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KATHMANDU UNIVERSITY  
End Semester Examination  
August/September, 2017

AUG 27 2017

Level : B. E.

Year : III

Course : MEEG 309

Semester : II

Exam Roll No. :

Time: 30 min

F. M. : 20

Registration No.:

Date :

SECTION "A"

[20 Q × 1 = 20 marks]

Tick the most appropriate answer. Formula sheet is not required in this section.

- A free water jet has a velocity of 15 m/s and an area of  $0.012 \text{ m}^2$ . This jet impinges normally on a vertical plate moving with a velocity of 5 m/s in the direction of the jet. The force on the plate due to this impingement of the jet, by considering the density of water  $1000 \text{ kg/m}^3$ , is  
 2700 N       1800 N       1200 N       120 N
- A free water jet acts upon a water wheel that has semicircular vanes fitted on its periphery. The theoretical maximum efficiency of this wheel system is  
 29 %       50 %       59 %       100 %
- A Pump and its (1/4) scale model are being compared. If the ratio of the heads is 5:1 then the ratio of the power consumed by the prototype and the model is  
 100       3.2       17       12.8
- The net available head in a Pelton turbine installation is the  
 head at the elevation of the nozzle  
 difference in elevation between the fore-bay water level and the nozzle outlet  
 difference in elevation between the fore-bay water level and the tail race water level  
 kinetic energy of the jet issuing from the nozzle
- The speed ratio of a Pelton wheel operating under a head of 900 m is 0.45. What is the peripheral velocity of the turbine while in m/s?  
 28       42       60       96
- A split bucket is used in Pelton wheel to  
 provide a spherical shape to the surface of spoon  
 minimize the axial thrust on the bearings supporting the wheel shaft  
 avoid the possibility of erosion from impurities present in the jet striking the buckets  
 prevent disturbance to incoming bucket from the deflected jet
- If 'n' is the number of jets in a Pelton turbine, then its specific speed is proportional to  
 n        $\sqrt{n}$         $n^2$        independent of n
- Consider the following energies associated with a Pelton turbine:  
1. Mechanical      2. Kinetic      3. Potential  
The correct sequence of energy conversion starting from entry fluid is  
 1-2-3       2-3-1       3-2-1       1-3-2

9. In a Francis turbine, maximum efficiency is obtained when  
 relative velocity is radial at the outlet       velocity of flow is constant  
 absolute velocity is radial at the outlet       guide vane angle is 90 degree
10. For a given conditions, Francis turbines have a wide range of speed. If the speed of the turbine made higher, then,  
 1. specific speed will increases  
 2. the size of the turbine will become smaller  
 3. smaller number of pair of poles are required  
 4. turbine and generator will be costly  
 Of these statement  
 1, 2 and 3 are correct       1 and 2 are correct  
 2, 3 and 4 are correct       1, 2, 3 and 4 are correct
11. Consider the following attributes in respect of Kaplan turbine:  
 1. Reaction turbine      2. Mixed flow turbine      3. Adjustable blades  
 Which of the attributes given above are correct?  
 1, 2 and 3       2 and 3       1 and 3       1 and 2
12. A Kaplan turbine has a runner of 5 m diameter. The diameter of the hub is 2 m. If the peripheral velocity and the swirl velocity at the inlet side of the blade tip are 40 m/s and 5 m/s respectively, the peripheral velocity and swirl velocities at the inlet side of the mid radius section are, respectively,  
 40 m/s and 7.1 m/s       57.1 m/s and 3.5 m/s  
 28 m/s and 5 m/s       28 m/s and 7.1 m/s
13. Which one of the following forms of draft tube will not improve the hydraulic efficiency of the turbine?  
 straight cylindrical       conical type  
 bell- mounted       bent tube
14. Main characteristic curves of a turbine means the curves drawn at constant  
 head       discharge       speed       efficiency
15. Cavitation in a hydraulic turbine may occur in all likelihood  
 in the spiral casing       in the guide passages  
 at the inlet to runner       at the inlet to draft tube
16. The flow in the volute casing outside the rotating impeller of a centrifugal pump is  
 radial flow       axial flow  
 free vortex flow       force vortex flow
17. Which one of the following is the correct statement? For a given centrifugal pump,  
 the discharge varies directly as the speed  
 the head varies inversely as the speed  
 the power varies as the square of the speed  
 the discharge varies as the square of the speed

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18. Which of the following are the functions of a volute casing in centrifugal pumps?
1. to collect water from the periphery of the impeller and to transmit it to the delivery pipe at a constant velocity
  2. to increase the discharge of the pump
  3. to increase the efficiency of the pump
  4. to reduce the loss of head in discharge

Select the correct answer from the codes given below:

1, 2 and 3                       2, 3 and 4                       1, 3 and 4                       1 and 2

19. A discharge of  $0.4 \text{ m}^3/\text{s}$  of water is needed to be pumped to a total head of 240 m. How many pumps connected in series and each having a specific speed of 35 and running at a speed of 1500 rpm would be needed for the job? The dynamic head in the system can be neglected.

3                                       4                                       5                                       6

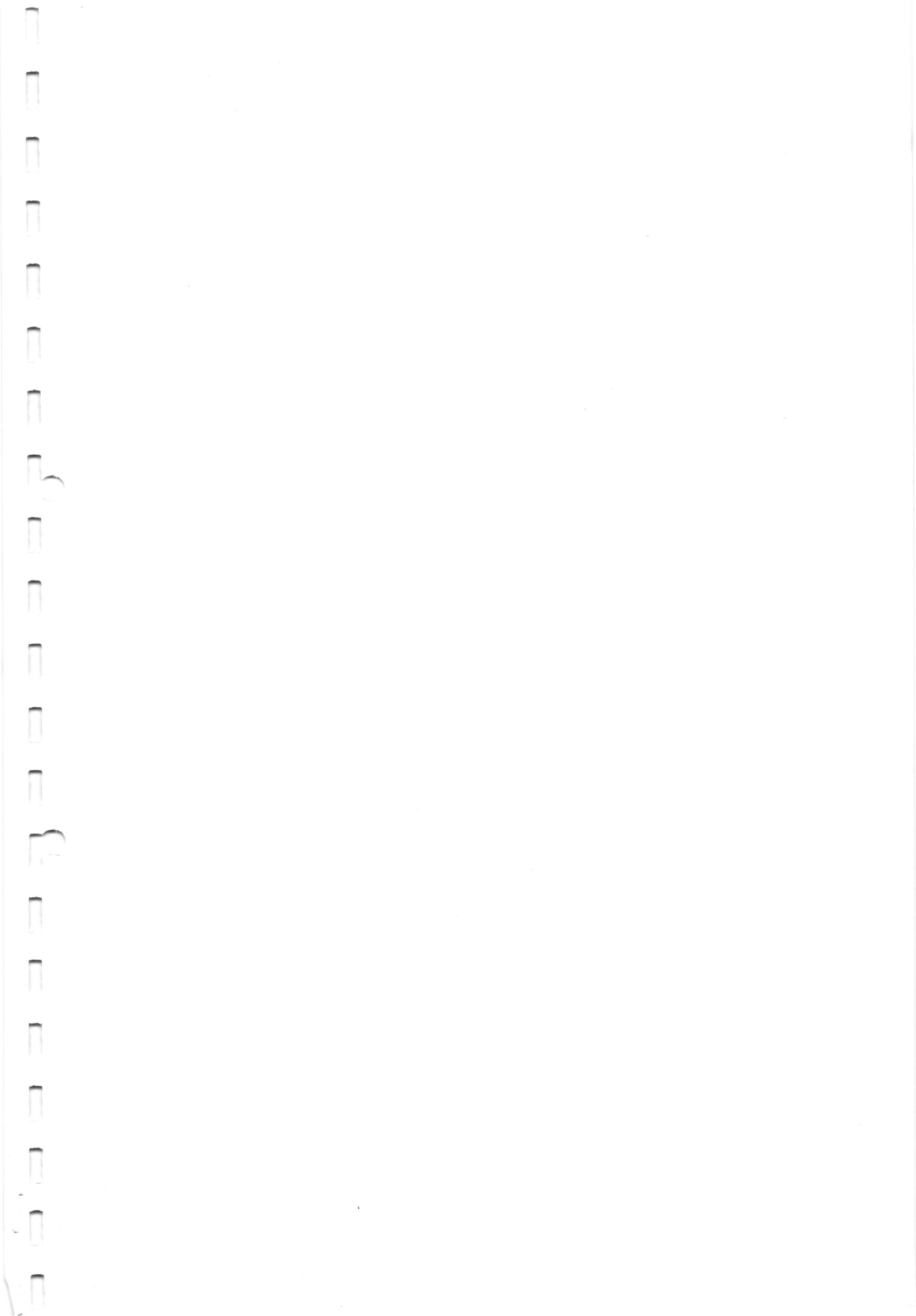
20. An impeller with backward curved vanes

is easier to fabricate

has a falling head discharge characteristic

cannot run at speeds other than design speed

has greater absolute velocity at outlet than that with forward curved vanes



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Semester : II  
F. M. : 55

SECTION "B"  
[5 Q. × 11 = 55 marks]

Attempt *ALL* the questions. Formula sheet is supplied in this exam along with the question. Assume suitable data if missing/necessary.

**Q. N. 1**

- Differentiate between force exerted by a fluid jet on a curved moving plate and a series of curved moving plates. [2]
- How are the velocity diagrams for the flow over the moving vanes drawn? What are velocity of whirl and velocity of flow and why are they so named? [4]
- A jet of water of 5 cm diameter impinges on a curved vane and is deflected through an angle of 175 deg. The vane moves in the same direction as that of the jet with a velocity of 35 m/s. If the water flow rate is 170 liters per second, determine the component of force on the vane in the direction of motion. How much would be the power developed by the vane and what would be the vane efficiency? Neglect friction. How these parameters would change if instead of one vane there is a series of vanes fixed to a wheel & moving in the direction of jet with vel. 35 m/s. [5]

**Q.N. 2**

- In the case of a Pelton wheel, two hemispherical cups are joined together and water is directed at the junction; what are the advantages of this arrangement? [2]
- Justify for the same type of turbine: "If speed number is less, the size of the runner is more". Derive that minimum speed number for Pelton turbine is 0.09. [3]
- A double overhung Pelton wheel unit is to operate at 30,000 kW generator under and effective head of 300 m at the base of the nozzle. Find the size of the jet, mean diameter of runner, synchronous speed and specific speed of each wheel. Assume generator efficiency 93 %, Pelton wheel efficiency 85 %, co-efficient of nozzle 0.97, speed ratio 0.46 and jet ratio 12. [6]

**Q.N.3**

- What are the important component parts of a Kaplan turbine and what are their functions? How the governing operation of Francis and Kaplan turbines are different. [3]
- What is meant by cavitation? How can it be avoided in reaction turbine? What is Thoma's cavitation factor, what is its significance for water turbines? [3]
- A Kaplan turbine develops 6 MW under and effective head of 5 m. Its speed ratio is 2 and flow ratio is 0.6 and the diameter of boss equals to 0.35 times the external diameter of the runner. Mechanical efficiency of the turbine is 90 %. Calculate the diameter of the runner speed of the runner and also its specific speed. [5]

**Q.N. 4**

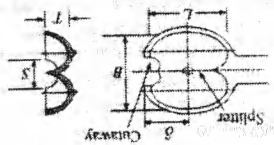
- a. Explain the purpose of stay vanes in reaction turbines. Why are spiral casings of varying area employed in Kaplan and Francis turbines? [2]
- b. Draw neat sketches of a Francis turbine installation and a Francis runner and label the following: shroud ring, crown of the runner, blade, wicket gate, scroll casing and draft tube. [3]
- c. A Francis turbine supplied through a 6 m diameter penstock has the following particulars:  
Output of installation = 63500 kW  
Flow = 117 m<sup>3</sup>/s  
Speed = 150 rpm  
 $\eta_h = 92\%$   
Mean diameter of turbine at entry = 4 m  
Mean blade height at entry = 1 m  
Entry diameter of draft tube = 4.2 m  
Velocity in tail race = 2.4 m/s  
The static pressure head in the penstock measured just before entry to the runner is 57.4 m. The point of measurement is 3 m above the level of tail race. The loss in the draft tube is equivalent to 30 % of the velocity head at entry to it. The exit plane of the runner is 2 m above the tail race and the flow leaves the runner without swirl. Determine: (a) Overall efficiency, (b) Direction of flow relative to runner at inlet, (c) Pressure head at entry to the draft tube. [6]

**Q.N. 5**

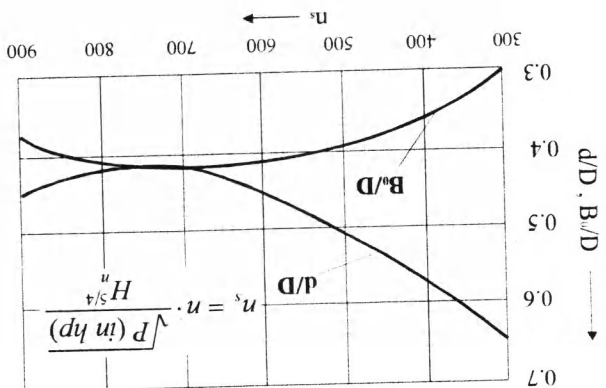
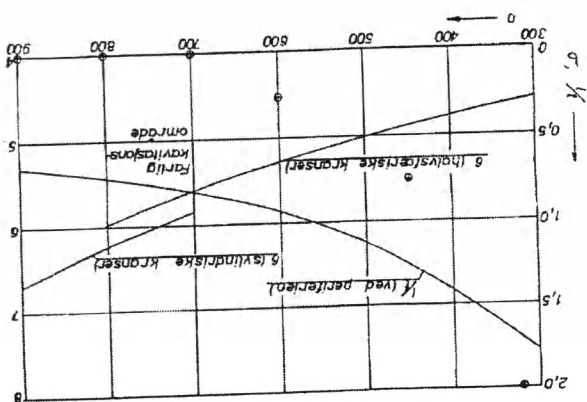
- a. Discuss in general the main and operating characteristics of a hydraulic turbine. Which of the Pelton, Francis and Propeller turbines gives better off-design performance and why? [3]
- b. What is the influence of exit blade angle on the head capacity relationship of a centrifugal pump? Assume radial flow at entrance. [3]
- c. A centrifugal pump working in a dock pump 1565 l/s against a mean lift of 6.1 m when the impeller rotates at 200 rpm. The impeller diameter is 1.22 m and the area at outer periphery is 6450 cm<sup>2</sup>. If the vanes are set back at an angle of 26° at the outlet, determine: (a) hydraulic efficiency, (b) power required to drive the pump, and (c) minimum speed to start pumping if the ratio of external to internal diameter is 2. [5]

$\eta = \frac{u_1 \cdot v_{u1} - u_2 \cdot v_{u2}}{g \cdot H_n}$	$13^\circ < \beta_2 < 22^\circ$ (lowest value for highest head) $35 < U_2 < 43 \text{ m/s}$ (highest value for highest head)	$H_m = h_s + h_d + h_{fs} + h_{fd} + \frac{v_d^2}{2}$
$h_f = f \cdot \frac{L}{D} \cdot \frac{v^2}{2 \cdot g}$	$v_{m2} = 1.1 \cdot v_{m1}$ $H_m = \left[ \frac{p_o}{\rho \cdot g} + \frac{v_o^2}{2 \cdot g} + z_o \right] - \left[ \frac{p_i}{\rho \cdot g} + \frac{v_i^2}{2 \cdot g} + z_i \right]$	$n_q = n \cdot \frac{\sqrt{Q}}{H^{3/4}}$ $n_{s,turbine} = 2.97 \cdot n_{q,pump}$
$N_s = \frac{N \cdot \sqrt{p}}{H^{5/4}}$ (P in kW) Pelton, 1 jet: 12 - 30 Pelton, 2 jet: 17 - 50 Pelton, 4 jet: 24 - 70 High head Francis: 80 - 150 Medium head Francis: 150 - 250 Low head Francis: 250 - 400 Propeller/ Kaplan: 300 - 1000 Bulb or Tubular: 1000 - 2000	$H_s = 10 - NPSH_R$ $NPSH_R = a \cdot \frac{v_{m2}^2}{2 \cdot g} + b \cdot \frac{u_2^2}{2 \cdot g}$ <i>Turbines</i> <i>Pumps</i> $a$ 1.05 < $a$ < 1.15    1.6 < $a$ < 2.0 $b$ 0.05 < $b$ < 0.15    0.2 < $b$ < 0.25 $d_s = \sqrt{\frac{4 \cdot Q}{z \cdot \pi \cdot v_1}}$	Affinity Law 1: $\frac{Q_1}{Q_2} = \frac{n_1}{n_2}$ $\frac{H_1}{H_2} = \left( \frac{u_1}{u_2} \right)^2 = \left( \frac{n_1}{n_2} \right)^2$ $\frac{P_1}{P_2} = \left( \frac{n_1}{n_2} \right)^3$
$n_q = n \cdot \frac{\sqrt{Q}}{H^{0.75}}$	$\underline{Q}_n = \frac{\pi \cdot (D^2 - d^2)}{4} \cdot c_{1m}$ $D = \sqrt{\frac{\underline{Q}_n \cdot 4}{\pi \cdot c_{1m}}} \quad n = \frac{3000}{z_p}$ $\sigma = \frac{10 - H_s}{H}$	Affinity Law 2: $\frac{Q_1}{Q_2} = \left( \frac{D_1}{D_2} \right)^3$ $\frac{H_1}{H_2} = \left( \frac{D_1}{D_2} \right)^2$ $\frac{P_1}{P_2} = \left( \frac{D_1}{D_2} \right)^5$
$\Omega = \omega \cdot \sqrt{Q}$ $\Omega \leq 0.22$ (Pelton) $0.2 < \Omega < 1.25$ (Francis) $\Omega > 1.0$ (Kaplan/Bulb)	$H_e = \frac{u_2 \cdot v_{u2}}{g} = \frac{u_2}{g} [u_2 - v_{f2} \cdot \cot \beta_2]$	$P = \rho \cdot Q \cdot g \cdot H_i$
$v_1 = C_d \cdot \sqrt{2 \cdot g \cdot H_n}$ $[C_d = 0.97 \text{ to } 0.98]$	$c_{1m} = 0.12 + 0.18 \cdot \Omega$	$H_i = \frac{u_2 \cdot v_{u2} - u_1 \cdot v_{u1}}{g}$
$\phi = \frac{u}{v} = 0.45 - 0.48$ Pelton $\phi = \frac{u}{v} = 0.62 - 0.82$ Francis	$\frac{P_2}{\gamma} = \frac{P_a}{\gamma} - h_s - \left( \frac{v_2^2 - v_3^2}{2g} - h_f \right)$	$H_i = \frac{u_2^2 - u_1^2}{2 \cdot g} + \frac{v_2^2 - v_1^2}{2 \cdot g} - \frac{w_2^2 - w_1^2}{2 \cdot g}$
$\frac{1 - \eta_M}{1 - \eta_p} = \left( \frac{D_p}{D_M} \right)^{1/5}$ $\frac{0.94 - \eta_w}{0.94 - \eta_p} = \left( \frac{Q_w}{Q_p} \right)^{0.32}$	$\eta_d = \frac{\frac{v_2^2 - v_3^2}{2g} - h_f}{\frac{v_2^2}{2g}}$	$\eta_{man} = \frac{g \cdot H_m}{v_{u2} \cdot u_2}$
$3.1 > \frac{B}{d_s} \geq 3.4$ $D = 10 \cdot d_s$ , for $H_n \leq 500 \text{ m}$ $D = 15 \cdot d_s$ , for $H_n = 1300 \text{ m}$	$n_{min} = \frac{120 \cdot \eta_{man} \cdot v_{u2} \cdot D_2}{\pi (D_2^2 - D_1^2)}$ $D_{Housing} = D + K \cdot B$	$\varphi = \frac{v_{m2}}{\sqrt{2 \cdot g \cdot H_m}} [0.1 - 0.25]$
$Pr. \text{ rise} = \frac{P_2 - P_1}{\rho g} = \frac{1}{2g} [v_1^2 - v_2^2 + 2v_{u2} \cdot u_2]$	head or lift co-efficient: $\frac{\sqrt{H}}{D \cdot n}$	power co-efficient: $\frac{P}{D^5 \cdot n^3}$
$I = \frac{p}{\rho \cdot g} + \frac{w^2}{2 \cdot g} - \frac{(\omega \cdot r)^2}{2 \cdot g} = const$	flow co-efficient: $\frac{Q}{D^3 \cdot n}$	

Radial length = $L$	Radial width of bucket = $B$	Depth of bucket of cutaway = $F$	Radial width of cutaway = $S$	Radial length of bucket = $F_1$	Inlet bucket angle = $\beta_1$	Outlet bucket angle = $\beta_2$
3.0	2.0 to 3.0	5.0	1.2	0.8 to 1.2	5° to 8°	165° to 170°
2.0 to 3.0	1.1 to 1.2	0.18 to 0.20	$S/D$	$T/D$	$\beta_1$	$\beta_2$



Basic geometrical dimensions of the Pelton bucket



$\sigma \geq \sigma_c$  Or  $NPSH \geq \sigma_c H \Rightarrow$  no cavitation

$$NPSH_{min} = \sigma_c H$$

$$(\sigma_c)^{Kaplan} = 1.03 \cdot 10^{-3} \cdot n_s^3$$

$$(\sigma_c)^{Kaplan} = 0.28 + \left( \frac{1}{7.5} \left( \frac{380.78}{n_s} \right)^3 \right)$$

$$(\sigma_c)^{Francis} = 0.625 \cdot \left( \frac{380.78}{n_s} \right)^2 \approx 431 \cdot 10^{-8} \cdot n_s^2$$