[ENG37]

UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

MSC MECHANICAL ENGINEERING

SEMESTER TWO EXAMINATION 2021/22

ADVANCED THERMAL POWER AND ENERGY SYSTEMS

MODULE NO: AME7008

Date: Tuesday 17th May 2022 **Time: 10:00 – 12:30**

INSTRUCTIONS TO CANDIDATES:

There are FIVE questions.

Answer ANY FOUR questions.

All questions carry equal marks.

Marks for parts of questions are shown in brackets.

This examination paper carries a total of 100 marks.

All working must be shown. A numerical solution to a question obtained by programming an electronic calculator will not be accepted.

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QUESTION 1

You were just hired as an engineer by an energy storage start-up. The product you are developing, will store energy as Potential Energy. When there is excess power from the grid, a motor connected to a winch will pull a mass connected to a spring. Then a brake system will lock the mass in position. When the grid requires power, the mass is allowed to return to its resting position. Your line manager suggested that the product can be simulated as a solid wall, a spring with stiffness K1, a spring with stiffness K2, a damper with damping coefficient C and a mass with mass M.

Figure Q1 shows the model of your product. The input to the system is the Force F acting from the winch to the mass and the outputs are displacements y_1 and y_2.

a) Develop the differential equations for the displacements y_1 and y_2 of the machine system. **[10 marks]**

b) Determine the Laplace transforms of the differential equations obtained from (a) above. Assume the initial conditions of the system are zeros (i.e. at time = 0,y_1 $\dot{y}_1$, $\ddot{y}_1$ are all zeros). **[5 marks]**

c) Determine the transfer function $G(s) = \frac{y_2(s)}{F(s)}$. **[10 marks]**

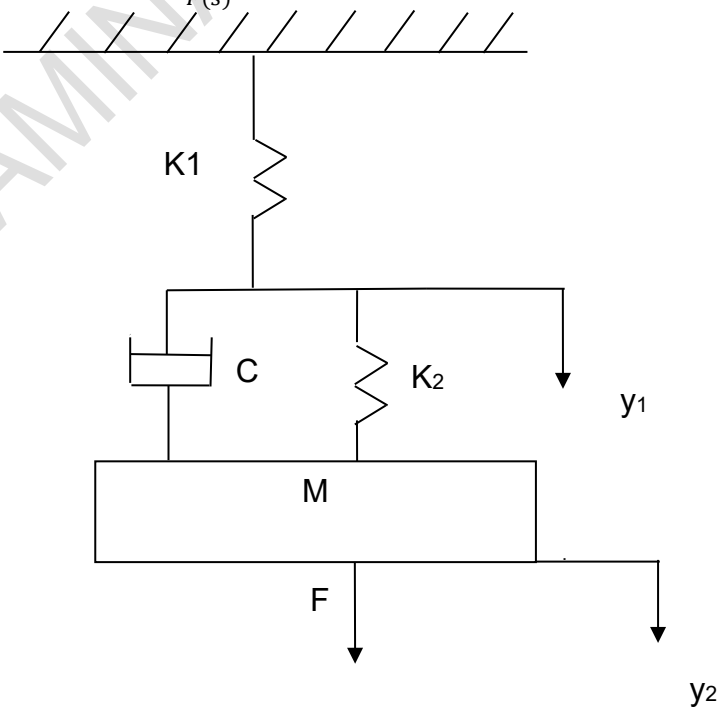

Figure Q1 **Total 25 marks**

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QUESTION 2

a) Solar panels are getting cheaper and more efficient. Currently, the cost of a solar cell is about $1 per Watt. Why does solar account for only about 2% of the electricity generation? (About 200 words).

[5 Marks]

b) Describe the components of a modern horizontal axis wind turbine

[5 Marks]

c) A wind turbine is rated at 5 MW, at the rated wind speed of 15 m/s, with a blade diameter of 100 m.

i. What is the overall efficiency of the turbine?

[5 Marks]

ii. What is the power coefficient of the turbine?

[5 Marks]

The air density is ρ = 1.29 kg/m3. The gearbox efficiency and the generator efficiency are $\eta_{gb} = 0.9$ and $\eta_g = 0.9$, respectively

d) A wind turbine is required to deliver 1 MW at a rated wind average speed of 25 mph. The rotational speed of the rotor is 22 rpm. The overall efficiency is 35%. The air density is 1.29 kg/m3. Calculate the corresponding tip speed ratio

[5 Marks]

Total 25 marks

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QUESTION 3

a) Discuss irreversibilities and losses in a gas turbine and explain how they affect the operating conditions in the basic gas turbine. Provide a T-s diagram for the same.

[6 Marks]

b) In a gas turbine plant, air is supplied at 1.5 bar and 20°C to compressor for getting compressed up to 8 bars with isentropic efficiency of 84%. Compressed air is heated up to 1100 K in combustion chamber where also occurs a pressure drop of 0.3 bar. Subsequently expansion occurs to 1.5 bar in turbine. Determine isentropic efficiency of turbine if thermal efficiency of plant is 20%. You should also provide a T-s diagram.

Take $\gamma = 1.4$ and $c_p = 1.005$ kJ/kg/K.

[19 Marks]

Total 25 marks

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QUESTION 4

Consider a 5-m-high, 8-m-long, and 0.22-m-thick wall whose representative cross section is as given in figure Q4. The thermal conductivities of various materials used, in W/(m °C), are $k_A = k_F = 2$, $k_B = 8$, $k_C = 20$, $k_D = 15$, and $k_E = 35$. The left and right surfaces of the wall are maintained at uniform temperatures of 300°C and 100°C, respectively.
Assuming heat transfer through the wall to be one-dimensional and disregarding any contact resistances at the interfaces,

a) Sketch the thermal resistance network and determine the rate of heat transfer through the wall.

[15 Marks]

b) Calculate the temperature at the point where the sections B, D, and E meet.

[6 Marks]

c) Find the temperature drop across the section F.

[4 Marks]

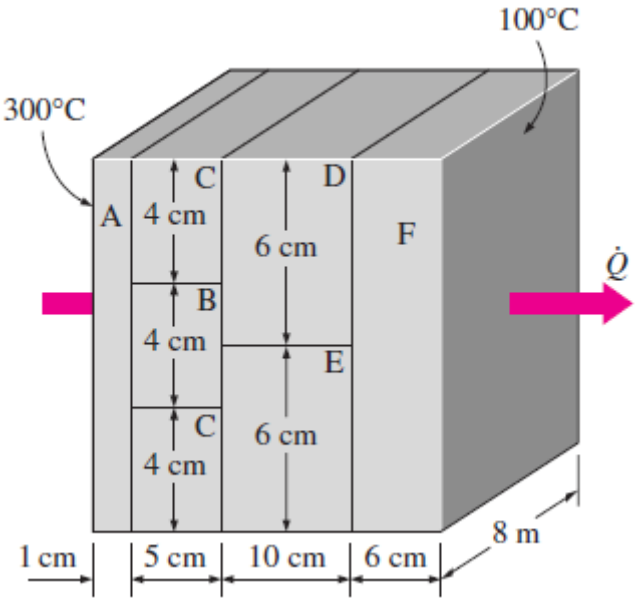

Figure Q4

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Total 25 marks

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QUESTION 5

a) Draw the T-S diagram of a turbojet engine considering irreversibilities. Provide the equations for the diffusor efficiency, compressor efficiency, turbine efficiency and nozzle efficiency.

[6 marks]

b) An aircraft running with speed of 900 kmph uses turbojet engine taking air at rate of 60 kg/s. The air-fuel ratio is 110 and combustion efficiency is 0.9. Fuel has lower calorific value of 43000 kJ/kg. The turbo jet engine nozzle has isentropic enthalpy change of 200 kJ/kg and velocity coefficient is 0.9.

Calculate thrust, thrust power, propulsive power, propulsive efficiency, fuel flow rate, heat supplied and overall efficiency. Neglect mass of the fuel and pressure thrust.

[19 marks]

Total 25 marks

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