Department of Civil Engineering

Institute of Technology, GGV

B.Tech. Third Year [Vth Sem.]

Subject: Fluid Mechanics II (Old)

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) Wall Shear stress τ_0 in turbulent flow in pipe is given by

(a) u_*^2/ρ (b) $u_*^2\rho$ (c) $u_*\rho$ (d) ρ^2/u_*

Q(2) Prandtl's universal velocity distribution equation for pipe flow is

(a) $u = u_{max} + 2.5\ u_*\ log_e\ (y/R)$ (b) $u = u_{max} + 2.5\ log_e\ (y/R)$

(c) $u = u_{max} + 2.5\ u_*\ log_{10}\ (y/R)$ (d) $u = u_{max} + 2.5\ u_*\ log_e\ (R/y)$

where u_* = Shear velocity, y = distance from pipe wall, R =Radius of pipe

Q(3) For boundary layer thickness δ

(a) $u=0.88\ U_\infty$ (b) $U_\infty=0.99\ u$ (c) $u=0.99\ U_\infty$ (d) $U_\infty=0.88\ u$

where y is wall distance

Q(4) For a sphere falling at a terminal velocity in the stokes law range, the drag coefficient is given by

(a) $\frac{64}{R_e}$ (b) $\frac{24}{R_e}\left[1+\frac{3}{24R_e}\right]$ (c) $\frac{24}{R_e}$ (d) $\left[1+\frac{3}{24R_e}\right]$

Q(5) Non uniform flow occurs when

(a) Direction and magnitude of velocity at all points are identical

(b) Velocity of successive fluid particles, at any point, is same at successive periods of time

(c) Magnitude and direction of velocity do not change from point to point in the fluid

(d) Velocity, depth, pressure, etc. changes point to point in the fluid flow

Q(6) The critical depth y_c is given by

(a) $(q^2/g)^{0.5}$ (b) $(q^2/g)^{0.33}$ (c) $(g^2/q)^{0.33}$ (d) $(q^2/g)^{0.75}$

Q(7) Weber Number is ratio of

(a) Inertia force / pressure force (b) Inertia force / viscous force

(c) Inertia force / Surface tension force (d) Inertia force / gravity force

Q(8) The dimensions of torque (T) are

(a) ML^2T^{-2} (b) ML^{-1} (c) L^2T^{-2} (d) $ML^{-2}T^{-2}$

Q(9) Which one of the following forms of draft tube will not improve the hydraulic efficiency of The turbine?

(a) Straight cylindrical (b) Conical type (c) Bell - mouthed (d) Bent tube

Q(10) Kaplan turbine the number of blades are:

(a) 13- 26 (b) 5- 16 (c) 3- 6 (d) 10- 20

SECTION – B

Unit-I

Q (1) (a) Discuss the Colebrook-White equation for turbulent flow in pipe. **Marks 02**

Acording colebrook white –

(1.) For Smooth Pipes :-

$$\frac{1}{\sqrt{4f}} = 2\log_{10}\left(\frac{R}{K}\right) = 2\log_{10}\left(Re\sqrt{4f}\right) - 0.8 - 2\log_{10}\left(\frac{R}{K}\right) = 2\log_{10}\left[\frac{Re\sqrt{4f}}{R/K}\right] - 0.80$$

(2.) For Rough Pipes :- $\frac{1}{\sqrt{4f}} = 2\log_{10}\left(\frac{R}{K}\right) = 2\log_{10}\left(\frac{R}{K}\right) + 1.74 - 2\log_{10}\left(\frac{R}{K}\right) = 1.74$

(b) A rough plastic pipe 600 mm in diameter and 3500 m in length carrying water with a discharge of 0.60 m^3/sec has an absolute roughness of 0.30 mm find the power required to maintain this flow. **Marks 06**

$D = 600\,mm \quad R = \frac{D}{2} = \frac{600}{2} = 300\,mm = 0.30\,m$

$L = 3500\,m \quad Q = 0.60\,m^3/sec \quad K = 0.30\,mm = 0.3\times10^{-3}\,m$

$$\therefore \frac{1}{\sqrt{4f}} = 2\log_{10}\left(\frac{R}{K}\right) + 1.74 = 2\log_{10}\left(\frac{0.30}{0.3\times10^{-3}}\right) + 1.74$$

$$\because \frac{1}{\sqrt{4f}} = 2\log_{10}(1000) + 1.74$$

$$= 6 + 1.74 = 7.74$$

$$\because \frac{1}{7.74} = \sqrt{4f} \quad \therefore 4f = \left(\frac{1}{7.74}\right)^2 \Rightarrow 4f = 0.0166$$

Head lost due to friction $h_f = \frac{4fLV^2}{2gD}$

$$h_f = \frac{0.0166\times3500\times V^2}{2\times9.81\times0.60} \qquad V = \bar{U} = \frac{0.6}{\frac{\pi\times0.6^2}{4}}$$

$$h_f = \frac{0.0166\times3500\times(2.12)^2}{2\times9.81\times0.60} = 22.28\,m \qquad = \frac{4}{\pi\times0.6} = 2.12\ m^3/sec$$

$$\because \text{Power Required } P = \frac{\gamma Q h_f}{1000} = \frac{\rho g Q h_f}{1000} = \frac{\cancel{1000}\times9.81\times0.6\times22.28}{\cancel{1000}}$$

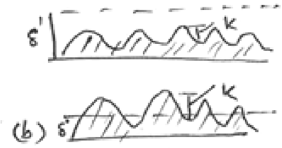
$$P = 9.81\times0.6\times22.28$$

$$P = 130.56\ KW.$$

OR

(c) Define hydro dynamically smooth and rough boundaries in turbulent flow on the basis of Reynolds Number. **Marks 02**

Hydrodynamically smooth and Rough boundaries : (a) Smooth Boundary



(a) Smooth Boundary $- \frac{k}{\delta'} < 0.25$ OR $\frac{u_* k}{\nu} < 4.0$

(b) Rough Boundary $- \frac{k}{\delta'} > 6.0$ OR $\frac{u_* k}{\nu} > 100$

Rough Boundary

(d) 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

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

$y = 1.0\,cm \qquad u = u$

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

$y = 2.0\,cm \qquad u = 1.25u$

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

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

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

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

$$\therefore k_s = 1.8805\ cm.$$

The height of roughness (k_s) element = 1.8805 cm.

Unit-II

Q (2) (a) Define stream line body. **Marks 02**

A stream lined body is defined as that body whose surface coincides with the stream-lines, when body is placed in a flow.

Total drag on the stream lined body is due to friction OR shear drag.

(b) Find out the shape factor for given velocity distribution of a boundary layer is given by

$$\frac{u}{U} = \left[\frac{y}{\delta}\right]$$

Marks 06

(i) Displacement thickness δ^* is given by

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

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

(ii) Momentum thickness θ is given by

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

$$\theta = \int_0^{\delta}\left(\frac{y}{\delta} - \frac{y^2}{\delta^2}\right)dy = \left[\frac{y^2}{2\delta} - \frac{y^3}{3\delta^2}\right]_0^{\delta}$$

$$\theta = \left[\frac{\delta^2}{2\delta}\right] - \left[\frac{\delta^3}{3\delta^2}\right]$$

$$\theta = \left[\frac{\delta}{2} - \frac{\delta}{3}\right] = \frac{\delta}{6}$$

(iii) Shape Factor

$$\frac{\delta^*}{\theta} = \frac{\left(\frac{\delta}{2}\right)}{\left(\frac{\delta}{6}\right)} = \frac{\delta}{3}$$

OR

(c) Explain in brief terminal velocity. **Marks 02**

Terminal Velocity is defined as the maximum constant Velocity of a falling body (Such as Sphere) with which the body will be travelling.

Net Force on body is zero

W = Wt. of body (↓)

F_D = Drag Force (↑)

F_B = Buoyant Force (↑

$$W = F_D + F_B$$

(d) Find the diameter of parachute with which a man of mass 80 kgf descends to the ground from an aeroplane against the resistance of air, with a velocity 25m/s. Take $C_d = 0.5$ and density of air $=1.25\ kg/m^3$

Marks 06

$W = 80kgf = 80 \times 9.81 = 784.80N$

$U = 25\ m/sec$

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

$C_D = 0.5$

$\rho = 1.25 kg/m^3$

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

$784.80 = 0.50 \times \frac{\pi \times D^2}{4} \times \frac{1.25 \times 25^2}{2}$

$6278.40 = 0.50 \times 3.14 \times D^2 \times 1.25 \times 25^2$

$\therefore D^2 = \frac{6278.40}{0.50 \times 3.14 \times 1.25 \times 25^2} = \frac{6278.40}{1226.56} = 5.1186\ m^2$

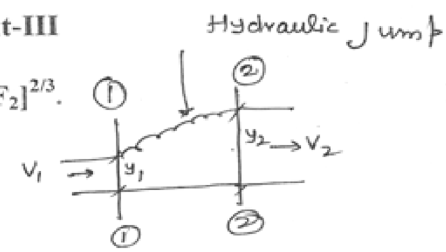
$\because D = \sqrt{5.1186} = 2.262\ m$

$\therefore$ Diameter of Parachute $D = 2.262\ m.$

Unit-III

Q (3) (a) Prove that $y_2/y_1 = [F_1/F_2]^{2/3}$.

Marks 02



In a hydraulic Jump

at Section 1 - 1

$F_1 = \frac{V_1}{\sqrt{gy_1}}$ —— (1)

at Section 2 - 2

$F_2 = \frac{V_2}{\sqrt{gy_2}}$ —— (2)

If the width of channel is b

$\therefore V_1 = \frac{Q}{by_1} = \frac{q}{y_1}$

$\because V_2 = \frac{Q}{by_2} = \frac{q}{y_2}$

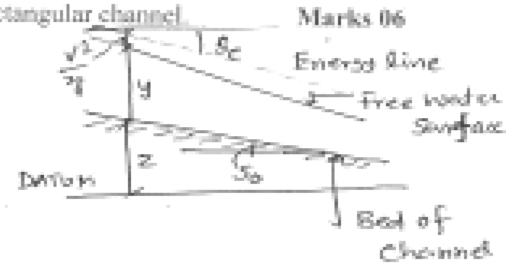
Put value of V_1 and V_2 in equation (1) and (2)

$\therefore F_1^2 = \frac{q^2}{gy_1^3}$ $\quad F_2^2 = \frac{q^2}{gy_2^3}$

$\therefore \left[\frac{F_1^2}{F_2^2}\right] = \frac{\cancel{q^2}}{\cancel{g}y_1^3} \times \frac{\cancel{g}y_2^3}{\cancel{q^2}}$

$\therefore \left[\frac{F_1}{F_2}\right]^2 = \left[\frac{y_2}{y_1}\right]^3$ $\quad \left\{\therefore \frac{y_2}{y_1} = \left[\frac{F_1}{F_2}\right]^{2/3}\right\}$

(b) Derive an expression for gradually varied flow for rectangular channel. Marks 06



Assumptions:-

(1) bed slope of Channel is small

(2) The flow is steady

(3) Pressure Distribution is Hydrostatic

(4) The energy Correction factor α is Unity

(5) The Roughness coefficient is constant

(6) Chesy's formula and Manning's formula is used for determining Channel slope.

$$\therefore E = z + y + \frac{V^2}{2g} \qquad \therefore \frac{dE}{dx} = \frac{dz}{dx} + \frac{dy}{dx} + \frac{d}{dx}\left(\frac{V^2}{2g}\right)$$

$$\therefore \frac{dE}{dx} = \frac{dz}{dx} + \frac{dy}{dx} - \frac{V^2}{gy}\cdot\frac{dy}{dx} = \frac{dz}{dx} + \frac{dy}{dx}\left[1 - \frac{V^2}{gy}\right]$$

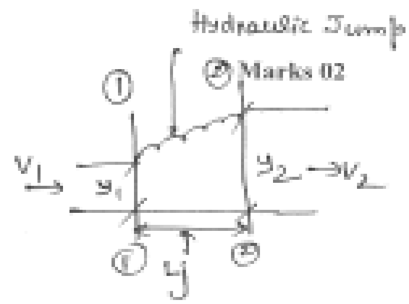
$$\because -S_e = -S_0 + \left[1 - \frac{V^2}{gy}\right]\frac{dy}{dx} \qquad \therefore \frac{S_0 - S_e}{\left[1 - \frac{V^2}{gy}\right]} = \frac{dy}{dx}$$

$$\therefore \frac{dy}{dx} = \frac{S_0 - S_e}{\left[1 - \frac{V^2}{gy}\right]} = \left[\frac{S_0 - S_e}{1 - F_r^2}\right]$$

Equation of G.V.F. is $\left[\frac{dy}{dx} = \frac{(S_0 - S_e)}{(1 - F_r^2)}\right]$

OR

(c) Discuss the elements of hydraulic jump. Marks 02



Elements of Hydraulic Jump are

(i) $E_1 = y_1 + \frac{V_1^2}{2g}$ sp. energy before jump

(ii) $E_2 = y_2 + \frac{V_2^2}{2g}$ sp. energy after jump

(iii) Length of jump $= 5H_j = 5(y_2 - y_1)$

(iv) Height of jump $= (y_2 - y_1)$

(v) Loss of energy in Hydraulic jump

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

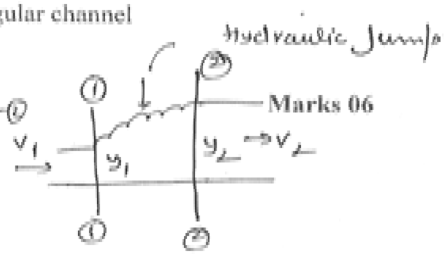
(vi) y_1 - pre jump depth

(vii) y_2 - Post jump depth.

(d) Prove that for Power lost in hydraulic jump in a rectangular channel

$$P = \frac{\gamma Q}{4}\frac{(y_2-y_1)^3}{y_1 y_2} \text{ in watts}$$

Marks 06



at section ①-①

$\therefore E_1 = y_1 + \frac{V_1^2}{2g}$ $\quad E_2 = y_2 + \frac{V_2^2}{2g}$ at section ②-②

$\therefore \Delta E$ = loss of Energy in Hydraulic jump

$$\because \Delta E = E_1 - E_2 = \left(\frac{V_1^2}{2g} - \frac{V_2^2}{2g}\right) + \left[y_1 - y_2\right]$$

$$= \left(\frac{V_1^2}{2g} - \frac{V_2^2}{2g}\right) - \left[y_2 - y_1\right]$$

$$h_L = \left[\frac{q^2}{2gy_1^2} - \frac{q^2}{2gy_2^2}\right] - \left[y_2 - y_1\right]$$

$$\left[\frac{2q^2}{g} = y_1 y_2 (y_1 + y_2)\right]$$

$$\therefore h_L = \frac{q^2}{2g}\left[\frac{y_2^2 - y_1^2}{y_1^2 y_2^2}\right] - (y_1 - y_2)$$

$$= \frac{\cancel{y_1 y_2}}{4}\frac{[y_2^2 - y_1^2]}{(\cancel{y_1 y_2})\, y_1 y_2} - (y_1 - y_2)$$

$$= (y_2 - y_1)\left[\frac{(y_2 + y_1)^2}{4y_1 y_2} - 1\right]$$

$$\therefore h_L = \frac{(y_2 - y_1)(y_2 - y_1)^2}{4y_1 y_2} = \frac{(y_2 - y_1)^3}{4y_1 y_2}$$

$P = \gamma Q h_L$ watts

OR

But

$$P = \frac{\gamma Q h_L}{1000} \text{ kW}$$

$$\therefore P = \gamma Q \frac{(y_2 - y_1)^3}{4y_1 y_2}$$

$$\because P = \frac{\gamma Q}{4} \times \frac{(y_2 - y_1)^3}{4y_1 y_2}$$

Unit-IV

Q (4) (a) Write condition for sudden closure of valve when pipe is rigid. **Marks 02**

Sudden Closure of Valve when pipe is rigid

Loss of K.E. $= \frac{1}{2} m \times V^2$

$$= \frac{1}{2} \times \rho A L \times V^2$$

Gain of strain energy

$$= \frac{1}{2}\frac{p^2}{K} \times AL$$

$$\therefore \cancel{\tfrac{1}{2}} \rho \cancel{A} \cancel{L} V^2 = \cancel{\tfrac{1}{2}} p^2/K \times \cancel{A} \cancel{L}$$

$$\therefore p^2 = \rho K V^2 \qquad \therefore p = V\sqrt{K\rho}$$

$$\text{OR } p = \rho V C \qquad \left(\text{But } \sqrt{\frac{K}{\rho}} = C\right)$$

(b) State Buckingham's π- theorem and explain it in brief. **Marks 06**

Buckingham's π - therrem which states. 'If there are n' Variables (independent and dependent Variables) in a physical phenomena and if these Variables contain m fundamental dimensions (MLT) then the Variables are arranged into (n-m) dimensionless terms each term is called π – term.'

$$\therefore \; x_1 = f(x_2, x_3, x_4 \cdots x_n)$$

$$\text{OR} \; f_1(x_1, x_2, x_3, x_4 \cdots x_n) = 0$$

π terms (n-m)

$$\therefore \; \pi_1 = x_2^{a_1} x_3^{b_1} x_4^{c_1} \cdots x_1$$

$$\pi_2 = x_2^{a_2} x_3^{b_2} x_4^{c_4} \cdots x_5$$

$$\vdots$$

$$\pi_{n-m} = x_{2}^{a(n-m)} \cdot x_{3}^{b(n-m)} \cdots x_n$$

OR

$$\pi_1 = \phi_1 [\pi_2, \pi_3 \cdots \pi_{n-m}]$$

$$\pi_2 = \phi_2 [\pi_1, \pi_3 \cdots \pi_{n-m}]$$

OR

(c) Define Froude number in dimensional analysis. **Marks 02**

$$\text{Froude Number } F_r = \sqrt{\frac{F_i}{F_g}} = \sqrt{\frac{\text{Inertia force}}{\text{Gravity force}}}$$

$$\therefore F_r = \frac{V}{\sqrt{gy}}$$

$$\left(F_r = \sqrt{\frac{\rho A V^2}{\rho A y g}} = \frac{V}{\sqrt{gy}} \right)$$

(d) 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 the model and discharge. If the model experiences a force of 7500N, determine the corresponding force on the prototype.

Marks 06

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

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

$F_p = 7500\ N$

(i) Model Dimensions (h_m and L_m)

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

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

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

(ii) Head over Model

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

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

(iii) Discharge through Model (Q_m)

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

(iv) Force on the Prototype

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

Unit-V

Q (5) (a) Explain in brief Over all Efficiency of turbine.

Marks 02

$$\eta_0 = \frac{\text{Shaft Power}}{\text{Water Power}}$$

$$\eta_0 = \frac{S.P.}{W.P.} = \frac{S.P.}{R.P.} \times \frac{R.P.}{W.P.}$$

$$\boxed{\eta_0 = \eta_m \times \eta_h}$$

η_0 = Over all efficiency

η_m = Mechanical efficiency

η_h = Hydraulic efficiency

(b) Single stage centrifugal pump with impeller diameter of 30cm rotates at 2000 r.p.m. and lifts 3 m^3 of water per second to a height of 30 m with an efficiency of 75%. Find the number of stages and diameter of each impeller of a similar multistage pump to lift 5 m^3 of water per second to a height of 200 meters when rotating at 1500 r.p.m. **Marks 06**

$D_1 = 30\,cm = 0.30\,m \quad N_1 = 2000$ r.p.m.

$Q_1 = 3.0\,m^3/sec \quad H_{m_1} = 30\,m \quad \eta_{max} = 75\% = 0.75$

$Q_2 = 5\,m^3/sec \quad$ Total Height = 200m $\quad$ impeller diameter = D

$$\left(\frac{N_1\sqrt{Q}}{H_m^{3/4}}\right)_1 = \left(\frac{N\sqrt{Q}}{H_m^{3/4}}\right)_2 \quad \therefore \frac{N_1\sqrt{Q_1}}{H_{m_1}^{3/4}} = \frac{N_2\sqrt{Q_2}}{H_2^{3/4}}$$

$$\frac{2000\sqrt{3}}{30^{3/4}} = \frac{1500\times\sqrt{5}}{H_m^{3/4}} \quad \therefore H_m = 28.71\,m.$$

$$\therefore \text{Number of stages} = \frac{\text{Total Head}}{\text{Head per stage}} = \frac{200}{28.71} = 6.96 \approx 7.0$$

$$\frac{\sqrt{H_{m_1}}}{D_1N_1} = \frac{\sqrt{H_{m_2}}}{D_2N_2} \Rightarrow \frac{\sqrt{30}}{0.30\times2000} = \frac{\sqrt{28.71}}{D_2\times1500}$$

$$\therefore D_2 = \frac{0.30\times2000\times\sqrt{28.71}}{1500\times\sqrt{30}} = 0.3913\,m = 391.30\,mm.$$

OR

(c) Define Slip and percentage Slip for pump. **Marks 02**

$Slip = Q_{th} - Q_{act}$

Q_{th} – theoretical Discharge

Q_{act} – actual Discharge.

$$\therefore \%\ Slip = \frac{Q_{th} - Q_{act}}{Q_{th}}\times100$$

$$= \left(1 - \frac{Q_{act}}{Q_{th}}\right)\times100$$

$$= (1 - C_d)\times100$$

C_d = coefficient of Discharge.

$$\therefore \%\ Slip = (1 - C_d)\times100$$

(d) Obtain an expression for unit speed and unit discharge for a turbine. **Marks 06**

Unit speed - It is defined as the speed of a turbine under unit head are such that the efficiency of the turbine remains unaffected.

$\therefore u \propto V \quad \propto \sqrt{H} \qquad (V = \sqrt{2gH})$

But $u = \frac{\pi DN}{60}$

$u \propto \frac{DN}{60}$

But $u \propto V \propto N$ (Dia. of turbine is constant)

$\therefore u \propto N$

$\because u = k_1 N = k_1 \sqrt{H}$

when $H = 1$ $N = N_u$

$\therefore N_u = k_1 \sqrt{1.0} \Rightarrow N_u = k_1$

So $N = k_1 \sqrt{H}$

OR $N = N_u \sqrt{H} \Rightarrow N = N_u \sqrt{H} \Rightarrow \boxed{N_u = \frac{N}{\sqrt{H}}}$

Unit Discharge - It is defined as the Discharge passing through a turbine which is working under a unit head (1.0 m) $Q \propto V \Rightarrow Q \propto \sqrt{H}$

$Q = k_2 \sqrt{H}$

$Q_u = k_2 \sqrt{1.0} = k_2$ when $H = 1$ $Q = Q_u$

$Q = Q_u \sqrt{H}$ $\therefore \boxed{Q_u = \frac{Q}{\sqrt{H}}}$