UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2016/2017

COURSE NAME	:	HEAT TRANSFER
COURSE CODE	:	BDA 30603
PROGRAMME	:	BDD
EXAMINATION DATE	:	JUNE 2017
DURATION	:	3 HOURS
INSTRUCTIONS	:	

A) ANSWER **ONLY** FIVE (5) QUESTIONS FROM SEVEN (7) QUESTIONS

B) SYMBOLS HAVE COMMON DEFINITION UNLESS STATED OTHERWISE

C) STATE RELEVANT ASSUMPTIONS WHERE NECESSARY

THIS QUESTION PAPER CONSISTS OF **TEN (10)** PAGES

Q1 (a) As shown in **FIGURE Q1**, a hot surface at 100°C is to be cooled by attaching 3 cm long, 0.25 cm diameter aluminum pin fins (k = 237 W/m·K) to it, with a center to center distance of 0.6 cm. The temperature of the surrounding medium is 30°C, and the heat transfer coefficient on the surfaces is 35 W/m^2·K.

(i) Draw the thermal circuit diagram.
(ii) Determine the efficiency of each fin.
(iii) Determine the rate of heat transfer from the surface for a 1 m x 1 m section of the plate, including both finned and un-finned areas.
(iv) Determine the overall effectiveness of the fins.

(20 marks)

Q2 (a) The equation for constant thermal conductivity for a cylinder can be written as

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial T}{\partial r}\right)+\frac{\dot{e}_{gen}}{k}=\frac{1}{\alpha}\frac{\partial T}{\partial t}$$

where, k – thermal conductivity, [W·m^{-1}·K^{-1}]

please re-write the equation based on these specified conditions:

(i) Steady-state condition.
(ii) Steady-state with no heat generation.
(iii) Transient with no heat generation.
(iv) Transient with heat generation.

(8 marks)

(b) A 20 meter long steel pipe (k = 15 W·m^{-1}·K^{-1}) has inner and outer diameter of 8 cm and 10 cm, respectively. The pipe carries steam at 230 °C in an environment at 10 °C. To minimize heat loss to surrounding, the pipe is insulated with 5 mm thick fiberglass insulation (k = 0.035 W·m^{-1}·K^{-1}). If the heat transfer coefficients on the inside and outside of the pipe are 170 W·m^{-2}·K^{-1} and 30 W·m^{-2}·K^{-1} respectively, determine the heat loss from the steam through the pipe.

(12 marks)

Q3 (a) A transformer that is 10 cm long, 6.2 cm wide, and 5 cm high is to be cooled by attaching a 10-cm x 6.2-cm wide polished aluminum heat sink (emissivity = 0.03) to its top surface. The heat sink has seven fins, which are 5 mm high, 2 mm thick, and 10 cm long. A fan blows air at 25 °C parallel to the passages between the fins. The heat sink is to dissipate 12W of heat and the base temperature of the heat sink is not to exceed 60 °C. Determine the minimum free-stream velocity the fan needs to supply to avoid overheating for the following cases:

(i) Assuming the fins and the base plate to be nearly isothermal and the radiation heat transfer to be negligible.

(ii) Assuming the heat sink to be black-ionized and thus to have an effective emissivity of 0.90. Note that in radiation calculations the base area (10 cm x 6.2 cm) is to be used, not the total surface area.

(20 marks)

Q4 (a) Differentiate the application of Reynolds Number and Grasshoff Number in convective heat transfer analysis.

(3 marks)

(b) In a plant that manufactures steel balls, the balls go through a surface treatment process at 30°C before being cooled in a water bath at 10°C. The cooling process involves batch cooling consists of 100 steel balls for each water bath. Assume there are no radiative heat transfer and the balls diameter to be at D = 2cm, determine the heat transfer rate of the steel balls.

(14 marks)

(c) As an engineer you have been given a task to design a new cooling system with air as the cooling medium to replace water bath system mentioned in Q4(b). Three possible designs have been proposed as in **FIGURE Q4 (c)**. Choose your preferred design and clarify your choice.

(3 marks)

Q5 (a) To simplify the analysis of heat exchanger, several approximations are usually made. Discuss three (3) of them.

(6 marks)

(b) A shell-and-tube heat exchanger with 1-shell pass and 20–tube passes is used to heat glycerin (C_p = 2480 J·kg^{-1}·°C^{-1}) in the shell, with hot water in the tubes. The tubes are thin-walled and have a diameter of 1.5 cm and length of 2 m per pass. The water enters the tubes at 100 °C at a rate of 5 kg.s^{-1} and leaves at 55 °C. The glycerin enters the shell at 15 °C and leaves at 55 °C. Determine the mass flow rate of the glycerin and the overall heat transfer coefficient of the heat exchanger.

(14 marks)

Q6 (a) Consider a heat exchanger that has an NTU of 4. Someone proposes to double the size of the heat exchanger and thus double the NTU to 8 in order to increase the effectiveness of the heat exchanger and thus save energy. Discuss whether you will support or reject this proposal

(5 marks)

(b) Hot oil (C_p = 2200 J·kg^{-1}·°C^{-1}) is to be cooled by water (C_p = 4180 J·kg^{-1}·°C^{-1}) in a 2-shell passes and 12-tube passes heat exchanger. The tubes are thin walled and are made of copper with a diameter of 1.8 cm. The length of each tube pass in the heat exchanger is 3 m, and the overall heat transfer co-efficient is 340 W·m^{-2}·°C^{-1}. Water flow rate inside the tube is 0.1 kg·s^{-1} while the oil flow rate inside the shell is 0.2 kg·s^{-1}. If the water and oil enters the heat exchanger at 18 °C and 160 °C respectively, determine the heat transfer rate inside the heat exchanger and the outlet temperatures of both water and oil.

(15 marks)

Q7 (a) Two parallel concentric discs are shown in **FIGURE Q7 (a)**, where diameters D_1 = 40 cm and D_2 = 20 cm. The disks are separated by a distance by a distance of L = 10 cm. The smaller disk (ε = 0.80) is at a temperature of 300°C, whilst the larger one (ε = 0.60) is at a temperature of 800°C

(i) Calculate the radiation view factors.
(ii) Determine the rate of radiation heat exchange between the disks.
(iii) Suppose that the space between the two disks is completely surrounded by a reflective surface. Estimate the rate of radiation heat exchange between the two disks.

(10 marks)

(b) A 2 m internal diameter double walled spherical tank, shown in **FIGURE Q7 (b),** is used to store iced water at 0°C. Each wall is 0.5 cm thick, and the 1.5 cm thick air space between the two walls of the tank is evacuated in order to minimize heat transfer. The surfaces surrounding the evacuated space are polished so that each surface has an emissivity of 0.15. The temperature of the outer wall of the tank is measured to be 20°C. Assuming the inner wall of the steel tank to be at 0°C, determine:

(i) The rate of heat transfer to the iced water in the tank.
(ii) The amount of ice at 0°C that melts during a 24 hour period.

(10 marks)

- END OF QUESTIONS –

FINAL EXAMINATION

SEMESTER/SESSION : SEM II 2016/2017 PROGRAMME : BDD
COURSE NAME : HEAT TRANSFER COURSE CODE : BDA30603

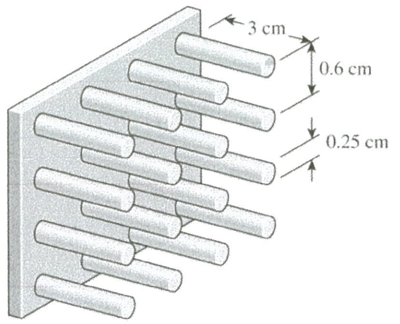


FIGURE Q1

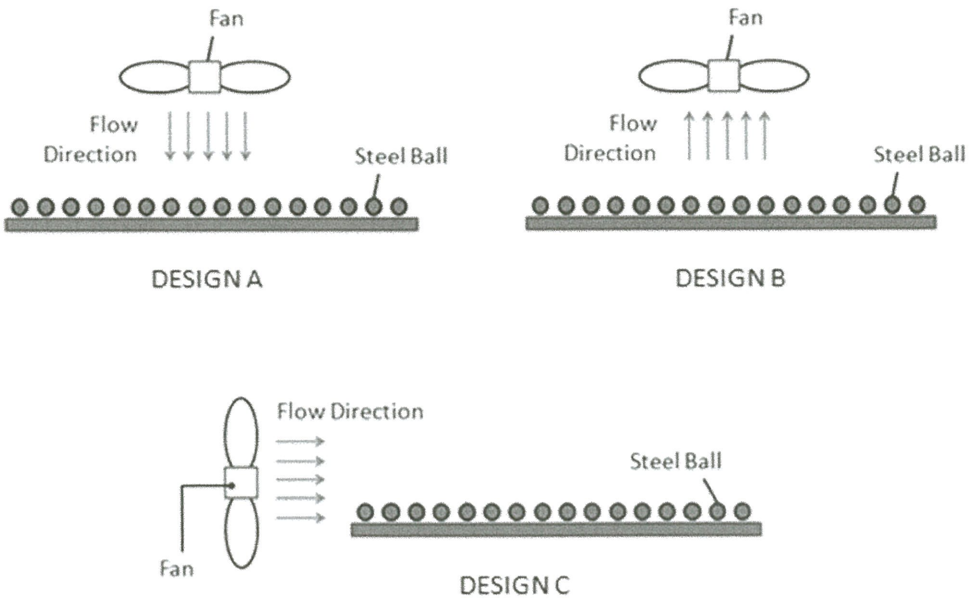


FIGURE Q4 (c)

FINAL EXAMINATION

SEMESTER/SESSION : SEM II 2016/2017 PROGRAMME : BDD
COURSE NAME : HEAT TRANSFER COURSE CODE : BDA30603

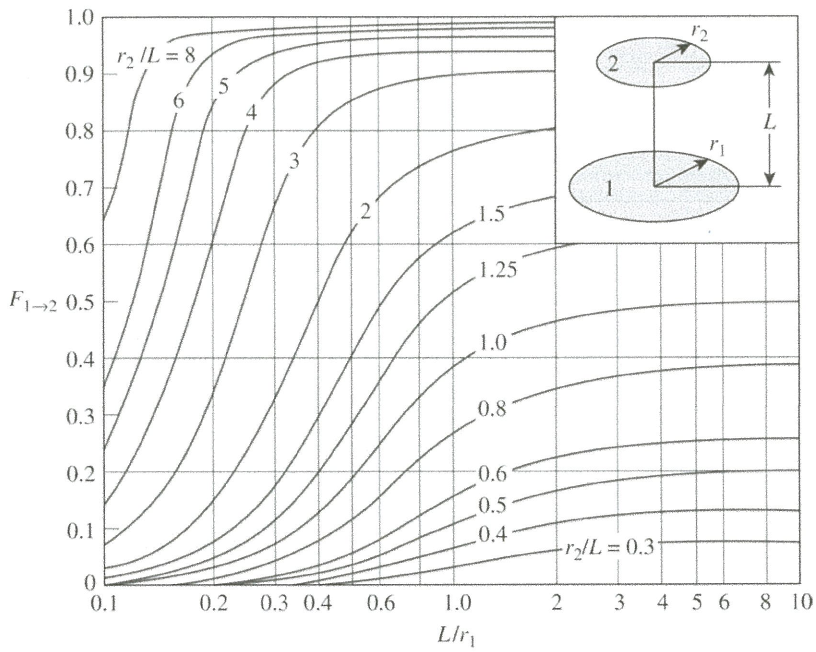


FIGURE Q7 (a)

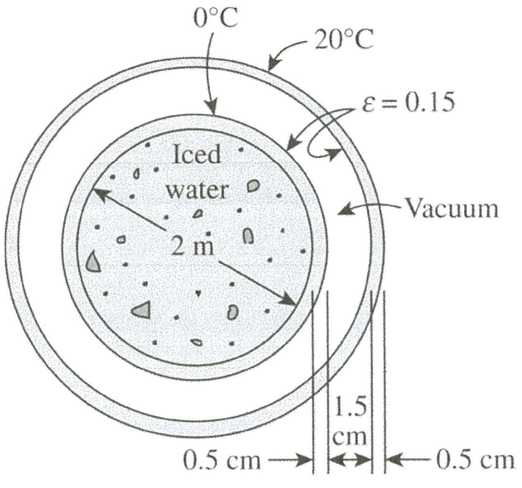


FIGURE Q7 (b)

APPENDIX A

Efficiency and surface areas of common fin configurations

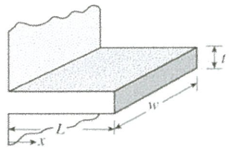
Straight rectangular fins

$m = \sqrt{2h/kt}$

$L_c = L + t/2$

$A_{fin} = 2wL_c$

$$\eta_{fin} = \frac{\tanh mL_c}{mL_c}$$

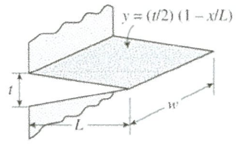


Straight triangular fins

$m = \sqrt{2h/kt}$

$A_{fin} = 2w\sqrt{L^2 + (t/2)^2}$

$$\eta_{fin} = \frac{1}{mL}\frac{I_1(2mL)}{I_0(2mL)}$$



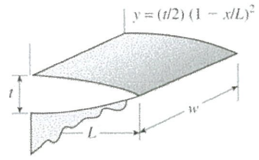
Straight parabolic fins

$m = \sqrt{2h/kt}$

$A_{fin} = wL[C_1 + (L/t)\ln(t/L + C_1)]$

$C_1 = \sqrt{1 + (t/L)^2}$

$$\eta_{fin} = \frac{2}{1 + \sqrt{(2mL)^2 + 1}}$$



Circular fins of rectangular profile

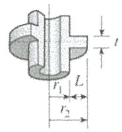
$m = \sqrt{2h/kt}$

$r_{2c} = r_2 + t/2$

$A_{fin} = 2\pi(r_{2c}^2 - r_1^2)$

$$\eta_{fin} = C_2\frac{K_1(mr_1)I_1(mr_{2c}) - I_1(mr_1)K_1(mr_{2c})}{I_0(mr_1)K_1(mr_{2c}) + K_0(mr_1)I_1(mr_{2c})}$$

$$C_2 = \frac{2r_1/m}{r_{2c}^2 - r_1^2}$$



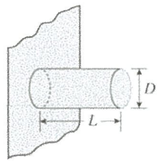
Pin fins of rectangular profile

$m = \sqrt{4h/kD}$

$L_c = L + D/4$

$A_{fin} = \pi DL_c$

$$\eta_{fin} = \frac{\tanh mL_c}{mL_c}$$



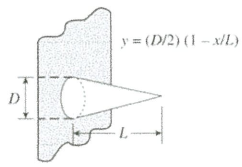
Pin fins of triangular profile

$m = \sqrt{4h/kD}$

$A_{fin} = \frac{\pi D}{2}\sqrt{L^2 + (D/2)^2}$

$$\eta_{fin} = \frac{2}{mL}\frac{I_2(2mL)}{I_1(2mL)}$$

$I_2(x) = I_0(x) - (2/x)I_1(x)$ where $x = 2mL$



Pin fins of parabolic profile

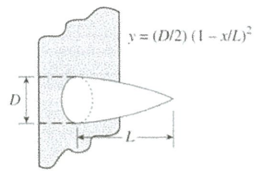
$m = \sqrt{4h/kD}$

$A_{fin} = \frac{\pi L^3}{8D}[C_3C_4 - \frac{L}{2D}ln(2DC_4/L + C_3)]$

$C_3 = 1 + 2(D/L)^2$

$C_4 = \sqrt{1 + (D/L)^2}$

$$\eta_{fin} = \frac{2}{1 + \sqrt{(2mL/3)^2 + 1}}$$



Pin fins of parabolic profile (blunt tip)

$m = \sqrt{4h/kD}$

$A_{fin} = \frac{\pi D^4}{96L^2}\left\{[16(L/D)^2 + 1]^{3/2} - 1\right\}$

$$\eta_{fin} = \frac{3}{2mL}\frac{I_1(4mL/3)}{I_0(4mL/3)}$$

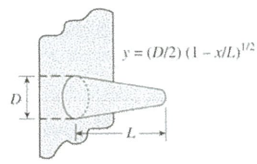


FIGURE A1: Efficiency and Surface Areas of Common Fin Configurations

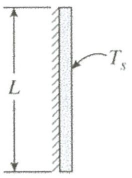
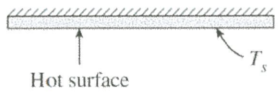
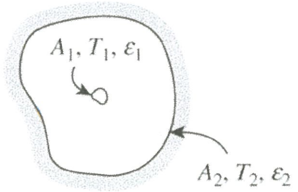
Empirical correlations for the average Nusselt number for natural convection over surfaces			
Geometry	Characteristic length L_c	Range of Ra	Nu
Vertical plate 	L	10^4–10^9 10^{10}–10^{13} Entire range	$Nu = 0.59Ra_L^{1/4}$ $Nu = 0.1Ra_L^{1/3}$ $Nu = \left\{0.825 + \frac{0.387Ra_L^{1/6}}{[1 + (0.492/Pr)^{9/16}]^{8/27}}\right\}^2$ (complex but more accurate)
Horizontal plate (Surface area A and perimeter p) (*a*) Upper surface of a hot plate (or lower surface of a cold plate)  (*b*) Lower surface of a hot plate (or upper surface of a cold plate) 	A_s/p	10^4–10^7 10^7–10^{11} 10^5–10^{11}	$Nu = 0.54Ra_L^{1/4}$ $Nu = 0.15Ra_L^{1/3}$ $Nu = 0.27Ra_L^{1/4}$

FIGURE A2: Empirical Correlation for Average Nusselt Number for Natural Convection

Radiation heat transfer relations for some familiar two-surface arrangments.

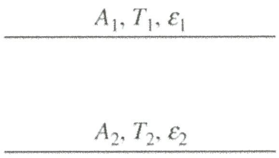
Small object in a large cavity



$$\frac{A_1}{A_2} \approx 0 \qquad F_{12} = 1$$

$$\dot{Q}_{12} = A_1 \sigma \varepsilon_1 (T_1^4 - T_2^4) \qquad \textbf{(13–37)}$$

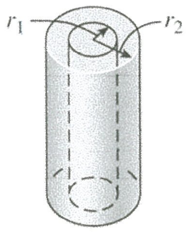
Infinitely large parallel plates



$$A_1 = A_2 = A \qquad F_{12} = 1$$

$$\dot{Q}_{12} = \frac{A\sigma(T_1^4 - T_2^4)}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1} \qquad \textbf{(13–38)}$$

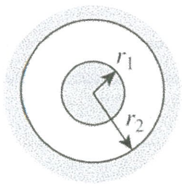
Infinitely long concentric cylinders



$$\frac{A_1}{A_2} = \frac{r_1}{r_2} \qquad F_{12} = 1$$

$$\dot{Q}_{12} = \frac{A_1\sigma(T_1^4 - T_2^4)}{\frac{1}{\varepsilon_1} + \frac{1 - \varepsilon_2}{\varepsilon_2}\left(\frac{r_1}{r_2}\right)} \qquad \textbf{(13–39)}$$

Concentric spheres



$$\frac{A_1}{A_2} = \left(\frac{r_1}{r_2}\right)^2 \qquad F_{12} = 1$$

$$\dot{Q}_{12} = \frac{A_1\sigma(T_1^4 - T_2^4)}{\frac{1}{\varepsilon_2} + \frac{1 - \varepsilon_2}{\varepsilon_2}\left(\frac{r_1}{r_2}\right)^2} \qquad \textbf{(13–40)}$$

FIGURE A3: Radiation Heat Transfer Relations for Some Familiar Two-surface Arrangements