本試題是否可以使用計算機： ☑可使用 ， □不可使用 （請命題老師勾選）

1. Water at 59°F flows through a straight section of a 6 inch ID (inside diameter) smooth pipe with an average velocity of 5 ft/sec. The pipe is 150 ft long, and there is an increase in elevation of 3 ft from the inlet of the pipe to its exit. Find the power required to produce this flow rate for the specified conditions. (expressed as horse power, hp) (20%)

   **Note**: $h_L = 2f(L/D)(U^2/g)$

   $f = 16/Re$, for Re<2300,

   $1/\sqrt{f} = 4.0 \log \{Re\sqrt{f}\} - 0.4$, for Re>3000

   where $h_L$ is the friction loss, $f$ is the friction factor, $U$ is the average velocity, **Re** is the Reynolds number.

2. It is known that $f$Re = 13.33 for laminar Newtonian flow through a long straight duct whose cross section is an equilateral triangle (正三角形). Here $f$ is the friction factor, Re is the Reynolds number, Re = $4r_h U\rho/\mu$, $r_h$ is the hydraulic radius, $U$ is the average velocity, $\rho$ and $\mu$ are density and viscosity of the fluid, respectively. Determine the ratio of cross-sectional areas of a duct of circular cross section to one whose cross section is an equilateral triangle, under conditions that equal pressure gradients produce equal volumetric flow rates. Show details of your calculation. (20%)

3. A cylindrical coal (pure carbon) rod of length 30 cm and initial radius of 1.5 cm is inserted into a flowing air stream at 1145 K and 1 atm total pressure. The flowing gas creates a stagnant gas boundary layer of 5 mm thickness around the external surface of the rod. At the surface, the solid carbon (C) oxidizes to carbon dioxide ($CO_2$) gas

$$C(s) + O_2(g) \rightarrow CO_2(g)$$
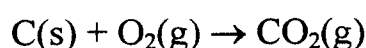
The oxidation reaction is limited by the molecular diffusion of oxygen ($O_2$) through the stagnant gas film surrounding the surface of the rod. Outside of the gas film, the bulk composition of the air stream (21% $O_2$ and 79% $N_2$) prevails. Under the conditions of the combustion process, the diffusivity of oxygen in the gas mixture at 1145 K is 1.3 cm²/sec.

   (a) Write down the governing equation(s) and boundary conditions for oxygen transfer in the stagnant gas film. Assume: (1) pseudo-steady-state, one-dimensional diffusion; (2) Fick's equation applicable; (3) instantaneous reaction at the surface; (4) no homogeneous chemical reaction. (6 %)

   (b) Estimate the initial rate of $O_2$ consumption from the rod. (8 %)

   (c) How long will it take for the rod to disappear? The density of coal is 1.28 g/cm³. (6%)

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4. A copper wire with 0.813 mm in diameter is immersed in an oil bath which is at 25°C. The physical properties of the copper wire are listed as follows:

    Density ($\rho$): 8890 kg/m$^3$

    Specific heat (Cp): 385.4 J/kg.K

    Thermal conductivity (k): 386 W/m.K

    Electrical resistance of the copper wire with this size (R): 0.0682 $\Omega$/m.

    (a) Determine the steady state temperature of the wire if 60 A current is flowing through the wire and the heat transfer coefficient at the surface between wire and oil bath is 500 W/m$^2$.K (6%)

    (b) What might happen to the wire if the oil bath is replaced with water bath? (2%)

    (c) How long will it take for the wire to reach a temperature within 5°C of its steady state value after the current is supplied? (8%)

    (d) After reaching the steady state value, how long will it take for the wire to cool down to 50°C after turning off the electric power? (4%)

5. 在平衡級操作中，常用 Kremser 方程式來計算板數(N)：

$$N = \frac{\ln\left[(x_a - x_a^*)/(x_b - x_b^*)\right]}{\ln\left[(x_a - x_b)/(x_a^* - x_b^*)\right]}$$

若 $x$、$y$ 分別是某一成份(A)在液、氣相中的莫耳分率，$x_a$、$x_b$ 分別代表成分 A 在進口及出口處之液相莫耳分率，$x_a^*$、$x_b^*$ 分別代表成分 A 在進口及出口處與氣相達平衡時之液相莫耳分率，試回答下列問題：

(a) 一稀薄(dilute)氨水溶液，欲利用一連續逆流之氣提(stripping)裝置，以空氣來移除水溶液中的氨($NH_3$)。系統中空氣的莫耳流率為 V，氨水溶液之莫耳流率為 L，且 $NH_3$ 在氣/液相間的平衡關係可利用 $y = 0.8\,x$ 來表示，請問此一操作中，若欲達 95% 之移除率，則空氣對水溶液之最小流率比(V/L)$_{min}$ 為何？此時所需之理想板數為何？(5%)

(b) 承上一小題。若空氣的流率(V)是氨水流率(L)的 1.5 倍，整個裝置有 8 個板，總板效率為 75%。請利用 Kremser 方程式計算此一條件下 $NH_3$ 的移除率。(12%)

(c) 承上一小題。若將空氣的流率(V)增加，而其他條件不變，則 $NH_3$ 的移除率會如何變化？請說明為什麼(3%)