國立清華大學 105 學年度碩士班考試入學試題

系所班組別：工程與系統科學系　乙組(0525)

考試科目（代碼）：熱傳學 (2504)

　　*請在【答案卷】作答

1. Please describe the terms or answer the question briefly (20%)
   (a) Fourier's law of heat conduction
   (b) Newton's law of cooling
   (c) Stefan-Boltzmann law of thermal radiation
   (e) Show that, for an ideal gas, the volumetric thermal expansion coefficient **(β)** at a given temperature **(T)** is equal to **1/T.**　　Hint: **β** is defined as:

$$\beta = -\frac{1}{\rho}\left(\frac{\partial \rho}{\partial T}\right)_P$$

2. Considering a thin micro-electronic component mounted on a thick aluminum substrate with epoxy joint. The component and substrate are each 50 mm a side and their exposed surfaces are cooled by a dielectric fluid at 25 ℃ with heat transfer coefficient of 1000 W/m^2K. The thickness and the thermal conductivity for the aluminum substrate are 8 mm and 240 W/mK, respectively. The thermal resistance due to the epoxy joint ($R''_{t,c}$)is estimated to be 0.9×10^{-4} m^2K/W. If the maximum allowable temperature for the electronic component is 85 ℃, please determine the maximum possible power generated by the micro-electronic component. (20%)

3. A semi-infinite plane wall is initially at temperature T_i and for t≧ 0 the plane surface at x =0 is subjected to a fluid flow at temperature T_b and heat transfer coefficient h . Determine the transient temperature distribution in the wall. Hint: You may use the Laplace transform table given for your solution.(20%)

4. Considering fully-developed internal flow with a mass flow rate W (kg/s) and inlet temperature T_{in} (K) in a circular pipe with diameter D (m) and length L (m). (a) Please determine the mean temperature of the fluid as a function of distance from the tube inlet (x), if the channel wall is kept at uniform temperature T_s (K). In the fully-developed region, the heat transfer coefficient is determined to be h (W/m^2K) and the specific heat of the fluid is Cp (J/kgK).
(b) Please also show that the total heat transfer rate from the channel wall to the fluid may be expressed as:

$q = h\pi DL\Delta T_{lm}$

where ΔT_{lm} is the log-mean temperature difference defined as:

$\Delta T_{lm} = (\Delta T_e - \Delta T_i)/\ln(\Delta T_e/\Delta T_i)$

$\Delta T_i = T_s - T_{in}$; $\Delta T_e = T_s - T_e$. T_e is fluid temperature at the channel exit. (20%)

5. A counter flow, concentric tube heat exchanger is designed to heat water with a 0.2 kg/s flow rate from 35℃ to some temperature using hot oil with a flow rate of 0.1 kg/s, which is supplied to the annulus at 100 ℃ and discharged at 60 ℃. The thin-walled inner tube has a diameter of 25 mm, and the heat transfer coefficient for the oil side is determined to be 40 W/m^2K. Please determine (a) the total heat transfer rate, (b) the overall heat transfer coefficient, and (c) the length of the heat exchanger. (20%)

Hint: Use an appropriate correlation in the appendix below to determine the heat transfer coefficient for convection inside the inner tube.

The water properties are given as:

ρ =992 kg/m^3 ; Cp=4.18×10^3 J/kgK; k_f=0.628 W/mK; μ=6.95×10^{-4} kg/ms.

The specific heat for oil is 2131 J/kgK.

TABLE 8.4 Summary of convection correlations for flow in a circular tube[a,b,e]

Correlation		Conditions
$f = 64/Re_D$	(8.19)	Laminar, fully developed
$Nu_D = 4.36$	(8.53)	Laminar, fully developed, uniform q''_s
$Nu_D = 3.66$	(8.55)	Laminar, fully developed, uniform T_s
$\overline{Nu}_D = 3.66 + \dfrac{0.0668\, Gz_D}{1 + 0.04\, Gz_D^{2/3}}$	(8.57)	Laminar, thermal entry (or combined entry with $Pr \gtrsim 5$), uniform T_s, $Gz_D = (D/x)\, Re_D\, Pr$
$\overline{Nu}_D = \dfrac{\dfrac{3.66}{\tanh[2.264\, Gz_D^{-1/3} + 1.7\, Gz_D^{-2/3}]} + 0.0499\, Gz_D \tanh(Gz_D^{-1})}{\tanh(2.432\, Pr^{1/6}\, Gz_D^{-1/6})}$	(8.58)	Laminar, combined entry, $Pr \gtrsim 0.1$, uniform T_s, $Gz_D = (D/x)\, Re_D\, Pr$
$\dfrac{1}{\sqrt{f}} = -2.0 \log\left[\dfrac{e/D}{3.7} + \dfrac{2.51}{Re_D \sqrt{f}}\right]$	(8.20)[c]	Turbulent, fully developed
$f = (0.790 \ln Re_D - 1.64)^{-2}$	(8.21)[c]	Turbulent, fully developed, smooth walls, $3000 \lesssim Re_D \lesssim 5 \times 10^6$
$Nu_D = 0.023\, Re_D^{4/5}\, Pr^n$	(8.60)[d]	Turbulent, fully developed, $0.6 \lesssim Pr \lesssim 160$, $Re_D \gtrsim 10{,}000$, $(L/D) \gtrsim 10$, $n = 0.4$ for $T_s > T_m$ and $n = 0.3$ for $T_s < T_m$
$Nu_D = 0.027\, Re_D^{4/5}\, Pr^{1/3} \left(\dfrac{\mu}{\mu_s}\right)^{0.14}$	(8.61)[d]	Turbulent, fully developed, $0.7 \lesssim Pr \lesssim 16{,}700$, $Re_D \gtrsim 10{,}000$, $L/D \gtrsim 10$
$Nu_D = \dfrac{(f/8)(Re_D - 1000)\, Pr}{1 + 12.7(f/8)^{1/2}(Pr^{2/3} - 1)}$	(8.62)[c]	Turbulent, fully developed, $0.5 \lesssim Pr \lesssim 2000$, $3000 \lesssim Re_D \lesssim 5 \times 10^6$, $(L/D) \gtrsim 10$

From: Incropera et al., Principles of Heat and Mass Transfer, 7th Ed.

Table of Laplace Transform of some functions (From: M. Necati Ozisik, Heat Conduction, 1980)

No	$\bar{F}(s)$	$F(t)$
34	$\dfrac{(\sqrt{s^2+a^2}-s)^\nu}{\sqrt{s^2+a^2}}\ (\nu > -1)$	$a^\nu J_\nu(at)$
35	$\dfrac{(s-\sqrt{s^2-a^2})^\nu}{\sqrt{s^2-a^2}}\ (\nu > -1)$	$a^\nu I_\nu(at)$
36	$\dfrac{1}{s}e^{-ks}$	$u(t-k)$
37	$\dfrac{1}{s^2}e^{-ks}$	$(t-k)u(t-k)$
38	$\dfrac{1}{s}e^{-k/s}$	$J_0(2\sqrt{kt})$
39	$\dfrac{1}{s^\mu}e^{-k/s}\ (\mu > 0)$	$\left(\dfrac{t}{k}\right)^{(\mu-1)/2} J_{\mu-1}(2\sqrt{kt})$
40	$\dfrac{1}{s^\mu}e^{-k/s}\ (\mu > 0)$	$\left(\dfrac{t}{k}\right)^{(\mu-1)/2} I_{\mu-1}(2\sqrt{kt})$
41	$e^{-k\sqrt{s}}\ (k > 0)$	$\dfrac{k}{2\sqrt{\pi t^3}}\exp\left(-\dfrac{k^2}{4t}\right)$
42	$\dfrac{1}{s}e^{-k\sqrt{s}}(k \ge 0)$	$\operatorname{erfc}\dfrac{k}{2\sqrt{t}}$
43	$\dfrac{1}{\sqrt{s}}e^{-k\sqrt{s}}\ (k \ge 0)$	$\dfrac{1}{\sqrt{\pi t}}\exp\left(-\dfrac{k^2}{4t}\right)$
44	$\dfrac{1}{s^{3/2}}e^{-k\sqrt{s}}\ (k \ge 0)$	$2\sqrt{\dfrac{t}{\pi}}\exp\left(-\dfrac{k^2}{4t}\right) - k\operatorname{erfc}\dfrac{k}{2\sqrt{t}}$ $= 2\sqrt{t}\, i\operatorname{erfc}\dfrac{k}{2\sqrt{t}}$
45	$\dfrac{1}{s^{1+n/2}}e^{-k\sqrt{s}}\ (n = 0, 1, 2, \ldots, k \ge 0)$	$(4t)^{n/2} i^n \operatorname{erfc}\dfrac{k}{2\sqrt{t}}$
46	$\dfrac{e^{-k\sqrt{s}}}{a+\sqrt{s}}(k \ge 0)$	$\dfrac{1}{\sqrt{\pi t}}\exp\left(-\dfrac{k^2}{4t}\right) - ae^{ak}e^{a^2 t}$ $\times \operatorname{erfc}\left(a\sqrt{t} + \dfrac{k}{2\sqrt{t}}\right)$
47	$\dfrac{e^{-k\sqrt{s}}}{\sqrt{s}(a+\sqrt{s})}(k \ge 0)$	$e^{ak}e^{a^2 t}\operatorname{erfc}\left(a\sqrt{t} + \dfrac{k}{2\sqrt{t}}\right)$