BUILDING ENERGY SUPPLY SYSTEMS AND DISTRICT ENERGY NETWORKS
(21CVP306)

Semester 2 2021-22 Online Short-window Exam paper

This is an online short-window examination, meaning you have a total of **2 hours plus additional 30 minutes** to complete and submit this paper. The additional 30 minutes are for downloading the paper and uploading your answers when you have finished. If you have extra time or rest breaks as part of a Reasonable Adjustment, you will have further additional time as indicated on your exam timetable.

It is your responsibility to submit your work by the deadline for this examination. You must make sure you leave yourself enough time to do so.

It is also your responsibility to check that you have submitted the correct file.

Exam Help
If you are experiencing difficulties in accessing or uploading files during the exam period, you should contact the Exam Helpline. For urgent queries please call **01509 222900**. For other queries email examhelp@lboro.ac.uk

You may handwrite and/or word process your answers, as you see fit.

You may use a calculator for this exam.

Answer **THREE** questions.

All questions carry equal marks.

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1. a) Describe and analyse the operation of Lithium Bromide/water absorption systems using the most common system diagram.

[17 marks]

b) A Refrigerant R134a refrigeration plant has a constant condenser pressure of 12 bar and a constant evaporator pressure of 2 bar to meet a cooling load of 55 kW. The vapour leaving the evaporator is superheated by 10 °C and the liquid leaving the condenser is sub-cooled by 7 °C. If the compressor has an isentropic efficiency of 80%, determine:

i) The rate at which heat is rejected at the condenser.

[6 marks]

Question 1 continues/…

ii) The mass flow rate of the refrigerant.

[3 marks]

iii) The actual COP.

[3 marks]

iv) The Carnot COP.

[2 marks]

Compare the two COP results for (iii) and (iv) and comments on the above results.

[2 marks]

You may use the pressure-enthalpy chart given in Figure Q1.

2. a) The annual heating demands for a house are 25,000 kWh per year. Heating is supplied by an 80% efficient boiler fuelled by wood pellets with the properties as given in Table Q2a.

i) Calculate the total mass and volume of wood pellets needed to meet the heating demand.

[4 marks]

ii) Estimate the size of fuel store needed if 14 days of fuel storage are required.

[4 marks]

Table Q2a: Wood pellet properties

Moisture content (% by mass)	8
Bulk density (kg/m^3)	650
Energy content (kWh/kg)	4.7
Energy density (kWh/m^3)	3200
Ash content (% by mass)	0.5

b) In your own words, discuss the process of sizing a biomass boiler. This discussion should include aspects such as biomass boiler capacity, thermal stores, auxiliary boilers, annual load duration curves and suitability of biomass in different applications. Write this report in your own words making sure that any quotes from other sources are fully referenced.

[8 marks]

c) Describe the second law of thermodynamics and the two corollaries associated to this law.

[9 marks]

d) Derive the equation for Carnot efficiency and draw the Carnot cycle on a T-S diagram together with the areas of heat, and work on separate T-S diagrams.

[8 marks]

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3. a) Three solar collector systems have been shortlisted for a new solar collector installation. The collector performance characteristics provided by the manufacturer is summarised below in Table Q3a.

Table Q3a. Solar collector performance characteristics

	F_R	$\tau\alpha$	U_L
Collector A	0.92	0.75	3.4
Collector B	0.90	0.89	6.5
Collector C	0.75	0.72	2.1

Determine which system will have the highest efficiency when the incident radiation is 600Wm^{-2}, the ambient temperature is 20°C and,

i) the inlet temperature is 40°C.

[2 marks]

ii) the inlet temperature is 70°C.

[2 marks]

Indicate which collector should be selected for each inlet temperature.

b) By drawing the Hottel Whillier Bliss (HWB) efficiency plot for these solar collectors or otherwise determine the range of inlet temperatures over which each solar collector performs most efficiently.

[5 marks]

c) Given that the mass flow rate of water, (Cp = 4200Jkg^{-1}K^{-1}) through the collector is 0.05kgs^{-1}, the collector area is 4m^2, calculate the increase in temperature that you will obtain through the selected collectors for part a), and thus the outlet temperature.

[4 marks]

d) A new flat plate solar collector system in which the space between the absorber plate and collector cover is evacuated to a pressure of less than 0.1Pa to suppress gaseous conduction and convection is proposed. The heat transfer between the absorber and cover being made up of conduction through a support matrix equivalent to 0.2Wm^{-2}K^{-1} and long wave radiation.

Two of the design engineers are discussing if a solar selective surface should be used to improve the system performance for water heating, one claiming it is unnecessary expense given the suppression of gaseous conduction and convection the other arguing the performance improvement of including a selective surface makes it worthwhile.

Question 3 continues/…

For the non-selectively coated absorber system using an iterative solution method they calculate the collector top loss coefficient to be 4.95W/m^{2}K.

Calculate the top loss coefficient for the selective surface coated absorber system. Use an iterative method with an initial guess for the cover temperature of 14°C.

[16 marks]

Parameters for the two systems are provided below.

Table Q3d. Parameters for the two systems

Non Selective Absorber System	Selective Surface Absorber System
Plate to cover spacing 3mm	Plate to cover spacing 3mm
Plate emittance 0.9	Plate emittance 0.1
Ambient air and sky temperature 10°C	Ambient air and sky temperature 10°C
Wind speed 2ms^{-1}	Wind speed 2ms^{-1}
Mean plate temperature 80°C	Mean plate temperature 80°C
Collector inclination 45	Collector inclination 45
Glass emittance 0.9	Glass emittance 0.9
Fr=0.7	Fr=0.7
τα=0.65	τα=0.7

e) Given that that the average solar radiation incident on the collector aperture when the collector is to be used is 400Wm^{-2} and the back and side losses combined are 0.5 Wm^{-2}K^{-1} for both system variants and T_i and T_a are 80 and 10°C respectively what are the average efficiencies of the collectors and which system would you chose?

[4 marks]

Equations provided:

$$\frac{Q_u}{AI} = \eta$$

$$\eta = F_r\left[\tau\alpha - U_L\frac{(T_i - T_a)}{I}\right]$$

$$h_{r_{p-c}} = \sigma(T_p + T_c)(T_p^2 + T_c^2)/(\frac{1}{\varepsilon_p} + \frac{1}{\varepsilon_g} - 1)$$

$$h_{r_{c-sky}} = \varepsilon_g\sigma(T_c + T_{sky})(T_c^2 + T_{sky}^2)$$

$$T_c = T_p - \frac{U_t(T_p - T_a)}{h_{c,p-c} + h_{r,p-c}}$$

$$h_\omega = 5.7 + 3.8V$$

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4. a) The building sited in a Northern European Climate has a heat demand load profile given in Table Q4a:

   i) comment on the likely uses of that heat at different times in the year.
   [4 marks]

   ii) Suggest boiler strategy that you might expect to yield the most efficient delivery of that heat throughout the year.
   [6 marks]

   iii) Explain why that boiler strategy you selected is likely to be the most efficient, use diagrams where appropriate.
   [10 marks]

   b) For a large commercial building development in a city location where space is at a premium, discuss the factors that work against the selection of solid and liquid-based fuels and make the selection of natural gas more attractive. What are the other factors that make natural gas a preference over liquid and solid fuels?
   [13 marks]

Table Q4a heat demand load profile

Months	Jan-Feb	Mar-Apr	May-June	July-Aug	Sept-Oct	Nov-Dec
Heating demand kW	600	450	225	90	180	375

M Eftekhari
S Firth
P Eames
R Buswell

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Figure Q1. P-H chart for R134