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IMPORTANT QUESTION ANSWERS

Department of Mechanical Engineering

SUBJECT CODE: CE3391

SUBJECT NAME: FLUID MECHANICS & MACHINERY

REGULATION 2021

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CE3391 - ANNA UNIVERSITY

FLUID MECHANICS AND MACHINERY **L T P C**

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OBJECTIVES:

- The applications of the conservation laws to flow through pipes and hydraulic machines are studied
- To understand the importance of dimensional analysis.
- To understand the importance of various types of flow in pumps and turbines.

UNIT I FLUID PROPERTIES AND FLOW CHARACTERISTICS 8

Units and dimensions- Properties of fluids- mass density, specific weight, specific volume, specific gravity, viscosity, compressibility, vapor pressure, surface tension and capillarity. Flow characteristics – concept of control volume - application of continuity equation, energy equation and momentum equation.

UNIT II FLOW THROUGH CIRCULAR CONDUITS 8

Hydraulic and energy gradient - Laminar flow through circular conduits and circular annuli-Boundary layer concepts – types of boundary layer thickness – Darcy Weisbach equation –friction factor- Moody diagram- commercial pipes- minor losses – Flow through pipes in series and parallel.

UNIT III DIMENSIONAL ANALYSIS 9

Need for dimensional analysis – methods of dimensional analysis – Similitude – types of similitude - Dimensionless parameters- application of dimensionless parameters – Model analysis.

UNIT IV PUMPS 10

Impact of jets - Euler‟s equation - Theory of roto-dynamic machines – various efficiencies– velocity components at entry and exit of the rotor- velocity triangles

- Centrifugal pumps– working principle - work done by the impeller - performance curves - Reciprocating pump- working principle – Rotary pumps – classification.

UNIT V TURBINES **10**

Classification of turbines – heads and efficiencies – velocity triangles. Axial, radial and mixed flow turbines. Pelton wheel, Francis turbine and Kaplan turbines- working principles - work done by water on the runner – draft tube. Specific speed - unit quantities – performance curves for turbines – governing of turbines.

TOTAL: 45 PERIODS

1. List of Text Book:

T1. Modi P.N. and Seth, S.M. "Hydraulics and Fluid Mechanics", Standard Book House, New Delhi 2004.

2. List of Reference Books:

R1.Streeter, V. L. and Wylie E. B., "Fluid Mechanics", McGraw Hill Publishing Co. 2010

R2. Kumar K. L., "Engineering Fluid Mechanics", Eurasia Publishing House(p) Ltd., New Delhi 2004.

R3. Robert W.Fox, Alan T. McDonald, Philip J.Pritchard, "Fluid Mechanics and Machinery", 2011.

R4. Graebel. W.P, "Engineering Fluid Mechanics", Taylor & Francis, Indian Reprint, 2011.

3. TABLE OF CONTENTS

4a. AIM & OBJECTIVES

AIM

- The goal is to understand the fundamentals and applications of fluid mechanics.
- The course will emphasize the solution to real life problems using basic theories and principles.

OBJECTIVES:

1. Identify and obtain values of fluid properties and relationship between them.

2. Understand the principles of continuity, momentum, and energy as applied to fluid motions.

3. Recognize these principles written in form of mathematical equations.

4. Apply these equations to analyze problems by making good assumptions and learn systematic engineering method to solve practical fluid mechanics problems.

5. Apply fundamental principles of fluid mechanics for the solution of practical civil engineering problems of water conveyance in pipes, pipe networks, and open channels.

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1. List of Text Book:

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R4. Graebel. W.P, "Engineering Fluid Mechanics", Taylor & Francis, Indian Reprint, 2011.

3. Web resources.

1) http://www.nptel.iitm.ac.in/courses.php?disciplineId=112105171
2) http://www.learnerstv.com/video/Free-video-Lecture-2625-Engineering.htm

4. Lesson plan

Topic No	Topic Name	No of Periods	Cumulative Hours	Teaching Aid	Books Reffered
UNIT I – FLUID PROPERTIES AND FLOW CHARACTERISTICS					
1.	Fluid – definition, distinction between solid and fluid - Units and dimensions - Properties of fluids - density, specific weight, specific volume, specific gravity.	2	2	Chalk & Board	T1,R3, R4

2.	Temperature, viscosity, compressibility, Vapour pressure, capillary and surface tension.	2	4	Chalk & Board	R1,R3, R4
3.	Continuity equation (one and three dimensional differential forms), Stream function, Velocity potential function	2	6	Chalk & Board	T1
4.	Energy equation, Eulers equation, application of energy equation.	1	7	Chalk & Board	T1,R1
5.	Problems on velocity and acceleration	1	8	Chalk & Board	T1
6.	Problems on velocity potential function	1	9	Chalk & Board	T1,R1
7.	Problems on venturimeter	1	10	Chalk & Board	T1,R2
8.	Problems on orificemeter,pitot tube.	1	11	Chalk & Board	T1,R2
UNIT II – FLOW THROUGH CIRCULAR CONDUITS					
9.	Viscous flow - Navier-Stoke's equation (Statement only) - Shear stress, pressure gradient relationship	1	12	Chalk & Board	T1,R2
10.	laminar flow between parallel plates	1	13	Chalk & Board	T1,R2
11.	Laminar flow through circular tubes (Hagen poiseulle's)	1	14	Chalk & Board	R4
12.	Hydraulic and energy gradient	1	15	Chalk & Board	R4
13.	flow through pipes - Darcy - weisback's equation - pipe roughness -friction factor	2	17		T1, R4
14.	Moody's diagram-minor losses	1	18	Chalk & Board,	R1, R2

15.	flow through pipes in series and in parallel - power transmission	2	20		R1
16.	Boundary layer flows, boundary layer thickness	1	21	Chalk & Board,	R1, R2
17.	boundary layer separation	1	22	Chalk & Board	R1, R2
18.	drag and lift coefficients	1	23	Chalk & Board	T1,R2
19.	Problems	2	25	Chalk & Board	T1,R2
20.	Problems	2	27	Chalk & Board	T1,R2
UNIT III - DIMENSIONAL ANALYSIS					
21.	Need for dimensional analysis, statement	1	28	Chalk & Board,	T1, R4
22.	Methods of Dimensional analysis	1	29	Chalk & Board,	R4
23.	Similitude, Types of similitude	1	30	Chalk & Board,	T1,R4
24.	Dimensionless parameters, Application of dimensionless parameters	1	31	Chalk & Board,	R2
25.	Model Analysis	1	32	Chalk & Board	R2, R4
26.	Problems	4	36	Chalk & Board,	T1, R4
UNIT IV – PUMPS					
27.	Pumps: definition and classifications - Centrifugal pump: classifications	1	37	Chalk & Board	R3,R4
28.	Working principle, velocity triangles,	1	38	Chalk & Board	R3,R4
29.	Specific speed, efficiency and performance curves	1	39	Chalk & Board	R3,R4

30.	Indicator diagram	1	40	Chalk & Board	R3,R4
31.	Reciprocating pump: classification, working principle	1	41	Chalk & Board	R3,R4
32.	Cavitations in pumps	1	42	Chalk & Board	R3,R4
33.	Rotary pumps: working principles of gear and vane pumps	1	43	Chalk & Board	R3,R4
34.	Problems	3	46	Chalk & Board	R3,R4
UNIT V – TURBINES					
35.	Hydro turbines: definition and classifications	1	47	Chalk & Board	T1, R4
36.	Pelton turbine - Francis turbine Kaplan turbine – Working principle	1	48	Chalk & Board	T1, R4
37.	Velocity triangles	2	50	Chalk & Board	T1, R4
38.	Efficiencies -performance curve for turbines.	1	51	Chalk & Board	T1, R4
39.	Problems on pelton wheel turbine	2	53	Chalk & Board	T1, R4
40.	Problems on francis turbine	1	54	Chalk & Board	T1, R4
41.	Problems on Kaplan turbine	1	55	Chalk & Board	T1, R4
42.	Specific speed	1	56	Chalk & Board	T1, R4

7) Seminar topics:

- ✓ Hydrodynamics
- ✓ Turbulent flow
- ✓ Similitude
- ✓ Theory of roto-dynamic machines

8) Additional Topics:

- ✓ Manometers.
- ✓ Cae Theory.
- ✓ Indicator diagrams.

4c. IMPORTANT QUESTION & ANSWERS

UNIT –I

FLUID PROPERTIES AND FLOW CHARACTERISTICS

1. **Explain the variation of viscosity with temperature**

   (Nov/Dec 2015,April/May 08)

   For liquids viscosity inversely vary with the temperature and for gases the viscosity varies directly with the temperature.

2. **Define –Incompressible fluid.** **(Nov/Dec 2014)**

   The density of the fluid is not constant for the fluid, generally all the liquids are incompressible

3. **State the assumption used in the derivation of the Bernoulli's equation.** **(Nov/Dec 2014)**

   1. The fluid is ideal
   2. the flow is steady
   3. the flow is incompressible
   4. The flow is irrotational

4. **What is cohesion and adhesion in fluids?**

   Cohesion is due to the force of attraction between the molecules of the same liquid. Adhesion is due to the force of attraction between the molecules of two different liquids or between the molecules of the liquid and molecules of the solid boundary surface

5. **What is kinematics viscosity? State its units**

   (May/june 14, April/May11, May/June 09)

   It is defined as the ratio of dynamic viscosity (μ) to mass density (ρ). (m^2/sec)

6. **State momentum of momentum equation?** **(May/June 14)**

   It states that the resulting torque acting on a rotating fluid is equal to the rate of change of moment of momentum.

7. **Define density and specific weight.** **(May/June 12)**

   a. Density is defined as mass per unit volume (kg/m^3)
   b. Specific weight is defined as weight possessed per unit volume

(N/m^3)

8. **What are the properties of real fluid? (Nov/Dec 2011,08)**
    1. It is compressible
    2. They are viscous in nature
    3. Shear force exists always in such fluid.

9. **Define Surface tension and Capillarity?**

(Nov/Dec 2010, 04, April/May 09)

Surface tension is due to the force of cohesion between the liquid particles at the free surface.

Capillary is a phenomenon of rise or fall of liquid surface relative to the adjacent general level of liquid.

10. **Differentiate absolute and gauge pressure? (Nov/Dec 2007)**

Gauge pressure is measured by gauge which is above atmospheric pressure, absolute pressure which measured from absolute zero level.

11. **Determine the capillary rise of mercury in a 2 mm ID glass tube. Assume, σ = 0.5 N/m and β = 130°. (Nov/Dec 2016)**

Specific weight of mercury, $\gamma = 13600 \times 9.81\ N/m^3$,

Therefore, $h = (4\sigma \cos\beta)/\rho g D$

$h = (4 \times 0.5 \times \cos 130)/13600 \times 9.8 \times 0.002$

$\mathbf{h = -4.82 \times 10^{-3} = -4.82\ mm}$

PART-B

1. A 15 cm diameter vertical cylinder rotates concentrically inside another cylinder of diameter 15.10 cm. Both cylinders are 25 cm high. The space between the cylinders is filled with a liquid whose viscosity is unknown. If a torque of 12.0 Nm is required to rotate the inner cylinder at 100 r.p.m. determine the viscosity of the fluid. & Calculate the Power? [May / June - 2013]

Given :

Diameter of cylinder = 15 cm = 0.15 m

Dia. of outer cylinder = 15.10 cm = 0.151 m

length of cylinders, L = 25 cm = 0.25 m

Torque T = 12 Nm.

Speed N = 100 r.p.m.

To Find :

Viscosity $\mu = ?$; Power (P) = ?

Formula :

$$\mu = \tau / \frac{du}{dy} \qquad \left[\because \tau = \mu . \frac{du}{dy} \right]$$

$$P = \frac{2\pi N T}{60}$$

Solution :

(i) Tangential Velocity of cylinder $u = \frac{\pi D N}{60}$

$$u = \frac{\pi \times 0.15 \times 100}{60} \Rightarrow 0.7854 \text{ m/s}.$$

(ii) Surface area of cylinder, $A = \pi D \times L$

$$A = \pi \times 0.15 \times 0.25 = 0.1178.$$

$$dy = \frac{0.151 - 0.15}{2} = 0.0005\,m.$$

$$\text{Shear stress } (\tau) = \mu \cdot \frac{du}{dy}$$

$$\tau = \frac{\mu \times 0.7854}{0.0005}$$

$$\underset{(F)}{\text{Shear force}} = \underset{(\tau)}{\text{Shear stress}} \times \text{Area}.(A)$$

$$\text{Torque } (T) = F \times D/2$$

$$12 = F \times \left(\frac{0.15}{2}\right)$$

$$F = \frac{12}{0.075} \Rightarrow 160\ N.$$

$$\boxed{F = 160\ N.}$$

$$\text{Shear Stress } (\tau) = \frac{F}{A}$$

$$= \frac{160}{0.1178} \Rightarrow 1358.23.$$

$$\boxed{\tau = 1358.23\ N/m^2}$$

$$\text{Viscosity } (\mu) = \frac{\tau}{\left(\frac{du}{dy}\right)}$$

$$\tau = 1358.23\ N/m^2.$$

$du = u - 0$; $u = 0.7854$ m/s.

$dy = 0.0005$ m.

$$\mu = \frac{1358.23}{\left(\frac{0.7854}{0.0005}\right)} \Rightarrow 0.864 \text{ Ns/m}^2.$$

Viscosity $\mu = 0.864$ Ns/m². (or)

$= 0.864 \times 10 \Rightarrow 8.64$ poise.

$$\text{Power (P)} = \frac{2\pi N T}{60}$$

$$= \frac{2 \times \pi \times 100 \times 12}{60}$$

$$P = 125.66 \text{ W}$$

2. The velocity distribution over a plate is given by the relation, $u = y\left(\frac{2}{3} - y\right)$; where y is the vertical distance above the plate in meters. Assuming a viscosity of 0.9 Pa.s, find the shear stress at $y = 0$ and $y = 0.15$m. [Nov - Dec - 2012]

Given:

Velocity distribution $(u) = y\left(2/3 - y\right)$ (or)

$$\frac{2}{3}y - y^2.$$

Viscosity $(\mu) = 0.9$ Poise.

$\left[1 \text{ Poise} = \frac{1}{10} \frac{Ns}{m^2} \right.$

$0.9 \text{ Poise} = \frac{0.9}{10}$

$\left. = 0.09 \text{ Ns/m}^2 \right]$

To Find :

Shear Stress at a distance $y = 0$; $y = 0.15m$

Formula required :

$$\text{Shear Stress } (\tau)_{y=0;\ y=0.15m} = \mu \cdot \frac{du}{dy}$$

Solution :

$$u = \frac{2}{3} y - y^2 \quad \ldots [\text{ diff. w.r.t } y]$$

we get ,

$$\frac{du}{dy} = \frac{2}{3} - 2y.$$

At $y = 0$;

$$\frac{du}{dy} = \frac{2}{3} - 2(0)$$

$$\frac{du}{dy} = \frac{2}{3} / s$$

(i) Shear stress $(\tau)_{y=0} = \mu \cdot \left(\frac{du}{dy} \right)$

$$= 0.09 \times 2/3$$

$$(\tau)_{y=0} = 0.06 \ N/m^2 .$$

(ii) Shear stress $(\tau)_{y=0.15} = \mu \cdot \left(\frac{du}{dy}\right)$

At $y = 0.15$,

$$\frac{du}{dy} = \frac{2}{3} - 2(0.15)$$

$$= 0.36 /s .$$

$$\therefore (\tau)_{y=0.15} = 0.09 \times 0.36$$

$$= 0.033 \ N/m^2 .$$

Result :

(i) Shear stress at $y = 0$ $(\tau)_{y=0}$ $= 0.06 \ N/m^2$.

(ii) Shear stress at $y = 0.15m$ $\left.(\tau)_{y=0.15}\right\} = 0.033 \ N/m^2$

3(a) Water flows at the rate of 200 litres per second upwards through a tapered vertical pipe. The diameter at the bottom is 240mm and at the top 200mm and the Pressure at the bottom is 8 bar, the length is 5m. The Pressure at the topside is 7.3 bar. Determine the head loss through the pipe. Express it as a function of exit velocity head. & (10) [NOV / DEC – 2014]
also the direction of flow.

Given:

$Q = 200 \text{ lit/s} \Rightarrow 0.2 m^3/s$.

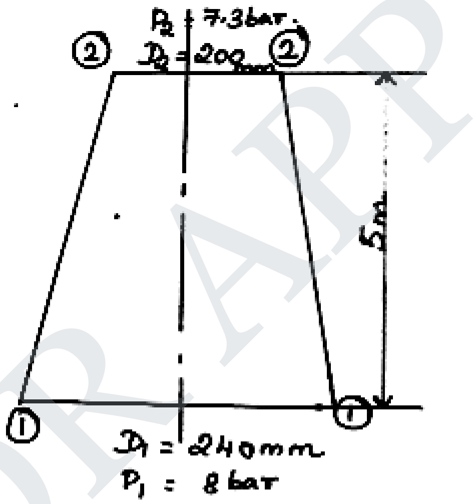
$D_1 = 0.24$ m.

$D_2 = 0.2$ m.

$Z_2 = 5m$.

$P_1 = 8 \times 10^5 \ N/mm^2$

$P_2 = 7.3 \times 10^5 \ N/mm^2$.



Find:

(i) Head Loss (h_L) = ?

(ii) Direction of flow : ?

Formula required :

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

Solution:

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

$$\frac{8 \times 10^5}{\rho g} + \frac{V_1^2}{2g} + 0 = \frac{7.3 \times 10^5}{\rho \times g} + \frac{V_2^2}{2g} + 5 + h_L \rightarrow (1)$$

$$Q = A_1 V_1 = A_2 V_2 .$$

$$V_1 = Q/A_1 = \frac{0.2}{\pi/4\,(0.24)^2} \qquad \left[\begin{array}{l} A_1 = \pi/4\,(d_1)^2 \\ A_2 = \pi/4\,(d_2)^2 \end{array} \right]$$

$$= 4.42 \ m/s .$$

$$V_2 = Q/A_2 = \frac{0.2}{\pi/4\,(0.2)^2} = 6.36 \ m/s .$$

Submit V_1 & V_2 Value on equation (1).

We get, $\left[\because \rho \text{ of water } 1000 \quad g = 9.81 \right]$

$$\frac{8\times10^5}{1000\times9.81} + \frac{(4.42)^2}{2\times9.81} + 0 = \frac{7.3\times10^5}{1000\times9.81} + \frac{(6.36)^2}{2\times9.81} + 5 + h_l$$

$$81.5 + 0.995 = 74.4 + 2.06 + 5 + h_l$$

$$82.495 = 81.46 + h_L$$

$$h_L = 82.495 - 81.46$$

$$\boxed{h_L = 1.035 \ m}$$

Express it a function of velocity head.

$$h_L = \frac{V_2^2}{2g} - \frac{V_1^2}{2g}$$

$$h_L = \frac{(6.36)^2}{2\times9.81} - \frac{(4.42)^2}{2\times9.81}$$

$$= 2.06 - 0.99$$

$$h_L = \frac{(6.36)^2}{2\times 9.81} - \frac{(4.42)^2}{2\times 9.81}$$

$$= 2.06 - 0.99$$

$$= 1.06\, m.$$

$$\boxed{h_L = 1.06\, m}$$

(ii) Direction of flow.

$$E_A = E_B + h_L \qquad \left[\because E_A = 82.495,\; E_B = 81.46\right]$$

$$h_L = E_A - E_B$$

As E_A is more than E_B and hence flow is taking place from A to B.

Result :

(i) Loss of head (h_L) = 1.035 m.

(ii) Direction of flow = From A to B.

3(b) Determine the viscous drag torque & Power absorbed on one surface of a collar bearing of 0.2 m ID & 0.3 m OD with an oil film thickness of 1mm & a viscosity of 30 centipoise if it rotates at 500. r.p.m. (6)

[Nov /Dec - 2014]

Given :

$D_i = 0.2\ m$

$D_0 = 0.3\ m$

$dy = 1\ mm.$

$\mu = 30\ c.p = 0.03\ Ns/m^2.$

$N = 500\ r.p.m.$

Find :

Drag Torque (T) : ?

Formula :

$$T = F \times D/2.$$

Solution :

(i) Velocity $u = \frac{\pi d_i N}{60}$

$$= \frac{\pi \times 0.2 \times 500}{60}$$

$$= 5.23\ m/s.$$

$du = u - 0$; $du = 5.23\ m/s.$

(ii) Shear Stress $\tau = \mu . \frac{du}{dy}$ $[\because \tau = F/A$
$F = \tau \times A]$

$$= 0.03 \times \frac{5.23}{0.001}$$

$$\boxed{\tau = 156.9\ N/mm^2}$$

(iii) Area of contact (A) $= 2\pi \times r \times l$. $\left[\because l = \frac{0.3-0.2}{2} = 0.05\,m\right]$

$= 2\pi \times \left(\frac{0.2}{2}\right) \times 0.05$

$$\boxed{\text{Area (A)} = 0.0314\,m^2}$$

(iv) Force (F) = Shear Stress (τ) × Area (A)

$= 156.9 \times 0.0314$

$$\boxed{F = 4.92\,N.}$$

(v) Drag Torque (T) $= F \times \frac{D_i}{2}$.

$= 4.92 \times \left(\frac{0.2}{2}\right)$

Drag Torque (T) = 0.492 N-m.

Result :

Velocity (u) = 5.23 m/s

Shear Stress (τ) = 156.9 N/mm^2

Area of Contact (A) = 0.0314 m^2

Force (F) = 4.92 N.

Drag Torque (T) = 0.492 N-m.

4. A Pipeline of 175 mm diameter branches into two types which delivers the water at atmospheric pressure. The diameter of branch 1 which is at 35° counter clockwise to the pipe axis is 75mm & velocity at outlet is 15 m/s. The branch 2 is at 15° with the pipe center line in the clockwise direction. has a diameter of 100mm. The outlet velocity is 15 m/s. The pipes lie in a horizontal plane. Determine the magnitude & direction of forces on the pipes. (16) [NOV/DEC - 2011].

Given:

Dia. of Main pipe $(d) = 175\text{ mm} = 0.175\text{ m}$.

Dia. of branch pipe 1 $(d_1) = 75\text{ mm} = 0.75\text{ m}$.

Velocity of branch pipe 1 $(V_1) = 15\text{ m/s}$.

Dia. of branch pipe 2 $(d_2) = 100\text{ mm} = 0.1\text{ m}$.

Velocity of branch pipe 2 $(V_2) = 15\text{ m/s}$.

Find:

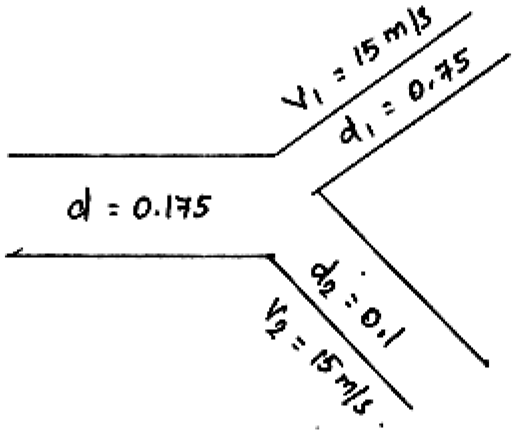
Determine magnitude & direction of forces.

Formula:

$$F_R = \sqrt{F_x^2 + F_y^2}$$

$$\tan\theta = \frac{F_y}{F_x}$$

Solution:



By Continuity equation,

$$Q = Q_1 + Q_2$$

$$AV = A_1V_1 + A_2V_2. \qquad [\because Q = A \times V]$$

$$\frac{\pi}{4} d^2 \times V = \frac{\pi}{4} d_1^2 \times V_1 + \frac{\pi}{4} d_2^2 \times V_2. \qquad A = \pi/4\, d^2.$$

$$\frac{\pi}{4} \times 0.175^2 \times V = \frac{\pi}{4} \times 0.75^2 \times 15 + \frac{\pi}{4} \times 0.1^2 \times 15.$$

$$\boxed{V = 7.65 \text{ m/s}}$$

By resolving forces in x- direction,

$$F_x = F\cos\theta + F_1 \cos\theta_1 + F_2 \cos(360 - \theta_2) \rightarrow ①$$

We Know that,

$$\underset{(F)}{\text{Force}} = \text{Mass} \times \text{acceleration}.$$

$$\text{Mass of water } (M) = \rho AV. \longrightarrow ②$$

Substituting ② in equ. ①

$$F_x = \rho AV^2 \cos\theta + \rho A_1 V_1^2 \cos\theta_1 + \rho A_2 V_2^2 \cos(360 - \theta_2)$$

$$= 1000 \times \frac{\pi}{4} \times (0.175)^2 \times 7.65 \cos\theta.$$

$$F_x = 1000 \times \frac{\pi}{4} \times 0.075^2 \times 15 \cos 35°$$

$$= 1000 \times \frac{\pi}{4} \times 0.1^2 \times 15 \cos(360 - 15^\circ).$$

$$\boxed{F_x = 352.08\ N.}$$

By resolving force in y- direction.

$$F_y = F \sin\theta + F_1 \sin\theta_1 + F_2 \sin(360 - \theta_2).$$

$$F_y = 1000 \times \frac{\pi}{4} \times 0.075^2 \times 15 \sin 35^\circ + 1000 \times \frac{\pi}{4} \times 0.1^2 \times 15 . \sin(360 - 15)^\circ$$

$$\boxed{F_y = 7.52\ N}$$

$$F_R = \sqrt{(F_x)^2 + (F_y)^2} = \sqrt{352.08^2 + 7.52^2}$$

$$\boxed{F_R = 352.16\ N.}$$

The direction of resultant force x. axis,

$$\tan\theta = \frac{F_y}{F_x}$$

$$= \frac{7.52}{352.08} \Rightarrow 0.0214$$

Result :

$F_R = 352.16\,N.$

$\tan\theta = 0.0214.$

5. A pipe 200m long slopes down at 1 in 100. and tapers from 600mm diameter at the lower end, and carries 100 lit/sec of oil having specific gravity 0.8. If the pressure gauge at the higher end reads 60 kN/m², determine the velocities at the two end. also the pressure at the lower end. Neglect all losses. (16) [Apr/may - 2015]

Given:

$L = 200 m.$

Slopes at $= 1/100.$

$D_1 = 600 mm.$

$D_2 = 300 mm.$

$Q = 100$ lit/sec $= 0.1 m^3/s.$

$P_1 = 60 \times 10^3 N/m^2$; $S = 0.8.$

Find :

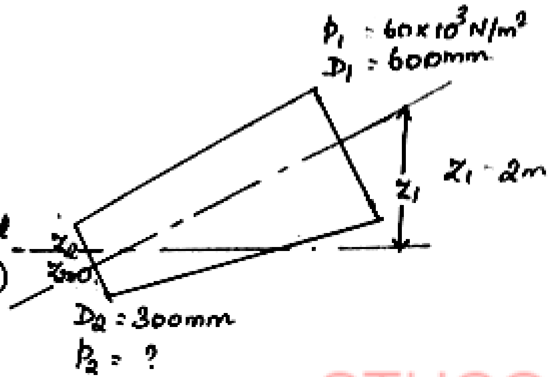
pressure at the lower end $(p_2) = ?$

formula required; Apply bernoulli's equation.

$$\frac{p_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{p_2}{\rho g} + \frac{V_2^2}{2g} + Z_2.$$

Solution:

$Z_2 = 0$ (b'coz it's located at Datum line)



$Z_1 = \frac{1}{100} \times 200 = 2m.$

$$Q = A_1 V_1 = A_2 V_2.$$

$$Q = A_1 V_1$$

$$0.1 = \frac{\pi}{4}(d_1)^2 \times V_1 \; ; \; \frac{\pi}{4} \times (0.6)^2 \times V_1$$

$$V_1 = \frac{0.1}{\frac{\pi}{4}(0.6)^2} \Rightarrow \frac{0.1}{0.2827} \Rightarrow 0.353 \text{ m/s}$$

$$\boxed{V_1 = 0.353 \text{ m/s}}$$

$$Q = A_2 V_2.$$

$$0.1 = \frac{\pi}{4}(d_2)^2 \times V_2 \; ; \; \frac{\pi}{4} \times (0.3)^2 \times V_2.$$

$$V_2 = \frac{0.1}{\frac{\pi}{4}(0.3)^2} \Rightarrow \frac{0.1}{0.0706} \Rightarrow 1.4164 \text{ m/s.}$$

$$V_2 = 1.4164 \text{ m/s.}$$

Apply bernoulli's equation,

$$\frac{p_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{V_2^2}{2g} + z_2.$$

$$\frac{60 \times 10^3}{1000 \times 9.81} + \frac{(0.353)^2}{2 \times 9.81} + 2 = \frac{p_2}{\rho g} + \frac{(1.416)^2}{2 \times 9.81} + 0$$

$$6.116 + \frac{0.1246}{19.62} + 2 = \frac{p_2}{\rho g} + \frac{2.005}{19.62} + 0$$

$$6.116 + 6.35 \times 10^{-3} + 2 = \frac{p_2}{\rho g} + 0.102 + 0.$$

$$8.12 = \frac{p_2}{\rho g} + 0.102 + 0$$

$$\frac{p_2}{\rho g} = 8.12 - 0.102$$

$$p_2 = 8.018 \times \rho \times g.$$

$$= 8.018 \times 1000 \times 9.81$$

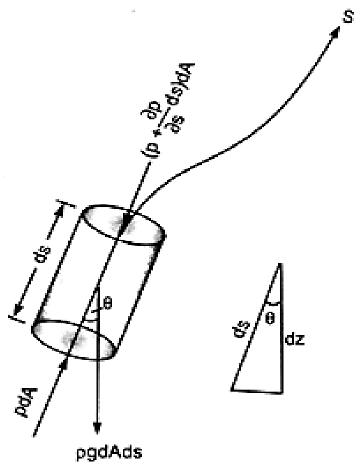
$$= 78656.58 \text{ N/m}^2 \text{ (or)}$$

$$= 78.65 \text{ kN/m}^2$$

Result:

Pressure at the lower end (p_2) = 78.65 kN/m².

6. Derive the Bernoulli's equation from Euler's Equation. (Nov/Dec 2015)



Forces on a fluid element.

This is equation of motion in which the forces due to gravity and pressure are taken into consideration. This is derived by considering the motion of a fluid element along a stream line as

1. Pressure force pdA in the direction of low

2. Pressure force $\{p+\frac{\partial p}{\partial s}\ ds\}$ dA opposite to the direction of flow

3. Weight of element ρgdAds

Let θ is the angle between 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 X acceleration in the direction s.

$$pdA - \{p+\frac{\partial p}{\partial s}\ ds\}\ dA - \rho gdAds\ \cos\theta$$

$$= \rho dAds \times a_s \text{-----------------------} 1$$

Wherea_s is the acceleration in the direction of s

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

$$= \frac{\partial v}{\partial s}\frac{ds}{dt} + \frac{\partial v}{\partial t}$$

$$= v\frac{\partial v}{\partial s} + \frac{\partial v}{\partial t} \qquad \{v = \frac{ds}{dt}\}$$

If the flow is steady, $\frac{dv}{dt} = 0$

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

Substituting the value of a_l in equation 1 and simplifying the equation, we get

$$\frac{-\partial p}{\partial s}\ ds - \rho gdAds\ \cos\theta = \rho dAds \times \frac{\partial v}{\partial s}$$

Dividing by ρdAds, $\frac{-\partial p}{\rho\partial s} - g\cos\theta = v\frac{\partial v}{\partial s}$

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

From fig $\cos\theta = \frac{dz}{ds}$

$$\frac{1}{\rho}\frac{dp}{ds} + g\frac{dz}{ds} + v\frac{dv}{ds} = 0$$

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

This equation is known as Euler's equation of motion

BERNOULLI' S EQUATION FROM EULER'S EQUATION

Bernoulli's equation is obtained by integrating the Euler's equation of motion

$$\int\frac{dp}{\rho} + \int g\,dz + \int v\,dv = \text{constant} \quad \text{-----------2}$$

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

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

$\frac{p}{\rho g}$ = pressure energy per unit weight of fluid pressure head

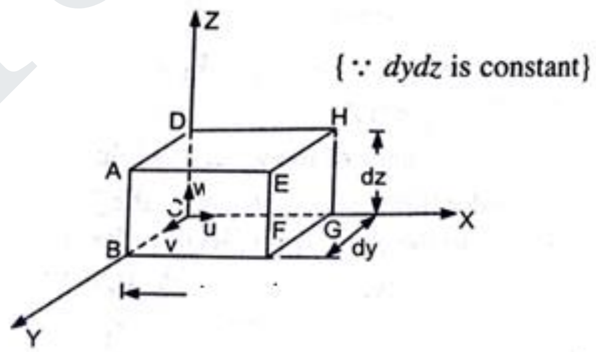
$\frac{v^2}{2g}$ = kinetic energy per unit weight or kinetic head

Z= potential energy per unit weight or potential head

Equation 2 is called Bernoulli's equation.

7. Derive the continuity equation for three dimensional flow of a fluid with neat skeatch. (April/May 2011)

CONTINUITY EQUATION IN THREE-DIMENSIONS



Consider a fluid element of lengths dx, dy and dz in the direction of x, y and z. Let u, v and w are the inlet velocity components in x, y and z directions respectively. Mass of fluid entering the face ABCD per second

$=\rho \times$ Velocity in x-direction $\times$ Area of ABCD

$=\rho \times \upsilon \times (dy \times dz)$

Then mass of fluid leaving the face EFGH per second

$= \rho\upsilon\, dydz \frac{\partial}{\partial x}(\partial u\ dy\ dz)\ dx$

$\therefore$ Gain of mass in X-direction

=Mass through ABCD-Mass through EFGH per sec

$=\rho u\ dy\ dz - \rho u\ dydz - \frac{\partial}{\partial x}(\partial u\ dy\ dz)\ dx$

$=-\frac{\partial}{\partial x}(\rho u\ dydz)\ dx$

$=-\frac{\partial}{\partial x}(\rho u) dx\ dydz$

Similarly, the net gain of mass in Y-direction

$=-\frac{\partial}{\partial y}(\rho v)\ dxdydz$

and in Z-direction $=-\frac{\partial}{\partial z}(\rho w) dxdydz$

$\therefore$ Net gain of masses$=-\left[\frac{\partial}{\partial x}(\rho u) + \frac{\partial}{\partial y}(\rho v) + \frac{\partial}{\partial z}(\rho w)\right]\ dxdydz$

Since the mass is neither created nor destroyed in the fluid element, the net increase of mass per unit time in the fluid element must be equal to the rate of increase of mass of fluid in the element.

But mass of fluid in the element is ρ. dx.dy.dz and its rate of increase with time

is $\frac{\partial}{\partial t}(\rho\ dx.dy.dz)$ or

$\frac{\partial \rho}{\partial t}.\ dx\ dy\ dz.$

Equating the two expressions

Or

$$-\left[\frac{\partial}{\partial x}(\rho u) + \frac{\partial}{\partial y}(\rho v) + \frac{\partial}{\partial z}(\rho w)\right]\ dxdydz = \frac{\partial \rho}{\partial t}.dxdydz$$

Or

$=\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x}(\rho u) + \frac{\partial}{\partial y}(\rho v) + \frac{\partial}{\partial z}(\rho w) = 0$ [cancelling dx.dy.dz from both sides]..............1

Equation (1) is the continuity equation in Cartesian co-ordinates in its most general form. This Equation is applicable to:

(i) Steady and unsteady flow,

(ii) Uniform and non –uniform flow, and

(iii) Compressible and incompressible fluids.

For steady flow, $\frac{\partial \rho}{\partial t}=0$ and hence equation (1) becomes as

$$\frac{\partial}{\partial x}(\rho u)+\frac{\partial}{\partial y}(\rho v)+\frac{\partial}{\partial z}(\rho w)=0$$

If the fluids is incompressible, then ρ is constant and the above equation becomes as

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0$$

This Equation is continuity equation in three –dimensions. For a two –dimensional flow, the component w=0 and hence continuity equation becomes as $\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0$.

8. Derive Reynold's transport theorem (Nov/Dec 2016)

The basic equations, involving the time derivative of extensive properties (total mass linear momentum, angular momentum, energy) are applicable for systems. In solid mechanics we often use a system representing a quantity of mass of fixed identity so, the basic equations are directly applied to know the time derivatives of extensive properties.

In fluid mechanics it is convenient to work with control volume, representing region in space considered for study.

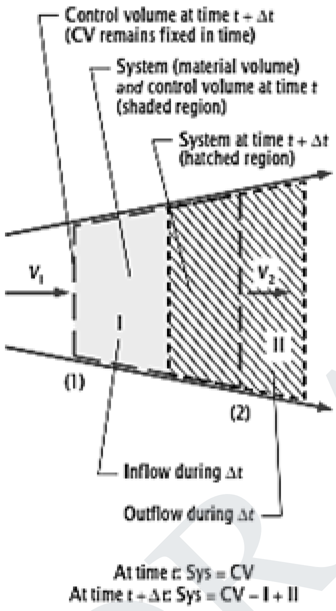
Different types of control volumes: fixed control volume, control volume moving at constant speed and deforming control volume. Therefore this is essential to derive a relationship between the time derivative of system property and the rate of change of that property within a control volume. This relationship is expressed by the Reynolds transport theorem (RTT) which establishes the link between the system and control volume approaches.

Before deriving the general form of the RTT, a derivation for one dimensional fixed control volume is given below.

One- dimensional fixed control volume:

Consider a diverging (expanding) of a flow field bounded by a stream tube. The selected control volume is considered to be fixed between sections 'a' and section

’b’. Note that both the sections are normal to the direction of flow. At some initial time t, system I exactly coincides. The control volume and therefore system and control volume are identical at that time. At time $t+\Delta t$ system I has moved in the flow direction at uniform speed V_1 and a part of system II has centered into the control volume.



Let ‘N’ represents any properties of the fluid (mass, momentum, energy) and ‘n’ represent the amount of ‘N’ per unit mass (called as intensive properties) in a small proportion of the fluid. The total amount of ‘N’ in a control volume is expresses as

$$N = \int_{cv} \eta dm = \int_{cv} \eta \rho dv \quad , \eta = \frac{dN}{dm} \qquad \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_(1)}$$

As the system coincides with the control volume at time ‘t’, a relation between the system and the control volume is

$$N_{system,t} = N_{cv,t}$$

At time $t+dt$,

$$N_{system,t+\Delta t} = N_{cv,t+dt} - N_{II\,t+dt} + N_{1,t+dt}$$

Using the definition of derivatives, we can write,

$$\frac{dN_{sys}}{dt} = \lim_{\Delta t \to o} \frac{N_{sys,t+dt} - N_{sys,t}}{\Delta t}$$

$$= \lim_{\Delta t \to o} \frac{N_{cv_1 t+\Delta t} - N_{cv_1 t}}{\Delta t} - \lim_{\Delta t \to o} \frac{N_{II,t+\Delta t}}{\Delta t} + \lim_{\Delta t \to o} \frac{N_{I,t+\Delta t}}{\Delta t}$$

or

$$\frac{dN_{sys}}{dt} = \frac{dN_{cv}}{dt} - N_{ix,t+\Delta t} + N_{out,w+\Delta t} \qquad \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_(2)}$$

$$\begin{bmatrix}\text{the time rate of}\\ \text{change of } N \text{ of}\\ \text{the system}\end{bmatrix}\begin{bmatrix}\text{the rate change}\\ \text{of } N \text{ within the}\\ cv\end{bmatrix}\begin{bmatrix}\text{the flux of } N\\ \text{passing into the}\\ \text{control fans}\end{bmatrix}\begin{bmatrix}\text{the flux of } N\\ \text{passing out the}\\ \text{control surface}\end{bmatrix}$$

The influx rate of n into the control surface be computed as

$$N_{in,t+\Delta t} = \lim_{\Delta t \to 0} \frac{N_{II,t+\Delta t}}{\Delta t}$$
$$= (\eta\rho A v)_{II}, N_{II,t+\Delta t} = (\eta\rho A v)_{II} \times \Delta t$$

Finally, Equation ( ) can be written as

$$\frac{dN_{sys}}{dt} = \frac{dN_{cv}}{dt} - (\eta\rho A v)_{II} + (\eta\rho A v)_{I} \qquad \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_(3)}$$

This equation implies that the time rate of change of any extensive property for a system is equal to the rate of change of that extensive property inside the control volume plus the net of efflux of the property through the control surface. This is known as RTT which relates the change of a property of a system to the change of that property for a control volume.

Arbitrary fixed control volume:

As similar to the previous derivation a fixed control volume with an arbitrary flow pattern passing through. At time 't' the system coincides with the control volume which is fixed relative to the x, y, z axes. At time '$t+\Delta t$ the system has moved and occupies the region II and III. Note that the region II is common to the system at both times t and $t+\Delta t$. The time rate of change of 'N' for the system can be given by

$$\left(\frac{dN}{dt}\right)_{system} = \lim_{\Delta t\to 0}\frac{1}{\Delta t}\left[\left(\iiint_{III}\eta\rho dv + \iint_{II}\eta\rho dv\right)_{t+\Delta t} - \left(\iiint_{I}\eta\rho dv + \iiint_{II}\eta\rho dv\right)_{t}\right]$$

Rearranging the above equation we have

$$\left(\frac{dN}{dt}\right)_{system} = \lim_{\Delta t\to 0}\left[\frac{\left(\iiint_{III}\eta\rho dv\right)_{t+\Delta t} - \left(\iiint_{II}\eta\rho dv\right)_{t}}{\Delta t}\right] + \lim_{\Delta t\to 0}\left[\frac{\left(\iiint_{III}\eta\rho dv\right)_{t+\Delta t}}{\Delta t}\right] - \lim_{\Delta t\to 0}\left[\frac{\left(\iiint_{I}\eta\rho dv\right)_{t}}{\Delta t}\right]$$

______________(4)

As $\Delta t \to 0$ region II becomes that of control volume, the first term on the right becomes $\frac{d}{dt}\iiint_{cv} \eta\rho dv$. The integral for region III approximates the amount of 'N' that has crossed the control surface ABCD shown in fig.

Let an area dA on the control surface where a steady flow velocity v is attained during time interval Δt, the interface has moved a distance vdt along a direction which is tangential to stream line at that point.

The volume of the fluid swept across the area dA is $dv = (V.dt)(dA\cos\alpha)$

Using the dot product we can define

$dv = (V.n)(dAdt)$

So, the integral for the region III, is expressed by substituting dv. Efflux rate through control surface ABC

$$= \iint_{ABC} \eta\rho(\dot{V}.\dot{n})(dA)$$

Similarly, the influx rate through control surface ADC can be expressed

Influx rate: $-\iint_{ADC} \eta\rho\left(\vec{v}\,\overset{n}{n}\right)dA$

The negative sign indicates influx rate of 'N' through the control surface. The net efflux rate of N through the whole control surface is

$$= [\text{Efflux rate on } ABC] - [\text{influx rate on } ADC]$$

$$= \iint_{ABC} \eta(\rho\vec{V}n)dAt \iint_{ADC} \eta\rho(\vec{V}.n)dA$$

Net efflux rate $= \iint_{Control\ fans} \eta\rho(\vec{V}.\hat{n})dA$

_______________(5)

Collecting the terms of equation ( ) gives the compact from of RTT as

$$\left(\frac{dN}{dt}\right)_{sys} = \frac{d}{dt}\iiint_{cv} \eta\rho dv + \iint_{control\ surface} \eta\rho(\vec{V}.\hat{n})dA$$

9 Calculate the dynamic viscosity of the oil which is used for lubrication between a square plate of 0.8m × 0.8m, and an inclined plane with an angle of inclination 30°, as shown in the fig. The weight of the square plate is 300 N and its slides down the inclined plane with a uniform velocity of 0.3 m/s. The thickness of oil film is 1.5 mm.

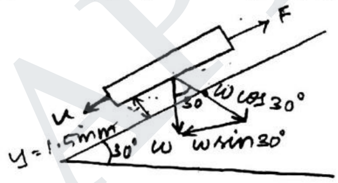
Given:

$W \sin 30° - F = 0$

$F = W \sin 30°$

$F = W/2$

$= \frac{300}{2}$



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shear force, F = 150 N.

* Surface area of square plate, A = 0.8m × 0.8m = 0.64 m².
* Angle of inclination, θ = 30°
* Weight of plate, W = 300N
* Tangential velocity of the plate, u = 0.3 m/s
* Thickness of oil film, y = 1.5 mm = 1.5×10^{-3} m.

To find μ:

* Resolving the force F_1

$$W \sin 30° - F = 0$$

$$F = W \sin 30°$$

$$F = 300 \times 1/2$$

shear force, $F = 150$ N

* shear stress, $\tau = \frac{F}{a}$

$$= \frac{150}{0.64}$$

$$\tau = 234.375 \ N/m^2$$

* Dynamic viscosity, $\mu = \tau \times \frac{dy}{du}$

$$= 234.375 \times \frac{1.5 \times 10^{-3}}{0.3}$$

$$\mu = 1.171875 \ Ns/m^2$$

$$\mu = 11.718 \text{ Poise} . \left[\because 1 \text{ Poise} = \frac{1}{10} Ns/m^2\right]$$

Result: Dynamic viscosity of oil = 11.718 Poise.

PART C

1. Explain Reynold's experiment. (Nov/Dec 2016)

In 1880's, Professor Osborne Reynolds carried out numerous experiment on fluid flow. We will now discuss the laboratory set up of his experiment. The experimental set used by Prof. Osborne Reynold is shown in Fig 1. As you can see from the figure, Reynolds injected dye jet in a glass tube which is submerged in the large water tank. Please see that the other end of the glass tube is out of water tank and is fitted with a valve. He made use of the valve to regulate the flow of water. The observations made by Reynolds from his experiment are given shown through Figures 5 to 7.

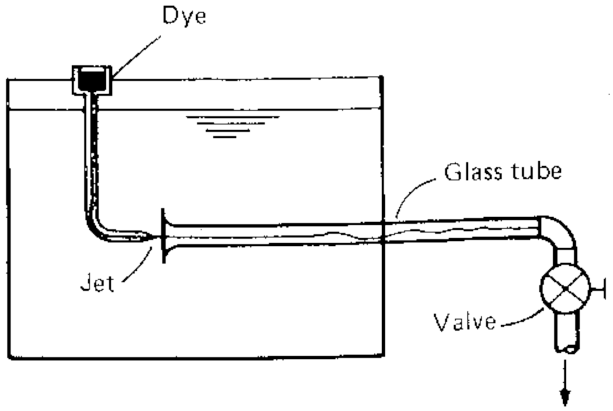


Fig. 1 Experimental Set up for Reynold's Experiment

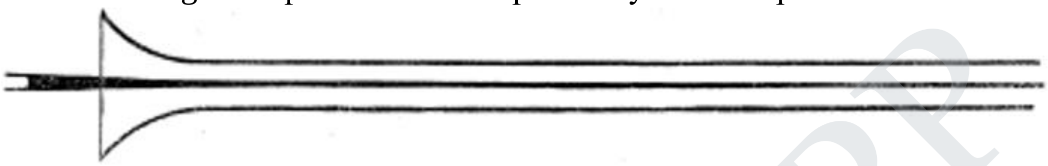


Fig. 2 Sketch showing the flow to be simple and ordered at low velocity

Fig. 3 The flow of dye forming wavy pattern at medium velocity

Fig. 4 The flow of dye is complex at higher velocity

APPROACH TOWARDS REYNOLDS' NUMBER

Throughout the experiment, Reynolds thought that the flow must be governed by a dimensionless quantity. What he observed was that Inertial force/Viscous force is unit less (dimensionless). Let us see the mathematical expression of inertial force and viscous force.

Inertial force is the force due to motion i.e. which may be also called as kinetic force.

Kinetic energy = $\frac{1}{2} mv^2$

Inertia force = $\rho v^2/2$

Viscous force = μ (du/dy)

Reynold's Number = Inertia force/ Viscous force

$= \rho v^2 dy/\mu\ du$

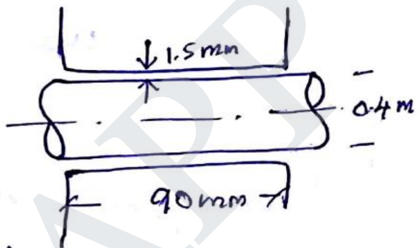
Now, for a finite length we can write dy = l, and du = v

Reynold's Number = Inertia force/ Viscous force

$= \rho v^2 l/\mu\ v$

Reynold's number $= \rho.v.l/\mu$

2. The dynamic viscosity of an oil used for lubrication between a shaft and sleeve is 6 poise. The shaft is of diameter 0.4 m and rotates at 190 rpm. Calculate the power lost in the bearing for a sleeve length of 90 mm. The thickness of the oil film is 1.5 mm.



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$$\text{Power} = \frac{2\pi N T}{60} = 716.48\,W$$

$$T = \text{Force} \times \frac{D}{2} = 36.01\,Nm$$

$$\text{Force} = \text{shear stress} \times \text{Area}$$
$$= 1592 \times \pi D L$$

$$\text{shear stress}, \tau = \mu \frac{du}{dy} = 1592\ N/m^2$$

$$du = u - 0 = 3.98\,m/s$$
$$dy = t = 1.5 \times 10^{-3}\,m$$

$$\text{Tangential Velocity}, u = \frac{\pi D N}{60} = 3.98\,m/s$$

UNIT –II

FLOW THROUGH CIRCULAR CONDUITS

1. Difference between hydraulic Gradient line and Energy Gradient line. (Nov/Dec 2015, May/June 14,09)

Hydraulic gradient line :-

Hydraulic gradient line is defined as the line which gives the sum of pressure head and datum head of a flowing fluid in a pipe with respect the reference line

Total energy line :-

Total energy line is defined as the line which gives the sum of pressure head , datum head and kinetic head of a flowing fluid in a pipe with respect to some reference line

2. Mention the general characteristics of laminar flow. (May/june 14)

1. There is a shear stress between fluid layers
2. 'No slip' at the boundary
3. The flow is rotational
4. There is a continuous dissipation of energy due to viscous shear

3. Define boundary layer thickness (Nov/Dec 15)

It is defined as the distance from the solid boundary in the direction perpendicular to the direction of flow where the velocity of fluid is approximately equal to 0.99 times the free stream velocity

4. What is Hagen poiseuille's formula ? (May/june12,Nov/Dec 2012)

P1-P2 / pg = h f = 32 μUL / _gD^2

The expression is known as Hagen poiseuille formula .

Where P1-P2 / _g = Loss of pressure head U = Average velocity

μ = Coefficient of viscosity D = Diameter of pipe

L = Length of pipe

5. What is the expression for head loss due to friction in Darcy formula? (Nov/Dec 2010)

hf = 4fLV^2 / 2gD

Where f = Coefficient of friction in pipe L = Length of the pipe

D = Diameter of pipe V = velocity of the fluid

6. List the minor energy losses in pipes? (Nov/Dec 2010,May/June 07)

This is due to

i. Sudden expansion in pipe ii. Sudden contraction in pipe .

iii. Bend in pipe . iv. Due to obstruction in pipe

7. What are the factors influencing the frictional loss in pipe flow?

Frictional resistance for the turbulent flow is

1. Proportional to vn where v varies from 1.5 to 2.0 .
2. Proportional to the density of fluid .
3. Proportional to the area of surface in contact .
4. Independent of pressure . Depend on the nature of the surface in contact.

8. What are the basic educations to solve the problems in flow through branched pipes?

i. Continuity equation .

ii. Bernoulli's formula .

iii. Darcy weisbach equation .

9. What is Dupuit's equation ?

$$(L_1/d_1^5)+(L_2/d_2^5) +(L_3/d_3^5) = (L / d^5)$$

Where

L1, d1 = Length and diameter of the pipe 1

L2, d2 = Length and diameter of the pipe 2

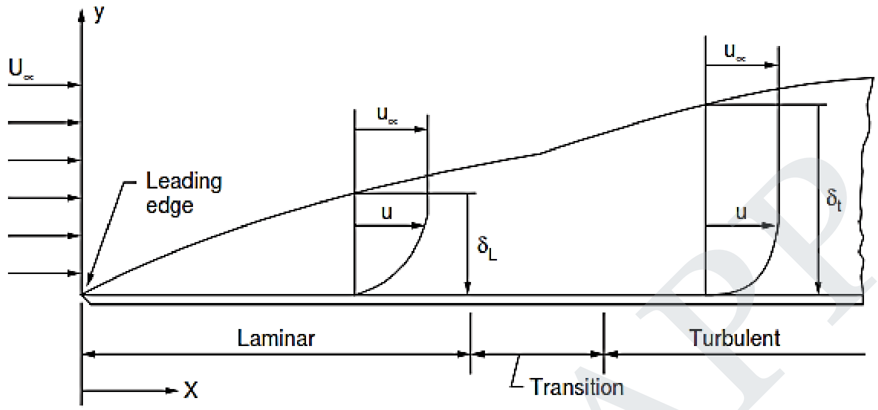
L3, d3 = Length and diameter of the pipe 3

10. Define Moody diagram (Nov/Dec 2012, April/May 11)

It is a graph in non-dimensional form that relates the Darcy friction factor, Reynolds number and relative roughness for fully developed flow in a circular pipe.

11. Define boundary layer. (April/May 2017)

When fluids flow over surfaces, the molecules near the surface are brought to rest due to the viscosity of the fluid. The adjacent layers also slow down, but to a lower and lower extent. This slowing down is found limited to a thin layer near the surface. The fluid beyond this layer is not



affected by the presence of the surface. The fluid layer near the surface in which there is a general slowing down is defined as boundary layer.

12. What are equivalent pipes? Mention the equation used for it. (April/May 2017)

Equivalent pipes are defined as the pipes of uniform diameter having loss of head and discharge equal to the loss of head and discharge of a compound pipe consisting of several pipes of different lengths and diameters. The uniform diameter of the equivalent pipe is called equivalent size of the pipe.

The equation used to represent equivalent pipe is called Dupit's equation which is given as,

$$(L_1/d_1^5) + (L_2/d_2^5) + (L_3/d_3^5) = (L / d^5)$$

Where

L1, d1 = Length and diameter of the pipe 1

L2, d2 = Length and diameter of the pipe 2

L3, d3 = Length and diameter of the pipe 3

PART-B

1. A laminar flow is taking place in a pipe at dia 20 cm. The maximum velocity 1.5 m/s. Find mean velocity and radius at which this occurs. Also calculate velocity at 4 cm from wall of pipe. (16)

[Nov/Dec-2013]

Given:

$D = 20 cm = 0.20 m$.

$U_{max} = 1.5 m/s$.

Find : (i) mean velocity, $\bar{u}$.

(ii) Radius at which $\bar{u}$ occurs.

(iii) Velocity at 4 cm from the wall.

Solution:

(i) Ratio of $\frac{U_{max}}{\bar{u}} = 2.0$ [Taken from the Derivation]

$\frac{1.5}{\bar{u}} = 2$

$\bar{u} = \frac{1.5}{2} = 0.75$ m/s

$$\boxed{\bar{u} = 0.75 \text{ m/s}}$$

(ii) Radius at which $\bar{u}$ occurs.

The velocity u, at any radius 'r' is given by

$$u = -\frac{1}{4\mu}\left(\frac{\partial p}{\partial x}\right)[R^2 - r^2] \text{ (or)}$$

$$-\frac{1}{4\mu}\left(\frac{\partial p}{\partial x}\right) R^2 \left[1 - r^2/R^2\right]$$

But from equation U_{max} is given by

$$U_{max} = -\frac{1}{4\mu}\left(\frac{\partial p}{\partial x}\right) \cdot R^2.$$

$$\left[\because u = U_{max}\left[1 - \left(\frac{r}{R}\right)^2\right]\right]$$

Now, the radius at which $u = \bar{u} = 0.75\ m/s$.

$$0.75 = 1.5\left[1 - \left(\frac{r}{(D/2)}\right)^2\right]$$

$$= 1.5\left[1 - \left(\frac{r}{0.2/2}\right)^2\right]$$

$$= 1.5\left[1 - \left(r/0.1\right)^2\right]$$

$$\frac{0.75}{1.5} = 1 - \left(r/0.1\right)^2$$

$$\frac{r}{0.1} = 1 - \frac{0.75}{0.1.5} = 1 - \frac{1}{2} = 1/2$$

$$r = 0.1 \times \sqrt{0.5}$$

$$= 0.1 \times 0.707 = 0.0707\ m.$$

$$\boxed{r = 70.7\ mm.}$$

(iii) Velocity at 4cm from the wall,

$$r = R - 4.0$$
$$= 10 - 4 \Rightarrow 6.cm\ (or)\ 0.06m.$$

The velocity at a radius = 0.06 m (or) 4 cm from pipe wall is given by

$$= U_{max}\left[1-\left(r/R\right)^2\right]$$

$$= 1.5\left[1-\left(\frac{0.06}{0.1}\right)^2\right]$$

$$= 1.5\left[1.0-0.36\right]$$

$$= 1.5 \times 0.64 = 0.96 \text{ m/s.}$$

$$\boxed{u = 0.96 \text{ m/s.}}$$

Result:

Mean velocity $\bar{u}$: 0.75 m/s.

radius at which $\bar{u}$ occurs (r) = 70.7 mm.

velocity at 4 cm from the wall (u) = 0.96 m/s.

2. An oil of specific gravity 0.80 & Kinematic Viscosity $15 \times 10^{-6}\, m^2/s$ flows in a smooth pipe of 12 cm diameter at a rate of 150 lit/min. Determine whether the flow is laminar or turbulent. Also calculate the velocity at the center line & velocity at a radius of 4 cm. What a head loss for a length of 10 m? what will be the entry length? Also determine the wall shear (16)

[Nov/Dec -2014]

Given:

$$S = 0.80.$$

$$\nu = 15 \times 10^{-6}\, m^2/s.$$

$$d = 0.12\, m.$$

$$Q = 150\, l/min = \frac{15 \times 10^{-3}}{60} = 0.0025\, m^3/s$$

$$r = 4\, cm = 0.04\, m.$$

$$(x_2 - x_1)\ dx = 10\, m.$$

Find:

head loss $h_f = ?$

Entry length $= ?$

Wall shear $\tau_0 = ?$

Solution:

(i) $Re = \frac{VD}{\nu}$

$$Q = A \times V$$

$$V = Q/A$$

$$V = \frac{0.0025}{\pi/4\,(0.12)^2}$$

$$\boxed{V = 0.221\ m/s}$$

$$Re = \frac{0.221 \times 0.12}{15 \times 10^{-6}} \Rightarrow 1768.3$$

$Re < 2000$; ∴ The flow is laminar.

(ii) $$U_{max} = \frac{1}{4\mu}\left(\frac{\partial p}{\partial x}\right) \cdot R^2.$$

$$p_1 - p_2 = \frac{32 \mu \bar{u} L}{D^2} \qquad \frac{\partial p}{\partial x} = \frac{p_2 - p_1}{x_2 - x_1}.$$

$$\boxed{\bar{u} = V = 0.221\ m/s}$$

$$p_1 - p_2 = \frac{32 \times 0.012 \times 0.221 \times 10}{(0.12)^2}$$

$$p_1 - p_2 = 58.946\ N/m^2.$$

$$U_{max} = \frac{1}{4 \times 0.012} \times \frac{58.94}{10} \times 0.06^2$$

$$U_{max} = 0.441\ m/s$$

[∵ $V = m/\rho$

$m = V \times \rho$

$m = 15 \times 10^{-6} \times \rho$

$\rho = 1000 \times 0.8$

$= 800\ kg/m^3$]

(iii) Velocity at 4 cm from center.

$$r = 0.04\,m.$$

$$= U_{max}\left(1 - (r/R)^2\right).$$

$$= 0.441\left(1 - \left(\frac{0.04}{0.06}\right)^2\right)$$

$$= 0.245\ m/s.$$

(iii) wall shear.

$$\tau_0 = -\left(\frac{\partial p}{\partial x}\right) \times (R/2)$$

$$= \frac{p_1 - p_2}{x} \times (R/2)$$

$$= \frac{58.94}{10} \times \frac{0.06}{2}$$

$$\tau_0 = 0.1767\ N/m^2.$$

V) Head loss for length 10m.

$$h_f = \frac{32\mu \bar{u} L}{\rho g D^2}$$

$$= \frac{32 \times 0.012 \times 0.221 \times 10}{800 \times 9.81 \times (0.12)^2}$$

$$\boxed{h_f = 0.0075\,m}$$

Result :

(i) $h_f = 0.0075$ m.

(ii) wall shear $(\tau_0) = 0.1767$ N/m².

(iii) The velocity at 4 cm from center (u) $\} = 0.245$ m/s.

3. Oil flows through a pipe 150 mm in diameter and 650 mm in length with a velocity of 0.5 m/s. If the kinematic viscosity of oil is 18.7×10^{-4} m²/s. Find the power lost in over coming friction. Take sp.g. of oil as 0.9. (16) [APr/may - 2015]

Given :

$d = 150\,mm = 0.15$

$L = 650\,mm = 0.65$

$V = 0.5\,m/s$

$\nu = 18.7 \times 10^{-4}\,m^2/s$

$S = 0.9$

$[\because \rho = 0.9 \times 1000$
$= 900\,kg/m^3]$

Find :

Power lost (P)

Formula :

$$P = \frac{\rho Q g h_f}{1000}\ kW.$$

Solution:

$$Re = \frac{VD}{\nu}$$

$$= \frac{0.5 \times 0.15}{18.7 \times 10^{-4}} \Rightarrow \frac{0.075}{18.7 \times 10^{-4}}$$

$$Re = 40.106 < 2000.$$ [Re Value is less than 2000]

The flow is laminar.

$$h_f = \frac{4fLV^2}{2g \times d}.$$

[∵ if the flow is laminar Calculate $f = 16/Re$]

$$f = \frac{16}{Re}$$

$$= \frac{16}{40.106}$$

$$f = 0.3$$

$$h_f = \frac{4 \times 0.3 \times 650 \times (0.5)^2}{0.15 \times 2 \times 9.81}$$

$$h_f = \frac{195}{2.943} \Rightarrow 66.25$$

$$\boxed{h_f = 66.25\ m}$$

Power lost (P) $= \dfrac{\rho g Q h_f}{1000}$ kw

$$= \frac{9.81 \times 1900 \times 0.0088 \times 66.25}{1000}$$

$$\boxed{P = 5.147\ kw}$$

Result : (i) Head Loss $(h_f) = 66.25\,m$
(ii) Power lost $(P) = 5.147\,kW$.

4. Two pipes of dia 40cm & 20 Cm are each 300m long. when pipes connected in series & $0.10\,m^3/s$. Find loss of head & loss of head in S/m to pass the same total discharge when pipes connected in parallel Take $f = 0.0075$ for each pipe. (16)

[Nov/Dec - 2010]

Given:

$D_1 = 40cm = 0.4\,m.$

$D_2 = 20cm = 0.2\,m.$

$L_1 = L_2 = 300m.$

$Q = 0.1\,m^3/s.$

$f = 0.0075.$

Find : (i) head loss for series & parallel.

Solution:

For series connection,

$$Q = A_1 V_1 = A_2 V_2$$

$Q = A_1 V_1$

$0.1 = \frac{\pi}{4}(0.4)^2 \times V_1$

$\boxed{V_1 = 0.79\,m/s}$

$Q_2 = A_2 V_2$

$0.1 = \frac{\pi}{4}(0.2)^2 \times V_2$

$\boxed{V_2 = 3.18\,m/s}$

Neglecting the minor losses.

$$H = \frac{4fL_1V_1^2}{2gd_1} + \frac{4f.L_2V_2^2}{2gd_2}.$$

$$= \frac{4\times0.0075\times300\times(0.79)^2}{2\times9.81\times0.4} + \frac{4\times0.0075\times300\times(3.18)^2}{2\times9.81\times0.2}$$

$$H = 0.715 + 23.19$$

$$\boxed{H = 23.4\,m}$$

For parallel connection,

$$h_f = \frac{4fL_1V_1^2}{2g\times d_1} = \frac{4fL_2V_2^2}{2g\times d_2}$$

$$\frac{V_1^2}{D_1} = \frac{V_2^2}{D_2}$$

$$\frac{V_1^2}{0.4} = \frac{V_2^2}{0.2}$$

$$V_1 = 1.41.V_2$$

$$Q = A_1V_1$$

$$0.1 = \pi/4\,(0.4)^2 \times V_1$$

$$= \pi/4\,(0.4) \times V_1$$

$$V_1 = 0.79\,m/s$$

$$Q = A_1 V_1 = A_2 V_2.$$

$$Q = A_2 V_2$$

$$\boxed{V_2 = 0.56\ m/s}$$

$$h_f = \frac{4 f L_1 V_1^2}{2g \times d_1}$$

$$= \frac{4 \times 0.0075 \times 300 \times (0.79)^2}{2 \times 9.81 \times 0.4}$$

$$\boxed{h_f = 0.71\ m}$$

Result;

Head Loss for series pipe is 23.9 m

Head Loss for parallel pipe is 0.71 m.

5. A pipe line of 0.6m diameter is 1.5 Km long. To Increase the discharge, another line of the same diameter is Introduced Parallel to the first in the second half of the length. Neglecting minor losses. find the Increase in discharge if $4f = 0.04$. The head at Inlet is 300mm. (16) [Apr/may - 2015]

Given.

Dia. of pipe line (D) = 0.6m

Length of pipe line (L) = 1.5 Km

= 1.5x1000 = 1500m

$4f = 0.04$ (or)

$f = 0.01$

Head at Inlet $h = 300mm = 0.3m$

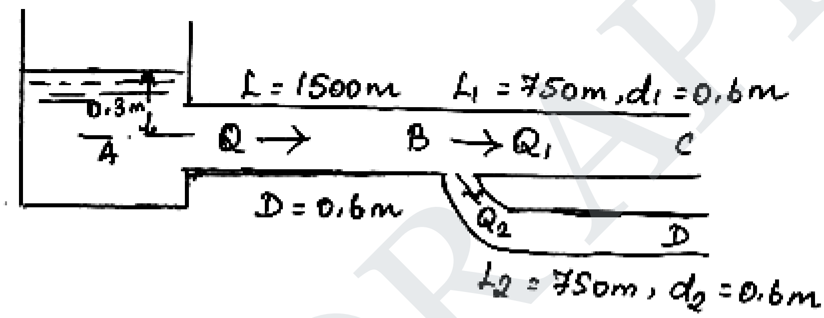
Head at outlet = atmospheric head = 0

$\therefore$ Head loss $(h_f) = 0.3m$

Length of another parallel pipe $L_1 = \frac{1500}{2}$

$= 750m$.

Dia. of another parallel pipe. $d_1 = 0.6m$.



I st case.

Discharge for a single pipe of length 1500m & dia $\int = 0.6m$

This head lost due to friction in single pipe is $h_f = \frac{4fLV^2}{d \times 2g}$.

Where $V^* =$ velocity of flow for single pipe.

$$0.3 = \frac{4 \times 0.01 \times 1500 \times V^{*2}}{0.6 \times 2g}$$

$$V^* = \sqrt{\frac{0.3 \times 0.6 \times 2 \times 9.81}{4 \times 0.01 \times 1500}} \Rightarrow 0.2426 \, m/s.$$

Discharge $Q^* = \text{Area} \times V^*$

$= 0.2426 \times \pi/4 \, (0.6)^2$

$= 0.0685 \, m^3/s$.

2^{nd} case.

When an additional pipe of length 750m & diameter 0.6 m is connected in parallel with the last half length of the pipe.

Let, $Q_1 \rightarrow$ discharge in 1^{st} parallel pipe.
$Q_2 \rightarrow$ discharge in 2^{nd} parallel pipe

$$Q = Q_1 + Q_2.$$

where, $Q \rightarrow$ discharge in mainpipe when pipes are parallel.

But as the length & diameters of each parallel pipe is same.

$$\because \quad Q_1 = Q_2 = Q/2$$

Consider the flow through pipe ABC or ABD

$$\text{Head loss through ABC} = \underset{\text{through AB}}{\text{Head lost}} + \underset{\text{through BC}}{\text{Head lost}} \rightarrow (1)$$

But head lost due to friction through ABC = 0.3m given.

$$\text{Head loss due to friction through AB} = \frac{4 \times f \times 750 \times V^2}{0.6 \times 2 \times 9.81},$$

where V = Velocity of flow through AB.

$$= \frac{Q}{\text{Area}} = \frac{Q}{\pi/4\,(0.6)^2} = \frac{4Q}{\pi \times 0.36}$$

$\therefore$ Head loss due to friction through AB

$$= \frac{4 \times 0.01 \times 750}{0.6 \times 2 \times 9.81} \times \left(\frac{4Q}{\pi \times 0.36}\right)^2$$

$$= 31.87\, Q^2$$

Head loss due to friction through BC

$$= \frac{4 \times f \times L_1 \times V_1^2}{d_1 \times 2g}$$

$$= \frac{4 \times 0.01 \times 750}{0.6 \times 2 \times 9.81} \times \left[\frac{Q}{2 \times \pi/4 (0.6)^2}\right]$$

$$\left[\because V_1 = \frac{\text{Discharge}(Q)}{\text{Area}(A)} = \frac{Q}{\pi/4 (0.6)^2}\right]$$

$$= \frac{4 \times 0.01 \times 750}{0.6 \times 2 \times 9.81} \times \frac{16 \, Q^2}{4 \times \pi^2 \times 0.36^2}$$

$$= 7.969 \, Q^2$$

Substituting these values in equ (1) we get,

$$0.3 = 31.87 \, Q^2 + 7.969 \, Q^2$$

$$= 39.839 \, Q^2$$

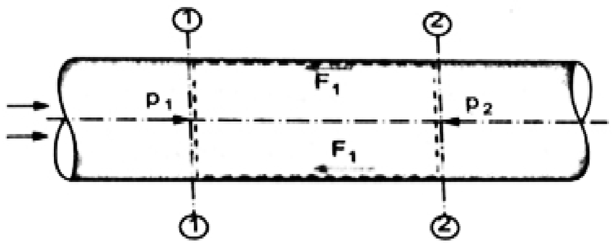
$$Q = \sqrt{\frac{0.3}{39.839}} = 0.0867 \, m^3/s.$$

$\therefore$ Increase in discharge $= Q - Q^*$

$$= 0.0867 - 0.0685$$

$$= 0.0182 \, m^3/s.$$

6. Derive the Darcy-Weisbach equation for calculating pressure drop in pipe. (Nov/Dec 2011)



Uniform horizontal pipe.

Consider a uniform horizontal pipe, having steady low as shown figure let 1-1 and 2-2 are two sections of pipe

P_1= pressure intensity at section 1-1

V_1 = velocity of flow at section 1-1

L = length of the pipe between sections 1-1 and 2-2

D = Diameter of pipe

F = Frictional resistance per unit wetted area per unit velocity

h_f = loss of head due to friction

P_2 and V_2 are values of pressure intensity and velocity at section 2-2

Applying Bernoulli's equation between sections 1-1 and 2-2,

Total head at 1-1 = total head at 2-2 + loss of head due to friction between 1-1 and 2-2

$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + z_2 + h_f$$

z_1= $z_2$as pipe is horizontal

v_1 = v_2 as dia of pipe is same at 1-1 and 2-2

$$\frac{p_1}{\rho g} = \frac{p_2}{\rho g} + h_f$$

$$h_f = \frac{p_1}{\rho g} - \frac{p_2}{\rho g} \text{ ------------------------- } 1$$

But h_f is the head lost due to friction and hence intensity of pressure will be reduced in the direction of row by frictional resistance

Now frictional resistance = frictional resistance per unit wetted area per unit velocity X wetted area X velocity²

$F_1 = f' \text{ X } \pi d L \text{ X } V^2$ {Wetted area = , $V = V_1 = V_2$, Perimeter $P = \pi d$}

$$F_1 = f' P\ L\ V^2$$

The forces acting on the fluid between sections 1-1 and 2-2 are

- Pressure force at section 1-1 = $p_1 A$
  - Where A = Area of pipe
- Pressure force at section 2-2 = p_2 A
- Frictional force F_1

Resolving all Forces in the horizontal direction, we have

$$p_1 A - p_2 A - F_1 = 0$$

$$(p_1 - p_2)\ A = F_1 = f' P\ L\ V^2$$

$$(p_1 - p_2) = \frac{f' P\ L v^2}{A}$$

But from equation 1 $(p_1 - p_2) = \rho g h_f$

Equating the value of $(p_1 - p_2)$ we get

$$\rho g h_f = \frac{f' P\ L v^2}{A}$$

$$h_f = \frac{f}{\rho g A} \qquad \left\{ \frac{P}{A} = \frac{\pi d}{\frac{\pi d^2}{4}} \right\}$$

$$h_f = \frac{f'}{\rho g} \frac{4}{d} L\ V^2 \qquad \text{putting } \frac{f'}{\rho} = \frac{f}{2}$$

Where f is known as co- efficient of friction

So final equation becomes

$$h_f = \frac{4f}{2g} \frac{L v^2}{d} = \frac{4f\ L v^2}{2 g d}$$

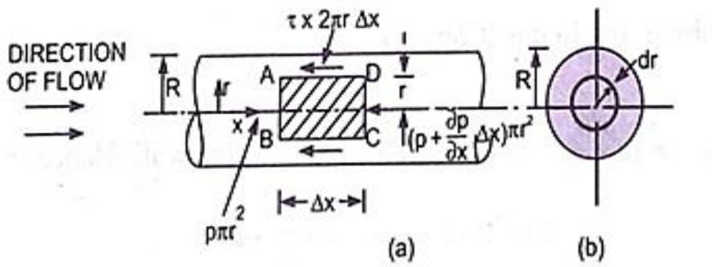
This equation is known as Darcy- Weisbach equation. This equation commonly used for finding loss of head due to friction in pipes.

7. Derive the expression for shear stress and velocity distribution for the flow through circular pipe and using that derive the Hagen Poiseuille formula. (Nov/Dec 2015)

FLOW OF VISCOUS FLUID THROUGH CIRCULAR PIPE

For the flow of viscous fluid through circular pipe, the velocity distribution across a section The ratio of maximum velocity to average velocity, the shear stress distribution and drop of Pressure or a given length is to be determined. The flow through the circular pipe will be viscous Or laminar, if the Reynolds number (R_e) is less than 2000.The expression for Reynolds number is given by

$$R_e = \frac{\rho V D}{\mu}$$



Viscous flow through a pipe.

ρ=Density of fluid flowing through pipe

V=Average velocity of fluid

D=Diameter of pipe and

μ =Viscosity of fluid

Consider the horizontal pipe of radius R. The viscous fluid is flowing from left to right in the pipe as Shown in fig. consider a fluid n element of radius r, sliding in a cylindrical fluid element of radius

1. Shear stress distribution

(r+dr).Let the length of fluid element be Δx. If 'p' is the intensity of pressure on the face AB,thenthe intensity of pressure on the face CD will be (p+$\frac{\partial p}{\partial x}\Delta x$).Then the forces acting on the fluid element are

1. The pressure force, p$\times \pi r^2$ on face AB.

2. The pressure force, (p+$\frac{\partial p}{\partial x}\Delta x$) πr^2 on force CD.

3. The shear force, $\tau \times 2\pi r \Delta x$ on the surface of fluid element .As there is no acceleration; hence the Summation of all forces of all forces in the direction of flow must be zero i.e.

$$p\pi r^2 - (p+\frac{\partial p}{\partial x}\Delta x)\,\pi r^2 - \tau\times 2\pi r\times \Delta x.=0$$

Or

$$-\frac{\partial p}{\partial x}\,\Delta x\,\pi r^2 - \tau\times 2\pi r\times\Delta x = 0$$

Or

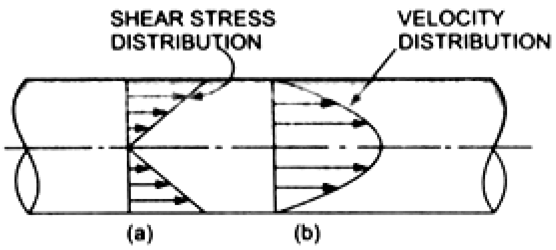
$$-\frac{\partial p}{\partial x}.r - 2\tau=0$$

$$\therefore\ \tau=-\frac{\partial p}{\partial x}\frac{r}{2} \quad ----------- (1)$$

The shear stress τ across a section varies with 'r' as $\frac{\partial p}{\partial x}$ across a section is constant. Hence shear stress distribution across a section is linear as shown in Fig

2. Velocity Distribution.

To obtain the velocity distribution across a section, the value of shear stress $\tau = \mu \frac{du}{dy}$ is substituted in equation (1)



Shear stress and velocity distribution across a section.

But in the relation $\tau = \mu \frac{du}{dy}$, y is measured from the pipe wall. Hence

Y=R-r and dy = -dr

$$\therefore \quad \tau = \mu \frac{du}{-dr} = -\mu \frac{du}{dr}$$

Substituting this value in (1), we get

$$-\mu \frac{du}{dr} = -\frac{\partial p}{\partial x}\frac{r}{2} \text{ or } \frac{du}{dr} = \frac{1}{2\mu}\frac{\partial p}{\partial x} r$$

Integrating this above equation w.r.t. 'r', we get

$$\mu = \frac{1}{4\mu}\frac{\partial p}{\partial x} r^2 + C$$

Where C is the Constant of Integration and its value is obtained from boundary condition that at r=R, μ=0.

$$\therefore \quad 0 = \frac{1}{4\mu}\frac{\partial p}{\partial x} R^2 + C$$

$$\therefore \quad C = -\frac{1}{4\mu}\frac{\partial p}{\partial x} R^2 \text{ ------------------(2)}$$

Substituting this value of C in equation

$$\mu = \frac{1}{4\mu}\frac{\partial p}{\partial x} r^2 - \frac{1}{4\mu}\frac{\partial p}{\partial x} R^2$$

$$\therefore \quad = -\frac{1}{4\mu}\frac{\partial p}{\partial x}[R^2 - r^2] \text{ ---------------------(3)}$$

In equation (3), values of μ, $\frac{\partial p}{\partial x}$ *and R are constant, which means the velocity*, μ varies with the square of r. Thus equation (3) is an equation o parabola. This shows that the velocity distribution across the section of a pipe is parabolic. This velocity distribution is shown in fig.

1. Ratio of Maximum Velocity to Average Velocity.

The velocity is maximum, when r=0 in equation Thus maximum velocity, U_{max} is obtained as

$$U_{max} = -\frac{1}{4\mu}\frac{\partial p}{\partial x}R^2 \text{ ---------------------(4)}$$

The average velocity, u, is obtained by dividing the discharge of the fluid across the section by the area of the pipe (πR^2). The discharge (Q) across the section is obtained by considering the flow through a circular ring element of radius r and thickness dr as shown in Fig. The fluid flowing per second through this elementary ring

dQ = velocity at a radius r ×area of ring element

$$= u \times 2\pi r dr$$

$$= -\frac{1}{4\mu}\frac{\partial p}{\partial x}[R^2 - r^2]\times 2\pi r dr$$

$$Q = \int_0^R dQ = \int_0^R -\frac{1}{4\mu}\frac{\partial p}{\partial x}(R^2 - r^2)\times 2\pi r dr$$

$$= \frac{1}{4\mu}\left(-\frac{\partial p}{\partial x}\right)\times 2\pi\int_0^R (R^2 - r^2)\, r dr$$

$$= \frac{1}{4\mu}\left(-\frac{\partial p}{\partial x}\right)\times 2\pi\int_0^R ((R^2 r - r^3))\, dr$$

$$= \frac{1}{4\mu}\left(-\frac{\partial p}{\partial x}\right)\times 2\pi\left[\frac{R^2 r^2}{2} - \frac{r^4}{4}\right] = \frac{1}{4\mu}\left(-\frac{\partial p}{\partial x}\right)\times 2\pi\left[\frac{R^2 r^2}{2} - \frac{r^4}{4}\right]$$

$$= \frac{1}{4\mu}\left(-\frac{\partial p}{\partial x}\right)\times 2\pi\times\frac{R^4}{4} = \frac{\pi}{8\mu}\left(-\frac{\partial p}{\partial x}\right)R^4$$

$$\therefore \text{ Average velocity, } \bar{u} = \frac{Q}{Area} = \frac{\frac{\pi}{8\mu}\left(-\frac{\partial p}{\partial x}\right)R^4}{\pi R^2}$$

$$\bar{u} = \frac{1}{8\mu}\left(-\frac{\partial p}{\partial x}\right)R^2 \text{ ---------------------(5)}$$

or

Dividing equation (4) by equation (5),

$$\frac{U_{max}}{\bar{u}} = \frac{-\frac{1}{4\mu}\left(\frac{\partial p}{\partial x}\right)R^2}{\frac{1}{8\mu}\left(-\frac{\partial p}{\partial x}\right)R^2} = 2.0$$

∴ Ratio of maximum velocity to average velocity = 2.0.

4. Drop of Pressure for a given Length (L) of a pipe

From equation (5), we have

$$\bar{u} = \frac{1}{8\mu}\left(-\frac{\partial p}{\partial x}\right)R^2 \text{ or } \left(-\frac{\partial p}{\partial x}\right) = \frac{8\mu\bar{u}}{R^2}$$

Integrating the above equation w.r.t. x, we get

$$-\int_2^1 dp = \int_2^1 \frac{8\mu\bar{u}}{R^2}\, dx$$

$$-[P_1 - P_2] = \frac{8\mu\bar{u}}{R^2}[X_1 - X_2] \text{ or } (p_1 - p_2) = \frac{8\mu\bar{u}}{R^2}[X_1 - X_2]$$

$$= \frac{8\mu\bar{u}}{R^2}L \qquad \{\therefore X_2\text{-}X_1\text{=L from Fig.}\}$$

$$= \frac{8\mu\bar{u}L}{\left(\frac{D}{2}\right)^2}$$

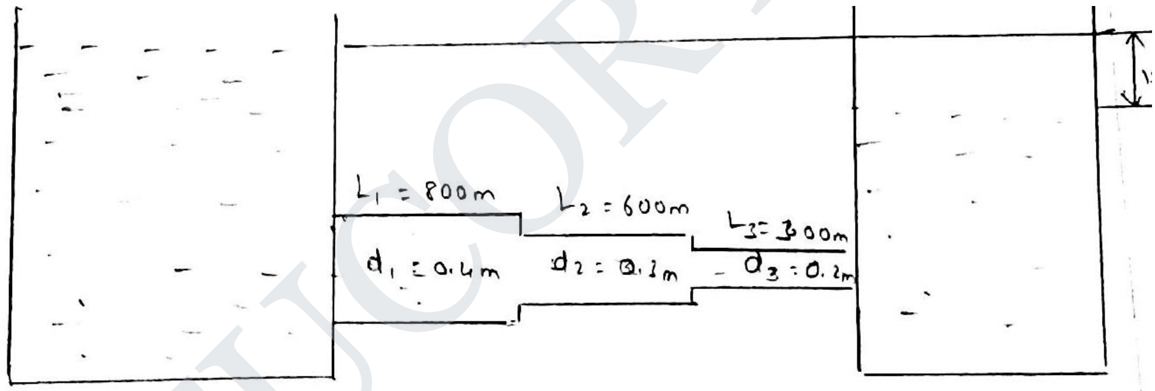
$(p_1\text{-}p_2) = \frac{32\mu\bar{u}L}{D^2}$, where $p_1\text{-}p_2$ is the drop of pressure.

$\therefore$ Loss of pressure head $= \frac{p_1-p_2}{\rho g}$

$$\therefore \frac{p_1-p_2}{\rho g} = h_f = \frac{32\mu\bar{u}L}{\rho g D^2}$$

This Equation is called Hagen Poiseuille Formula.

8. Three pipes of 400 mm, 200 mm and 300 mm diameters have lengths of 400 m, 200 m, and 300 m respectively. They are connected in series to make a compound pipe. The ends of the compound pipe are connected with two tanks whose difference of water levels is 16 m. if the coefficient of friction for these pipes is same and equal to 0.005, determine the discharge through the compound pipe neglecting first the minor losses and then including them. ***(Nov/Dec 2016)***



Given:

Length of pipe ①, L_1 = 800 m

Length of pipe ②, L_2 = 600 m

Length of pipe ③, L_3 = 300 m

Diameter of pipe ①, d_1 = ~~0.~~400 mm = 0.4 m

Diameter of pipe ②, d_2 = ~~60~~300 mm = 0.3 m

Diameter of pipe ③, d_3 = 200 mm = 0.2 m

Difference head at inlet and outlet, H = 15 m

Soln:-

Given: Total head loss, $H = 15\,m$

$$\Rightarrow h_i + h_o + h_{c_2} + h_{c_3} + hf_1 + hf_2 + hf_3 = 15$$

$$\Rightarrow \frac{0.5V_1^2}{2g} + \frac{V_2^2}{2g} + \frac{0.5V_2^2}{2g} + \frac{0.5V_3^2}{2g} + \frac{4fL_1V_1^2}{2gd_1} + \frac{4fL_2V_2^2}{2gd_2} + \frac{4fL_3V_3^2}{2gd_3} = 15 \quad \text{--- (1)}$$

By continuity eqn:

$$Q = A_1V_1 = A_2V_2 = A_3V_3$$

$$A_1V_1 = A_2V_2 \qquad A_3V_3 = A_2V_2$$

$$\frac{\pi}{4} \times 0.4^2 V_1 = \frac{\pi}{4} \times 0.3^2 V_2 \qquad \frac{\pi}{4} \times 0.2^2 V_3 = \frac{\pi}{4} \times 0.3^2 V_2$$

$$\boxed{V_1 = 0.562\,V_2} \qquad \boxed{V_3 = 2.25\,V_2}$$

Sub: V_1 and V_3 in (1)

$$\Rightarrow \frac{0.5(0.562V_2)^2}{2g} + \frac{(2.25V_2)^2}{2g} + \frac{0.5V_2^2}{2g} + \frac{0.5(2.25V_2)^2}{2g}$$

$$+ \frac{4 \times 0.005 \times 800 \times (0.562V_2)^2}{2g \times 0.4} + \frac{4 \times 0.005 \times 600 \times V_2^2}{2g \times 0.3}$$

$$+ \frac{4 \times 0.005 \times 300\,(2.25V_2^2)}{\ldots} = 15$$

$$\Rightarrow \frac{0.1579 V_2^2}{2g} + \frac{5.0625 V_2^2}{2g} + \frac{0.5 V_2^2}{2g} + \frac{2.53 V_2^2}{2g}$$

$$+ \frac{12.63 V_2^2}{2g} + \frac{40 V_2^2}{2g} + \frac{151.875 V_2^2}{2g} = 15$$

$$\Rightarrow \frac{212.75 V_2^2}{2g} = 15$$

$$\Rightarrow V_2^2 = \frac{15 \times 9.81 \times 2}{212.75}$$

$$\boxed{V_2 = 1.176} \text{ m/s}$$

Discharge, $Q = A_2 \times V_2$

$$= \frac{\pi}{4} \times 0.3^2 \times 1.17$$

$$\boxed{Q = 0.083 \text{ m}^3/\text{sec}}$$

W.K.T,

$$\frac{L}{d^5} = \frac{L_1}{d_1^5} + \frac{L_2}{d_2^5} + \frac{L_3}{d_3^5}$$

$$\frac{1700}{d^5} = \frac{800}{(0.4)^5} + \frac{600}{(0.3)^5} + \frac{300}{(0.2)^5}$$

$$\frac{1700}{d^5} = 78125 + 246913.5 + 937500$$

$$\frac{1700}{d^5} = 1262538.5$$

$$d^5 = 1.3468 \times 10^{-3}$$

$$d = 0.2665 \text{ m}$$

$$= 0.2665 \times 1000 \text{ mm}$$

$$\boxed{d = 266.5 \text{ mm}}$$

9. A fluid of viscosity 8 poise and specific gravity 1.2 is flowing through a circular pipe of diameter 100 mm. The maximum shear stress at the pipe wall is 210 N/m². Find:

(i) The pressure gradient.
(ii) The average velocity and
(iii) Reynold's number of flow.

Solution:

Viscosity of fluid, $\mu = 8$ poise $= 0.8$ Ns/m².

Specific gravity $= 1.2$

$\therefore$ Mass density, $\rho = 1.2 \times 1000 = 1200$ kg/m³.

Diameter of the pipe, $D = 100$ mm $= 0.1$ m.

Maximum shear stress, $\tau_0 = 210$ N/m²

(i) The pressure gradient, $\frac{\partial p}{\partial x}$:

We know that, $\tau_0 = -\frac{\partial p}{\partial x} \cdot \frac{R}{2}$

$$210 = -\frac{\partial p}{\partial x} \cdot \frac{(0.1/2)}{2}$$

$$\Rightarrow \boxed{\frac{\partial p}{\partial x} = -8400 \text{ N/m}^2 \text{ per m.}}$$

(ii) The average velocity, $\bar{u}$:

We know that, $\bar{u} = \frac{1}{2} U_{max}$

$$= \frac{1}{2}\left[-\frac{1}{4\mu}\cdot\frac{\partial p}{\partial x}\cdot R^2\right]$$

$$= \frac{1}{2}\left[-\frac{1}{4\times 0.8}\times(-8400)\times(0.1/2)^2\right]$$

$$\boxed{\bar{u} = 3.28\ m/s}$$

PART- C

1. The velocity distribution in the boundary layer is given by,

$$\frac{u}{U} = 2\left(\frac{y}{\delta}\right)-\left(\frac{y}{\delta}\right)^2,$$ δ being boundary layer thickness.

Nov/Dec 2016

Calculate the following:

(i) Displacement thickness.

(ii) Momentum thickness. &

(iii) Energy thickness.

Solution:

(i) Displacement thickness, δ^*:

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

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

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

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

$$\boxed{\delta^* = \delta/3}$$

(ii) Momentum thickness, θ:

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

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

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

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

$$= \int_0^\delta \left[\frac{2y}{\delta} - \frac{5y^2}{\delta^2} + \frac{4y^3}{\delta^3} - \frac{y^4}{\delta^4}\right] dy$$

$$= \left[\frac{2}{2} \times \frac{y^2}{\delta} - \frac{5}{3} \times \frac{y^3}{\delta^2} + \frac{4}{4} \times \frac{y^4}{\delta^3} - \frac{1}{5} \times \frac{y^5}{\delta^4}\right]_0^\delta$$

$$= \left[\delta - \frac{5}{3}\delta + \delta - \frac{1}{5}\delta\right]$$

$$\boxed{\theta = \frac{2}{15}\delta}$$

(iii) Energy thickness, δ_e:

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

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

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

$$= \int_0^\delta \left[\frac{2y}{\delta} - \frac{8y^3}{\delta^3} - \frac{2y^5}{\delta^5} + \frac{8y^4}{\delta^4} - \frac{y^2}{\delta^2} + \frac{4y^4}{\delta^4} + \frac{y^6}{\delta^6} - \frac{4y^5}{\delta^5}\right] dy$$

$$= \left[\frac{2}{2} \times \frac{y^2}{\delta} - \frac{1}{3} \times \frac{y^3}{\delta^2} - \frac{8}{4} \times \frac{y^4}{\delta^3} + \frac{12}{5} \times \frac{y^5}{\delta^4} - \frac{6}{6} \times \frac{y^6}{\delta^5} + \frac{1}{7} \times \frac{y^7}{\delta^6}\right]_0^\delta$$

$$= \left(\delta - \frac{\delta}{3} - 2\delta + \frac{12\delta}{5} - \delta + \frac{\delta}{7}\right)$$

$$\boxed{\delta_e = \frac{22\delta}{105}}$$

UNIT –III

DIMENSIONAL ANALYSIS

1. **Define dimensional homogeneity. (Nov/Dec 15,Non/Dec 11)**

    The dimensions of each term in an equation on both sides are equal. Thus if the dimensions of each term on both sides of an equation are the same the equation is known as dimensionally homogeneous equation

2. **Derive the expression for Reynold's number? (Nov/Dec 15,12)**

    It is the ratio between inertia forces to the viscous force

    Re=ρvD/μ

3. **Define Mach number? (Nov/Dec 14)**

    It is defined as the square root of the ratio of the inertia force of a flowing fluid to the elastic force

4. **State the Buckingham's π theorem? (Nov/Dec 12)**

    If there are n variables (dependent and independent) in a physical phenomenon and if these variables contain m fundamental dimensions, then these variables are arranged into (n-m) dimensionless terms called Pi terms

5. **Name the methods for determination of dimensionless groups. (Nov/Dec 11)**

    i) Buckinghams pi theorem
    ii) Raleyritz method

6. **State Froude's dimensionless number. (May/June 14)**

    It is defined as the square root of the ratio of inertia force of a flowing fluid to the gravity force

    $F_e=\sqrt{Fi/Fg}$.

7. **Define dynamic similarity.**

    Dynamic similarity is said to exist between the model and the prototype if the ratios of corresponding forces at the corresponding points in the model are the same.

8. What are the advantages of model and dimensional analysis?

(May/June 09)

1. The performance of the structure or the machine can be easily predicted.
2. With the dimensional analysis the relationship between the variables influencing a flow in terms of dimensionless parameter can be obtained.
3. Alternative design can be predicted and modification can be done on the model itself and therefore, economical and safe design may be adopted.

9. List the basic dimensional units in dimensional analysis.

(Nov/Dec 10)

1. Length(L)-meter
2. Mass(M)- kilogram
3. Time (T)- seconds

10. What are distorted models? State its merits and demerits.

(May/June 14)

A model is said to be distorted if it is not geometrically similar to its prototype. For a distorted model different scale ratios for the linear dimensions are adopted.

Merits

1. The vertical dimensions of the model can be measured accurately
2. The cost of the model can be reduced
3. Turbulent flow in the model can be maintained.

Demerits

1. The results of the distorted model cannot be directly transferred to its prototype.

11. Derive the scale ratio for velocity and pressure intensity using Froude model law. (Nov/Dec 2016)

$$(F_e)_m = (F_e)_p \Rightarrow \frac{V_m}{\sqrt{g_m L_m}} = \frac{V_p}{\sqrt{g_p L_p}}$$

Scale ratios based on Froude number

(a) Scale ratio for time, $T_r = \frac{T_p}{T_m} = \sqrt{L_r}$

(b) Scale ratio for acceleration,

$$a_r = \frac{V_p}{V_m} \times \frac{T_m}{T_p} = \sqrt{L_r} \times \frac{1}{\sqrt{L_r}}$$

$$a_r = 1$$

Scale ratio for pressure intensity,

$$p = \frac{Force}{Area} = \frac{\rho L^2 V^2}{L^2}$$

$$p = \rho V^2$$

$$p_r = \frac{\rho_p}{\rho_m} \cdot \frac{V_p^2}{V_m^2}$$

for same fluid, $\rho_p = \rho_m$

$$p_r = \frac{V_p^2}{V_m^2} = \sqrt{L_r}^2 = L_r$$

$$\boxed{p_r = L_r}$$

PART-B

1. Using Buckingham's π - theorem, show that the velocity through a circular orifice is given by $V = \sqrt{2gH}\ \phi\left[D/H, \frac{\mu}{\rho V H}\right]$, where H is the head causing flow, D is the diameter of the orifice, μ is co-efficient of viscosity, ρ is the mass density and g is the acceleration due to gravity. (16)

[Apr/May - 2010].

Solution:

Given:

V is a function of H, D, μ, ρ and g

$$V = f(H, D, \mu, \rho, g) \text{ (or)} \rightarrow (i)$$

$$f_1(V, H, D, \mu, \rho, g) \longrightarrow (ii)$$

Total no. of variables, $n = 6$.

dimensions of each variable,

$V = LT^{-1}$; $\mu = ML^{-1}T^{-1}$

$H = L$; $\rho = ML^{-3}$

$D = L$; $g = LT^{-2}$

No. of fundamental dimensions $m = 3$

$\therefore$ Number of π - terms $= n - m$

$= 6 - 3 = 3$

Equation (i) can be written as $f_1(\pi_1, \pi_2, \pi_3) = 0$.

Each π-term contains m+1 variables, where m = 3 and is also equal to repeating variables, Here V is a dependent variable and hence should not be selected as repeating variable. Choosing H, g, ρ as repeating variable, we get three π-terms as,

$$\pi_1 = H^{a_1} . g^{b_1} . \rho^{c_1} . V. \longrightarrow (1)$$

$$\pi_2 = H^{a_2} . g^{b_2} . \rho^{c_2} . D \longrightarrow (2)$$

$$\pi_3 = H^{a_3} . g^{b_3} . \rho^{c_3} . \mu . \longrightarrow (3)$$

First π-term :

$$\pi_1 = H^{a_1} . g^{b_1} . \rho^{c_1} . V.$$

Substituting dimensions on both sides,

$$M^0 L^0 T^0 = L^{a_1} . (LT^{-2})^{b_1} . (ML^{-3})^{c_1} . LT^{-1}$$

Equating the power of M, L, T on both sides,

Power of M, $\boxed{0 = c.}$

Power of L, $0 = a_1 + b_1 - 3c_1 + 1$

$a_1 = -b_1 + 3c_1 - 1$

$= 1/2 + 0 - 1$; $\boxed{a_1 = -1/2}$

Power of T, $0 = -2b_1 - 1$

$\boxed{b_1 = -1/2}$

Third π-term :

$$\pi_3 = H^{a_3} . g^{b_3} . \rho^{c_3} . \mu .$$

$$M^0 L^0 T^0 = L^{a_3} . (LT^{-2})^{b_3} . (ML^{-3})^{c_3} . ML^{-1} T^{-1}$$

Equ. the power of M, L, T on both,

Power of M : $0 = c_3 + 1$; $\boxed{c_3 = -1}$

Power of L : $0 = a_3 + b_3 - 3c_3 - 1$

$a_3 = -b_3 + 3c_3 + 1$; $1/2 - 3 + 1 = -3/2$

$\boxed{a_3 = -3/2}$

Power of T $= 0 = -2b_3 - 1$; $\boxed{b_3 = -1/2}$

Sub. the abc values on π_3 term,

$$\pi_3 = H^{-3/2} \cdot g^{-1/2} \cdot \rho^{-1} \cdot \mu$$

$$\boxed{\pi_3 = \frac{\mu}{H^{3/2} \cdot \rho\sqrt{g}}} \quad (\text{or}) \quad \frac{\mu}{H\rho\sqrt{gH}} = \frac{\mu V}{H\rho V\sqrt{gH}}$$

[Multiply & ÷ by V]

$$\boxed{\pi_3 = \frac{\mu}{H\rho V} \cdot \pi_1}$$

$\left[\because \frac{V}{\sqrt{gH}} = \pi_1\right]$

Substituting the values of π_1, π_2, π_3 in equation (ii)

$$f_1\left(\frac{V}{\sqrt{gH}}, \frac{D}{H}, \pi_1 \frac{\mu}{H\rho V}\right) = 0 \quad (\text{or})$$

$$\frac{V}{\sqrt{gH}} = \varphi\left[D/H, \pi_1 \frac{\mu}{H\rho V}\right] \quad (\text{or})$$

$$V = \sqrt{2gH}\ \varphi\left[D/H, \frac{\mu}{\rho V H}\right]$$

Multiplying by a constant does not change the character of π- terms.

2. The Power developed by hydraulic machine is found to depend on the head H, flow rate Q, density ρ, speed N, runner diameter D and acceleration due to gravity g. Obtain suitable dimensionless parameters to correlate experimental results. [16]

[Nov/DEC - 2014]
May/June - 2012

Solution:

$$P = f(H, Q, \rho, N, D, g) \longrightarrow (1)$$

$$f_1(P, H, Q, \rho, N, D, g) = 0 \longrightarrow (2)$$

Total. no. of Variables $n = 7$.

No. of fundamental dimensions $m = 3$

$\therefore$ No. of π - terms $= n - m$

$= 7 - 3 \Rightarrow 4.$

$f_1 (\pi_1, \pi_2, \pi_3, \pi_4) = 0 \longrightarrow (iii)$

$\pi_1 = H^{a_1} . N^{b_1} . \rho^{c_1} . P \longrightarrow ①$

$\pi_2 = H^{a_2} . N^{b_2} . \rho^{c_2} . Q \longrightarrow ②$

$\pi_3 = H^{a_3} . N^{b_3} . \rho^{c_3} . g \longrightarrow ③$

$\pi_4 = H^{a_4} . N^{b_4} . \rho^{c_4} . D \longrightarrow ④$

dimensions of each variables.

$H = L \; ; \quad N = T^{-1} \; ; \quad \rho = ML^{-3}$

$P = ML^2 T^{-3}, \quad Q = L^3 T^{-1}, \quad g = LT^{-2}, \quad D = L.$

First π. term :

$\pi_1 = H^{a_1} . N^{b_1} . \rho^{c_1} . P . \longrightarrow ①$

applying dimensions on both sides

$M^0 L^0 T^0 = L^{a_1} . (T^{-1})^{b_1} . (ML^{-3})^{c_1} . ML^2 T^{-3}.$

Equating Power of M, L, T on both.

Power of M $= 0 = c_1 + 1$; $\boxed{c_1 = -1}$

Power of L $= 0 = a_1 - 3c_1 + 2$

$a_1 = 3c_1 - 2$

$= -3 - 2$

$\boxed{a_1 = -5}$

Power of T $= 0 = -b_1 - 3$

$$\boxed{b_1 = -3}$$

Substituting a_1, b_1, c_1 value in equation ①.

$$\pi_1 = H^{-5} \cdot N^{-3} \cdot \rho^{-1} \cdot P$$

$$\pi_1 = \frac{P}{H^5 N^3 \rho}$$

Second π-term:

$$\pi_2 = H^{a_2} \cdot N^{b_2} \cdot \rho^{c_2} \cdot Q \longrightarrow ②$$

applying dimension on both sides,

$$M^0 L^0 T^0 = (L)^{a_2} \cdot (T^{-1})^{b_2} \cdot (ML^{-3})^{c_2} \cdot L^3 T^{-1}$$

Equating Power of M, L, T on both sides.

Power of M $= \boxed{c_2 = 0}$

Power of L $= a_2 - 3c_2 + 3 = 0$

$$a_2 = 3c_2 - 3$$

$$\boxed{a_2 = -3}$$

Power of T $= -b_2 - 1$

$$\boxed{b_2 = -1}$$

Substituting a_2, b_2, c_2 value in equation ②

$$\pi_2 = (H)^{-3} \cdot N^{-1} \cdot \rho^{0} \cdot Q$$

$$\boxed{\pi_2 = \frac{Q}{H^3 N}}$$

Third π-term:

$$\pi_3 = (H)^{a_3} \cdot (N)^{b_3} \cdot \rho^{c_3} \cdot g \longrightarrow ③$$

applying dimension on both sides,

$$M^0 L^0 T^0 = (L)^{a_3} \cdot (T^{-1})^{b_3} \cdot (ML^{-3})^{c_3} \cdot LT^{-2}$$

Power of M = $\boxed{c_3 = 0}$

Power of L = $a_3 - 3c_3 + 1$

$a_3 = 3c_3 - 1$; $\boxed{a_3 = -1}$

Power of T = $-b_3 - 2$; $\boxed{b_3 = -2}$

Substituting a_3, b_3, c_3 value in equ (3)

$$\Pi_3 = H^{-1}, N^{-2}, \rho^0 . g.$$

$$\boxed{\Pi_3 = \frac{g}{N^2 H}}$$

Fourth Π- term :

$$\Pi_4 = (H)^{a_4} . (N)^{b_4} . (\rho)^{c_4} . D \longrightarrow (4)$$

applying dimension on both sides,

$$M^0 L^0 T^0 = (L)^{a_4} . (T^{-1})^{b_4} . (ML^{-3})^{c_4} . L$$

equating the power of M, L, T on both.

Power of M = $\boxed{c_4 = 0}$

Power of L = $a_4 - 3c_4 + 1$

$a_4 = 0 - 1$

$\boxed{a_4 = -1}$

Power of T = $-b_4 = 0$. ; $\boxed{b_4 = 0}$

Substituting a_4, b_4, c_4 values on equ (4)

$$\Pi_4 = H^{-1} . N^0 . \rho^0 . D$$

$$\boxed{\Pi_4 = D/H}$$

Substitute Π values in equation. (ii)

$$f(\Pi_1, \Pi_2, \Pi_3, \Pi_4) = 0.$$

$$f\left[\frac{P}{H^5 . N^3 . \rho}, \frac{Q}{H^3 . N}, \frac{g}{N^2 H}, \frac{D}{H}\right] = 0.$$

$$\frac{P}{H^5 . N^3 . \rho} = \phi\left[\frac{Q}{H^3 . N}, \frac{g}{N^2 . H}, \frac{D}{H}\right]$$

$$P = H^5 N^3 \rho \; \phi\left[\frac{Q}{H^3 . N}, \frac{g}{N^2 . H}, \frac{D}{H}\right]$$

3. Derive on the basis of dimensional analysis suitable parameters to present the thrust developed by a propeller. Assume that the thrust P depends on the angular velocity ω, speed of advance V, diameters D, dynamic viscosity μ, mass density ρ, and elasticity of the fluid medium which can be denoted by the speed of sound in the medium 'c'. [16] [Nov/Dec – 2012]

Solution:

Thrust P is a function of $\omega, V, D, \mu, \rho, c$.

$$P = f(\omega, V, D, \mu, \rho, c) \longrightarrow (i)$$

$$f_1(P, \omega, V, D, \mu, \rho, c) = 0 \longrightarrow (ii)$$

$\therefore$ Total no. of variables $n = 7$.

dimensions of each variable,

$P = MLT^{-2}$; $\omega = T^{-1}$; $V = LT^{-1}$; $D = L$.

$\mu = ML^{-1}T^{-1}$; $\rho = ML^{-3}$; $c = LT^{-1}$

$\therefore$ No. of fundamental dimensions, $m = 3$.

Total. No. of π - terms $= n - m \Rightarrow 7 - 3$

$\Rightarrow 4$

Hence equation ① can be written as,

$$f_1(\pi_1, \pi_2, \pi_3, \pi_4) = 0 \rightarrow (iii)$$

$$\pi_1 = D^{a_1} \cdot V^{b_1} \cdot \rho^{c_1} \cdot P$$

$$\pi_2 = D^{a_2} \cdot V^{b_2} \cdot \rho^{c_2} \cdot \omega$$

$$\pi_3 = D^{a_3} \cdot V^{b_3} \cdot \rho^{c_3} \cdot \mu$$

$$\pi_4 = D^{a_4} \cdot V^{b_4} \cdot \rho^{c_4} \cdot C$$

First π-term;

$$\pi_1 = D^{a_1} \cdot V^{b_1} \cdot \rho^{c_1} \cdot P \rightarrow ①$$

applying dimensions on both sides,

Equating power of M, L, T on both sides,

Power of M $= 0 = c_1 + 1$; $\boxed{c_1 = -1}$

Power of L $= 0 = a_1 + b_1 - 3c_1 + 1$

$a_1 = -b_1 + 3c_1 - 1$

$= 2 - 3 - 1 = -2$. $\boxed{a_1 = -2}$

Power of T $= 0 = -b_1 - 2$

$\boxed{b_1 = -2}$

Substituting the values of a_1, b_1 & c_1 in eqn ①

$$\pi_1 = D^{-2} \cdot V^{-2} \cdot \rho^{-1} \cdot P$$

$$\boxed{\pi_1 = \frac{P}{D^2 V^2 \cdot \rho}}$$

Second π-term: $\pi_2 = D^{a_2} \cdot V^{b_2} \cdot \rho^{c_2} \cdot \omega$

applying dimension on both sides,

$$M^0 L^0 T^0 = L^{a_2} \cdot (LT^{-1})^{b_2} \cdot (ML^{-3})^{c_2} \cdot T^{-1}$$

Equating the power of M, L, T on both,

Power of M = 0 = c_2 ; $\boxed{c_2 = 0}$

Power of L = 0 = $a_2 + b_2 - 3c_2$

$a_2 = -b_2 + 3c_2$.

$= 1 + 0 = 1$

$\boxed{a_2 = 1}$

Power of T = 0 = $-b_2 - 1$

$\boxed{b_2 = -1}$

Substituting the value of a_2, b_2, c_2 in π_2.

$\pi_2 = D^1 . V^{-1} . \rho^0 . \omega$

$$\boxed{\pi_2 = \frac{D\omega}{V}}$$

Third π-term:

$\pi_3 = D^{a_3} . V^{b_3} . \rho^{c_3} . \mu . \longrightarrow$ (3)

applying dimension on both,

$M^0 L^0 T^0 = L^{a_3} . (LT^{-1})^{b_3} . (ML^{-3})^{c_3} . ML^{-1}T^{-1}$

Equating the power of M, L, & T on both,

Power of M = 0 = $c_3 + 1$; $\boxed{c_3 = -1}$

Power of L = 0 = $a_3 + b_3 - 3c_3 - 1$

$a_3 = -b_3 + 3c_3 + 1$

$= 1 - 3 + 1 = -1$

$\boxed{a_3 = -1}$

Power of T = 0 = $-b_3 - 1$

$\boxed{b_3 = -1}$

Substituting the values of a_3, b_3 & c_3 in π_3

$\pi_3 = D^{-1} . V^{-1} . \rho^{-1} . \mu$

$$\boxed{\pi_3 = \frac{\mu}{DV\rho}}$$

Fourth π - term :

$$\pi_4 = D^{a_4} . V^{b_4} . \rho^{c_4} . c .$$

applying dimensions on both sides,

$$M^0L^0T^0 = L^{a_4} . (LT^{-1})^{b_4} . (ML^{-3})^{c_4} . LT^{-1}$$

Equating the power of M, L, T on both sides.

Power of M = $0 = c_4$; $\boxed{c_4 = 0}$

Power of L = $0 = a_4 + b_4 - 3c_4 + 1$

$$a_4 = -b_4 + 3c_4 - 1$$
$$= 1 + 0 - 1 = 0$$
$$\boxed{a_4 = 0}$$

Power of T = $0 = -b_4 - 1$

$$\boxed{b_4 = -1}$$

Substituting the values of a_4, b_4, c_4 in eqn (A)

$$\pi_4 = D^0 . V^{-1} . \rho^0 . c = c/V$$

$$\boxed{\pi_4 = c/V}$$

Substituting the values of π_1, π_2, π_3 & π_4 in eqn (iii)

$$f_1\left(\frac{P}{D^2V^2.\rho}, \frac{D\omega}{V}, \frac{\mu}{DV\rho}, \frac{c}{V}\right) = 0 \quad (\text{or})$$

$$\frac{P}{D^2V^2.\rho} = \phi\left[\frac{D\omega}{V}, \frac{\mu}{DV\rho}, \frac{c}{V}\right] \quad (\text{or})$$

$$P = D^2V^2\rho\ \phi\left[\frac{D\omega}{V}, \frac{\mu}{DV\rho}, \frac{c}{V}\right]$$

4. A pipe of diameter 1.5m is required to transport an oil of sp. gr. 0.90 and viscosity 3×10^{-2} poise at the rate of 3000 l/s. Tests were conducted on a 15cm dia pipe using water at 20°c. Find velocity & rate of flow in model. Viscosity of water at 20°c = 0.01 poise (16)
[NOV/DEC - 2012]

Given:

Dia of Prototype $(D_p) = 1.5m$.

Viscosity of prototype (μ_p) = 3×10^{-2} poise

$Q_p = 3000$ l/s ; 3 m^3/s

$S_p = 0.9$

∴ Density of Prototype $(\rho_p) = S_p \times 1000$
$= 0.9 \times 1000$
$= 900$ kg/m^3.

Find:

Velocity & rate of flow in model.

$V_m = ?$

$Q_m = ?$

Formula required:

Using Reynold's model law.

$$\frac{\rho_m \cdot V_m \cdot D_m}{\mu_m} = \frac{\rho_p V_p D_p}{\mu_p}$$

$$Q_m = A_m \times V_m$$

Solution:

For pipe flow, the dynamic similarity will be obtained if the Reynold's Number in the model & prototype are equal.

Hence using equation.,

$$\frac{\rho_m V_m D_m}{\mu_m} = \frac{\rho_p V_p D_p}{\mu_p}$$

$$\therefore \frac{V_m}{V_p} = \frac{\rho_p}{\rho_m} \cdot \frac{D_p}{D_m} \cdot \frac{\mu_m}{\mu_p}$$ [For pipe, linear Dimension is D]

$$= \frac{900}{1000} \times \frac{1.5}{0.15} \times \frac{1\times10^{-2}}{3\times10^{-2}}$$

$$= \frac{900}{1000} \times 10 \times \frac{1}{3} = 3.0$$

$$V_p = \frac{\text{Rate of flow in Prototype } (Q_p)}{\text{Area of prototype } (A_p)} = \frac{3}{\pi/4 \, (D_p)^2}$$

$$V_p = \frac{3}{\pi/4\,(1.5)^2} \Rightarrow \frac{3\times4}{\pi\times2.25} = 1.697 \text{ m/s}$$

$$V_m = 3\times V_p \Rightarrow 3\times1.697 = 5.091 \text{ m/s}$$

Rate of flow through model $(Q_m) = A_m \times V_m$

$$= \frac{\pi}{4}(D_m)^2 \times V_m$$

$$= \frac{\pi}{4}(0.15)^2 \times 5.091$$

$$= 0.0899 \text{ m}^3/\text{s}$$

$$= 0.0899 \times 1000 \text{ lit/s}$$

$$= 89.9 \text{ lit/s}.$$

Result :

(i) Velocity of model $(V_m) = 5.091$ m/s

(ii) Rate of flow through model $(Q_m) = 89.9$ lit/s.

5. The Efficiency η of a fan depends on the density ρ, the dynamic viscosity μ of the fluid, the angular velocity ω, diameter D of the rotor, and the discharge Q. Express η in terms of dimensionless parameters. Use Rayleigh's method. (16)

[APR/May - 2015]

Solution:

$$\eta = K . \rho^{a} . \mu^{b} . \omega^{c} . D^{d} . Q^{e} \longrightarrow ①$$

Where K = Non dimensional constant.

dimensions of each variables.

$\rho = ML^{-3}$; $\mu = ML^{-1}T^{-1}$; $\omega = T^{-1}$;

$D = L$; $Q = L^{3}T^{-1}$

Substituting the dimensions on both sides in equ ①

$$M^{0}L^{0}T^{0} = K (ML^{-3})^{a} . (ML^{-1}T^{-1})^{b} . (T^{-1})^{c} . (L)^{d} . (L^{3}T^{-1})$$

Power of M, $0 = a + b$

Power of L, $0 = -3a - b + d + 3e$

Power of T, $0 = -b - c - e$

Hence expressing $a, c, \& d$ in terms of $b \& e$, we get,

$a = -b$

$b = -(b+e)$

$d = 3a + b - 3e$

$= -3b + b - 3e$

$= -2b - 3e$.

Substituting a, b, d values in equation ① we get,

$$\eta = K \cdot \rho^{-b} \cdot \mu^{b} \cdot \omega^{-(b+e)} \cdot D^{-2b-3e} \cdot Q^{e}$$

$$= K \cdot \rho^{-b} \cdot \mu^{b} \cdot \omega^{-b} \cdot \omega^{-e} \cdot D^{-2b} \cdot D^{-3e} \cdot Q^{e}$$

Result:

$$= K\left(\frac{\mu}{\rho \omega D^2}\right)^{b} \cdot \left(\frac{Q}{\omega D^3}\right)^{e} = \phi\left[\left(\frac{\mu}{\rho \omega D^2}\right) \cdot \left(\frac{Q}{\omega D^3}\right)\right]$$

6. Using Buckingham's π theorem, show that the velocity through a circular orifice is given by $V = \sqrt{2gH}\, \phi\left[\frac{D}{H}, \frac{\mu}{\rho V H}\right]$, where H is the head causing flow, D is the diameter of the orifice, μ is the co-efficient of viscosity, ρ is the mass density and g is the acceleration due to gravity.

April/May 2017

Solution: Given: V is a function of H, D, μ, ρ, g

$$V = f(H, D, \mu, \rho, g)$$

$$f_1(H, D, \mu, \rho, g, V) = 0 \qquad (1)$$

(i) Total number of fundamental dimensions, m=3.

(ii) Total number of Variables, n=6

$\therefore$ Number of π-terms = n-m = 6-3 = 3.

Equation (1) can be written as,

$$f_1(\pi_1, \pi_2, \pi_3) = 0. \qquad (2)$$

Each π term has m=3 repeating Variables and m+1 = 3+1 = 4 total Variables.

The repeating Variables are H, g, ρ

π terms can be written as,

$$\pi_1 = H^{a_1} g^{b_1} \rho^{c_1} V$$

$$\pi_2 = H^{a_2} g^{b_2} \rho^{c_2} D$$

$$\pi_3 = H^{a_3} g^{b_3} \rho^{c_3} \mu$$

Analysis of π terms:

First π term: $\pi_1 = H^{a_1} g^{b_1} \rho^{c_1} V$

substituting dimensions on both sides,

$$M^0 L^0 T^0 = L^{a_1} (LT^{-2})^{b_1} (ML^{-3})^{c_1} (LT^{-1})$$

Equating powers of M, L, T on both sides

Power of M, $0 = c \quad \therefore c_1 = 0$

Power of L, $0 = a_1 + b_1 - 3c_1 + 1; \quad 0 = a_1 + b_1 + 1, \; 0 = a_1 - \frac{1}{2} + 1$

Power of T, $0 = -2b_1 - 1, \; 2b_1 = -1; \; b_1 = -\frac{1}{2} \quad a_1 = -\frac{1}{2}$

substituting the value of a_1, b_1, c_1 in π_1

$$\pi_1 = H^{-1/2} g^{-1/2} \rho^0 . V$$

$$\pi_1 = \frac{V}{\sqrt{gH}}$$

Second π term:

substituting dimensions on both sides,

$$M^0 L^0 T^0 = L^{a_1} (LT^{-2})^{b_1} (ML^{-3})^{c_1} L$$

Equating powers of M, L, T on both sides

Power of M, $0 = c_1 \Rightarrow c_1 = 0$

Power of L, $0 = a_1 + b_1 - 3c_1 + 1 \Rightarrow 0 = a_1 + 1 \Rightarrow a_1 = -1$

Power of T, $0 = -2b_1 \Rightarrow b_1 = 0$

substituting a_1, b_1, c_1 in π_2

$$\pi_2 = H^{-1} g^0 \rho^0 D$$

$$\pi_2 = \frac{D}{H}$$

Third π term:

substituting the dimensions on both sides.

$$M^0 L^0 T^0 = L^{a_3} (LT^{-2})^{b_3} (ML^{-3})^{c_3} ML^{-1} T^{-1}$$

Equating powers of M, L, T on both sides,

Power of M, $0 = c_3 + 1 \Rightarrow c_3 = -1$

Power of L, $0 = a_3 + b_3 - 3c_3 - 1 \Rightarrow 0 = a_3 - \frac{1}{2} + 2 \Rightarrow a_3 = -\frac{3}{2}$

Power of T, $0 = -2b_3 - 1 \Rightarrow b_3 = -\frac{1}{2}$

Substituting the values of a_3, b_3 and c_3 in π_3

$$\pi_3 = H^{-3/2} g^{-1/2} \rho^{-1} \mu$$

$$= \frac{\mu}{H^{3/2}\sqrt{g}\,\rho}$$

$$= \frac{\mu}{H\sqrt{H}\sqrt{g}\,\rho} \Rightarrow \frac{\mu}{H\rho\sqrt{gH}} \Rightarrow \frac{\mu}{HV\rho} \cdot \frac{V}{\sqrt{gH}}$$

$$\pi_3 = \frac{\mu}{HV\rho} \cdot \pi_1$$

Substituting π_1, π_2 and π_3 in equation (2),

$$f_1\left(\frac{V}{\sqrt{gH}}, \frac{D}{H}, \pi_1 \frac{\mu}{HV\rho}\right) = 0;$$

$$\frac{V}{\sqrt{gH}} = \phi\left[\frac{D}{H}, \pi_1 \frac{\mu}{HV\rho}\right]$$

$\times \frac{1}{\sqrt{2}}$

$$\frac{V}{\sqrt{2gH}} = \phi\left[\frac{D}{H}, \frac{\mu}{HV\rho}\right]$$

$$V = \sqrt{2gH}\;\phi\left[\frac{D}{H}, \frac{\mu}{HV\rho}\right]$$

Multiplying by a constant does not change the character of π-terms.

7. The pressure difference Δp in a pipe of diameter D and length l due to turbulent flow depends on the velocity V, viscosity μ, density ρ and roughness k. Using Buckingham's π theorem obtain an expression for Δp.

Nov/Dec 2016

Solution: Given $\Delta p = f(D, l, V, \mu, \rho, k)$

$$\Rightarrow f_1(D, l, V, \mu, \rho, k, \Delta p) = 0 \quad \text{---(1)}$$

Dimensions:

$\Delta p - ML^{-1}T^{-2}$

$D - L$ $\quad \mu - ML^{-1}T^{-1}$

$l - L$ $\quad \rho - ML^{-3}$

$V - LT^{-1}$ $\quad k - L$

No. of variables, $n = 7$

No. of fundamental dimensions, $m = 3$

No. of π-terms $= n - m = 7 - 3 = 4$.

Eqn. (1) can be written as. $f_1(\pi_1, \pi_2, \pi_3, \pi_4) = 0$;

π-terms:

$$\pi_1 = D^{a_1} V^{b_1} \rho^{c_1} \Delta p$$

$$\pi_2 = D^{a_2} V^{b_2} \rho^{c_2} \lambda$$

$$\pi_3 = D^{a_3} V^{b_3} \rho^{c_3} \mu$$

$$\pi_4 = D^{a_4} V^{b_4} \rho^{c_4} k$$

Results:

$$\pi_1 = \frac{\Delta p}{\rho V^2} \qquad \pi_3 = \frac{\mu}{DV\rho}$$

$$\pi_2 = \frac{l}{D} \qquad \pi_4 = \frac{K}{D}$$

$$\frac{\Delta p}{\rho V^2} = \phi\left[\frac{l}{D}, \frac{\mu}{DV\rho}, \frac{K}{D}\right]$$

PART-C

1. The aerodynamic drag of a new sports car is to be predicted at a speed of 50.0 mi/h at an air temperature of 25°C. Automotive engineers build a one- fifth scale model of the car to test in a wind tunnel. It is winter and the wind tunnel is located in an unheated building; the temperature of the wind tunnel air is only about 5°C. Determine how fast the engineers should run the wind tunnel in order to achieve similarity between the model and the prototype.

SOLUTION

We are to utilize the concept of similarity to determine the speed of the wind tunnel. Assumptions 1. Compressibility of the air is negligible (the validity of this approximation is discussed later). 2. The wind tunnel walls are far enough away so as to not interfere with the aerodynamic drag on the model car. 3. The model is geometrically similar to the prototype. 4. The wind tunnel has a moving belt to simulate the ground under the car, as in Fig. (The moving belt is necessary in order to achieve kinematic similarity everywhere in the flow, in particular underneath the car.)

Properties

For air at atmospheric pressure and at T = 25°C, ρ = 1.184 kg/m^3 and μ= 1.849x 10^{-5} kg/m.s. Similarly, at T = 5°C, ρ = 1.269 kg/m3 and μ = 1.754x 10^{-5} kg/m · s.

Since there is only one independent π in this problem, the similarity equation holds if $\pi_{2m} = \pi_{2\rho}$

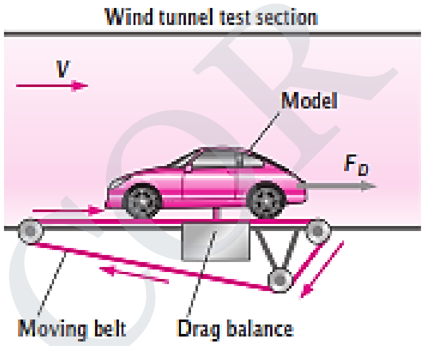
$$\Pi_{2,m} = Re_m = \frac{\rho_m V_m L_m}{\mu_m} = \Pi_{2,p} = Re_p = \frac{\rho_p V_p L_p}{\mu_p}$$

which can be solved for the unknown wind tunnel speed for the model tests, Vm,

$$V_m = V_p\,(\mu_m/\mu_p)(\rho_p/\rho_m)(L_p/L_m)$$

Substituting the values we have,

$$\mathbf{V_m = 221\ m/h}$$



Thus, to ensure similarity, the wind tunnel should be run at 221 mi/h (to three significant digits). Note that we were never given the actual length of either car, but the ratio of Lp to Lm is known because the prototype is five times larger than the scale model. When the dimensional parameters are rearranged as non-dimensional ratios (as done here), the unit system is irrelevant. Since the units in each numerator cancel those in each denominator, no unit conversions are necessary.

UNIT –IV

PUMPS

1. **What is meant by Cavitations? Nov/Dec 15**

   It is defined phenomenon of formation of vapor bubbles of a flowing liquid in a region where the pressure of the liquid falls below its vapor pressure and the sudden collapsing of theses vapor bubbles in a region of high pressure.

2. **Define Slip of reciprocating pump. When the negative slip does occur?**

   (Nov/Dec 15,12,May/June 14)

   The difference between the theoretical discharge and actual discharge is called slip of the pump.

   But in sometimes actual discharge may be higher then theoretical discharge, in such a case coefficient of discharge is greater then unity and the slip will be negative called as negative slip.

3. **What is meant by NSPH? (Nov/Dec 14,May/june 14)**

   Is defined as the absolute pressure head at the inlet to the pump, minus the vapour pressure head plus velocity head

4. **What is indicator diagram? (May/june 09)**

   Indicator diagram is nothing but a graph plotted between the pressure head in the cylinder and the distance traveled by the piston from inner dead center for one complete revolution of the crank

5. **What are rotary pumps? (May/june 11)**

   Rotary pumps resemble like a centrifugal pumps in appearance. But the working method differs. Uniform discharge and positive displacement can be obtained by using these rotary pumps, It has the combined advantages of both centrifugal and reciprocating pumps.

6. **What is meant by Priming? (April/may 08)**

   The delivery valve is closed and the suction pipe, casing and portion of the delivery pipe upto delivery valve are completely filled with the liquid so that no air pocket is left. This is called as priming.

7. **Define speed ratio, flow ratio** **(Nov/Dec 12)**

Speed ratio: It is the ratio of peripheral speed at outlet to the theoretical velocity of jet corresponding to manometric head.

Flow ratio: It is the ratio of the velocity of flow at exit to the theoretical velocity of jet corresponding to manometric head.

8. **Mention the main parts of the centrifugal pump.**

(Nov/Dec 12)

1. Impeller
2. Casing
3. Suction pipe with foot valve and a strainer
4. Delivery pipe

9. **What is an air vessel? What are its uses?**

May/june 12,Nov/Dec 10)

It is a closed chamber containing compressed air in the top portion and liquid at the bottom of the chamber

Uses

To obtain a continuous supply of liquid at a uniform rate

To save a considerable amount of work in overcoming the frictional resistance in the suction pipe

10. **Specific speed of a centrifugal pump.** **(Nov/Dec 09)**

It is defined as the speed of a geometrically similar pump which would deliver one cubic metre of liquid per second against a head of one metre.it is denoted by 'N_S'

PART-B

1. The cylinder bore diameter of a single-acting reciprocating pump is 150mm and it's stroke is 300mm. The pump runs at 50 rpm and lifts water through a height of 25m. The delivery pipe 22m long & 100 mm in diameter. find the discharge and the theoritical power required to run the pump. If actual discharge 4.2 l/s. Find the percentage of slip. (16) [Nov/Dec - 2012]
Also determine the acceleration head at the begining & middle of the delivery stroke.

Given:

diameter (d) = 150 mm = 0.15m

Length of stroke (L) : 300mm = 0.3m

Speed (N) = 50 r.p.m.

Height (H) : 25m

Length of delivery pipe (l_d) = 22m

dia. of delivery pipe (d_d) = 100 mm = 0.1m

Actual discharge Q_{act} = 4.2 l/s = 0.0042 m^3/s.

Find:

(i) Theoretical discharge (Q_{th})

(ii) Theoretical power (P)

(iii) percentage of slip (%)

Formula:

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

(ii) $P = \frac{\rho g Q_{th} \times H}{1000}$

(iii) % of slip $= \left(\frac{Q_t - Q_a}{Q_t}\right) \times 100$

Solution:

(i) Theoretical discharge (Q_{th})

$$Q_{th} = \frac{ALN}{60}$$

$$A = \frac{\pi}{4}(d^2)$$

$$= \frac{\pi}{4}(0.15)^2$$

$$= 0.1767\, m^2.$$

$$Q_{th} = \frac{0.1767 \times 0.3 \times 50}{60} \Rightarrow 0.0044175\ m^3/s$$

$$\boxed{Q_{th} = 4.417\ l/s}$$

(ii) Theoretical Power (P) $= \frac{\rho g Q_{th} \times H}{1000}$ (or) $\frac{\left(\frac{\text{workdone}}{\text{sec}}\right)}{1000}$

$$= \frac{1000 \times 9.81 \times 0.00441 \times 25}{1000}$$

$$\boxed{\text{Power (P)} = 1.0833\ kW}$$

(iii) Percentage of slip (%) $= \left(\frac{Q_{th} - Q_{act}}{Q_{th}}\right) \times 100$

$$= \left(\frac{4.4175 - 4.2}{4.4175}\right) \times 100 \Rightarrow 4.92\ \%$$

$$\boxed{\%\ \text{of slip} = 4.92\ \%}$$

$Q_{th} = 4.417\ l/s$
$P = 1.0833\ kW$
% of slip $= 4.92\ \%$

(iv) Acceleration head at the beginning of delivery stroke

$$h_{ad} = \frac{l_d}{g} \times \frac{A}{a_d} \times \omega^2 r \cdot \cos\theta$$

$$a_d = \pi/4\ (0.1)^2 = 0.007854$$

$$\omega = \frac{2\pi N}{60} \Rightarrow \frac{2\pi \times 50}{60} \Rightarrow 5.236\ r/s$$

$$\boxed{\omega = 5.236\ rad/s}$$

$$r = \frac{H}{2} = \frac{0.3}{2} \Rightarrow 0.15\ m$$

$$h_{ad} = \frac{22}{9.81} \times \frac{0.01767}{0.007854} \times 5.236^2 \times 0.15 \times \cos\theta$$

$$= 20.75 \times \cos\theta$$

At the beginning of delivery stroke $\theta = 0°$ & hence $\cos\theta = 1$

$$\boxed{h_{ad} = 20.75\,m} \qquad [\because \cos\theta = 1]$$

(v) Acceleration head at the middle of delivery stroke

$\theta = 90°$ and hence $\cos\theta = 0$

$\therefore\ h_{ad} = 20.75 \times 0$

$$\boxed{h_{ad} = 0}$$

Result :

$Q_{th} = 4.417\ l/s$ $\quad$ h_{ad} at begining $= 20.75m$

$P = 1.0833\ KW$ $\quad$ h_{ad} at middle $= 0$

% of slip $= 4.92\%$

2. A single acting reciprocating pump running at 50 r.p.m delivers $0.01\ m^3/sec$ of water. The diameter of the piston is 20 cm & stroke length 40cm. Determine.

(i) The Theoretical discharge of the pump

(ii) Co-efficient of discharge.

(iii) Slip of the pump. (16) [NOV/Dec - 2008]

Given :

Speed of the pump (N) = 50 r.p.m

Actual discharge $(Q_a) = 0.01\ m^3/s$

Dia. of Piston (D) = 200mm = 0.20m

$$\text{Area } (A) = \frac{\pi}{4}(0.2)^2$$

$$= 0.0314\ m^2$$

$$L = 400mm = 0.40m$$

Find :

(i) Theoretical discharge

(ii) Co-efficient of discharge

(iii) Slip of the pump.

Formula:

$$Q_t = \frac{ALN}{60}$$

$$C_d = \frac{Q_{act}}{Q_t}$$

$$Slip = Q_{th} - Q_{act}$$

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

$$= \frac{0.031416 \times 0.40 \times 50}{60}$$

$$= 0.01047 \ m^3/s.$$

(ii) Co-efficient of discharge

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

(iii) Slip $= Q_{th} - Q_{act}$

$$= 0.01047 - 0.01$$

$$= 0.00047 \ m^3/s$$

Result:

(i) Theoretical Discharge $(Q_{th}) = 0.01047 \ m^3/s$

(ii) Coefficient of discharge $(C_d) = 0.955$

(iii) Slip of the reciprocating pump is $= 0.00047 m^3/s$.

3. The Internal and external diameter of Impeller of a Centrifugal pump are 200mm & 400mm respectively. The Pump is running at 1200 rpm. The Vane angles of cylinder at Inlet and outlet are 20° & 30° respectively. The water enters Impeller radially & velocity of flow is constant. Determine Workdone by Impeller per unit weight of water (16) [NOV/DEC - 2012]

Given:

$$D_1 = 200mm = 0.20m$$

$$D_2 = 400mm = 0.40m$$

$N = 1200$ rpm.

$\theta = 20^\circ$; $\varphi = 30^\circ$

Find:

(i) workdone by Impeller.

Formula:

$$W = \frac{1}{g} V_{w_2} u_2 .$$

Solution:

$\alpha = 90^\circ$ and $V_{w_1} = 0$

$\because V_{f_1} = V_{f_2}$.

$$U_1 = \frac{\pi D_1 N}{60} = \frac{\pi \times 0.20 \times 1200}{60}$$

$$\boxed{U_1 = 12.56 \text{ m/s}}$$

$$U_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 0.40 \times 1200}{60}$$

$$\boxed{U_2 = 25.13 \text{ m/s}}$$

$$\tan\theta = \frac{V_{f_1}}{U_1} = \frac{V_{f_1}}{12.56}$$

$$V_{f_1} = 12.56 \times \tan 20^\circ$$

$$= 4.57 \text{ m/s}$$

$$\boxed{V_{f_1} = V_{f_2} = 4.57 \text{ m/s}}$$

$$\tan\varphi = \frac{V_{f_2}}{U_2 - V_{w_2}} = \frac{4.57}{25.13 - V_{w_2}}$$

$$25.13 - V_{w_2} = \frac{4.57}{\tan\varphi}$$

$$25.13 - V_{w_2} = \frac{4.57}{\tan 30}$$

$$V_{w_2} = 25.13 - 7.915$$

$$\boxed{V_{w_2} = 17.215 \text{ m/s}}$$

Work done by Impeller,

$$W = \frac{1}{g} V_{w_2} U_2$$

$$= \frac{17.215 \times 25.13}{9.81}$$

$$= 44.1 \text{ Nm/s}$$

Result :

Workdone by the Impeller = 44.1 Nm/s.

4. A centrifugal pump delivers water against a net head of 14.5 meters and a design speed of 1000 rpm. The vanes are curved back to an angle of 30° with the periphery. The Impeller diameter is 300 mm and outlet width 50 mm. Determine the discharge of the pump if Manometric Efficiency is 95%.

Given:

Net head $(H_m) = 14.5$ m

Speed $N = 1000$ r.p.m

Vane angle at outlet $\phi = 30°$

Diameter $D_2 = 300$ mm $= 0.30$ m

Out let width $B_2 = 50$ mm $= 0.05$ m

Manometric Efficiency. $\eta_{man} = 95\% = 0.95$

Find :

Discharge of the pump $(Q) = ?$

Formula :

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

Solution : Tangential velocity of Impeller at outlet $(U_2) = \frac{\pi D_2 N}{60}$

$$= \frac{\pi \times 0.30 \times 1000}{60} \Rightarrow 15.70 \text{ m/s}$$

$$\boxed{U_2 = 15.70 \text{ m/s}}$$

$$\eta_{man} = \frac{g H_m}{V_{w_2} \times U_2}$$

$$0.95 = \frac{9.81 \times 14.5}{V_{w_2} \times 15.70} \quad ; \quad \boxed{V_{w_2} = 9.54 \text{ m/s}}$$

From outlet velocity triangle, we have

$$\tan\phi = \frac{V_{f_2}}{u_2 - V_{w_2}} \Rightarrow \tan 30^\circ = \frac{V_{f_2}}{(15.70 - 9.54)}$$

$$\tan 30^\circ = \frac{V_{f_2}}{6.16} \; ; \quad \because V_{f_2} = 6.16 \times \tan 30^\circ$$

$$\boxed{V_{f_2} = 3.556 \text{ m/s}}$$

Discharge of the pump $(Q) = \pi D_2 B_2 \times V_{f_2}$

$= \pi \times 0.30 \times 0.55 \times 3.55$

$= 0.1840 \text{ m}^3/\text{s}$

Result:

Discharge of the centrifugal pump is $(Q) = 0.1840 \text{ m}^3/\text{s}$

5. The length & diameter of a suction pipe of a single acting reciprocating pump are 5m & 10cm respectively. The pump has a plunger of diameter 15cm & a stroke length of 35cm. The center of the pump is 3m above the water surface in the pump. The atmospheric pressure head is 10.3m of water. and pump is running at 35 r.p.m (16) [NOV/DEC -2011]

Determine,

(i) Pressure head due to acceleration at the begining of the suction stroke.

(ii) Max. Pressure head due to acceleration, and

(iii) Pressure head in the cylinder at the beginning & at the end of the stroke.

Given:

Length of suction pipe $(l_s) = 5\text{m}$.

Dia. of suction pipe $(d_s) = 10\text{cm} = 0.1\text{m}$.

$$\therefore \text{Area } (a_s) = \frac{\pi}{4}(d_s)^2$$

$$= \frac{\pi}{4}(0.1)^2 = 0.007854 \text{ m}^2$$

Dia of plunger $D = 15\text{cm} = 0.15\text{m}$.

$\therefore$ Area of Plunger $A = \frac{\pi}{4} D^2$

$= \frac{\pi}{4} \times 0.15^2$

$= 0.01767 m^2$

Stroke length, $L = 35cm = 0.35 m$

$\therefore$ Crank radius $r = L/2$

$= \frac{0.35}{2} = 0.175 m$

Suction head $(h_s) = 3m$

Atmospheric pressure head, $H_{atm} = 10.3$ m of water.

Speed $(N) = 35$ r.p.m.

Angular speed of the crank is,

$$\omega = \frac{2\pi N}{60} = \frac{2\pi \times 35}{60}$$

$$\omega = 3.665 \text{ rad/s.}$$

(i) The pressure head due to acceleration in the suction pipe

$$h_{as} = \frac{l_s}{g} \times \frac{A}{a_s} \times \omega^2 r \cos\theta .$$

At the beginning of stroke $\theta = 0°$ and hence $\cos\theta = 1$

$$h_{as} = \frac{l_s}{g} \times \frac{A}{a_s} \times \omega^2 r$$

$$= \frac{5}{9.81} \times \frac{0.01767}{0.007854} \times 3.665^2 \times 0.175$$

$$\boxed{h_{as} = 2.695 m}$$

(ii) Max. pressure head due to acceleration in suction pipe

$$(h_{as})_{max} = \frac{l_s}{g} \times \frac{A}{a_s} \omega^2 r.$$

$$(h_{as})_{max} = \frac{5}{9.81} \times \frac{0.01767}{0.007854} \times 3.66^2 \times 0.175$$

$$= 2.695 m$$

(iii) Pressure head in the cylinder at the beginning of the suction stroke

$$= h_s + h_{as}$$
$$= 3 + 2.695 = 5.695.$$

This pressure head in the cylinder is below the atmospheric pressure head.

$\therefore$ Absolute pressure head in the cylinder at the beginning of suction stroke $= H_{atm} - h_{as}$

$$= 10.3 - 5.695$$
$$= 4.605 \text{ m of water (abs.)}$$

(iv) Similarly, The pressure head in the cylinder at the end of suction stroke.

$$= h_s - h_{as}$$
$= 3 - 2.695 = 0.305$ m which is below the atmospheric pressure head.

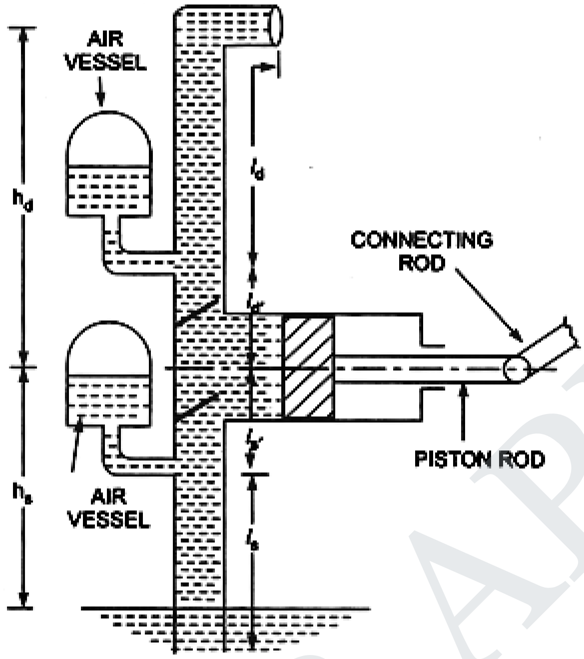
$\therefore$ Absolute pressure head in the cylinder at the end of suction stroke $= H_{atm} - h_{as}$

$$= 10.3 - 0.305$$
$$= 9.995 \text{ m of water (abs.)}$$

6(a) What is an air vessel? Describe the function of the air vessel for reciprocating pump with neat sketch. (8)

It is a closed chamber containing compressed air in the top portion and liquid (or water) at the bottom of the chamber. This is used to obtain a continuous supply of liquid at a uniform rate, to save a considerable amount of work in overcoming the frictional resistance in the suction and delivery pipes and to run the pump at high speed without separation.

The figure shows the single acting reciprocating pump to which air vessels are fitted to the suction and delivery pipes. The air vessels act like an intermediate reservoir. During the first half of the stroke, the piston moves with acceleration, which means the velocity of water in the suction pipe is more than



the mean velocity and hence the discharge of water entering the cylinder will be more than the mean discharge. This excess quantity of water will be supplied from the air vessel to the cylinder in such a way that the velocity in the suction pipe below the air vessel is equal to mean velocity of flow. During the second half of the suction stroke, the piston moves with retardation and hence the velocity of flow n the suction pipe is less than the mean velocity of flow. Thus, the discharge entering the cylinder will be less than the mean discharge. The velocity of water in the suction pipe due to air vessel is equal to mean velocity of flow and discharge required in cylinder is less than the mean discharge. Thus the excess water flowing in suction pipe will be stored into air vessel, which will be supplied during the first half of the stroke.

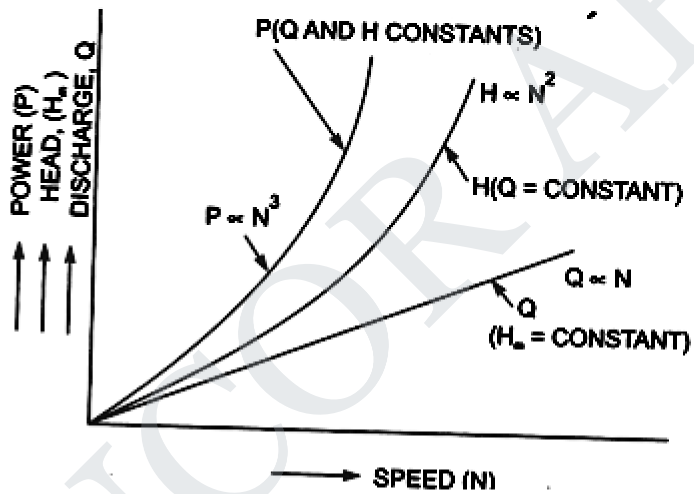
During the second half of the delivery stroke, the piston moves with retardation and the velocity of water in the delivery pipe will be less than the mean velocity. The water already stored into the air vessel will start flowing into the delivery pipe and the velocity of flow in the delivery pipe beyond the point to which air vessel is fitted will become equal to the mean velocity. Hence the rate of flow of water in the delivery pipe will be uniform.

6(b) Draw and discuss the characteristic curves of centrifugal pumps. (8)

Main characteristic curves

The main characteristic curves of a centrifugal pump consists of variation of head H_m, power and discharge with respect to speed. For plotting curves of manometric head versus speed, discharge, is kept constant. For plotting curves of discharge versus speed, manometric head H_m is constant

For plotting the graph of H_m versus speed N, the discharge is kept constant. From equation $H \alpha N^2$.this means that head developed by pump is proportional to the N^2 hence the curve is a parabolic curve. $P \alpha N^3$. This means the curve is a cubic curve $Q \alpha N$ hence it is a straight line.



Operating characteristic curves

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

The input 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 overcome mechanical losses.

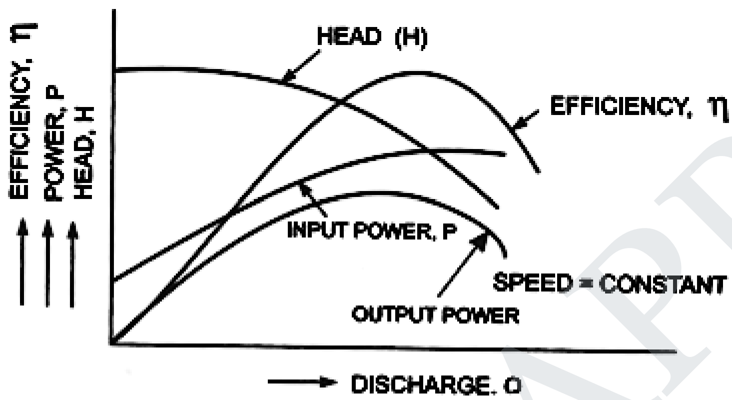
The head curve will have maximum value of head when discharge is zero.

The output power curve will start from origin as at Q=0, output power will be zero.

The efficiency curve will start from the origin as at Q=0,η=0

Constant Efficiency Curves

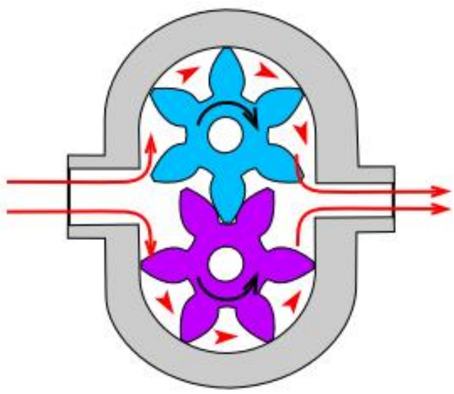
For obtaining constant efficiency curves for the pump, the head versus discharge curves and efficiency versus discharge curves for different speed are used. Fig shows the head versus discharge curves for different speeds. The efficiency versus discharge curves for the different speeds are as shown in Fig. by



combining these curves (H-Q curves and η –Q curves), constant efficiency curves are obtained

For plotting the constant efficiency curves (also known as iso -efficiency curves), horizontal lines representing constant efficiencies are drawn on the η-Q curves. The points, at which these lines cut the efficiency curves at various speed, are transferred to the corresponding H-Q curves. The points having the same efficiency are then joined by smooth curves. These smooth curves represent the iso efficiency curves.

7. Discuss the working of gear pump with its schematic (April/May 2017)



Gear pump-Schematic

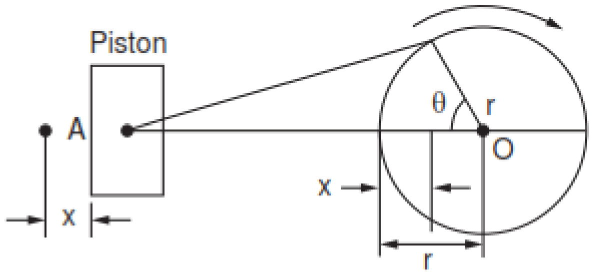
Gear pump is a robust and simple positive displacement pump. It has two meshed gears revolving about their respective axes. These gears are the only moving parts in the pump. They are compact, relatively inexpensive and have few moving parts. The rigid design of the gears and houses allow for very high pressures and the ability to pump highly viscous fluids. They are suitable for a wide range of fluids and offer self-priming performance. Sometimes gear pumps are designed to function as either a motor or a pump. These pump includes helical and herringbone gear sets (instead of spur gears), lobe shaped rotors similar to Roots blowers (commonly used as superchargers), and mechanical designs that allow the stacking of pumps.

Construction:

One of the gears is coupled with a prime mover and is called as driving gear and another is called as driven gear. The rotating gear carries the fluid from the tank to the outlet pipe. The suction side is towards the portion whereas the gear teeth come out of the mesh. When the gears rotate, volume of the chamber expands leading to pressure drop below atmospheric value. Therefore the vacuum is created and the fluid is pushed into the void due to atmospheric pressure. The fluid is trapped between housing and rotating teeth of the gears. The discharge side of pump is towards the portion where the gear teeth run into the mesh and the volume decreases between meshing teeth. The pump has a positive internal seal against leakage; therefore, the fluid is forced into the outlet port. The gear pumps are often equipped with the side wear plate to avoid the leakage. The clearance between gear teeth and housing and between side plate and gear face is very important and plays an important role in preventing leakage. In general, the gap distance is less than 10 micrometers.

8. Derive the expression for pressure head due to acceleration in the suction and delivery pipes of the reciprocating pumps. (Nov/Dec 2016)

The piston in the reciprocating pump has to move from rest when it starts the suction stroke. Hence it has to accelerate. The water in the suction pipe which is also not flowing at this point has to be accelerated. Such acceleration results in a force which when divided by area results as pressure. When the piston passes the mid-point, the velocity gets reduced and so there is retardation of the piston together with the water in the cylinder and the pipe. This again results in a pressure. These pressures are called acceleration pressure and is denoted as head of fluid (h = P/ρg) for convenience.



Configuration of piston crank

Let ω be the angular velocity.

Then at time t, the angle travelled θ = ωt

Distance x = r – r cos θ = r – r cos ωt

Velocity at this point,

$$V = \frac{dx}{dt} = \omega r\ sin\omega t \qquad \_\_\_\_\_\_\_\_ (1)$$

The acceleration at this condition

$$x = \frac{dx}{dt} = \omega^2 r\ cos\omega t \qquad \_\_\_\_\_\_\_\_\_ (2)$$

This is the acceleration in the cylinder of area A. The acceleration in the pipe of area a is,

$$= \frac{A}{a}\ \omega^2 r\ cos\omega t \qquad \_\_\_\_\_\_\_\_\_ (3)$$

Accelerating force = mass × acceleration

Mass in the pipe = ρ al $= \frac{\gamma al}{g}$

$$\text{Acceleration force } = \frac{\gamma al}{g} x \frac{A}{a}\ \omega^2 r\ cos\omega t \qquad \_\_\_\_\_\_\_\_ (4)$$

Pressure = force/area

$$= \frac{\gamma al}{g} x \frac{1}{a} x \frac{A}{a}\ \omega^2 r\ cos\omega t$$

$$= \frac{\gamma l}{g} x \frac{A}{a}\ \omega^2 r\ cos\theta$$

Head = Pressure/γ

$$\mathbf{h_d} = \frac{l}{g} x \frac{A}{a}\ \boldsymbol{\omega^2 r\ cos\theta} \qquad \_\_\_\_\_\_\_\_ \mathbf{(5)}$$

This head is imposed on the piston in addition to the static head at that condition.

PART – C

1. In a single acting reciprocating pump with plunger diameter of 120 mm and stroke of 180 mm running at 60 rpm, an air vessel is fixed at the same level as the pump at a distance of 3 m. The diameter of the delivery pipe is 90 mm and the length is 25 m. Friction factor is 0.02. Determine the reduction in accelerating head and the friction head due to the fitting of air vessel.

Without air vessel:

$$\mathbf{h_d} = \frac{\boldsymbol{l}}{\boldsymbol{g}} \boldsymbol{x} \frac{\boldsymbol{A}}{\boldsymbol{a}} \boldsymbol{\omega^2 r} = \frac{25}{9.81} x \frac{0.12^2}{0.09^2} (\frac{2\pi\, x\, 60}{60})^2 x0.09$$

$= 16.097$ m

With air vessel:

$$h'_{ad} = \frac{3}{9.81} x \frac{0.12^2}{0.09^2} (\frac{2\pi\, x\, 60}{60})^2 x0.09 = 1.932 \text{ m}$$

Reduction = 16.097 - 1.932 = 14.165 m

Fitting air vessel reduces the acceleration head.

Without air vessel:

$$\text{Friction head, } h_f = \frac{\boldsymbol{4flv^2}}{\boldsymbol{2gd}} = \frac{4fl}{2gd} (\frac{A}{a}\ \omega r\ sin\theta)^2$$

At θ = 90°,

$$h_{fmax} = \frac{4\ x\ 0.02\ x\ 25}{2\ x\ 9.81\ x\ 0.09} (\frac{0.12}{0.09}\ \frac{2\pi\ x\ 60}{60}\ x\ 0.09\ x\ 1)^2 = \mathbf{1.145m}$$

With air vessel, the velocity is constant in the pipe.

$$\text{Velocity, } V = \frac{\boldsymbol{LAN}}{\boldsymbol{60}} \boldsymbol{x} \frac{\boldsymbol{4}}{\boldsymbol{\pi d^2}} = \frac{\boldsymbol{\pi x 0.12^2}}{\boldsymbol{4}} \boldsymbol{x} \frac{\boldsymbol{0.18x60x4}}{\boldsymbol{60x\pi x0.09^2}} = \mathbf{0.102\ m/s}$$

$$\text{Friction head, } h_f = \frac{4 \text{ x } 0.02 \text{ x } 25 \text{ x } 0.102^2}{2 \text{ x } 9.81 \text{ x } 0.09} = 0.012\ m$$

$$\text{Percentage saving over maximum, } = \frac{\mathbf{1.145 - 0.012}}{\mathbf{1.145}} \boldsymbol{x}\ \mathbf{100 = 99\%}$$

Thus, Air vessel reduces the frictional loss.

UNIT –V

TURBINES

1. **Define volumetric efficiency? (Nov/Dec14), (Nov/Dec15)**

   It is defined as the volume of water actually striking the buckets to the total water Supplied by the jet

2. **Write short notes on Draft tube? (Nov/Dec15)**

   It is a gradually increasing area which connects the outlet of the runner to the tail race. It is used for discharging water from the exit of the turbine to the tail race.

3. **How are hydraulic turbine classified? (May/june14,April/May 11)**

   1. According to the type of energy
   2. According to the direction of flow
   3. According to the head at inlet
   4. According to the specific speed of the turbine

4. **What is mean by hydraulic efficiency of the turbine? (Nov/Dec13,12)**

   It is ratio between powers developed by the runner to the power supplied to the water jet

5. **Define specific speed of the turbine (April/may 08, May/June 07)**

   The speed at which a turbine runs when it is working under a unit head and develop unit power

6. **What is meant by governing of a turbine?**

   It is defined as the operation by which the speed of the turbine is kept constant under all conditions of working. It is done by oil pressure governor.

7. **List the important characteristic curves of a turbine**

   a. Main characteristics curves or Constant head curves
   b. Operating characteristic curves or Constant speed curves
   c. Muschel curves or Constant efficiency curves

8. Define gross head and net or effective head.

Gross Head: The gross head is the difference between the water level at the reservoir and the level at the tailstock.

Effective Head: The head available at the inlet of the turbine.

9. What is the difference between impulse turbine and Reaction turbine?

(April/May 2011,08)

S.No	Reaction turbine	Impulse turbine
1.	Blades are in action at all the time	Blades are only in action when they are in front of nozzle
2.	Water is admitted over the circumference the wheel	Water may be allowed to enter a part or whole of the wheel circumference

10. Give example for a low head, medium head and high head turbine

(Nov/Dec 09)

Low head turbine – Kaplan turbine

Medium head turbine – Modern Francis

High head turbine – Pelton wheel

11. Explain the type of flow in Francis turbine? (Nov/Dec 2016)

The type of flow in Francis turbine is inward flow with radial discharge at outlet.

12. How do you classify turbine based on flow direction and working medium? (April/May 2017)

According to the direction of flow turbines are classified into

(i) Tangential flow turbine

(ii) Radial flow turbine

(iii) Axial flow turbine

(iv) Mixed flow turbine

According to the working medium turbines are classified into

(i) Gas turbine

(ii) Water turbine

(iii) Steam turbine

PART-B

1. A Pelton wheel has a mean bucket speed of 10 metres per second. with a jet of water flowing at rate of 700 l/s. Under a head of 30 meters. The bucket deflect the jet through an angle 160°. Calculate power again by runner and hydraulic efficiency of turbine. Assume co-efficient of velocity as 0.98. (16)

[NOV/DEC - 2012]

Given:

$U = u_1 = u_2 = 10\ m/s.$

$Q = 700\ l/s = 0.7\ m^3/s.$

$H = 30\ m$

$\phi = 180° - 160° = 20°$

$C_v = 0.98.$

Find:

(i) Power given to turbine (P) = ?

(ii) Hydraulic efficiency of turbine (η_h) = ?

formula:

(i) $\text{Power} = \dfrac{\text{Work done by the jet / second}}{1000}\ kW$

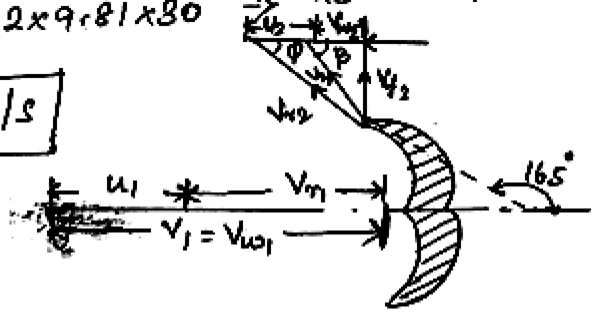
(ii) Hydraulic Efficiency $(\eta_h) = \dfrac{2[V_{w_1} + V_{w_2}] \times U}{(V_1)^2}$

Solution: (i) The velocity of jet $V_1 = C_v\sqrt{2gH}$.

$$V_1 = C_v\sqrt{2gH}.$$

$$= 0.98\sqrt{2\times 9.81\times 30} \Rightarrow 23.77\ m/s$$

$$\boxed{V_1 = 23.77\ m/s}$$



$$V_{r_1} = V_1 - u_1$$

$$V_{r_1} = 23.77 - 10 \Rightarrow 13.77\ m/s.$$

$$\boxed{V_{r_1} = 13.77\ m/s}$$

$$\boxed{V_{w_1} = V_1 = 23.77\ m/s}$$

From outlet velocity triangle,

$$V_{r_2} = V_{r_1} = 13.77\ m/s$$

$$V_{w_2} = V_{r_2}\cos\phi - u_2$$

$$= 13.77\cos 20° - 10.0$$

$$\boxed{V_{w_2} = 2.94\ m/s}$$

(ii) Work done by the jet per second on the runner is given by equation.

$$= \rho a V_1 [V_{w_1} + V_{w_2}] \times u$$

$$= 1000 \times 0.7 \times [23.77 + 2.94] \times 10$$

$$= 186970\ Nm/s \qquad [\because aV_1 = Q = 0.7\ m^3/s]$$

(iii) Power given to turbine $= \dfrac{\text{Work done/sec}}{1000}$ kW

$$\Rightarrow \frac{186970}{1000}$$

$$\Rightarrow 186.97\ kW.$$

(iv) The hydraulic Efficiency of the turbine (η_h) $= \dfrac{2[V_{w_1}+V_{w_2}]\times u}{(V_1)^2}$

$$\Rightarrow \frac{2[28.77 + 2.94]\times 10}{(28.77)^2}$$

$$\Rightarrow 0.9454 \text{ (or) } 94.54\,\%$$

Result :

(i) Power given to turbine (P) $= 186.97$ KW

(ii) The hydraulic efficiency of the turbine (η_h) $= 94.54\,\%$

2. In an Inward radial flow turbine, water enters at an angle of 22° to wheel tangent to outer rim and leaves at 3 m/s. Inner diameter 300mm & outer dia 600 mm. Speed is 300 rpm. The discharge through the runner radial.

Find the, (i) Inlet & outlet blade angles.
(ii) Taking Inlet width as 150mm. Find power developed by the turbine. (16)

[APr/may-2010]

Given:

Guide blade angles $\alpha = 22^\circ$.

Velocity of flow $V_{f_1} = V_{f_2} = 3$ m/s.

$D_1 = 300$mm ; 0.3m.

$D_2 = 600$ mm ; 0.6 m.

$N = 300$ rpm.

$\beta = 90^\circ$ & $V_{w_2} = 0$

Inlet width $(B_1) = 150$mm $= 0.15$ mm.

Find:

(i) Inlet & outlet blade angles.

(ii) Power developed by the turbine.

Formula :

(i) Inlet & outlet velocity triangles

$$\text{Inlet velocity triangle } (\tan\theta) = \frac{V_{f_1}}{V_{w_1} - u_1}$$

$$\text{outlet velocity triangle } (\tan\phi) = \frac{V_{f_2}}{u_1}$$

(ii) $$\text{Power developed } (P) = \frac{\text{workdone per second}}{1000} \text{ kW}.$$

Solu:

Tangential velocity of wheel at Inlet.

$$u_1 = \frac{\pi D_1 N}{60} = \frac{\pi \times 0.3 \times 300}{60}$$

$$u_1 = 4.71 \text{ m/s}.$$

Tangential Velocity of wheel at outlet.

$$u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 0.6 \times 300}{60}$$

$$u_2 = 9.43 \text{ m/s}.$$

Absolute velocity of water at Inlet.

$$V_1 = \frac{V_{f_1}}{\sin\alpha} = \frac{3}{\sin 22} = 8.0084 \text{ m/s}.$$

Velocity of wheel at Inlet.

$$V_{w_1} = V_1 \cos\alpha = 8.0084 \times \cos 22$$

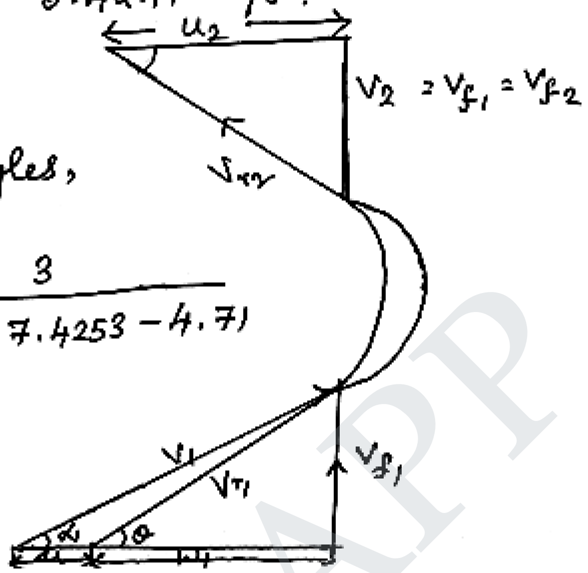
$$V_{w_1} = 7.4253 \text{ m/s}.$$

The Discharge $Q = \pi D_1 B_1 V_{f_1}$

$= \pi \times 0.3 \times 0.15 \times 3$

$= 0.4241\ m^3/s$.

For runner blade angles;



From Inlet velocity triangles,

$$\tan\theta = \frac{V_{f_1}}{V_{w_1} - u_1} = \frac{3}{7.4253 - 4.71}$$

$$\tan\theta = 1.1048$$

$$\theta = 47.85^\circ$$

From outlet velocity triangles,

$$\tan\phi = \frac{V_{f_2}}{u} = \frac{3}{9.43}$$

$$= 0.3181.$$

$$\phi = \tan^{-1}(0.3181)$$

$$\phi = 17.65^\circ.$$

Power developed,

$$P = \frac{\rho Q (V_{w_1} \times u_1)}{1000}$$

$$= \frac{1000 \times 0.4241 (7.4253 \times 4.71)}{1000}$$

$$\boxed{P = 14.83\ \text{Kw}}$$

Result :

(i) Inlet velocity triangle θ } $= 47.85^\circ$

Outlet velocity triangle ϕ $= 17.65^\circ$

(ii) Power developed $(P) = 14.83$ Kw.

3. A Kaplan turbine working under a head of 20m developes 15 MW brake. The hub diameter 1.5m. runner diameter is 4m. The guide blade angle $\eta_h = 0.9$ & $\eta_0 = 0.8$ Find runner vane angles & turbine speed. [16] [Apr/may-2010]

Solution:

$H = 20\,m.$

$P = 15MW = 15000\,KW.$

$D_0 = 4m.$

$D_b = 1.5\,m$

$\alpha = 30^\circ$

$\eta_h = 0.9 = 90\%.$

$\eta_0 = 0.8 = 80\%.$

$\beta = 90^\circ$ & $V_{w_2} = 0$

Find :

$\theta = ?$

vane angles $\phi = ?$

turbine speed $N = ?$

Formula :

(i) $\eta_0 = \dfrac{\text{Shaft power}}{\text{water power}} = \dfrac{S.P}{\rho g Q H}.$

$\eta_0 = 0.80$

(ii) vane angles $\tan\alpha = \dfrac{V_{f_1}}{V_{w_1}}$

$\tan\phi = \dfrac{V_{f_2}}{u_2}$; $\tan\theta = \dfrac{V_{f_1}}{V_{w_1}-u_1}$

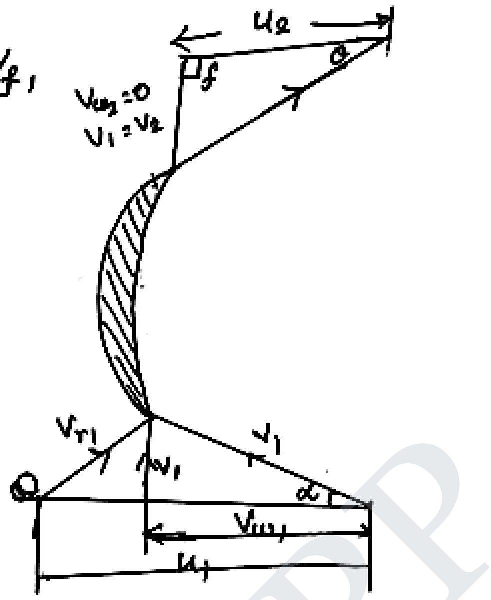
(iii) Speed of the turbine $N = ?$

Solution:

$$\eta_0 = \frac{S.P}{\rho g Q H}$$

We Know than

$$Q = \frac{\pi}{4}(D_a^2 - D_b^2) \times V_{f1}$$



$$95.56 = \frac{\pi}{4}(4^2 - 1.5^2) \times V_{f1}$$

$$\boxed{V_{f1} = 8.8487 \text{ m/s}}$$

From Inlet velocity triangle

$$\tan\alpha = \frac{V_{f1}}{V_{w1}}$$

$$\tan 30^\circ = \frac{8.8487}{V_{w1}}$$

$$\boxed{V_{w1} = 15.33 \text{ m/s}}$$

Hydraulic Efficiency $\eta_h = \dfrac{V_{w1} u_1}{gH}$

$$0.9 = \frac{15.33 \times u_1}{9.81 \times 20}$$

$$\boxed{u_1 = 11.518 \text{ m/s}}$$

$$\tan\theta = \frac{V_{f1}}{V_{w1} - u_1}$$

$$= \frac{8.8487}{15.33 - 11.51}$$

$$= 2.3216$$

$$\tan\theta = 2.3216$$

$$\theta = \tan^{-1}(2.3216)$$

$$= 66.69$$

$$\boxed{\theta = 66.69^\circ}$$

For Kaplan turbine,

$$u_1 = u_2 = 11.518\ m/s$$

$$V_{f_1} = V_{f_2} = 8.8487\ m/s$$

$$\tan\varphi = \frac{V_{f_2}}{u_2} = 0.7682.$$

$$\varphi = \tan^{-1}(0.7682) = 37.53.$$

$$u_1 = \frac{\pi D N}{60.}$$

$$11.51 = \frac{\pi \times 4 \times N}{60}$$

$$\boxed{N = 54.997\ rpm.}$$

Result:

$$\theta = 66.69^\circ$$

$$\varphi = 37.53^\circ$$

$$N = 54.997\ rpm.$$

4. A Francis turbine developing 16120 KW under a head of 260 m runs at 600 rpm. The runner outside diameter is 1500 mm & the width is 135 mm. The flow rate is 7 m³/s. The exit velocity at the draft tube outlet is 16 m/s. Assuming zero whirl velocity at exit and neglecting blade thickness, determine the overall & hydraulic efficiency & rotor blade angle at inlet. Also find the guide vane outlet angle. (16) [Nov/Dec-2014]

Given:

$P = 16120\ KW$; $H = 260m$; $N = 600 rpm$.

$D_2 = 1.5m$; $B = 0.135m$; $Q = 7 m^3/s$.

$V_2 = V_{f_2} = 16 m/s$; $V_{w_2} = 0$.

To Find:

$\eta_0 = ?$; $\eta_h = ?$

$\alpha = ?$; $\varphi = ?$

Solution:

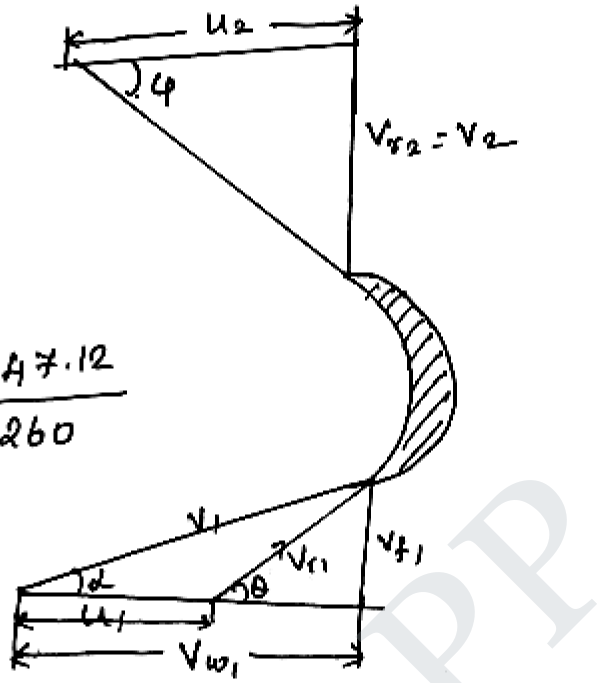
$$u_1 = \frac{\pi D_1 N}{60} = \frac{\pi \times 1.5 \times 600}{60}$$

$$= 47.12\ m/s.$$

$$\text{Power developed } (P) = \frac{\rho Q V_{w_1} u_1}{1000}$$

$$\therefore 16120 = \frac{1000 \times 7 \times V_{w_1} \times 47.12}{1000}$$

$$\boxed{V_{w_1} = 48.86\ m/s}$$



$$\eta_h = \frac{V_{w1} u_1}{gH}$$

$$= \frac{48.86 \times 47.12}{9.81 \times 260}$$

$$\boxed{\eta_h = 0.902}$$

$$\boxed{\eta_h = 90.2\%}$$

$$\eta_o = \frac{S.P}{W.P} = \frac{S.P}{\rho g Q H}$$

$$= \frac{16120}{1000 \times 9.81 \times 7 \times 260}$$

$$\boxed{\eta_o = 90\%}$$

$$\tan\alpha = \frac{V_{f1}}{V_{w1}}$$

$$Q = \pi D_1 B_1 V_{f1}$$

$$7 = \pi \times 1.5 \times 0.135 \times V_{f1}$$

$$\boxed{V_{f1} = 11 \text{ m/s}}$$

$$\tan\alpha = \frac{11}{48.86} = 0.225$$

$$\alpha = \tan^{-1}(0.225) = 12.68^\circ$$

$D_1 = 2 D_2$ (Assume most of the case)

$$D_2 = \frac{1.5}{2} = 0.75$$

$$u_2 = \frac{\pi D N}{60} = \frac{\pi \times 0.75 \times 600}{60} = 23.56 \text{ m/s}$$

$$\tan\varphi = \frac{18}{23.56} = 0.679$$

$$\varphi = \tan^{-1}(0.679) = 34^\circ 18' \quad \boxed{\varphi = 34^\circ 18'}$$

Result :

$$\eta_o = 90\% \; ; \; \eta_h = 90.2\% \; ; \; \alpha = 12.68'$$
$$\varphi = 34^\circ 18'$$

5. With a neat sketch, explain the construction and working of Pelton wheel. [APR./MAY 2008]

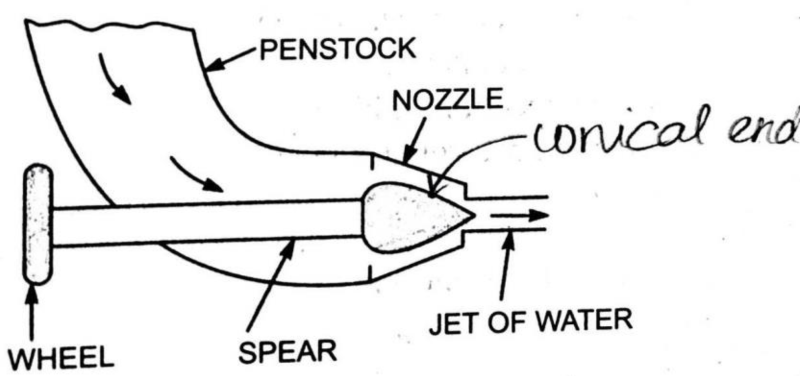
Pelton turbine is a tangential flow impulse turbine. It is named after L.A.Pelton, an American engineer. This turbine is used for high heads.

MAIN PARTS:

1. Nozzle and flow regulating valve
2. Runner and buckets
3. Casing
4. Breaking jet

1. Nozzle and flow regulating valve

The nozzle increases the kinetic energy of water flowing through the penstock. At the outlet of the nozzle, the water comes out in the form of jet and strikes the bucket of the runner. The amount of water striking the buckets of the runner is controlled by providing a spear in the nozzle. The spear is a conical needle which can be operated manually. When the spear is pushed forward or backward into



the nozzle the amount of water striking the runner is reduced or increased.

2. Runner and buckets

The runner consists of a circular disc with a number of bucket evenly spaced round its periphery. The shape of the bucket is of semi ellipsoidal cups. Each bucket is divided into two symmetrical parts by a dividing which is known as splitter. The splitter divides the jet into two equal parts and the jet comes out at the outer edge of the bucket.

The bucket is made up of cast iron, cast steel bronze or stainless steel depending upon the head at the inlet of the turbine.

3. Casing:

The function of casing is to prevent the splashing of the water and to discharge water to tail race. It also acts as a safeguard against accident.

It is made up of cast iron or fabricated steel plates.

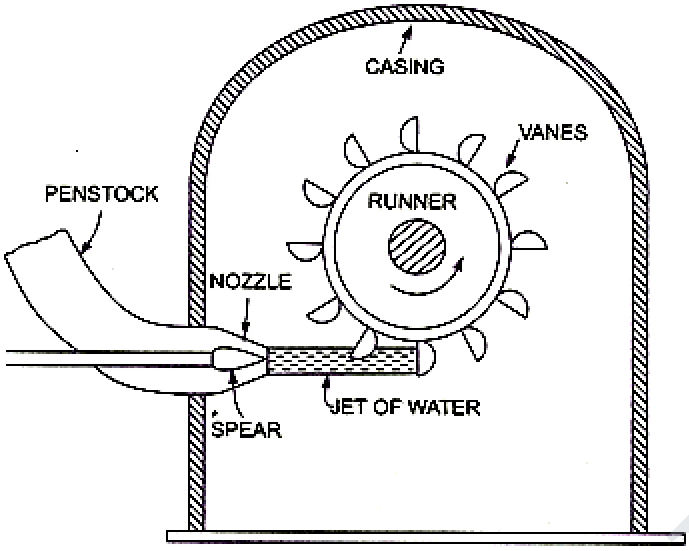
4. Breaking jet:

When the nozzle is completely closed by moving the spear in the forward direction, the amount of water striking the runner reduces to zero. But the runner due to inertia goes on revolving for a long time. To stop the runner in a short time, a small nozzle is provided which directs the jet of water on the back of the vanes. This jet of water is called breaking jet.

Working:

The water from the reservoir flows through the penstocks at the outlet of which a nozzle is fitted. The nozzle increases the kinetic energy of water flowing through the penstock. At the outlet of the nozzle, the water comes out in the form of jet and strikes the bucket of the runner.

The water flows along the tangent to the path of rotation of the runner. The runner revolves freely in air. The water is in contact with only a part of the runner at a time, and throughout its action on the runner and in its subsequent flow to the tail race, the water is at atmospheric pressure. Casing is to prevent the splashing of the water and to discharge water to tail race.



Pelton turbine.

6. Draw the characteristic curves of the turbines. Explain the significance?

Characteristics curves of a hydraulic turbine are the curves, with the help of which the exact behavior and performance of the turbine under different working conditions can be obtained. These curves are plotted from the results of the tests performed on the turbine.

The important parameters which are varied during a test on a turbine:

1.Speed (N) 2.Head(H) 3. Discharge(Q) 4.Power(P)

5.overall deficiency(η_o) 6. Gate opening

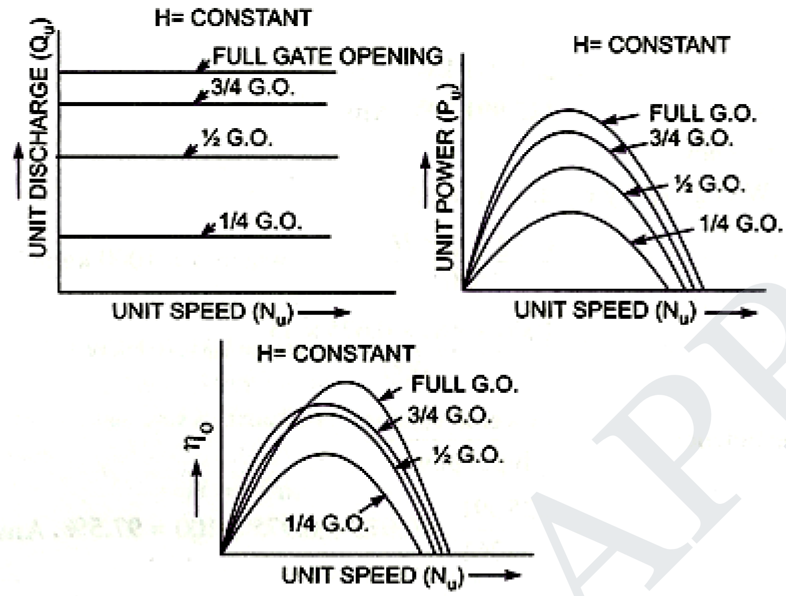
Speed (N), Head(H), Discharge(Q) are independent parameters. One of the parameters are kept constant and the variation of the other four parameters with respect to any one of the remaining two independent variables are plotted and various curves are obtained. These curves are called characteristics curves. The following are the important characteristic curves of a turbine.

1. Main characteristics curves or constant head curves.
2. Operating characteristics curves or constant speed curves
3. Muschel curves of constant efficiency curves

MAIN CHARACTERISTICS CURVES OR CONSTANT HEAD CURVES.

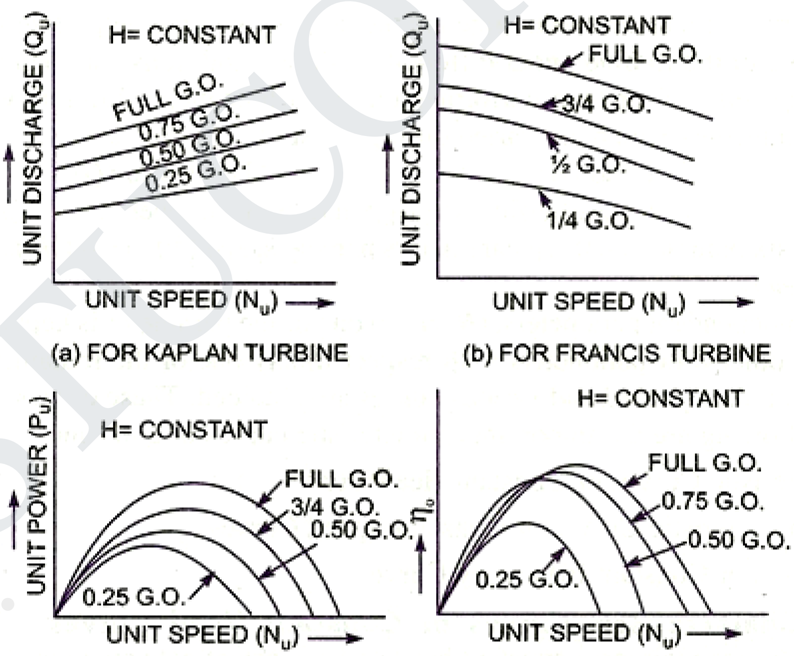
Main characteristics curves are obtained by maintaining a constant head and a constant gate opening on the turbine. The speed of the turbine is varied by changing load on the turbine. For each value of the speed , the corresponding values of the power (P) and discharge(Q) are obtained. Then the overall efficiency (η_o) for each value of the speed is calculated. From these readings the values of unit speed (N_u), unit power (P_u),and unit discharge (Q_u) are determined.

Main characteristics curves of a Pelton wheel as shown below.



Main characteristic curves for a Pelton wheel.

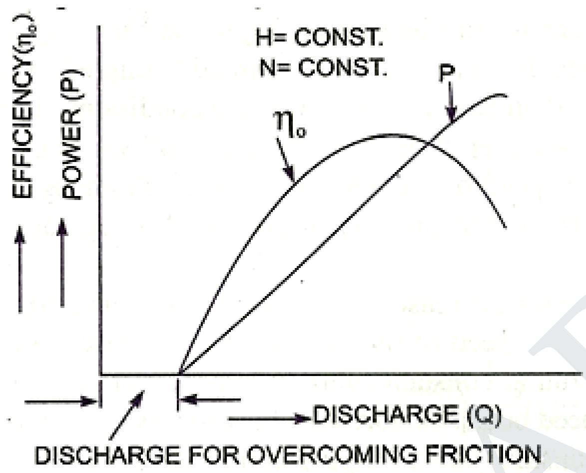
Main characteristics of a Kaplan and reaction turbine as shown below.



Main characteristic curves for reaction turbine.

OPERATING CHARACTERISTICS CURVES OR CONSTANT SPEED CURVES :

Operating Characteristics Curves are plotted when the speed on the turbine is constant. There are three independent parameters namely N, H and Q. For operating characteristics N and H are constant and hence the variation of power and efficiency with respect to discharge Q are plotted. The power curve for turbines shall not pass through the origin because certain amount of discharge is needed to produce power to overcome initial friction. Hence the power and efficiency curves will be slightly away from the origin on the x-axis as to overcome initial friction certain amount of discharge will be required.



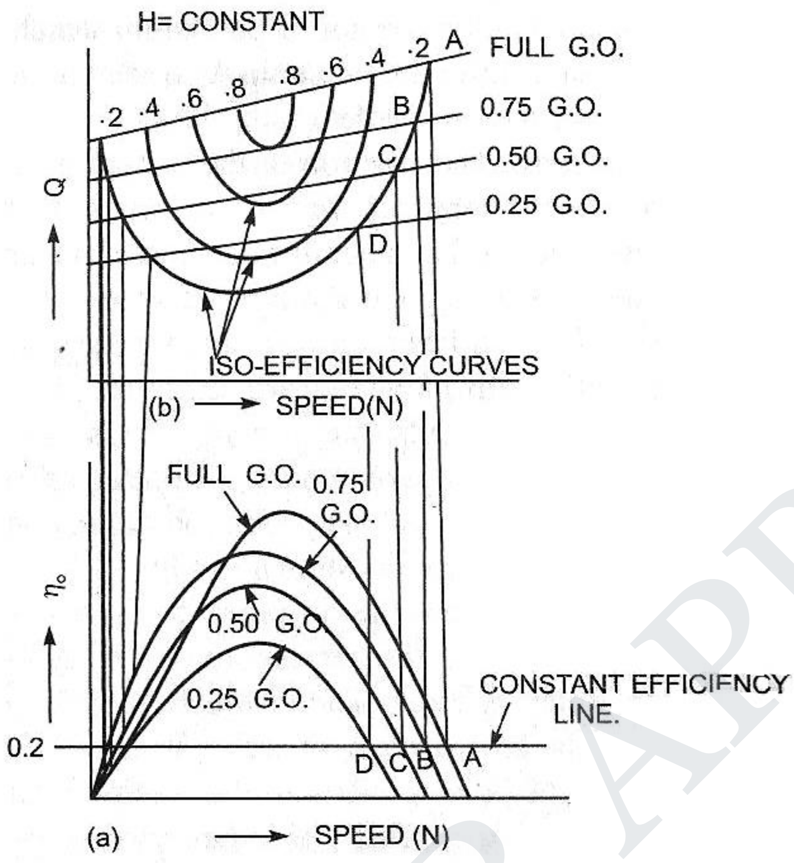
Operating characteristic curves.

MUSCHEL CURVES OF CONSTANT EFFICIENCY CURVES :

These curves are obtained from the speed Vs efficiency and speed Vs discharge curves for different gate openings. For a given efficiency, from the N_u vs η_o. curves, there are two speeds. From the N_u vs Q_u curves, corresponding to two values of speeds there are two values of discharge. If the efficiency is maximum there is only one value. These two values of speed and two values of discharge corresponding to a particular gate opening are plotted.

The procedure is repeated for different gate opening and the curve Q vs N are plotted. The points having the same efficiency are iso-efficiency curves. These curves are useful to determine the zone of constant efficiency and for predicting the performance of the turbine at various efficiencies.

Horizontal lines representing the same efficiency are drawn on the η_o speed curves. The points at which these lines cut the efficiency curves at various gate opening are transferred to the corresponding Q- speed curves. The points having the same efficiency are then joined by smooth curves. These smooth curves represent the iso-efficiency curve.



Constant efficiency curve.

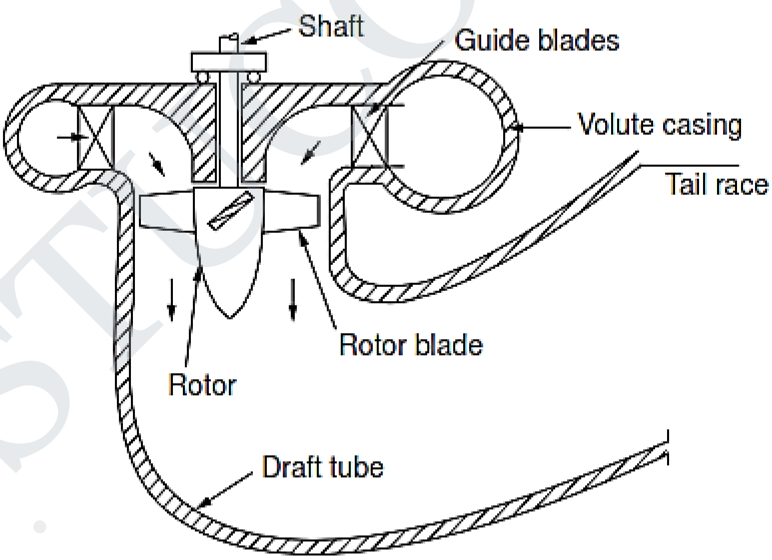
7. Explain the working of Kaplan turbine. Construct its velocity triangles.

(Nov/Dec 2016)

The popular axial flow turbines are the Kaplan turbine and propeller turbine. In propeller turbine the blades are fixed. In the Kaplan turbines the blades are mounted in the boss in bearings and the blades are rotated according to the flow conditions by a servomechanism maintaining constant speed. In this way a constant efficiency is achieved in these turbines. The system is costly and where constant load conditions prevail, the simpler propeller turbines are installed. There are many locations where large flows are available at low head. In such a case the specific speed increases to a higher value. In such situations axial flow turbines are gainfully employed. A sectional view of a kaplan turbines in shown in figure. These turbines are suited for head in the range 5 – 80 m and specific speeds in the range 350 to 900. The water from supply pipes enters the spiral casing as in the case of Francis turbine. Guide blades direct the water into the chamber above the blades at the proper direction. The speed governor in this case acts on the guide blades and rotates them as per load requirements.

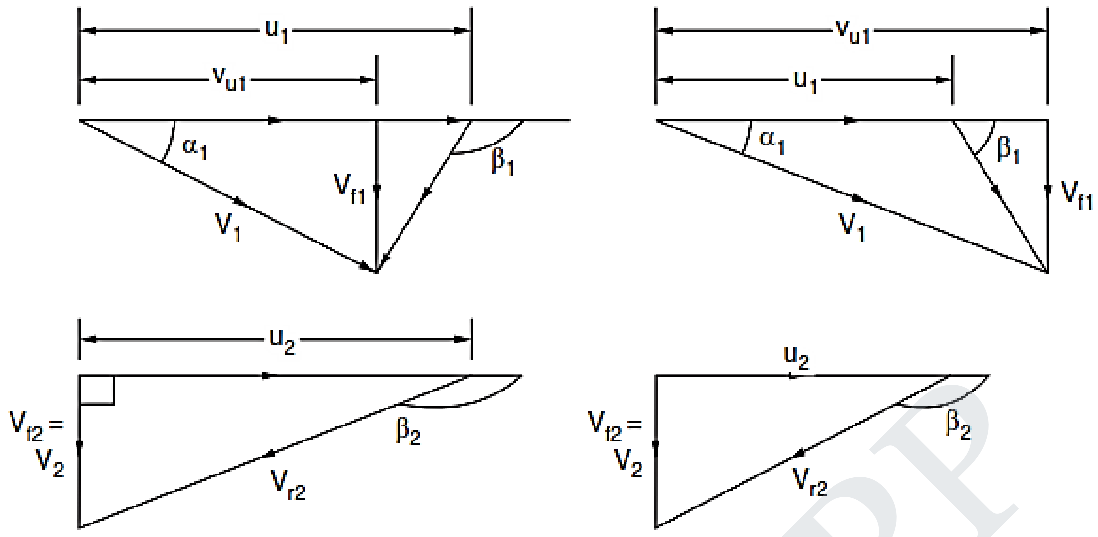
The flow rate is changed without any change in head. The water directed by the guide blades enters the runner which has much fewer blades (3 to 10) than the Francis turbine. The blades are also rotated by the governor to change the inlet blade angle as per the flow direction from the guide blades, so that entry is without shock. As the head is low, many times the draft tube may have to be elbow type. The important dimensions are the diameter and the boss diameter which will vary with the chosen speed. At lower specific speeds the boss diameter may be higher.

The number of blades depends on the head available and varies from 3 to 10 for heads from 5 to 70 m. As the peripheral speed varies along the radius (proportional to the radius) the blade inlet angle should also vary with the radius. Hence twisted type or Airfoil blade section has to be used. The speed ratio is calculated on the basis of the tip speed as $\emptyset = \frac{u}{\sqrt{2gH}}$ and varies from 1.5 to 2.4. The flow ratio lies in the range 0.35 to 0.75.



Sectional view of Kaplan turbine

Velocity triangles



(*a*) At Tip (*b*) At Hub

PART-C

1. The head available at a location was 1500 m. It is proposed to use a generator to run at 750 rpm. The power available is estimated at 20,000 kW. Investigate whether a single jet unit will be suitable. Estimate the number of jets and their diameter. Determine the mean diameter of the runner and the number of buckets.

Solution:

The specific speed is calculated to determine the number of jets,

$$N_s = \frac{750}{60} \frac{\sqrt{20{,}000 \times 10^3}}{1500^{5/4}}$$

$$N_s = 5.99$$

So a single jet will be suitable.

The overall efficiency is assumed as 0.87.

$$20{,}000 \times 10^3 = 0.87 \times Q \times 1000 \times 9.81 \times 1500$$

$$\Rightarrow \boxed{Q = 1.56225 \ m^3/s}$$

To determine the jet velocity, the value of C_v is required. It is assumed as 0.97.

$$V = 0.97\sqrt{2gH}$$
$$= 0.97\sqrt{2\times 9.81\times 1500}$$
$$\boxed{V = 166.4\ m/s}$$

We know, $Q = A.V$

$$1.56225 = \frac{\pi}{4} d^2 \times 166.4$$
$$\Rightarrow \boxed{d = 0.1093\ m}$$

Assume, $\phi = 0.46$

$$u = 166.4 \times 0.46$$

Also, $u = \frac{\pi DN}{60}$

$$\Rightarrow D = \frac{60u}{\pi N}$$
$$= \frac{60\times 166.4\times 0.46}{\pi\times 750}$$
$$\boxed{D = 1.95\ m}$$

Number of buckets, $= z. \frac{D}{2d} + 15$

$$= \frac{1.95}{2\times 0.1093} + 15$$
$$= 24$$

2. At a location selected to install a hydroelectric plant, the head is estimated as 550 m. The flow rate was determined as 20 m 3m/s. The plant is located at a distance of 2 m from the entry to the penstock pipes along the pipes. Two pipes of 2 m diameter are proposed with a friction factor of 0.029. Additional losses

amount to about 1/4th of frictional loss. Assuming an overall efficiency of 87%, determine how much single jet unit running at 300 rpm will be required.

Solution:

Specific speed

Net head = Head available − loss in head

$$\text{Friction Loss} = \frac{fLV_p^2}{2gD}$$

$Q = V_p \times A_p \times$ number of pipes

$Q = 20 m^3/s$ (given).

$$\Rightarrow V_p = \frac{20}{(\frac{\pi}{4} \times 2^2) \times 2} = 3.183 \text{ m/s}$$

$V_p = 3.183$ m/s

$L = 2000$ m, $f = 0.029$

$$h_f = \frac{0.029 \times 2000 \times 3.183^2}{2 \times 9.81 \times 2}$$

$$\boxed{h_f = 14.98 \text{ m}}$$

$$\text{Total loss of head} = \left(1 - \frac{1}{4}\right) \times 14.98$$

$$= \frac{5}{4} \times 14.98$$

$$= 18.72 \text{ m}$$

$\therefore$ Net head $= 550 - 18.72$

$= 531.28$ m

$\therefore$ Power, $P = \eta Q \rho g H$

$P = 0.87 \times 20 \times 1000 \times 9.81 \times 531.28$

$$\boxed{P = 90.6863 \times 10^3 \text{ W}}$$

$$\text{specific speed, } N_s = \frac{300}{60} \cdot \frac{\sqrt{90.686 \times 10^3}}{531.28^{5/4}}$$

$$\boxed{N_s = 18.667}$$

Suitability of single jet unit

$$V_j = C_v \sqrt{2gH}$$

$$= 0.98 \sqrt{2 \times 9.81 \times 531.28}$$

Velocity of jet, $V_j = 100.05$ m/s

Discharge, $Q = A \cdot V_j$

$$= \frac{\pi}{4} d^2 \times V_j$$

$$d = \left(\frac{4Q}{\pi V_j}\right)^{1/2}$$

$$d = \left(\frac{4 \times 20}{\pi \times 100.05}\right)^{1/2}$$

$d = 0.5$ m (high)

Also, $\frac{\pi D N}{60} = 0.46 \times 100.05$

$$D = 2.93 \text{ m}$$

Jet speed ratio $= \frac{2.95}{0.5}$

$= 6$ (low)

If three jets are suggested,

then $d = 0.29$ m

Jet speed ratio $= 10$ (Suitable).

$$\therefore \quad N_s = \frac{300}{60} \frac{\sqrt{90.6863 \times 10^6 / 3}}{531.28^{5/4}}$$

$$N_s = 10.77$$

Hence a three jet unit can be suggested.

3d. INDUSTRIAL CONNECTIVITY

Applications in Mechanical Engineering

1. Creating a draft
2. Pumps
3. Turbo machine
4. Air jet weaving machine

Applications in Civil Engineering

1. Wind tunnel
2. Syphon
3. Hydraulic machines

Applications in chemical Engineering

1. Process industry
2. CFS for oil industry

UNIVERSITY QUESTION PAPERS

1. CE 6451-APRIL/MAY 2017

Reg. No. :

Question Paper Code : 71563

B.E./B.Tech. DEGREE EXAMINATION, APRIL/MAY 2017.

Third/Fourth Semester

Mechanical Engineering

CE 6451 — FLUID MECHANICS AND MACHINERY

(Common to Aeronautical Engineering, Automobile Engineering, Industrial Engineering, Industrial Engineering and Management, Manufacturing Engineering, Mechanical and Automation Engineering, Mechatronics Engineering, Production Engineering)

(Regulations 2013)

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — ($10 \times 2 = 20$ marks)

1. Define Viscosity and what is the effect due to temperature on liquid and gases.

2. Calculate the height of capillary rise for water in a glass tube of diameter 1mm?

3. What are equivalent pipes? Mention the equation used for it.

4. Define Boundary Layer.

5. Explain the types of Similarities.

6. Write the expression for Mach number and state its application.

7. Explain the purpose of Air Vessel and in which pump it is used?

8. Define cavitation and its effects.

9. How do you classify turbines based on flow direction and working medium?

10. What is meant by Governing of Turbines?

PART B — (5 × 13 = 65 marks)

11. (a) (i) Calculate the dynamic viscosity of an oil, which is used for lubrication between a square plate of size 0.8 m × 0.8 m in an inclined plane with an angle of inclination 30° to the horizontal. The weight of the square plate is 300N and it slides down the inclined plane with a uniform velocity of 0.3 m/s. The thickness of oil film is 1.5mm. (8)

(ii) An oil of specific gravity 0.8 is flowing through a venturimeter having inlet diameter 20 cm and throat diameter 10 cm. The oil-mercury differential manometer shows a reading of 25 cm. Calculate the discharge of oil through the horizontal venturimeter. Take $C_d = 0.98$. (5)

Or

(b) Derive the expression of Bernoulli's equation from the Euler's equation and state the assumptions made for such a derivation? (13)

12. (a) (i) A fluid of viscosity 0.7 Pa.s and specific gravity 1.3 is flowing through a pipe diameter 120 mm. The maximum shear stress at the pipe value is 205.2 N/m². Determine the pressure gradient, Reynolds number and average velocity? (9)

(ii) A crude oil of kinematic viscosity 0.4 strokes is flowing through a pipe of diameter 300mm at the rate of 300 litres per sec. Find the head lost due to friction for a length of 50 m of the pipe. Take Coefficient of friction as 0.006. (4)

Or

(b) For a flow of viscous fluid flowing through a circular pipe under laminar flow conditions show that the velocity distribution is a parabola. And also show that the average velocity is half of the maximum velocity. (13)

13. (a) A 1:100 model is used for model testing of ship. The model is tested in wind tunnel. The length of ship is 400 m. The velocity of air in the wind tunnel around the model is 25 m/s and the resistance is 55N. Determine the length of model. Also find the velocity of ship as well as resistance developed. Take density of air and sea water as 1.24 kg/m³ and 1030 kg/m³. The kinematic viscosity of air and seawater are 0.018 stokes and 0.012 stokes respectively. (13)

Or

(b) Using Buckingham's π theorem, show that the velocity through a circular orifice is given by $V = \sqrt{2gH\,\phi\left[\frac{D}{H}, \frac{\mu}{\rho v H}\right]}$, where H is the head causing flow, D is the diameter of the orifice, μ is coefficient of viscosity, ρ is the mass density and g is the acceleration due to gravity. (13)

14. (a) (i) A Single acting reciprocating pump running at 50 RPM delivers 0.01 m^3/s of water. The diameter of the piston is 200mm and stroke length 400 mm. Determine

(1) The theoretical discharge of the pump

(2) Coefficient of discharge

(3) Slip and Percentage slip of the pump. (8)

(ii) Discuss the working of Gear pump using its schematic. (5)

Or

(b) A Centrifugal pump having outer diameter equal to two times the inner diameter and running at 1000 rpm works against a head of 40m. The velocity of flow through the impeller is constant and equal to 2.5 m/s. The vanes are set back at angle of 40° at outlet. If the outer diameter of the impeller is 500 mm & width at outlet is 50 mm determine (i) Vane angle at inlet, (ii) Manometric efficiency, (iii) Workdone by impeller on water per second. (13)

15. (a) (i) A kaplan turbine runner is to be designed to develop 9100 kW. The net available head is 5.6m. If the speed ratio = 2.09, flow ratio = 0.68, overall efficiency = 86% and the diameter of the boss is 1/3 the diameter of the runner. Find the diameter of the runner, its speed and the specific speed of the turbine? (8)

(ii) Explain the Performance Characteristics curves of turbine. (5)

Or

(b) The following data is given for a Francis turbine. Net head H = 60 m, Speed N = 700 RPM, Shaft power 294.3 kw, Overall efficiency 84%, Hydraulic efficiency 93%. Flow ratio = 0.2, breadth ratio n = 0.1, Outer diameter of the runner is two times inner diameter of the runner. The thickness of vanes occupies 5% of circumference area of the runner. Velocity of flow is constant at inlet and outlet and the discharge is radial at outlet. Determine (i) Guide blade angle, (ii) Runner vane angle at inlet and outlet, (iii) Diameter of runner inlet and outlet, (iv) Width of wheel at inlet. (13)

PART C — (1 × 15 = 15 marks)

16. (a) A liquid has a specific gravity of 0.72. Find its density, specific weight and its weight per litre of the liquid. If the above liquid is used as the lubrication between the shaft and the sleeve of length 100mm. Determine the power lost in the bearing, where the diameter of the shaft is 0.5 m and the thickness of the liquid film between the shaft and the sleeve is 1 mm. Take the viscosity of fluid as 0.5 N-s/m^2 and the speed of the shaft rotates at 200 rpm. (15)

Or

(b) For a high head storage capacity dam of net head 800 m, it has been decided to design and install a Pelton wheel for generating power of 13,250 kw running at a speed of 600 RPM, if the coefficient of jet is 0.97 Speed Ratio = 0.46 and the Ratio of jet diameter is 1/15 of the wheel diameter calculate (i) Number of jets, (ii) Diameter of jets, (iii) Diameter of Pelton wheel, (iv) No of buckets and (v) Discharge of one jet. (15)

2. CE 6451-NOV/DEC 2016

Reg. No. :

Question Paper Code : 80203

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2016.

Third Semester

Mechanical Engineering

CE 6451 — FLUID MECHANICS AND MACHINERY

(Common to Aeronautical Engineering, Automobile Engineering, Mechatronics Engineering, Mechanical and Automation Engineering and Production Engineering, Also common to Fourth Semester Industrial Engineering, Industrial Engineering and Management and Manufacturing Engineering)

(Regulations 2013)

Time : Three hours Maximum : 100 marks

Any missing data can be suitably assumed

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Write down the effect of temperature on viscosity of liquids and gases.

2. Calculate the capillary rise in a glass tube of 2.5 mm diameter when immersed vertically in (a) water and (b) mercury. Take surface tension σ = 0.0725 N/m for water and σ = 0.52 N/m for mercury in contact with air. The specific gravity for mercury is given as 13.6 and angle of contact = 130°.

3. Find the displacement thickness for the velocity distribution in the boundary layer given by $u/U = 2(y/\delta) - (y/\delta)^2$.

4. Draw the velocity distribution and the shear stress distribution for the flow through circular pipes.

5. State Buckingham's π theorem. Why this method is considered superior to Rayleigh's method?

6. Derive the scale ratio for velocity and pressure intensity using Froude model law.

7. What is meant by priming of a centrifugal pump? Why is it necessary?

8. What is the function of air vessel in reciprocating pumps?

9. Explain the type of flow in Francis turbine.

10. What is draft tube?

PART B — (5 × 13 = 65 marks)

11. (a) (i) Derive the Reynold's Transport theorem. (6)

(ii) The dynamic viscosity of an oil used for lubrication between a shaft and sleeve is 6 poise. The shaft is of diameter 0.4 m and rotates at 190 rpm. Calculate the power lost in the bearing for a sleeve length of 90 mm. The thickness of oil film is 1.5 mm. (7)

Or

(b) Derive the Bernoulli's equation with the basic assumptions. (13)

12. (a) Derive the Hagen Poiseuille formula for the flow through circular pipes. (13)

Or

(b) Three pipes of 400 mm, 200 mm and 300 mm diameters have lengths of 400 m, 200 m and 300 m respectively. They are connected in series to make a compound pipe. The ends of this compound pipe are connected with two tanks whose difference of water levels is 16 m. If the coefficient of friction for these pipe is same and equal to 0.005, determine the discharge through the compound pipe neglecting first the minor losses and then including them. (13)

13. (a) (i) The pressure difference Δp in a pipe of diameter D and length l due to turbulent flow depends on the velocity υ, viscosity μ, density ρ and roughness k. Using Buckingham's π theorem, obtain an expression for Δp. (7)

(ii) Define similitude and explain its types. (6)

Or

(b) (i) The pressure drop in an airplane model of size 1/10 of its prototype is $80\,\text{N/cm}^2$. The model is tested in water. Find the corresponding pressure drop in the prototype. Take density of air = $1.24\,\text{kg/m}^3$. The viscosity of water is 0.01 poise while the viscosity of air is 0.00018 poise. (6)

(ii) Derive the five different types of dimensionless numbers. (7)

14. (a) Derive the expression for pressure head due to acceleration in the suction and delivery pipes of the reciprocating pumps. (13)

Or

(b) The internal and external diameter of an impeller of a centrifugal pump which is running at 1200 rpm are 300 mm and 600 mm. The discharge through the pump is 0.05 m^3/s and the velocity of the flow is constant and equal to 2.5 m/s. The diameters of the suction and delivery pipes are 150 mm and 100 mm respectively and suction and delivery heads are 6 m(abs) and 30 m(abs) of water. If the outlet vane angle is 45° and power required to drive the pump is 17 kW determine :

(i) Vane angle of the impeller at inlet

(ii) Overall efficiency of the pump

(iii) Manometric efficiency of pump. (13)

15. (a) (i) Describe the efficiencies of a turbine. (6)

(ii) Explain the working of Kaplan turbine. Construct its velocity triangles. (7)

Or

(b) The following data is given for Francis turbine : Net Head = 60 m, speed = 700 rpm, shaft power = 294.3 kW, $\eta_0 = 84\%$, $n_h = 93\%$, flow ratio = 0.2, breadth ratio = 0.1, outer diameter of the runner = 2 inner diameter of runner. The thickness of vanes occupies 5% of the circumferential area of the runner. Velocity of flow is constant at inlet and outlet and discharge is radial at outlet. Determine :

(i) The guide blade angle

(ii) Runner vane angle at the inlet and outlet

(iii) Diameter of the runner at inlet and outlet

(iv) Width of the wheel at inlet. (13)

PART C — (1 × 15 = 15 marks)

16. (a) Find the displacement thickness, the momentum thickness and the energy thickness for the velocity distribution in the boundary layer given by $u/U = 2(y/\delta) - (y/\delta)^2$. (15)

Or

(b) (i) Explain the Reynold's Experiment. (5)

(ii) Derive the Darcy – Weisbach equation for the loss of head due to friction in Pipes. (10)

3. CE 6451-MAY/JUNE 2016

Reg. No.

Question Paper Code : 57164

B.E./B. Tech. DEGREE EXAMINATION, MAY/JUNE 2016

Third Semester

Mechanical Engineering

CE 6451 – FLUID MECHANICS AND MACHINERY

(Common to Aeronautical Engineering, Automobile Engineering, Mechatronics Engineering, Mechanical and Automation Engineering and Production Engineering and also common to Fourth Semester Industrial Engineering, Industrial Engineering and Management and Manufacturing Engineering)

(Regulation 2013)

Time : Three Hours **Maximum : 100 Marks**

Any missing data can be suitably assumed.

Answer ALL questions.

PART – A (10 × 2 = 20 Marks)

1. Brief on the effect of temperature on viscosity in gases.
2. How does Redwood viscometer work ?
3. Brief on Darcy-Weisbach equation.
4. What is the condition for maximum power transmission w.r.t. head available ?
5. Brief on Euler number.
6. What is meant by kinematic similarity ?
7. When does negative slip occur ?
8. Why is forward curved blading rarely used in pumps ?
9. List down the main components of pelton wheel.
10. Differentiate between Kaplan turbine and propeller turbine.

PART – B (5 × 16 = 80 Marks)

11. (a) (i) At a certain location, wind at a temperature of 30 °C is blowing steadily at 15 m/s. Determine the mechanical energy of air per unit mass and the power generation potential of a wind turbine with 40-m diameter blades at that location. Also determine the actual electric power generation assuming an overall efficiency of 35%. **(10)**

(ii) A hydraulic lift shaft of 450 mm diameter moves in a cylinder of 451 mm diameter with the length of engagement of 3 m. The interface is filled with oil of kinematic viscosity of 2.5×10^{-4} m^2/s and density of 900 kg/m^3. Determine the uniform velocity of movement of the shaft if the drag resistance was 320 N. **(6)**

OR

(b) (i) In cold climates, the water pipes may freeze and burst if proper precautions are not taken. In such an occurrence, the exposed part of a pipe on the ground ruptures, and water shoots up to 34 m. Estimate the gage pressure of water in the pipe. State your assumptions and discuss if the actual pressure is more or less than the value you predicted. **(10)**

(ii) A conical bearing of outer radius 0.5 m and inner radius 0.3 m and height 0.3 m runs on a conical support with a uniform clearance between surfaces. Oil with viscosity 33 centi. Poise is used. The support is rotated at 450 rpm. Determine the clearance if the power required was 1400 W. **(6)**

12. (a) Shell-and-tube heat exchangers with hundreds of tubes housed in a shell are commonly used in practice for heat transfer between two fluids. Such a heat exchanger used in an active solar hot-water system transfers heat from a water-antifreeze solution flowing through the shell and the solar collector to fresh water flowing through the tubes at an average temperature of 60 °C at a rate of 15 L/s. The heat exchanger contains 80 brass tubes 1 cm in inner diameter and 1.5 m in length. Disregarding inlet, exit and header losses, determine the pressure drop across a single tube and the pumping power required by the tube-side fluid of the heat exchanger. The density and dynamic viscosity of water at 60 °C are $\rho = 983.3$ kg/m^3 and $\mu = 0.467 \times 10^{-3}$ kg/m s, respectively. The roughness of brass tubing is 1.5×10^{-6} m. **(16)**

OR

(b) Water at 15 °C is to be discharged from a reservoir at a rate of 20 L/s using two horizontal cast iron pipes connected in series and a pump between them. The first pipe is 22 m long and has a 6 cm diameter, while the second pipe is 33 m long and has a 4 cm diameter. The water level in the reservoir is 30 m above the centerline of the pipe. The pipe entrance is sharp-edged, and losses associated with the connection of the pump are negligible. Determine the required pumping head and the minimum pumping power to maintain the indicated flow rate. The density and dynamic viscosity of water at 15 °C are $\rho = 999.1$ kg/m^3 and $\mu = 1.138 \times 10^{-3}$ kg/ms. The roughness of cast iron pipes is 0.00026 m. **(16)**

13. (a) The temperature difference θ at a location x at time τ in a slab of thickness L originally at a temperature difference θ_o with outside is found to depend on the thermal diffusivity α, thermal conductivity k and convection coefficient h. Using dimensional analysis determine the dimensionless parameters to correlate the situation. **(16)**

OR

(b) Convective heat transfer coefficient in free convection over a surface is found to be influenced by the density, viscosity, thermal conductivity, coefficient of cubical expansion, temperature difference, gravitational acceleration, specific heat, the height of surface and the flow velocity. Using dimensional analysis, determine the dimensionless parameters that will correlate the phenomenon. **(16)**

14. (a) An axial flow pump running at 620 rpm deliver 1.5 m^3/s against a head of 5.2 m. The speed ratio is 2.5. The flow ratio is 0.5. The overall efficiency is 0.8. Determine the power required and the blade angles at the root and tip and the diffuser blade inlet angle. Inlet whirl is zero. **(16)**

OR

(b) Discuss about air vessel used with reciprocating pump. A single acting reciprocating pump handles water. The bore and stroke of the unit are 22 cm and 32 cm. The suction pipe diameter is 12 cm and length is 10 m. The delivery pipe diameter is 12 cm and length is 30 m. Take frictional factor as 0.02. The speed of operation is 32 rpm. Determine the friction power with and without air vessels. **(16)**

15\. (a) At a location selected to install a hydro electric plant, the head is estimated as 540 ms. The flow rate was determined as 22 m^3/s. The plant is located at a distance of 2 km from the entry to the penstock pipes along the pipes. Two pipes of 2 m diameter are proposed with a friction factor of 0.03. Additional losses amount to about $1/4^{th}$ of frictional loss. Assuming an overall efficiency of 85%, determine how many single jet unit running at 330 rpm will be required. **(16)**

OR

(b) A Kaplan turbine delivering 40 MW works under a head of 40 m and runs at 150 rpm. The hub diameter is 3 m and runner tip diameter is 6 m. The overall efficiency is 90%. Determine the blade angles at the hub and tip and also at a diameter of 4 m. Also find the speed ratio and flow ratio based on tip velocity. Assume hydraulic efficiency as 95%. **(16)**

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4. <u>ME 2204-MAY/JUNE 2016</u>

Reg. No. | | | | | | | | | | | | |

Question Paper Code : 51847

B.E./B.Tech. DEGREE EXAMINATION, MAY/JUNE 2016

Third Semester

Mechanical Engineering

ME 2204/CE 3213/ME 34/CE 1208/080180007/IE 41/10122 ME 305 – FLUID MECHANICS AND MACHINERY

(Common to Aeronautical Engineering, Automobile Engineering, Production Engineering, Mechatronics Engineering, Mechanical and Automation Engineering and Fourth Semester Manufacturing Engineering, Industrial Engineering and Industrial Engineering and Management)

(Regulations 2008/2010)

(Common to PTME 2204/10122 ME 305 – Fluid Mechanics and Machinery for B.E. (Part-Time) Third Semester – Mechanical Engineering and Management)

Time : Three Hours **Maximum : 100 Marks**

Answer ALL questions.

PART – A (10 × 2 = 20 Marks)

1. State the conditions under which uniform and non-uniform flows are produced.
2. What is an impulse-momentum equation ?
3. State the equation of discharge of water through an open channel.
4. How does the roughness of channel affect the Chezy's constant ?
5. State the application of dimensional numbers and mention its significance.
6. What is the effect of scale effect and distorted model in dimensional analysis ?
7. Francis turbine is not used as a high head turbine ?
8. In what respects outward flow reaction turbine differs from inward flow reaction turbine ? Which one is better and why ?
9. What is cavitation in pump ? How it can be avoided ?
10. List importance of air vessels in reciprocating pump.

PART – B (5 × 16 = 80 Marks)

11. (a) An incompressible fluid flows downward through a vertical cylindrical pipe under the action of gravity. The flow is fully developed and laminar. Use the Navier-Strokes equations to derive an expression for the flow rate for the case of zero pressure gradients along the pipe. **(16)**

OR

(b) A thin layer of liquid of constant thickness flow down an inclined plate such that the only velocity component is parallel to the plate. Use the Navier-Strokes equations to determine the relationship between the thickness of the layer and the flow rate per unit width. Assume a steady, laminar, and uniform flow. Also assume that air resistance is negligible. **(16)**

12. (a) (i) Derive an expression for the depth of paraboloid formed by the surface of a liquid contained in a cylindrical tank which is rotated at a constant angular velocity w about its vertical axis. **(6)**

(ii) 250 litres/sec., of water is flowing in a pipe having diameter of 300mm. If the pipe is bent by 135°, find the magnitude and direction of the resultant force on the bend. The pressure of the water flowing is $400 kN/m^2$. Take specific weight of water as $9.81 kN/m^3$. **(10)**

OR

(b) (i) Enumerate the different laws on which models are designed for dynamic similarity. Where are they used ? **(6)**

(ii) Water having a coefficient of kinematic viscosity of $1.12 \times 10^{-6}\ m^2/s$ and a mass density of $1\ mg/m^3$ flows at a mean speed of 1.75m/s through a 75mm diameter pipe line. What corresponding volumetric rate (measured at atmospheric pressure) of air flow through this pipeline would give rise to essentially similar dynamical flow conditions and why would this be so ? Air may be assured to have a coefficient of kinematic viscosity of $14.7 \times 10^{-6}\ m^2/s$ and a mass density of $1.23\ kg/m^3$ Determine for each fluid, the pressure drop which would occur in 10m length of this pipeline. Take f = 0.010 (Darcy's friction factor) for both fluids. **(10)**

13. (a) An oil of specific gravity 0.92 and viscosity 0.03 poise is to be transported at the rate of 2500 litres/sec. through a 1.2 m diameter pipe. Tests were conducted on a 12cm diameter pipe using water at 20°C. If the viscosity water at 20°C is 0.01 poise, find :

(i) Velocity of flow in the model (6)

(ii) Rate of flow in the model (10)

OR

(b) The model of tidal channel in a coastline study is scaled to 1/100 of actual size. Fresh water is to be used in place of sea water in the model. Assuming the Reynolds number must be matched, what model velocity is needed to ensure dynamic viscosity ? Will similarly also be achieved for free surface effects related to the Weber and Froude numbers ? In your calculations, note that the appropriate velocity and length scales for the actual tidal channel are V = 0.5 m/s and L = 10 m, respectively. (16)

14. (a) A Pelton wheel has to be designed for the following data :

HP to be developed	= 8500
Net head available	= 280 m
RPM	= 650
Ratio of jet diameter to wheel diameter	= 1/9
Mechanical efficiency	= 88%

Find the number of jets, diameter of jet, diameter of wheel and quantity of water required. (16)

OR

(b) A Francis turbine working under a head of 20 m is supplied with 1.5 m^3/sec of water. Wheel diameter at the entrance and exit are 1 m and 0.6 m respectively. It is developing 300 HP at 300 rpm. Velocity of water at exit is 3 m/sec. Assuming wheel width constant, find (i) theoretical hydraulic efficiency (ii) actual efficiency (iii) suitable angles of guide vanes and runner vanes at inlet. (16)

15. (a) A centrifugal pump has a head discharge characteristic given by $H = 35 - 2200\,Q^2$, where H is head developed by pump in 'm' and Q is discharge in m^3/sec. The pump is to deliver a discharge against a static head of 12 m. The suction pipe is 15 cm diameter and 20 m long with an f value of 0.018. The delivery pipe is 20 cm diameter and 40 m long with an f value 0.02. Calculate the head and discharge delivered by the pump. If the overall efficiency is 0.7, calculate the power supplied. **(16)**

OR

(b) A single acting reciprocating pump has following dimensions :

Piston diameter	= 25 cm
Stroke	= 35 cm
Speed	= 40 rpm
Suction head	= 4.5 m
Delivery head	= 18 m
Suction pipe: Diameter = 15 cm; length	= 9 m
Delivery pipe: Diameter =12 cm; length	= 32 m
Coefficient of friction	= 0.028
Atmospheric pressure	= 10.3 m of water

Find (i) pressure head on the piston at the beginning, middle and end of the suction and delivery strokes, (ii) HP required to driving the pump. **(16)**

5. CE6451-NOV/DEC 2015

Reg. No: | | | 6. | | | | | | | |

Question Paper Code : 27113

B. E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2015.

Third Semester

Mechanical Engineering

CE 6451—FLUID MECHANICS AND MACHINERY

(Common to Aeronautical Engineering, Automobile Engineering, Mechatronics Engineering and Mechanical Engineering, and Automation Engineering and Production Engineering and also common to Fourth semester Industrial Engineering, Industrial Engineering and management and Manufacturing Engineering)

(Regulations 2013)

Time : Three hours Maximum : 100 marks

Any missing data can be suitably assumed

Answer ALL questions.

PART A—(10X2=20marks)

1. Calculate the specific weight and specific gravity of 1 litre of a liquid with a density of 713.5kg/m^3 and which weighs 7 N
2. Explain the variation of viscosity with temperature
3. Differentiate Hydraulic Gradient Line and Total Energy Line.
4. Define Boundary line thickness
5. Define Dimensional homogeneity
6. Derive the expression for Reynold's Number
7. Explain the cavitation problem in Centrifugal pumps
8. Define slip of the Reciprocating pump
9. Write short notes on Draft tube
10. Define the volumetric efficiency of the turbine

Part B (5X 16= 80marks)

11. (a) With the basic assumptions derive the Bernoulli's Equation from the Euler's Equation.(16)

Or

(b) (i) Water is flowing through a pipe of diameter 30 cm and 20 cm at sections 1 and 2 respectively. The rate of flow through pipe is 35 lps.The section 1 is 8m above datum and section 2 is 6m above datum. If the pressure at section 1 is 44.5N/cm^2. Find the intensity of pressure at section 2. (8)

(ii) Calculate the dynamic viscosity of oil which is used for lubrication between a square plate of size 0.8 m X 0.8m and an inclined plane with angle of inclination 30^0. The weight of the square plate is 330 N and it slide down the inclined plane with a uniform velocity of 0.3 m/s. The thickness of the oil film is 1.5 mm. (8)

12. (a) Derive the expression for shear stress and velocity distribution for the flow through circular pipe and using that derive the Hagen Poiseuille formula. (16)

Or

(b) Three pipes of 400 mm, 200 mm and 300 mm diameters have lengths of 400 m, 200 m, and 300 m respectively. They are connected in series to make a compound pipe. The ends of the compound pipe are connected with two tanks whose difference of water levels is 16 m. if the coefficient of friction for these pipes is same and equal to 0.005, determine the discharge through the compound pipe neglecting first the minor losses and then including them. (16)

13 (a) Using Buckingham's π theorem, show that the velocity through the circular orifice is given by v =$\sqrt{gH\phi}\left[\frac{D}{H},\frac{\mu}{\rho v H}\right]$, Where H is the head causing flow, D is the Diameter of the orifice, μ is the co efficient of viscosity, ρ is the mass density and g is the acceleration due to gravity. (10)

Or

(b) (i)Explain similitude with types of similarities (8)

(ii) The ratio of lengths of a submarine and its model is 30: 1. The speed of the prototype is 10 m/s. The model is to be tested in a wind tunnel. Find the speed of air in wind tunnel Also determine the ratio of the drag between the model and prototype. Take values kinematic viscosities of sea water and air as 0.012 stokes and 0.016 stokes respectively. The density of sea water and air is given as 1030 kg/m^3 and 1.24 kg/m^3 respectively.

14 (a)i)Explain the working principle with the main parts of centrifugal pump. (8)

ii) The internal and external diameters of the impeller of a centrifugal pump are 300 mm and 600 mm respectively. The pump is running at 1000 rpm. The vane angles of the impeller at inlet and outlet 20^o and 30^o respectively. The water enters the impeller radially and velocity of flow is constant. Determine work done by the impeller per unit weight of water . Sketch the velocity triangle. (8)

Or

(b) i)Explain the working principle of a reciprocating pump with a neat sketch. (8)

ii) A single acting reciprocating pump running at 60 rpm delivers $0.02 m^3/s$ of water. The diameter of the piston is 250 mm and stroke length 450 mm. determine (1) Theoretical discharge of the pump (2) coefficient of discharge (3) slip of the pump (4) % of slip of the pump. (8)

15. (a)Design a pelton wheel for a head of 400m when running at 750 rpm. The pelton develop 12110KW shaft power. The ratio of jet diameter to the wheel diameter is 1/6. The overall efficiency, η_o = 0.86 coefficient of velocity C_v= 0.985 and speed ratio, ϕ = 0.45. (16)

Or

(b) A Francis turbine with an overall efficiency of 70% is required to produce 147.15 KW. It is working under a head of 8 m. The peripheral velocity = $0.30\sqrt{2gH}$ and the radial velocity of the flow at inlet is = $0.96\sqrt{2gH}$. The wheel runs at 200 rpm and hydraulic losses in the turbine are 20% of the available energy. Assume radial discharge, determine (i) guide blade angle, (ii)Wheel vane angle at inlet, (iii) Diameter of wheel at inlet and (iv) width of wheel at inlet. Draw the suitable velocity triangle. (16)

27375

6. ME 2204-NOV/DEC 2014

Reg. No. :

Question Paper Code : 91636

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2014.

Third Semester

Mechanical Engineering

ME 2204/CE 3213/ME 34/CE 1208/080180007/IE 41/10122 ME 305 — FLUID MECHANICS AND MACHINERY

(Common to Aeronautical Engineering, Automobile Engineering, Production Engineering , Mechatronics Engineering, Mechanical and Automation Engineering and Fourth Semester Manufacturing Engineering, Industrial Engineering and Industrial Engineering and Management)

(Regulation 2008/2010)

(Common to PTME 2204/10122 ME 305 – Fluid Mechanics and Machinery for B.E. (Part-time) Third Semester – Mechanical Engineering Regulation 2009/2010)

Time : Three hours Maximum : 100 marks

Any missing data can be suitably assumed with justification.

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Brief on the significance of vapour pressure.

2. State the empirical pressure density relation for a liquid.

3. What is meant by laminar flow instability?

4. State the importance of Moody's chart.

5. Brief on dimensional variables with examples.

6. What is meant by kinematic similarity?

7. Draw the velocity triangles for the pelton wheel.

8. Define – Net Positive Suction Head.

9. What are the materials used for manufacturing reciprocating pumps?

10. List the advantages of double acting reciprocating pumps.

PART B — (5 × 16 = 80 marks)

11. (a) (i) Determine the velocity of a jet directed at 35° to the horizontal to clear 8 m height at a distance of 22 m. Also determine the maximum height this jet will clear and the total horizontal travel. What will be the horizontal distance at which the jet will be again at 8 m height? (10)

(ii) The viscosity of a fluid is to be measured by a viscometer constructed of two 80-cm-long concentric cylinders. The outer diameter of the inner cylinder is 16 cm, and the gap between the two cylinders is 0.12 cm. The inner cylinder is rotated at 210 rpm, and the torque is measured to be 0.8 N m. Determine the viscosity of the fluid. (6)

Or

(b) (i) A cylinder of radius 0.65 m filled partially with a fluid and axially rotated at 18 rad/s is empty upto 0.3 m radius. The pressure at the extreme edge at the bottom was 0.3 bar gauge. Determine the density of the fluid. (10)

(ii) Determine the gage pressure inside a soap bubble of diameter 0.25 cm and 6 cm at 22°C. (6)

12. (a) (i) Kerosene (SG = 0.810) at a temperature of 22°C flows in a 75-mm diameter smooth brass pipeline at a rate of 0.90 lit/s. Find the friction head loss per meter, For the same head loss, what would be the flow rate if the temperature of the kerosene were raised to 40°C? (10)

(ii) Discuss on minor losses in pipe flow. (6)

Or

(b) (i) Water at 20°C flow through a 160-mm-diameter pipe with roughness of 0.015 mm. If the mean velocity is 6 m/s, what is the nominal thickness of the viscous sub-layer? What will be the viscous sub-layer if the velocity is increased to 7.2 m/s? (10)

(ii) Discuss on hydraulic and energy gradient. (6)

13. (a) (i) Vortex shedding at the rear of a structure of a given section can create harmful periodic vibration. To predict the shedding frequency, a smaller model is to be tested in a water tunnel. The air speed is expected to be about 75 kmph. If the geometric scale is 1 : 6.5 and the water temperature is 25°C determine the speed to be used in the tunnel. Consider air temperature as 38°C. If the shedding frequency of the model was 60 Hz, determine the shedding frequency of the prototype. The dimensions of the structure are diameter 0.12 m and height 0.36 m. (10)

(ii) Discuss on the applications of dimensionless parameters. (6)

Or

(b) (i) Oil is moved up in a lubricating system by a rope dipping in the sump containing oil and moving up. The quantity of oil pumped Q, depends on the speed u of the rope, the layer thickness δ, the density and viscosity of the oil and acceleration due to gravity. Obtain the dimensionless parameters to correlate the flow. (10)

(ii) Discuss on Buckingham's Π theorem. (6)

14. (a) (i) A centrifugal pump delivers 0.18 m^3/s of water against a head of 15 m and runs at 620 rpm. The outer and inner diameters of impeller are 0.4 m and 0.2 m respectively and the vanes are bent back at 38° C to the tangent at exit. If the area of flow remains at 0.1 m^2 from inlet to outlet, calculate manometric efficiency, vane angle at inlet and loss of head at inlet to impeller when the discharge is reduced by 40% without changing the speed. (10)

(ii) Discuss on the performance characteristics of centrifugal pumps. (6)

Or

(b) (i) Calculate guide blade angles, vane angles, runner diameters at inlet and outlet and width of the wheel at outlet for a Francis turbine with the following data : Net head : 70 m; Speed : 720 rpm; Shaft Power : 310 kW; Overall efficiency : 0.85; Hydraulic efficiency : 0.9; Flow ratio : 0.2; Breadth ratio : 0.1; OD/ID ratio : 1.8; The thickness of vanes occupy 7.5% of circumferential area of runner velocity of flow is Constant and discharge is radial at outlet. (10)

(ii) Discuss on the cascade theory. (6)

15. (a) Explain the various types of rotary pumps with its construction details and its applications. (16)

Or

(b) Explain in detail about the concept of pressure vessels with its characteristics. (16)

7. **ME CE 6451-NOV/DEC 2014**

Reg. No. :

Question Paper Code : 97031

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2014.

Third Semester

Mechanical Engineering

CE 6451 — FLUID MECHANICS AND MACHINERY

(Common to Aeronautical Engineering, Automobile Engineering, Mechatronics Engineering, Mechanical and Automation Engineering and Production Engineering)

(Regulation 2013)

Time : Three hours Maximum : 100 marks

Any missing data can be suitably assumed.

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. What is the importance of kinematic viscosity?
2. Define – Incompressible fluid.
3. State the assumptions used in the derivation of the Bernoulli's equation.
4. Differentiate between hydraulic grade line and energy grade line.
5. Brief on Intuitive method. Give some examples.
6. Define – Mach number and state its application.
7. List the losses in centrifugal pump.
8. What is meant by NPSH?
9. State and concise on Euler turbine equation.
10. Define – volumetric efficiency of turbine.

PART B — ($5 \times 16 = 80$ marks)

11. (a) (i) Water flows at the rate of 200 litres per second upwards through a tapered vertical pipe. The diameter at the bottom is 240 mm and at the top 200 mm and the length is 5 m. The pressure at the bottom is 8 bar, and the pressure at the topside is 7.3 bar. Determine the head loss through the pipe. Express it as a function of exit velocity head. (10)

(ii) Determine the viscous drag torque and power absorbed on one surface of a collar bearing of 0.2 m ID and 0.3 m OD with an oil film thickness of 1 mm and a viscosity of 30 centi poise if it rotates at 500 rpm. (6)

Or

(b) (i) The water level in a tank is 20 m above the ground. A hose is connected to the bottom of the tank, and the nozzle at the end of the hose is pointed straight up. The tank is at sea level, and the water surface is open to the atmosphere. In the line leading from the tank to the nozzle is a pump, which increases the pressure of water. If the water jet rises to a height of 27 m from the ground, determine the minimum pressure rise supplied by the pump to the water line. (10)

(ii) A hollow cylinder of 150 mm OD with its weight equal to the buoyant forces is to be kept floating vertically in a liquid with a surface tension of 0.45 N/m². The contact angle is 60°. Determine the additional force required due to surface tension. (6)

12. (a) (i) An oil of specific gravity 0.80 and kinematic viscosity 15×10^{-6} m²/s flows in a smooth pipe of 12 cm diameter at a rate of 150 lit/min. Determine whether the flow is laminar or turbulent. Also, calculate the velocity at the centre line and the velocity at a radius of 4 cm. What is head loss for a length of 10 m? What will be the entry length? Also determine the wall shear. (10)

(ii) Describe the Moody's chart. (6)

Or

(b) Oil at 27°C (ρ = 900 kg/m³ and μ = 40 centi poise) is flowing steadily in a 1.25-cm-diameter, 40-m-long pipe. During the flow, the pressure at the pipe inlet and exit is measured to be 8.25 bar and 0.97 bar, respectively. Determine the flow rate of oil through the pipe assuming the pipe is

(i) horizontal,

(ii) inclined 20° upward, and

(iii) inclined 20° downward. (16)

PART B — (5 × 16 = 80 marks)

11. (a) (i) Water flows at the rate of 200 litres per second upwards through a tapered vertical pipe. The diameter at the bottom is 240 mm and at the top 200 mm and the length is 5 m. The pressure at the bottom is 8 bar, and the pressure at the topside is 7.3 bar. Determine the head loss through the pipe. Express it as a function of exit velocity head. (10)

(ii) Determine the viscous drag torque and power absorbed on one surface of a collar bearing of 0.2 m ID and 0.3 m OD with an oil film thickness of 1 mm and a viscosity of 30 centi poise if it rotates at 500 rpm. (6)

Or

(b) (i) The water level in a tank is 20 m above the ground. A hose is connected to the bottom of the tank, and the nozzle at the end of the hose is pointed straight up. The tank is at sea level, and the water surface is open to the atmosphere. In the line leading from the tank to the nozzle is a pump, which increases the pressure of water. If the water jet rises to a height of 27 m from the ground, determine the minimum pressure rise supplied by the pump to the water line. (10)

(ii) A hollow cylinder of 150 mm OD with its weight equal to the buoyant forces is to be kept floating vertically in a liquid with a surface tension of 0.45 N/m^2. The contact angle is 60°. Determine the additional force required due to surface tension. (6)

12. (a) (i) An oil of specific gravity 0.80 and kinematic viscosity 15×10^{-6} m^2/s flows in a smooth pipe of 12 cm diameter at a rate of 150 lit/min. Determine whether the flow is laminar or turbulent. Also, calculate the velocity at the centre line and the velocity at a radius of 4 cm. What is head loss for a length of 10 m? What will be the entry length? Also determine the wall shear. (10)

(ii) Describe the Moody's chart. (6)

Or

(b) Oil at 27°C (ρ = 900 kg/m^3 and μ = 40 centi poise) is flowing steadily in a 1.25-cm-diameter, 40-m-long pipe. During the flow, the pressure at the pipe inlet and exit is measured to be 8.25 bar and 0.97 bar, respectively. Determine the flow rate of oil through the pipe assuming the pipe is

(i) horizontal,

(ii) inclined 20° upward, and

(iii) inclined 20° downward. (16)

13\. (a) The power developed by hydraulic machines is found to depend on the head H, flow rate Q, density ρ, speed N, runner diameter D and acceleration due to gravity g. Obtain suitable dimensionless parameters to correlate experimental results. (16)

Or

(b) Obtain a relation using dimensional analysis, for the resistance to uniform motion of a partially submerged body in a viscous compressible fluid. (16)

14\. (a) (i) The dimensionless specific speed of a centrifugal pump is 0.06. Static head is 32 m. Flow rate is 50 l/s. The suction and delivery pipes are each of diameter 15 cm. The friction factor is 0.02. Total length is 60 m other losses equal 4 times the velocity head in the pipe. The vanes are forward curved at 120°. The width is one tenth of the diameter. There is a 7% reduction in flow area due to the blade thickness. The manometric efficiency is 80%. Determine the impeller diameter if inlet is radial. (10)

(ii) Explain about the performance characteristics of centrifugal pumps. (6)

Or

(b) (i) A centrifugal pump running at 920 rpm and delivering 0.32 m^3/s of water against a head of 28 m, the flow velocity being 3 m/s. If the manometric efficiency is 80% determine the diameter and width of the impeller. The blade angle at outlet is 25°. (10)

(ii) Discuss the working of Lobe and vane pumps. (6)

15\. (a) (i) A Francis turbine developing 16120 kW under a head of 260 m runs at 600 rpm. The runner outside diameter is 1500 mm and the width is 135 mm. The flow rate is 7 m^3/s. The exit velocity at the draft tube outlet is 16 m/s. Assuming zero whirl velocity at exit and neglecting blade thickness determine the overall and hydraulic efficiency and rotor blade angle at inlet. Also find the guide vane outlet angle. (10)

(ii) Discuss about draft tube and its types. (6)

Or

(b) (i) A Kaplan turbine delivers 10 MW under a head of 25 m. The hub and tip diameters are 1.2 m and 3 m. Hydraulic and overall efficiencies are 0.90 and 0.85. If both velocity triangles are right angled triangles, determine the speed, guide blade outlet angle and blade outlet angle. (10)

(ii) Discuss about construction details of Kaplan turbine with a neat sketch. (6)

8. ME 1202-NOV/DEC 2013

Reg. No. :

Question Paper Code : 33574

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2013.

Third Semester

Mechanical Engineering

ME 1202/CE 1207/070120003 — FLUID MECHANICS AND MACHINERY

(Common to Aeronautical Engineering/Automobile Engineering/Mechatronics Engineering and Production Engineering)

(Regulation 2004/2007)

(Common to B.E. (Part-Time) Second semester – Mechanical Engineering – Regulation 2005)

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. State Newton's law of viscosity.
2. Establish the relationship between Absolute pressure, Gauge pressure and Atmospheric pressure.
3. State "Buckingham's π Theorem".
4. Name any two device used for measuring the rate of flow of a fluid flowing through a pipe.
5. Write down the relationship between Shear stress and pressure gradient for Incompressible fluid flow.
6. Write down the Darcy–weisback's equation to estimate the loss of head due to friction in pipes.
7. Define "Specific speed of a Turbine".
8. How will you classify turbines?
9. What is the significance of an Indicator diagram?
10. How will you avoid Cavitations in pumps?

PART B — (5 × 16 = 80 marks)

11. (a) (i) Calculate the capillary effect in millimeter in a glass tube of 4 mm diameter, when immersed in (1) water, and (2) mercury. The temperature of the liquid is 20°C and the values of the surface tension of water and mercury at 20°C in contact with air are 0.073575 N/m and 0.51 N/m respectively. The angle of contact for water is zero that for mercury 130°. Take density of water at 20°C as equal to 998 kg/m³. (8)

(ii) Define the following terms:

(1) Specific weight

(2) Specific Gravity

(3) Dynamic Viscosity

(4) Mass Density. (8)

Or

(b) (i) Prove that the relationship between surface tension and pressure inside a Liquid droplet in excess of outside pressure is given by $P = 4\sigma / d$. (8)

(ii) A U–tube manometer is used to measure the pressure of water in a pipe line, which is in excess of atmospheric pressure. The right limb of the manometer contains mercury and is open to atmosphere. The contact between water and mercury is in the left limb. Determine the pressure of water in the main line, if the difference in level of mercury in the limbs of U–tube is 10 cm and the free surface of mercury is in level with the centre of the pipe. If the pressure of water in pipe line is reduced to 9810 N/m², calculate the new difference in the level of mercury. (8)

12. (a) Using Buckingham's π theorem, show that the velocity through a circular orifice is given by $\sqrt{2gH}\ \phi\left[\frac{D}{H}, \frac{\mu}{\rho VH}\right]$, where H is the head causing flow, D is the diameter of the orifice, μ is co–efficient of viscosity, ρ is the mass density and g is he acceleration due to gravity.

Or

(b) (i) Derive the Bernoulli's equation from Euler's equation of motion. State its assumptions. (10)

(ii) Find the velocity of the flow of an oil through a pipe when the difference of mercury level in a differential U–Tube manometer connected to the two tappings of the pitot–tube is 100 mm. Take Co–efficient of pitot–tube 0.98 specific gravity of oil = 0.8. (6)

13\. (a) Derive the Hagen – Poiseuille formula used to find the loss of pressure head when viscous fluid flow through circular pipe. Also derive the condition of maximum velocity.

Or

(b) (i) An oil of specific gravity 0.7 is flowing through a pipe of diameter 300 mm at the rate of 500 litres/sec. Find the head lost due to friction and power required to maintain the flow for a length of 1000 m. Take kinematic viscosity as 0.29 stokes. (8)

(ii) Three pipes of lengths 800 m, 500 m and 400 m and of diameters 500 mm, 400 mm and 300 mm respectively are connected in series. These pipes are to be replaced by a single pipe of length 1700 m. Find the diameter of the single pipe. (8)

14\. (a) A Kaplan turbine develops 24647.6 kw power at an average head of 39 meters. Assuming a speed ratio of 2, flow ratio 0.6, diameter of the boss equal to 0.35 times the diameter of the runner and overall efficiency of 90%, Calculate the diameter, speed and specific speed of the turbine.

Or

(b) (i) With a neat sketch, explain the working of a pelton wheels. (8)

(ii) Compare impulse turbine and reaction turbine. (8)

15\. (a) Draw a neat sketch of a reciprocating pumps. List the components and briefly explain their functions.

Or

(b) (i) Explain in detail the working of a gear pumps with a neat diagram. (8)

(ii) Define Specific speed of a centrifugal pump. Derive an expression in terms of head 'H' discharge 'Q' and speed 'N'. (8)

9. ME 1202-NOV/DEC 2012

Reg. No. :

Question Paper Code : 13574

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2012.

Third Semester

Mechanical Engineering

ME 1202/CE 1207/070120003 — FLUID MECHANICS AND MACHINERY

(Common to Aeronautical Engineering/Automobile Engineering/Mechatronics Engineering and Production Engineering)

(Regulation 2004/2007)

(Common to B.E. (Part-Time) Second Semester – Mechanical Engineering – Regulation 2005)

Time : Three hours

Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Define density and specific gravity of a fluid.
2. Define coefficient of volume expansion.
3. Distinguish between local acceleration and convective acceleration.
4. What are the assumptions made in the derivation of Bernoulli's equation?
5. What is boundary layer separation?
6. Define hydrodynamic entry length.
7. Define hydraulic efficiency and overall efficiency of a turbine.
8. List the main parts of a Kaplan turbine.
9. Define the suction head and manometric head of a centrifugal pump.
10. What is a draft tube?

PART B — (5 × 16 = 80 marks)

11. (a) (i) What are the various classifications of fluids? Discuss. (8)

(ii) State Newton's law of viscosity. The velocity distribution over a plate is given by the relation, $u = y\left(\frac{2}{3} - y\right)$, where y is the vertical distance above the plate in meters. Assuming a viscosity of 0.9 Pa.s, find the shear stress at $y = 0$ and $y = 0.15$ m. (8)

Or

(b) (i) A spherical water droplet of 5 mm in diameter splits up in air into 16 smaller droplets of equal size. Find the work involved in splitting up the droplet. The surface tension of water may be assumed as 0.072 N/m. (8)

(ii) Define the terms gage pressure and absolute pressure. A U-tube containing mercury has its right limb open to atmosphere. The left limb is full of water and is connected to a pipe containing water under pressure, the center of which is in level with the free surface of mercury. If the difference in levels of mercury in the limbs is 5.1 cm, calculate the water pressure in the pipe. (8)

12. (a) (i) Derive the general form of continuity equation in Cartesian coordinates. (8)

(ii) Explain stream lines, path lines and flow net. (8)

Or

(b) With a neat sketch, explain briefly an orifice meter and obtain an expression for the discharge through it.

13. (a) (i) Considering laminar flow through a circular pipe, obtain an expression for the velocity distribution. (8)

(ii) Consider flow of oil through a pipe of 0.3 m diameter. The velocity distribution is parabolic with the maximum velocity of 3 m/s at the pipe center. Estimate the shear stresses at the pipe wall and within the fluid 50 mm from the pipe wall. The viscosity of the oil is 1.7 Pa.s. (8)

Or

(b) A pipeline conveys 10 lit/s of water from an over head tank to a building. The pipe is 2 km long and 15 cm diameter, the friction factor is 0.03. It is planned to increase the discharge by 30% by installing another pipeline in parallel with this over half the length. Find the suitable diameter of the pipe to be installed. Is there any upper limit on discharge augmentation by this arrangement?

14. (a) With a neat sketch, explain the working of a Pelton turbine. Also obtain an expression for the work done.

Or

(b) In an outward flow reaction turbine, the internal and external diameters are 2 m and 2.7 m respectively. The turbine speed is 275 rpm and the and the water flow rate is 5.5 m^3/s. The width of the runner is constant at inlet and outlet and equal to 250 mm. The head acting on the turbine is 160 m. The vanes have negligible thickness and the discharge at the outlet is radial. Determine the vane angles and velocity of flow at inlet and outlet.

15. (a) A centrifugal pump running at 1200 rpm has a discharge of 13 m^3/min. The pump has a manometric efficiency of 85% and working against a head of 22 m. The impeller has an outlet vane angle of 40°. If the velocity of flow at outlet is 2.6 m/s, determine the diameter of the impeller and the width of the impeller at the outlet.

Or

(b) (i) What is an air vessel? Derive an expression for the percentage work saved by using an air vessel. (8)

(ii) Discuss briefly the working principle of a vane pump with a schematic diagram. (8)

10. ME 2204-NOV/DEC 2012

Reg. No. :

Question Paper Code : 11520

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2012.

Third Semester

Mechanical Engineering

ME 2204/CE 3213/ME 34/CE 1208/10122 ME 305/080180007 — FLUID MECHANICS AND MACHINERY

(Common to Aeronautical Engineering, Automobile Engineering, Production Engineering, Mechatronics Engineering, Mechanical and Automation Engineering and Fourth Semester Manufacturing Engineering)

(Regulation 2008)

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — ($10 \times 2 = 20$ marks)

1. Define Newton's law of viscosity.
2. Write the continuity equation.
3. Write the Hagen-Poiseuille equation for laminar flow.
4. What is the use of moody's diagram?
5. Define Reynolds number.
6. State the Buckingham π theorem.
7. What is meant by hydraulic efficiency of turbine?
8. Define flow ratio of reaction radial flow turbine.
9. Mention the main parts of the Centrifugal pump.
10. Define slip of Reciprocating pump.

PART B — ($5 \times 16 = 80$ marks)

11. (a) The space between two square flat parallel plate is filled with oil. Each side of the plate is 600 mm. The thickness of the oil films is 12.5 mm. The upper plate, which moves at 2.5 m/s requires a force of 98.1 N to maintain the speed. Determine

(i) The dynamics viscosity of the oil in poise and

(ii) The kinematic viscosity of the oil in strokes if the specific gravity of the oil is 0.95. (16)

Or

(b) Derive the Euler's equation of motion and deduce the expression to Bernoulli's equation. (16)

12. (a) (i) A plate of 600 mm length and 400 mm wide is immersed in a fluid of specific gravity 0.9 and kinematic viscosity of (υ) = 10^{-4} m²/s. the fluid is moving with the velocity of 6 m/s. determine

(1) Boundary layer thickness

(2) Shear stress at the end of the plate and

(3) Drag force on one the sides of the plate. (10)

(ii) Derive Chezy's formula for loss of head due to friction in pipes. (6)

Or

(b) A 150 mm diameter pipe reduces in diameter abruptly to 100 mm diameter. If the pipe carries water at 30 liters per second, calculate the pressure loss across the contraction. Take coefficient of contraction as 0.6. (16)

13. (a) Derive on the basis of dimensional analysis suitable parameters to present the thrust developed by a propeller. Assume that the thrust P depends on the angular velocity w, speed of advance V, diameters D, dynamic viscosity μ, mass density ρ, and elasticity of the fluid medium which can be denoted by the speed of sound in the medium 'C'. (16)

Or

(b) A pipe of diameter 1.5 m is required to transport an oil of specific gravity 0.90 and viscosity 3×10^{-2} poise at the rate of 3000 litre/sec. Tests were conducted on a 15 cm diameter pipe using water at 20°C. Find the velocity and the rate of flow in the model. Viscosity of water at 20°C = 0.01 poise. (16)

14. (a) The following data is given for a Francis turbine. Net head H = 60 m, speed N = 700 rpm, shaft power = 294.3 kW, overall efficiency = 84%, hydraulic efficiency = 93%, flow ratio = 0.20, breadth ratio n = 0.1, outer diameter of runner = 2 × inner diameter of runner, the thickness of vanes occupies 5% of circumferential area of runner, velocity of flow is constant at inlet and outlet and discharge is radial at outlet. Determine :

(i) Guide blade angle

(ii) Runner vane angle at inlet and outlet

(iii) Diameter of runner at inlet and outlet

(iv) Width of the wheel at inlet. (16)

Or

(b) A pelton wheel has a mean bucket speed of 10 m/s with a jet of water flowing at the rate of 0.7 m^3/s under a head of 30 m. If the buckets deflect the jet through an angle of 160°. Calculate the power given by water to the runner and hydraulic efficiency of turbine. Assume the coefficient of velocity of 0.98. (16)

15. (a) The cylinder bore diameter and stroke of a single acting reciprocating pump are 150 mm and 300 mm respectively. The pump runs at 50 rpm and lifts water to a height of 25 m. The delivery pipe is 22 m long 100 mm in diameter. Find the theoretical discharge and theoretical power required to run the pump. If the actual discharge is 4.2 liters/s, find the percentage of slip. (16)

Or

(b) The internal and external diameters of the impeller of a centrifugal pump are 200 mm and 400 mm respectively. The pump is running at 1200 rpm, the vane angle of the impellor at inlet and outlet are 20° and 30° respectively. The water enters the impeller radially and the velocity of flow is constant. Determine the work done by the impeller per unit weight of water. (16)

11. ME 2204-NOV/DEC 2012

P607

B.E. /B.TECH. DEGREE EXAMINATIONS, NOV/DEC-2011

REGULATIONS 2008

THIRD SEMESTER

ME 34 – FLUID MECHANICS AND MACHINERY

MECHANICAL ENGINEERING

(Common to Aeronautical Engineering and Automobile Engineering)

Time: Three Hours Maximum: 100 Marks

ANSWER ALL THE QUESTIONS

PART-A (10X2=20 MARKS)

1. What is the real fluid? Give examples.
2. Determine the surface tensions acting on the surface of vertical thin plate of 1m length when it is lifted vertically from a liquid using a force of 0.3 N.
3. What is a Laminar flow?
4. What is the use of Moody diagram?
5. Name three methods for determination of dimensionless groups.
6. State the principle of dimensional homogeneity.
7. What is slip factor?
8. Define hydraulic efficiency.
9. Differentiate between Single acting Double acting Reciprocating pump.
10. State the advantages of installing air vessel.

PART-B (5X16=80 marks)

11. (a) (i) Distinguish between Newtonian and non-Newtonian Fluids.

(ii) Determine the power required to run a 300mm diameter shaft at 400rpm in journals with uniform oil thickness of 1mm. Two bearings of 300mm width are used to support the shaft. The dynamic viscosity of oil is 0.03 Pas. (Pas=(N/m^2)xs)

Or

(b) Derive the continuity equation in differential form. Discuss whether the equation is valid for a steady or unsteady flow, viscous or inviscous flow, compressible or incompressible flow.

12. (a)(i) Illustrate the boundary layer development in pipe flow with diagram.

(ii)Lubricating Oil at a velocity of 1m/s (average) flows through a pipe of 100mm ID. Determine whether the flow is lamina or turbulent. Also determine the friction factor and the pressure drop over 10m length. What should be the velocity for the flow to turn turbulent? Density = 930 kg/m^3, Dynamic viscosity μ = 0.1 Ns/m^2. (as N/m^2 is call Pascal, μ can be also expressed as Pa.s).

Or

(b)Derive Darcy-Weisbach equation for calculating pressure drop in pipe.

13. (a) Show that the power P, developed by a hydraulic turbine can be correlated by the dimensionless parameter $P/\rho N^3D^3$ and N^2D^2/gh, where ρ is the density of water and N is the rotational speed, D is the runner diameter, h is the head and g is acceleration due to gravity.

Or

(b) Describe the step by step procedure for determination of dimensionless group by Buckingham Pi Theorem

14. (a)(i) Derive Euler's turbine equation.

(ii)What is cavitation? How does it affect the performance of hydraulic machines?

Or

(b) The following details refer to a centrifugal pump. Outer diameter: 30cm. Eye diameter: 15cm. Blade angle at inlet: 30˚. Blade angle at outlet: 25˚. Speed 1450 rpm. The flow velocity remains constant. The whirl at inlet is zero. Determine the work done per kg. If the manometric efficiency is 82%. Determine the working head. If width at outlet is 2cm, determine the power $ή_0$=76%

15. (a) In a reciprocating pump the bore is 180mm and stoke is 280mm. Water level is 5m from the pump level. The suction pipe is 110mm diameter and 9m long. The atmospheric pressure head is 10.3m water. Determine the maximum speed not be less than 2.5m head of water. If the suction diameter is increased 125mm and length reduced to 6m, what will be the maximum speed?

Or

(b) Explain with sketch the following Rotary Positive Displacement Pumps.

I. Gear Pump
II. Vane Pump