MACHAKOS UNIVERSITY

University Examinations 2016/2017

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF BUILDING AND CIVIL ENGINEERING

FIFTH YEAR FIRST SEMESTER EXAMINATION FOR BACHELOR OF SCIENCE IN ELECTRICAL AND ELECTRONICS ENGINEERING

EEE 501: RENEWABLE ENERGY TECHNOLOGIES

DATE: 25/7/2017 **TIME:11:00 – 1:00 PM**

Instructions

- *This paper consists of Five Questions*
- *Question* ***One is Compulsory***
- *Attempt Any other Two Questions*

Some Useful Constants

- Plank's Constant:$h = 6.63x10^{-34}Js$
- Speed of Light in a Vacuum :$c = 3.0x10^{8}m/s$
- Stefan Boltzmann's Constant :$\sigma = \frac{5.67x10^{-8}W}{m^2}/k^4$
- Gravitational Acceleration :$g = 9.81N/Kg$
- Kinematic viscosity of water at $20℃$ is $10^{-6}\mathrm{m/s}$

QUESTION ONE (COMPULSORY) (30 MARKS)

a) With the help of *Energy Flow Diagrams*, explain the difference between Renewable and Finite Energy Supplies (4 marks)

b) Explain the three categories of Renewable Energy Supply systems giving examples of each. (3 marks)

c) Explain the Six Types of Renewable Energy Storage, giving examples in each case (3 marks)

d) Giving examples in each case, explain the Classes of wind power electricity systems in terms of their generation capacity and Control modes. (5 marks)

e) With the help of a well labelled sketch of the turbine output power v/s the wind speed, explain the four regions of operation of the wind turbine. (4 marks)

f) The term hybrid power system is used to describe any power system combine two or more energy conversion devices, or two or more fuels for the same device, that when integrated, overcome limitations inherent in either. The design and structure of a hybrid energy system obviously take into account the types of renewable energy sources available locally, and the consumption the system supports.

(i) State four merits of hybrid power systems

(ii) State and explain the three configurations of hybrid systems using diagrams (6.5 marks)

g) State the three factors affecting Daily Insolation for Solar Energy. (1.5 marks)

h) State any Six Instruments used in measuring Solar Radiation. (3 marks)

QUESTION TWO (20 MARKS)

a) Show that for Hydro Generators and Wind Turbines, the Bernoulli's Equations for the fluids involved in each case is given by the relation

$$\frac{P}{\rho g} + Z + \frac{u^2}{2g} = H$$

All the symbols carry their usual meaning (6 marks)

b) Explain and the derive the modifications that must be made in a) above to make the equation practically suitable for a Solar Heating System (SHS). (4 marks)

c) Show that the coefficient of friction of water in a Penstock is inversely proportional to the square of the Reynolds Number. (4 marks)

d) Determine the pressure head required to force $0.01m^3/s$ of water at $20℃$ through a concrete penstock of length 200m and diameter 0.30m. The roughness of various materials for penstock manufacture are as shown in Table 2.0. Further, the friction coefficient for the penstock flow are as shown in Figure 2.0. (6 marks)

Table 2.0

Material	ξ (mm)
PVC	0 ('smooth')
Asbestos cement	0.012
New steel	0.1
'Smooth' concrete	0.4

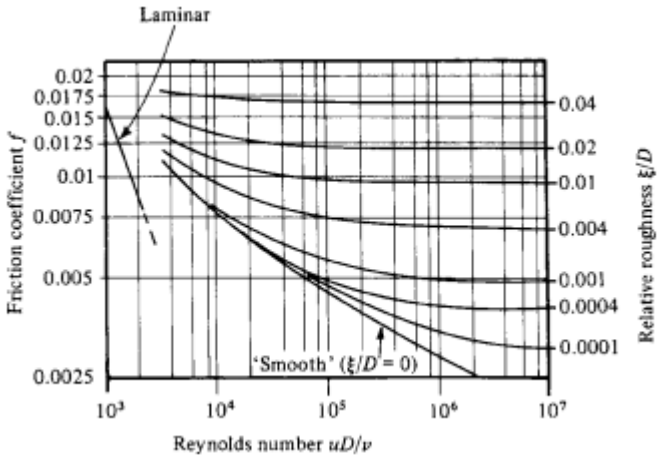

Figure 2.0

QUESTION THREE (20 MARKS)

a) Using the *BETZ Model* for an expanding air stream, show that the power extracted from wind is at a maximum of 59% and this occurs when the fractional wind speed decrease at the turbine is 0.33. Explain all the symbols used (7 marks)

b) Using the *Bernoulli's Principle* and *BETZ Model*, show that the *Axial Force Coefficient* attains a maximum of *unity* when the fractional wind decrease across the turbine is 0.5. Explain all the symbols used. (6 marks)

c) For a practical wind turbine, show that

$$C_{\Gamma} = \frac{0.59}{\lambda}$$

All the symbols carry their usual meaning which must be defined. (7 marks)

QUESTION FOUR (20 MARKS)

a) Explain the following terms as used in Solar Radiation Analysis with the help of expressions

(i) Hour angle

(ii) Declination (2 marks)

b) With the help of a well labelled diagram of the Solar Beam and its Collector, define the various related angles, hence write the expression(s) of the angle of incidence. (4 marks)

c) A beam of solar radiation on a surface is located at Glasgow $(56°N, 4°W)$ at 10AM on February 1st. The surface is oriented $20°$ east of south and tilted at $40°$ to the horizontal. Determine the angle of incidence of the beam. (5 marks)

d) Beginning from the *Plank's Radiation Law* for a Solar Heating System, show that the *Wien's Displacement Law* can be defined by the relation

$$\lambda_m T = 2898 \mu m K$$

All the symbols carry their usual meaning (5 marks)

e) From the heat exchange relationship between two *Gray Surfaces*, show that for a Flat Plate Solar Water Heater (FPSWT) and PV generator, the thermal resistance is a function of the inverse of the mean temperature and the geometry relationship of the surfaces. (4 marks)

QUESTION FIVE (20 MARKS)

a) Using equations explain the principle of Discounted Cash Flow with Inflation (DCFI) as applied in Renewable Energy Economics. (4 marks)

b) A wind farm is located on an open plain in Ngong Hils Kenya. It comprises 10 turbines, each rated at 600 kW and with a cut-in speed of 4m/s. The wind is fairly steady, so that the turbines are observed to be nearly always turning, but is of only moderate speed 6m/s the actual capacity factor of the turbines is 0.25. For each turbine, the cost ex-factory is US$440 000 and the cost of installation (including civil and electrical engineering) is US$300 000. Operation and maintenance (O&M) costs are about US$18 000y per turbine. (These costs exclude the cost of land).The average ('levelised') cost of production of electricity at the site basically is determined for a discount rate of 5% and an assumed life of the system of 15 years. Under an emissions-trading regime, the generator receives credit for carbon dioxide abated at US$30/tCO2.Each KWh produced entails the emission of 1.0kg CO2. Determine the effective change in the cost of production due to this carbon credit. (9 marks)

c) Explain the terms Life Cycle Cost (LCC) and Annual Life Cycle Costing(ALCC) as used in Hybrid Power Systems economics. (2 marks)

d) A PV array of 500W has been installed to pump water from a bore-well of 2 meters deep using a submergible motor and pump system to an over-head tank. The length of pipe required to pump the water is 30 meters. The Costs involved for the sub-systems and their life spans are as shown in Table 5.0

Table 5.0	
Particulars	Life span(Years)
PV Array: $8/peak watt	15
Motor and pump: $2/watt	7.5
Pipe cost: $8/meter	5
Cost of digging the bore-well: $20/meter	
Maintenance cost: $80/year	
Miscellaneous cost: $3.5/watt	

If the interest rate is 10%, determine the Life Cycle Cost (LCC) of the water for a period of 15 Years and water cost per year (ALCC). (5 marks)