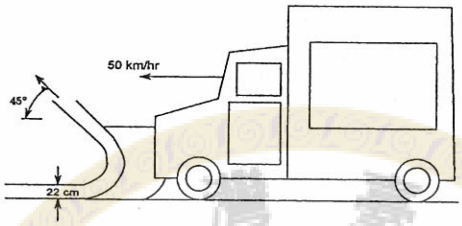
國立臺灣大學101學年度碩士班招生考試試題

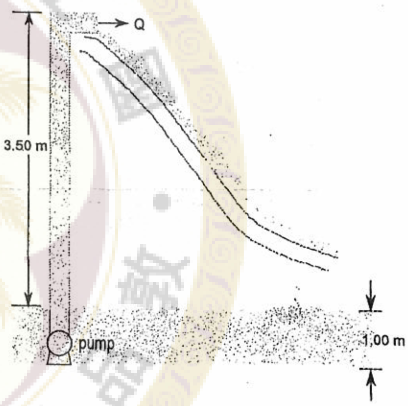
Problem 1. (10%)

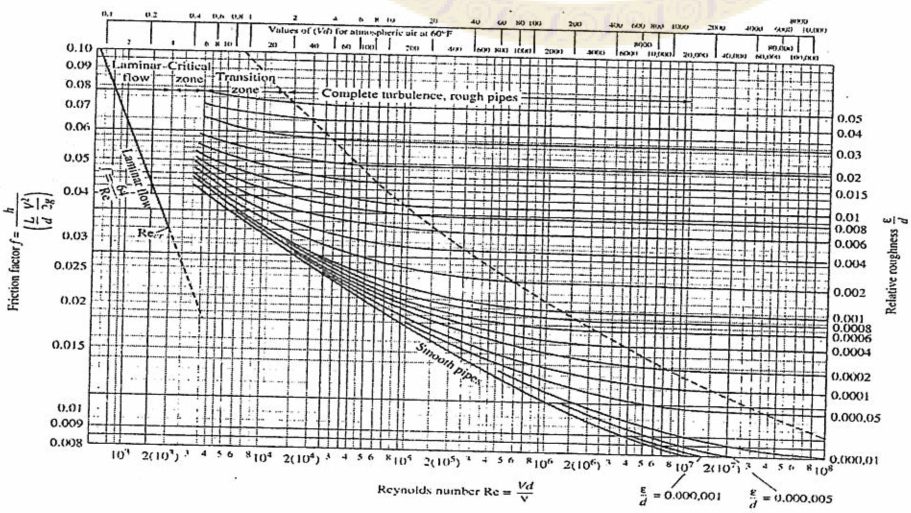
A snowplow mounted on a truck clears a path of 3.2 m wide through heavy wet snow, as shown in the figure. The snow is 22 cm deep and its density is 160 kg/m^3. The truck travels at 50 km/hr. The snow is discharged from the plow at an angle of 45° from the direction of travel and the horizontal, as shown in the figure. Estimate the force required to push the plow. Please state clearly all your assumptions. (Assume steady state.)



Problem 2. (20%)

A small water slide is to be installed inside a swimming pool. The slide manufacturer recommends a continuous water flow rate $Q = 1.0\times10^{-3}$ m^3/s down the slide, to ensure that the customers do not burn their bottoms. A pump is to be installed under the slide, with a 4.5-m-long, 4.0-cm-diameter hose supplying swimming pool water for the slide. The pump is 80 percent efficient and will rest fully submerged 1.00 m below the water surface. The roughness inside the hose is about 0.0080 cm. The hose discharges the water at the top of the slide, 3.5 m above the water surface, as a free jet. Ignore minor losses and assume α = 1.06. Find the brake horsepower needed to drive the pump. (The term α is the kinetic energy correction factor and $\alpha = \frac{1}{A}\int\left(\frac{V}{V_{av}}\right)^3 dA$.)





(L. F. Moody, "Friction factors for pipe flow", ASME. Trans. V66, pp67-684, 1944.)

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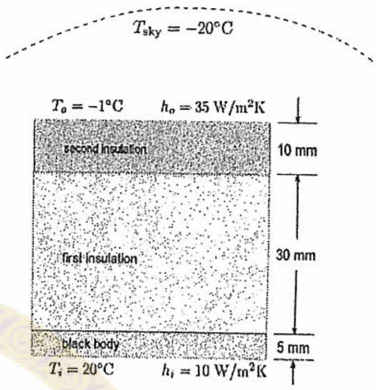
Problem 3. (20%)

Solar radiant energy falls on a rectangular black body, 10 m × 25 m × 0.005 m, at a rate of 800 w/m^2. The body is provided with two layers of insulation of 30 mm and 10 mm thickness, respectively. The thermal conductivities of the body and the insulations are 500 W/m·K, 0.05 W/m·K (30 mm) and 0.15 W/m·K (10 mm), respectively. The inside air temperature is 20°C and the inside convective heat transfer coefficient is 10 W/m^2·K. The outside air temperature is -1°C and the outside convective heat transfer coefficient is 35 W/m^{2}K. The temperature of space is -20°C. Determine the heat transfer rate through the body. (Stefan-Boltzmann constant $\sigma = 5.668\times10^{-8}$ W/m^{2}K^4)



Problem 4. (30%)

A planar drug release device is implanted in an abnormal tissue region, and the drug diffusion process in the tissue is analogous to one-dimensional transient heat conduction in a semi-infinite solid. There is no drug arriving at the normal tissue region far away from the drug release device (C = 0 at x = ∞).

(a) For one-dimensional transient heat conduction in a semi-infinite solid, the temperature response T(x, t) is like below if an amount of energy E per unit area is released instantaneously on the surface (x=0) at t = 0, and none of this energy is lost from the surface.

$$T = T_0 + \frac{E}{\rho c(\pi\alpha t)^{1/2}} e^{-x^2/4\alpha t}$$

Write down the (i) differential equation, (ii) initial and boundary conditions, and (iii) solving approach (you don't have to really solve it) for obtaining such a temperature response. (6%)

(b) What are the definitions and SI units for c, α and E in the above equation? (6%)

(c) By analogy to (a), please write down an equation to describe the drug concentration response C(x,t) if an dose of the drug per unit area (N_0 [=] mol/m^2) is released instantaneously on the device surface (x=0) into the tissue at t = 0, and none of this drug is lost. (6%)

(d) According to (c), please draw x-y plots to show how C(x) varies with time, t. (4%)

(e) Now consider that the drug release device constantly supplies a drug concentration of C_0 at the surface (x=0), and assume the drug is cleared in the tissue at a rate of –kC. Prove that the steady-state concentration profile of the drug release in the tissue is

$C(x) = C_0 \exp(-\sqrt{\frac{k}{D}}x)$, where D is the diffusion coefficient of the drug in the tissue. (8 %)

(Note: provide reasonable assumptions during mathematical derivation, and you may correct the expression if you don't agree with them.)

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Problem 5. (20%)

Consider a scene with water flow past a surface of salt that causes the salt, species 1, dissolving in water, species 2. The concentration of salt in water at the salt-water interface is $m_{1,s}$, the equilibrium value obtained from solubility data; at the outer surface of the water flow, the salt concentration is $m_{1,e}$. The mass flow rate $\dot{m}_1$ (kg/s) at which salt is transferred into the water from a surface area A (m^2) is

$$\dot{m}_1 = j_{1,s}A = g_{m1}A(m_{1,s} - m_{1,e})$$

If we now imagine the transfer process to be that of diffusion across an equivalent of film thickness δ_f, then we have

$$\dot{m}_1 = \frac{\rho D_{12} A}{\delta_f}(m_{1,s} - m_{1,e}).$$

(a) Give the SI units for $j_{1,s}$, g_{m1}, $m_{1,s}$, D_{12}, and δ_f. (5%)

(b) The equivalent stagnant film concept can be applied to the heterogeneous catalysis for CO removal from an automobile exhaust. Let's label CO as species 1. For a time-wise steady state and no reactions in the gas phase (no homogeneous reactions), the removal rate for species 1, $\dot{m}_1$, is a constant. Prove that

$$\dot{m}_1 = \frac{m_{1,e}}{1/\rho k'' A + \delta_f / \rho D_{1m} A}$$

where k" and D_{1m} are the surface catalytic rate constant and the effective binary diffusion coefficient for species 1 diffusing through the mixture, respectively. (10%)

(c) According to (b), if the pressure in the reactor is 1.15×10^5 Pa and the mean molecular weight of the exhaust gases is 28, calculate the CO reduction rate per area (kg/m^2-s) at a location where the CO concentration is 0.187% by weight. The values of ρ, k", D_{1m}, and g_{m1} with SI units are 0.484, 0.070, 93.4×10^{-6}, and 0.135, respectively. (5%)

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