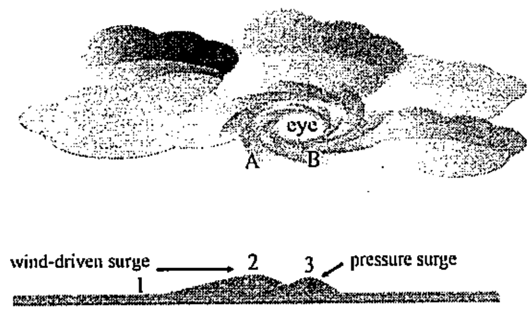
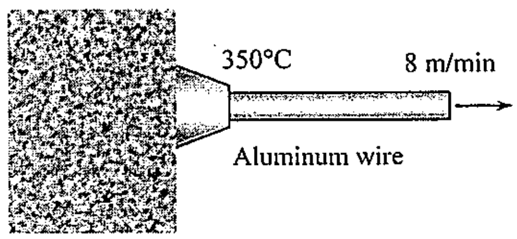
1. A class-4 hurricane features wind speed of 220 km/h, while the wind velocity at the eye is very slow. The atmospheric pressure 320 km away from the eye is 760 mmHg (at point 1) and the winds are calm. The atmospheric pressure at the eye of the storm is 550 mmHg. Estimate the ocean rise at the eye at point 3 (10%), and (b) point 2, where the wind velocity is 220 km/h (10%). (The density of the seawater is assumed 1025 kg/m^3. The air density at 1 atm is 1.225 kg/m^3.) Please state all your assumptions.



2. Consider an explosion occurs in the atmosphere when a missile hits a target. A shock wave spreads out from the explosion. The pressure difference across the shock save ΔP and its radial distance r from the center are functions of time t, speed of sound c, and the total amount of energy E released by the explosion. (a) Analyze the dimensionless relationship between ΔP and the other parameters, and between r and the other parameters. (10%) (b) For a given explosion, if the time t since the explosion triples, all others parameters remain the same, by what factor will ΔP increase? (5%)

3. A long aluminum wire of diameter 5 mm (ρ=2702 kg/m^3 and $c_p = 0.896$ kJ/kg·°C) is extruded at a temperature of 350 °C and are cooled to 50°C in atmospheric air at 25°C. If the wire is extruded at a velocity of 8 m/min, determine the rate of heat transfer from the wire to the extrusion room. (Please state all your assumptions.) (15%)



4. Conceptual diffusion problem sets:

(a) Below is the Einstein diffusion equation.

$$c(x,t) = \frac{c_0}{\sqrt{4\pi Dt}} exp\left(\frac{-x^2}{4Dt}\right)$$

Show that the mean squared displacement of a molecule for two-dimensional diffusion is 4Dt. The following expoential integrals are useful. (6%)

$$\int_{-\infty}^{\infty} e^{-ax^2}dx = \sqrt{\frac{\pi}{a}} \qquad \int_{-\infty}^{\infty} x^2 e^{-ax^2}dx = \frac{1}{2a}\sqrt{\frac{\pi}{a}}$$

(b) For sucrose in water at 25 °C, D = 5 x 10^{-6} cm^2·s^{-1}. Assume that in a region of an unstirred aqueous solution of sucrose the molar concentration gradient is -0.1 M·cm^{-1}. The amount of sucrose molecules passing through a 10 cm^2 window in 100 sec is X μmol. X = ? (6%)

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(c) Consider a concentration profile $C(x) = a(x-1)^2 + b(x+1) + c$ in an aqueous solution, where a, b, and c are x-independent coefficients. (i) Derive the molar flux function J(x) with a diffusion coefficient D. (ii) Show that the concentration profile cannot be kept unchanged with time. (8%)

5. A graduate student adds a new anti-cancer drug S (with a diffusion coefficient D) into a static, unstirred culture dish, where a planar layer of a cancer tissue is grown and attached on the bottom in the presence of a culture medium (a nutrient solution for growing cells). The bulk concentration (far enough from the surface of the cancer tissue) of the added drug S is kept constant as C_0, and the drug S at the cancer tissue surface is up-taken (absorbed) at once (becoming zero concentration).

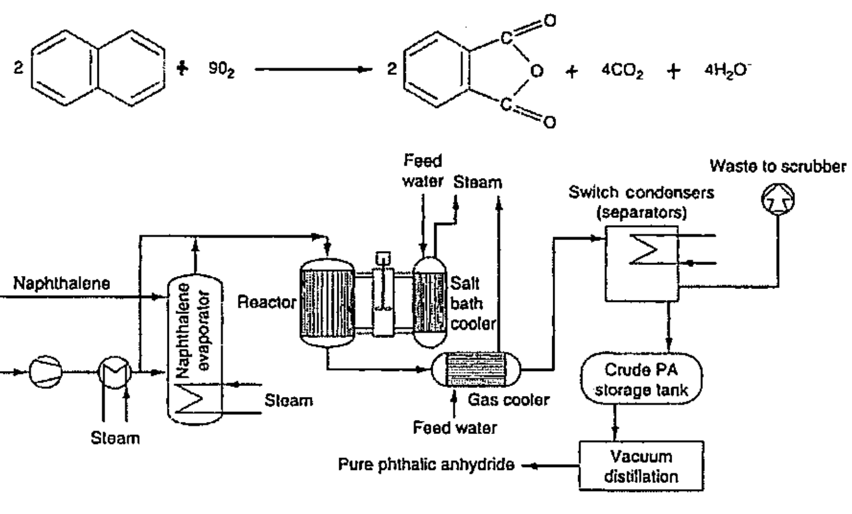
(a) Write down the diffusion equation with appropriate initial and boundary conditions for solving the concentration profile of S. Assume that only one-dimensional diffusion of S along the vertical direction (z-axis) occurs. (6%)

(b) Show that the concentration profile of S in the drug-testing process can be expressed as follows. (z is the distance away from the cancer tissue's surface at the bottom of the culture dish, and t is time.) (8%)

$$C(z,t) = C_0 erf\left[\frac{z}{2(Dt)^{1/2}}\right], \text{ where } erf(u) \equiv \frac{2}{\pi^{1/2}}\int_0^u e^{-y^2}dy.$$

(c) Derive an equation expressing the accumulated amount of drug uptake by the cancer tissue after a period of time, τ, if the area of the cancer tissue layer is A. (6%)

6. The following scheme (a reprint form H. Scott Fogler's Essentials of Chemical Reaction Engineering) illustrates the chemical engineering process for production of phthalic anhydride. Draw a similar scheme to illustrate the chemical engineering process for production of high-purity ethanol (99.5%) from corn powder (the main component is starch), and name the unit operations involved in your process design. (10%)



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