KIBABII UNIVERSITY

2020/2021 ACADEMIC YEAR

FOURTH YEAR FIRST SEMESTER

SPECIAL/SUPPLEMENTARY EXAMINATIONS

FOR THE DEGREE OF BACHELOR OF SCIENCE IN RENEWABLE ENERGY AND BIOFUELS TECHNOLOGY

COURSE CODE: IET 411

COURSE TITLE: Hydropower and Tidal Energy

DATE: 13/1/2022 **TIME:8-10PM**

INSTRUCTIONS TO CANDIDATES

Answer question ONE and any other two questions

This paper consists of 6 printed pages. Please Turn over

Question One

(a) The table below is a SWOT analysis of hydropower plants

Table 1.1: SWOT analysis for hydropower

Strengths	*Weaknesses*	*Opportunities*	*Threats*
• Cheapest renewable energy option • Water remains available for other purposes after use • Continuous availability of power on demand • Concentrated energy source given a reasonable head • Predictable quantity of available energy • Requires no fuel and only limited maintenance for low running costs (compared with diesel power) • Long-lasting and robust, systems can last 50+ years without major new investments • Simple enough to be transferred to and used in remote rural areas	• Mostly site-specific • Reliable site data must be collected to guarantee output • Lengthy planning and permit procedures • Seasonal variations affect performance • Dams and rivers collect water for electricity production, which alters the natural water flow system and thus deprives other needs. • Potential for serious disputes caused by changes to the river pathway and water shortages	• Large demand and supply gap • Major opportunities in hydroelectric consultancy in Nigeria and abroad • New sources of power generation • Opportunity to go global through tie-ups	• Rising cost of production • Competition from other new and environmentally friendly sources of power • Local opposition to environmental impacts and displacement of people

(i) Select any ONE item from each column and explain it **[6 Marks]**

(ii) Climate change is an additional risk to the future of hydro power. Explain this **[2 Marks]**

(iii) With the help of a sketch, describe the hydrologic (water) cycle **[5 Marks]**

(iv) Give two arguments against tidal energy and why we should avoid investing in that technology **[4 Marks]**

(b) Show that the available power from the water in the plant can be written as **[5 Marks]**

$P = \rho g Q H$

Where

ρ is the density of water [kg/m^3],

g is the gravitational constant [m/s^2],

Q is the flow rate of water [m^3/s] and

H corresponds to the head height [m].

(c) The basin area of a tidal power plant is 20×10^6 m^2. The tidal range is 8m. Determine the energy that can be generated in kWh. **[5 Marks]**

(d) Solar energy, wind energy and hydro-power are all intermittent in their availability. Explain how the problems caused by the intermittency can be mitigated **[3 Marks]**

Question Two

(a) Kaplan, Francis & Pelton turbines have characteristics which suit them to different conditions. Which would you select for the following sites and why?

(i) Head of 250m and flow of 0.2 cumec **[2 Marks]**

(ii) Head of 3.5m and a flow of 1.0 cumec in summer and 11.0 cumec in winter **[2 Marks]**

(iii) Head of 15m and a flow of 8.0cumec **[2 Marks]**

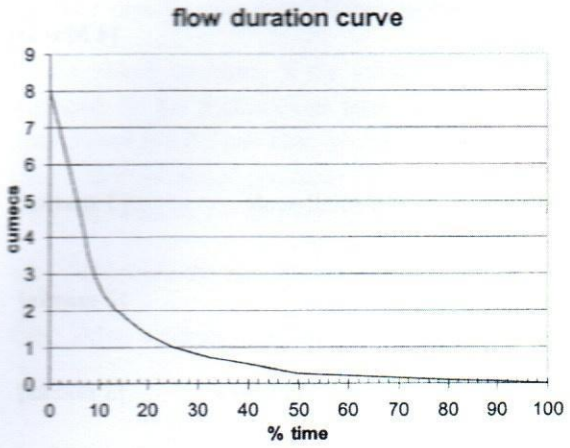
(b) The rainfall catchment area in a mountainous region is 26.5km^2. If the annual rainfall is 1.19m, and the only path for water to flow out of the region is over a single natural waterfall (head = 9m), determine

(i) The total water volume collected in a year **[1 Mark]**

(ii) The average water flow that this would produce **[1 Mark]**

(iii) Theoretical power available **[1 Mark]**

(c) Just below the waterfall a measuring weir was used to monitor the flow. The resulting Flow Duration Curve (FDC) is plotted in figure below



The Francis turbine suitable for this location is 85% efficient at a water flow of 1 cumec, and can be considered to have zero efficiency at all other flow rates.

(i) Use this information to estimate annual energy output of such a Francis turbine fitted into the weir. Assume the electrical generator is 100% efficient, and that the authorities do not insist on compensation flow because the river bed is virtually dry for part of the year anyway. **[1 Mark]**

(ii) For what fraction of the year can this scheme provide useful output? **[1 Mark]**

(iii) What is the total annual energy output? **[3 Marks]**

(d) (i) By building a dam wall on the weir site it would be possible to store water and so generate with a steady flow of 1 cumec throughout the year. What would the annual energy output be in this case? **[3 Mark]**

(ii) If energy is valued at KES 7/kWh, how much could be spent on building the dam for a payback period of 5 years? **[3 Mark]**

Question Three

(a) (i) Describe the purpose of Silt Basins and forebay tanks in a hydropower scheme **[4 marks]**

(ii) Explain the key principles in the design of the forebay tank (silt basin) **[8 marks]**

(b) State the characteristics considered in selection of a penstock **[4 marks]**

(c) State the main components of a small hydropower scheme **[4 Marks]**

Question Four

(a) (i) State the main instruments used to measure the hydraulic head of a small-scale hydropower scheme **[3 marks]**

(ii) Explain how the precision of a measurement be estimated **[2 marks]**

(ii) Explain why it is important to measure the head under a number of different flow regimes for a low head site. **[3 marks]**

(b) Explain what would be considered when deciding between leat, penstock and leat/penstock **[4 marks]**

(c) Explain how you evaluate the hydro-electric potential of a site on a particular river on the basis of river flow measurements **[8 marks]**

Question Five

(a) A hydropower plant is to be installed in **Kasese, Uganda**. The power plant has the following characteristics:

- Gross Head: 300 m; Design flow=0.6m^3/s

The length of the penstock pipe is 1868 m long.

Find out the following in these two cases if
(a) the penstock pipe is Mild steel (MS) with the manning roughness coefficient "n" = 0.012
(b) the penstock pipe is Glass Reinforced Pipe (GRP) with the manning roughness coefficient "n" =0.009. Diameter of the penstock pipes, assuming that the allowable velocity in the penstock pipe is 2 m/s

Use the following formulae in your calculations

$$D = \left(\frac{4Q}{\pi.V}\right)^{0.5} \quad \text{.....eq 1}$$

$$Head\ loss = \langle 10.29 \times n^2 \times Q^2/D^{5.333} \rangle L$$

(i) Net head in both the cases. Assume the summation of other head losses (viz bend, trash rack and expansion/contraction) is about 2% of the pipe friction loss. **[4 Marks]**

(ii) Electrical Power output from the project in the above two cases. If the efficiency of the turbine is 89% and generator efficiency is 94% **[4 Marks]**

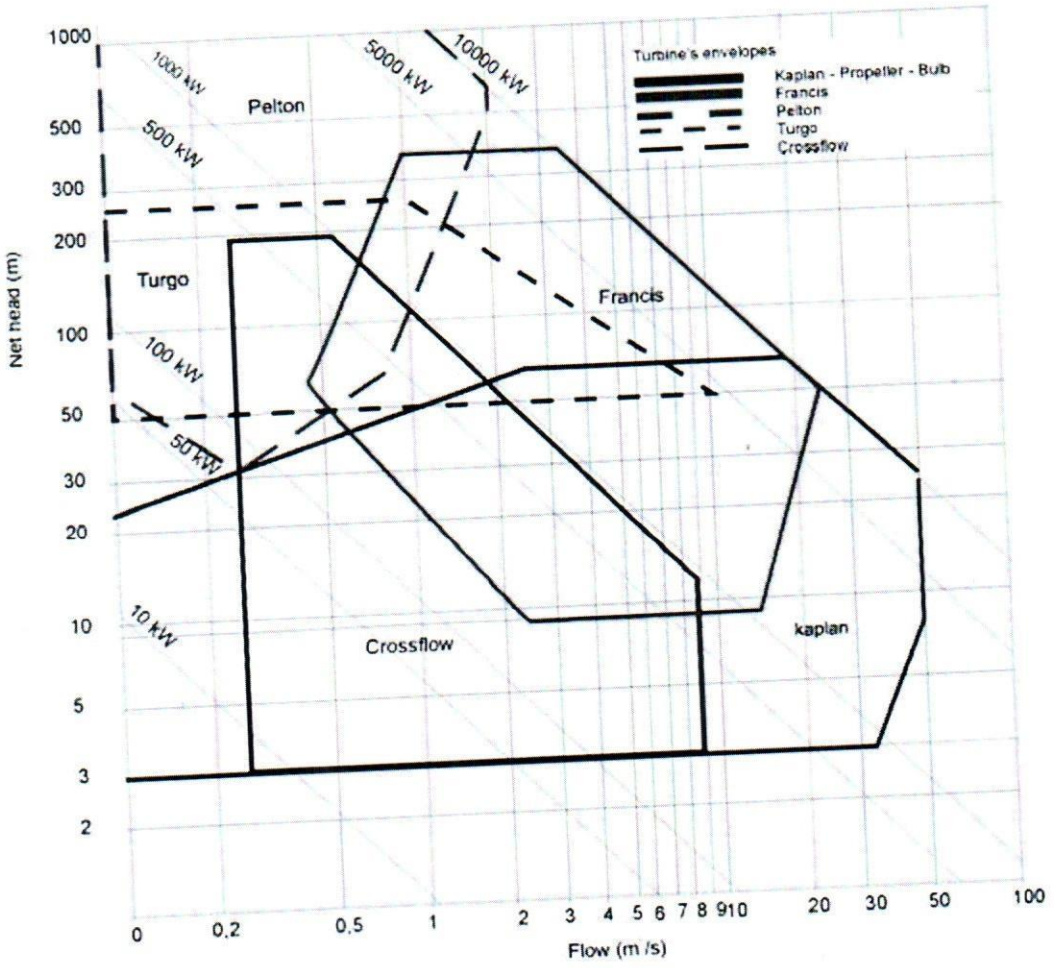
(b) What type of turbine will you use in such cases? (*Use the graph at the back of this question paper to select the turbine*) **[2 Marks]**

(c) With the capacity factor of 0.5 and unit rate for power selling to the grid at 0.12USD/kWh & if the total GRP pipe installation is 30,000 USD more expensive in the installation compare to MS pipe, figure out in which year the project gets payback for this additional cost spent for GRP pipe for penstock. Other cost remaining same. **[5 Marks]**

(d) In the above problem, if the village was earlier powered by a diesel generator and was replaced by the hydropower later: (Assume *that the CO_2 tax is 360 USD/m^3 diesel fuel. Diesel cost is $ 0.7 per liter, specific fuel consumption of diesel engine is 0.5 liters per kWhr, and 1 liter of diesel produces 2.65kg of CO_2. Also assume that the electricity is produced with full capacity for an average 10 hours a day.)*

(i) Calculate the annual cost saving in terms of avoided fuel cost and CO_2 emission tax. **[3 Marks]**

(ii) Also, estimate CO_2 emission avoided. **[2 Marks]**


Turbine's envelopes
Kaplan - Propeller - Bulb
Francis
Pelton
Turgo
Crossflow
1000 kW
500 kW
5000 kW
10000 kW
100 kW
50 kW
10 kW
Pelton
Turgo
Francis
Crossflow
kaplan
Net head (m)
1000
500
300
200
100
50
30
20
10
5
3
2
0
0,2
0,5
1
2
3
4
5
6
7
8
9
10
20
30
50
100
Flow (m /s)