UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2011/2012

SUBJECT : HEAT TRANSFER

CODE : BDA 3063/30603

PROGRAMME : BACHELOR OF MECHANICAL ENGINEERING WITH HONOURS

EXAMINATION DATE : JUNE 2012

DURATION : 3 HOURS

INSTRUCTIONS:

1. ANSWER ONLY **FIVE (5)** QUESTIONS FROM **SEVEN (7)** QUESTIONS

2. SYMBOLS HAVE COMMON DEFINITION UNLESS STATED OTHERWISE

3. STATE RELEVANT ASSUMPTIONS WHERE NECESSARY

THIS QUESTION PAPER CONTAINS **SEVEN (7)** PAGES

Q1 (a) Consider the flow of fluid in a tube. The fluid is at temperature differs from the temperature of the internal surface of the tube. Describe the meaning of thermal entry length for the fluid flow in the tube and define the region where the flow is fully developed.

(5 marks)

(b) Air enters an 18-cm-diameter 12-cm-long underwater pipe system at 50 °C and 1 atm at a mean velocity of 7 m/s, and is cooled by the surrounding water. If the average heat transfer coefficient is 65 $W/m^2 \cdot K$ and the tube temperature is nearly equal to the water temperature of 10 °C, determine

(i) the exit temperature of air and;

(ii) the rate of heat transfer.

(15 marks)

Q2 (a) Define the physical meaning of Grashof number. How does it differ from Reynolds number?

(4 marks)

(b) An aluminium isotonic drink can of 150-mm in length and 60-mm in diameter is placed horizontally inside a refrigerator compartment that maintains a temperature of 4 °C. If the surface temperature of the can is 36 °C, estimate heat transfer rate from the can surface. Neglect the heat transfer from the ends of the can.

(16 marks)

Q3 (a) The simplest type of heat exhanger consists of two-concentric pipes of different diameters where one fluid flows through the smaller pipe while the other fluid flows through the annular space between the two pipes. Describe the types of flow arrangement that are possible during heat transfer application for this heat exchanger (also called as double-pipe heat exchanger). *You may sketch approriate diagrams to support your answers.*

(6 marks)

(b) The LMTD method is very useful when the mass flow rate and the inlet and/or outlet temperatures of the hot and cold fluid are specified. In a water heating system, a double-pipe parallel-flow heat exchanger is used to heat water from 25 °C to 60 °C at a rate of 0.2 kg/s. The heating process is to be accomplished by geothermal water supply available at 140 °C at a mass flow rate of 0.3 kg/s. The inner tube is thin-walled and has a diameter of 0.8 cm. If the overall heat transfer coefficient of the heat exchanger is 550 $W/m^2 \cdot K$, determine :

(i) the rate of heat transfer for the heat exchanger;
(ii) the outlet temperature of the geothermal water;
(iii) the heat transfer surface area on the inner side of the tube; and
(iv) the length of tube required to achieve the desired heating.

(14 marks)

Q4 (a) Someone proposes to increase the size of a heat exchanger in order to increase its effectiveness. This gives an increase to the ***number of transfer units*** of the heat exchanger. What does the NTU of a heat exchanger represent?

`(5 marks)

(b) The analysis of a heat exchanger with unknown outlet temperatures can be carried out in straightforward manner using effectiveness–NTU method. Hot water (C_{ph} = 4188 J/kg·K) with mass flow rate of 2.5 kg/s at 100 °C enters a thin-walled concentric tube counter-flow heat exchanger with a surface area of 23 m^2 and an overall heat transfer coefficient, U of 1000 $W/m^2 \cdot K$. Cold water (C_{pc} = 4178 J/kg · °C) with mass flow rate of 5kg/s enters the heat exchanger at 20 °C. Determine;

(i) the effectiveness ε of the counter-flow heat exchanger;

(ii) the heat transfer rate; and

(iii) the outlet temperature of the cold water; and

(iv) the outlet temperature of the hot water.

(15 marks)

Q5 (a) Explain how the fins enhance heat transfer from a surface and give a practical example in heat transfer application.

(5 marks)

(b) Consider a plane wall with *surface temperature* of 350 °C. This wall is attached with a straight rectangular fin (k = 235 W/m·K) as shown in **Figure Q5**. The fin is exposed to an ambient air condition of 25 °C and the convection heat transfer coefficient is 154 $W/m^2 \cdot K$. The fin has a length of 50 mm, a base of 5 mm thick and a width of 100 mm. Calculate;

(i) the fin efficiency η_{fin} using **Table Q5**;

(ii) the heat transfer rate ; and

(iii) the fin effectiveness ε_{fin}.

(15 marks)

Q6 (a) A typical human eye responds to radiation wavelength in the 390 to 750 Nm range. Based on the Plank distribution shown in **Figure Q6 (a)**, estimate the minimum surface temperature of a material that would be visible to human eye?

(5 marks)

(b) For the enclosure shown in **Rajah Q6 (b)**, determine the view factors F_{12} and F_{21}.

(5 marks)

(c) A hangar shown in **Figure Q6 (c)** is constructed of a long semi-cylindrical roof of 30 m radius. The floor and the roof of the hangar have emissivities of 0.5 and 0.9 and are maintained at uniform temperatures of 30°C and 50°C respectively. Determine the net rate of radiation heat transfer from the dome to the floor surface per unit length. You may use the equation given in the figure.

(10 marks)

Q7 (a) Discuss **how** does radiosity for a surface differ from the emitted energy and **state** for what kind of surfaces these quantities become identical.

(5 marks)

(b) Explain **what** radiation shield is and **why** it is used.

(5 marks)

(c) An experiment is conducted to determine the emissivity of an unknown material. A long cylinder rod having diameter of $D_1 = 0.01$ m is coated with this unknown material and is placed in an evacuated long cylindrical enclosure of diameter $D_2 = 0.1$ m and emissivity $\varepsilon_2 = 0.95$, which is cooled externally and maintained at a temperature of 200 K. The rod is heated and at steady operating conditions, the rod dissipates electric power at a rate of 12 W per unit of its length and its surface temperature is 600 K. Based on these measurements, determine the emissivity of the unknown material, ε_1.

(10 marks)

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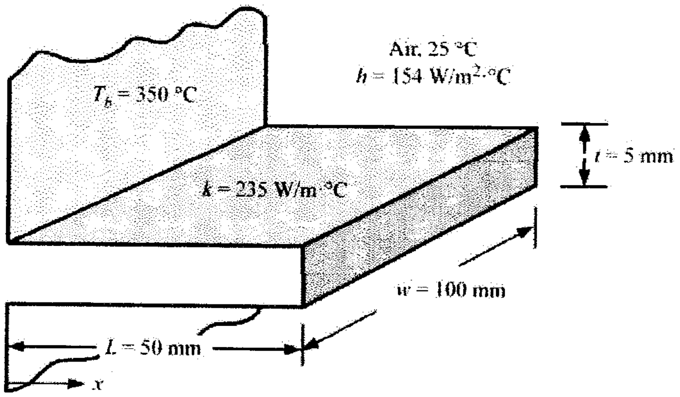
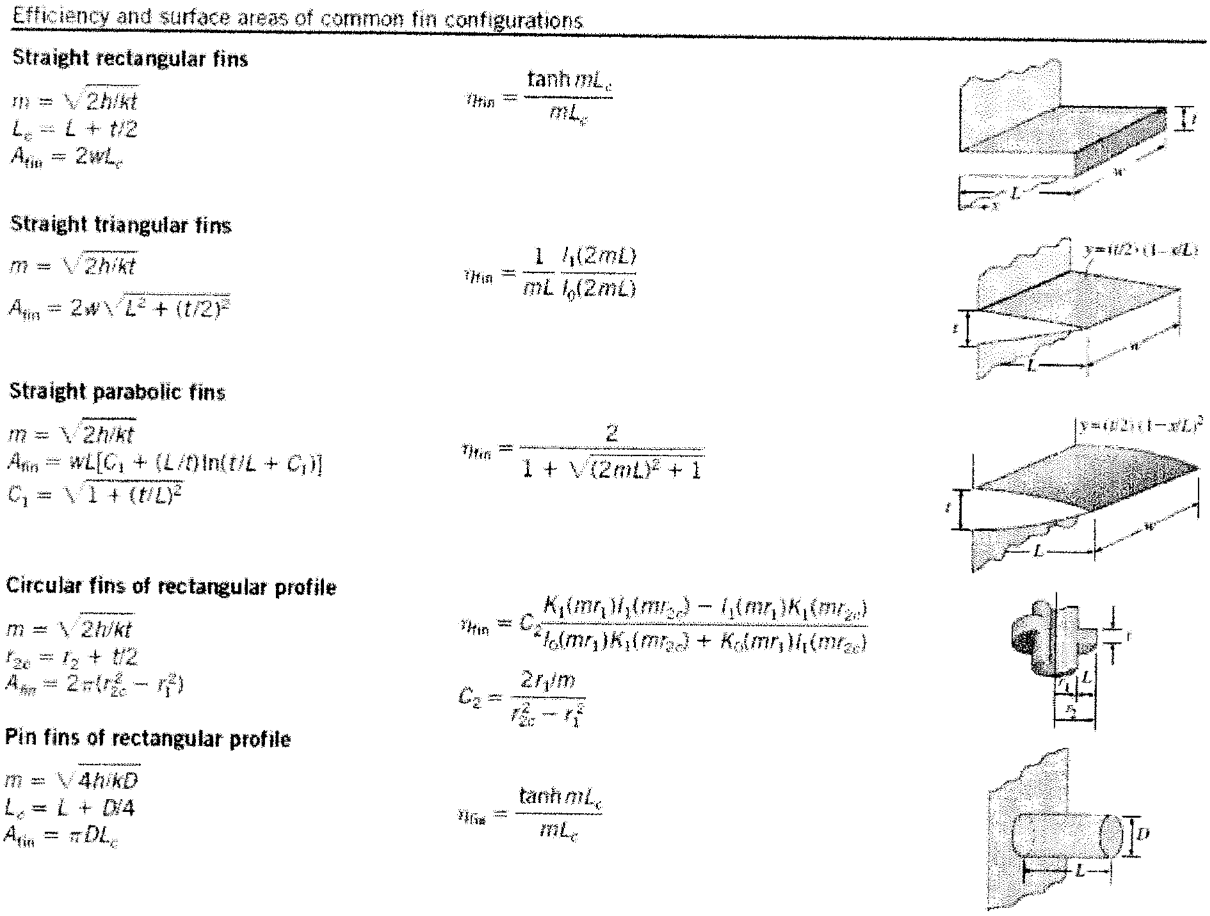


Figure Q5



Efficiency and surface areas of common fin configurations

Straight rectangular fins $m = \sqrt{2h/kt}$ $L_c = L + t/2$ $A_{fin} = 2wL_c$	$\eta_{fin} = \dfrac{\tanh mL_c}{mL_c}$	
Straight triangular fins $m = \sqrt{2h/kt}$ $A_{fin} = 2w\sqrt{L^2 + (t/2)^2}$	$\eta_{fin} = \dfrac{1}{mL}\dfrac{I_1(2mL)}{I_0(2mL)}$	
Straight parabolic fins $m = \sqrt{2h/kt}$ $A_{fin} = wL[C_1 + (L/t)\ln(t/L + C_1)]$ $C_1 = \sqrt{1 + (t/L)^2}$	$\eta_{fin} = \dfrac{2}{1 + \sqrt{(2mL)^2 + 1}}$	
Circular fins of rectangular profile $m = \sqrt{2h/kt}$ $r_{2c} = r_2 + t/2$ $A_{fin} = 2\pi(r_{2c}^2 - r_1^2)$	$\eta_{fin} = C_2\dfrac{K_1(mr_1)I_1(mr_{2c}) - I_1(mr_1)K_1(mr_{2c})}{I_0(mr_1)K_1(mr_{2c}) + K_0(mr_1)I_1(mr_{2c})}$ $C_2 = \dfrac{2r_1/m}{r_{2c}^2 - r_1^2}$	
Pin fins of rectangular profile $m = \sqrt{4h/kD}$ $L_c = L + D/4$ $A_{fin} = \pi DL_c$	$\eta_{fin} = \dfrac{\tanh mL_c}{mL_c}$	

Table Q5

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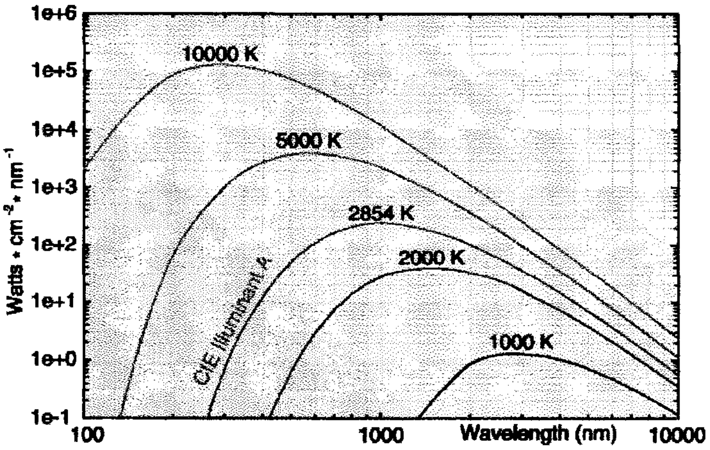


Figure Q6 (a)

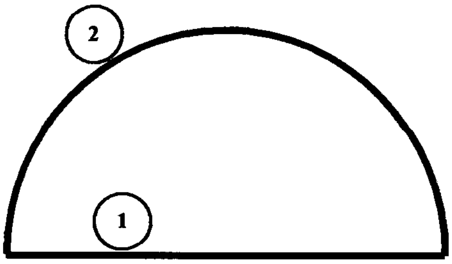
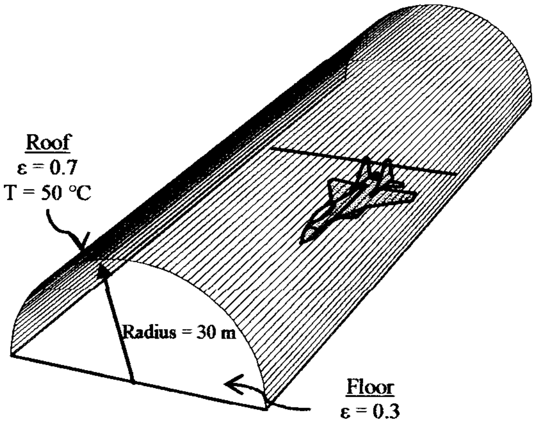


Figure Q6 (b)



$$\dot{Q}_{12} = \frac{\sigma(T_1^4 - T_2^4)}{\left(1-\varepsilon_1 \big/ A_1\varepsilon_1\right) + \left(1 \big/ A_1F_{12}\right) + \left(1-\varepsilon_2 \big/ A_2\varepsilon_2\right)}$$

Figure Q6 (c)