PHY 381, Homework #4, Due November 15, 2019

7.16 As electric current moves through a wire (Fig. P7.16), heat generated by resistance is conducted through a layer of insulation and then convected to the surrounding air. The steady-state temperature of the wire can be computed as

$$T = T_{\text{air}} + \frac{q}{2\pi}\left[\frac{1}{k}\ln\left(\frac{r_w + r_i}{r_w}\right) + \frac{1}{h}\frac{1}{r_w + r_i}\right]$$

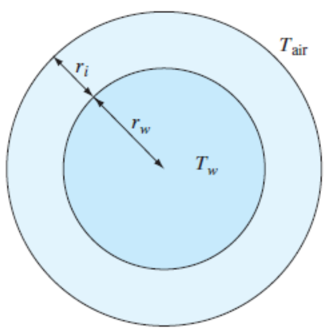

FIGURE P7.16
Cross-section of an insulated wire.

Determine the thickness of insulation r_i(m) that minimizes the wire's temperature given the following parameters: q = heat generation rate = 75 W/m, r_w = wire radius = 6 mm, k = thermal conductivity of insulation = 0.17 W/(m K), h = convective heat transfer coefficient = 12 W/(m^2 K), and T_{air} = air temperature = 293 K.

7.28 The specific growth rate of a yeast that produces an antibiotic is a function of the food concentration c:

$$g = \frac{2c}{4 + 0.8c + c^2 + 0.2c^3}$$

As depicted in Fig. P7.28, growth goes to zero at very low concentrations due to food limitation. It also goes to zero at high concentrations due to toxicity effects. Find the value of c at which growth is a maximum.

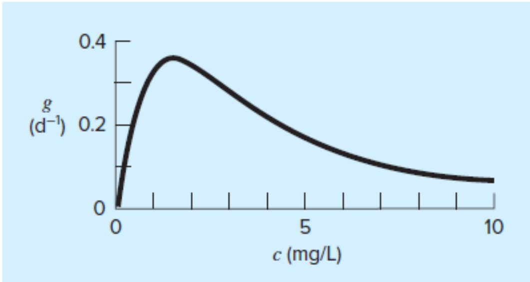

FIGURE P7.28
The specific growth rate of a yeast that produces an antibiotic versus the food concentration.

7.32 The two-dimensional distribution of pollutant concentration in a channel can be described by

$$c(x, y) = 7.9 + 0.13x + 0.21y - 0.05x^2 - 0.016y^2 - 0.007xy$$

Determine the exact location of the peak concentration given the function and the knowledge that the peak lies within the bounds $-10 \le x \le 10$ and $0 \le y \le 20$.

7.33 A total charge Q is uniformly distributed around a ring-shaped conductor with radius a. A charge q is located at a distance x from the center of the ring (Fig. P7.33). The force exerted on the charge by the ring is given by

$$F = \frac{1}{4\pi e_0} \frac{qQx}{(x^2 + a^2)^{3/2}}$$

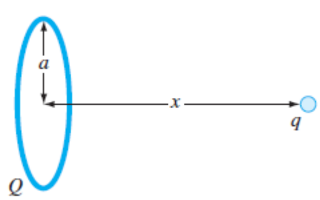

FIGURE P7.33

where $e_0 = 8.85 \times 10^{-12}$ C^2/(N m^2), $q = Q = 2 \times 10^{-5}$ C, and $a = 0.9$ m. Determine the distance x where the force is a maximum.

7.44 As depicted in Fig. P7.44, a mobile fire hose projects a stream of water onto the roof of a building. At what angle, θ, and how far from the building, x_1, should the hose be placed in order to maximize the coverage of the roof; that is, to maximize: $x_2 - x_1$? Note that the water velocity leaving the nozzle has a constant value of 3 m/s regardless of the angle, and the other parameter values are $h_1 = 0.06$ m, $h_2 = 0.2$ m, and $L = 0.12$ m. [Hint: The coverage is maximized for the trajectory that just clears the top front corner. That is, we want to choose an x_1 and θ that just clear the top corner while maximizing $x_2 - x_1$.]

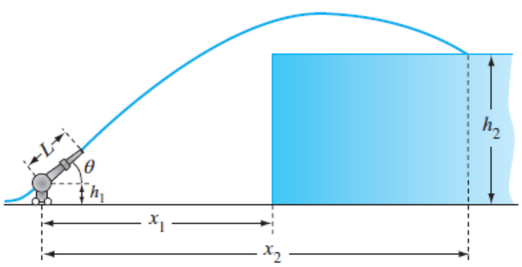

FIGURE P7.44