CMR INSTITUTE OF TECHNOLOGY

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Internal Assesment Test - II

Sub:	Turbo Machines							Code:	10ME56
Date:	04 / 11 / 2016	Duration:	90 mins	Max Marks:	50	Sem:	V	Branch:	Mechanical

Answer any **ONE full question from PART – A**
Answer all questions from **PART – B**

		Marks	OBE CO	OBE RBT
	PART - A			
1.(a)	Explain with a neat sketch how a steam turbine is compounded for pressure.	[07]	CO3	L4
(b)	A steam jet enters a row of blades with a velocity of 375m/s at an angle of 20° with the direction of motion of moving blades. If the blade speed is 165m/s, find the suitable inlet and outlet blade angles, assuming that there is no thrust on the blades. The relative velocity of steam passing over the blades is reduced by 15%. Also determine power developed per kg of steam flowing over the blades per second. F_A= 0, V_{f1}= V_{f2}.	[13]	CO4	L3, L4
2. (a)	With a neat sketch explain the working of Pelton wheel.	[07]	CO3	L4
(b)	The following data pertains to a vertical shaft inward flow reaction turbine. Net head = 24.5m, discharge through turbine = 10.5m^3/s, speed of turbine = 225rpm, inlet angle of runner vane = 115°, velocity of flow at inlet = 6.5m/s, velocity with which the water enters the draft tube without swirl = 6m/s, discharge velocity from exit of draft tube = 2.5m/s, the mean height of runner entry surface = 1.5m, the mean height of entrance to the draft tube = 1.2m, hydraulic efficiency = 90%. Determine :- i) Dia of runner at entry surface, ii) Pressure head at entry to the runner and entrance to draft tube. Frictional loss in runner is 0.9m and that of draft tube is 0.6m of water.	[13]	CO4	L3, L4
	PART - B			
3	Derive a condition for max blade efficiency for a Parson turbine (50% reaction turbine)	[10]	CO3	L4
4.	The blade speed of a single ring impulse blading is 250m/s and the nozzle angle is 20°. The heat drop is 550KJ/kg and nozzle efficiency is 0.85. The blade discharge angle is 30° and the machine develops 30kW when consuming 360kg of steam per hour. Draw the velocity diagram and calculate:- 1) Axial thrust on the blading, 2) The heat equivalent per kg of steam friction of the blade.	[12]	CO4	L3, L4
5.	With a neat sketch, explain the parts of a Kaplan Turbine	[08]	CO3	L4

Course Outcomes		PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1:	Define and classify turbo machines by contrasting the design and performance.	3	-	-	-	-	-	-	-	-	-	-	2
CO2:	Understand the fluid mechanics responsible for limits of turbo-machinery operability and stability, particularly stall, surge, cavitation and choke.	3	3	1	-	-	-	-	-	-	-	-	2
CO3:	Explain the operations of various turbo-machine applications such as compressors, turbines, and pumps with the aid of thermodynamic equations and velocity triangles.	3	3	1	-	-	-	-	-	-	-	-	-
CO4:	Apply the concept of velocity triangles to quantitatively evaluate the performance of turbo-machines using graphical and analytical methods	3	3	-	-	-	-	-	-	-	-	-	-

Cognitive level	KEYWORDS
L1	List, define, tell, describe, identify, show, label, collect, examine, tabulate, quote, name, who, when, where, etc.
L2	summarize, describe, interpret, contrast, predict, associate, distinguish, estimate, differentiate, discuss, extend
L3	Apply, demonstrate, calculate, complete, illustrate, show, solve, examine, modify, relate, change, classify, experiment, discover.
L4	Analyze, separate, order, explain, connect, classify, arrange, divide, compare, select, explain, infer.
L5	Assess, decide, rank, grade, test, measure, recommend, convince, select, judge, explain, discriminate, support, conclude, compare, summarize.

PO1 - *Engineering knowledge*; PO2 - *Problem analysis*; PO3 - *Design/development of solutions*; PO4 - *Conduct investigations of complex problems*; PO5 - *Modern tool usage*; PO6 - *The Engineer and society*; PO7- *Environment and sustainability*; PO8 – *Ethics*; PO9 - *Individual and team work*; PO10 - *Communication*; PO11 - *Project management and finance*; PO12 - *Life-long learning*

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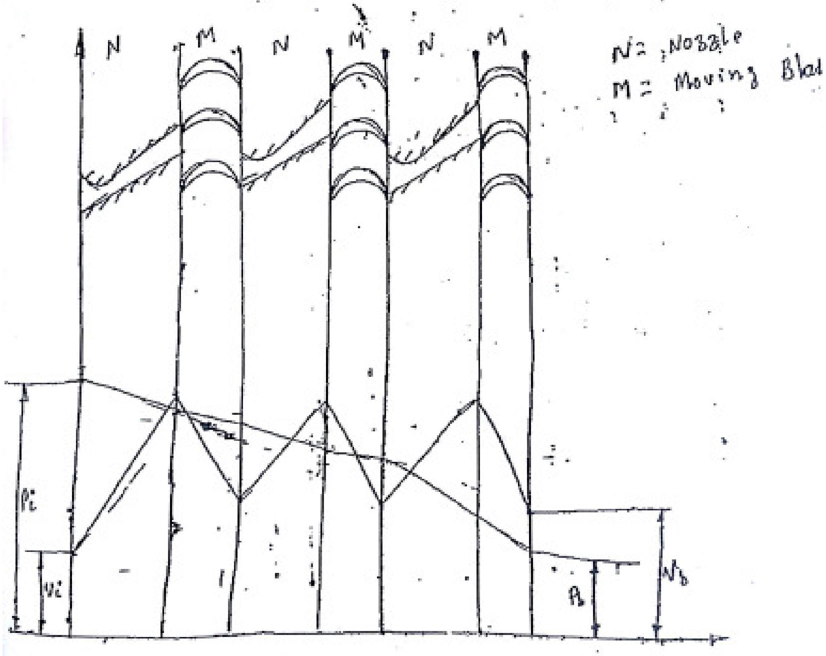
Internal Assessment Test 2 – Solution

Sub:	Turbo Machines							**Code:**	10ME56
Date:	04/04/2015	Duration:	90 mins	Max Marks:	50	**Sem:**	5	**Section:**	A/B

PART-A

1. A) Explain with a neat sketch how a steam turbine is compounded for pressure.

Pressure Compounding (Rateau stage).



The schematic diagram of pressure compounding is shown in figure.

The steam from the boiler is passed through the first nozzle where the velocity of steam increases and little pressure decreases. The steam is now directed on to the first moving blade ring where the pressure of steam slightly alters and velocity decreases. The steam from moving blade ring enters the second nozzle where the pressure further reduced. The process is repeated in the remaining rings until condenser pressure is reached.

This method is used in Rateau and Zoelly turbine.

1. B) A steam jet enters a row of blades with a velocity of 375m/s at an angle of 20° with the direction of motion of moving blades. If the blade speed is 165m/s,find the suitable inlet and outlet blade angles, assuming that there is no thrust onthe blades. The relative velocity of steam passing over the blades is reduced by 15%. Also determine power developed per kg of steam flowing over the blades per second. $F_A = 0$, $V_{f1} = V_{f2}$.

given

$V_1 = 375 m/s$

$\alpha_1 = 20°$ $\qquad \dot{m} = 1 kg/s$

$u = 165 m/s$

$F_A = 0 \Rightarrow V_{f1} = V_{f2}$

$\frac{V_{r2}}{V_{r1}} = 1 - 0.15 = 0.85$

To find:

β_1, β_2, P

$\beta_1 = 34°$

$V_{r1} = 4.6 cm$

$\Rightarrow V_{r2} = 0.85 \times 4.6 = 3.91 cm$

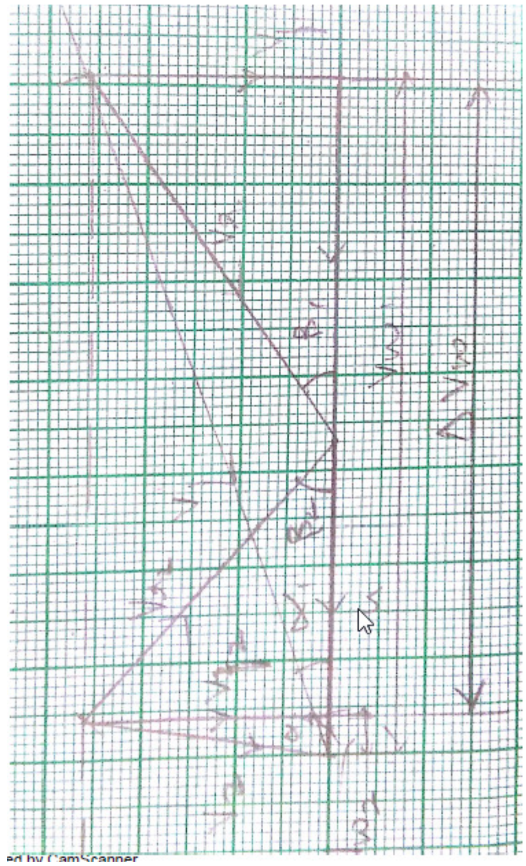
$\Delta V_w = 6.6 cm$

$= 6.6 \times 50 = 330 m/s$

$\beta_2 = 42°$

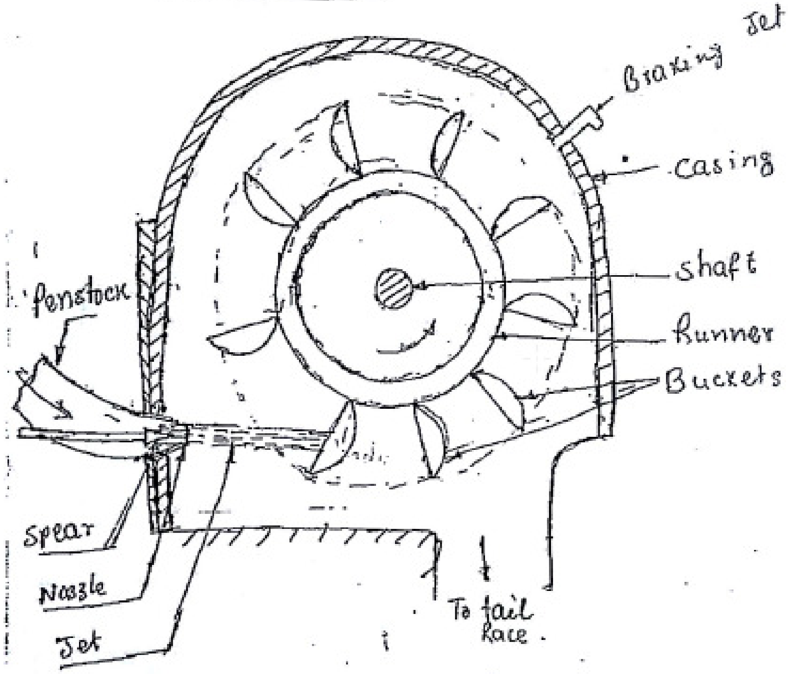
$P = \dot{m} u \Delta V_w$

$= 1 \times 165 \times 6.6 \times 50 = 54.45 kW$



2. A) With a neat sketch explain the working of Pelton wheel.

PELTON WHEEL



Pelton wheel (Lester. A. Pelton, an American engineer invented this turbine in 1880) is a high head, low discharge, low specific speed, tangential flow (water flows along the tangent to the path of rotation of the runner), impulse turbine.

The main components of Pelton wheel are (1) Nozzle (2) Runner and Buckets, (3) casing (4) Braking Jet.

(1). Nozzle : It is a tapered mouth piece fitted at the end of the penstock. It converts available energy of water into Kinetic energy. It also guides the high velocity water to flow in desired direction. The amount of water striking the turbine can be regulated by pushing the spear forward into the nozz. The spear is operated by hand or automatically.

(2) Runner and Buckets:

Runner is a circular disc on which number of buckets evenly spaced are fixed. The shape of the buckets is of a hemispherical cup or bowl. Each bucket is divided into symmetrical parts by a dividing wall called splitter. Buckets are made up cast iron, Bronze, or stainless steel.

Runner and buckets absorbs kinetic energy of the jet an converts it into mechanical energy

(3) Casing : The function of casing is to prevent the splashing of water and to discharge it to tail race. It also acts as a safe gaurd against accidents.

(4) Braking Jet : The main function of braking jet is to stop the runner in a short time.

When the nozzle is completely closed by moving the spear in the forward direction, the amount of water strikin the runner reduces to zero. But the runner due to inertia goes on revolving for a long time. When the brake nozzle provided on the casing is opened, the water present in the buckets is made to flow through it. Due to this, inertia of the runner is reduced and runner comes to rest in a short time.

2. B) The following data pertains to a vertical shaft inward flow reaction turbine. Net head = 24.5m, discharge through turbine = 10.5m^3/s, speed of turbine = 225rpm, inlet angle of runner vane = 115°, velocity of flow at inlet = 6.5m/s, velocity with which the water enters the draft tube without swirl = 6m/s, discharge velocity from exit of draft tube = 2.5m/s, the mean height of runner entry surface = 1.5m, the mean height of entrance to the draft tube = 1.2m, hydraulic efficiency = 90%. Determine :- i) Dia of runner at entry surface, ii) Pressure head at entry to the runner and entrance to draft tube. Frictional loss in runner is 0.9m and that of draft tube is 0.6m of water.

given

$H_{net} = 24.5 m$

$Q = 10.5 m^3/s$

$N = 225 rpm$

$\beta_1' = 115^\circ$

$\beta_1 = 180 - 115 = 65^\circ$

$V_{f_1} = 6.5 m/s$

$V_{w_1} = 0$

$V_2 = 6 m/s$

$V_3 = 2.5 m/s$

$h_{Lg} = 0.9 m$

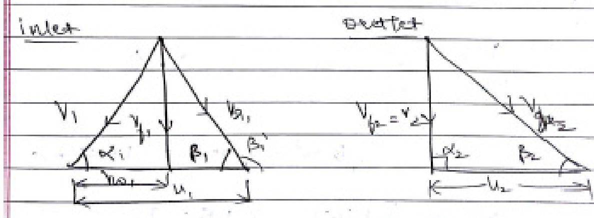
$d_{Ld} = 0.6 m$

$H_{runner} = 1.5 m$

$H_{draft\ tube} = 1.2 m$

$\eta_H = 90\% = 0.9$

TF: i) D, ii) pressure head to runner & entrance to draft tube



from inlet Δ^{le}

$$\tan\beta_1 = \frac{V_{f_1}}{u_1 - V_{w_1}}$$

$$u_1 - V_{w_1} = \frac{6.5}{\tan 65}$$

$$u_1 = V_{f_1} + 3.03 \quad \text{—①}$$

$$\eta_H = \frac{\dot{m} V_{w_1} u_1}{\rho g Q H}$$

$$0.9 = \frac{V_{w_1} u_1}{9.81 \times 24.5}$$

$$V_{w_1} u_1 = 216.31$$

$$\therefore V_{w_1} = \frac{216.31}{u_1}$$

$$\therefore u_1 = \frac{216.31}{u_1} + 3.03$$

$$u_1 = 16.3 m/s \Rightarrow V_{w_1} = 13.27 m/s$$

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

$$D_1 = \frac{60 \times 16.3}{\pi \times 225} = 1.38 m$$

Pressure at inlet to runner $[P_1/\rho g]$

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = H \quad \text{—②}$$

$$V_1 = \sqrt{6.5^2 + 13.27^2} = 14.78 m/s$$

$$24.5 - \frac{(14.78)^2}{2 \times 9.81} + 1.5 = \frac{P_1}{\rho g}$$

$$\frac{P_1}{\rho g} = 11.87 m \text{ of water}$$

ii) Pressure head at entry to draft tube $[P_2/\rho g]$

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + z_2 + W + Loss$$

$$H = \frac{P_2}{\rho g} + \frac{(6)^2}{2 \times 9.81} + 1.2 + \frac{216.31}{9.81} + 0.9$$

$$\frac{P_2}{\rho g} = -1.485 m \text{ of water}$$

PART- B

3. Derive a condition for max blade efficiency for a Parson turbine (50% reaction turbine)

Work done per kg of steam:

$$W = u[\Delta V_w] = u[V_{w_1} + V_{w_2}] \quad \text{--- (1)}$$

From Δle

$$V_{w_1} = V_1 \cos\alpha_1$$
$$V_{w_2} = V_2 \cos\alpha_2 \quad \text{--- (2)}$$

but $\frac{V_{w_2} + u}{V_{r_2}} = \cos\beta_2$

$$V_{r_2}\cos\beta_2 = V_{w_2} + u$$
$$V_{r_2}\cos\beta_2 - u = V_{w_2} \quad \text{--- (3)}$$

$$V_{r_2}\cos\beta_2 - u = V_2\cos\alpha_2$$
$$V_2\cos\alpha_2 = V_{r_2}\cos\beta_2 - u$$
$$V_2\cos\alpha_2 = V_1\cos\alpha_1 - u \quad \text{— from relation}$$

∴ (1)

$$W = u[V_1\cos\alpha_1 + V_1\cos\alpha_1 - u]$$
$$= u[2V_1\cos\alpha_1 - u]$$
$$= 2uV_1\cos\alpha_1 - u^2$$

using speed ratio $\phi = \frac{u}{V_1}$

$$W = V_1^2\left[\frac{2uV_1\cos\alpha_1}{V_1^2} - \left(\frac{u}{V_1}\right)^2\right]$$

$$\boxed{W = V_1^2\left[2\phi\cos\alpha_1 - \phi^2\right]}$$

Blade efficiency:

It is defined as the ratio of work done by turbine to energy supplied.

$$\therefore \eta_b = \frac{W}{\text{Energy Supplied}}$$

Energy supplied for a reaction turbine is:

The kinetic energy of the fluid i.e. $\frac{1}{2}[V_1^2]$

The pressure energy i.e. $\frac{1}{2}[V_{r_2}^2 - V_{r_1}^2]$

$$\text{Total energy supplied} = \frac{V_1^2}{2} + \frac{V_{r_2}^2}{2} - \frac{V_{r_1}^2}{2}$$

but $V_{r_2} = V_1$

$$\text{Total energy supplied} = \frac{V_1^2}{2} + \frac{V_1^2}{2} - \frac{V_{r_1}^2}{2}$$
$$= V_1^2 - \frac{V_{r_1}^2}{2}$$

applying cosine rule in the inlet vel. Δle:

$$V_{r_1}^2 = V_1^2 + u^2 - 2uV_1\cos\alpha_1$$
$$= V_1^2\left[1 + \left(\frac{u}{V_1}\right)^2 - 2\frac{u}{V_1}\cos\alpha_1\right]$$
$$V_{r_1}^2 = V_1^2\left[1 + \phi^2 - 2\phi\cos\alpha_1\right]$$

∴ Total energy supplied

$$= V_1^2 - \frac{V_1^2[1 + \phi^2 - 2\phi\cos\alpha_1]}{2}$$
$$= \frac{2V_1^2 - V_1^2[1 + \phi^2 - 2\phi\cos\alpha_1]}{2}$$
$$= \frac{V_1^2}{2}\left[2 - 1 - \phi^2 + 2\phi\cos\alpha_1\right]$$
$$= \frac{V_1^2}{2}\left[1 - \phi^2 + 2\phi\cos\alpha_1\right]$$

$$\eta_b = \frac{V_1^2[2\phi\cos\alpha_1 - \phi^2]}{\frac{V_1^2}{2}[1 - \phi^2 + 2\phi\cos\alpha_1]}$$

$$\eta_b = 2\left[\frac{2\phi\cos\alpha_1 - \phi^2}{1 - \phi^2 + 2\phi\cos\alpha_1}\right]$$

Adding & subtracting 1.

$$\eta_b = 2\frac{\left[(1 - \phi^2 + 2\phi\cos\alpha_1) - 1\right]}{\left[1 - \phi^2 + 2\phi\cos\alpha_1\right]}$$

$$\eta_b = 2 - \frac{2}{1 - \phi^2 + 2\phi\cos\alpha_1}$$

Condition for maximum blade efficiency

$$\frac{d\eta_b}{d\phi} = 0$$

$$\Rightarrow \frac{d}{d\phi}\left[1 - \phi^2 + 2\phi\cos\alpha_1\right] = 0$$

$$-2\phi + 2\cos\alpha_1 = 0$$

$$2\cos\alpha_1 = 2\phi$$

$$\boxed{\phi = \cos\alpha_1}$$

The above expression is the condition

4. The blade speed of a single ring impulse blading is 250m/s and the nozzle angle is 20°. The heat drop is 550KJ/kg and nozzle efficiency is 0.85. The blade discharge angle is 30° and the machine develops 30kW when consuming 360kg of steam per hour. Draw the velocity diagram and calculate:-
1) Axial thrust on the blading, 2) The heat equivalent per kg of steam friction of the blade.

given

$u = 250\ m/s$

$\alpha_1 = 20^\circ$

Heat drop = Isentropic enthalpy change $= 550\ kJ/kg = 550 \times 10^3\ J/kg$

$\eta_{nozzle} = 0.85$

$\beta_2 = 30^\circ$

$P = 30\ kW$

$\dot{m} = 360\ kg/hr = 360/3600 = 0.1\ kg/s$

TF: F_A, $W_L = \frac{1}{2}[V_{R1}^2 - V_{R2}^2]$

$\eta_{nozzle} = \frac{\text{Actual enthalpy change}}{\text{Isen. enthalpy "}} = \frac{\frac{1}{2}V_1^2}{\Delta h}$

$\therefore V_1 = \sqrt{0.85 \times 550 \times 10^3 \times 2} = 966.95\ m/s \approx 967\ m/s$

$P = \dot{m} u [V_{w1} - V_{w2}]$

$V_{w1} = 9cm = 900\ m/s$

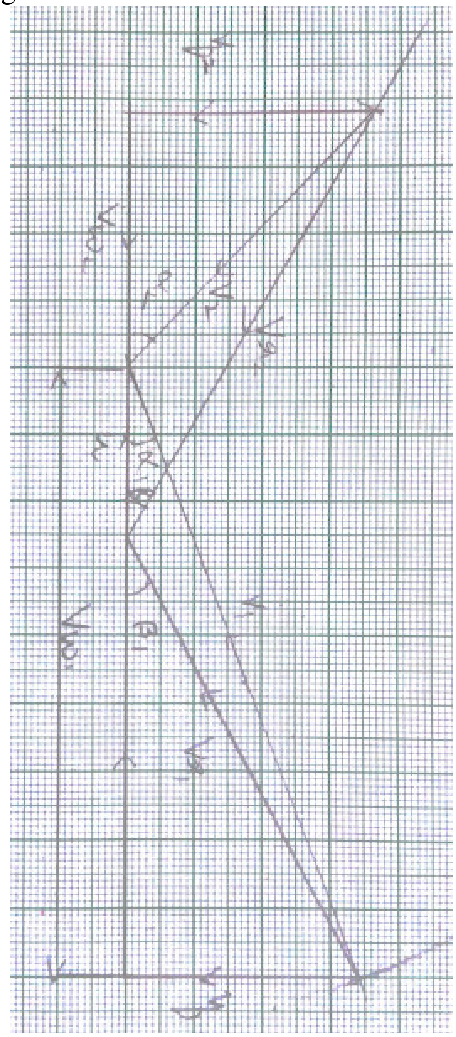
~~$\Rightarrow 30 \times 10^3 = 0.1 \times 250 [900 - V_{w2}]$~~

~~Assuming $V_{a1} = V_{a2}$ — as it is an impulse turbine~~

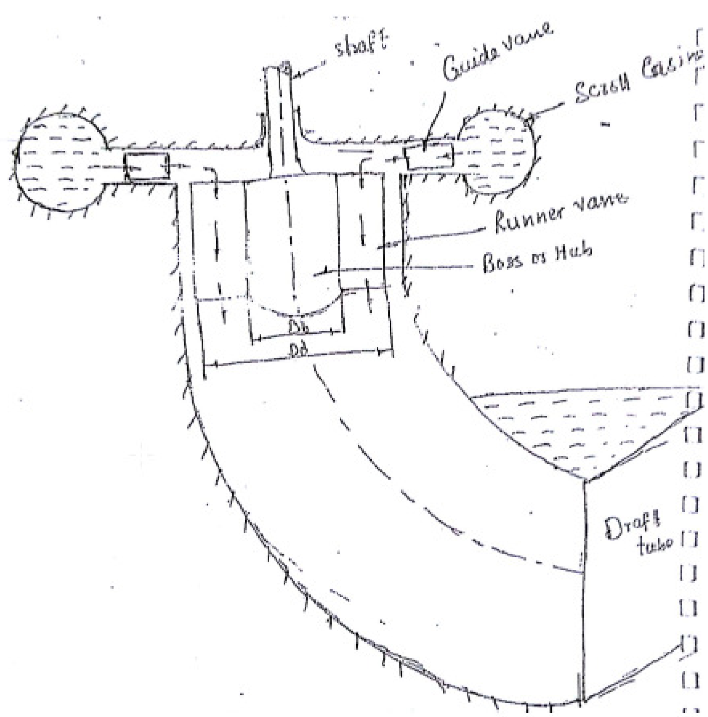
impulse turbine $V_{a2} = V_{a1}$

$W_L = 0$

$F_A = \dot{m}[V_{f1} - V_{f2}]$



5. With a neat sketch, explain the parts of a Kaplan Turbine



Kaplan turbine (V. Kaplan, Austrian engineer invented it) is an axial flow reaction turbine. (Axial flow is one in which the water flows parallel to the axis of rotation of the shaft). The head at the inlet of the turbine is the sum of pressure energy and kinetic energy.

Kaplan turbine consists a hub or boss. The vanes are fixed around the circumference of the hub. Hub acts as a runner. The remaining parts of Kaplan turbine are scroll casing, guide vanes, runner wheel and draft tube.

Water from head race enters the scroll casing and then moves to the guide vanes. From the guide vanes water turns through 90°. and flows axially through the runner.

Kaplan turbine is used for low head and large discharge of water.