Department of Civil Engineering

Institute of Technology, GGV

B.Tech. Third Year [Vth Sem.]

Subject: Fluid Mechanics II

Maximum Masks: 60

Note: (i) Section-A, all questions carry equal marks. 02 Marks allotted for each question.
(ii) Section-B, Attempt any one question from each Unit. All question carry equal Marks.

SECTION – A

Q(1) The flow in pipe is said to be turbulent when Reynolds number is
(a) Less than 1000 (b) Equal to 2000 (c) Greater than 4000 (d) none of these

Q(2) The velocity distribution in rough pipes
(a) $\frac{u}{u*} = 5.75 \log \frac{y}{ks} + 8.5$ (b) $\frac{u}{u*} = 5.75 \log \frac{u*y}{ks} + 8.5$
(c) $\frac{u}{u*} = 5.75 \log \frac{y}{ks} + 5.5$ (d) $\frac{u}{u*} = 5.75 \log \frac{u*y}{\nu} + 5.5$

Q(3)The pressure drag depends upon:
(a) shear stresses generated on the body surface (b) weight component in flow direction
(c) separation of boundary layer and size of wake (d) none

Q(4) The wake
(a) always occurs before a separation point (b) always occurs after a separation point
(c) is a region of high pressure intensity (d) none of the above

Q(5) For Strong jump energy dissipation % is
(a) 30 (b) 85 (c) 45 (d) 10

Q(6) When Froude Number is in between 2.5 to 4.5, type of jump is
(a) Oscillating Jump (b) Strong Jump (c) Uniform Jump (d) Weak Jump

Q(7) The pressure wave in a fluid medium travels as a sound wave, the velocity of which is given by:
(a) $C = \sqrt{K}/\rho$ (b) $C = \sqrt{\rho}/K$ (c) $C = \sqrt{\rho}K$ (d) $C = K/\rho$

Q(8) . Dimensional analysis is useful in
(a) checking the correctness of a physical equation
(b) determining the number of variables involved in a particular phenomenon
(c) determining the dimensionless groups from the given variables
(d) the exact formulation of a physical phenomenon

Q(9) The specific speed of turbine (N=Speed, P=Power, H=Head)
(a) $N\sqrt{P}/H^{4/5}$ (b) $N\sqrt{P}/H^{5/4}$ (c) $P\sqrt{N}/H^{5/4}$ (d) $P\sqrt{N}/H^{4/5}$

Q(10) Compared to cylindrical draft tube, a tapered draft tube
(a) prevent hammer blow and surges
(b) responds better to load fluctuations
(c) convert more of kinetic head into pressure head
(d) prevents cavitation even under reduced discharges

SECTION – B

Unit-I

Q (1)(a) Explain in brief shear velocity. **Marks 02**

$\sqrt{\frac{\tau_0}{\rho}} = \sqrt{\frac{ML^{-1}T^{-2}}{ML^{-3}}} = \sqrt{\frac{L^2}{T^2}} = \frac{L}{T}$ = Velocity So $\sqrt{\frac{\tau_0}{\rho}} = u_*$ where u_* = shear velocity

The dimension of $\sqrt{\frac{\tau_0}{\rho}}$ is same as velocity.

(b) In a smooth pipe of diameter 0.5 and length 1000 m water is flowing at the rate of 0.05 m^3/sec. Assuming the kinematic viscosity of water as 0.02 stokes, find :

(i) Head lost due to friction
(ii) Wall shear stress
(iii) Centerline Velocity

Marks 06

Diameter of smooth pipe $D = 0.50m$ $R = \frac{0.50}{2} = 0.25m$

Length of pipe $L = 1000\,m$ Discharge through pipe = $0.05\ m^3/sec$

Kinematic viscosity of water $\nu = 0.02 \times 10^{-4}\ m^2/sec$

Avg. Velocity (V) or $\bar{U} = \frac{Q}{Area} = \frac{0.05}{\frac{\pi}{4} \times (0.5)^2} = 0.2546\ m/sec$

∴ Reynolds Number $Re = \frac{\bar{U} \times D}{\nu} = \frac{0.2546 \times 0.5}{0.02 \times 10^{-4}} = 6.365 \times 10^{+4}$

$Re > 4000$ for pipe the flow is turbulent

So for turbulent flow $f = \frac{0.0791}{Re^{1/4}} = \frac{0.0791}{(6.365 \times 10^4)^{1/4}} = 0.00498$

(i) Head loss due to friction

$hf = \frac{4fLV^2}{2gD} = \frac{4 \times 0.00498 \times 1000 \times (0.2546)^2}{2 \times 9.81 \times 0.50}$

$hf = 0.1316\,m$

(ii) Wall shear stress τ_0: $\tau_0 = \frac{f\rho V^2}{2} = \frac{f\rho \bar{U}^2}{2} = \frac{0.00498 \times 1000 \times (0.2546)^2}{2}$

$\tau_0 = 0.1614\ N/m^2$

(iii) Centre-line velocity

Umax. $\frac{u}{u_*} = 5.75 \log_{10}\left(\frac{u_* y}{\nu}\right) + 5.5$

But at $y = R$, $u = u_{max}$

$\frac{u_{max}}{u_*} = 5.75 \log_{10}\left(\frac{u_* R}{\nu}\right) + 5.50 \Rightarrow \frac{u_{max}}{0.0127} = 5.75 \log_{10}\left(\frac{0.0127 \times 0.25}{0.02 \times 10^{-4}}\right) + 5.50$

$u_* = \sqrt{\frac{\tau_0}{\rho}} = 0.0127\ m/sec$

$u_{max} = 0.303\ m/sec$

OR

Q (2) (a) What is Aging in pipes? **Marks 02**

The Values of equivalent sand grain roughness is increased due to dirt with age. This deterioration of pipe surface depends upon the nature of the material and also the fluid.

$k_s = k_0 + \alpha t$, k_s = roughness at any time t, α = time rate of increase of roughness

(b) The velocity of flow in a badly corroded 8 cm pipe is found to increase 25% as a pilot tube is moved from a point 1cm from the wall to a point 2 cm from the wall. Estimate the height of roughness element.

Marks 06

The Velocity distribution near Rough boundaries is given by

$$\frac{u}{u_*} = 5.75 \log_{10}\left(\frac{y}{k_s}\right) + 8.50$$

$y = 1.0$ cm $\quad u = u$

$$\frac{u}{u_*} = 5.75 \log_{10} \frac{1}{k_s} + 8.50$$

$y = 2.0$ cm. $\quad u = 1.25u$

$$\frac{1.25u}{u_*} = 5.75 \log_{10} \frac{2}{k_s} + 8.50$$

$$\therefore \frac{1}{1.25} = \frac{5.75 \log_{10}\left(\frac{1}{k_s}\right) + 8.50}{5.75 \log_{10}\left(\frac{2}{k_s}\right) + 8.50}$$

$$5.75 \log_{10}\left(\frac{2}{k_s}\right) + 8.50 = 7.187 \log_{10}\left(\frac{1}{k_s}\right) + 10.625$$

$$\therefore \log_{10} k_s = \frac{0.3943}{1.4375} = 0.0274$$

$$\therefore k_s = 1.8805 \text{ cm.}$$

Ans. - $\therefore$ The height of roughness element = 1.8805 cm.

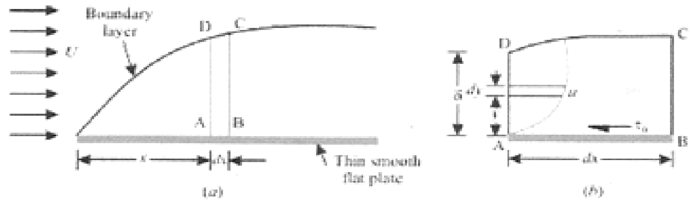
Unit-II

Q (1) (a) What is Boundary layer thickness? **Marks 02**

Boundary Layer thickness (δ). It is defined as the distance from the boundary of solid body measured in the y-direction to the point, where the velocity of the fluid is approximately equal to 0.99 times the free stream velocity(U) of the fluid. It is denoted by δ.

(b) Explain in brief von karman Momentum integral equation for boundary layer flow.

Marks 06



Let $ABCD$ be a small element of a boundary layer (the edge DC represents the outer edge of the boundary layer).

Mass rate of fluid entering through AD

$$= \int_0^\delta \rho u dy$$

Mass rate of fluid leaving through BC

$$= \int_0^\delta \rho u dy + \frac{d}{dx}\left[\int_0^\delta \rho u dy\right] dx$$

$\therefore$ Mass rate of fluid entering the control volume through the surface DC

= Mass rate of fluid through BC – mass rate of fluid through AD

$$= \int_0^\delta \rho u dy + \frac{d}{dx}\left[\int_0^\delta \rho u dy\right] dx - \int_0^\delta \rho u dy = \frac{d}{dx}\left[\int_0^\delta \rho u dy\right] dx$$

$$= \frac{d}{dx}\left[\int_0^\delta \rho u^2\, dy - \int_0^\delta \rho u\, U\, dy\right] dx$$

$$= \frac{d}{dx}\left[\int_0^\delta (\rho u^2\, dy - \rho u\, U\, dy)\right] dx$$

$$= \frac{d}{dx}\left[\rho \int_0^\delta (u^2 - uU)\, dy\right] dx$$

(ρ is constant for incompressible fluid)

$$= \rho \frac{d}{dx}\left[\int_0^\delta (u^2 - uU)\, dy\right] dx$$

$$\Delta F_D = \tau_0 \times dx$$

Thus the total external force in the direction of rate of change of momentum

$$= -\tau_0 \times dx$$

Equating the eqns. (13.4) and (13.5), we have:

$$-\tau_0 \times dx = \rho \frac{d}{dx}\left[\int_0^\delta (u^2 - uU)\, dy\right] dx$$

or,
$$\tau_0 = -\rho \frac{d}{dx}\left[\int_0^\delta (u^2 - uU)\, dy\right]$$

or,
$$= \rho \frac{d}{dx}\left[\int_0^\delta (uU - u^2)\, dy\right]$$

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

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

or,
$$\frac{\tau_0}{\rho U^2} = \frac{d}{dx}\left[\int_0^\delta \frac{u}{U}\left(1 - \frac{u}{U}\right) dy\right]$$

But, $\int_0^\delta \frac{u}{U}\left(1 - \frac{u}{U}\right) dy$ = momentum thickness (θ)

$\therefore$
$$\frac{\tau_0}{\rho U^2} = \frac{d\theta}{dx}$$

OR

Q (2) (a) Explain in brief local friction coefficient. **Marks 02**

$$C_D = \frac{F_D}{\frac{1}{2}\rho U^2 A}$$

Where A = Projected area of the body ⊥ to the direction of flow

C_D = Coefficient of drag ($\int p \cos\theta \, dA$ = local friction drag)

(b) The velocity distribution in the boundary layer is given by $\frac{u}{U} = (y/\delta)^{1/7}$ Find out Momentum thickness and energy thickness. **Marks 06**

(*ii*) **Momentum thickness, θ:**

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

$$= \int_0^\delta \left(\frac{y}{\delta}\right)^{1/7}\left[1 - \left(\frac{y}{\delta}\right)^{1/7}\right] dy = \int_0^\delta \left[\left(\frac{y}{\delta}\right)^{1/7} - \left(\frac{y}{\delta}\right)^{2/7}\right] dy$$

$$= \left[\frac{7}{8}\frac{y^{8/7}}{\delta^{1/7}} - \frac{7}{9}\cdot\frac{y^{9/7}}{\delta^{2/7}}\right]_0^\delta = \left[\frac{7}{8}\frac{\delta^{8/7}}{\delta^{1/7}} - \frac{7}{9}\frac{\delta^{9/7}}{\delta^{2/7}}\right]$$

$$= \left(\frac{7}{8}\delta - \frac{7}{9}\delta\right) = \frac{7}{72}\delta \text{ (Ans.)}$$

(*iv*) **Energy thickness, δ_e:**

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

$$= \int_0^\delta \left(\frac{y}{\delta}\right)^{1/7}\left[1 - \left(\frac{y}{\delta}\right)^{2/7}\right] dy = \int_0^\delta \left[\left(\frac{y}{\delta}\right)^{1/7} - \left(\frac{y}{\delta}\right)^{3/7}\right] dy$$

$$= \left[\frac{7}{8}\times\frac{y^{8/7}}{\delta^{1/7}} - \frac{7}{10}\times\frac{y^{10/7}}{\delta^{3/7}}\right]_0^\delta = \left[\frac{7}{8}\delta - \frac{7}{10}\delta\right] = \frac{7}{40}\delta \text{ (Ans.)}$$

Unit-III

Q (1) (a)What is hump. **Marks 02**

Flow over a raised ~~floor~~ floor which is called a hump.

$E_1 = E_2 + \Delta z$ E_1 and E_2 are specific energy at section (1)-(1) and (2)-(2)

$\therefore (\Delta z)_{max} = y_1 + \frac{V_1^2}{2g} - \frac{3}{2} y_c = E_1 - E_{min}$

(b) Find out the expression for relative loss of energy ($\Delta E/E_1$) in hydraulic jump

Marks 06

Relative loss of Energy $\left(\frac{\Delta E}{E_1}\right)$ - It is defined as the ratio of energy loss and the specific energy before the jump.

$$\Delta E = \frac{(y_2 - y_1)^3}{4 y_1 y_2}$$

$$\frac{\Delta E}{y_1} = \frac{\left(\frac{y_2}{y_1} - 1\right)^3}{4\left(\frac{y_2}{y_1}\right)}$$

$$E_1 = y_1 + \frac{V_1^2}{2g}$$

$$\frac{E_1}{y_1} = 1 + \frac{V_1^2}{2gy_1} = 1 + \frac{F_1^2}{2}$$

$$\therefore \frac{\Delta E}{E_1} = \frac{\left(\frac{y_2}{y_1} - 1\right)^3}{4\left(\frac{y_2}{y_1}\right)} \times \left(\frac{1}{1 + \frac{F_1^2}{2}}\right)$$

$$= \frac{\left[\frac{1}{2}(\sqrt{1+8F_1^2} - 1) - 1\right]^3}{4 \times \frac{1}{2}\left(\left[\sqrt{1+8F_1^2} - 1\right) \times \left(1 + \frac{F_1^2}{2}\right)}$$

$$= \frac{\left[\sqrt{1+8F_1^2} - 1 - 2\right]^3 \cancel{2} \times \cancel{2}}{8 \times \cancel{4} \times \frac{1}{\cancel{2}}\left[\sqrt{1+8F_1^2} - 1\right]\left[2 + F_1^2\right]}$$

$$= \frac{\left[\sqrt{1+8F_1^2} - 3\right]^3}{8\left[F_1^2 + 2\right]\left[\sqrt{1+8F_1^2} - 1\right]}$$

$$\therefore \frac{\Delta E}{E_1} = \frac{\left[\sqrt{1+8F_1^2} - 3\right]^3}{8\left[F_1^2 + 2\right]\left[\sqrt{1+8F_1^2} - 1\right]}$$

OR

Q (2) (a) Explain in brief steady hydraulic jump. **Marks 02**

This type of jump occurs in the Froude numbe range of 4.5 to 9.0. The fluctuation in the tail water depth have a very little effect on the position and the action of the jump. The energy dissipation may be in the range of 45% to 70%.

(b) Uniform flow occurs at a depth of 1.5 m in a long rectangular channel 3.0 m wide and laid slope of 0.0009. If Manning's N= 0.015 calculate:

(i) Maximum height of hump on the floor to produce critical depth

(ii) Width of contraction which will produce critical depth without increasing the upstream depth of flow. **Marks 06**

$$Q = A \times \frac{1}{N} R^{2/3} S^{1/2} = 3 \times 1.5 \times \frac{1}{0.015} \times \left[\frac{4.5}{3+2\times1.5}\right]^{2/3} \times (0.0009)^{1/2}$$

$$Q = 7.43\ m^3/sec \qquad q = \frac{7.43}{3.0} = 2.477\ m^3/sec/m$$

$$\therefore y_c = \left(\frac{q^2}{g}\right)^{1/3} = \left[\frac{(2.477)^2}{9.81}\right]^{1/3} = 0.855\ m$$

ⓐ Equating the specific energies up stream and at the hump.

$$1.5 + \left[\frac{\left(\frac{7.43}{4.5}\right)^2}{2\times9.81}\right] = \Delta z + y_c + \frac{V^2}{2g}$$

$$1.5 + 0.139 = \Delta z + 0.855 + \frac{0.855}{2} = \Delta z + 1.2825$$

$$\therefore \Delta z = 1.639 - 1.2825 = 0.3525\ m$$

The height of hump = 0.3565 m.

ⓑ Let b be the width at the contracted portion to produce critical depth.

U/S Specific energy = Sp. energy at the contracted portion

$$1.639 = y_c + \frac{V_c^2}{2g} = \frac{3}{2} y_c \left(\frac{Q^2}{b^2 g}\right)^{1/3}$$

$$1.639 = \frac{3}{2}\left[\frac{(7.43)^2}{b^2\times9.81}\right]^{1/3} \therefore \left[\frac{(7.43)^2}{b^2\times9.81}\right] = (1.09267)^3$$

$$\therefore b^2 = \frac{7.43^2}{1.09267^3\times9.81} = 4.313 \qquad \therefore b = 2.076\ m.$$

Unit-IV

Q (1) (a) Discuss the factor which affect the magnitude of pressure rise in water hammer in pipes. **Marks 02**

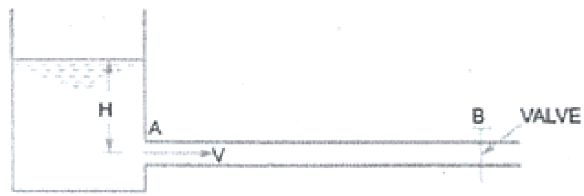


Fig. 11.32 *Water hammer.*

The pressure rise due to water hammer depends upon : (*i*) the velocity of flow of water in pipe, (*ii*) the length of pipe, (*iii*) time taken to close the valve, (*iv*) elastic properties of the material of the pipe. The following cases of water hammer in pipes will be considered :

(b) What do you mean by repeating variables how are the repeating variables selected for dimensional analysis.

Marks 06

Method for selection of repeating variables

1. As far as possible, the dependent variable should not be selected as repeating variable.
2. The repeating variables should be choosen in such a way that one variable contains geometric property, other variable contains flow property and third variable contains fluid property.

Variables with Geometric Property are

(*i*) Length, l (*ii*) d (*iii*) Height, H etc.

Variables with flow property are

(*i*) Velocity, V (*ii*) Acceleration etc.

Variables with fluid property : (*i*) μ, (*ii*) ρ, (*iii*) ω etc.

3. The repeating variables selected should not form a dimensionless group.
4. The repeating variables together must have the same number of fundamental dimensions.
5. No two repeating variables should have the same dimensions.

OR

Q (2) (a) Explain in brief dimensional analysis. **Marks 02**

In engineering the application of fluid mechanics in designs make much of the use of empirical results from a lot of experiments. This data is often difficult to present in a readable form. Even from graphs it may be difficult to interpret. Dimensional analysis provides a strategy for choosing relevant data and how it should be presented. This is a useful technique in all experimentally based areas of engineering. If it is possible to identify the factors involved in a physical situation, dimensional analysis can form a relationship between them. The resulting expressions may not at first sight appear rigorous but these qualitative results converted to quantitative forms can be used to obtain any unknown factors from experimental analysis.

(b) 15 m long and 7.2 m high spillway discharges 94 m^3/sec of water under a head of 2.0 m. If a 1: 9 scale model of this spillway is to be constructed, determine model dimensions, head over spillway model and the model discharge. If the model experiences a force of 7500N, determine to corresponding force on the prototype.

Marks 06

$h_p = 7.20\,m \quad L_p = 15\,m \quad Q_p = 94\,m^3/sec \quad H_p = 2.0\,m$

Size of model $= \frac{1}{9} \quad L_r = 9.0$

$F_p = 7500\,N$

(i) Model Dimensions (h_m and L_m)

$$\frac{h_p}{h_m} = \frac{L_p}{L_m} = L_r = 9.0$$

$$h_m = \frac{h_p}{9} = \frac{7.2}{9.0} = 0.8\,m$$

$$L_m = \frac{L_p}{9} = \frac{15}{9} = 1.67\,m$$

(ii) Head over Model

$$\frac{H_p}{H_m} = L_r = 9.0$$

$$H_m = \frac{H_p}{9.0} = \frac{2.0}{9.0} = 0.222\,m.$$

(iii) Discharge through model (Q_m)

$$\frac{Q_p}{Q_m} = L_r^{2.50}$$

$$Q_m = \frac{Q_p}{L_r^{2.5}} = \frac{94}{9^{2.5}} = \frac{94}{243} = 0.387\,m^3/sec$$

(iv) Force on the Prototype

$$F_r = \frac{F_p}{F_m} = L_r^3 \qquad F_p = F_m \times L_r^3 = 7500 \times 9^3 = 5467500\,N$$

Unit-V

Q (1) (a) What is Tangential flow Turbine?

Marks 02

Tangential flow turbines: In this type of turbines, the water strikes the runer in the direction of tangent o the whel. Example: Pelton whel turbine.

(b) A turbine is to operate under a head of 25 m at 250 r.p.m. The discharge is $10 m^3/sec$. If the efficiency is 85%, determine the performance of the turbine under a water head of 20 m.

Marks 06

$H_1 = 25 m \quad N_1 = 250$ r.p.m. $\quad Q = 10 m^3/sec \quad \eta = 85\%$.

$$\eta_0 = \frac{P}{W.P.} = \frac{P_1}{\frac{\rho \times g \times Q H}{1000}}$$

$$\therefore P_1 = \frac{\eta_0 \times \rho \times g \times Q_1 \times H_1}{1000} = \frac{0.85 \times 1000 \times 9.81 \times 10 \times 25}{1000}$$

$P_1 = 2084.625$ kW

$$\therefore \frac{N_1}{\sqrt{H_1}} = \frac{N_2}{\sqrt{H_2}} \Rightarrow N_2 = 250 \times \sqrt{\frac{20}{25}} = 223.606 \text{ r.p.m.}$$

$$\frac{Q_1}{\sqrt{H_1}} = \frac{Q_2}{\sqrt{H_2}} \Rightarrow Q_2 = 10 \times \sqrt{\frac{20}{25}} = 10 \times \sqrt{0.8} = 8.944 \text{ m}^3/\text{sec}$$

$$\frac{P_1}{H_1^{3/2}} = \frac{P_2}{H_2^{3/2}}$$

$$\therefore P_2 = \frac{P_1 \times H_2^{3/2}}{H_1^{3/2}} = P_1 \left(\frac{H_2}{H_1}\right)^{3/2}$$

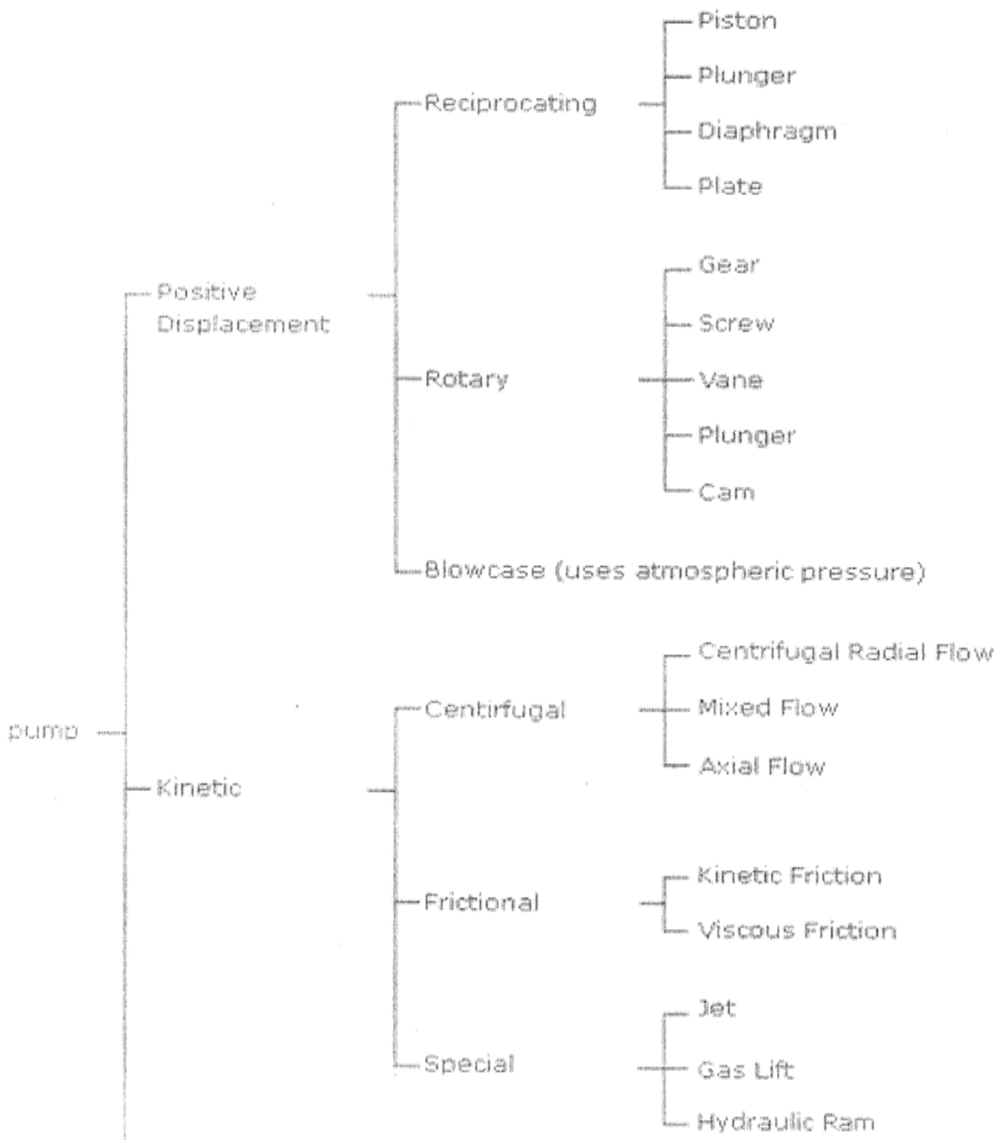
$$\therefore P_2 = 2084.625 \times \left(\frac{20}{25}\right)^{3/2} = 1491.63 \text{ kW.}$$

OR

Q (2) (a) Discuss cavitations in pump. **Marks 02**

Pump cavitation is the formation and subsequent collapse or implosion of vapor bubbles in a pump. It occurs when the absolute pressure on the liquid falls below the liquid's vapor pressure. When the vapor bubbles collapse with high enough frequency, it sounds like marbles and rocks are moving through the pump. If the vapor bubbles collapse with high enough energy, they can remove metal from the internal casing wall, and leave indent marks appearing like blows from a large ball pein hammer.

(b) Explain in brief classification of pumps. **Marks 06**



Explain: (a) Positive Displacement Pump

(i) Reciprocating Pump

(ii) Rotary Pump

(b) Kinetic Pump

(i) Centrifugal Pump

(ii) Frictional Pump

(iii) Special Pump