Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2016/2017

COURSE NAME	:	HEAT TRANSFER
COURSE CODE	:	BNL 30703
PROGRAMME CODE	:	BNL
EXAMINATION DATE	:	JUNE 2017
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWERS **ALL** QUESTIONS

THIS QUESTION PAPER CONSISTS OF **NINE (9)** PAGES

Q1 (a) An aluminuim pan whose thermal conductivity is 240 W/m.K has a flat bottom with a diameter of 16 cm and a thickness of 0.6 cm, as shown in **Figure Q1(a)**. Heat is transferred steadily to boiling water in the pan through its bottom at a rate of 1800 W. If the inner surface of the bottom of the pan is at 105 °C, calculate the temperature of the outer surface of the bottom of the pan.

(8 marks)

(b) Consider a 1.2 m high and 2 m wide double-pane window consisting of 3 mm thick layers of silica glass (k = 1.38 W/m.K) separated by a 12 mm wide stagnant air space (k = 0.026 W/m.K). The room is maintained at 25 °C while the temperature of the outdoors is - 7 °C. Take the convection heat transfer coefficients on the inner and outer surfaces of the window to be h_1 = 12 W/m^2. K and h_2 = 30 W/m^2.K, and disregard any heat transfer by radiation

(i) Determine the rate of heat transfer through the double-pane window.

(10 marks)

(ii) Calculate the inner surface temperature of the window glass.

(2 marks)

Q2 (a) Discuss whether the efficiency and the effectiveness of a fin will decrease or increase as the fin length is increased.

(4 marks)

(b) A 15 cm × 20 cm integrated circuit board is to be cooled by attaching 4 cm long aluminum (k = 237 W/m.K) fins on one side of it, as shown in **Figure Q2 (b)**. Each fins has a 2 mm × 2 mm square cross section. The surrounding ambient temperature is 25 °C and the convection heat transfer coefficient on each fin surface is 20 W/m^2.K. To prevent the circuit board from overheating, the upper surface of the circuit board needs to be at 85 °C or cooler. Design a finned surface having the appropriate number of fins, with an overall effectiveness of 3 that can keep the circuit board surface from overheating.

(16 marks)

Q3 (a) Write the difference between heat conduction and heat convection.

(3 marks)

(b) A 10 m long section of an 8 cm diameter horizontal hot-water pipe shown in **Figure Q3(b)** passes through a large room whose temperature is 10 °C and the outer surface temperature of the pipe is 70 °C. By using **Table Q3(b)**,

(i) Calculate the value of Rayleigh number.

(6 marks)

(ii) Calculate the value of the Nusselt number.

(3 marks)

(iii) Determine the rate of heat loss from the pipe by natural convection.

(6 marks)

(iii) Assuming the outer surface of the of the pipe to be black, and the inner surfaces of the walls of the room to be at room temperature, determine the radiation heat transfer rate, where $\sigma = 5.67 \times 10^{-8}$ W/m^2.K^4, respectively.

(2 marks)

Q4 (a) Outline the common causes of fouling in a heat exchanger.

(5 marks)

(b) Briefly explain how does the fouling affect heat transfer and pressure drop.

(4 marks)

(c) Steam in the condenser of a steam power plant is to be condensed at a temperature of 50 °C (h_{fg} = 2305 kJ/kg) with cooling water (c_p = 4180 J/kg. °C) from a nearby lake, which enters the tubes of the condenser at 18 °C and leaves at 27 °C, as shown in **Figure Q4(c)**. The surface area of the tubes is 58 m^2, and the overall heat transfer coefficient is 2400 W/m^2. °C.

(i) Determine the mass flow rate of the cooling water needed.

(8 marks)

(ii) Calculate the rate of condensation of steam in the condenser.

(3 marks)

Q5 **(a)** Describe the difference between microwave cooking and conventional cooking.

(6 marks)

(b) Charge-coupled device (CCD) image sensors, that are common in modern digital cameras, respond differently to light sources with different spectral distributions. Daylight and incandescent light may be approximated as a blackbody at the effective surface temperatures of 6000 K and 3000 K, respectively. By using **Table Q5(b),** determine the fraction of radiated emitted within the visible spectrum wavelengths, from 0.40 μm (violet) to 0.76 μm (red), for each of the lighting sources.

The fraction of radiation energy can be determined by using the following equation;

$$f_{\lambda_1-\lambda_2}(T) = f_{\lambda_2}(T) - f_{\lambda_2}(T)$$

where, $f_{\lambda_2}(T)$ and $f_{\lambda_2}(T)$ are blackbody radiation functions corresponding to $\lambda_1 T$ and $\lambda_2 T$, respectively.

(14 marks)

-END OF QUESTIONS -

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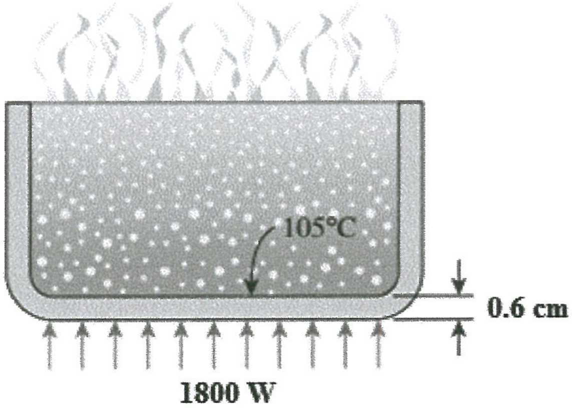
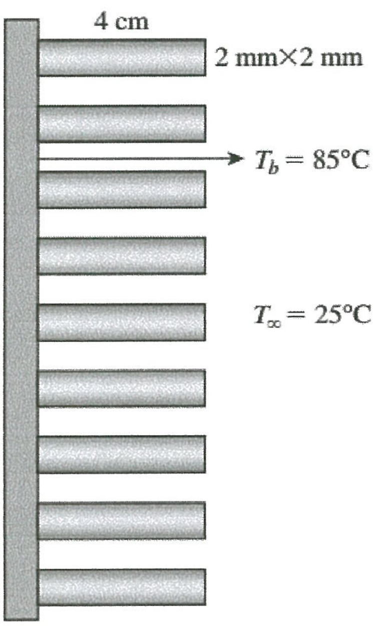


Figure Q1(a)



Straight rectangular fins

$$m = \sqrt{\frac{hp}{kA_c}} = \sqrt{\frac{4ha}{ka^2}}$$

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

$$\dot{Q}_{finned} = \eta_{fin}\dot{Q}_{fin,max} = \eta_{fin} h A_{fin}(T_b - T_\infty)$$

$$\dot{Q}_{finned} = hA_{unfinned}(T_b - T_\infty)$$

$$\dot{Q}_{no\ fin} = hA_{no\ fin}(T_b - T_\infty)$$

$$\varepsilon_{fin} = \frac{\dot{Q}_{fin}}{\dot{Q}_{no\ fin}}$$

Figure Q2(b)

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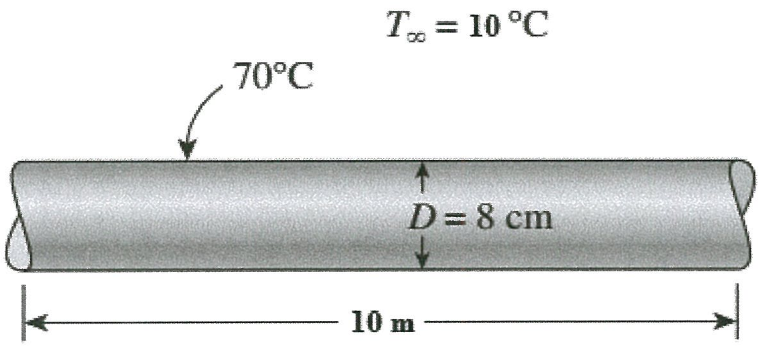

$$Ra_L = \frac{g\beta(T_s - T_\infty)D^3}{v^2}$$

$$Nu = \left\{0.6 + \frac{0.387\, Ra_D^{1/6}}{[1 + (0.559/Pr)^{9/16}]^{8/27}}\right\}^2$$

$$Nu = \frac{hD}{k}$$

Figure Q3(b)

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Table Q3(b)

Properties of air at 1 atm pressure

Temp. T, °C	Density ρ, kg/m³	Specific Heat c_p, J/kg·K	Thermal Conductivity k, W/m·K	Thermal Diffusivity α, m²/s	Dynamic Viscosity μ, kg/m·s	Kinematic Viscosity ν, m²/s	Prandtl Number Pr
−150	2.866	983	0.01171	4.158×10^{-6}	8.636×10^{-6}	3.013×10^{-6}	0.7246
−100	2.038	966	0.01582	8.036×10^{-6}	1.189×10^{-5}	5.837×10^{-6}	0.7263
−50	1.582	999	0.01979	1.252×10^{-5}	1.474×10^{-5}	9.319×10^{-6}	0.7440
−40	1.514	1002	0.02057	1.356×10^{-5}	1.527×10^{-5}	1.008×10^{-5}	0.7436
−30	1.451	1004	0.02134	1.465×10^{-5}	1.579×10^{-5}	1.087×10^{-5}	0.7425
−20	1.394	1005	0.02211	1.578×10^{-5}	1.630×10^{-5}	1.169×10^{-5}	0.7408
−10	1.341	1006	0.02288	1.696×10^{-5}	1.680×10^{-5}	1.252×10^{-5}	0.7387
0	1.292	1006	0.02364	1.818×10^{-5}	1.729×10^{-5}	1.338×10^{-5}	0.7362
5	1.269	1006	0.02401	1.880×10^{-5}	1.754×10^{-5}	1.382×10^{-5}	0.7350
10	1.246	1006	0.02439	1.944×10^{-5}	1.778×10^{-5}	1.426×10^{-5}	0.7336
15	1.225	1007	0.02476	2.009×10^{-5}	1.802×10^{-5}	1.470×10^{-5}	0.7323
20	1.204	1007	0.02514	2.074×10^{-5}	1.825×10^{-5}	1.516×10^{-5}	0.7309
25	1.184	1007	0.02551	2.141×10^{-5}	1.849×10^{-5}	1.562×10^{-5}	0.7296
30	1.164	1007	0.02588	2.208×10^{-5}	1.872×10^{-5}	1.608×10^{-5}	0.7282
35	1.145	1007	0.02625	2.277×10^{-5}	1.895×10^{-5}	1.655×10^{-5}	0.7268
40	1.127	1007	0.02662	2.346×10^{-5}	1.918×10^{-5}	1.702×10^{-5}	0.7255
45	1.109	1007	0.02699	2.416×10^{-5}	1.941×10^{-5}	1.750×10^{-5}	0.7241
50	1.092	1007	0.02735	2.487×10^{-5}	1.963×10^{-5}	1.798×10^{-5}	0.7228
60	1.059	1007	0.02808	2.632×10^{-5}	2.008×10^{-5}	1.896×10^{-5}	0.7202
70	1.028	1007	0.02881	2.780×10^{-5}	2.052×10^{-5}	1.995×10^{-5}	0.7177
80	0.9994	1008	0.02953	2.931×10^{-5}	2.096×10^{-5}	2.097×10^{-5}	0.7154
90	0.9718	1008	0.03024	3.086×10^{-5}	2.139×10^{-5}	2.201×10^{-5}	0.7132
100	0.9458	1009	0.03095	3.243×10^{-5}	2.181×10^{-5}	2.306×10^{-5}	0.7111

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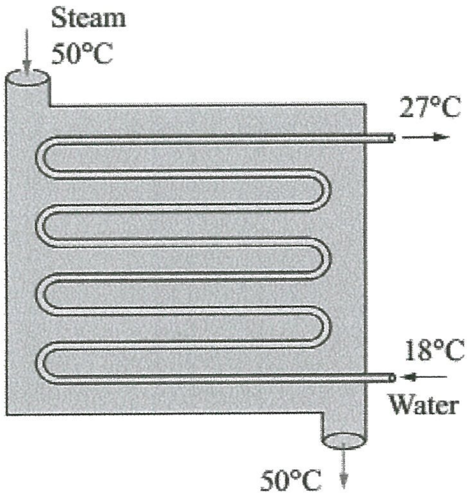

$$\dot{Q} = UA_s \Delta T_{lm}$$

$$\Delta T_{lm} = \frac{\Delta T_1 - \Delta T_2}{ln\,(\Delta T_1 / \Delta T_2)}$$

Figure Q4(c)

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Table Q5(b)

Blackbody radiation functions f_λ

λT, μm·K	f_λ	λT, μm·K	f_λ
200	0.000000	6200	0.754140
400	0.000000	6400	0.769234
600	0.000000	6600	0.783199
800	0.000016	6800	0.796129
1000	0.000321	7000	0.808109
1200	0.002134	7200	0.819217
1400	0.007790	7400	0.829527
1600	0.019718	7600	0.839102
1800	0.039341	7800	0.848005
2000	0.066728	8000	0.856288
2200	0.100888	8500	0.874608
2400	0.140256	9000	0.890029
2600	0.183120	9500	0.903085
2800	0.227897	10,000	0.914199
3000	0.273232	10,500	0.923710
3200	0.318102	11,000	0.931890
3400	0.361735	11,500	0.939959
3600	0.403607	12,000	0.945098
3800	0.443382	13,000	0.955139
4000	0.480877	14,000	0.962898
4200	0.516014	15,000	0.969981
4400	0.548796	16,000	0.973814
4600	0.579280	18,000	0.980860
4800	0.607559	20,000	0.985602
5000	0.633747	25,000	0.992215
5200	0.658970	30,000	0.995340
5400	0.680360	40,000	0.997967
5600	0.701046	50,000	0.998953
5800	0.720158	75,000	0.999713
6000	0.737818	100,000	0.999905