國立中山大學114學年度
碩士班考試入學招生考試試題

科目名稱：基礎熱傳學【機電系碩士班甲組】

—作答注意事項—

考試時間：100分鐘

- **考試開始鈴響前不得翻閱試題，並不得書寫、劃記、作答。**請先檢查答案卷（卡）之應考證號碼、桌角號碼、應試科目是否正確，如有不同立即請監試人員處理。
- **答案卷限用藍、黑色筆(含鉛筆)書寫、繪圖或標示**，可攜帶橡皮擦、無色透明無文字墊板、尺規、修正液（帶）、手錶(未附計算器者)。每人每節限使用一份答案卷，請衡酌作答。
- 答案卡請以2B鉛筆劃記，不可使用修正液（帶）塗改，未使用2B鉛筆、劃記太輕或污損致光學閱讀機無法辨識答案者，後果由考生自負。
- 答案卷（卡）應保持清潔完整，不得折疊、破壞或塗改應考證號碼及條碼，亦不得書寫考生姓名、應考證號碼或與答案無關之任何文字或符號。
- 可否使用計算機請依試題資訊內標註為準，如「可以」使用，廠牌、功能不拘，唯不得攜帶書籍、紙張（應考證不得做計算紙書寫）、具有通訊、記憶、傳輸或收發等功能之相關電子產品或其他有礙試場安寧、考試公平之各類器材入場。
- 試題及答案卷（卡）請務必繳回，未繳回者該科成績以零分計算。
- 試題採雙面列印，考生應注意試題頁數確實作答。
- 違規者依本校招生考試試場規則及違規處理辦法處理。

1. (6%) Explain the difference between Biot number and Nusselt number.

2. (6%) Write the criterion for lumped system analysis. Illustrate the physical meaning.

3. (12%) Oil is cooled by spraying a mist of the hot liquid through cool air at $T_\infty = 27°C$. Two droplets with diameter D = 50 μm and temperature 300°C suddenly collide and merge into a single droplet. The velocity of the droplets is V = 5 m/s. Assume the velocities and temperatures are identical before and after the droplets merge. Please calculate the heat transfer rate from the oil to the air before and after the droplets merge.

4. (18%) To use a natural cooling source to cool a home without a vapor compression cycle, the air is routed through a plastic pipe with a thermal conductivity of 0.15 W/mK, an inner diameter of 0.15m, and an outer diameter of 0.17m. The plastic is submerged in an adjacent lake with a nominal temperature $T_\infty = 20°C$, and a convection coefficient of $h_o = 1500$ W/m^{2}K is maintained at the outer surface of the pipe. The flowrate entering the pipe is 0.030 m^3/s with a temperature of $T_{m,i} = 27°C$.

   (a) What pipe length L is needed to provide a discharge temperature of $T_{m,o} = 23°C$? (6%)

   (b) What fan power is required to move the air through this length of pipe if its inner surface is smooth? (6%)

   (c) What is the length of the pipe if it is to be replaced by AISI304 stainless steel pipe with the same inner and outer diameters and the same discharge temperature? The thermal conductivity of AISI304 is 14.9 W/mK (6%)

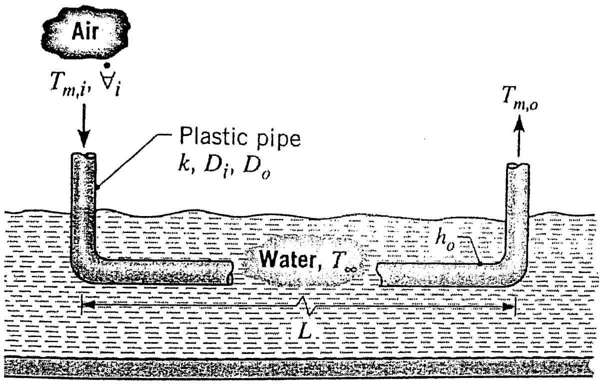

Fig. 1

5. (26%) As shown in Fig. 2, a fin with a thickness t = 3 mm, a width w = 50 mm, and a length L = 20 mm is exposed to ambient air at 25°C with a convection heat transfer coefficient of 100 W/m^2 K. The base surface temperature T_b is 100°C, and the material of the fin is aluminum with a thermal conductivity of 180 W/mK. Please calculate:

   (a) Temperature distributions along the x-direction from the fin base to the fin tip. (5%)

   (b) The rate of heat transfer. (5%)

   (c) The fin resistance (4%)

   (d) The fin efficiency by using the corrected fin lengths. (5%)

   (e) To increase the rate of heat transfer, the fin length can be extended to 30mm, or the material of the fin is replaced by copper with a thermal conductivity of 398 W/mK. Which method has the better fin effectiveness? (7%)

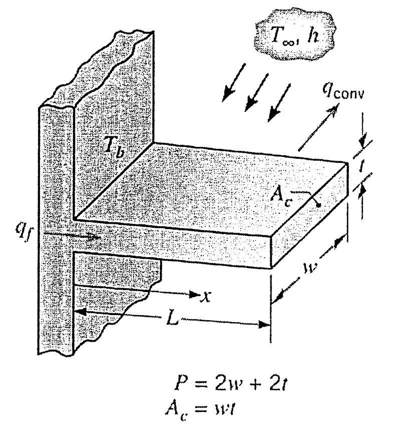

Fig. 2

6. (14%) A plate with a surface area of 0.001 m^2 is in ambient air at T_∞ = 25°C, and the convection heat transfer coefficient by natural convection from the plate surface is h = 5 W/m^2 K. The plate surface temperature is T_p = 10°C, and the absorptivity of the plate surface is α = 0.78. If the plate surface is covered with a 3-mm-thick layer of frost, the frost surface is 0°C with the absorptivity α = 0.95, and the convection heat transfer coefficient changes to 10 W/m^2 K. The thermal conductivity of frost is 0.3 W/mK. The bottom surface of the plate is well insulated. Assume the exposure surface is gray and the surroundings are large.

(a) Draw the thermal circuit between the plate surface T_p and the ambient T_∞ before and after the frost generation. (4%)

(b) Calculate the total thermal resistance before and after the frost generation. (4%)

(c) The plate surface temperature is 0°C, the same as the frost surface after the frost generation. Assume the water melt falls away from the frost surface. The mass density of frost is 700 kg/m^3, and the latent heat of frost fusion is 334 kJ/kg. Estimate the time required to melt the frost completely. (6%)

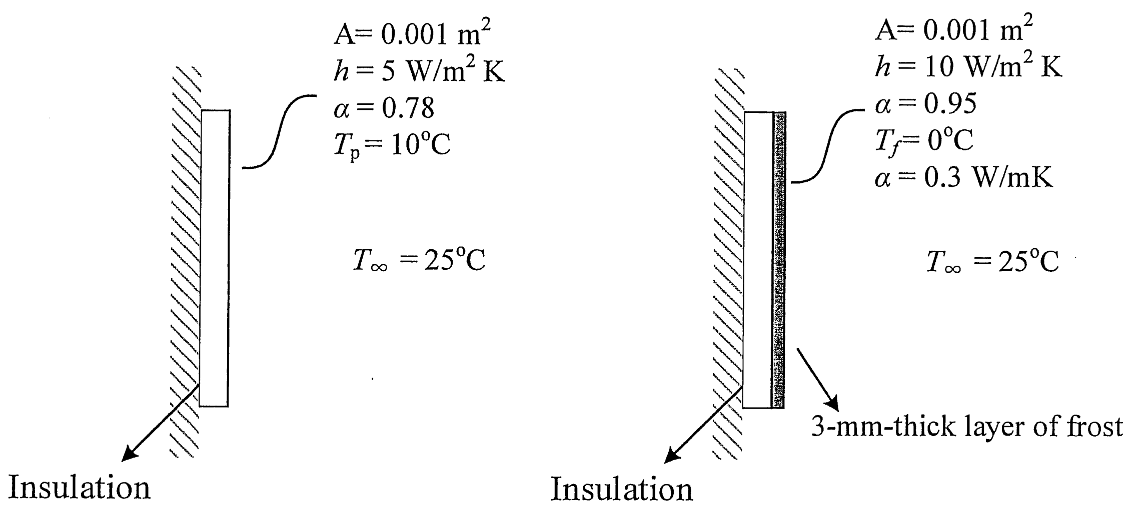

Fig. 3

7. (18%) Small solution droplets with diameter D = 300μm from a nozzle drop with a terminal velocity. The drops are at an initial temperature of T_i = 200°C, and the surroundings are at T_∞ = 25°C. The properties of the solution are ρ_d = 1136 kg/m^3, c_d = 2200 J/kg K, and k_d = 5 W/mK. Neglect radiation effects and phase change during the drop.

   (a) If the Reynold number of droplets is between 1 and 1000, determine the terminal velocity (6%)

   (b) The droplets are cooled by surroundings during the drop. Please calculate the drop time if the droplets were cooled to T_f=50°C. (6%)

   (c) If the terminal velocity is 2 m/s, the drop time is 0.2 sec., and the droplet generates 0.02 W during the drop time, please calculate the final temperature T_f. (6%)

Appendix

Selected material properties

Property	Material	Temperature	Value
Density, ρ	Air	300K	1.1614 kg/m^3
	Air	348K	1.0020 kg/m^3
Dynamic Viscosity, μ	Air	298K	183.6× 10^{-7} N s/m^2
Kinematic Viscosity, v	Air	298K	15.71 × 10^{-6} m^2/s
	Air	300K	15.89 × 10^{-6} m^2/s
	Air	348K	20.72 × 10^{-6} m^2/s
Prandtl Number, Pr	Air	298K	0.707
	Air	300K	0.707
Thermal Conductivity, k	Air	298K	0.0261 W/m K
	Air	300K	0.0263 W/m K
Specific Heat, C_p	Air	298K	1007 J/kg K

Correlations for Nusselt Numbers

- A sphere falling freely in a fluid:

$$\overline{Nu_D} = 2 + 0.6\, Re^{\frac{1}{2}}\, Pr^{\frac{1}{3}}, \qquad 0 < Re < 1$$

$$\overline{Nu_D} = 2 + 0.4\, Re^{\frac{1}{2}}\, Pr^{\frac{1}{3}}, \qquad 1 < Re < 1000$$

$$\overline{Nu_D} = 2 + 0.3\, Re^{\frac{1}{2}}\, Pr^{\frac{1}{3}}, \qquad Re > 1000$$

- Fully developed turbulent flow in a smooth circular tube:

$$\overline{Nu_D} = 0.023\, Re^{\frac{4}{5}}\, Pr^{n}, \quad \begin{cases} n = 0.4 \ for\ heating \\ n = 0.3\ for\ cooling \end{cases}$$

$$\begin{bmatrix} 0.6 \le Pr \le 160 \\ Re \ge 10{,}000 \\ \frac{L}{D} \ge 10 \end{bmatrix}$$

Friction Factor

- Fully developed laminar flow:

$$f = \frac{64}{Re_D}$$

- For a smooth surface condition:

$$f = (0.790 \ln Re_D - 1.64)^{-2}, \qquad 3000 \le Re \le 5 \times 10^6$$

Drag Coefficient

- For a sphere:

$$C_d = \frac{24}{Re}, \qquad Re < 1$$

$$C_d = \frac{24}{Re}(1 + 0.15\, Re^{0.687}), \qquad 1 < Re < 1000$$

$$C_d \approx 0.44, \qquad 1000 < Re < 10^5$$

$$C_d = 0.1 + \frac{0.1}{\sqrt{Re}}, \qquad Re > 10^5$$