ Nm}^{-2}$$

Q.11. What should be the average velocity of water in a tube of radius 0.005 m so that the flow is just turbulent? The viscosity of water is 0.001 Pa-s.

Ans. Here, r = 0.005 m, diameter D = 2r = 0.010 m

$\eta = 0.001$ Pa – s, $\rho = 1000$ kgm^{-3}

For flow to be just turbulent, $R_e = 3000$

$$\therefore \quad v = \frac{R_e \eta}{\rho D} = \frac{3000 \times 0.001}{1000 \times 0.010} = 0.3 ms^{-1}$$

Q.15. The terminal velocity of a copper ball of radius 2.0 mm falling through a tank of oil at 20°C is 6.5 cms^{-1}. Compute the viscosity of the oil at 20°C. Density of oil is 1.5 × 10^{3} kg m^{-3}, density of copper is 8.0 × 10^{3} kg m^{-3}.

Ans. Given, $v_t = 6.5 \times 10^{-2}$ m/s

$r = 2 \times 10^{-3} m$, g = 9.8 m/s^2

$\rho = 8.9 \times 10^3$ kg/m^3 , $\sigma = 1.5 \times 10^3$

As we know terminal velocity

i.e., $$v_t = \frac{2}{9} \frac{r^2(\rho - \sigma)}{\eta} g$$

Address: Plot No 420, Behind Shopprix Mall, Vaishali Sector 5, Ghaziabad – 201010
M: 9999907099, 9818932244 O: 0120-4130999
Website: www.vaishalieducationpoint.com , www.educationsolution.co

$\eta = \frac{2}{9} \times \frac{(2\times10^{-3})^2\times9.8}{(6.5\times10^{-2})} \times 7.4 \times 10^3$

$\eta = 9.9 \times 10^{-1} kg/ms$

Q.16. The cylindrical tube of a spray pump has a cross-section of 8.0 cm^2 one end of which has 40 fine holes each of diameter 1.00 mm. If the liquid flow inside the tube is 1.5 m/min, what is the speed of ejection of the liquid through the holes?

Ans. Area of cross-section of tube (A) = 8 cm^2 = 8 × 10^{-4} m^2

Number of holes (N) = 40

Diameter of each hole (2r) = 1.0 mm

∴ Radius of each hole (r) = 0.5 mm = 5 × 10^{-4} m

Velocity of liquid flow in tube = 1.5 m/min = $\frac{1.5}{60} m/s$

= 2.5 × 10^{-4} m

Total area of holes = N × πr^2 = 40 × 3.14 × (5 × $10^{-4})^2$

= 3.14 × 10^{-5} m^2

According to equation of continuity,

$A_1v_1 = A_2v_2$

or $v_2 = \frac{A_1v_1}{A_2} = \frac{8\times10^{-4}\times2.5\times10^{-2}}{3.14\times10^{-5}}$

$= \frac{20}{3.14} \times 10^{-1}$ = 0.64 m/s

Q.17. (i) What is the largest average velocity of blood flow in an artery of radius 2 × 10^{-3} m, if the flow must remain laminar?

Address: Plot No 420, Behind Shopprix Mall, Vaishali Sector 5, Ghaziabad – 201010
M: 9999907099, 9818932244 O: 0120-4130999
Website: www.vaishalieducationpoint.com , www.educationsolution.co

(ii) What is the corresponding flow rate? (Take viscosity of blood to be 2.084 × $10^{-3} Pa - s$)

Ans. Given, radius of artery (r) = 2 × 10^{-3} m

∴ Diameter of artery D = 2r = 4 × 10^{-3} m

Density of whole blood (ρ) = 1.06 × 10^{3} kg/m^3

Coefficient of viscosity of blood (η) = 2.084 × 10^{3} Pa-s

For laminar flow, maximum value of Reynold's number

k_R = 2000

(i) Critical velocity (v_c) = $\frac{k_n \eta}{\rho D}$

$= \frac{2000 \times 2.084 \times 10^3}{1.06 \times 10^3 \times 4 \times 10^{-3}}$

= 9.83 × 10^5m/s

(ii) Flow rate of blood = Volume of blood flowing per second

= Av_c

= $\pi r^2 \times v_c$

= 3.14 × $(2 \times 10^{-3})^2$ × 9.83 × 10^5

= 12.35 m^3/s

Q.18. Show that if n equal rain droplets falling through air with equal steady velocity of 10 cms^{-1} coalesce, the resultant drop attains a new terminal velocity of 10 n$^{2/3}$ cms^{-1}.

Ans. Volume of a bigger drop

Address: Plot No 420, Behind Shopprix Mall, Vaishali Sector 5, Ghaziabad – 201010
M: 9999907099, 9818932244 O: 0120-4130999
Website: www.vaishalieducationpoint.com , www.educationsolution.co

= n × Volume of a smaller droplet

or $\frac{4}{3}\pi R^3$ = n × $\frac{4}{3}\pi r^3$ or R^3 = nr^3

or R = $n^{1/3}r$

Terminal velocity of a small droplet is given by

$$v_s = \frac{2}{9}\frac{r^2}{\eta}(\rho - \rho')g$$

Terminal velocity of a bigger drop is given by

$$v_b = \frac{2}{9}\frac{R^2}{\eta}(\rho - \rho')g$$

Dividing Eq. (ii) by Eq. (i), we get

$$\frac{v_b}{v_s} = \frac{R^2}{r^2}$$

But R = $n^{1/3}$r and v_s = 10 cm/s

$$v_b = v_s \times \left(\frac{R^2}{r^2}\right) = 10 \times \frac{n^{2/3}r^2}{r^2}$$

$$v_b = 10\, n^{2/3} \text{ cm/s}$$

Q.19. In a test experiment on a model aeroplane in a wind tunnel, the flow of speeds on the upper and lower surfaces of the wings are 70 m/s and 63 m/s respectively. What is the lift on the wings, if its area is 2.5 m^2 ? Take the density of air to be 1.3 kg/m^3.

Ans. Let the lower and upper surface of the wings of the aeroplane be at the same height h and speeds of air on the upper and lower surfaces of the wings be v_1 and v_2.

Address: Plot No 420, Behind Shopprix Mall, Vaishali Sector 5, Ghaziabad – 201010
M: 9999907099, 9818932244 O: 0120-4130999
Website: www.vaishalieducationpoint.com , www.educationsolution.co

Q.20. A cylindrical vessel filled with water upto a height of 2 m stands on a horizontal plane. The side wall of the vessel has a plugged circular hole touching the bottom. Find the minimum diameter of the hole so that the vessel begin to move on the floor, if the plug is removed. The coefficient of friction between the bottom of the vessel and the plane is 0.4 and total mass of water plus vessel is 100 kg.

Ans. Velocity of efflux through the hole, v = $\sqrt{2gh}$

∴ Distance moved by water in one second v = $\sqrt{2gh}$

∴ Rate of the momentum = (ρA $\sqrt{2gh}$) ($\sqrt{2gh}$) = 2 ghAρ

According to Newton's second law of motion,

force due to the velocity of efflux = 2 gh Aρ.

Now, according to Newton's third law of motion,

Force on the vessel = Rate of the momentum

Force on the vessel = 2 gh Aρ

The vessel will move if force on the vessel = force of friction

or 2gh Aρ = μMg

or A = $\frac{\mu M}{2h\rho} = \frac{0.4\times100}{2\times2\times1000} = \frac{1}{100}$

Since, the hole is circular therefore

A = $\pi r^2 = \frac{\pi D^2}{4}$

∴ D = $\sqrt{\frac{4A}{\pi}} = \sqrt{\frac{4\times1}{100\times3.14}}$ = 0.113 m

Address: Plot No 420, Behind Shopprix Mall, Vaishali Sector 5, Ghaziabad – 201010
M: 9999907099, 9818932244 O: 0120-4130999
Website: www.vaishalieducationpoint.com , www.educationsolution.co

So, diameter of a hole D = 0.113 m

Q.21. Air is streaming past a horizontal air plane wing such that its speed is 120 ms^{-1} over the upper surface and 90 ms^{-1} at the lower surface. If the density of air is 1.3 kgm^{-3} , find the difference in pressure between the top and bottom of the wing. If wing is 10 m long and has an average width of 2 m, calculate the gross lift of the wing.

Given, v_2 = 120 m/s, v_1 = 90 m/s, ρ_α = 1.3 kg/m^3, h_1 = 10m, a_1 = 10 × 2 = 20m^2

Ans. According to Bernoulli's theorem,

$$\frac{P_1}{\rho} + gh_1 + \frac{1}{2}v_1^2 = \frac{P_2}{\rho} + gh_2 + \frac{1}{2}v_2^2$$

For the horizontal flow, $h_1 = h_2$

$$\therefore \quad \frac{P_1}{\rho} + \frac{1}{2}v_1^2 = \frac{p_2}{\rho} + \frac{1}{2}v_2^2$$

Given, v_1 = 90 m/s, v_2 = 120 m/s, ρ = 1.3 kg/m^3

$$\therefore \quad \frac{p_1 - p_2}{\rho} = \frac{1}{2}(v_2^2 - v_1^2)$$

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

$$= 1.3\frac{(14400 - 8100)}{2} = \frac{1.3 \times 6300}{2}$$

$P_1 - P_2 = 4.095 \times 10^3$ N/m^2

It is the pressure difference between the top and the bottom of the wing.

Now, gross lift the using (i.e., force)

$= (p_1 - p_2) \times$ Area of the wing

$= 4.095 \times 10^3 \times 10 \times 2$

Address: Plot No 420, Behind Shopprix Mall, Vaishali Sector 5, Ghaziabad – 201010
M: 9999907099, 9818932244 O: 0120-4130999
Website: www.vaishalieducationpoint.com , www.educationsolution.co

= 8.190 × 10^4 N

Q.22. The flow rate of water from a top of diameter 1.25 cm is 0.48 L/min. The coefficient of viscosity of water is 10^{-3} Pa s. After sometime the flow rate is increased to 3L/min. Characterise the flow for both the flow rates.

Ans. Let the speed of the flow be v and d = 1.25 cm

Volume of water flowing out per second.

$$Q = v \times \frac{\pi d^2}{4},\ v = \frac{4Q}{d^2\pi}$$

Estimate Reynold's number $R_e = \frac{4\rho Q}{\pi d\eta}$

Q = 0.48 L/min = 8 cm^3/s = $8\times10^{-6} m^3/s$

$$R_e = \frac{4\times10^3\times8\times10^{-6}}{3.14\times1.25\times10^{-2}\times10^{-3}}$$

R_e = 815 [i.e., below 1000, the flow is steady]

After sometime, when

Q = 3L/min = 50 cm^3/s = $5 \times 10^{-5} m^3/s$, R_e = 5095

∴ The flow will be turbulent.

Q.23. Sahil was going to his friend's house to give him Diwali gift on his motorcycle. He was going at a speed of 60 km/h. When he saw the red light, he applied the brakes but a car which was behind him, coming at a very high speed, could not stop in time and hit a scooter coming from side and ran away.

Sahil saw that accident and immediately ran to help the person on scooter. He was bleeding profusely. Sahil stopped an autorikshaw and took the accident

Address: Plot No 420, Behind Shopprix Mall, Vaishali Sector 5, Ghaziabad – 201010
M: 9999907099, 9818932244 O: 0120-4130999
Website: www.vaishalieducationpoint.com , www.educationsolution.co

victim to a hospital. Doctor attending to victim said that since lot of blood is lost, he had to be given a blood transfusion.

Sahil immediately offered to donate blood and save a life.

(i) What values of Sahil do you appreciate ?

(ii) What is the attitude of people towards road accident victim?

(iii) In the blood transfusion, the bottle is set up so that the level of blood is 1.3 m above the needle, which has an internal diameter of 0.36 mm and is 3 cm in length. If 4.5 cm^3 of blood passes through the needle in one minute, calculate the viscosity of blood. The density of blood is 1020 kg m^{-3}.

Ans. (i) Sahil is very helpful and generous person.

(ii People don't bother about the road accident victims because they probably think that they don't know the victim or they don't want to get involved in a police case.

(iii Given, h = 1.3 m, ρ = 1020 kg/m^3 , p = hρg

p = 1.3 × 1020 × 9.8

r = $\frac{D}{2}$ = $\frac{0.36}{2}$ = 0.18 mm = 0.18 × 10^{-3} m

l = 3 cm = 3 × 10^{-2} m

v = $\frac{Total\ volume}{Time}$ = $\frac{4.5\times10^{-6}}{60}$ m^3/s

Viscosity η = $\frac{\pi\rho r^4}{8Vl}$

Address: Plot No 420, Behind Shopprix Mall, Vaishali Sector 5, Ghaziabad – 201010
M: 9999907099, 9818932244 O: 0120-4130999
Website: www.vaishalieducationpoint.com , www.educationsolution.co

$$= \frac{22}{7} \times \frac{(1.3\times1020\times9.8)\times(0.18\times10^{-3})^{-4}}{8\times\left(\frac{4.5\times10^{-6}}{60}\right)\times3\times10^{-2}}$$

η = 0.00238 Pa-s

Q.24. It was the occasion of Diwali. Everyone was in festive mood. Houses were decorated with diyas and candles and children were bursting crackers. Suddenly, a cracker misfired and instead of going up in the air, it went inside a house and house caught fire. Everyone ran here and there. They brought buckets of water to douse the fire. But the fire was increasing. People called up fire brigade but since roads were narrow, it couldn't reach the house. Some of the boys got an idea.

They went to the garden nearby and brought the water pipe used to water the plants. Pipe was of varying cross-section but water was coming at very fast rate. Four to five boys holded the pipe and sprinkled water on house and the fire was gradually doused. Everyone thanked the boys and praised them.

(i) What values of boys do you appreciate ?

(ii) If the water flows through the pipe of varying cross-section at the rate of 20L/min. Determine the velocity of water at a point where diameter is 4 cm.

(iii) Why should we say no to crakers?

Ans. (i) Boys were courageous and have presence of mind.

(ii) Volume of water flowing per second,

Address: Plot No 420, Behind Shopprix Mall, Vaishali Sector 5, Ghaziabad – 201010
M: 9999907099, 9818932244 O: 0120-4130999
Website: www.vaishalieducationpoint.com , www.educationsolution.co

V = 20 L/min

= $\frac{20\times1000}{60\times(100)^3}$ = $\frac{1}{3}$ × 10^{-3} m^3/s

Radius of pipe, r = $\frac{4}{2} = 2$ cm = 0.02 m

Area of cross – section, a = πr^2 = $\frac{22}{7}$ × $(0.02)^2$ m^2

Let v be the velocity of the flow of water, at the given point,

So, volume, V = av

or $\frac{1}{3} \times 10^{-3}$ = $\frac{22}{7} \times (0.02)^2$ × v

v = $\frac{7\times10^{-3}}{3\times22\times(0.02)^2}$ = 0.2651 m/s

v = 0.2651 m/s

(iii) We should say no to crakers, because

(a) bursting of crakers pollutes the environment.

(b) craker industry employs a lot of children for the job and if we don't buy craker, they will be rescued

Q.25. Glycerine flows steadily through a horizontal tube of length 1.5 m and radius 1.0 cm. If the amount of glycerine flowing per second at one end is 4.0 × 10^{-3}kg/s. What is the pressure difference between the two ends of the tube? (Density of glycerine = 1.3 × 10^3kg/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).

Address: Plot No 420, Behind Shopprix Mall, Vaishali Sector 5, Ghaziabad – 201010
M: 9999907099, 9818932244 O: 0120-4130999
Website: www.vaishalieducationpoint.com , www.educationsolution.co

Ans. Given, length of the tube(l) = 1.5 m

Radius of the tube (r) = 1.0 cm = 1 × 10^{-2} cm

Mass of glycerine flowing per second = 4 × 10^{-3} kg/s

Density of glycerine (ρ) = 1.3 × 10^3 kg/m^3

Viscosity of glycerine (η) = 0.83 Pa – s

Volume of glycerine flowing per second (V) = $\frac{m}{\rho}$

$$\left[\because Density = \frac{Mass}{Volume}\right]$$

$$= \frac{4\times10^{-3}}{1.3\times10^3} m^3/s = \frac{4}{1.3} \times 10^{-6} m^3/s$$

According to Poiseuille's formula, the rate of flow of liquid through a tube

$$V = \frac{\pi}{8}\frac{\rho r^4}{\eta\rho}$$

Where, p is the pressure difference between the two ends of the tube.

or $$p = \frac{8\eta\rho V}{\pi r^4} = \frac{8\times0.83\times1.5\times4\times10^{-6}}{3.14\times(1\times10^{-2})^4\times1.3}$$

= 976 Pa

To check the laminar flow in the tube, the value of Reynold's number should be less than 2000.

Reynold's number k = $\frac{\rho D v_c}{\eta}$

where, v_c is the critical velocity and D is the diameter of the tube.

Critical velocity v_c = $\frac{Volume\ flowing\ out\ per\ second}{Area\ of\ cross-section}$

$$= \frac{m/\rho}{A} = \frac{m}{\rho\pi r^2} \qquad (\because A = \pi r^2)$$

Address: Plot No 420, Behind Shopprix Mall, Vaishali Sector 5, Ghaziabad – 201010
M: 9999907099, 9818932244 O: 0120-4130999
Website: www.vaishalieducationpoint.com , www.educationsolution.co

∴ Reynold's number K = $\frac{\rho D}{\eta} \times \frac{m}{\rho \pi r^2}$

$$= \frac{2r \times m}{\eta \pi r^2} \qquad (\because D = 2r)$$

$$= \frac{2m}{\pi r \eta} = \frac{2 \times 4 \times 10^{-3}}{3.14 \times 10^{-2} \times 0.83} = 0.31$$

As k < 2000, therefore flow of glycerine is laminar.

Address: Plot No 420, Behind Shopprix Mall, Vaishali Sector 5, Ghaziabad – 201010
M: 9999907099, 9818932244 O: 0120-4130999
Website: www.vaishalieducationpoint.com , www.educationsolution.co