DIMENSIONAL ANALYSIS

M Mass, L Length, T Time, θ Temp

Dimensional Formulae

$Vel = \frac{m}{sec} = LT^{-1}$

$Acc = m/sec^2 = LT^{-2}$

$\omega = rad/sec = T^{-1}$

$F = ma = MLT^{-2}$

$Power = \frac{W}{Time} = F \times V$
$= FLT^{-1}, ML^2T^{-3}$

W/Energy $= F \times$ displacement $= FL = ML^2T^{-2}$

$\rightarrow \mu = \frac{N \cdot sec}{m^2} = \frac{kg}{m \cdot sec} = ML^{-1}T^{-1}$

$\rightarrow C_p$ (or) $C_v = kJ/kgK = \frac{ML^2T^{-2}}{M\theta} = L^2T^{-2}\theta^{-1}$

$\rightarrow K = \frac{W}{m \cdot K} = \frac{ML^2T^{-3}}{L\theta} = MLT^{-3}\theta^{-1}$

ρ, V, L, μ, Re

$$\boxed{Re = \frac{\rho V L}{\mu}}$$

Dimensionless numbers

① Rayleigh's Method → Conv

② Buckingham's 'π' theorem → Obj

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→ Buckingham - π theorem

m = no. of Total variable

→ n = no. of repeated variable

No. of π - terms (Dimension less term)

Each π term contains → variably (m-n)

Selection of Repeated variably

(1) At least one should represent
1) Geometry property
(2) Flow property $M^0 L^0 T^0$
(3) Fluid property

(2) Selected group should be dimensional

ρ, V, L, μ, Re

m - Total no. of variable = 5

n = No. of repeated var. = 3

No. of π terms = m - n = 5-3 = 2

$$\Pi_1 = (\rho^{a_1} V^{b_1} L^{c_1}) \mu = \left[\frac{\mu}{\rho V L}\right]$$

$$\Pi_2 = [\rho^{a_2} V^{b_2} L^{c_2}] Re = [Re] \rightarrow$$

$$\Pi_1 = \rho^{a_1} V^{b} L^{c_1}$$

$$M^0 L^0 T^0 = (M L^{-3})^{a_1} [L T^{-1}]^{b_1} L^{c_1}$$

$$\Rightarrow (M L^{-1} T^{-1})$$

$ML^{-1}T^{-1}$

Comparing powers 'M' $\Rightarrow a_1 + 1 = 0 \Rightarrow a_1 = -1$

$L \Rightarrow -3a_1 + b_1 + c_1 - 1 = 0 \quad a_1 = -1$

$\Rightarrow -3(-1) + (-1) + c_1 - 1 = 0 \Rightarrow c_1 = -1$

$-b_1 - 1 = \quad b = -1$

$\pi_1 = [\rho^{-1} V^{-1} L^{-1}] = \boxed{\pi_1 = f\left[\frac{\mu}{\rho V L}\right]}$

$Re = f\left[\frac{\mu}{\rho V L}\right] \quad \rightarrow$ Rayleigh $= \pi_2 = f(\pi_1)$

Dimension less numbers

V/L

(1) Reynold's number : $(Re) = \frac{F_i}{F_V} = \frac{\rho V L}{\mu}$

Inertia

viscous

(2) Froude's Number (F_r) :- $\sqrt{\frac{F_i}{F_G}} = \frac{V}{\sqrt{gL}}$

Gravity

(3) weber number (W_e) :- $\sqrt{\frac{F_i}{F_\sigma}} = \frac{V}{\sqrt{\sigma/\rho L}}$

Surface tension

(4) Mach number $= M = \sqrt{\frac{F_i}{F_E}} = \frac{V}{\sqrt{K/\rho}}$

Elastic

(5) Eular's number $Eu = \sqrt{\frac{F_i}{F_p}} = \frac{v}{\sqrt{P/\rho}}$

pressure

↓

Newton number $N = \frac{1}{Eu}$

↓

pressure coefficient $= \left(\frac{1}{Eu}\right)^2 = \frac{P}{\rho v^2}$

$M = \frac{v - \text{obj}}{c - \text{sound}} \Rightarrow m = v/c$

Inter
Contential
Balastic
Missle

$M << 1$ ultrasonic

$M < 0.4$ Compressibility can be neglected

Turbo Prop $0.9 < M < 1.1$ Transonic

Turbo jet $M < 1$ Sub sonic

Ram jet $m = 1$ Sonic

Scram jet $m > 1$ Supersonic

$M > 5$ Hyper sonic

open channel

$F_r = 1 \rightarrow$ Critical flow

$F_r < 1 \rightarrow$ sub critical (Tranquil flow)

$F_r > 1 \rightarrow$ Super critical (Torrential flow)

↳ Froude's number

G-7

1)

$Re = \frac{\rho V d}{\mu}$

$Re = 5$

$F_i / F_V = ?$ ⇒ 5 ✓

$\frac{F_i}{F_V}$ ⇒ $\frac{\text{inertia force}}{\text{viscous forces}}$

G-14:

P(2) For a flow water through a circular pipe at a rate of 36 kg/hour of 100 MM inner radius at a rate. Then reynold's number of flow? $\mu_w = 0.001$ kg/...

Sol.

$Re = ?$ $R = 100$ MM $\mu_w = 0.001$ kg/m-sec

$D = 200$

$\dot{m} = 36$ kg/hr

$\dot{m}$ (mass of flow rate) $= 36$ kg/hr

$$\boxed{Re = \frac{\rho V d}{\mu}}$$

$\rho Q = \dot{m}$ ✓

$$\rightarrow Re = \frac{\rho \left(\frac{Q}{A}\right) d}{\mu} = \frac{\dot{m}\ d}{\mu \left(\frac{\pi d^2}{4}\right)} = \frac{4 \cdot \dot{m}}{\mu \pi d}$$

$\mu_w = 0.001$ kg/m-sec

10^{-3} ✓

$$= \frac{4 \times \frac{36}{3600}}{\pi \times 200 \times 10^{-3} \times 10^{-3}} = \frac{4 \times \frac{36}{3600}}{\pi \times 200 \times 10^{-3} \times 10^{-3}}$$

$Re = 636$ ✓

G-16

$$\left[P+\frac{a}{V^2}\right][V-b] = R\cdot T$$

Dim 'a' ✓ $P_{Dim} = \left(\frac{a}{V^2}\right)_{Dim}$

$v = $ sp. vol

Sol. $\cancel{A}$ [kg, m, sec] $\Rightarrow$ Dim a $= P_{Dim} \times v^2$

$\rightarrow$ $P_{Dim} = \left(\frac{a}{V^2}\right)_{Dim}$ ✓

$$P_{Dimension} = \left(\frac{a}{V^2}\right)_{Dim}$$

$$Dim^a = P_{Dim} \times (V^2)_{Dim}$$

$$= N/m^2 \times \left(\frac{m^3}{kg}\right)^2 = \frac{kg\cdot \cancel{m}/s^2 \cdot \cancel{m^6}}{\cancel{m^2}\cdot kg^{\cancel{2}}}$$

$$= \frac{m^5}{kg\cdot sec^2}$$

DRDO - 9

A fluid flow — ρ Q, μ, L — — dimensionless no.

(a) $\frac{\rho Q L}{\mu}$ (c) $\frac{\rho Q}{\mu L}$

(b) $\frac{\rho L}{\mu Q}$ (d) $\rho/\mu Q L$

$$\rho = ML^{-3}$$
$$Q = L^3T^{-1}$$
$$\mu = ML^{-1}T^{-1}$$
$$L = L$$

$$Re = \frac{\rho V L}{\mu}$$ $$\boxed{V = \frac{Q}{A} = \frac{Q}{L^2}}$$

$$= \frac{\rho Q / L^2 \cdot L}{\mu}$$

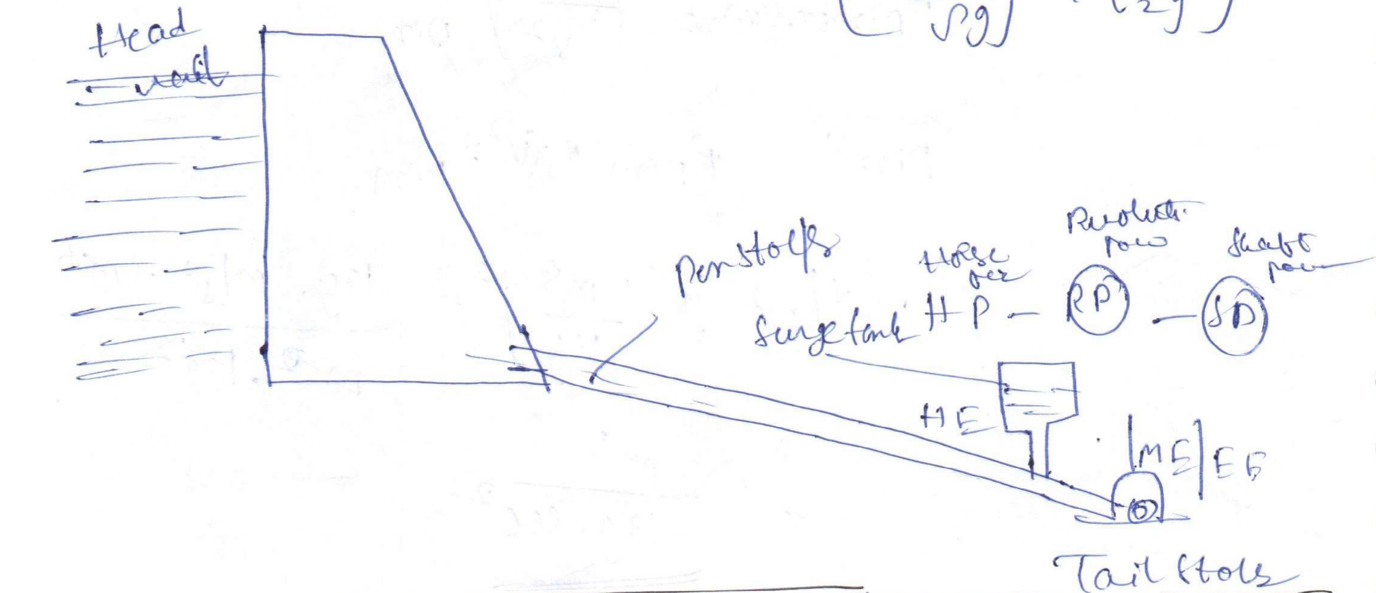
$$= \frac{\rho Q}{\mu L}$$ ✓

Hydraulic machines (Turbine)

Hydel power
(Hydroelectric power)

PE + KE

$$\left(z + \frac{P}{\rho g}\right) + \left(\frac{V^2}{2g}\right)$$



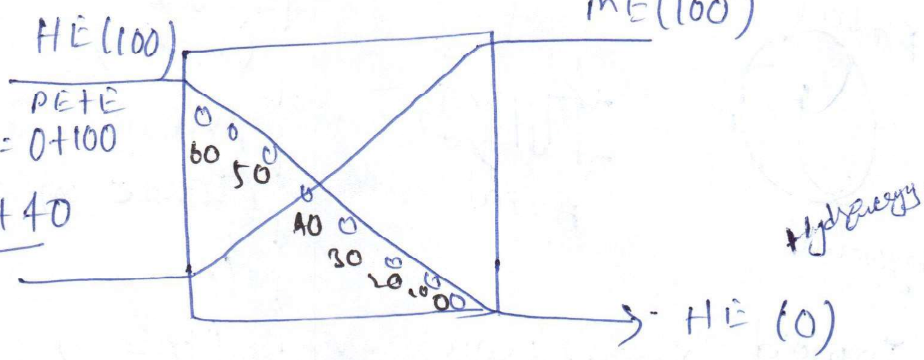
	Impulse turbine	Reaction turbine
Input energy →	only K.E	(PE + KE)
Nozzle →	is Required Convert (PE → KE)	Not required
→ Pressure Across Runner } →	Constant (or) Atmospheric	Varying Different pressure on both sides of blade.

Casing :	Simple enclosure	Scroll casing [leak proof]
		→ Runfull always.
		→ Draft tube required
	velocity turbine	pressure turbine (R+I)

Runner

→ IM = IT = 0+100

→ RT = 60+40



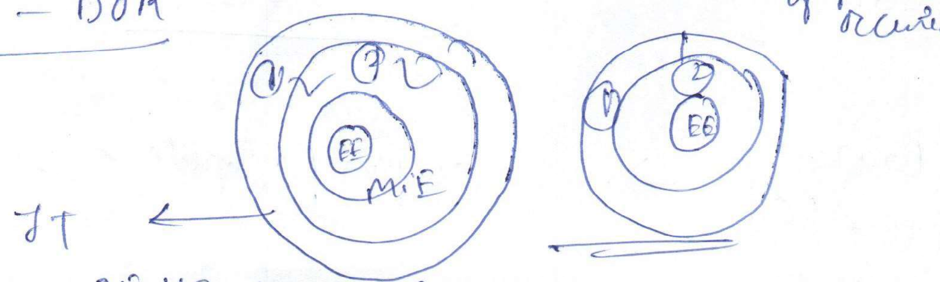
→ drag force is acted in reaction turbine
i.e water force are equal in both sides
hit side of the blade &
back side of the blade.

→ Degree of Reaction (DOR) = $\left(\frac{R}{R+I}\right)$ ✓
Reaction

→ DOR of impulse = 0

→ DOI = 1 − DOR

But RT is only 2 type of process are occurred



PE+KE there some energys are placed in JT

Degree of reaction	IM = 0	$Rec = \frac{R}{R+1}$
Degree of Impulse	DOI = 1-DOR η is less	η more

T/U = High head applications

Turbine

Classification

$$\left(N_s = \frac{N\sqrt{P}}{H^{5/4}}\right)$$

↑ RPM   Power

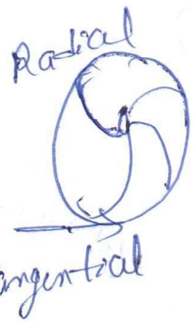
T/U Turbine = Specific Speed
SI units

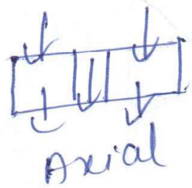
Impulse / Reaction | Head

High
(H > 300)

Medium
(50 < H < 300)

Low
(H < 50)





Inward / outward (mixed flow)

Head M		Turbine T/U		Specific Speed (SI) M
High (H > 300)	→	Pelton wheel	→	Low $N_s < 60$
Medium (50 ≤ H < 300)	→	Francis / M. Francis turbine	→	Medium $60 < N_s < 300$
Low (H < 50)	→	Kaplan / propeller	→	High ($300 < N_s < 1000$)

Design → RT (Ref mater)

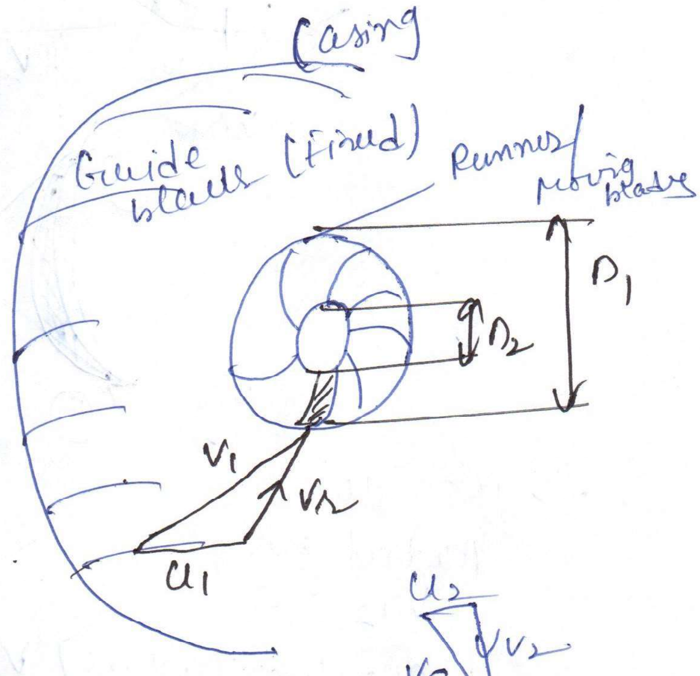
- Pelton wheel → Tangential flow I.T (Impulse turbine)
- Francis turbine → Inward radial flow R.T (Reaction turbine)
- Modern Francis → mixed flow R.T
- Kaplan / propeller → Axial flow R.T

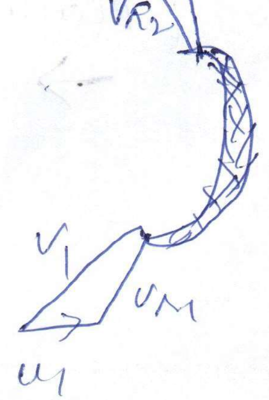
$u_1 = \frac{\pi D_1 N}{60}$

$u_2 = \frac{\pi D_2 N}{60}$

Velocity triangles :-

	① Inlet	② Exit
Absolute velocity jet	V_1	V_2
Blade velo	u_1	u_2
Relative velocity	V_{r}	V_{R_2}
flow velocity	V_{f1}	V_{f2}
whirl velocity	V_{w1}	V_{w2}
Jet Angle	α	β
Blade angle	θ	ϕ





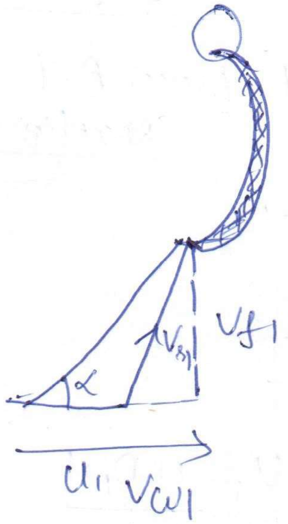
$Q = A_f V_f$

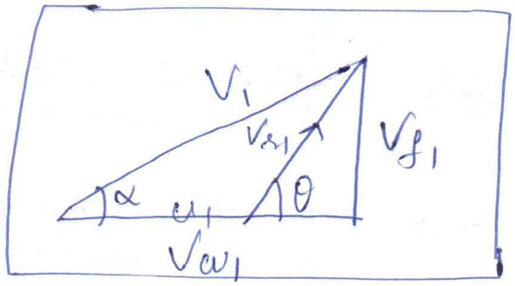
$P = F_n \times u$

$\dot{m}\,(\Delta\,vel)_n$

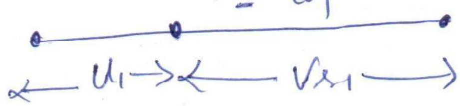
22/7/17 Velocity Δle :- (Inlet)

Impulse

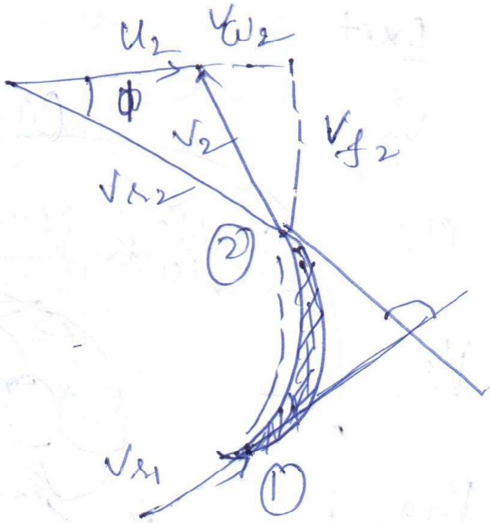


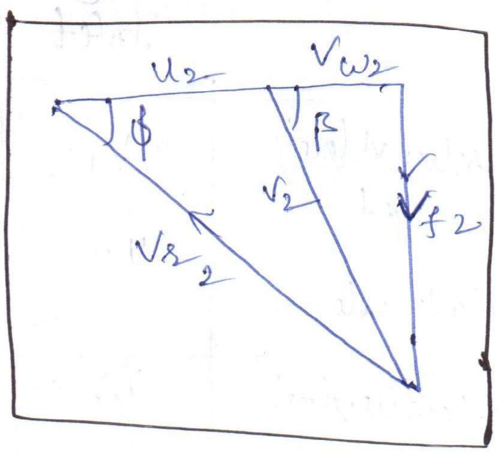


Tangential flow



Exit velocity Δle:

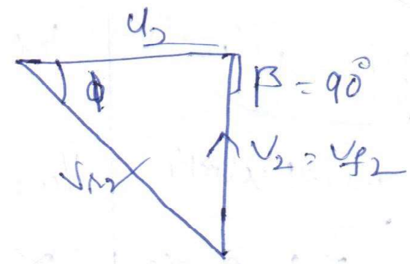




→ $\beta = 90°$

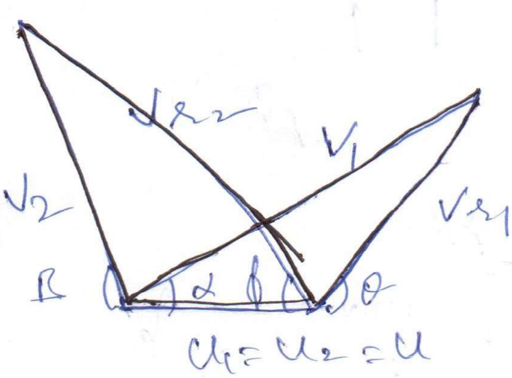
Radial exit

$V_{w_2} = 0$



[Reaction Turbine] $V_{w_2} = 0$

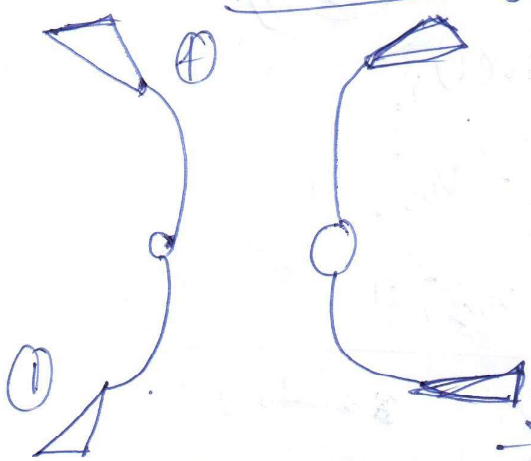
→



$$\boxed{V_{r_2} = k \cdot V_{r_1}}$$

k = Blade friction factor

Mirror images :



powers & η :

SP : Shaft power = Rating

*) RP = Runner power

$= \rho Q [V_{w_1} U_1 - V_{w_2} U_2]$

*) $\frac{\text{KE of jet}}{\text{time}} = \frac{1}{2} m V_1^2 = \frac{1}{2} \rho Q V_1^2$

*) H.P = Hydraulic power = $\gamma Q H = \rho g Q H$

Impulse turbine

I.T

$$\boxed{\eta_{nozzle} = \frac{KE\ jet}{H.P}}, \quad \boxed{\eta_{hyd} = \frac{R.P}{KE}}, \quad \boxed{\eta_{mech} = \frac{S.P}{H.P}}$$

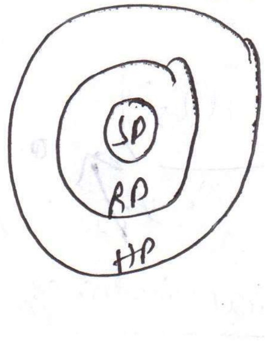
$$\eta_{overall} = \eta_{nozzle} \times \eta_{Hyd} \times \eta_{mech}$$

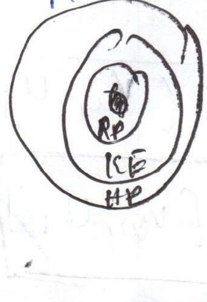
Reaction turbine :

$$\eta_{hyd} = \frac{R.P}{H.P}$$

$$\boxed{\eta_{overall} = \eta_{hyd} \times \eta_{mech}}$$

$$\eta_{mech} = \frac{S.P}{R.P}$$





$\eta_{RT} > \eta_{IT}$

As RT is only 2 stage & in IT KE is produced.

→ Runner power $\boxed{(R.P) = \rho Q [V_{w_1} u_1 - V_{w_2} u_2]}$

$$\boxed{RP = \rho Q [V_{w_1} u_1 - V_{w_2} u_2]}$$

$P = \frac{2\pi NT}{60}$

Torque $(T) = \frac{d}{dt}[mvr]$

$P = F_x \times vel$

$F_x = \dot{m} (\Delta vel)_x$

$RP = \rho Q [V_{w_1} - V_{w_2}] u$

$RP = \rho Q [V_{w_1} - V_{w_2}] u$

$$\boxed{RP = \rho Q [V_{w_1} u_1 - V_{w_2} u_2]}$$

$$\boxed{RP = \rho \cdot Q [V_{w_1} \cdot u_1 - V_{w_2} \cdot u_2]}$$

$V_{w_1} \Rightarrow +ve$

$u_1 \Rightarrow +ve$

$u_2 = +ve$

	$-ve$	zero
u_2	X	X
V_{w_2}	✓(I.T) X(R.T)	✓(R.T)

→ Fixing V_{w_1}, U_1 (+ve) : to increase the power changes in V_{w_2}, U_2 are made

Note:–

To have a maximum Runner power V_{w_2} canbe maintained negative for impulse turbine as it is not possible, for Reaction turbine Radial discharge is preferable ($V_{w_2} = 0$)

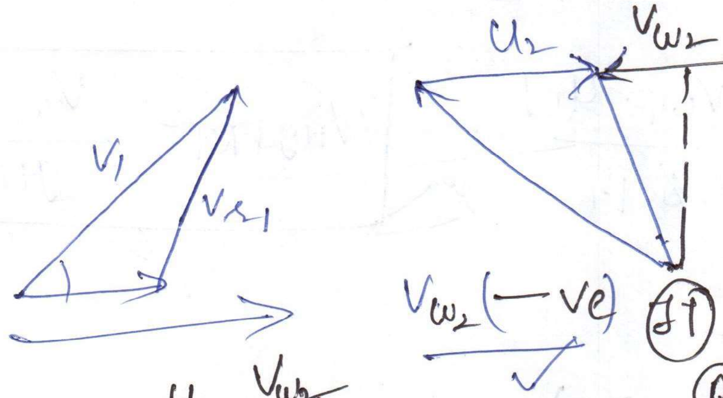
$$\boxed{RP_{(I.T)} = \rho Q (V_{w_1} u_1 \pm V_{w_2} u_2)}$$

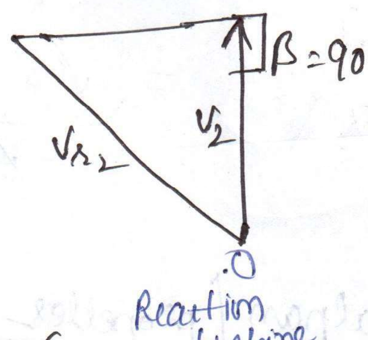
$$\boxed{RP_{(R.T)} = \rho Q [V_{w_1} u_1]} \quad (\because V_{w_2} = 0)$$

Radial discharge

Impulse Turbine :-

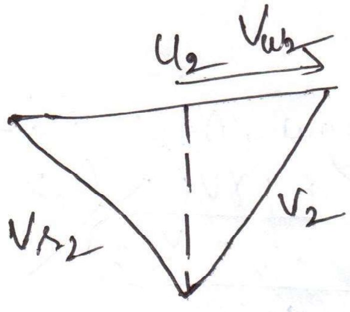
IT ✓ RT ✓



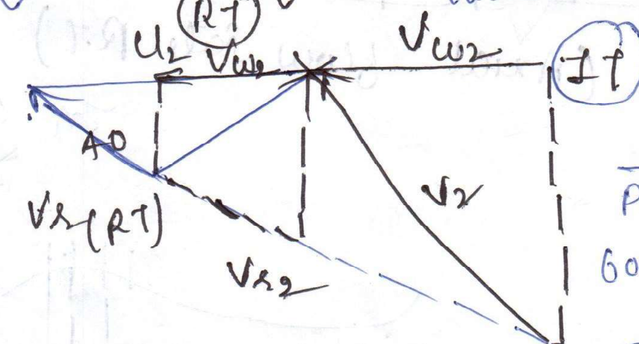


IT = +ve

RT = −ve



IT & RT +ve



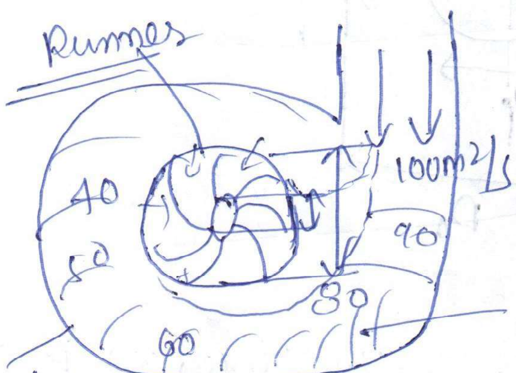
100

PE + KE

60 + 40 = 100

IT = $\frac{KE}{100}$

→ Francis Turbine :- (Inward Radial flow R.T)



Scroll

Spiral | volute casing

$\downarrow Q = \downarrow A\ V$

$$u_1 = \frac{\pi D_1 N}{60}$$

$$u_2 = \frac{\pi D_2 N}{60}$$

$\downarrow Q = \downarrow A\ V_{const}$

1) inlet

2) outlet

Note :- To maintain constant velocity of water circulating around the runner the flow rate will be decreased in the same proportion of flow rate reduction by using spiral casing.

$$\eta_{hyd} = \frac{RP}{HP}$$

$$= \frac{\rho \cancel{Q} [V_{w_1} \cdot u_1]}{\rho g \cdot \cancel{Q} H} = \boxed{\eta_{Hyd\, RT} = \frac{V_{w_1} u_1}{gH}}$$

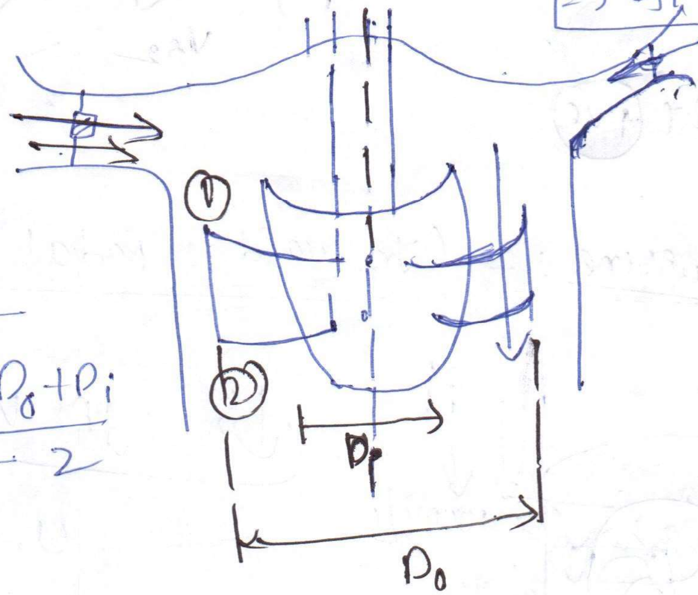
\# Kalpan / propeller :-

(Axial flow Rate R.T)

In axial flow, $A_{f_1} = A_{f_2}$

$Q = A_f \times V_f = A_{f_2} \times V_{f_2}$

$\boxed{\Rightarrow V_{f_1} = V_{f_2}}$



$u_1 = u_2 = u$

$D = D_{mean} = \frac{D_0 + D_i}{2}$

$u = \frac{\pi D N}{60}$

Note :-

If blades are permantly fixed ⇒ propeller
[more Rigid]

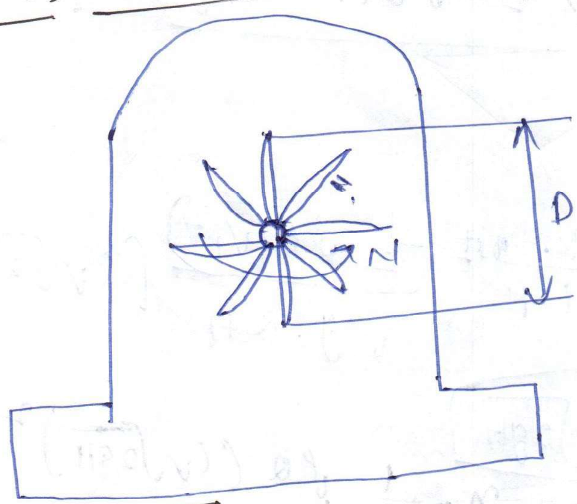
If blades are flexible (adjustable ⇒ kalpan

Hydraulic efficiency of R.T :-

$$\eta_{hyd} = \frac{R.P}{H.P} = \frac{\rho Q [V_{w_1} u_1]}{\gamma Q H}$$

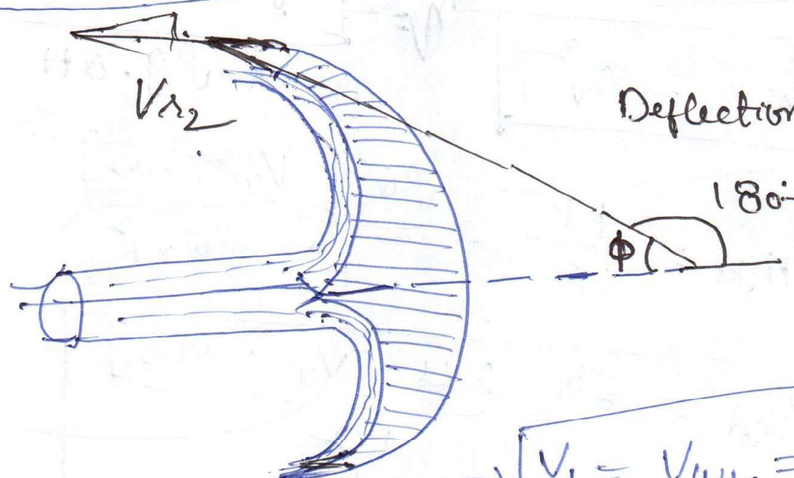
$$\boxed{\eta_{Hyd} = \frac{V_{w_1} u_1}{gH}}$$

* Pelton wheel :- (Tangential flow (T-T)):

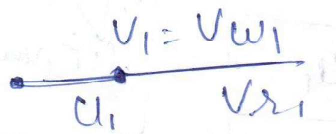


$u_1 = u_2$

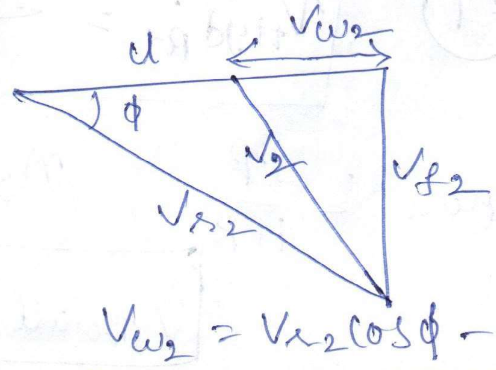
$u = \frac{\pi D N}{60}$



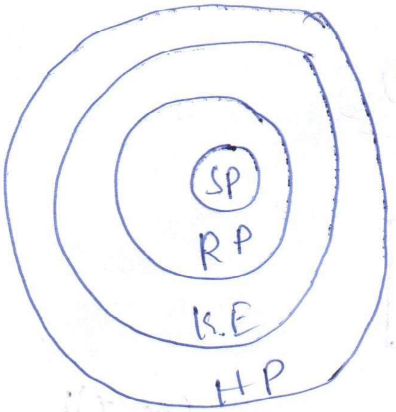
$\Rightarrow \boxed{V_1 = V_{w_1}, \Rightarrow V_{r_1} = V_1 - u}$



$V_{r_2} = k . V_{r_1}$



$V_{w_2} = V_{r_2} \cos\phi - u$



→ S.P = final power | Rating

$$\boxed{\begin{aligned} RP &= \rho Q\,[V_{w_1} + V_{w_2}]\,u \\ T &= \rho Q\,[V_{w_1} + V_{w_2}]\,R \end{aligned}}$$

→ $\dfrac{(K.E)}{\text{time}} = \dfrac{1}{2}\rho Q V_1^2$

$KE = \frac{1}{2}\rho Q V_1^2$

$$\boxed{HP = \gamma Q H = \rho g . Q H}$$

→ Efficiency of nozzle :-

→ $\eta_{nozzle} = \dfrac{K.E}{HP} = \dfrac{\frac{1}{2}\rho Q V_1^2}{\rho g . Q H}$ $\quad [C_v\sqrt{2gH}]^2$

JT $V_1 = C_1\sqrt{2gH}$

$\eta = \dfrac{\frac{1}{2}\rho Q\,(C_v\sqrt{2gH})^2}{\rho g . Q H}$

→ $\boxed{\eta_{nozzle} = C_v^2}$

$\eta_{Hyd} = \dfrac{RP}{KE} = \dfrac{\rho Q\,[V_{w_1} + V_{w_2}]\,u}{\frac{1}{2}\rho Q V_1^2}$

JT $\boxed{\eta_{Hyd} = \dfrac{2u\,[V_{w_1} + V_{w_2}]}{V_1^2}}$

$\boxed{\eta_{C.F\,pump} = \dfrac{g H_m}{V_{w_2} u_2}}$

RT $\boxed{\eta_{Hyd\,RT} = \dfrac{V_{w_1} u_1}{gH}}$

$\eta_{mech} = \dfrac{S.P}{HP}$, $\eta_{overall} = \dfrac{S.P}{HP} = \eta_{nozzle} \times \eta_{Hyd} \times \eta_{mech}$

$$\boxed{\eta_{overall} = \eta_{nozzle} \times \eta_{Hyd} \times \eta_{mech}}$$

$RP = \rho Q [V_{w_1} + V_{w_2}] u$

$T = \rho Q [V_{w_1} + V_{w_2}] R$

V_1 ✓ | HP | $V_1 = C_v \sqrt{2gH}$

u_1 ✓ | D, N | optimum blade speed ratio

$\left(\frac{\pi D N}{60}\right)$ | $u = \frac{V_1}{2}$

→ Condition of Max hyd. $u = \frac{V_1}{2}$

→ Speed ratio $= \frac{u}{\sqrt{2gH}}$

Ei at optimum blade speed

→ Speed ratio $= 0.5$ ---- $\left[\frac{V_1/2}{\sqrt{2gH}}\right] = 0.5$

→ Flow ratio $= \frac{V_f}{\sqrt{2gH}}$

η Hyd max $\left(u = \frac{V_1}{2}\right) \Rightarrow \frac{1 + K\cos\phi}{2}$ $\phi = 0$ is not possible so $\phi = 10^\circ$ to 20°

optimum deflection angle $= 160^\circ$ to 170°

i.e $\phi = 10^\circ$ to 20°

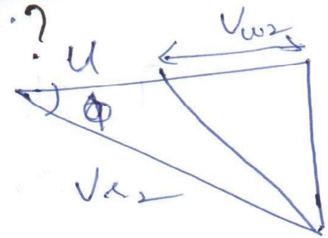
→ Jet ratio 'M' $= \frac{D}{d} = \frac{\text{Dia of runner}}{\text{Dia of jet}}$

→ No of blades $= 15 + \frac{M}{2}$

$= 15 + \frac{D}{2d}$

	No of blades
(1) pelton wheel	18 - 25
(2) Francis	12 - 16
(3) kaplan / propeller	4 - 6

problem G-06: In a pelton turbine the bucket peripheral speed is 10 m/s. The water jet velocity at the inlet is 25 m/s & with the flow rate of 0.1 m³/sec & getting deflected by 120° The power developed by Runner assuming ideal flow.?



Sol. $V_{w1} = V_1 = 25\,m/s$, $u = 10\,m/s$

$Q = 0.1\,m^3/sec$

$180 - \phi = 120^\circ \Rightarrow \phi = 60^\circ$

Ideal flow power kw?

$R.P = \rho Q [V_{w1} + V_{w2}]\, u$

$\rightarrow V_1 = V_{w1}$

$\rightarrow V_1 = V_{w1} = 25\,m/s$

$\rightarrow V_{r2} = K V_{r1}$

$\rightarrow V_1 - u = 25 - 10$

$\rightarrow V_{R2} = 15\,m/s$

$\rightarrow V_{w2} = V_{r2} \cos\phi - u$

$= 15 \cos 60^\circ - 10$

$= 7.5 - 10$

$= 7.5 - 10$

$V_{w2} = -2.5\,m/s$

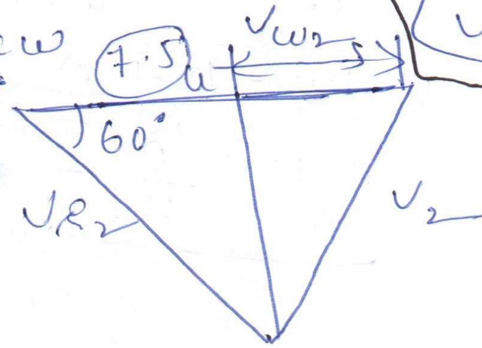
Finally

$R.P = \rho Q [V_{w1} + V_{w2}]\, u$

$= 10^3 \times 0.1 [25 + (-2.5)] \times 10$

$RP = 22.5\,kW$

$RP = 22.5\,kW$



(II) Another method

$$R.P = \rho Q\,[[V_{w_1} u_1] - [V_{w_2} u_2]]$$

$$= \rho Q\,[V_{w_1} - V_{w_2}]\,u$$

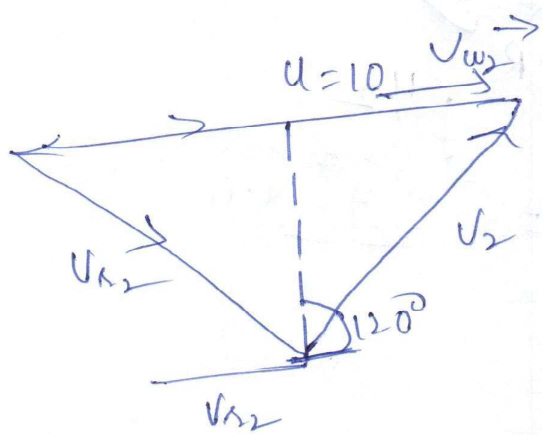
$\rightarrow \vec{V_1} = \vec{V_{w_1}} = +25\,m/s$ ✓

$V_1 = V_{w_1}$

u

$\Rightarrow V_{r_2} = V_{r_1} = \vec{V_1} - \vec{u} \Rightarrow 25 - 10 = 15\,m/s$ ✓

$\rightarrow V_{r_2} = k \cdot V_{r_1} = 15\,m/sec$ ✓



$\rightarrow \vec{u_{w_2}} = \vec{u} - V_{r_2}\cos\beta$

$= 10 - 7.5$

$\rightarrow \vec{V_{w_2}} = +2.5\,m/sec$

$R.P = 1000 \times 0.1\,[+25 - (2.5)] \times 10$

$= 22.5\,kW$

Q_08

water issue of nozzle with a velocity of 10m/s & striking on the runner of pelton wheel with mean dia of 1m & rotating at 10 rad/sec. Find the torque developed for unit mass flow rate. considering the blade as frictionless

~~ω = 2π A~~

Sf $\rightarrow V_1 = 10\,m/s = V_{w_1}$

$\rightarrow \phi = 180 - 120 = 60°$ $\rightarrow$ 1 m dia of mass flow rate

$1 = \dot{m}$

$V_1 = V_{w_1}$

$u \quad V_{r_1}$

$V_1 = V_{w_1} = 10\,m/s$

$\rightarrow \omega = \cancel{\omega_T} = 10$ Rad/sec ✓

$V_1 = V_{w_1} = 10$ m/s

$u = R \cdot \omega$ ✓
$= 0.5 \times 10$
$= 5$ m/sec ✓

$\rightarrow V_{r_2} = k \cdot V_{r_1} = V_1 - u$ (k = 1)
$= 10 - 5$
$= 5$ ✓

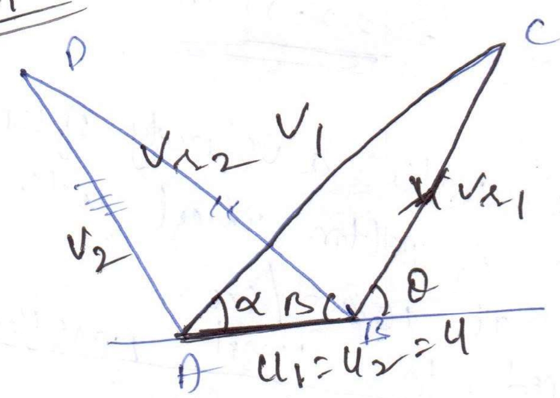
$V_1 = 10$ m/s

$V_{r_2} = 5$ m/s

$\rightarrow V_{w_2} = V_{r_2} \cos\phi - u$
$= 5 \cos 60^\circ - 5$
$= -2.5$ ✓

$\rightarrow T = \rho Q [V_{w_1} + V_{w_2}] \cdot R$
$\rightarrow T = 1 [10 + (-2.5)] \, 1/2$
$= 7.5 \times 1/2 = \underline{3.75 \text{ N·M}}$

G-12



$V_1 = V_{r_2}$
$V_{r_1} = V_2$
$\alpha = \phi$
$\beta = \theta$

equi angular Cond^n

DOR = ? 1) 25% ~~2)~~ 50% 3) 75% 4) 100%

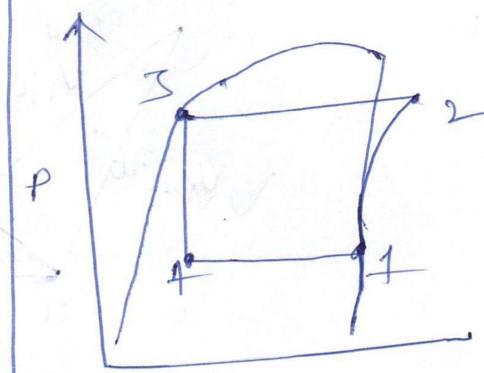
$\rightarrow$ For equiangular reaction condition
Degree of reaction = 50%.

$\rightarrow$ Degree of reaction

$$DOR = \frac{R}{(R + I)} \Rightarrow DOR(50\%) = \frac{(\Delta H)\, \text{Rotor}}{(\Delta H)\, \text{stage}}$$ ✓

$$DOR = \frac{(\Delta H)\, \text{Rotor}}{(\Delta H)\, \text{Stage} + (\Delta H)_{\text{Rotor}}}$$

$$(D.O.R)_{\text{steam turbine}} = \frac{(\Delta H)_{Rotor}}{(\Delta H)_{stage} + (\Delta H)_{Rotor}}$$



$$COP = \frac{H - h_3}{H_2 - H_1}$$

FM. Point of view

$$DOR = \frac{\Delta PE}{\Delta(PE+KE)}$$

$$\Rightarrow DOR = \frac{R}{(R+I)} = \frac{PE}{(PE+KE)}$$

$$= \frac{\left[\frac{P_1 - P_2}{\rho g}\right]}{R.P} = \frac{\frac{P_1 - P_2}{\rho g}}{R.P} \rightarrow m$$

watt — m per unit weight

R.P = Reactive principle

$$R.P = \rho Q[V_{w_1} u_1 - \overset{0}{V_{w_2}} u_2] \rightarrow$$ The power converted to head term

$$\frac{R.P}{\gamma Q} = \frac{\rho Q(V_{w_1} u_1)}{\rho g Q} = \frac{V_{w_1} u_1}{g}$$ ✓

$$RP = \frac{V_{w_1} u_1}{g}$$

$$\left\{ \begin{aligned} P &= \gamma Q H \\ H &= \frac{P}{\gamma Q} \end{aligned} \right.$$

→ RP per unit weight

$$DOR = \frac{\left(\frac{P_1 - P_2}{\rho g}\right)}{\left(\frac{V_{w_1} u_1}{g}\right)}$$