Sri Shridevi Charitable Trust (R)

ಶ್ರೀದೇವಿ ಇಂಜಿನಿಯರಿಂಗ್ ಮತ್ತು ತಾಂತ್ರಿಕ ಮಹಾವಿದ್ಯಾಲಯ

SHRIDEVI INSTITUTE OF ENGINEERING AND TECHNOLOGY

(Recognised by Govt. of Karnataka, Affiliated to VTU, Belagavi and Approved by AICTE, New Delhi)

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SHRIDEVI
EDUCATION

BLUE BOOK

USN : 1SV20ME009

Name of the Student : VIVEKA. E

Course : B. E Code : 18ME54

Semester : V Branch : Mechanical

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INTERNAL ASSESSMENT MARKS

Date	Test No.	Max. Marks	Marks Obtained	Course Instructor Signature
14/11/22	01	40	36	[signature]
23/12/22	02	40	36	[signature]
30/1/22	03	40	39	[signature]
	Average	30	28	[signature]

28+10 = 38/40

CERTIFICATE

This is to certify that Kum / Sri ............V.I.V.E.K.A. E............

with USN.......18V20ME009.............. has satisfactorily completed the Internal

Assessment tests in the subject ....Turbo machines............

with Subject Code ....18ME54.............. as prescribed by the

Visvesvaraya Technological University for the ....V.......... semester

B.E. / M.Tech / MBA degree course in the year 2022-2023

Course Instructor

Head of the Department

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TEST NO. 1

Q.No.	a	b	c	Total
Q1	6	10	4	20
Q2				
Q3	6	10		16
Q4				36
Test - 1 Marks				

TEST NO. 2

Q.No.	a	b	c	Total
Q1				
Q2		8	8	16
Q3	4	8	8	20
Q4				36
Test - 2 Marks				

TEST NO. 3

Q.No.	a	b	c	Total
Q1	4	8	8	20
Q2	4	8	7	19
Q3				
Q4				39
Test - 3 Marks				

REMARKS

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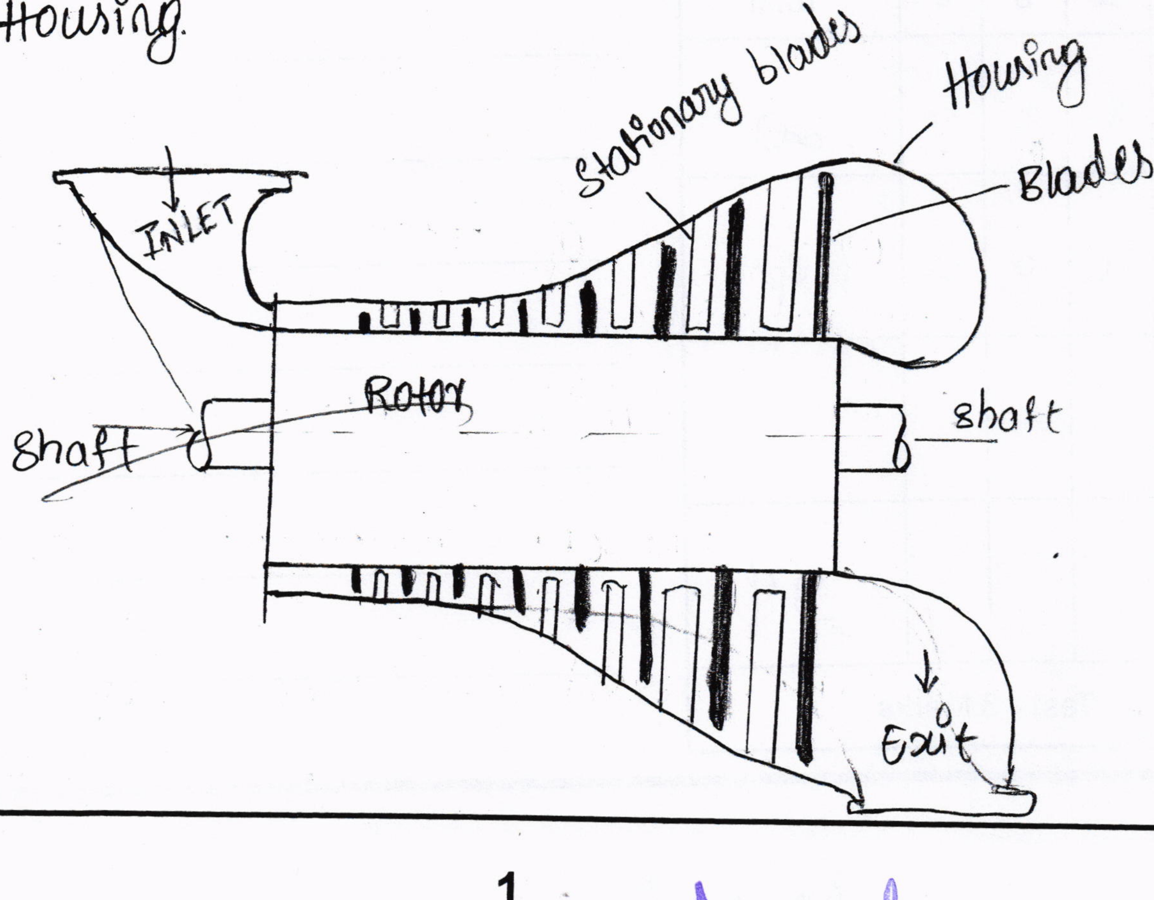
I Internal assessment test

1.

2. Turbo machine is a device in which the energy transfer takes place b/w a flowing fluid and rotating element due to the dynamic action and results in the pressure and momentum change.

Basic principal parts of turbo machine are:

-> Rotating element consisting a rotor
-> stationary element which guide a nozzle, blades etc..
-> Input or output shaft
-> Housing.



1. Rotating element :- Rotating elements are rotor, Runner, Impeller depending upon the type of flow. Energy transfer takes place b/w flowing fluid & a rotating element and Results in the momentum change.

Impeller :- In case of the Reciprocating pumps or Reciprocating compressor.

Runner :- In case of a radial hydraulic pumps

2. Stationary element

→ Stationary elements are not necessary to the turbo machine.

→ ceiling fan is an example of stationary element.

3. Shaft

→ Shaft is used depending upon the type of turbomachine.

→ Power absorbing turbomachine :- Only Input shaft

→ Power generating turbomachine :- only output shaft

→ Power transmitting turbomachine :- both Input and output shaft

4. Housing

→ It is compulsory part of turbomachine.

→ It is outfit for turbomachine & also protecting layer.

→ Housing which restrict the flow of fluid.

Positive displacement	Turbo machine
Action → Creates a thermodynamic & ~~dynamic~~ Mechanical action b/w a static fluid & a .	→ Creates a thermodynamic and dynamic action b/w a flowing fluid & rotating element.
Operation → Reciprocating motion	→ pure rotating motion
Mechanical feature. → Reciprocating speed is low. → Heavy foundation is required.	→ ~~Recip~~ Rotating speed is high → Light weight foundation is required.
efficiency. → Efficiency is high because of Static energy transfer	→ Efficiency is low because of dynamic energy transfer.

Volumetric efficiency	
→ Normally below that turbomachine	→ It is 100%
→ fluid handling capacity is low	→ fluid handling capacity is high.

5.

v) Flow co-efficient:- $\pi_1 = \frac{Q}{ND^3}$ is the flow co-efficient which signifies the volm flow rate of fluid through a turbomachine of unit dia. of runner operating at unit speed.

vi) Head co-efficient, $\pi_2 = \frac{H}{N^2D^3}$ is called the Head co-efficient. It represents the ratio of the K.E of the fluid under the head H to KE of running speed

vii) Power coefficient, $\pi_3 = \frac{P}{N^3D^5}$ is called the power co-efficient. It represents the relation b/w the power, fluid density, speed & wheel diameter.

viii) Specific speed of a turbine, $N_s = \frac{N\sqrt{P}}{H^{5/4}}$

Specific speed of turbine can be ~~obtained~~ defined as a speed of a geometrically similar machine which produce 1 kW power under a head of 1m.

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2. Given

$N = 2000 rpm$

$P = 5200 KW$

$H = 220 m$

$\eta = 80\% = 0.8$

$\rho = 1000 Kg/m^3$

i. unit speed. $N_u = \frac{N}{\sqrt{H}} = \frac{2000}{\sqrt{220}} = 135.1$ rpm

2. unit power, $P_u = \frac{P}{H^{3/2}} = \frac{5200}{(220)^{3/2}} = 3263.1$ Kw

3. unit flow, $Q_u = \frac{Q}{\sqrt{H}}$

~~$P = \rho g H Q$~~

$Q = \frac{5200}{1000 \times 9.81 \times 220 \times 0.8} \times 10^3$

$Q = 3.01 \; m^3/s$

3.01×10

$$\therefore Q_u = \frac{3.01}{\sqrt{220}} = 0.2029 \ m^3/s$$

~~If H = 140m~~

~~then, unit speed~~ $N_s = \frac{N\sqrt{P}}{H^{5/4}}$

$$= \frac{200\sqrt{5200}}{(220)^{5/4}}$$

Specific speed $N_s = 17.02$ rpm

If $H = 140m$.

then $N_u = \frac{N}{\sqrt{H}} \Rightarrow N = N_u \times \sqrt{H} = 135.1 \times \sqrt{140}$

$N = 1598.5$ rpm

$$Q = Q_u \times \sqrt{H} = 0.2029 \times \sqrt{140} = 2.4 \ m^3/s$$

$$P = P_u \times H^{3/2} = 3263.1 \times (140)^{3/2} = 5405 \ kW$$

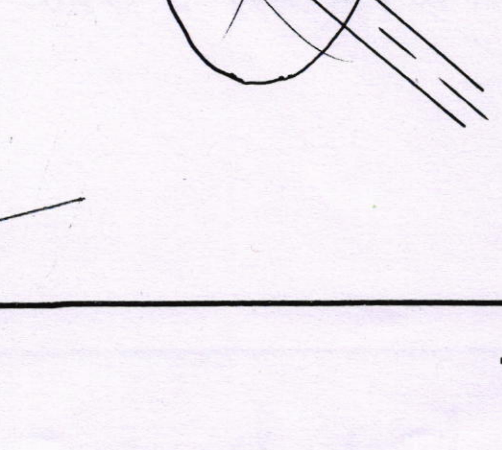
If we need to find unit speed, unit flow and unit power for the same speed, flow & power but H = 140 m.

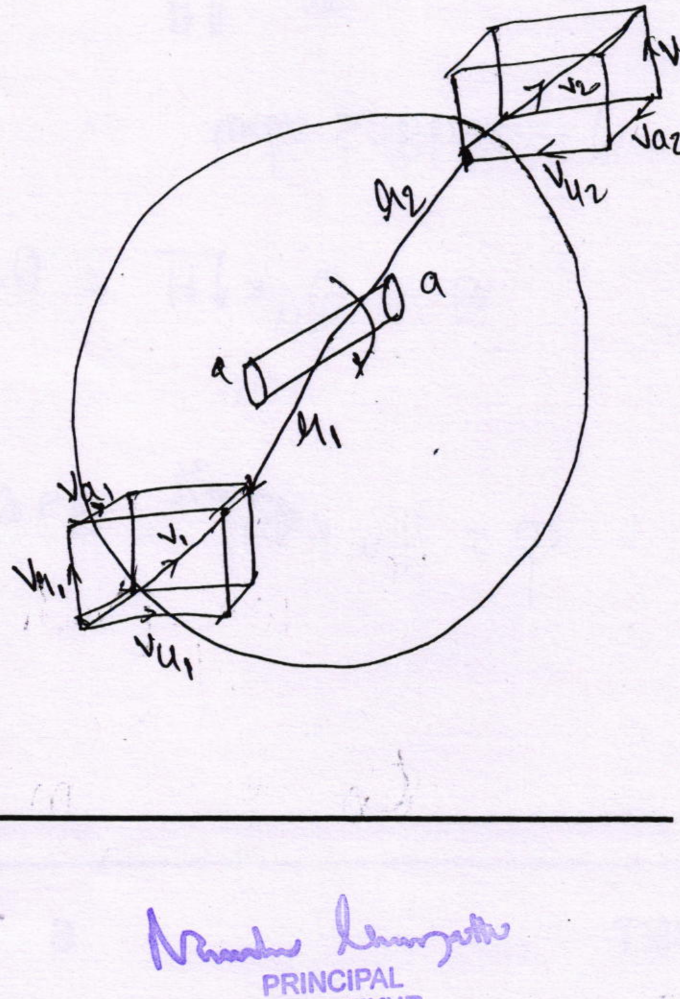
$$N_u = \frac{N}{\sqrt{H}} = \frac{200}{\sqrt{140}} = 16.9 \text{ rpm}$$

$$Q_u = \frac{Q}{\sqrt{H}} = \frac{3.01}{\sqrt{140}} = 0.25 \text{ m}^3/\text{s}$$

$$P_u = \frac{P}{H^{3/2}} = \frac{5200}{140^{3/2}} = 3.139 \text{ KW}$$

2.





Let $F = m \times \frac{a}{g_c}$

$$= \frac{1}{g_c}\left[\frac{\text{mass}}{\text{time}} \times \text{velocity}\right]$$

$$= \frac{1}{g_c}\left[\mathring{m} \times \text{velocity}\right]$$

$$= \frac{\mathring{m}}{g_c} \times \text{velocity}$$

$$F = \frac{\mathring{m}}{g_c} \times \left[V_{u_1} - V_{u_2}\right] \quad \text{—— (1)}$$

$$T = F \times r$$

$$T = \frac{\mathring{m}}{g_c}\left[V_{u_1} r_1 - V_{u_2} r_2\right]$$

$$\therefore \quad T = \frac{\mathring{m}}{g_c}\left[V_{u_1} r_1 - V_{u_2} r_2\right]$$

$$E_0 = \omega T$$

$$= \frac{\omega \mathring{m}}{g}\left[V_{u_1} r_1 - V_{u_2} r_2\right]$$

$$E = \frac{E_0}{m}$$

$$\therefore \quad E = \frac{V_{u_1} r_1 \omega - V_{u_2} r_2 \omega}{g_c}$$

$$\therefore \quad E = \frac{V_{u_1} U_1 - V_{u_2} U_2}{g_c} \quad (\because$$

If $g_c = 1$

$$\boxed{E = V_{u_1} U_1 - V_{u_2} U_2 = \Delta h_0}$$

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II Internal test

2.

c.

D = 0.75 m

N = 3500 rpm

V_1 = 275 m/s

α_1 = 20°

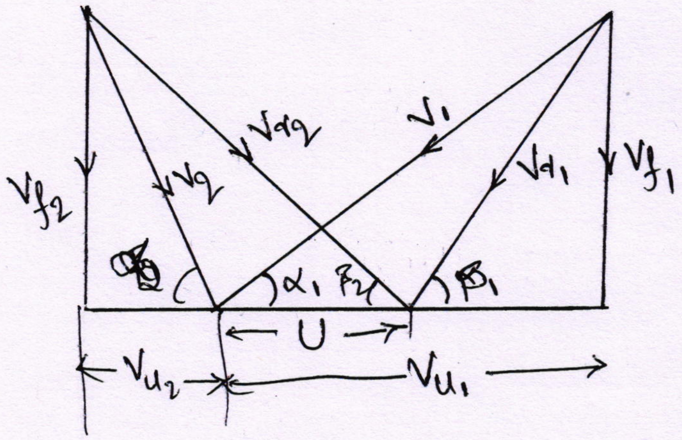
ε = 0.9

$V_{r_2} = 0.9 V_{r_1}$

$\dot{m}$ = 2 kg/s

F_a = ?

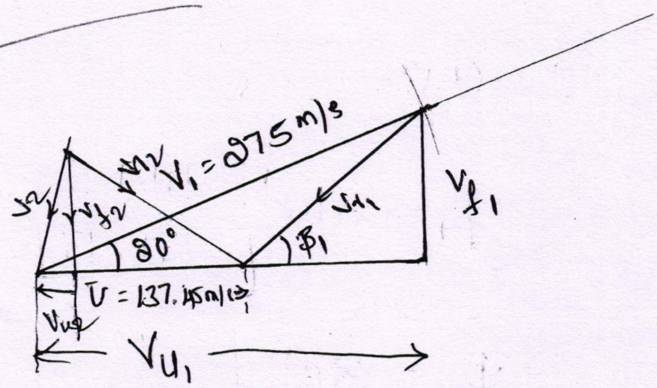
P = ?



$$U = \frac{\pi D N}{60} = \frac{\pi \times 0.75 \times 3500}{60} = 137.45 \text{ m/s}$$

scale 1cm = 50 m/s

8



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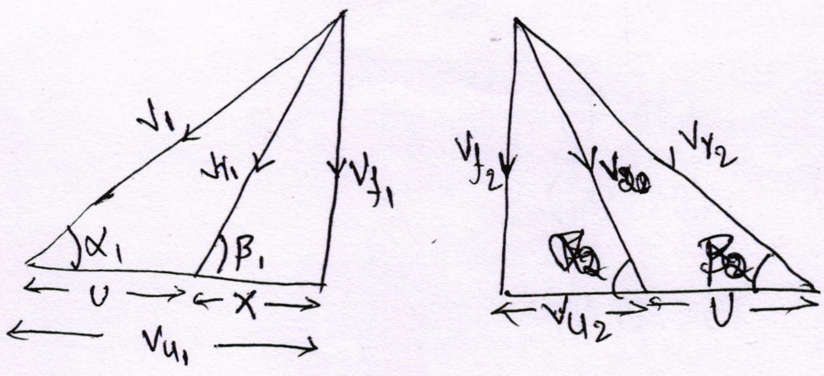


From fig. $\sin\alpha_1 = \frac{V_{f1}}{V_1}$

$$\sin(20) = \frac{V_{f1}}{275} \Rightarrow V_{f1} = 94.1\ m/s$$

Also, $\cos\alpha_1 = \frac{V_{u1}}{V_1}$

$$\cos 20^\circ = \frac{V_{u1}}{275} \Rightarrow V_{u1} = 258.42\ m/s$$

Let $X = V_{u1} - U$

$$= 258.42 - 137.45$$

$$X = 120.97\ m/s$$

Now, $\tan\beta_1 = \frac{V_{f1}}{X}$

$$\beta_1 = \tan^{-1}\left[\frac{94.1}{120.97}\right]$$

$$\boxed{\beta_1 = 38^\circ}$$

Also, $\cos\beta_1 = \frac{x}{V_{r_1}}$

$$V_{r_1} = \frac{120.97}{\cos(38^\circ)}$$

$$V_{r_1} = 153.5 \text{ m/s}$$

$\therefore$ given $V_{r_2} = 0.9 V_{r_1}$

$$= 0.9 \times 153.5$$

$$= 138.15 \text{ m/s}$$

By utilization factor, $\varepsilon = \frac{V_1^2 - V_2^2}{V_1^2 - R V_2^2}$ $(\because R = 0)$

$$0.9 = \frac{(275)^2 - V_2^2}{(275)^2 - 0}$$

$$V_2^2 = 275^2 - 68062.5$$

$$\boxed{V_2 = 86.96 \text{ m/s}}$$

WKT,

$$\therefore V_2^2 = V_{r_2}^2 + U^2 - 2V_{r_2} U \cos\beta_2$$

$$(86.96)^2 = (138.15)^2 + (137.45)^2 - 2(138.15)(137.45)\cos\beta_2$$

$37977.44 \cos\beta_2 = 30415.88$

$\cos\beta_2 = 0.8$

$\boxed{\beta_2 = 37^\circ}$

$\therefore \sin\beta_2 = \frac{V_{f_2}}{V_{r_2}}$

$\sin 37^\circ = \frac{V_{f_2}}{138.15} \Rightarrow V_{f_2} = 83.14 \text{ m/s}$

Also,

$\tan\beta_2 = \frac{V_{f_2}}{(V_{u_2} + U)}$

$\tan(37^\circ) = \frac{83.14}{(V_{u_2} + 137.45)}$

$\therefore \boxed{V_{u_2} = 27.119 \text{ m/s}}$

$\therefore$ Now, power, $P = \frac{\dot{m}}{g} U (V_{u_1} - V_{u_2})$

$= 2 \times 137.45 (258.42 - 27.119)$

~~$P = 231.3$~~ $\boxed{P = 63.58 \text{ KN}}$

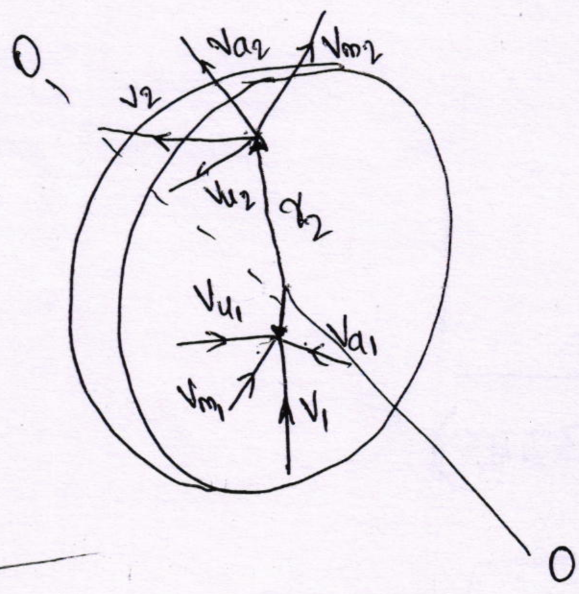
axial thrust, $F_a = \frac{m'}{g_c}(V_{f_1} - V_{f_2})$

$= \frac{2(94.1 - 83.14)}{1}$

$$\boxed{F_a = 21.92 N}$$

12

1.



Assumption

→ Fluid flow through the turbine is steady flow

→ Rate of energy transfer at the rotor is constant

→ Losses due to leakage are neglected.

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$$F = \Delta\left(\frac{mV_u}{t}\right) = m\left(V_{u_1} - V_{u_2}\right)$$

But Torque = Force x Radius

$$\tau = F \times r$$

Then $\tau = m\left(V_{u_1} r_1 - V_{u_2} r_2\right)$

But rate of energy = Torque x Angular velocity

$$\dot{E} = \tau \times \omega$$

$$\dot{E} = m\left(V_{u_1} r_1 \omega_1 - V_{u_2} r_2 \omega_2\right)$$

But tangential velocity, $U = r \times \omega$

$$\therefore \dot{E} = m\left(V_{u_1} U_1 - V_{u_2} U_2\right)$$

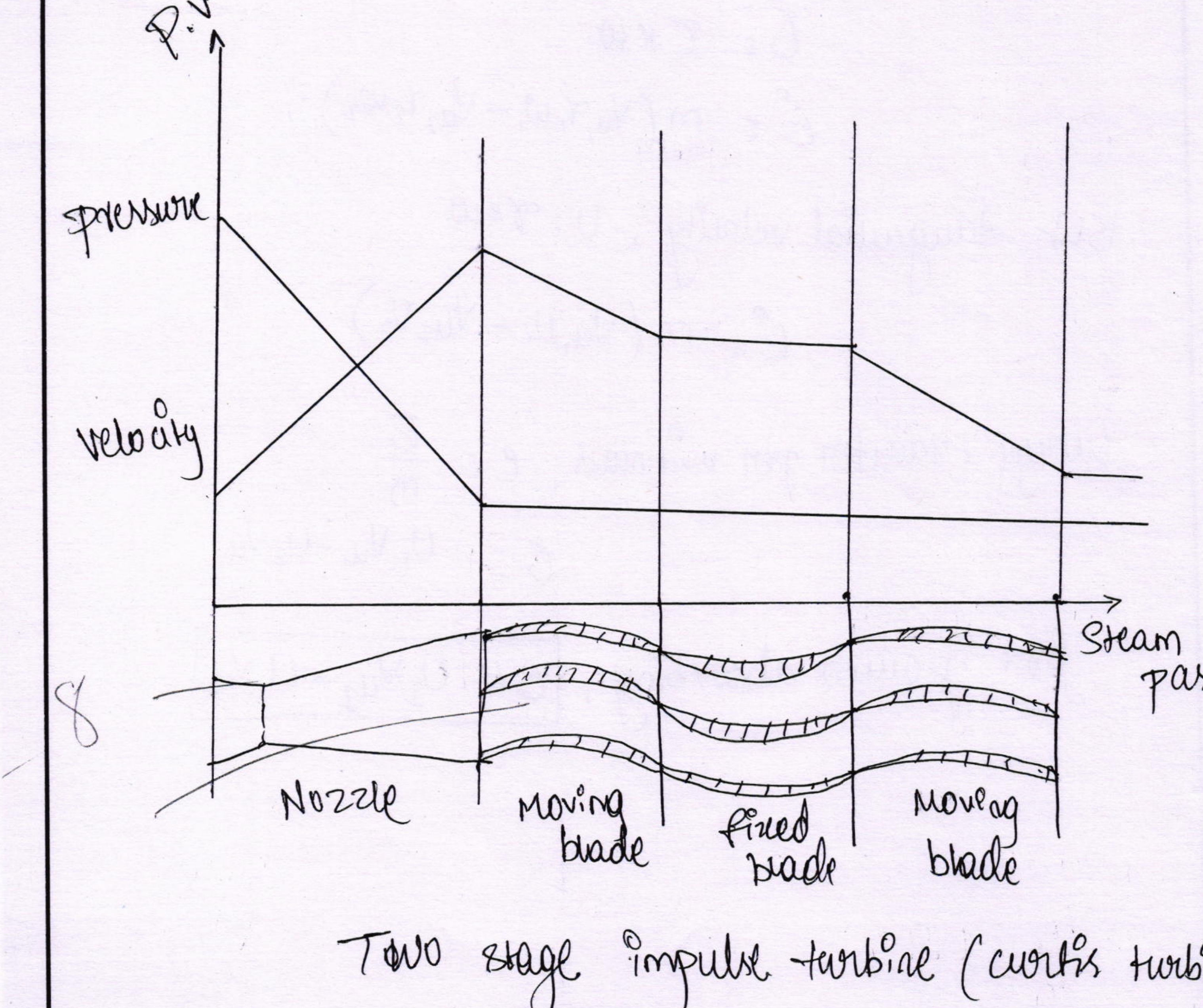
energy transfer per unit mass, $e = \frac{\dot{E}}{m}$

$$e = U_1 V_{u_1} - U_2 V_{u_2}$$

for power absorbing, $e = U_2 V_{u_2} - U_1 V_{u_1}$

3.

). Velocity compound turbine is a set of stationary nozzles is followed by two sets of moving blades with stationary row of impulse blades b/w them to redirect the flow.



Two stage impulse turbine (curtis turbine)

→ In an impulse turbine the relative velocity will remain unaltered as it passes over the blades.

→ If friction is neglected. In practice the flow of steam over the blades is resisted by friction

→ The effect of this friction is to reduce the relative velocity of steam as it passes over the blades.

→ In general, there is a loss of 10 to 15% in the relative velocity.

<u>Given</u>

$D = 1.6 m$

$N = 3500 rpm$, $\beta_2 = \beta_1 - 4$

$\alpha_1 = 22°$

$\dot{m} = 8 kg/s$

$\frac{U}{V_1} = 0.55$

$\frac{V_{r_2}}{V_{r_1}} = 0.95$

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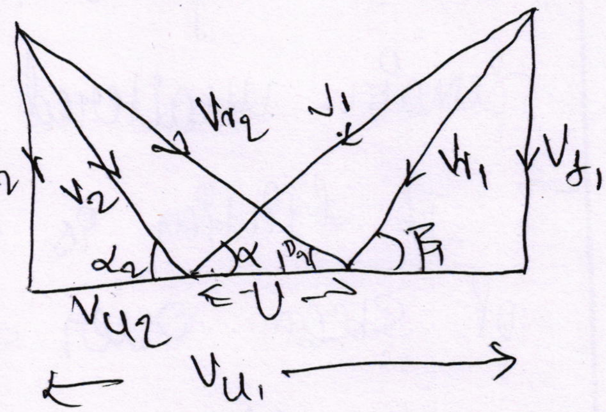
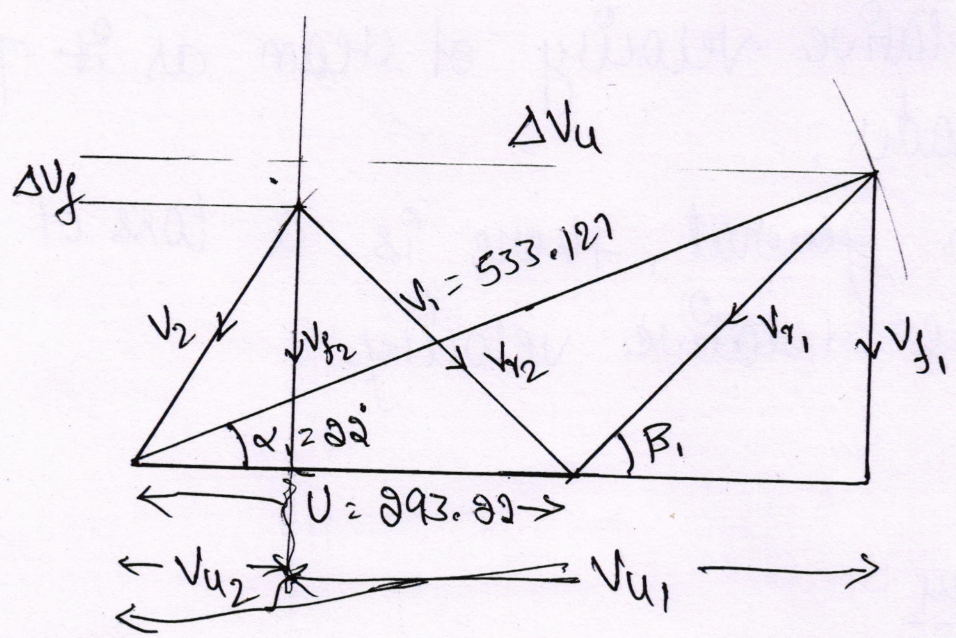
$$U = \frac{\pi D N}{60}$$

$$= \frac{\pi \times 1.6 \times 3500}{60}$$

$$U = 293.22 \text{ m/s}$$





$$V_1 = \frac{293.22}{0.55} = 533.127 \text{ m/s}$$

i) $V_{u_1} = 9.75$ cm $= 487.5$ m/s , ii) $V_{r_1} = 5.5$ cm $= 275$ m/s iii) $\beta_1 = 46^\circ$

iv) $V_{f_1} = 4$ cm $= 4 \times 50 = 200$ m/s

$\therefore \beta_2 = 46^\circ - 4$

$\beta_2 = 42^\circ$

387.5

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$V_{r_2} = 0.9 \times 275$

$= 247.5$

$V_{f_2} = 3.5$, $V_2 = 3.9$

$= 175\ m/s$ $= 195\ m/s$

$\therefore \Delta V_f = 25\ m/s$

$\Delta V_u = 387.5\ m/s$

$\therefore$ i) whirl velocity $\Delta V_f = 25\ m/s$

ii) $F_a = \frac{\dot{m}}{g}[\Delta V_f]$

$= \frac{8[25]}{1}$

$= 200\ N$

iii) $\beta_1 = 46^\circ$ & $\beta_2 = 42^\circ$

iv) $P = \frac{\dot{m}}{g} U \Delta V_u$

$= \frac{8[293.22 \times 387.5]}{1000}$ $\Rightarrow$ $P = 908.9\ KN$

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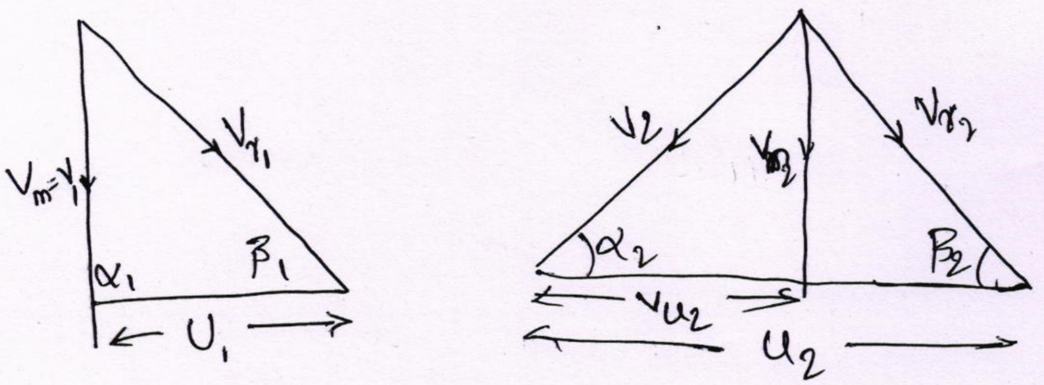
Internal Assessment test-3

2.

1.



Energy transfer due to static.

$$e_{static} = \left(\frac{U_2^2 - U_1^2}{2}\right) - \left(\frac{V_{r_2}^2 - V_{r_1}^2}{2}\right)$$

from inlet velocity Δles, $V_{r_1}^2 = U_1^2 + V_{m_1}^2$

from outlet velocity Δles, $V_{r_2}^2 = V_{m_2}^2 + x_2^2$

But $\cot\beta_2 = \frac{x_2}{V_{m_2}} \Rightarrow x_2 = V_{m_2}\cot\beta_2$

~~Then, $V_{r_2}^2 = V_{m_2}^2 + V_{m_2}^2\cot^2\beta_2$~~

4

$$\therefore e_{static} = \left(\frac{U_2^2 - U_1^2}{2}\right) - \frac{\left[V_{m_2}^2 + V_{m_2}^2\cot^2\beta_2 - U_1^2 - V_{m_1}^2\right)}{2}$$

$$= \frac{1}{2}\left[V_{m_1}^2 + U_2^2 - V_{m_2}^2(1+\cot^2\beta_2)\right]$$

$\therefore e_{static} = \frac{1}{2}\left[V_{m_1}^2 + U_2^2 - V_{m_2}^2 \operatorname{cosec}^2\beta_2\right]$

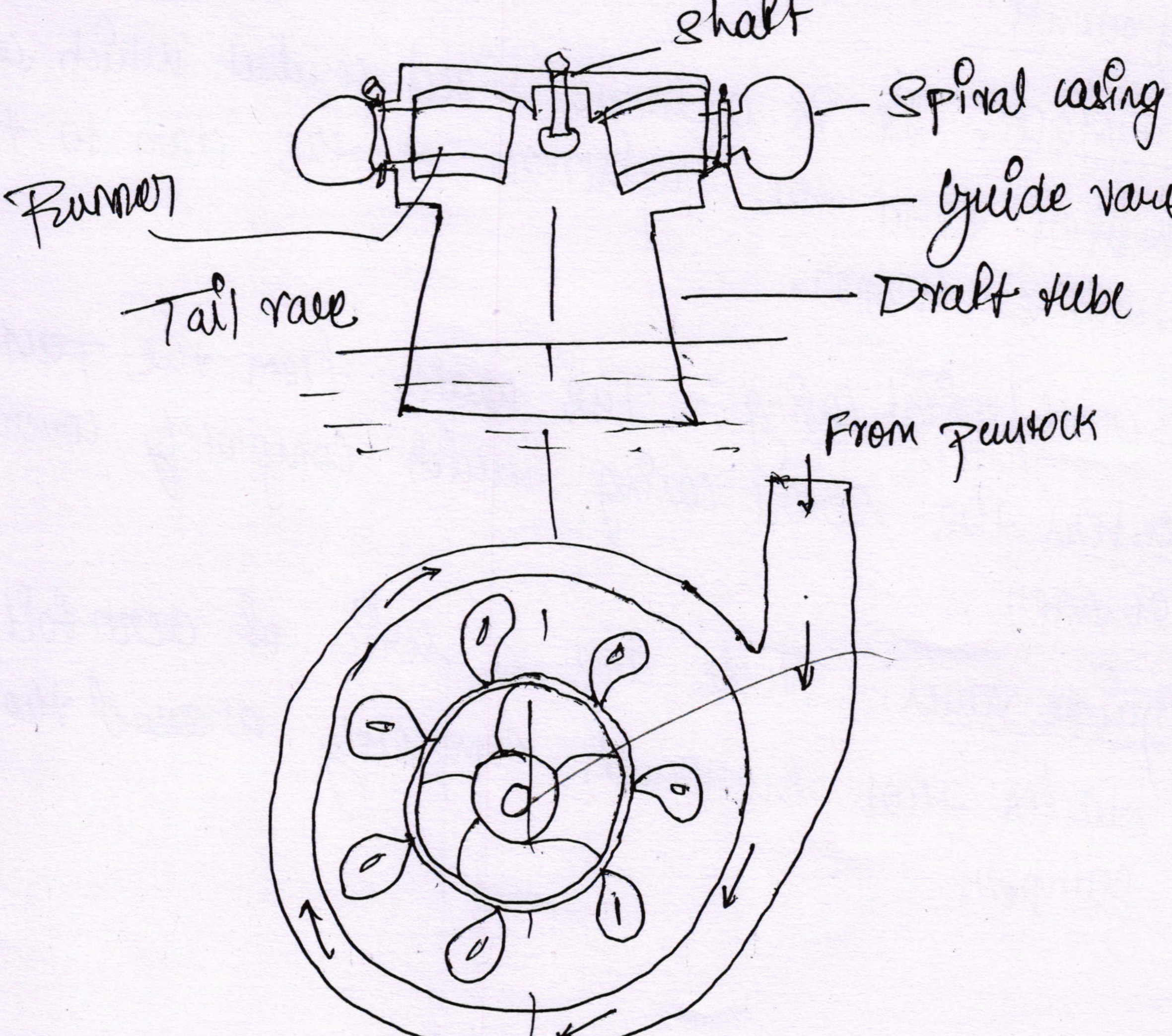
The static pressure rise is given by $(P_2-P_1) = \rho\, e_{static}$

$$(P_2-P_1) = \frac{\rho}{2}\left[V_{m_1}^2 + U_2^2 - V_{m_2}^2 \operatorname{cosec}^2\beta_2\right]$$

The static head rise is given by $h = \frac{P_2-P_1}{\rho g} = \frac{e_{static}}{g}$

$$\therefore \frac{P_2-P_1}{\rho g} = \frac{1}{2g}\left[V_{m_1}^2 + U_2^2 - V_{m_2}^2 \operatorname{cosec}^2\beta_2\right]$$

2)



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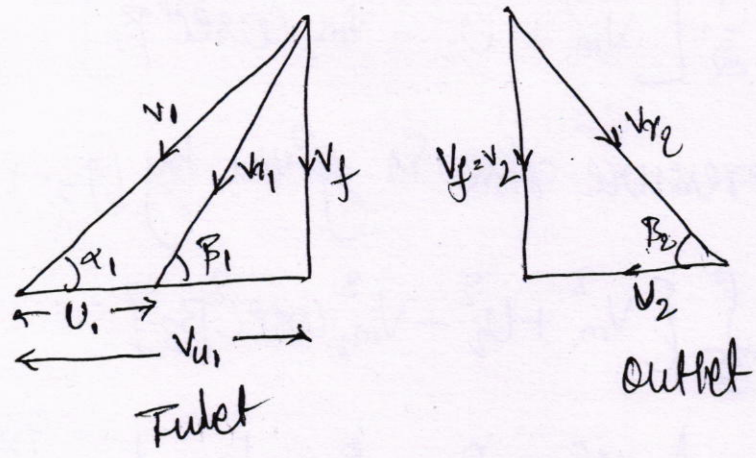

Francis turbine is an inward flow, medium head reaction turbine. Modern Francis turbines are mixed flow type, in which water enters the runner radially & leaves axially at the center.

Components

a. Penstock:- It is a large sized conduit which conveys water from the upstream of the dam to the turbine runner.

b. Scroll/spiral casing:- The water from the penstock ~~enters the scroll~~ casing which completely covers the runner.

c. Guide vanes:- These are a series of aero foil shaped blades that surrounds completely around the turbine runner.

→ Runner:- The main purpose of the other components is to lead the water to the runner with min loss of energy

⇒ Draft tube:- After passing through the runner, the water is discharged to the tail race through a generally expanding tube called the draft tube.

Given

$P = 24647 \text{ KW}$

$h = 39 m$

Speed ratio = 2

Flow ratio = 0.6

overall efficiency = 90%

dia of boss = 0.35 x dia of runner

$D_b = 0.35 d_0$

Now speed ratio = $\frac{U_1}{\sqrt{2gh}}$

$U_1 = 2 \times \sqrt{2 \times 9.81 \times 39}$

$U_1 = 55.32 \text{ m/s}$

flow ratio = $\frac{V_{f_1}}{\sqrt{2gh}}$

$V_{f_1} = 0.6 \times \sqrt{2 \times 9.81 \times 39}$

$V_{f_1} = 16.59 \text{ m/s}$

overall efficiency is given by

$$Q = \frac{P \times 1000}{\rho_w \times g \times H \times \eta_o}$$

$$Q = \frac{24647 \times 1000}{1000 \times 9.81 \times 39 \times 0.9}$$

$Q = 71.57 \text{ m}^3/\text{s}$

Discharge through kaplan turbine is

$$Q = \frac{\pi}{4}\left[D_0^2 - D_b^2\right] \times V_{f_1}$$

$$71.57 = \frac{\pi}{4}\left[D_0^2 - (0.35 D_0)^2\right] \times 16.59$$

$71.57 = 11.43 D_0^2$

$\therefore D_0 = 2.5 \text{m}$

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Speed of turbine, $V_1 = \frac{\pi D N}{60}$

$$N = \frac{60 \times 55.32}{\pi \times 32}$$

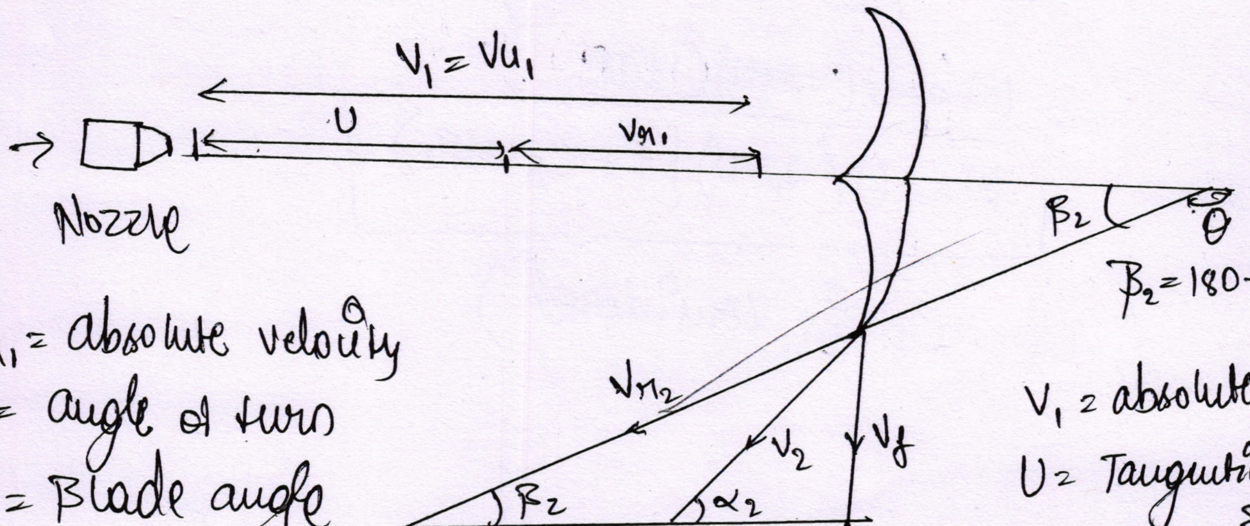
$$\boxed{N = 422.6 \text{ rpm}}$$

The specific speed is given by

$$N_s = \frac{N\sqrt{P}}{H^{5/4}}$$

$$= \frac{422.62 \times \sqrt{8246}}{(39)^{5/4}}$$

$$\boxed{N_s = 680.7 \text{ rpm}}$$



V_{u_1} = absolute velocity
θ = angle of turn
β_2 = Blade angle

V_1 = absolute velocity
U = Tangential blade speed
V_{r_1} = relative velocity

Let θ be the angle through which the jet gets deflected

then. $\beta_2 = 180^\circ - \theta$

from inlet velocity Δ^{le}, $\alpha_1 = 0$, $\beta_1 = 0$, $V_1 = V_{u_1}$ & $V_{r_1} = V_1 - U$

from outlet velocity Δ^{le}

$$V_{u_2} = V_{r_2} \cos\beta_2 - U$$

$$= V_{r_1} \cos\beta_2 - U \qquad \left[\because V_{r_1} = V_{r_2} \text{ No losses} \right)$$

$$V_{u_2} = (V_1 - U)\cos\beta_2 - U$$

work done per kg of water,

$$W = U\left[V_{u_1} + V_{u_2}\right]$$

$$W = U\left[V_{u_1} + \left[(V_1 - U)\cos\beta_2 - U\right]\right]$$

$$W = U\left[(V_1 - U) + (V_1 - U)\cos\beta_2\right]$$

$$W = U\left[V_1 - U\right]\left(1 + \cos\beta_2\right)$$

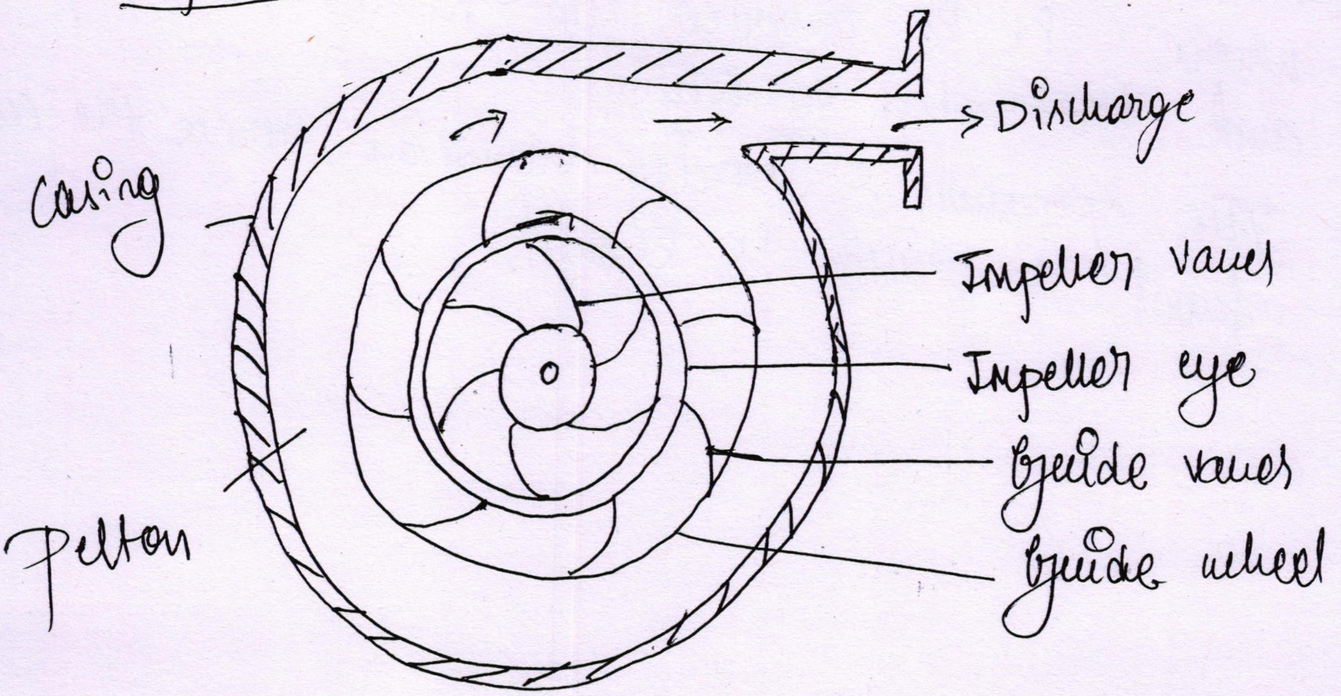
~~$\therefore W = U(V_1 - U)(1 + \cos$~~

$$\boxed{W = U(V_1 - U)\left[1 + C_b \cos\beta_2\right)}$$

($\because$ If C_b is considered)

2.

Compressor



→ compressor is consists of Impeller vanes, eye, Guide vanes, Guide wheel, casing.

→ The principal components are the impeller and the difference when the impeller is rotating at speed air is drawn through the eye of the impeller

→ The absolute velocity of the inflow air is axial.

→ The air flows radially through the impeller passages due to centrifugal force.

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→ The total mechanical energy driving the compressor is transmitted to the fluid system. In the impeller where it is converted into kinetic energy, pressure and heat due to friction.

→ The pressure & velocity variation across the centrifugal compressor is shown.

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