Module Title: BS Services Mechanical 5

Module Code: INTR 7001

School: Mechanical and Process Engineering

Programme Title: Bachelor of Engineering in Building Services Engineering - Award

Programme Code: EBSEN_7_Y3

External Examiner(s): Mr. Paul O'Sullivan, Dr. Ben Costelloe
Internal Examiner(s): Mr. W. M. Corr

Instructions: Answer any 3 questions.

Duration: 2 Hours

Sitting: Summer 2010

Requirements for this examination:

Note to Candidates: Please check the Programme Title and the Module Title to ensure that you have received the correct examination paper. If in doubt please contact an Invigilator.
Q1. (a) Light lubricating oil \((c_p = 2090 \text{ J/kg . K})\) is cooled by allowing it to exchange energy with water in a small heat exchanger. The oil enters and leaves the heat exchanger at 375 K and 350 K, respectively, and flows at a rate of 0.5 kg/s. Water at 280 K is available in sufficient quantity to allow 0.201 kg/s to be used for cooling purposes. Determine the required heat-transfer area for counterflow operation. The overall heat-transfer coefficient may be taken as 250 W/m\(^2\). K. (10 Marks)

(b) If the water flowrate is now reduced to 0.10 kg/sec, calculate the new exit temperatures for the oil and water. (10 Marks)

Refer to Figure 1
Q2. (a) Explain what is meant by a selective absorber and a selective reflector surface and give one example each of a suitable application. (4 Marks)

(b) (i) Consider a surface exposed to solar radiation. At a given time, the net solar radiation is 675 W/m², and the direct radiation makes a 20° angle with the normal of the surface. The surface temperature is observed to be 320 K at that time.

Assuming an effective sky temperature of 260 K, determine the net rate of radiation heat transfer for these cases:
1. \( \alpha_s = 0.9 \) and \( \varepsilon = 0.9 \)
2. \( \alpha_s = 0.1 \) and \( \varepsilon = 0.1 \)
3. \( \alpha_s = 0.9 \) and \( \varepsilon = 0.1 \)
4. \( \alpha_s = 0.1 \) and \( \varepsilon = 0.9 \) (8 Marks)

and say what type of surface is each.

(ii) Comment briefly on the result (4) compared to (1), (2), (3). (6 Marks)

(iii) Sketch the spectral emissivities of the four surfaces.

\[
\Omega_{NET} = \alpha_s G_{SOLAR} + \varepsilon \sigma \left(T_{SKY}^4 - T_S^4\right)
\]

Take Stefan-Boltzman Constant \( \sigma = 5.67 \times 10^{-8} \, \text{W/m}^2\cdot\text{K}^4 \) (2 Marks)
Q3. (a) Describe three key differences between the ventilation of a cleanroom and that of an ordinary ventilated room. (4 marks)

(b) Give one application each for a C1 and a C1000 cleanroom. (4 marks)

(c) A cleanroom 10m x 20m x 3m is ventilated at a rate of 40 air changes per hour. The design calls for a maximum three persons occupying the room at any one time. If each person produces 800,000 particles per minute of size $\geq 5 \mu m$, and capture by gowning-up is 95%:

(i) Calculate the expected ISO class. (6 marks)

(ii) How many air sampling points are required to ensure compliance? (3 marks)

(iii) What is the recommended sample volume in litres? (3 marks)

Assume the incoming air is particle-free, i.e. all contamination arises from personnel within the cleanroom.

$$C_N = 10^N \left( \frac{0.1}{D} \right)^{2.08} \quad N_L = \sqrt{A} \quad V_s = \frac{20}{C_N} \cdot 1000$$

<table>
<thead>
<tr>
<th>AIRBORNE PARTICULATE CLEANLINESS CLASSES</th>
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<tr>
<td>Maximum concentration limits (particles/m³ of air) for particles equal to and larger than the considered sizes shown below</td>
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<table>
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<tr>
<th>ISO Classification</th>
<th>0,1 μm</th>
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<th>0,3 μm</th>
<th>0,5 μm</th>
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Q4.  (a) Write a note comparing cooling towers and air-cooled condensers as methods of heat rejection to outdoor air in air conditioning. List key design parameters in each case.  

(8 marks)

(b) 250,000 kg/h of water at 35°C enters a cooling tower where it is to be cooled to 17.5°C. The energy is to be exchanged with atmospheric air entering the unit at 15°C and leaving the unit at 30°C. The air enters at 30% R.H. and leaves at 85% R.H. If all processes are assumed to occur at atmospheric pressure:

(i) determine approximately the mass flow (kg/h) of air required.  

(6 marks)

(ii) the amount of make-up water (kg/h) required  

(4 marks)

(iii) the percentage of the total water flow that is make-up water.  

(2 marks)

Assume an average specific heat of 4.190 kJ/kg·K for the water and refer to Figure A.

Q5. Write a detailed essay on heat pump collector design.  

(20 Marks)
Effectiveness for heat exchangers (from Kays and London, Ref. 5).

FIGURE 1