| | | UNIT-V | | | |
|---|---|---|---|---|---|
| 10 | a) | Draw and discuss characteristic curves of centrifugal pump. | L4 | CO5 | 5 M |
| | b) | A turbine is to operate under a head of 25 meters at 200 rpm. The discharge is 9 $m^3/s$. If the turbine efficiency is 90% determine:<br>(i) specific speed of the turbine<br>(ii) power generated<br>(iii) performance under a head of 20 meters.<br>Also state the type of the turbine. | L4 | CO5 | 5 M |
| | | OR | | | |
| 11 | a) | A single-acting reciprocating pump, running at 50 rpm delivers 0.01 $m^3/s$ of water. The diameter of the piston is 200 mm and stroke length 400 mm. Determine<br>(i) the theoretical discharge of the pump,<br>(ii) co-efficient of discharge and<br>(iii) slip and the percentage slip of the pump. | L3 | CO5 | 5 M |
| | b) | A centrifugal pump is to discharge 0.118 $m^3/s$ at a speed of 1450 rpm against a head of 25 m. The impeller diameter at outlet is 250mm and its width at outlet is 50mm and Manometric efficiency is 75%. Determine vane angle at outer periphery of the impeller. | L3 | CO5 | 5 M |





Code: 23ME3402

**II B.Tech - II Semester – Regular Examinations - MAY 2025**

# FLUID MECHANICS AND HYDRAULIC MACHINES

**(MECHANICAL ENGINEERING)**

Duration: 3 hours Max. Marks: 70

Note: 1. This question paper contains two Parts A and B.
2. Part-A contains 10 short answer questions. Each Question carries 2 Marks.
3. Part-B contains 5 essay questions with an internal choice from each unit. Each Question carries 10 marks.
4. All parts of Question paper must be answered in one place.

BL – Blooms Level CO – Course Outcome

## PART – A

| | | BL | CO |
|---|---|---|---|
| 1.a) | Write applications of capillarity. | L1 | CO1 |
| b) | What is Cohesion. | L1 | CO1 |
| c) | Classify fluid flows. | L2 | CO2 |
| d) | List application of Bernoulli's equation. | L1 | CO2 |
| e) | Define boundary layer separation. | L1 | CO3 |
| f) | Give two examples in everyday life where formation of boundary layer is important. | L2 | CO3 |
| g) | Write about draft tube. | L1 | CO4 |
| h) | Classify hydraulic turbines. | L1 | CO4 |
| i) | Write about cavitation in pumps. | L2 | CO5 |
| j) | How do you select the type of turbine. | L1 | CO5 |

## PART – B

| | | | BL | CO | Max. Marks |
|---|---|---|---|---|---|
| | | UNIT-I | | | |
| 2 | a) | The surface tension of water in contact with air is given as 0.0725 N/m. The pressure outside the droplet of water of diameter 0.02 mm is 100 kPa. Calculate the pressure within the droplet of water. | L3 | CO1 | 5 M |

| | | | | | |
|---|---|---|---|---|---|
| | b) | Classify differential manometers and explain anyone of them. | L2 | CO1 | 5 M |
| | | **OR** | | | |
| 3 | a) | In a stream of glycerin in motion, at a certain point the velocity gradient is 0.25 m/s. The mass density of fluid is 1270 kg/m$^3$ and kinematic viscosity is $6.3\times10^{-4}$ m$^2$/s. Calculate shear stress at that point. | L3 | CO1 | 5 M |
| | b) | A simple manometer (U-tube) containing mercury is connected to a pipe in which an oil of specific gravity 0.8 is flowing. The pressure in the pipe is vacuum. The other end of the manometer is open to atmosphere. Find the vacuum pressure in pipe, if the difference of mercury level in the two limbs is 200 mm and height of oil in the left-limb from the centre of the pipe is 150 mm below. | L3 | CO1 | 5 M |
| | | **UNIT-II** | | | |
| 4 | a) | A pipe line 300 m long has a slope of 1 in 100 and tapers from 1.2m diameter at the high end to 0.6m at the low end. The discharge through the pipe is 5.4 m$^3$ /min. If the pressure at the high end is 70 kPa, find the pressure at the low end. Neglect the losses. | L3 | CO2 | 5 M |
| | b) | Derive the Bernoulli's equation from the Euler's equation. | L3 | CO2 | 5 M |
| | | **OR** | | | |
| 5 | a) | Differentiate between the rotational and irrotational flows. | L2 | CO2 | 5 M |
| | b) | The water is flowing through a tapering pipe having diameters 0.3 m and 0.15 m at inlet and outlet respectively. The discharge through the pipe is 0.04 m$^3$/sec. The inlet is | L3 | CO2 | 5 M |



| | | | | | |
|---|---|---|---|---|---|
| | | 10 m above datum and outlet is 6 m above datum. Find the intensity of pressure at outlet if that at inlet is 400 kN/m$^2$. | | | |
| | | **UNIT-III** | | | |
| 6 | a) | Explain the different methods of preventing separation of boundary layers. | L2 | CO3 | 5 M |
| | b) | A smooth plate 2 m wide and 2.5 m long is towed in oil (sp. gr. = 0.8) at a velocity of 1.5 m/s along its length. Find the thickness of boundary layer and shear stress at the trailing edge of the plate. Kinematic viscosity of oil is $10^{-4}$ m$^2$/s. | L3 | CO3 | 5 M |
| | | **OR** | | | |
| 7 | a) | The velocity distribution in the boundary layer is $\frac{u}{U}=\frac{1.5y}{\delta}-\frac{y^2}{2\delta^2}$, where $\delta$ is the boundary layer thickness. Determine (i) displacement thickness (ii) Momentum thickness and (iii) Energy thickness. | L3 | CO3 | 5 M |
| | b) | Differentiate stream lined body and bluff body. | L2 | CO3 | 5 M |
| | | **UNIT-IV** | | | |
| 8 | a) | Find an expression for force exerted by a fluid jet on stationary flat plate. | L3 | CO4 | 5 M |
| | b) | Explain the working of Francis turbine with neat diagram. | L2 | CO4 | 5 M |
| | | **OR** | | | |
| 9 | a) | Differentiate between Impulse turbine and Reaction turbine. | L2 | CO4 | 5 M |
| | b) | A 150 mm diameter jet moving at 30m/s impinges on a curved vane moving at 15m/s in the direction of the jet. The jet leaves the vanes at 60° with the direction of motion of the vanes. Calculate: (i) Force exerted by the jet in the direction of motion of vanes (ii) Work done by the jet per second. | L3 | CO4 | 5 M |

P.V.P23 Scheme of valuation.

May. 2025

II - B.Tech II Semester - Regular Examination

Code: 23ME3402 :

Fluid Mechanics and Hydraulic Machines

Mechanical Engineering.

1. a. any two points — 2 marks.
   b. Definition — 2 marks
   c. any two — 2 marks
   d. any two — 2 marks
   e. Definition — 2 marks
   f. any two — 2 marks
   g. Definition — 2 marks
   h. any two — 2 marks
   i. Definition — 2 marks
   j. any two — 2 marks

2. a. Given Data — 2 marks } — 5 marks
   Solution — 3 marks }

2. b. ~~any~~ classification — 2.5 marks } — 5 marks
   any one of ~~Exp~~ Manometers explanation } — 2.5 marks }

3. a Given Data — 2 marks } — 5 marks
   Solution — 3 marks }

3. b Given Data — 2 marks } — 5 marks
   Solution — 3 marks }

4. a — Given Data — 2 marks; Solution — 3 marks } — 5 marks

4. b — Derivation — 5 marks

5. a — any five points — 5 marks

5. b — Given Data — 2 marks; Solution — 3 marks } — 5 marks

6. a — any five points — 5 marks

6. b — Given Data — 2 marks; Solution — 3 marks } — 5 marks

7. a — Given Data — 1 mark; Solution — 4 marks } — 5 marks

7. b — any four points — 5 marks

8. a — Derivation — 5 marks

8. b — Diagram — 2 marks; Explanation — 3 marks } — 5 marks.

9. a — any five points — 5 marks.

9. b — Given Data — 2 marks; Solution — 3 marks } — 5 marks

10. a — any one characteristic curves — diagram — 2 marks; Explanation — 3 marks } — 5 marks

10. b — Given Data — 2 marks; Solution — 3 marks } — 5 marks

11. a — Given Data + Solution = 2 + 3 — 5 marks

11. b — Given data + Solution = 2 + 3 — 5 marks

II B·Tech - II - Semester - Regular Examination - May 2025

Code : 23ME3402 — PVP23

Fluid Mechanics and Hydraulic Machines

Mechanical Engineering

1. a. (i) The ink rises into the pores when it is laid over i

(ii) Due to capillarity, sap rises from the tree's roots and up to the stem.

(iii) Because of their low surface tension, lubricating oils spread freely across all surfaces.

(iv) capillary motion is also responsible for the increase of oil in a lamp's wick.

(v) The rise of moisture from the air in the pores causes wood to swell during the rainy season.

b. The force of attraction between similar molecules (or) particles.

c. Steady Flow, unsteady flow, compressible flow, Incompressible flow, Laminar flow, Turbulent flow, Rotational flow, Ir-rotational flow.

d. (i) Venturimeter

(ii) Blood flow and Hear attack

(iii) Action of atomiser

(iv) Blowing of roofs by wind storms

(v) Dynamic Lift.

e. Boundary layer separation is the phenomenon where a boundary layer detaches from a surface due to adverse pressure gradients, leading to a reversed flo near the surface.

f. (i) while the aeroplane scenario offers a grand picture, the boundary layer also manifests in ordinary.

(ii) The behaviour of a ceiling fan cutting through air or the flow of blood through arteries.

(iii) For instance, when you toast a slice of bread, there exists a boundary layer of hot air around the toast.

g. The draft tube is a pipe of gradually increasing area which connects the outlet of the runner to the tail race. It is use for discharging water from the exit of the turbine to the tail race.

h. (i) According to the type of energy at inlet.
Impulse turbine, Reaction Turbine

(ii) According to the direction of flow through runner.
Tangential flow Turbine  Radial flow Turbine
Axial flow Turbine  Mixed flow Turbine

(iii) According to the head at the inlet of Turbine
High Head Turbine  Medium head Turbine
Low head Turbine.

(iv) According to specific speed of the turbine
Low specific speed Turbine  Medium Specific Speed Turbine  Low Specific Speed Turbine

(i). cavitation is defined as the phenomenon of formation of vapour bubbles of a flowing liquid in a region where the pressure of the liquid falls below its vapour pressure and the sudden collapsing of these vapour bubbles in a region of higher pressure.

(j). The type of Turbine selection depends on factors like available head, flow rate, desired efficiency and specific speed of the turbine.

2. (a) Given data.

$\sigma = 0.0725$ N/m.

$d = 0.02$ mm

$p = 100$ kPa.

$$p = \frac{4\sigma}{d} = \frac{4 \times 0.0725}{0.02 \times 10^{-3}} = 1.45 \times 10^{-6} \text{ Pa.}$$

2. b Manometers are classified as

(i) Simple Manometer

(ii) piezometer

(iii) U- tube Manometer

(iv) Single column manometer

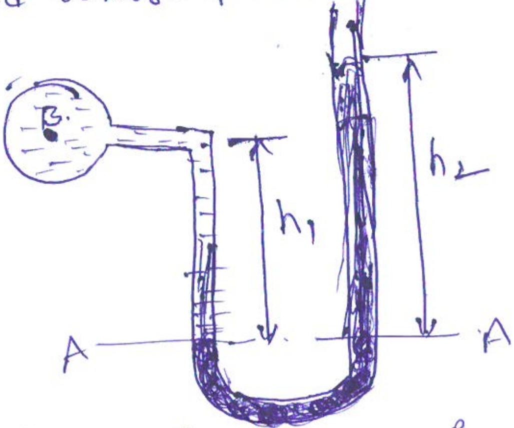
(v) Inclined tube Manometer

(vi) Differential manometer

(vii) U- tube differential manometer

(viii) Inverted U- tube differential manometer.

U- tube manometer :- It consists of glass tube bent in U-shape, one end of which is connected to a point at which pressure is to be measured and other end remains open to the atmosphere. The tube generally contains mercury or any other liquid whose sp. gr. is greater than the sp. gr. of liquid whose pressure is to be measured.




Let B is the point at which pressure is to be measured. whose value is p.

The datum line is A-A

Let $h_1$ = Height of light liquid above the datum line

$h_2$ = Height of heavy liquid above the datum line

$S_1$ = Sp. gr. of light liquid.

$\rho_1$ = Density of liquid = $1000 \times S_1$

$S_2$ = Sp. gr. of heavy liquid

$\rho_2$ = Density of heavy liquid = $1000 \times S_2$

Pressure above A-A in the left column = $p + \rho_1 \times g \times h_1$

pressure above A-A in the right column = $\rho_2 \times g \times h_2$

Hence equating two pressures.

$$p + \rho_1 \times g \times h_1 = \rho_2 \times g \times h_2$$

$$p = (\rho_2 g h_2 - \rho_1 g h_1)$$

3.a. Given Data

$\frac{du}{dy} = 0.25$ /sec.

$\rho = 1270$ kg/m³.

$\nu = 6.3 \times 10^{-4}$ m²/sec.

$\nu = \frac{\mu}{\rho}$

$\mu = \nu \times \rho$

$= 6.3 \times 10^{-4} \times 1270$

$\tau = \mu \frac{du}{dy}$.

$= 6.3 \times 10^{-4} \times 1270 \times 0.25$

$\tau = 0.2$ N/m²

3. b Given Data

$S_1 = 0.8$

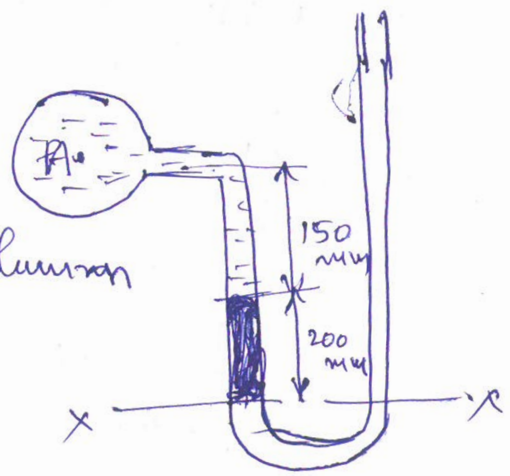
$\rho_1 = 1000 \times 0.8 = 800$ kg/m³.

$S_g = 13.6$

$\rho_g = 1000 \times 13.6 = 13600$ kg/m³

$h_1 = 150$ mm $= 0.15$ m.

$h_2 = 200$ mm $= 0.2$ m.




Pressure above x-x in the Left column

$= P_A + \rho_1 g h_1 + \rho_g g h_2$

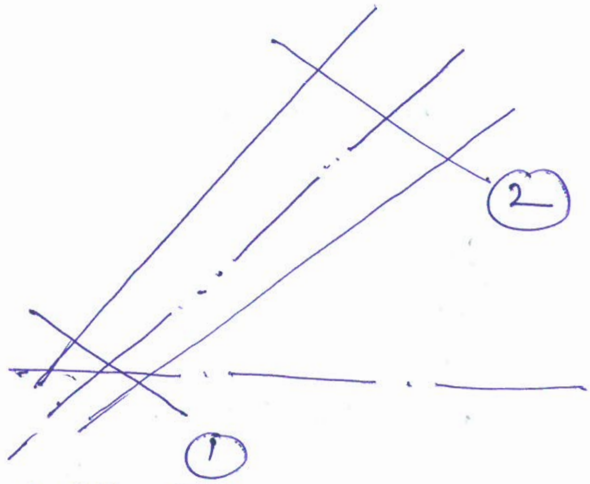
$P_A = -(\rho_g g h_2 + \rho_1 g h_1)$

$= -((13600 \times 9.81) \times 0.2 + 800 \times 9.81) \times 0.015)$

$= -27860.4$ Pa

$= -27.8604$ KPa //

4.a Given Data




L = 300 m.

$D_2 = 1.2$ m.

$D_1 = 0.6$ m.

$Q = 5.4\ m^3/min = 0.09\ m^3/sec$

$P_2 = 70$ kPa.

$z_1 = 0$, $z_2 = \frac{1}{100} \times 300 = 3$ m.

$Q = A_1 V_1 = A_2 V_2$

$$V_1 = \frac{Q}{A_1} = \frac{Q}{\frac{\pi}{4} d_1^2} = \frac{0.09}{\frac{\pi}{4} \times (0.6)^2} =$$

$$V_2 = \frac{Q}{A_2} = \frac{Q}{\frac{\pi}{4} d_2^2} = \frac{0.09}{\frac{\pi}{4} \times (1.2)^2} =$$

Applying Bernoulli's eqn

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + z_2$$

$$\frac{P_1}{1000 \times 9.81} + \frac{(0.318)^2}{2 \times 9.81} + 0 = \frac{70 \times 10^3}{1000 \times 9.81} + \frac{(0.079)^2}{2 \times 9.81} + 3$$

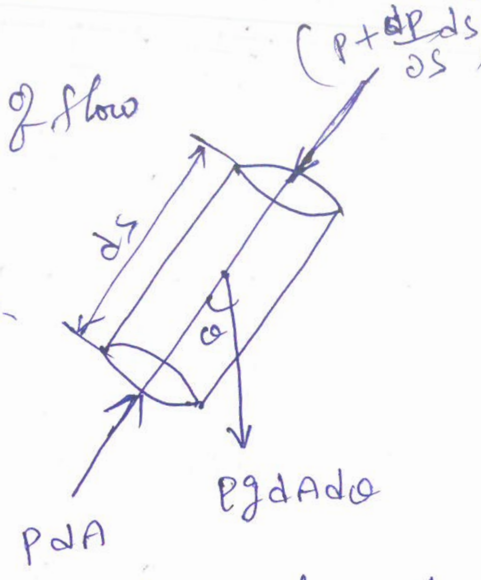
$P_1 = 6766206.63$ Pa

$= 6766.20663$ kPa.

Consider a cylindrical element of c/s dA and Length ds.

The pressure force pdA in direction of flow

The pressure force $\left(p + \frac{\partial p}{\partial s} ds\right) dA$ opposite to the direction of flow.




weight of element : ρg dA ds

Let θ is the angle b/w the direction of flow and the line of action of the weight of element.

The resultant force on the fluid element in the direction of s must be equal to the mass of fluid element × acceleration in the direction s.

$$pdA - \left(p + \frac{\partial p}{\partial s} ds\right) dA - \rho g\, dA\, ds \cos\theta = \rho\, dA\, ds \times a_s$$

where $a_s$ is the acceleration in the direction of s.

$a_s = \frac{dv}{dt}$, where v is a function of s and t.

$$= \frac{\partial v}{\partial s} \cdot \frac{ds}{dt} + \frac{\partial v}{\partial t} = \frac{v \partial v}{\partial s} + \frac{\partial v}{\partial t} \quad \left\{\frac{ds}{dt} = v\right\}$$

If flow is steady, $\frac{\partial v}{\partial t} = 0$

$$a_s = v \frac{\partial v}{\partial s}$$

Substituting the value of $a_s$ in the above eq'n.

$$-\frac{\partial p}{\partial s} ds\, dA - \rho g\, dA\, ds \cos\theta = \rho\, dA\, ds \times v \frac{\partial v}{\partial s}$$

dividing by ρ dA ds, $\frac{\partial p}{\rho \partial s} - g\cos\theta = \frac{v \partial v}{\partial s}$

$$\frac{\partial p}{\rho \partial s} + g\cos\theta + v\frac{\partial v}{\partial s} = 0$$

$$\theta = \frac{dz}{ds}$$

$$\frac{1}{\rho}\frac{\partial p}{\partial \rho} + g\frac{dz}{ds} + \frac{v\partial v}{\partial s} = 0 \quad (or) \quad \frac{\partial p}{\rho} + g\,dz + v\,\partial v = 0$$

This eq'n is known as Euler's eq'n of motion.

$$\frac{\partial p}{\rho} + g\,dz + v\,dv = 0$$

Integrating the eq'n.

$$\int \frac{\partial p}{\rho} + \int g\,dz + \int v\,dv = \text{constant}$$

If flow is incompressible, $\rho$ is constant.

$$\frac{p}{\rho} + gz + \frac{v^2}{2g} = \text{constant}$$

$$\frac{p}{\rho g} + \frac{v^2}{2g} + z = \text{constant}$$

This eq'n is known as Bernoulli's eq'n of motion.

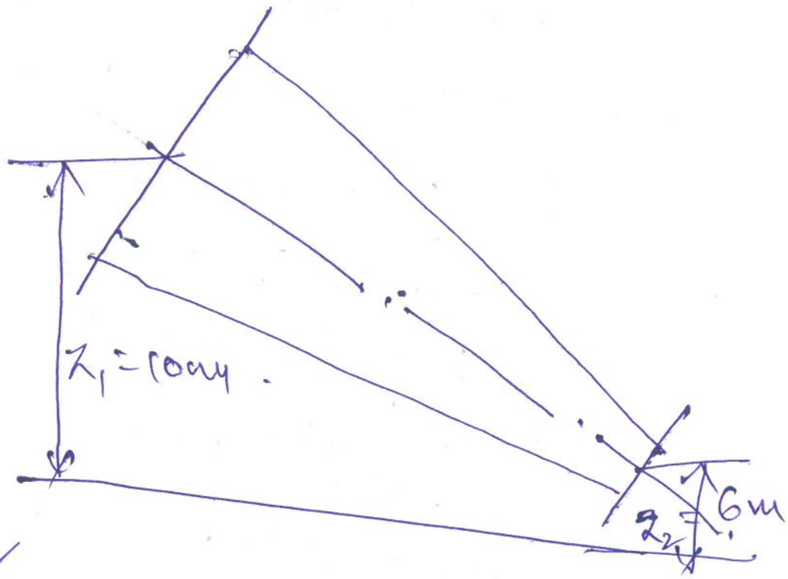
5-a

| Rotational flow | Ir-rotational flow |
|---|---|
| ① Fluid elements have angular velocity | ① Fluid elements do not have any angular velocity. |
| ② vorticity is non-zero | ② vorticity is zero |
| ③ The flow has circulating or spinning motion at points | ③ Flow moves smoothly without any spinning motion |

| | |
|---|---|
| ④ If the fluid particles rotate about their own centre | ④ If the fluid particles does not rotate about their own centre. |
| ⑤ Generally occuring in real fluids flows | ⑤ Generally occurs in ideal fluid flows. |

5-b

Given Data




$d_1 = 0.3\,m$

$d_2 = 0.15\,m$

$Q = 0.04\,m^3/sec$

$Z_1 = 10m$

$Z_2 = 6m.$

$P_1 = 400\,KN/m^2$

$Q = A_1V_1 = A_2V_2$

$$V_1 = \frac{Q}{A_1} = \frac{Q}{\frac{\pi}{4}d_1^2} = \frac{0.04}{\frac{\pi}{4}\times(0.3)^2} = 0.566\,m/sec$$

$$V_2 = \frac{Q}{A_2} = \frac{Q}{\frac{\pi}{4}d_2^2} = \frac{0.04}{\frac{\pi}{4}\times(0.15)^2} = 2.26\,m/sec$$

Applying Benoullis eqn

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2$$

$$\frac{400\times10^3}{1000\times9.81}+\frac{(0.566)^2}{2\times9.81}+10=\frac{P_2}{1000\times9.81}+\frac{(2.26)^2}{2\times9.81}+$$

$$P_2 = 436.74\ kN/m^2$$

6.a. Boundary layer separation occurs when the fluid f detaches from the surface of a body, often due to a adverse pressure gradient. ~~Se~~

(i) Suction of slow-Moving Fluid: Removing the slo -moving fluid near the surface using suction slots helps maintain the boundary layer attachments.

(ii) Supplying Additional Energy:- Blowers can inje energy into the boundary layer, energizing the flui and helping it overcome adverse pressure gradient

(iii) Bypass ~~sot~~ slotted wing:- Allowing high energy fluid to bypass and energize the boundary layer.

(iv) Rotating Boundaries:- Rotating the surface in the direction of the flow can help maintain attachment.

(v) Guide-Blades in Bends:- Installing guide-blades in pipe bends helps direct the flow and prevent separation

(vi) Small Divergence in Diffusers:- Minimizing the divergence angle in diffusers reduces the risk of separation.

Given Data

plate width, $b = 2\,m$.

plate length, $L = 2.5\,m$.

velocity, $U = 1.5\,m/sec$

oil sp. gr, $S = 0.8$

density, $\rho = 0.8 \times 1000 = 800\,kg/m^3$.

Kinematic viscosity, $\nu = 1.0 \times 10^{-4}\,m^2/sec$

Boundary layer thickness, $\delta$ at trailing edge

$$\delta = \frac{5.0x}{\sqrt{Re_x}}$$

where, $Re$ = Reynolds number

$$Re = \frac{Ux}{\nu}.$$

$x = L = 2.5\,m.$

$$Re_x = \frac{1.5 \times 2.5}{1.0 \times 10^{-4}} = \frac{3.75}{1.0 \times 10^{-4}} = 37{,}500$$

$$\delta = \frac{5.0 \times 2.5}{\sqrt{37500}} = \frac{12.5}{193.65} \simeq 0.0646\,m = 64.6\,mm$$

shear stress at trailing edge, $\tau_w = 0.332 \frac{\rho U^2}{\sqrt{Re_x}}$

$$\tau_w = \mu \left(\frac{\partial u}{\partial y}\right)_{y=0}$$

$\mu = \nu \times \rho$

$= 1.0 \times 10^{-4} \times 800$

$= ~~1.0 \times 10^{-4} \times 800 \times~~$

$$\tau_w = 0.332 \times \frac{800 \times 1.5^2}{\sqrt{37500}} = 0.332 \times \frac{800 \times 1.5^2}{193.65}$$

$=$

7. a

Given Data

$$\frac{u}{U} = \frac{1.5y}{\delta} - 0.5\frac{y^2}{\delta^2}$$

Displacement Thickness

$$\delta^* = \int_0^{\delta} \left(1 - \frac{u}{U}\right) dy.$$

$$= \int_0^{\delta}\left(1 - \frac{1.5y}{\delta} + 0.5\frac{y^2}{\delta^2}\right) dy$$

$$= \left[y - 1.5\frac{y^2}{2\delta} + 0.5\frac{y^3}{3\delta^2}\right]_0^{\delta}.$$

$$= \delta - 1.5\frac{\delta^2}{2\delta} + 0.5\frac{\delta^3}{3\delta^2}$$

$$= \delta - 1.5\frac{\delta}{2} + 0.5\frac{\delta}{3}$$

0.75

$$= \delta\left[1 - \frac{1.5}{2} + \frac{0.5}{3}\right]$$

0.16

$$\delta^* = 0.41\,\delta.$$

Momentum Thickness

$$\theta = \int_0^{\delta} \frac{u}{U}\left(1 - \frac{u}{U}\right) dy.$$

$$= \int_0^{\delta}\left\{\left(\frac{1.5y}{\delta} - 0.5\frac{y^2}{\delta^2}\right)\left(1 - \frac{1.5y}{\delta} + \frac{0.5y^2}{\delta^2}\right)\right\} dy$$

$$= \int_0^{\delta} \left[ \frac{1.5y}{\delta} - 0.5\frac{y^2}{\delta^2} - 2.25\frac{y^2}{\delta^2} + \frac{0.75y^3}{\delta^3} + \frac{0.75y^3}{\delta^3} - \frac{0.25y^4}{\delta^4} \right] dy$$

$$= \left[ \frac{1.5y^2}{2\delta} - \frac{0.5y^3}{3\delta^2} - 2.25\frac{y^3}{3\delta^2} + \frac{0.75y^4}{4\delta^3} + \frac{0.75y^4}{4\delta^3} - \frac{0.25y^5}{5\delta^4} \right]_0^{\delta}$$

$$= \frac{1.5\delta^2}{2\delta} - \frac{0.5\delta^3}{3\delta^2} - \frac{2.25\delta^3}{3\delta^2} + \frac{0.75\delta^4}{4\delta^3} + \frac{0.75\delta^4}{4\delta^3} - \frac{0.25\delta^5}{5\delta^4}$$

$$= \frac{1.5\delta}{2} - \frac{0.5\delta}{3} - \frac{2.25\delta}{3} + \frac{0.75\delta}{4} + \frac{0.75\delta}{4} - \frac{0.25\delta}{5}$$

$$= \frac{1.5\delta}{2} - \frac{0.5\delta}{3} - \frac{2.25\delta}{3} + \frac{1.5\delta}{4} - \frac{0.25\delta}{5}$$

$$= \delta \left[ \frac{1.5}{2} - \frac{0.5}{3} - \frac{2.25}{3} + \frac{1.5}{4} - \frac{0.25}{5} \right]$$

$$= \delta \left[ 0.75 - 0.16 - 0.75 + 0.375 - 0.05 \right]$$

$$= 0.165\delta$$

Energy Thickness: $\delta^{**}$

$$\delta^{**} = \int_0^\delta \frac{u}{U}\left[1-\left(\frac{u^2}{U^2}\right)\right]dy$$

$$= \int_0^\delta \left(\frac{1.5y}{\delta} - 0.5\frac{y^2}{\delta^2}\right)\left[1 - \left(\frac{1.5y}{\delta} - 0.5\frac{y^2}{\delta^2}\right)^2\right]dy,$$

$$= \int_0^\delta \left(\frac{1.5y}{\delta} - 0.5\frac{y^2}{\delta^2}\right)\left[1 - \left(\frac{2.25y^2}{\delta^2} + 0.25\frac{y^4}{\delta^4} - 2\,\frac{1.5y}{\delta}\times 0.5\frac{y^2}{\delta^2}\right)\right]dy$$

$$= \int_0^\delta \left(\frac{1.5y}{\delta} - 0.5\frac{y^2}{\delta^2}\right)\left[1 - \frac{2.25y^2}{\delta^2} - 0.25\frac{y^4}{\delta^4} + 1.5\frac{y^3}{\delta^3}\right]dy.$$

$$= \int_0^\delta \left[\frac{1.5y}{\delta} - \frac{0.5y^2}{\delta^2} - \frac{3.375y^3}{\delta^3} - \frac{0.375y^5}{\delta^5} + \frac{2.25y^4}{\delta^4} + \frac{1.125y^4}{\delta^4} + \frac{0.125y^6}{\delta^6} - \frac{0.75y^5}{\delta^5}\right]$$

$$= \left[\frac{1.5y^2}{2\delta} - \frac{0.5y^3}{3\delta^2} - \frac{3.375y^4}{4\delta^3} - \frac{0.375y^6}{6\delta^5} + \frac{2.25y^5}{5\delta^4} + \frac{1.125y^5}{5\delta^4} + \frac{0.125y^7}{7\delta^6} - \frac{0.75y^6}{6\delta^5}\right]_0^\delta.$$

$$= \frac{1.5\delta^2}{2\delta} - \frac{0.5\delta^3}{3\delta^2} - \frac{3.375\delta^4}{4\delta^3} - \frac{0.375\delta^6}{6\delta^5} + \frac{2.25\delta^5}{5\delta^4} + \frac{1.125\delta^5}{5\delta^4} + \frac{0.125\delta^7}{7\delta^6} - \frac{0.75\delta^6}{6\delta^5}.$$

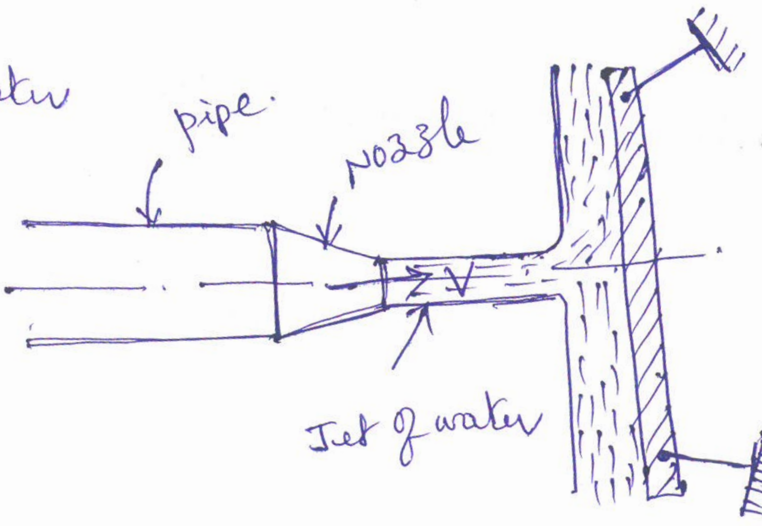
$$= 0.75\delta - 0.16\delta - 0.843\delta - 0.0625\delta + 0.45\delta + 0.225\delta + 0.0178\delta - 0.125\delta$$

$$= 0.2523\,\delta,$$

| Streamlined body | Bluff body |
| --- | --- |
| ① The shape of streamlined body is smooth, curved, tapers at rear | ① The shape of bluff broad, flat front or r |
| ② Drag is low | ② Drag is high |
| ③ Flow separation is delayed or avoided. | ③ Flow separation is oc early, large wake. |
| ④ Efficiency is high | ④ Eifficiency is low. |
| ⑤ Ex:- Aircraft wings, Sports cars, fish | ⑤ Ex:- Trucks, building Spheres, cylinders. |

8-a

consider a Jet of water coming out from the Nozzle, strikes a flat vertical plate.




V = velocity of the Jet,

d = diameter of the Jet

a = area of cross-section of the Jet = $\frac{\pi}{4} d^2$

The Jet after striking the plate, will move along the plate But the plate is right angles to the Jet. Hence the jet after striking will get deflected through 90°. Hence the component of the velocity of jet in the direction of jet, after striking will be zero.

The force exerted by the jet on the plate in the direction of jet.

$F_x$ = Rate change of momentum in the direction of force.

$$F_x = \frac{\text{Initial momentum} - \text{Final momentum}}{\text{Time}}$$

$$= \frac{\text{mass} \times \text{Initial velocity} - \text{Mass} \times \text{Final velocity}}{\text{Time}}$$

$$= \frac{\text{Mass}}{\text{Time}} \left[ \text{Initial velocity} - \text{Final velocity} \right]$$

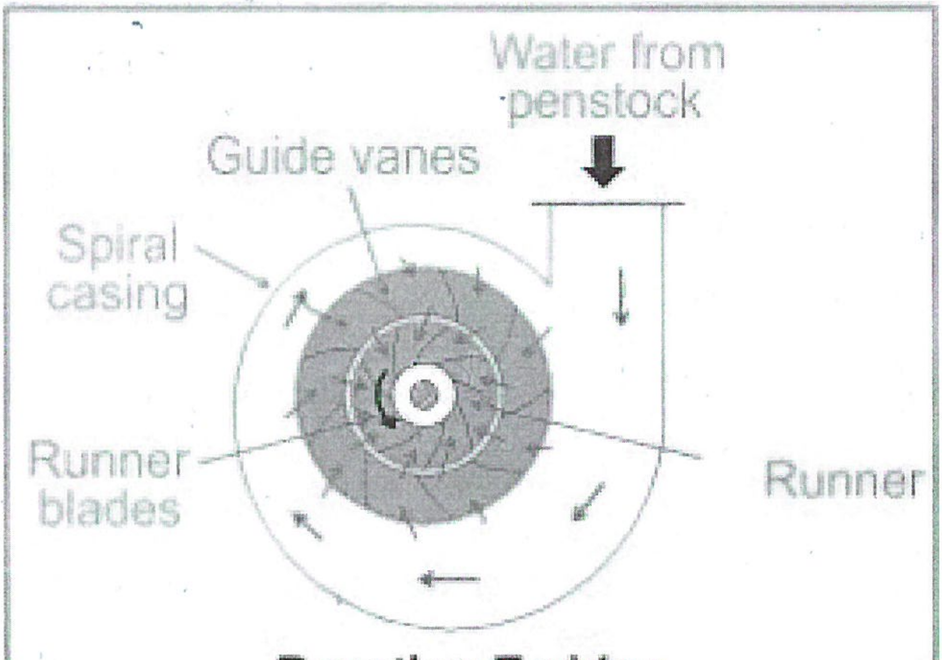
= Mass/sec [velocity of jet before striking − final velocity of jet after striking]

$= \rho a v \left[ v - 0 \right]$ $\quad$ $\left[ m/sec = \rho a v \right]$

$F_x = \rho a v^2$

8.b

Francis Turbine




Reaction Turbine

→ water enters the turbine through a spiral casing, passes through stationary stay vanes and adjustable guide vanes, which direct the flow into the runner blades.

→ The runner blades convert the kinetic energy and pressure energy of water into mechanical energy causing the runner to rotate.

→ water flows radially inward and exit axially.

→ The turbines operates efficiently over a wide range heads (40-600m) and is commonly used in hydroelectric power plants.

9. a

| Impulse Turbine | Reaction Turbine |
|---|---|
| ① The energy available is only kinetic energy | ① The energy available both kinetic energy as well as pressure energy. |
| ② Efficiency is low. | ② Efficiency is high |
| ③ The shape of the blade is profile type | ③ The shape of the blade is aerofoile type. |
| ④ ~~Low~~ High heads | ④ low heads |
| ⑤ Low power generated | ⑤ High power generated |
| ⑥ low specific speed | ⑥ High specific speed. |
| ⑦ Installation is easy | ⑦ Installation is Complicat-ed. |

9.b

Given Data

diameter of Jet, $d = 150mm = 0.15m$.

Jet velocity, $V = 30 m/sec$

vane velocity, $u = 15 m/sec$

Jet leaves at $60^\circ$ with direction of motion of vanes.

area of Jet, $A = \frac{\pi}{4} d^2 = \frac{\pi}{4} \times (0.15)^2 = 0.0177 m^2$

relative velocity at inlet, $V_{r_1} = V - u = 30 - 15$
$= 15 m/sec.$

velocity of Jet at outlet, $V_{r_2} = V_{r_1}$

$V_{w_2} = V_{r_2} \cos 60^\circ - u = 15 \times 0.5 - 15 = 7.5 m/sec.$

$V_{w_1} = V$, $V_{w_2} = -7.5 m/sec$

$Q = A \times V = 0.0177 \times 30 = 0.531 m^3/sec$

$\rho = 1000 kg/m^3$

(i) $F = \rho Q (V_{w_1} + V_{w_2})$

$= 1000 \times 0.531 [30 + (-7.5)] =$

$= 11947.5 N = 11.9475 kN$

(ii) work done per sec.

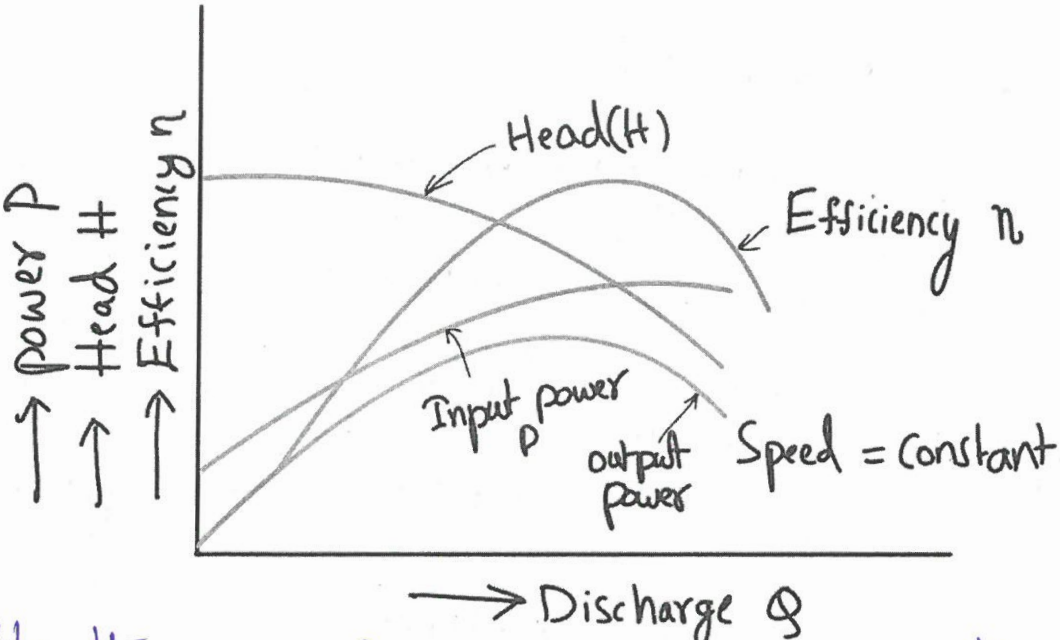
$W.D/sec = F \times u$

$= 11.9475 \times 15$

$= 179.2125 kW$

10.a






If the speed is kept constant, the variation of manometric head, power and efficiency with respect to discharge gives the operating characteristics of the pump.

The input power curve for pumps shall not pass through the origin. It will be slightly away from the origin on the y-axis, as even at zero discharge some power is needed to over come mechanical losses. The head curve will have maximum value of head when discharge is zero. The output power curve will start from origin as at $Q = 0$, output power ($\rho Q g H$) will be zero.

The efficiency curve will start from origin as at $Q = 0$, $\eta = 0$

10-b Given Data

Head, $H = 25\ m$

Discharge, $Q = 9\ m^3/sec$

Speed, $N = 200\ rpm$

Efficiency, $\eta = 90\%$
$= 0.9$

$$\eta = \frac{P}{\rho g Q H}$$

$$P = \eta \times \rho g Q H$$

$$= 0.9 \times 1000 \times 9.81 \times 9 \times 25$$

$$= 1986525 \text{ watts.}$$

$$= 1986.525 \text{ kW}$$

Specific speed, $N_s = \frac{N\sqrt{P}}{H^{5/4}} = \frac{200 \times \sqrt{1986.525}}{(25)^{5/4}}$

$$= \frac{8914.08}{55.9}$$

$$= 159.464$$

Performance under a head of 20 m.

$$Q \propto \sqrt{H}$$

$$\frac{Q_1}{\sqrt{H_1}} = \frac{Q_2}{\sqrt{H_2}} \Rightarrow Q_2 = Q_1 \times \sqrt{\frac{H_2}{H_1}}$$

$$Q_2 = 9 \times \sqrt{\frac{20}{25}} = 9 \times \sqrt{\frac{4}{5}} = 9 \times \sqrt{0.8}$$

$$Q_2 = 9 \times 0.894 = 8.05 \text{ m}^3/\text{sec}$$

$$P_2 = \eta \times \rho g Q_2 H_2 = 0.9 \times 1000 \times 9.81 \times 8.05 \times 20$$

$$P_2 = 1421.5 \text{ kW}$$

High discharge and low head.

Kaplan Turbine

11. a

Given Data

Actual discharge, $Q_{act} = 0.01\ m^3/sec$

piston diameter, $D = 200\ mm = 0.2\ m$.

Stroke, $L = 400\ mm = 0.4\ m$.

Speed, $N = 50\ rpm$

(i) Theoritical discharge, $Q_{th} = \frac{ALN}{60}$

$$A = \frac{\pi}{4} d^2 = \frac{\pi}{4} \times 0.2^2 = 0.0314\ m^2$$

$$Q_{th} = \frac{0.0314 \times 0.4 \times 50}{60} = 0.01047\ m^3/sec$$

(ii) coefficient of discharge, $C_d$

$$C_d = \frac{Q_{act}}{Q_{th}} = \frac{0.01}{0.01047} = 0.955$$

(iii) slip $= Q_{th} - Q_{act} = 0.01047 - 0.01 = 0.00047\ m^3/sec$

$$\%\ slip = \frac{Q_{th} - Q_{act}}{Q_{th}} = \frac{0.00047}{0.01047} = 4.49\%$$

11. b

Given Data

Discharge, $Q = 0.118\ m^3/sec$.

Speed, $N = 1450\ rpm$.

Head, $H = 25\ m$

outlet diameter, $D_2 = 250\ mm = 0.25\ m$

outlet width, $B_2 = 50\,mm = 0.05\,m$.

Manometric efficiency, $\eta_{mano} = 75\% = 0.75$

$$Q = \pi D_2 B_2 V_{f_2}$$

$$V_{f_2} = \frac{Q}{\pi D_2 B_2} = \frac{0.118}{\pi \times 0.25 \times 0.05} = 3.005\,m/sec$$

~~phori~~. peripheral velocity, $(u_2)$

$$u_2 = \frac{\pi D_2 N}{60} \Rightarrow u_2 = \frac{\pi \times 0.25 \times 1450}{60} = 19.02\,m/sec$$

$$\eta_{mano} = \frac{gH}{V_{w_2} u_2}$$

$$V_{w_2} = \frac{gH}{\eta_{mano} \times u_2} = \frac{9.81 \times 25}{0.75 \times 19.02} = 17.19\,m/sec$$

vane angle at outlet

$$\tan \beta_2 = \frac{V_{f_2}}{u_2 - V_{w_2}} = \frac{3.005}{19.02 - 17.19} = \frac{3.005}{1.83} = 1.642$$

$$\beta_2 = \tan^{-1}(1.642) = 58.5^\circ.$$