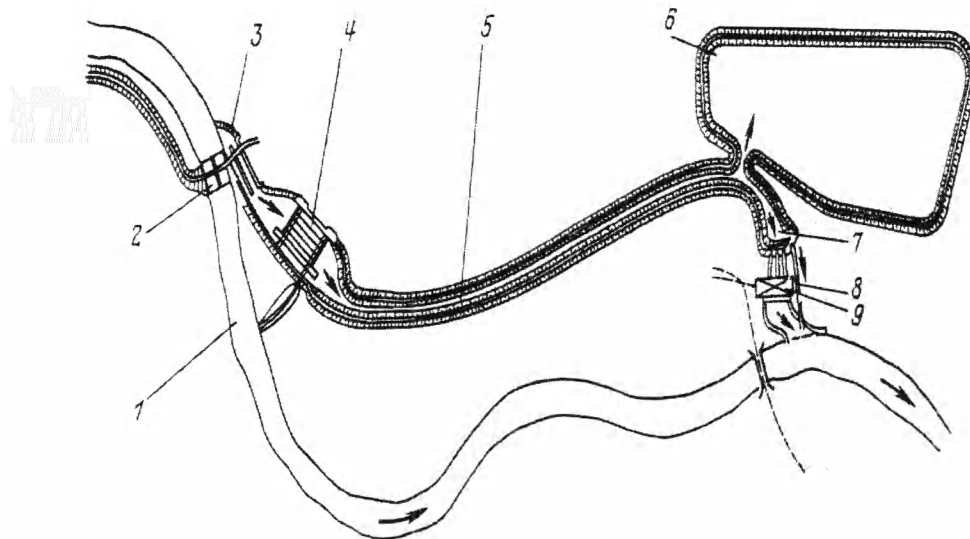


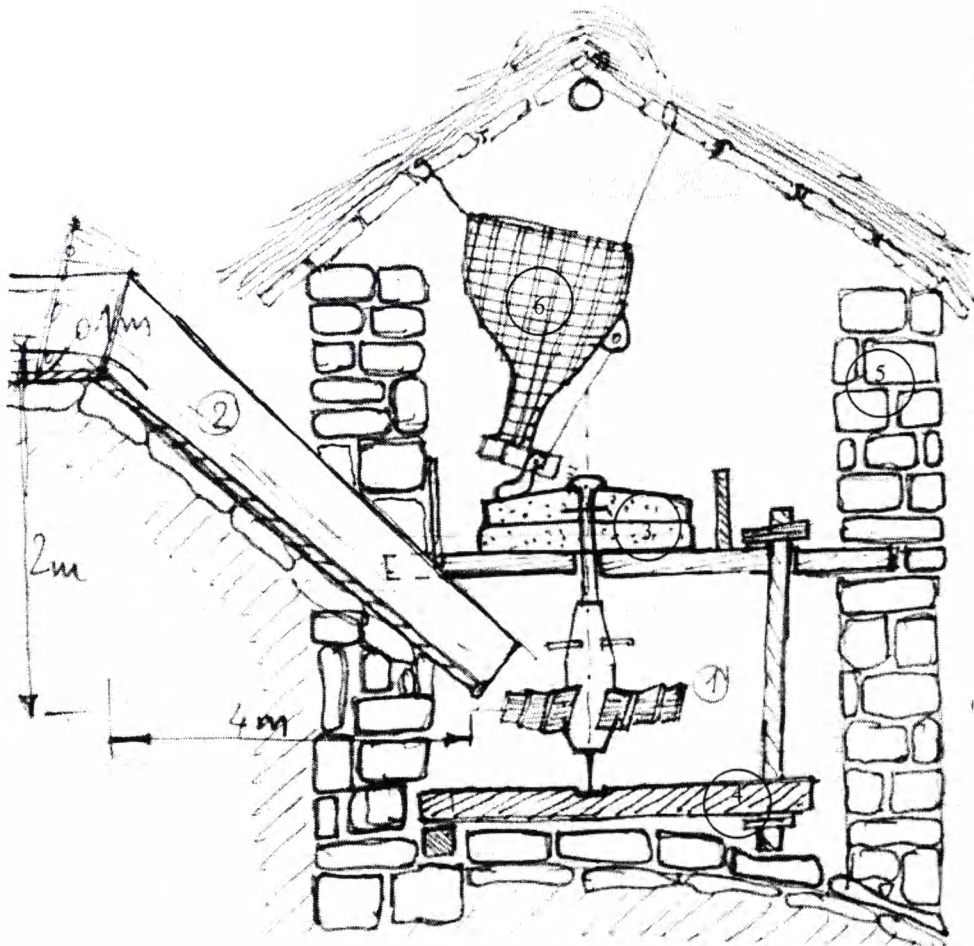


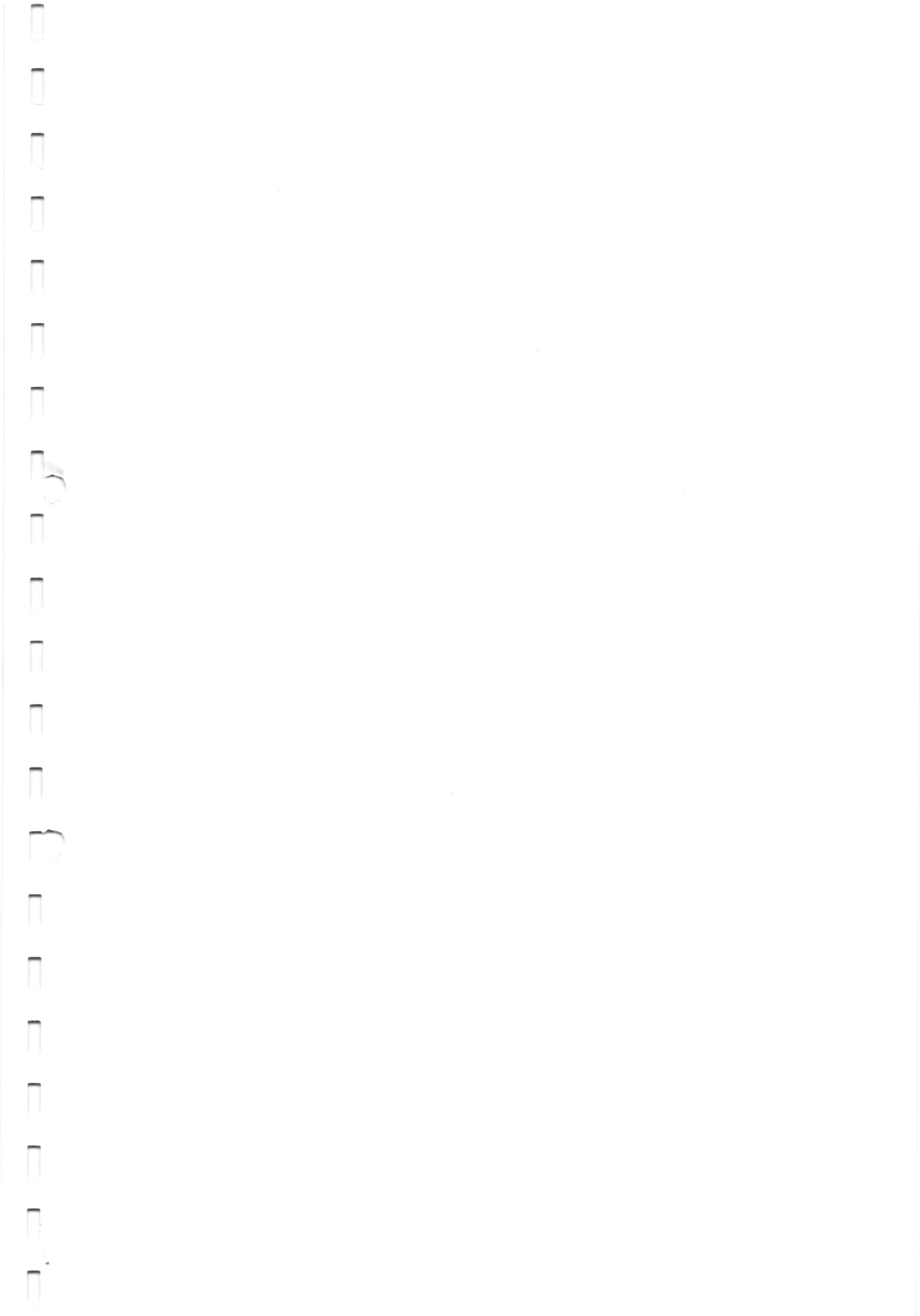
10. In the development of hydropower it is expedient to have the technology transfer. Which Act addresses this issue?
- |   |   |
|---|---|
| <input type="checkbox"/> Water Resources Act 1992 | <input type="checkbox"/> Foreign investment and technology transfer Act |
| <input type="checkbox"/> Electricity Act          | <input type="checkbox"/> Environmental Protection Act                   |
11. Which of the following is not considered as a loss in reservoir
- |   |  |
|---|--|
| <input type="checkbox"/> Evaporation Loss   | <input type="checkbox"/> Reservoir Leakage |
| <input type="checkbox"/> Sedimentation Loss | <input type="checkbox"/> Absorption Loss   |
12. The objectives of hydropower development policy are
- |   |   |
|---|---|
| <input type="checkbox"/> To minimize the potential risks in the Hydropower projects | <input type="checkbox"/> Basin wide planning.                           |
| <input type="checkbox"/> To tie-up electricity with renewable source                | <input type="checkbox"/> To tie-up electricity with economic activities |
13. Which of the following is not component of electricity tariff
- |  |  |
|--|--|
| <input type="checkbox"/> Transportation charges, related to management | <input type="checkbox"/> Connection and metering charge                      |
| <input type="checkbox"/> Management, Operation and maintenance charges | <input type="checkbox"/> Capacity (kW) charge, related to system peak demand |
14. Describe Tick the incorrect statement
- |  |   |
|--|---|
| <input type="checkbox"/> Both EIA and IEE are approved by Connected Body   | <input type="checkbox"/> EIA is compulsory if Hydropower having installed capacity of 30 MW is within national park |
| <input type="checkbox"/> IEE is approved by concerned ministry and EIA is sent to Ministry of Environment science and technology by concerned body | <input type="checkbox"/> Monitoring is done after 2 years of implementation of the project                          |
15. What type of power plant scheme is this Sketch (name in blank box)? Name all the components of it in the sequence.
- |                          |     |
|--------------------------|-----|
| <input type="checkbox"/> | [1] |
| [2]                      | [3] |
| [4]                      | [5] |
| [6]                      | [7] |
| [8]                      | [9] |



16. In a reservoir type of a project of installed capacity of 250 MW with the dam height =180 m. and overall efficiency is 87%, and reservoir volume of 3500 million cubic meter for its regulation period. Find the time taken for its regulation period if the regulated flow discharge is used for power generation.
- |   |   |
|---|---|
| <input type="checkbox"/> T= 248.93 days | <input type="checkbox"/> T= 280.34 days |
| <input type="checkbox"/> T= 148.93 days | <input type="checkbox"/> T= 116.08 days |
17. If we need to achieve the well-being of the society from a development works then
- |   |  |
|---|--|
| <input type="checkbox"/> Only tangible aspects must be considered   | <input type="checkbox"/> Tangible and intangible aspects must be given due consideration |
| <input type="checkbox"/> Only intangible aspects must be considered | <input type="checkbox"/> Only dollar evaluation may be adequate                          |

18. Indicate numerically the proper sequence to following activities and indicate which activities belong to Political Representation, Planning and Engineering showing the flow process between them:
- |                          |                           |                          |                                       |
|--------------------------|---------------------------|--------------------------|---------------------------------------|
| <input type="checkbox"/> | Social Needs              | <input type="checkbox"/> | Basic Data and its Analysis           |
| <input type="checkbox"/> | Engineering Objectives    | <input type="checkbox"/> | Technical, Social and Economic Review |
| <input type="checkbox"/> | Social Objectives         | <input type="checkbox"/> | Alternative Plans                     |
| <input type="checkbox"/> | Final Design              | <input type="checkbox"/> | Construction Management               |
| <input type="checkbox"/> | Operation and Maintenance | <input type="checkbox"/> | Selection of Plan                     |
| <input type="checkbox"/> | Political Representation  | <input type="checkbox"/> | Planning                              |
| <input type="checkbox"/> | Engineering Design        | <input type="checkbox"/> | Technical, Social and Economic Review |
19. Looking at the sequence of longitudinal profile of a river, the river may be zoned as upper course, middle course, lower course and estuary. Show qualitatively, where will be the equilibrium state of sediment transport occur?
- |                          |   |                          |                                     |
|--------------------------|---|--------------------------|-------------------------------------|
| <input type="checkbox"/> | In between middle course and lower course | <input type="checkbox"/> | In between lower course and estuary |
| <input type="checkbox"/> | In between upper course and middle course | <input type="checkbox"/> | In middle course                    |
20. What type of power plant is this (fill in blank box)? Name all the components of it in the sequence. Find the power in kW generated if it process 60 l/s from a fall of 2.0 m. It has got an efficiency of 50%.
- |                          |       |
|--------------------------|-------|
| <input type="checkbox"/> | [ P ] |
| [1]                      | [2]   |
| [3]                      | [4]   |
| [5]                      | [6]   |





KATHMANDU UNIVERSITY  
End Semester Examination  
March/April, 2017

MAR 30 2017

Level : B. E.  
Year : IV  
Time : 2 hrs. 30 mins.

Course : CIEG 406  
Semester : I  
F. M. : 40

SECTION "B"

[Short questions answer]

**Attempt ONLY THREE. Question no. 1 and 5 are compulsory. [14]**

1. Write Essay on the following statements: [6]
  - a. The Ministry of Energy of present government enforced NEA to cut the load shading completely in the Kathmandu Valley and has announced to do so in entire nation. How do you think it is possible to do so in lieu of insufficiency in power generation in foreseeable future? Substantiate your arguments with valid reasoning. [2]
  - b. In retrospect of speedy hydropower development, provide your analytical review on the Ministry of Energy's statement on "Nepal ko Pani-Janta ko Lagani (literally: Nepal's Water-People's Investment)" will move a power supply security to overcome the present and future energy crisis in Nepal. [2]
  - c. Describing your candid opinion on Nepal's Hydro-Vision 2026 "10 GW in 10 years", recommend necessary short-term, medium-term and long-term measures to follow (300-500 words) [2]
2. Answer the following questions in short: [4]
  - a. What are the requirements to plan and design of an intake structure? Write four major principles of the arrangement of an intake structure on the river. [2]
  - b. Describe the necessary steps and formula for hydraulic design of an outflow from side weir with sketch. Differentiate between a diversion weir and a retaining weir showing the sketches. [2]
3. Write short notes on.(*ANY FOUR*) [4]
  - a. Foreign investment tax rules. Importance of foreign direct investment and role of government in the sector of hydropower development.
  - b. Roles of water users association in an irrigation project.
  - c. Advantage and disadvantage of Rehabilitation, Upgradation and Modernization (RUM) of existing hydropower plants.
  - d. Boot rules for Construction of Hydropower
  - e. Hydropower Development Policy, 1992, 2001
  - f. The major factors that must be considered for while studying any hydropower projects, give your remarks based on the Environment protection act and regulations.
  - g. hydropower development in Nepal and World
  - h. pumped-stored hydropower plant
  - i. Renewable energy technology
  - j. Depression Power Plant
4. Enumerate and define the doctrines of International Laws on Water Course. [4]
5. Describe briefly the Issues and Principles guided to formulate the Water Resources Strategy of Nepal. What is the national goal and enumerate the ten outputs of Water Resources Strategy. With reference to special aspects of these outputs describe briefly how they will contribute to this goal through the achievement of short-, medium- and long-term purposes. [1+1+2=4]

SECTION "C"

[Long questions answer]

**Attempt ONLY THREE. Question no. 6 and 9 are compulsory. Assume necessary data appropriately. [26]**

6. Determine the electricity need of a Chepang village in Rakshirang of Makawanpur, Nepal for 30 households that has to be fulfilled by a multipurpose micro/mini-hydropower plant, which will be sited at nearby rivulet-fountain situated at a level 750 m amsl and about 1.5 km away North-West from the village. The Chepang community, which is 15 km North-East along the Manahari river from Narayanghat-Hetauda highway at Manahari bridge, is willing to have

their quality of life bettered through the utilization of its water and other natural resources through social-entrepreneurship. The daily requirement for various activities are as follows:

- [10]**
- a) Drinking, washing and cooking water need @ 50 liter/day/HH with pumping from 20 m depth to a storage water tank above ground height of 5 m. Take a head loss of 2 m and 50% of pump efficiency. Give a sketch. Pumping is required for 2 hrs in the morning and 2 hrs in the evening. [1]
  - b) Water for 150 cattle @40 liter/day/cattle with pumping from 20 m depth to a storage water tank above ground height of 5 m. Take a head loss of 2 m and 50% of pump efficiency. Give a sketch. Pumping is required for 4 hrs in the morning and 2 hrs in the evening. [1]
  - c) Irrigation for 20 ha @50 m<sup>3</sup>/ha with gravity flow from the powerhouse through an earthen channel. Select the canal type and design its size. A community fish-pond is also planned, which gets the water from draining the irrigation water as well as after power production. Irrigation is required for 5 hrs a day. Find out whether a storage for water at the intake is necessary or not. Ensure also that enough is available for gravity flow to irrigation and fish-ponds located at 700 m amsl and 695 m amsl respectively Explain the scheme with good sketch. [2]
  - d) Each household uses electricity for lighting of 4 no of 10 Watt Compact Fluorescent lamps (CFL) for 3 hrs in the evening after 18:00 and an oven of 1kW for cooking twice for 1 hr daily. [1]
  - e) Villagers are also planning to have a saw mill of 20 kW, a rice-flour and oil mill of 10 kW and an aqua-agriculture products processing unit of 10 kW to be operated each for 4 hrs per day during off peak hours. [1]
  - f) Put all these demand in a tabular format and calculate the total power need with respect to time of day. Plot the load curve and calculate energy analytically and graphically. [2]
  - g) If a nearby rivulet has a mean monthly average discharge of 400 liter/s then find out the gross vertical distance from intake to powerhouse (Gross-Head) needed to satisfy the total power (Installed capacity) and energy demand calculated above of the village. Assume turbine efficiency of 80%, generator efficiency of 95%, transformer efficiency of 97%, transmission and distribution efficiency of 90% and hydraulic efficiency of water ways of 95%. Select an appropriate type of turbine if the system frequency has to be maintained at 50 Hz and a synchronous generator with 2 pair-poles has to be synchronized. Find the capacity of generator if the altitude factor and power factor are 0.95 and 0.80 respectively. [1+1+1=3]
7. After observing the intake site in the Chepang village with a vertical drop, it was decided that a Coanda type bottom intake structure has to be constructed across the river to protect the natural beauty of the fountain for tourism as well as get rid of frequent debris cleaning. Check the hydraulics of the intake for a turbine discharge of 400 l/s. To allocate for evapo-transpiration and percolation in the collecting canal, the design discharge has to be increased by 10%. Check the discharge through the intake using Table 1 for the following input with neat sketch and dimensions: [8]

Given	Symbol	Value	Unit	Remarks
Turbine Discharge	$Q_t$	0.4	m <sup>3</sup> /s	
Clear spacing of trashrack bar	$a$	6	mm	6-15 mm
Thickness of bar	$t$	20	mm	Up to 50 mm wide flat bar
Angle of inclination with horizontal	$\beta$	6	degree	
Intake Trashrack Length	$L$	6	m	
Weir Coefficient	$C_w$	2.2	-	For round over fall
Contraction Coefficient	$\mu$	0.63	-	For square bar
Width of intake chamber opening	$b$	0.50	m	
Intake chamber slope	$S_i$	0.005	-	
Intake Canal Depth	$D_i$	1.00	m	
Manning's coefficient	$n$	0.015	-	

Table 1: Calculation table (use this table and attached to your answer sheet)

Find:	Sketch	Formula	Answer	Unit	Marks
1. Neat Sketch of intake					2
2. Design Discharge for intake $Q_d$		10% of $Q_t$			0.5
3. Initial water depth at u/s of intake					0.5
4. Area of flow u/s of intake					0.5
5. Velocity of water at u/s of intake					0.5
6. Velocity head at intake					0.5
7. $\chi$ Function of trashrack opening For $\beta=6^\circ$				-	0.5
8. Total head including velocity head					0.5
9. Design head					0.5
10. Centre to centre distance between bars					0.5
11. Correction factor for submergence					0.5
12. Discharge through intake					0.5
13. Additional discharge					0.5
14. Your concluding remarks					

8. Water is delivered from the upper impounding reservoir through a low-pressure tunnel and a high-pressure penstocks to the three turbine-generator units using a trifurcation in a high-head hydropower plant. The tunnel and penstock is separated by a simple surge chamber of 6 m diameter to cope with the transient in waterways. Due to ecological reason, only 50 % of maximum reservoir storage of  $25 \times 10^6 \text{ m}^3$  can be utilized continuously for 6 hours during the peak-demand time period. The volume of lower reservoir, which is an artificial lake, is only  $0.5 \times 10^6 \text{ m}^3$  to store incoming discharge from its rivers. Use Table 2 for calculation in the answer sheet The following data for the so-called peaking run-of-the-river hydropower plant are available: [8]

Given	Symbol	Value	Unit	
Elevation of the Impounding Reservoir water level	HWL	1500	m amsl	
Elevation of the downstream reservoir water level		900	m amsl	
Total volume of Impounding Reservoir (IR)	$V_{IR}$	$15 \times 10^6$	$\text{m}^3$	
Period of daily peaking	$T_{TM}$	6	hrs	
Length of low-pressure tunnel	$L_T$	3.5	km	
Diameter of low-pressure tunnel	$D_T$	3	m	
Friction factor of low-pressure tunnel	$f_T$	0.025	-	
Number of High pressure Penstock	$n$	1	Nos.	
Length of Penstock	$L_P$	500	m	
Diameter of steel Penstock	$D_P$	1.5	m	
Friction factor of Penstock material	$F_P$	0.016	-	
Turbine efficiency	$\eta_{TM}$	95	%	
Efficiency of Generator (Generator with 16 poles, 50 Hz)	$\eta_{GTM}$	98	%	
Barometric pressure	BP	10.3	m of WC	
Thoma's Cavitation coefficient	$\sigma_{TH}$	$0.043^*$ $(n_s/100)^{0.2}$	-	
<b>Table 2 Calculation Table: Determine:</b>				<b>Marks</b>
(a) Draw a neat profile of the project components and show all necessary descriptions with dimensions				[2]
(b) Determine the maximum power output from the installation for 6 hrs	P		MW	[0.5]
(c) Estimate the specific speeds and specify the type of turbine. Give the fundamental difference between these two specific speeds.	$n_s$		rpm	[0.5]
	$n_q$			
(d) Determine the safe turbine setting level relative to the downstream reservoir water level.	$H_s$		m amsl	[0.5]
(e) Determine the position of centerline of runner for vertical turbine setting.	$H_T$		m amsl	[0.5]

(f) Estimate:				
<ul style="list-style-type: none"> <li>The maximum upsurge and down surge in the surge chamber for a sudden rejection of one unit; and</li> </ul>	$Z_{max, US}$		m	[0.5 +
	$Z_{max, DS}$		amsl	0.5]
<ul style="list-style-type: none"> <li>The maximum down surge for sudden acceptance of demand on one unit. And the time of oscillation</li> </ul>	$Z_{max, DS}$		m	[0.5+
	T		s	0.5]
(g) Determine the power and energy from the powerhouse throughout a year of operation with 60% of Load Factor.	P		MW	[0.5+
	E		MWh	0.5]
(h) If the same project is planned to be modified to pump-storage type, then determine the extra volume of the lower reservoir that is needed to store the water during turbine mode. Give your final remarks on what needs to be done if the reservoir volume is not enough.	$V_{ELR}$		$m^3$	[0.5+ 0.5]

9. The Jure landslides in Sindhupalchok created a natural reservoir on Sunkoshi river at Ramche. To transform this devastation into a flourishing business (Bhaigayo Prakritik Hani-Banau Yasalai Aba Sampada ko Khani) and to support the affected families, a multipurpose reservoir type project is proposed for irrigation, water-supply, water navigation, recreation and power production. To maintain the ecological regime of the river downstream, an environmental flow shall also be released through a fish ladder, which equals 15% of mean annual river flow. Ten percent of produced electricity will be used for pumping water for irrigation and 5% - for water-supply through canal. The canal is located at a level of 960 m amsl from the reservoir water level at 950 m amsl. The rest of electricity will feed the grid. [8]

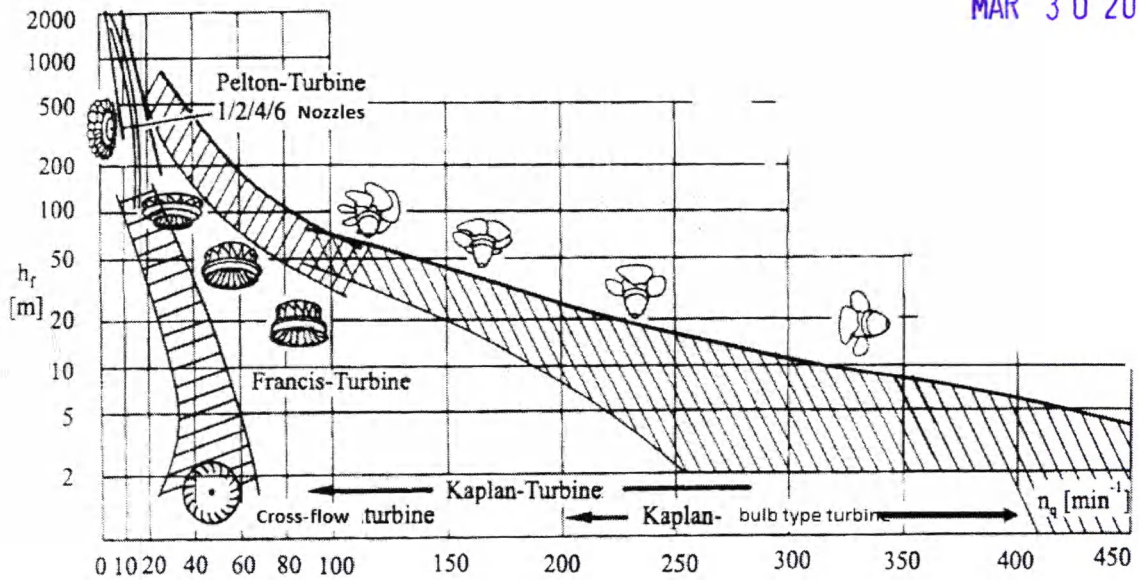
- What should be the installed capacity of power plant, irrigation pump, water-supply pump and the power to grid in kW? Take total efficiency of hydropower = 85%, efficiency of pump = 75%. Mean annual flow of river = 60  $m^3/s$ . The power plant is located at the top of 40 m high dam at 900 m amsl. All losses shall be ignored. Provide a neat sketch of the components of the multipurpose scheme. [3]
- How much of discharge for power plant, irrigation, water-supply and fish-ladder shall be released out of total river discharge? [2]
- If all the remaining power could be delivered to NEA grid each month throughout the year at the average rate of 7 Nrs/kWh at the rate of 85% Plant Factor, how much of money could the affected families get with a share of 20% every year? [3]

10. The base and peak power demand of an ideal Integrated Power System (IPS) is being covered optimally by a number of run-of-river hydropower plants and a number of diesel power plants with the annual operating cost respectively as given below. The maximum and minimum power demand of the IPS during the year is 1100 MW and 550 MW respectively. Assume reserve capacity of peak power plant as 20%. The cost equations of these stations are as follows: [8]

- $C_{therm} = \{1000/kW \times kW + 0.06/kWh \times kWh\}$  NRs.
- $C_{hydro} = \{2000/kW \times kW + 0.02/kWh \times kWh\}$  NRs.

If the load varies as a straight line, find the following:



- Duration of operation for peak load plant [1]
- Peak and base load on demand curve [1]
- Installed capacity of each station [1]
- The annual load factor, capacity factor and utilization factor of each stations [1]
- The average cost of production per kWh for the entire system [1]
- Minimum cost of generation [1]
- Neat sketch [2]



**Fig. 1 Head vs specific speed curve for the preliminary determination of turbine type**

**Table 3: Formulae List: Hydropower (assume appropriately if any missing data found)**

$S = \frac{1}{k_1} \left( \frac{t+a}{a} \right) \frac{Q}{v_0 \sin \alpha} \frac{1}{v_0 \sin \alpha}$ $h_r = k_s \left( \frac{t}{a} \right)^{\frac{4}{3}} \frac{v^2}{2g} \sin \alpha$ $h_i = k \frac{v^2}{2g}$	$Q = AC \sqrt{2g(NWL - TWL)}$ $Q = \frac{2}{3} c \mu b L \sqrt{2gh}$ $C = 0.6 \frac{a}{d} \cos^{\frac{3}{2}} \beta$ $h = \frac{2}{3} h_E \chi$
$P_{\max/\min} = \frac{\sum V}{B} \left[ 1 \pm \frac{6e}{B} \right]$ $\bar{x} = \frac{\sum M}{\sum V}, e = \bar{x} - \frac{B}{2}$ $F_{\text{sliding}} = \frac{cB + \sum V \tan \phi}{\sum H}$	$Q = Av$ $v = \frac{1}{n} R^{2/3} S^{1/2} \quad f_s = 1.76d^{1/2}$ $A = By + zy^2$ $P = B + 2y\sqrt{1+z^2}$ $R = \frac{A}{P} \quad P = 4.75Q^{1/2}$
$v_{\text{fall}} = \sqrt{0.33(s-1)gd}$ $v_{\text{permissible}} = a\sqrt{d}$ $a = 36; d > 1mm$ $a = 44; 0.1 \leq d \leq 1mm$ $a = 51; d < 0.1mm$ $f = \text{safety factor} = 1.2 \text{ to } 1.5$ $u_* = \sqrt{gRS_e}$ $S_e = \left( \frac{Q}{nAR^{2/3}} \right)^{1/2}$ $\sigma_c = 0.625 \left( \frac{n_s}{380.78} \right)^2 \text{ for Francis Turbine}$ $\text{Setting of turbine } H_s = (H_a - H_v) - \sigma_s H_n$	$n_q = n_{syn} \frac{\sqrt{Q}}{h_f^{0.75}} [\text{min}^{-1}]$ $n_{syn} = \frac{60 * f}{P} [\text{min}^{-1}]$ $n_s = \frac{2400}{\sqrt{H}} \text{ rpm for Francis Turbine}$ $D = \frac{84.6 \phi H}{n_{syn}} \text{ m}$ <div style="border: 1px solid black; padding: 5px; width: fit-content; margin: 5px auto;"> <math display="block">\phi = 0.0197 n_s^{2/3} + 0.025</math> </div> $n_s = \frac{n_{syn} \sqrt{P [kW]}}{H_n^{5/4}}$
$\text{submergence head } S = 1.5 \frac{v^2}{2g}$ <p>vortex free criteria</p> $\frac{S}{v\sqrt{d}} > 0.5$	$\lambda = 0.005 [1 + ((2000ks)/D + 10^6/Re)^{1/3}]$ $\frac{1}{\sqrt{\lambda}} = -2 \log \left( \frac{k_s}{3.7D} + \frac{5.1286}{Re^{0.89}} \right)$
$T_s = \frac{QL}{gH} \quad h_{\text{dyn}} = (a*v)T_R / (g*T_s)$	$\text{Generator rating} = 1.3 * \frac{\text{Turbine rating (kW)}}{A * B * C * D} [\text{kVA}]$

$t = \frac{\rho R}{\sigma_{st} \eta_j - 0.6 p} + 0.15 (cm)$ $v_{opt} = 0.125 \sqrt{2gH}$ $D = 0.52 H^{-0.17} (P/H)^{0.43}$ $\sigma_{st} = 1200 \text{ kg/cm}^2$	$A_{surge\ shaji} = \frac{v_0^2 A_i L_i}{2 g h_f (H g - h_f)}$ $h_f = \frac{f l v^2}{2 g D}$																																
$C_p = \sqrt{\frac{\frac{\kappa}{2}}{1 + \frac{\kappa}{r \cdot E}}} \text{ m/s}$ $t = \frac{P_c D}{2 \sigma} \text{ mm}$ $h_f = \frac{f L v^2}{2 g D} \text{ m}$ $T_c = 2 \times (L/Vc)$	$D_c = 0.62 \times \frac{P^{0.55}}{H^{0.55}} [m]$ $V_{cco} = 0.125 \sqrt{2gH} [m/s]$ $Z_{max} = v_0 \text{ Sqrt}(L_T A_T / (g A_{ST})) [m]$ $P_o = h_f / Z_{max} [-]$ $h_p = C_p * v_p / g [-]$ $Z_{max, US \text{ for sudden rejection}} = Z_{max} (1 - 2/3 P_o + 1/9 * P_o^2) [m]$ $Z_{max, DS \text{ for sudden rejection}} = Z_{max} (-1 + 2 P_o) [m]$ $Z_{max, DS \text{ for sudden acceptance}} = Z_{max} (-1 - 0.125 P_o) [m]$ $T = 2 \pi * \text{Sqrt}(L_T A_{ST} / (g A_T)) [s]$																																
$Q = Av$ $v = \frac{1}{n} R^{2/3} S^{1/2}$ $A = By + z y^2$ $P = B + 2y \sqrt{1 + z^2}$ $R = \frac{A}{P}$	$s = \frac{1}{k_1} \frac{t + a Q_i}{a v_o \sin \alpha}$ <p><math>K_1</math>-coefficient related to the partial clogging of the screen</p> <ul style="list-style-type: none"> <li>For no automatic raker = 0.20 to 0.30</li> <li>For automatic raker with hourly operation = 0.4 to 0.6</li> <li>For automatic raker with differential pressure sensor = 0.8 to 0.85</li> </ul>																																
$h_f = k \left( \frac{t}{a} \right)^3 \frac{v^2}{2g} \sin \alpha$ <p>Where; <math>h_f</math>- loss of head through racks, m  <math>t</math>- thickness of rack bars, mm  <math>a</math>- clear distance (spacing) between bars, mm  <math>v</math>- velocity of flow through the trashrack, m/s  <math>\alpha</math>- angle of bar inclination to the horizontal  <math>k</math>- factor depending on bar shape</p> <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;">  <p><math>k=2.42</math></p> </div> <div style="text-align: center;">  <p><math>k=1.83</math></p> </div> </div>	$h_a = \xi \frac{v_n^2}{2g}$ <p><math>v_n</math>- normal velocity through orifice  <math>\xi = \xi_s + \xi_a</math></p> <table border="1" style="width: 100%; border-collapse: collapse; text-align: center;"> <thead> <tr> <th>Shape</th> <th><math>\xi_s</math></th> <th>Cone angle</th> <th><math>\xi_a</math></th> </tr> </thead> <tbody> <tr> <td>Bell mouth</td> <td>0.03 to 0.05</td> <td>30°</td> <td>0.002</td> </tr> <tr> <td>Slightly rounded</td> <td>0.12 to 0.25</td> <td>45°</td> <td>0.04</td> </tr> <tr> <td>Sharp cornered</td> <td>0.5</td> <td>60°</td> <td>0.07</td> </tr> </tbody> </table>	Shape	$\xi_s$	Cone angle	$\xi_a$	Bell mouth	0.03 to 0.05	30°	0.002	Slightly rounded	0.12 to 0.25	45°	0.04	Sharp cornered	0.5	60°	0.07																
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Sharp cornered	0.5	60°	0.07																														
$Q_A = \frac{2}{3} c_d b L \sqrt{2gh}$ <p><math>c</math>- correction factor for submerged over-fall</p> $c = 0.5 \frac{a}{d} \cos^{1.5} \beta$ <p>Where <math>a</math>- internal width between bars  <math>d</math>- centre to centre distance between bars</p>	$h = \frac{2}{3} \chi h_z$ <table border="1" style="width: 100%; border-collapse: collapse; text-align: center;"> <thead> <tr> <th><math>\beta</math></th> <th><math>\chi</math></th> <th><math>\beta</math></th> <th><math>\chi</math></th> </tr> </thead> <tbody> <tr><td>0°</td><td>1.00</td><td>14°</td><td>0.899</td></tr> <tr><td>2°</td><td>0.980</td><td>16°</td><td>0.865</td></tr> <tr><td>4°</td><td>0.961</td><td>18°</td><td>0.851</td></tr> <tr><td>6°</td><td>0.944</td><td>20°</td><td>0.837</td></tr> <tr><td>8°</td><td>0.927</td><td>22°</td><td>0.825</td></tr> <tr><td>10°</td><td>0.910</td><td>24°</td><td>0.812</td></tr> <tr><td>12°</td><td>0.894</td><td>26°</td><td>0.800</td></tr> </tbody> </table>	$\beta$	$\chi$	$\beta$	$\chi$	0°	1.00	14°	0.899	2°	0.980	16°	0.865	4°	0.961	18°	0.851	6°	0.944	20°	0.837	8°	0.927	22°	0.825	10°	0.910	24°	0.812	12°	0.894	26°	0.800
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$v_{fall} = \sqrt{0.33(s-1)gd}$ $v_{permissible} = a \sqrt{d}$ <p><math>a = 36; d &gt; 1mm</math>  <math>a = 44; 0.1 \leq d \leq 1mm</math>  <math>a = 51; d &lt; 0.1mm</math></p>	$\text{submergence head } h_{sub} = 1.5 \frac{v^2}{2g}$ <p>vortex free criteria</p> $\frac{h_{sub}}{v \sqrt{d}} > 0.5$																																
$h = \frac{b_p - b_b}{c_b - c_p} \text{ [hour]}$ <p>Where <math>h</math>- duration of peak plant operation  <math>b_p</math>- cost of power for peak plant  <math>b_b</math>- cost of power for base plant  <math>c_p</math>- cost of energy for peak plant  <math>c_b</math>- cost of energy for base plant</p>	<p>Stored Energy in a reservoir</p> $E_{St} = 1 / (3.6 * 10^6) * g * \rho_w * V * h_s \text{ [kWh]}$ <p>Where, <math>h_s</math> is head over tailrace up to the centre of gravity of the reservoir</p>																																
<p>submergence head <math>S = 1.5 \frac{v^2}{2g}</math></p> <p>vortex free criteria</p> $\frac{S}{v \sqrt{d}} > 0.5$	$Q_{spillway} = \frac{2}{3} C_d \sqrt{2g} \cdot b \cdot H^{3/2}$																																