

Fluid Mechanics and Machinery (313309)

Model Question Paper — Set B · Model Answers

Q.1

a) Define surface tension and capillarity.

2 M

(i) Surface tension (σ): It is the tensile force acting per unit length on the free surface of a liquid, caused by cohesion between liquid molecules; the free surface behaves like a stretched membrane.
Unit: N/m.

(ii) Capillarity: It is the phenomenon of rise or fall of a liquid surface in a small-diameter tube dipped in the liquid, due to cohesion and adhesion. Water rises (capillary rise) and mercury falls (capillary depression). $h = 4\sigma \cos \theta / (\rho g d)$.

(1 M each)

b) Equivalent columns of oil and mercury for 25 m of water.

2 M

Given: Head of water $h_w = 25$ m; $S_{oil} = 0.8$; $S_{mercury} = 13.6$

$$\text{Pressure, } p = \rho_w g h_w = 1000 \times 9.81 \times 25 = 245\,250 \text{ N/m}^2 = 245.25 \text{ kN/m}^2$$

$$\text{Same pressure in any liquid: } p = \rho g h = S \rho_w g h \Rightarrow h = \frac{h_w}{S}$$

$$\text{Height of oil column} = \frac{25}{0.8} = \boxed{31.25 \text{ m of oil}}$$

$$\text{Height of mercury column} = \frac{25}{13.6} = \boxed{1.838 \text{ m of mercury}}$$

(Each answer 1 M)

c) Bernoulli's theorem and equation.

2 M

Statement: In a steady, ideal, incompressible flow, the sum of pressure energy, kinetic energy and potential energy per unit weight of the fluid is constant at every point along a streamline.

$$p/\rho g + V^2/2g + Z = \text{constant} \text{ (pressure head + velocity head + datum head = total head)}$$

(Statement 1 M, equation 1 M)

d) Working principle of Bourdon tube pressure gauge.

2 M

A curved tube of **elliptical cross-section** (Bourdon tube), closed at one end, tends to **straighten out when pressure is applied inside it** because the section tries to become circular. The movement

of the free end is proportional to the pressure; it is magnified by a link, toothed sector and pinion and shown by a pointer on a calibrated dial.

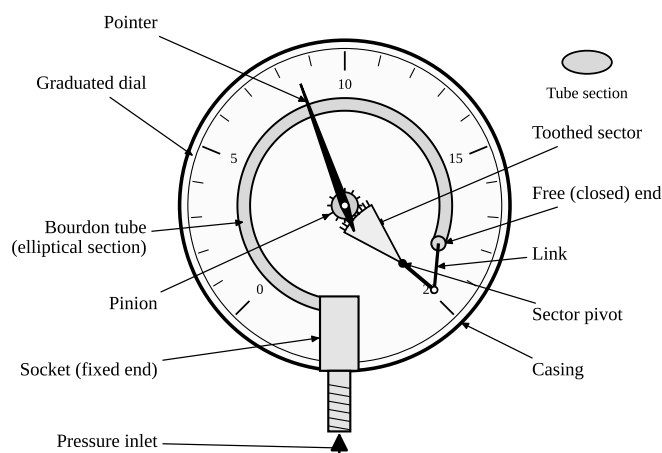


Fig.: Bourdon tube gauge

(Principle 2 M)

e) Causes and effects of water hammer.

2 M

Causes:

- Sudden closing of a valve (or sudden opening) at the end of a long pipe.
- Sudden stopping of a pump or failure of power supply to the pump.

Effects:

- Very high pressure rise which may burst the pipe or damage joints.
- Noise, vibration and hammering sound in the pipe line.

(½ M each)

f) Classification of hydraulic turbines.

2 M

1. **According to type of energy at inlet:** impulse turbine (Pelton) and reaction turbine (Francis, Kaplan).
2. **According to head:** high head (Pelton), medium head (Francis), low head (Kaplan, propeller).
3. **According to direction of flow through runner:** tangential (Pelton), radial — inward / outward (old Francis), axial (Kaplan, propeller), mixed (modern Francis).
4. **According to specific speed:** low (Pelton), medium (Francis), high (Kaplan).

(Any four bases, ½ M each)

g) Ideal indicator diagram.

2 M

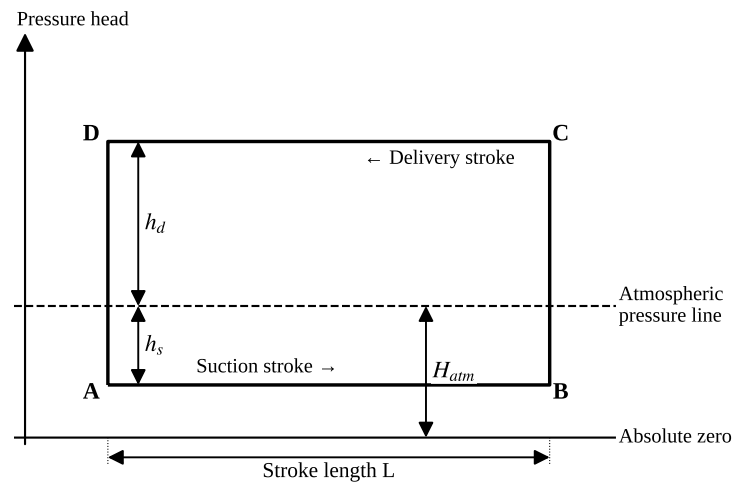


Fig.: Ideal (theoretical) indicator diagram of a reciprocating pump

AB — suction stroke at pressure head ($H_{atm} - h_s$); CD — delivery stroke at ($H_{atm} + h_d$); area ABCD $\propto$ work done per cycle.

(Labelled diagram 2 M)

Q.2

a) Total pressure and centre of pressure on vertical rectangular plate.

4 M

Given: $b = 1.5$ m, $d = 2.5$ m, upper edge 1 m below free surface

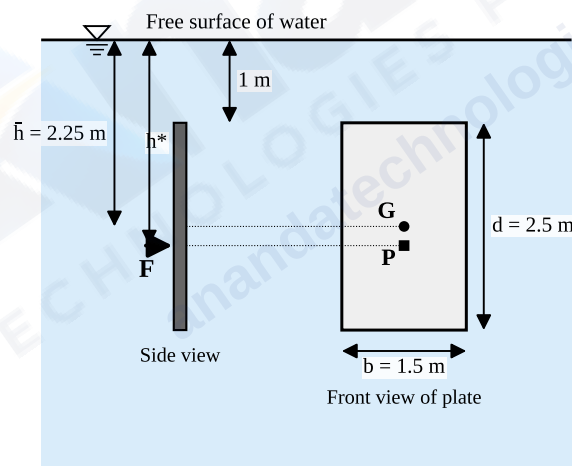


Fig.: Vertical rectangular plate

$$\text{Area, } A = b \times d = 1.5 \times 2.5 = 3.75 \text{ m}^2$$

$$\text{Depth of centroid below free surface, } \bar{h} = 1 + \frac{2.5}{2} = 2.25 \text{ m}$$

$$\text{Total pressure, } F = \rho g A \bar{h} = 1000 \times 9.81 \times 3.75 \times 2.25 = 82\,771.9 \text{ N} = \boxed{82.772 \text{ kN}}$$

$$\text{M.I. about centroidal axis, } I_G = \frac{b d^3}{12} = \frac{1.5 \times 2.5^3}{12} = 1.953 \text{ m}^4$$

$$\text{Centre of pressure, } h^* = \frac{I_G}{A \bar{h}} + \bar{h} = \frac{1.953}{3.75 \times 2.25} + 2.25 = 0.2315 + 2.25 =$$

2.481 m below free surface

(Total pressure 2 M, centre of pressure 2 M)

b) Atmospheric, gauge, vacuum and absolute pressure.

4 M

- **Atmospheric pressure:** the pressure exerted by the atmospheric air on the earth's surface; at sea level it is $101.325 \text{ kN/m}^2 = 10.3 \text{ m of water} = 760 \text{ mm of mercury}$. It is measured by a barometer.
- **Gauge pressure:** pressure measured above the local atmospheric pressure (atmospheric taken as zero datum) by gauges such as the Bourdon gauge or manometer.
- **Vacuum pressure:** pressure below atmospheric pressure, measured from atmospheric pressure downward (negative gauge pressure).
- **Absolute pressure:** pressure measured above absolute zero (complete vacuum).

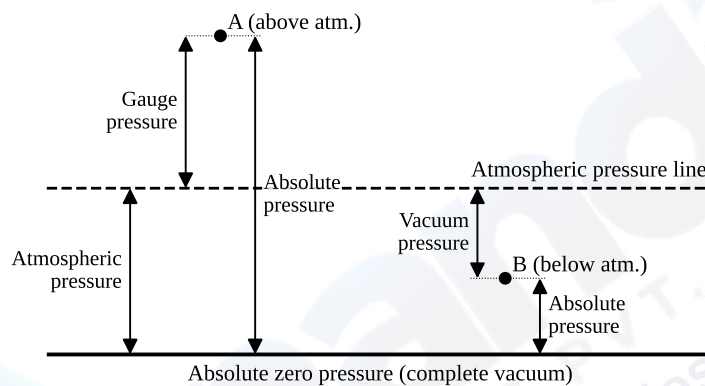


Fig.: Relation between absolute, gauge, atmospheric and vacuum pressure

$$\text{Absolute pressure} = \text{Atmospheric pressure} + \text{Gauge pressure}$$

$$\text{Absolute pressure} = \text{Atmospheric pressure} - \text{Vacuum pressure}$$

(Definitions 2 M, sketch 2 M)

c) Pressure difference by differential manometer (Fig. 1).

4 M

Given: Pipe A — water, $\rho_A = 1000 \text{ kg/m}^3$; pipe B — oil $S = 0.8$, $\rho_B = 800 \text{ kg/m}^3$; mercury $\rho_m = 13600$

kg/m^3 ; $y = 2.0 \text{ m}$, $h = 0.12 \text{ m}$, $x = 1.08 \text{ m}$

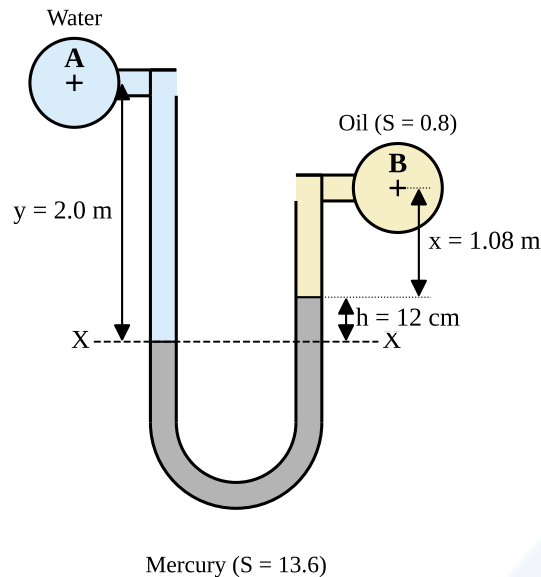


Fig.: Differential U-tube manometer

Take datum X-X at the lower mercury surface (left limb).

Pressure above X-X in left limb = $p_A + \rho_A g y$

Pressure above X-X in right limb = $p_B + \rho_B g x + \rho_m g h$

Equating: $p_A - p_B = \rho_B g x + \rho_m g h - \rho_A g y$

$$= 800 \times 9.81 \times 1.08 + 13\,600 \times 9.81 \times 0.12 - 1\,000 \times 9.81 \times 2$$

$$= 8\,475.8 + 16\,009.9 - 19\,620$$

$$p_A - p_B = \boxed{4\,865.8 \text{ N/m}^2 = 4.866 \text{ kN/m}^2}$$

Since the result is positive, pressure at A is greater than pressure at B.

(Equation 2 M, answer 2 M)

d) Pitot tube — construction and working.

4 M

Principle: A Pitot tube measures the velocity of flow at a point. At the open end facing the flow, the fluid is brought to rest (stagnation point); its kinetic energy is converted into pressure energy, so

the liquid in the tube rises above the free surface by $h = V^2/2g$.

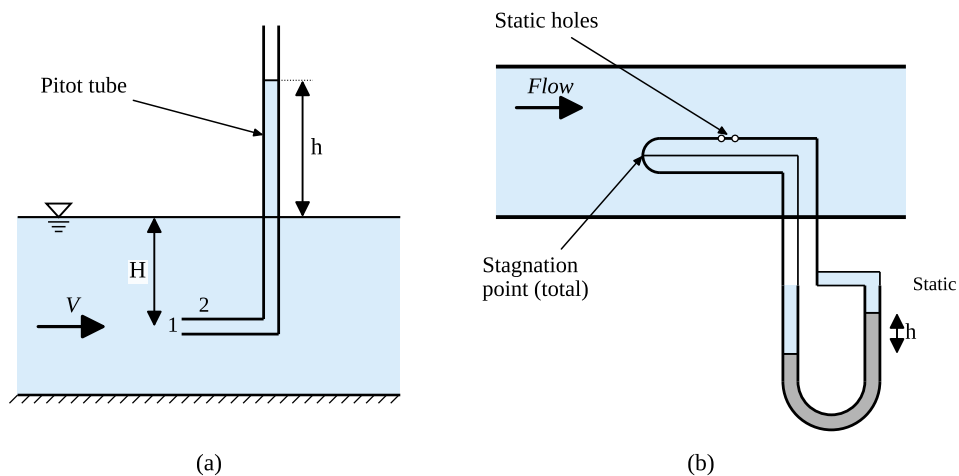


Fig.: (a) Simple Pitot tube in open channel (b) Pitot-static tube in a pipe

Construction: It is a small glass tube bent at right angles. The short horizontal limb, with its open end, faces the direction of flow; the vertical limb is open to the atmosphere (or connected to a manometer). In a pipe, a **Pitot-static tube** is used — an inner tube senses total (stagnation) pressure and an outer tube with side holes senses static pressure; the two are connected to a differential manometer.

Working: Apply Bernoulli between point 1 (upstream, velocity V) and point 2 (stagnation point, velocity zero):

$$p_1/\rho g + V^2/2g = p_2/\rho g \Rightarrow V^2/2g = (p_2 - p_1)/\rho g = h$$

$$\text{Theoretical velocity } V = \sqrt{2gh}; \text{ actual velocity } V = C_v \sqrt{2gh} \quad (C_v \approx 0.98)$$

(Sketch 2 M, construction & working 2 M)

Q.3

a) Discharge through orifice meter.

4 M

Given: $d_1 = 0.24$ m, $d_0 = 0.12$ m, $x = 0.25$ m of mercury, $C_d = 0.62$

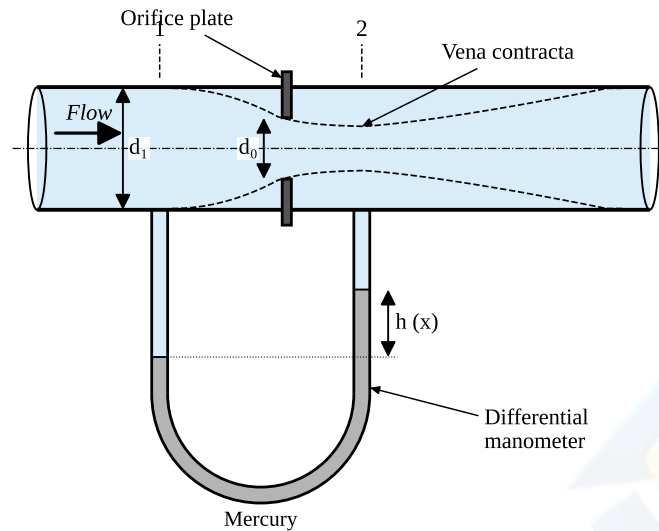


Fig.: Orifice meter

Area of pipe $a_1 = \frac{\pi}{4} \times 0.24^2 = 0.0452$ m²; area of orifice $a_0 = \frac{\pi}{4} \times 0.12^2 = 0.0113$ m²

Differential head $h = x (S_m/S_l - 1) = 0.25 \times (13.6/1.0 - 1) = 3.15$ m of liquid

$$Q = \frac{C_d a_0 a_1 \sqrt{(2gh)}}{\sqrt{(a_1^2 - a_0^2)}} = \frac{0.62 \times 0.0113 \times 0.0452 \times \sqrt{(2 \times 9.81 \times 3.15)}}{\sqrt{(0.0452^2 - 0.0113^2)}}$$

$$Q = \boxed{0.0569 \text{ m}^3/\text{s} = 56.933 \text{ litre/s}}$$

(Areas & head 1 M, formula 1 M, answer 2 M)

b) Laws of fluid friction — laminar and turbulent flow.

4 M

Laminar flow:

1. Frictional resistance is proportional to velocity of flow (V).
2. It is independent of the pressure.
3. It is proportional to the area of surface in contact.
4. It is independent of the nature (roughness) of the surface in contact.
5. It is greatly affected by temperature (since viscosity changes with temperature).

Turbulent flow:

1. Frictional resistance is proportional to V^n ($n = 1.72$ to 2 , nearly V^2).
2. It is proportional to the density of fluid.
3. It is proportional to the area of surface in contact.
4. It depends on the nature (roughness) of the surface.
5. It is slightly affected by temperature and independent of pressure.

(Laminar 2 M, turbulent 2 M)

c) HGL and TEL with sudden enlargement and contraction; minor losses.

4 M

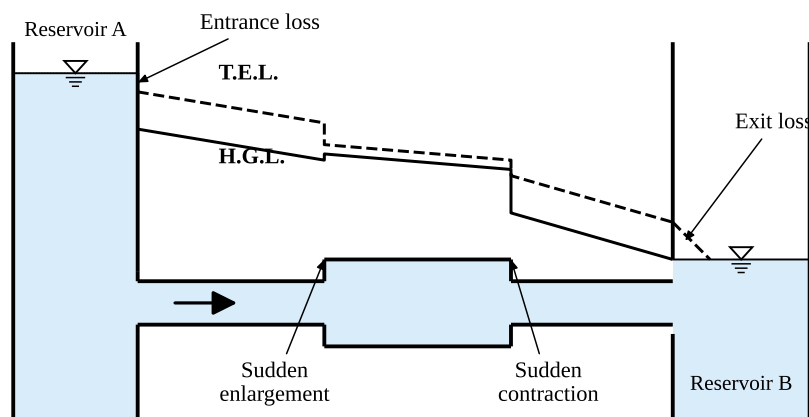


Fig.: HGL and TEL for a pipe with sudden enlargement and sudden contraction between two reservoirs

TEL falls gradually due to friction and suddenly at the entrance, enlargement, contraction and exit. HGL lies below TEL by $V^2/2g$; in the larger pipe $V^2/2g$ is small, so HGL comes closer to TEL (HGL rises at the enlargement).

Minor losses (losses due to change of velocity in magnitude or direction):

Minor loss	Formula
Sudden enlargement	$h_e = (V_1 - V_2)^2/2g$
Sudden contraction	$h_c = (1/C_c - 1)^2 V_2^2/2g \approx 0.5 V_2^2/2g$
Entrance of pipe	$h_i = 0.5 V^2/2g$
Exit of pipe	$h_o = V^2/2g$
Bend in pipe	$h_b = k V^2/2g$
Pipe fittings (valves, couplings)	$h = k V^2/2g$
Obstruction in pipe	$h = [A/(C_c(A - a)) - 1]^2 V^2/2g$

(HGL/TEL sketch 2 M, minor losses with formulae 2 M)

d) Kaplan turbine — construction and working.

4 M

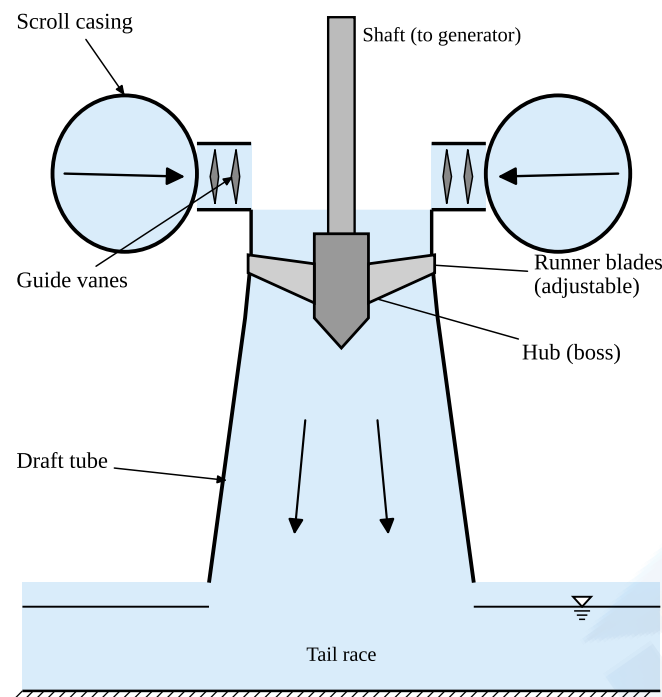


Fig.: Kaplan turbine (sectional elevation)

Kaplan turbine is an **axial flow reaction turbine** with **adjustable runner blades**, used for low head and large discharge.

- **Scroll casing:** distributes water all round the guide vanes.
- **Guide vanes:** direct water at the proper angle and regulate the flow; water then turns through 90° in the whirl space and flows axially.
- **Runner (hub with blades):** 3 to 8 blades mounted on a large hub; the blade angle is changed by a servo-mechanism inside the hub according to the load, giving high efficiency at part loads.
- **Draft tube:** discharges water to the tail race and recovers kinetic energy.

Working: Water from the scroll casing passes through the guide vanes, turns axially and flows over the runner blades. Due to the reaction of water on the blades (change of pressure and velocity), the runner rotates; water leaves axially through the draft tube to the tail race.

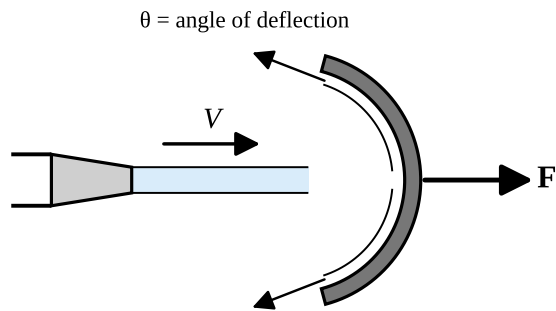
(Sketch 2 M, construction & working 2 M)

Q.4

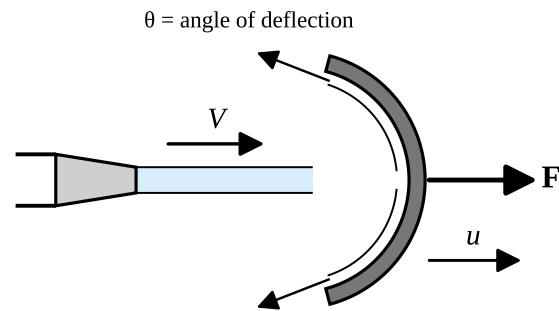
a) Jet on symmetrical curved vane — fixed and moving.

4 M

Given: $d = 0.06 \text{ m}$, $V = 22 \text{ m/s}$, $\theta = 160^\circ$, $u = 8 \text{ m/s}$



Fixed symmetrical curved vane (jet strikes at centre)



Symmetrical curved vane moving with velocity u

Area of jet $a = \frac{\pi}{4} \times 0.06^2 = 0.00283 \text{ m}^2$; jet deflected through $\theta = 160^\circ$, so $(1 - \cos \theta) = 1 - (-0.9397) = 1.9397$

(i) **Vane fixed:** $F_x = \rho a V^2 (1 - \cos \theta) = 1000 \times 0.00283 \times 22^2 \times 1.9397 = \boxed{2\ 654.4 \text{ N}}$

(ii) **Vane moving** with $u = 8 \text{ m/s}$: relative velocity $(V - u) = 14 \text{ m/s}$

$F_x = \rho a (V - u)^2 (1 - \cos \theta) = 1000 \times 0.00283 \times 14^2 \times 1.9397 = \boxed{1\ 074.9 \text{ N}}$

Work done per second $= F_x \times u = 1\ 074.9 \times 8 = \boxed{8\ 599.5 \text{ W} = 8.599 \text{ kW}}$

Efficiency $\eta = \frac{F_x u}{\frac{1}{2} \rho a V^3} = \frac{8\ 599.5}{15\ 053.3} = \boxed{57.127 \%}$

(Fixed vane 1 M, moving vane 1 M, work done 1 M, efficiency 1 M)

b) Need and types of draft tube.

4 M

Need of draft tube:

- It permits the turbine to be installed above the tail race level without loss of head (creates a negative / suction head at runner outlet), so the turbine can be inspected easily.
- Being a diverging tube, it converts a large part of the kinetic energy of water leaving the runner into useful pressure energy, so the net head and hence the **output and efficiency** of the turbine increase.
- It discharges water to the tail race safely without splashing.

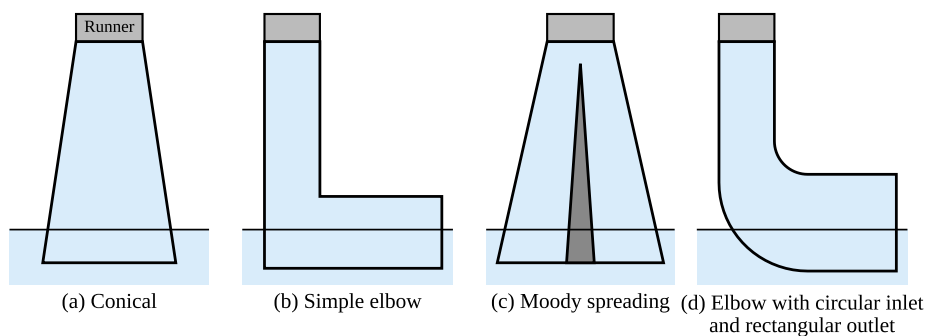


Fig.: Types of draft tubes

(Need 1 M, four sketches 3 M)

c) One, two and three dimensional flow; compressible and incompressible flow.

4 M

- **One-dimensional flow:** flow parameters (velocity, pressure) vary with only one space coordinate (along the flow); variation across the section is neglected. Example: flow through a pipe using mean velocity.
- **Two-dimensional flow:** flow parameters vary with two space coordinates and are the same in parallel planes. Example: flow between two wide parallel plates; flow over a long spillway.
- **Three-dimensional flow:** flow parameters vary with all three coordinates x , y and z . Example: flow in a river at a bend; flow at the inlet of a nozzle.
- **Compressible flow:** density of the fluid changes from point to point ($\rho \neq \text{constant}$). Example: flow of air/gas at high velocity (Mach number > 0.3), flow in gas turbines and compressors.
- **Incompressible flow:** density remains constant ($\rho = \text{constant}$). Example: flow of water / oil in pipes; flow of air at low speed.

(Each type with example $\frac{1}{2}$ –1 M)

d) Double acting reciprocating pump.

4 M

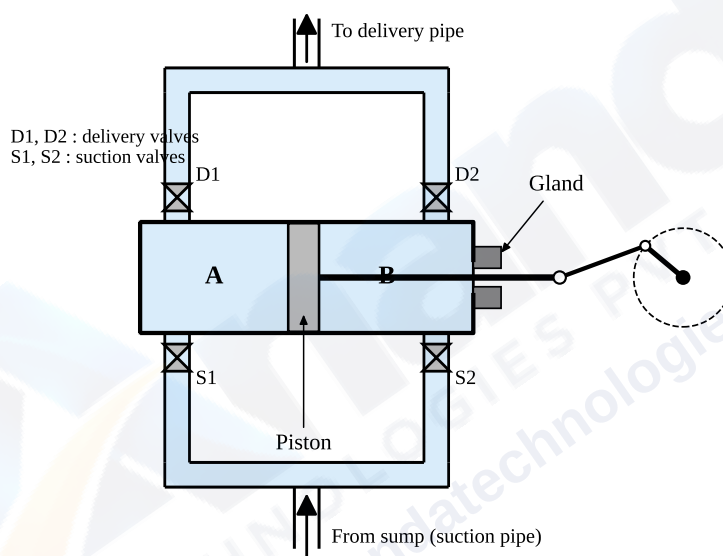


Fig.: Double acting reciprocating pump

Construction: The cylinder has suction and delivery valves at both ends (S1, D1 at the left end A and S2, D2 at the right end B). The piston rod passes through a stuffing box (gland) at one end and is driven by a crank and connecting rod.

- When the piston moves to the right, a vacuum is created on the left side (A): S1 opens and water is sucked into A; at the same time water on the right side (B) is pressurised: S2 closes, D2 opens and water is delivered.
- When the piston moves to the left, water is sucked into B through S2 and water in A is delivered through D1.
- Thus suction and delivery take place simultaneously in each stroke; water is delivered in both strokes, so discharge is nearly double and more uniform than a single acting pump.
- Theoretical discharge $Q_{th} = (2A - a_r) L N/60 \approx 2 A L N/60$ (a_r = area of piston rod).

(Sketch 2 M, working 2 M)

e) Priming of centrifugal pump.

4 M

Priming is the operation of completely filling the suction pipe, the casing and the portion of delivery pipe up to the delivery valve with the liquid to be pumped, so that no air remains in the pump.

Necessity: The head developed by the impeller is in metres of the fluid present in it ($H_m = V_{w2}u_2/g$). If air is present, a head of a few metres of air corresponds to negligible pressure (air is about 800 times lighter than water); the pressure produced is too small to lift water from the sump. Hence the pump must be primed before starting.

Methods of priming:

1. Manual priming — pouring water through a funnel with the air cock open (foot valve retains water in the suction pipe).
2. Priming with a vacuum pump that removes air from the casing and suction pipe.
3. Priming with a jet pump / ejector.
4. Priming from the delivery line or an overhead tank through a bypass.
5. Use of self-priming pumps.

(Definition 1 M, necessity 1 M, methods 2 M)

Q.5

a) Diameter of pipe and efficiency of transmission.

6 M

Given: $P = 180 \text{ kW}$, $L = 2500 \text{ m}$, $p_{\text{inlet}} = 4500 \text{ kN/m}^2$, pressure drop $\Delta p = 900 \text{ kN/m}^2$, $f = 0.0065$ ($h_f = 4fLV^2/2gD$)

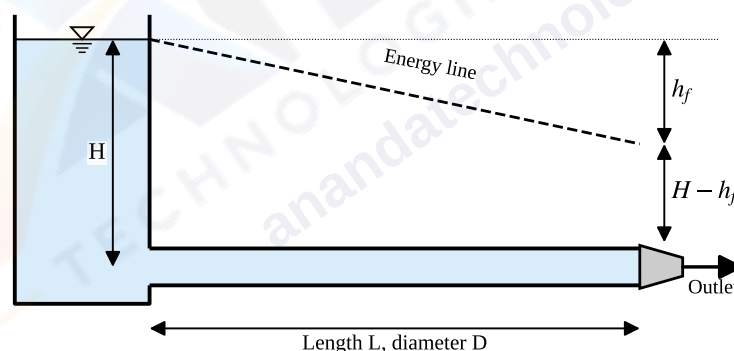


Fig.: Transmission of power through a pipe

$$\text{Head at inlet } H = \frac{p}{\rho g} = \frac{4\,500\,000}{9810} = 458.72 \text{ m}$$

$$\text{Head lost in friction } h_f = \frac{\Delta p}{\rho g} = \frac{900\,000}{9810} = 91.743 \text{ m}$$

$$\text{Power transmitted } P = \rho g Q (H - h_f) \Rightarrow Q = \frac{180\,000}{9810 \times (458.72 - 91.743)} = 0.05 \text{ m}^3/\text{s}$$

$$h_f = \frac{4 f L V^2}{2 g D} \text{ with } V = \frac{4Q}{\pi D^2} \Rightarrow h_f = \frac{4 f L \times 16 Q^2}{2 g \pi^2 D^5}$$

$$D^5 = \frac{4 \times 0.0065 \times 2500 \times 16 \times 0.05^2}{2 \times 9.81 \times \pi^2 \times 91.743} = 0.000146$$

$$(i) D = (0.000146)^{1/5} = \boxed{0.171 \text{ m} \approx 171 \text{ mm}}$$

$$(ii) \text{ Efficiency of transmission } \eta = \frac{H - h_f}{H} = \frac{458.72 - 91.743}{458.72} = \boxed{80 \%}$$

(Heads 1 M, discharge 1 M, diameter 3 M, efficiency 1 M)

b) Venturimeter — construction, working and discharge equation.

6 M

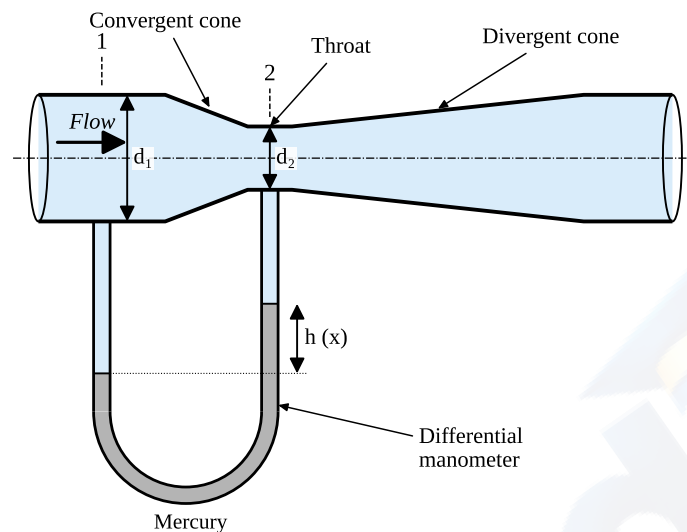


Fig.: Venturimeter with differential U-tube manometer

Construction:

- **Convergent cone (inlet):** short tapering section (cone angle about 20°–22°), in which the area decreases from pipe diameter d_1 to throat diameter.
- **Throat:** short parallel section of minimum area ($d_2 = \frac{1}{3}$ to $\frac{3}{4}$ of d_1 , usually $\frac{1}{2}$).
- **Divergent cone:** gradually diverging section (angle 5°–7°), longer than the convergent part to avoid flow separation and to recover pressure.
- A differential manometer is connected between the inlet (section 1) and the throat (section 2).

Working: As water flows through the convergent part, the velocity increases and the pressure decreases (Bernoulli). The pressure difference between inlet and throat is measured by the manometer and is used to calculate the discharge.

Expression for discharge: Applying Bernoulli between sections 1 and 2 of a horizontal venturimeter ($Z_1 = Z_2$):

$$p_1/\rho g + V_1^2/2g = p_2/\rho g + V_2^2/2g \Rightarrow (p_1 - p_2)/\rho g = h = (V_2^2 - V_1^2)/2g$$

$$\text{Continuity: } a_1 V_1 = a_2 V_2 \Rightarrow V_1 = (a_2/a_1) V_2$$

$$h = \frac{V_2^2}{2g} \left(1 - \frac{a_2^2}{a_1^2}\right) \Rightarrow V_2 = \frac{a_1}{\sqrt{a_1^2 - a_2^2}} \sqrt{2gh}$$

$$Q_{th} = a_2 V_2 = \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \sqrt{2gh}; \text{ Actual } Q = C_d \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \sqrt{2gh}$$

where $h = x (S_m/S - 1)$ for a differential U-tube with heavier manometric liquid; $C_d = 0.95$ to 0.98.

(Sketch 2 M, construction & working 1 M, derivation 3 M)

c) Design of Pelton wheel — D, d and number of jets.

6 M

Given: Shaft power $P = 9000$ kW, $H = 320$ m, $N = 600$ rpm, $\eta_o = 0.85$, $d \leq D/8$, $C_v = 0.98$, speed ratio = 0.46

$$\sqrt{(2gH)} = \sqrt{(2 \times 9.81 \times 320)} = 79.236 \text{ m/s}$$

$$\text{Jet velocity } V_1 = C_v \sqrt{(2gH)} = 0.98 \times 79.236 = 77.652 \text{ m/s}$$

$$\text{Bucket velocity } u = \text{speed ratio} \times \sqrt{(2gH)} = 0.46 \times 79.236 = 36.449 \text{ m/s}$$

$$(i) \text{ Wheel diameter: } u = \frac{\pi D N}{60} \Rightarrow D = \frac{60 u}{\pi N} = \frac{60 \times 36.449}{\pi \times 600} = \boxed{1.16 \text{ m}}$$

$$(ii) \text{ Jet diameter (limited to } D/8): d = \frac{1.16}{8} = \boxed{0.145 \text{ m} = 145.02 \text{ mm}}$$

$$\text{Total discharge } Q = \frac{\text{Shaft power}}{\rho g H \eta_o} = \frac{9\,000\,000}{9810 \times 320 \times 0.85} = 3.373 \text{ m}^3/\text{s}$$

$$\text{Discharge through one jet } q = \frac{\pi}{4} d^2 V_1 = 0.0165 \times 77.652 = 1.283 \text{ m}^3/\text{s}$$

$$(iii) \text{ Number of jets } n = Q/q = 3.373/1.283 = 2.63 \Rightarrow \boxed{n = 3 \text{ jets}} \text{ (next whole number)}$$

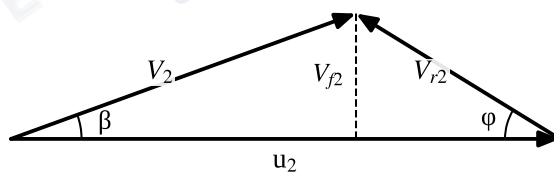
(Velocities 1 M, D 2 M, d 1 M, number of jets 2 M)

Q.6

a) Centrifugal pump — manometric, mechanical and overall efficiency.

6 M

Given: $D_2 = 0.5$ m, $b_2 = 0.06$ m, $\phi = 35^\circ$, $N = 1200$ rpm, $Q = 0.22$ m³/s, $H_m = 70$ m, shaft power = 230 kW, radial entry ($V_{w1} = 0$)



Outlet velocity triangle

Fig.: Outlet velocity triangle (not to scale); inlet: radial entry, $V_{w1} = 0$

$$u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 0.5 \times 1200}{60} = 31.416 \text{ m/s}$$

$$Q = \pi D_2 b_2 V_{f2} \Rightarrow V_{f2} = \frac{0.22}{\pi \times 0.5 \times 0.06} = 2.334 \text{ m/s}$$

$$V_{w2} = u_2 - \frac{V_{f2}}{\tan \phi} = 31.416 - \frac{2.334}{\tan 35^\circ} = 28.082 \text{ m/s}$$

$$\text{Work done per kg} = V_{w2} u_2 = 28.082 \times 31.416 = 882.23 \text{ N}\cdot\text{m/kg}$$

$$(i) \text{ Manometric efficiency } \eta_{\text{mano}} = \frac{g H_m}{V_{w2} u_2} = \frac{9.81 \times 70}{882.23} = \boxed{77.837 \%}$$

$$\text{Power given to water by impeller} = \rho Q V_{w2} u_2 = 1000 \times 0.22 \times 882.23 = 194.09 \text{ kW}$$

$$(ii) \text{ Mechanical efficiency } \eta_m = \frac{\text{Power at impeller}}{\text{Shaft power}} = \frac{194.09}{230} = \boxed{84.387 \%}$$

$$(iii) \text{ Overall efficiency } \eta_o = \frac{\rho g Q H_m}{\text{Shaft power}} = \frac{9810 \times 0.22 \times 70}{230 \ 000} = \boxed{65.684 \%}$$

$$\text{Check: } \eta_{\text{mano}} \times \eta_m = 0.7784 \times 0.8439 = 0.6568 = \eta_o \checkmark$$

(Velocities 2 M, each efficiency with formula 4 M)

b) Main characteristic curves of Pelton wheel.

6 M

Main characteristic curves are obtained by keeping the **head constant** and varying the speed (by changing the load) for different nozzle (spear) openings. Unit quantities are used: $N_u = N/\sqrt{H}$, $Q_u = Q/\sqrt{H}$, $P_u = P/H^{3/2}$.

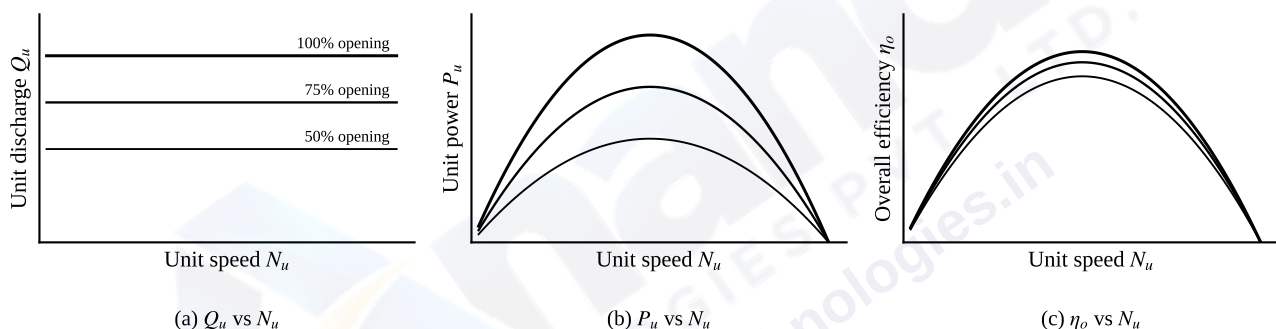


Fig.: Main characteristic curves of Pelton wheel (constant head)

- **(a) Q_u vs N_u :** horizontal straight lines — the discharge through the nozzle depends only on the head and the spear opening, not on the speed of the wheel.
- **(b) P_u vs N_u :** parabolic curves — power is zero at zero speed and at the run-away speed ($u = V_1$); it is maximum near $u \approx 0.46 V_1$.
- **(c) η_o vs N_u :** parabolic; maximum efficiency occurs at the design speed ratio (about 0.46). Efficiency is nearly the same for different openings, since the jet velocity does not change with opening.
- Operating characteristic (constant speed): efficiency of a Pelton wheel remains high over a wide range of load (flat curve), because the jet velocity is constant.

(Three curves 3 M, explanation 3 M)

c) Multistage centrifugal pumps.

6 M

A pump having two or more impellers is called a **multistage centrifugal pump**. The impellers may be mounted on the same shaft in series (to obtain high head) or separate pumps may be connected

in parallel (to obtain large discharge).

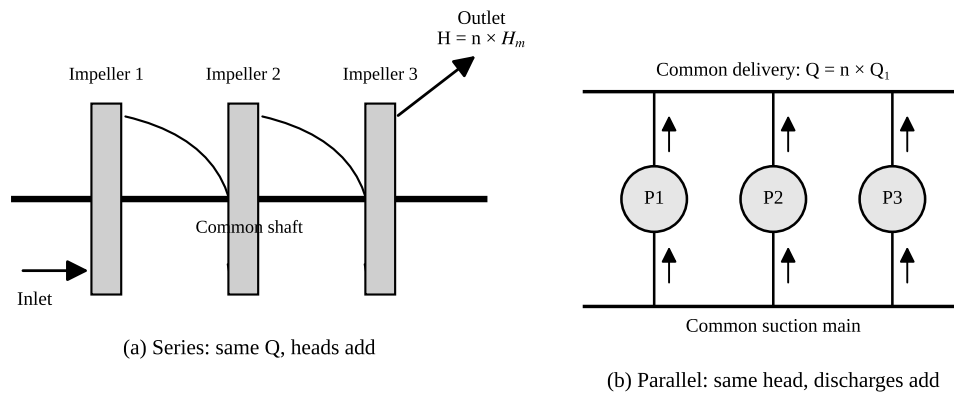


Fig.: Multistage centrifugal pumps — (a) impellers in series (b) pumps in parallel

(a) Impellers in series (for high head): two or more identical impellers are keyed to a common shaft in one casing. Water from the outlet of the first impeller is led through guide passages to the eye of the second impeller, and so on. The same discharge passes through all impellers and the total head = $n \times H_m$ (n = number of impellers).

(b) Pumps in parallel (for high discharge): two or more pumps lift water from a common sump and deliver it to a common delivery main. Each pump works against the same head; total discharge = $n \times Q$.

Applications: high head — boiler feed pumps, water supply to high-rise buildings, deep well (borewell submersible) pumps, mine drainage; parallel — municipal water supply and irrigation where large and variable quantity is needed.

(Sketch 2 M, series 1.5 M, parallel 1.5 M, applications 1 M)

Note: This is a **model question paper prepared by Ananda Technologies** only for practice and exam preparation, based on the pattern of previous MSBTE question papers and the K-scheme syllabus. It is **not an official MSBTE paper**, and it does **not** mean that these questions will come in the exam. Answers follow standard textbook points; marks shown are indicative. Free for students — anandatechnologies.in