國立臺灣科技大學 108 學年度碩士班招生試題

系所組別：化學工程系碩士班

科　　目：工程數學與輸送現象

(總分為 100 分)

1. (10 points) Solve the first-order ODE, $y' = (4x^2 + y^2)/(xy)$, with $y\,(e) = 3e$ (Hint: let $u = y/x$ )

2. (10 points) Solve the first-order ODE, $x^2y' + 3xy = x^{-1}$, with $y(1) = 2$

3. (10 points) Apply the second shifting theorem to do the Laplace transform, $\mathcal{L}\{t^2[H(t-2) - H(t-3)]\}$
   The second shifting theorem $\mathcal{L}\{H(t-a)f(t-a)\} = e^{-as}F(s)$, $H(t)$ is the Heaviside function.

4. (10 points) Solve the second-order ODE, $y'' - 2y' + 2y = e^x \sin x$

5. (10 points) Assume the parametric equations of $L_1$ and $L_2$
   $L_1: x = -1 + 7t_1, y = 4 - 6t_1, z = -6 + 6t_1$; $L_2: x = -1 + 6t_2, y = 4 - 5t_2, z = -6 - 3t_2$.
   Please find the equation of the plane which contains $L_1$ and $L_2$.

6. (22 points) A steel pipeline contains hot water flowing at 85°C with the velocity of 5 m/s. The inside diameter of pipe is 50 mm, the thickness of pipe wall is 4 mm and the pipe length is 10 m. The pipeline is covered with 20 mm of insulation. The surface temperature of insulation layer is 50°C. The surrounding air is at 30°C and 1atm. Assume that the viscosity of hot water is not varied significantly with temperature in the pipe when water temperature is higher than 75°C. The thermal conductivities (k) of steel and insulation layer are 45 and 0.18 $\frac{W}{m \cdot K}$, respectively.

   (a) (4 points) Derive the resistance of heat conduction in cylindrical coordinate is $R = \frac{\Delta r}{kA_{lm}}$. $\Delta r$ is the difference in radius and $A_{lm}$ is log-mean area.

   (b) (14 points) Calculate the heat transfer rate.

   (c) (4 points) Calculate the interface temperature between insulation layer and pipe.

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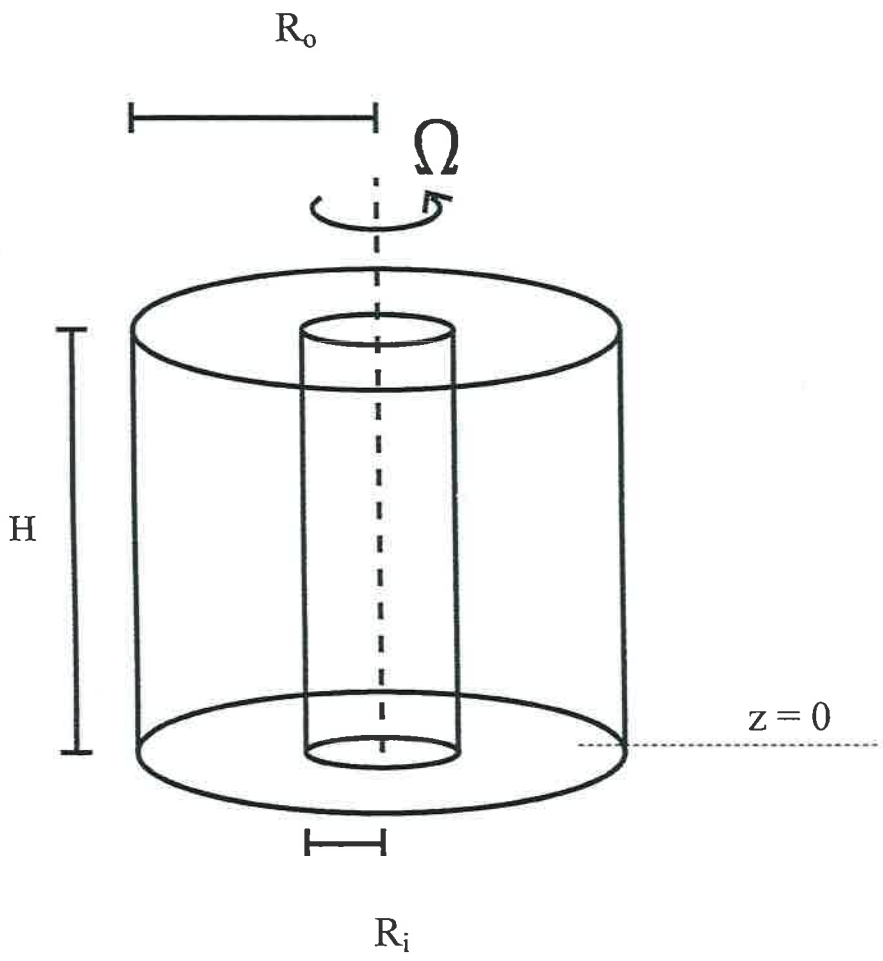
7. (20 points) A tank with its top open to the atmosphere contains liquid water at the bottom of the tank. The tank is maintained at 30 °C. The diameter of the cylindrical tank is 1.0 m, the total height of the tank is 3.0 m, and the liquid level at the bottom of the tank is 0.5 m. The gas space inside the tank is stagnant. The fresh air continuously flows over the top of tank with a dew point of 20 °C and temperature of 30°C. At 30 °C, the vapor pressure exerted by liquid water is 4245 Pa. What is the emission rate of water vapor from the tank when the tank is kept at a temperature of 30 °C? After 20 days, what is liquid level in the tank? Diffusivity of water vapor in air is $2.5\times10^{-6}$ $m^2/s$. Ideal gas constant is 8.314 $\frac{J}{K\cdot mol}$ . State all assumptions you make.

8. (8 points) The following figure describes the tangential in an annulus. The inner cylinder with radius $R_i$ is rotating with constant angular velocity, Ω. The outer cylinder with radius $R_o$ is fixed. The surfaces at z=0 and z=H are also fixed. The flow is laminar and at steady state. The fluid is Newtonian with constant viscosity, μ, and with constant density, ρ. With finite H, please derive the simplified governing equation and boundary conditions of fluid dynamics. (Final solution is not necessary)



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參考附件（第 6 至第 8 題）

1. Heat transfer in pipe:

$$(N_{Nu})_a = 1.86\left(N_{Re}N_{Pr}\frac{D}{L}\right)^{1/3}\left(\frac{\mu_b}{\mu_w}\right)^{0.14} \quad (N_{Re}<2100) \quad (N_{Re}N_{Pr}D/L)>100$$

$$N_{Nu} = 0.027N_{Re}^{0.8}N_{Pr}^{1/3}\left(\frac{\mu_b}{\mu_w}\right)^{0.14} \quad (N_{Re}>6000) \quad (0.7<N_{Pr}<16000) \quad (L/D>60)$$

D is pipe diameter. L is pipe length. $\mu_b$ is fluid bulk viscosity. $\mu_w$ is fluid viscosity on wall surface.

2. Physical Properties of Liquid Water

| Temperature (°c) | Density (kg/m$^3$) | Viscosity (x10$^{-3}$ Pa.s) | Kinematic Viscosity (x10$^{-6}$ m$^2$/s) | Specific Heat Capacity (kJ/kg.K) | Thermal Conductivity (W/m.K) | Prandtl Number |
|---|---|---|---|---|---|---|
| 30 | 995.65 | 0.797 | 0.801 | 4.180 | 0.616 | 5.41 |
| 35 | 994.04 | 0.719 | 0.724 | 4.179 | 0.623 | 4.82 |
| 40 | 992.22 | 0.653 | 0.658 | 4.179 | 0.631 | 4.33 |
| 45 | 990.22 | 0.596 | 0.602 | 4.179 | 0.637 | 3.91 |
| 50 | 988.05 | 0.547 | 0.553 | 4.180 | 0.644 | 3.55 |
| 55 | 985.71 | 0.504 | 0.511 | 4.181 | 0.649 | 3.25 |
| 60 | 983.21 | 0.466 | 0.474 | 4.183 | 0.654 | 2.98 |
| 65 | 980.57 | 0.433 | 0.442 | 4.185 | 0.659 | 2.75 |
| 70 | 977.78 | 0.404 | 0.413 | 4.188 | 0.663 | 2.55 |
| 75 | 974.86 | 0.378 | 0.387 | 4.192 | 0.667 | 2.37 |
| 80 | 971.80 | 0.354 | 0.365 | 4.196 | 0.670 | 2.22 |
| 85 | 968.62 | 0.333 | 0.344 | 4.200 | 0.673 | 2.08 |
| 90 | 965.32 | 0.314 | 0.326 | 4.205 | 0.675 | 1.96 |

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3. Psychrometric Chart