00068

The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Mechanical Engineering

Study Programme	Master of Energy Management (MEM)
Name of the Examination	Final Examination
Course Code and Title	**DMX9405 Renewable Energy Technology (RET)**
Academic Year	2020
Date	22nd August 2020 (Saturday)
Time	13.30 h– 16.30 h (IST)
Duration	**03 hours**

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **Five (5)** questions. **Answer all questions**.
3. All questions carry equal marks
4. **Answer for each question should commence from a new page.**
5. **Relevant charts/ codes are provided.**
6. This is a Closed Book Test (CBT).
7. Answers should be in clear hand writing.
8. Do not use Red color pen.

QUESTION 01 (20 marks)

Following paragraph is an extract from Sri Lanka Energy Policy which was published on 08th August 2019.

"Sri Lanka has achieved several goals set in the National Energy Policy and Strategies (2008) in complete electrification and renewable energy development. The main objective of the National Energy Policy and Strategies declared here is to ensure convenient and affordable energy services are available for equitable development of Sri Lanka using clean, safe, sustainable, reliable and economically feasible energy supply. This Policy is formulated in alignment with the future goals of Sri Lanka, current global trends in energy and the Goal 7 of the Sustainable Development Goals of the United Nations. This policy will impact the vast realm of social, economic and environmental spheres and pave the way to realize the vision of Sri Lanka in achieving carbon neutrality and complete transition of all the energy value chains by 2050"

Discuss about your strategies to meet carbon neutral energy system for Sri Lanka by 2050. Indicate what are the (SWOT) Strength, Weakness, Opportunities and Treats of achieving it.

(Limit answer to maximum 200 words)

Special note: SWOT analysis – your points for each section must be presented clearly.

QUESTION 02 (20 marks)

"**Gomala Oya**" originates from Peak Wilderness (Siri Pada) sanctuary. A private developer is planning to develop a run-off the river mini hydro power plant using water resources of "Gomala Oya".

Net head of the project is 150 m, design flow of the project has been selected as 1 m^3/s and the flow duration data are as follows (***Figure 1 and Table 1***). The developer is planning to go for one turbine unit.

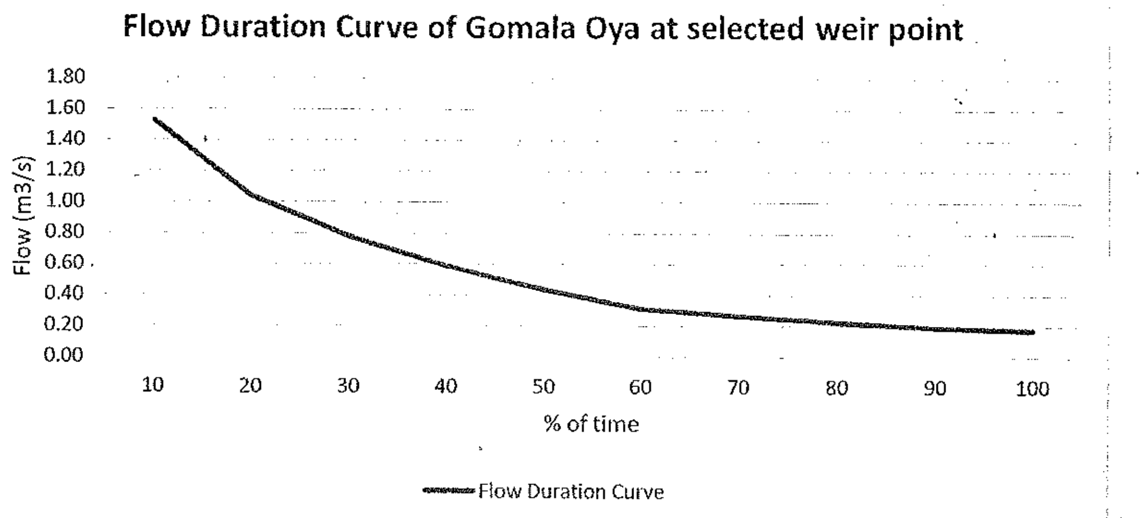

Figure 1: *Flow Duration Curve*

Table 1: *Coordinates of Flow Duration Curve*

Time (%)	10	20	30	40	50	60	70	80	90	100
Q (m3/s)	2.03	1.39	1.04	0.78	0.58	0.42	0.35	0.30	0.26	0.23

(a) As per the turbine selection chart (***Annexure- 1, Figure 2: Turbine selection chart***), both Francis and Pelton machines can be used for this project.

I. What is the plant capacity if Francis machine is been used? **(2.5 marks)**

II. What is the plant capacity if Pelton machine is been used? **(2.5 marks)**

Note: Use efficiency at 100% flow condition from efficiency values tables of both Francis and Pelton. (Use data from Annexure -01, Table 2: Francis turbine efficiency values and Table 3: Pelton turbine efficiency values)

(b) You are asked to select one machine type (Francis or Pelton) based on annual energy production. Justify your selection with annual energy calculation outputs. (***Annexure -01, Table 4: Energy calculation table format***)

I. What is the estimated annual energy with a Francis machine? **(5 marks)**

II. What is the estimated annual energy with a Pelton machine? **(5 marks)**

Notes:

- ***Use energy calculation table format for Francis and Pelton machines energy calculations.***
- ***The Françis machine manufacturer will not allow to operate the machine if the available flow is less than 30% of rated flow.***

(c) Mention **FIVE** points to be considered when design/optimize a hydro power plant.
(1 mark X 5 = 5 marks)

QUESTION 03 (mark 20)

(a) What are **FOUR** inverter topologies commonly available in the market?
(1 mark X 4 = 4 marks)

(b) Average monthly electricity consumption of Mr. Silva's house is about 840 kWh (840 units). He intends to invest for a roof top solar PV system under Net Metering system. The roof has been constructed in two angles.

i. Explain features of Net Metering system **(2 marks)**
ii. Assume 1 kWp solar PV system generate average 4kWh per day, what is the required solar PV system capacity? **(2 marks)**
iii. Suggest suitable capacity of an inverter for the project. **(2 marks)**
iv. What are the factors to be considered when selecting an inverter? **(2 marks)**

(c) Draw I-V curve of a solar module for following scenarios
i. I-V curve variation with change of solar irradiation **(2 marks)**
ii. I-V curve variation with change of module temperature **(2 marks)**

iii. What is mean by MPPT and explain importance of MPPT when selection of an inverter? **(4 marks)**

QUESTION 04 (mark 20)

Wood chips are used as the fuel for a hot water production boiler in an industrial application. A sample of wood chips (wood chips as received) is subjected to ultimate analysis to find its elementary composition. The composition is given below;

***Table 5:** Elementary composition of wood chips (wood chips as received)*

Substance	Carbon (C)	Hydrogen (H_2)	Oxygen (O_2)	Nitrogen (N_2)	Sulphur (S)	Inorganics (Ash)	Water (H_2O)
Percentage %	40.0	4.5	34.3	0.15	0.05	3.0	18.0

(a) Estimate the Lower Heating Value (LHV) of wood chips used for the boiler MJ/kg? **(5 marks)**
Supporting data are provided in annexure-02

(b) The feed rate of wood chips to boiler is 60 kg/hr and the combustion is performed with **40% excess air.**

i. Calculate the rate of energy (in fuel) supplied to the boiler (Kw) **(5 marks)**

ii. Estimate the mass flow rate of air required for the combustion process (in kg/hr). *Use the "combustion table for solid fuels"; format provided in the Annexure -02.* **(5 marks)**

Assume, the quantities of Nitrogen and Sulphur prevailed in the fuel are oxidized only to nitrogen oxide (NO) and Sulphur dioxide (SO_2) during the combustion. Ash in the fuel will not react and remains as residue in the boiler.

(c) What are the percentages of CO_2, H_2O, O_2 and SO_2 (V%, volume) in the exhaust stream of the boiler. **(5 marks)**

QUESTION 05 (mark 20)

The performance curve of a fixed speed, 70-meter (rotor diameter) horizontal axis wind turbine (HAWT) is shown in **figure 3.** Wind turbine rotor is rotating at the speed of 20 rpm (revolutions per minute)

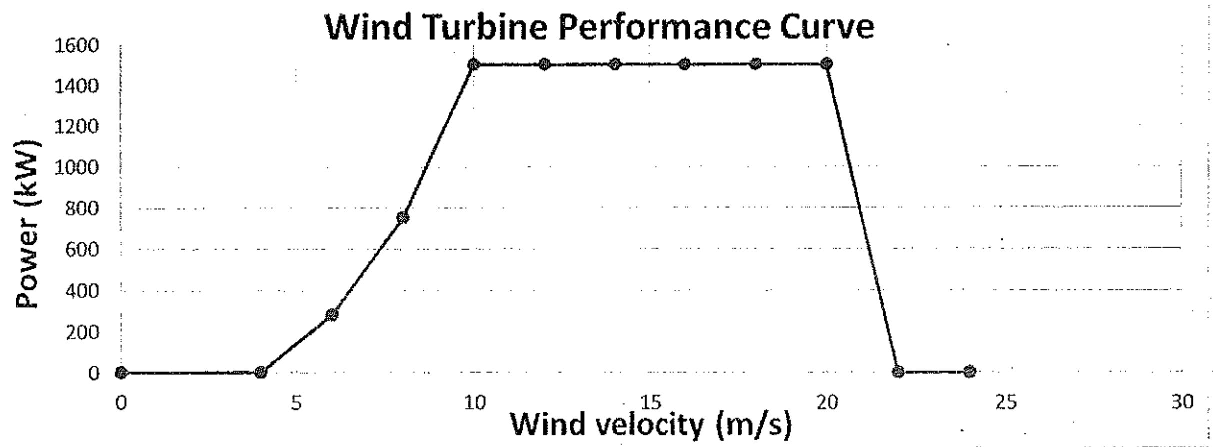

Figure 3: *Wind turbine performance curve*

(a) Determine the following;

i. Rated power of the wind turbine (MW)

ii. Cut-in wind velocity of the turbine (m/s)

iii. Rated wind velocity (m/s)

iv. Cut-off wind velocity (m/s)

(1 mark X 4 = 4 marks)

(b) Determine the power coefficient and tip speed ratio of the turbine at following wind velocities;

(1.5 marks X 4 = 6 marks)

Wind velocity (m/s)	Power coefficient	Tip sped ratio
6		
8		
10		
12		

Supporting data are provided in annexure-03

Figure 4, shows wind velocity data recorded during the past year at location where the wind turbine is installed.

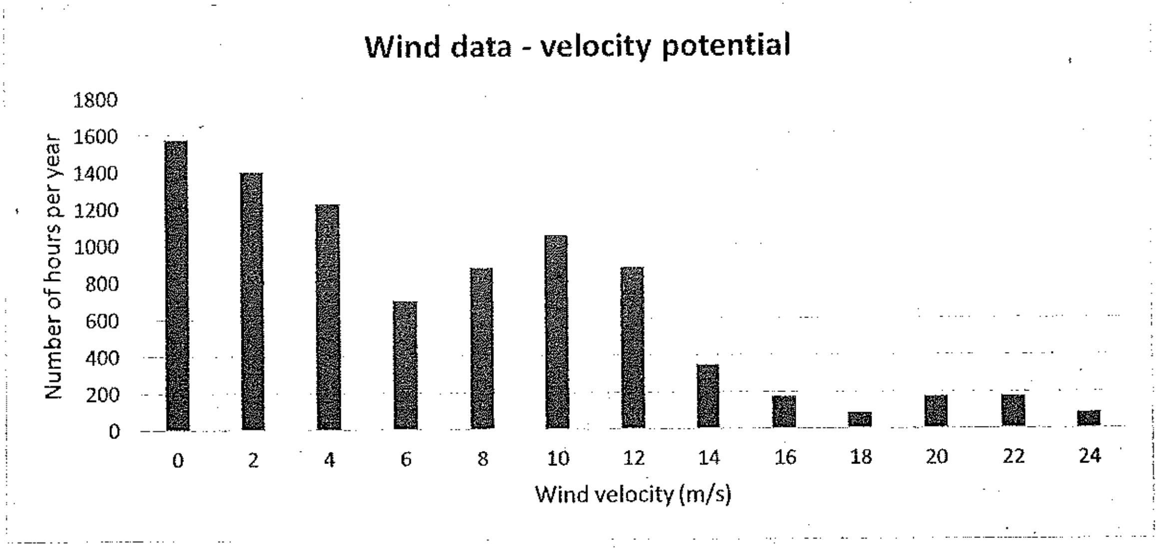

Figure 4: Wind data – histogram

(c) Assuming that the wind turbine was able to generate and deliver power at its maximum potential according to the availability of the wind. Determine the total amount of electrical energy (MWh) delivered to the electricity grid during the period of past year

(6 marks)

(d) Calculate the capacity factor of the wind turbine installation **(4 marks)**

Annexure-01

Supporting materials for Question 2
Turbine selection chart Source: **https://www.researchgate.net/figure/HYDRAULIC-TURBINE-SELECTION-CHART_fig1_302969536**

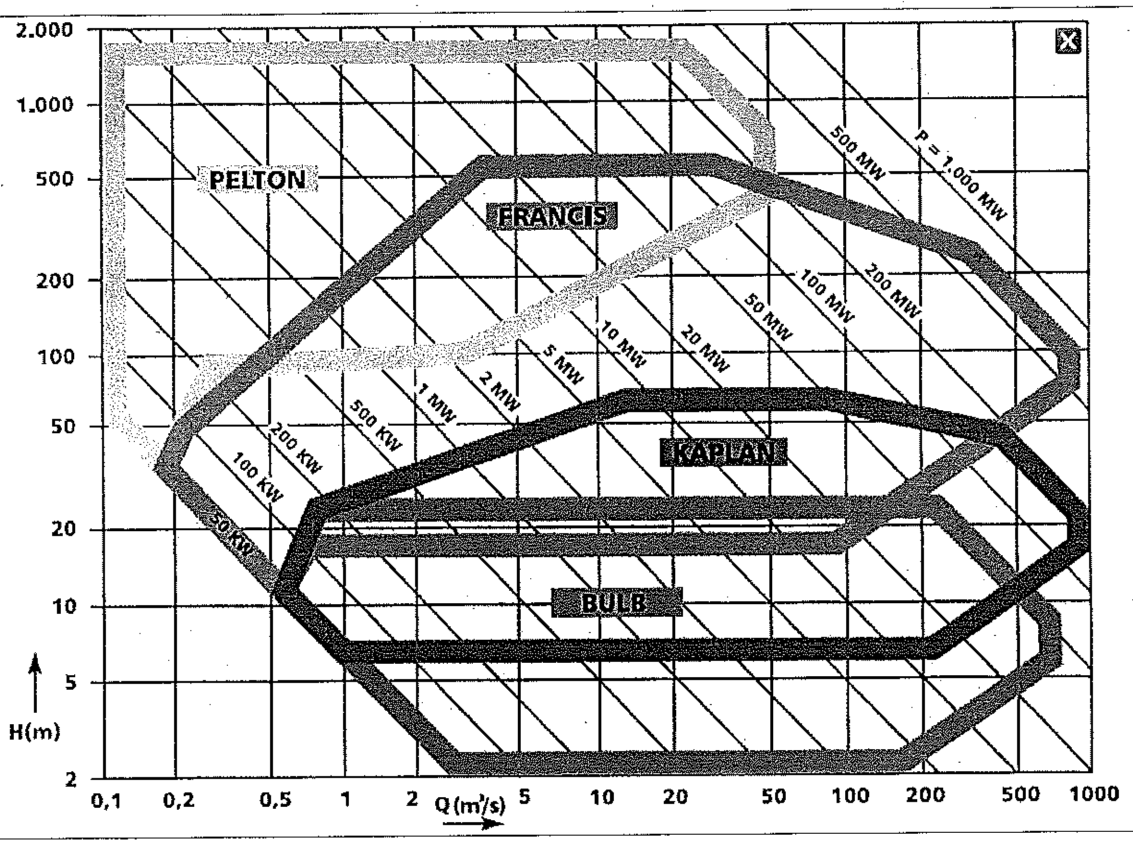

Figure 2: Turbine selection chart

Francis turbine efficiency values

Table 2: Francis turbine efficiency values

Flow in %	30	40	50	60	70	80	90	100
Efficiency	77.64	84.00	87.84	90.44	92.70	93.80	92.90	92.14

Pelton turbine efficiency values

Table 3: Pelton turbine efficiency values

Flow in %	15	20	25	30	30	40	50	60	70	80	90	100
Efficiency	88.80	89.54	90.02	77.64	90.49	90.65	90.81	90.97	91.04	91.06	90.90	90.60

Table 4: Energy calculation table format

Energy calculation table						
Time (%)	Q (m3/s)	Net Flow (m3/s)	Flow %	Turbine efficiency (%)	Turbine output (kW)	Energy (kWh)
10%	1.53	1.00	100%			
20%	1.04	1.00	100%			
30%	0.78	0.78	78%			
40%	0.59	0.59	59%			
50%	0.43	0.43	43%			
60%	0.31	0.31	31%			
70%	0.27	0.27	27%			
80%	0.23	0.23	23%			
90%	0.19	0.19	19%			
100%	0.17	0.17	17%			
					Total energy	

Annexure-02

Supporting materials for Question 4

- Higher Heating Value of the fuel;

$$HHV = \sum_{i=1}^{n} Xi\ HHVi$$

Where;
HHV = Higher Heating Value of the wet fuel (MJ/kg)
X*i* = mass of the *i* th component in 1 kg of the wet fuel (kg)
HHV*i* = Higher Heating Value of the *i* th component of the fuel (MJ/kg)
n = number of combustible components in the fuel
Higher Heating Value (HHV) of carbon (C) 36.8 MJ/kg, hydrogen (H_2) 142 MJ/kg, nitrogen (fuel N_2) 0.0 MJ/kg, Sulphur (S) 9.2 MJ/kg

- Lower Heating Value of the fuel;

$$LHV = HHV - L\,(H.\frac{MWH2O}{MWH2} + F)$$

Where;
HHV = Higher Heating Value of the wet fuel (MJ/kg)
LHV = Lower Heating Value of the fuel (MJ/kg)
L = Heat of vaporization of water = 2.4 MJ/kg
H = mass of hydrogen in 1 kg of wet fuel (kg)
MWH_2O = molar mass of water = 18 kg/kmol
MWH_2 = molar weight of hydrogen = 2 kg/kmol
MWN_2 = molar weight of nitrogen 28 kg/kmol
MWS = molar mass of sulphur 32 kg/kmol
F = mass of moisture in 1 kg of wet fuel (kg)

Air composed of 79% nitrogen and 21% oxygen (assume dry).

Oxygen (O_2), 32 kg/kmol; water (H_2O), 18 kg/kmol; nitrogen (N_2), 28 kg/kmol.

COMBUSTION TABLE FOR SOLID AND LIQUID FUELS

Fuel: Wood chips

Molar weight		Analysis	Oxygen		Flue gases (mol/kg)					
Cont	g/mol	g/kg	mol/kg	mol/kg	H_2O	CO_2	N_2	SO_2	O_2	N0
C	12,00									
H_2	2,00									
O_2	32,00									
N_2	28,00									
S	32,00									
Ash	---									
Water	18,00									
Sum:			Sum O_2							

Nitrogen in air	3,76 * O2							
Stoic. combustion dry air	l_{ot}							
Humid ratio in air: 0,000	-							
Stoic. combustion air need	l_o							
Stoichometric flue gas amc	g_o							
Stoichiometric dry flue gas	g_{ot}							

CO_{2dry}= O_{2dry}=

CO_{2odry}: *Excess air %* 40,00

O_{2wet}=

Nitrogen due to air in excess								
Oxygen due to air in excess								
Water in air excess								
Actual comb. air	l							
Actual comb. dry air	l_t							
Actual fluegas	g							
Actual dry fluegas	g_t							
Fraction in real flue gas:								
Fraction in dry flue gas:								

Annexure-03

Supporting materials for Question 5	
Power in the wind (across area A, perpendicular to the flowing wind stream at velocity v)	$P\ wind = \frac{1}{2}\rho A\ V3$
Power obtained by the wind turbine	$P\ wind = \frac{1}{2}\ Cp\ \rho A\ V3$
Power coefficient - Cp	Power obtained / power in the wind
Tip speed ratio	Velocity of blade tip / in coming wind speed
Angular velocity (ω)	(2π * rpm) /60
Capacity factor	Energy delivered/total potential of turbine