Building Energy Supply Systems and District Energy Networks
24CVP306

Semester 2 2025 Online Short-window Exam paper

This is an online short-window examination, meaning you have a total of **2 hours plus an 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) Compare and contrast the operation of a vapour compression and a lithium bromide absorption refrigeration system using schematics and heat balance equations. [10 marks]

b) A water chilling plant uses lithium bromide absorption system in which the generator is maintained at 80 °C using a hot-water coil. The evaporator and condenser saturation temperatures are 9 °C and 40 °C respectively, and the refrigeration capacity is 60 kW. It may be assumed that there is no undercooling in the condenser and that the water vapour leaving the evaporator is dry saturated. Assuming that there is a heat exchanger between the absorber and generator, sketch the plant, and calculate:

i) the heat supplied to the generator [8 marks]
ii) the heat rejected in the condenser [8 marks]
iii) the heat rejected in the absorber [7 marks]

You may use: hf at 45°C =167.5 kJ/kg, hg at 75°C = 2643.2 kJ/kg and hg at 9°C =2517.4 kJ/kg. For lithium bromide/water solutions, you may use the data given in Table Q1b.

Table Q1b: Data for lithium bromide/water solutions

	Mass concentration LiBr/mixture	Enthalpy kJ/kg
Weak solution leaving generator	0.60	-90.7
Strong solution leaving absorber	0.51	-172.1
Strong solution entering generator	0.51	-140.7

2 a) Renewable energy and low carbon technologies include solar thermal, solar PV, wind, biomass and heat pumps.

In your own words, for each of these technologies describe:
- the energy resource available including the origin and variability
- how the resource available compares with the typical energy demands of buildings
- reliability and maintenance requirements
- the potential for the technology to contribute to long-term national carbon dioxide emission reduction targets.

[10 marks]

Question 2 continues/…

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b) The annual heating demands for a house are 28,000 kWh per year. Heating is supplied by an 80% efficient boiler fuelled by wood pellets with the properties as given in Table 2b.

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

[2 marks]

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

[4 marks]

Table 2b: 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

c) Describe the second law of thermodynamics for a heat engine cycle, by drawing the cycle clearly and explaining the process.

[8 marks]

d) Describe the second law of thermodynamics and summarize the entropy changes of a closed system.

[5 marks]

e) A heat engine operates on the Carnot cycle. It produces 60 kW of power while operating between temperature limits of 600 ^{o}C and 100 ^{o}C.

Calculate the engine efficiency and the amount of heat added.

[4 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	τα	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 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 = 4200$Jkg^{-1}K^{-1}$) 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 0.2$Wm^{-2}K$ 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/…

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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 2m/s	Wind speed 2m/s
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 400W/m^2 and the back and side losses combined are 0.5 W/m^2/K 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) What is the difference between ‘net’ and ‘gross’ calorific value?

[3 marks]

b) With the aid of a diagram describe the principle features of a domestic/small commercial condensing boiler and how they affect the operation/efficiency of the boiler, and the space heating system, when compared to a conventional ‘high efficiency’ boiler system.

[16 marks]

c) State one gas, one liquid and one solid fuel used for heating boilers and state a typical calorific value for each. Compare these and discuss the advantages and disadvantages of each fuel in terms of delivery, handling and storage.

[8 marks]

d) Describe two possible boiler configuration options for supplying a maximum wintertime heat demand of 500kW, where there is a hot water heating load of 100kW required throughout the year. Comment on the advantages and/or disadvantages these options.

[6 marks]

M Eftekhari
R Buswell

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