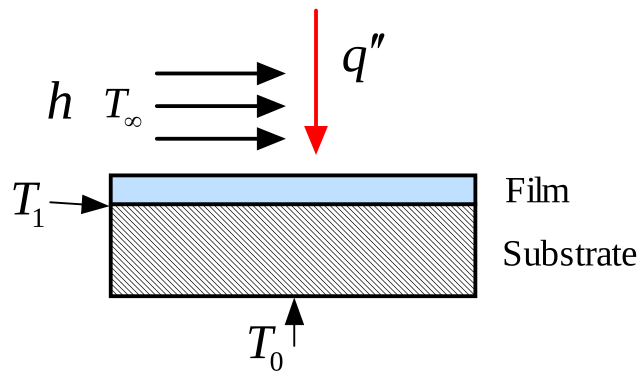
ME109 - Heat Transfer
Midterm 1- Fall'06
Instructor: Prof. A. Majumdar

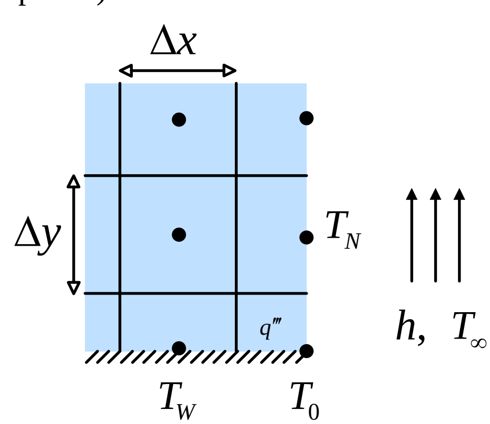
Oct. 13, 2006; 12:10 am - 1:00 pm; Maximum Points = 30

NOTE: This is an open book, open notes exam.

1. Consider a material manufacturing process, where a thin film is deposited on top of a substrate, as shown in the figure below. The temperature of the bottom surface of the substrate is kept at T_0 = 30 ^oC. The top surface is exposed to a radiative heat flux of q'' = 3000 [W/m^2], which is fully absorbed at the top surface. In addition, there is convective heat transfer with a fluid at temperature T_∞ = 20 ^oC and the convective coefficient h=40 W/(m^{2}K). Determine the temperature at the interface between the film and the substrate, T_1. The thickness of the film is a = 0.2 mm and the thickness of the substrate is b = 1.0 mm. Thermal conductivity of the film k_f is 0.02 W/(m.K), and the thermal conductivity of the substrate k_s is 0.06 W/(m.K). (10 points)



2. For solving a 2-D transient heat conduction problem, a node, T_o, is placed on the corner as shown in the figure below. There is a uniform internal heat generation in the solid, with a volumetric heat generation rate q''' [W/m^3]. The right surface is exposed to a flowing fluid at temperature T_∞ and convective coefficient is h. The bottom surface is thermally insulated. Using the first law of thermodynamics, derive a nodal equation for T_o in an explicit scheme in terms of the temperature of surrounding nodes, h, T_∞ and q''', as well as the properties of the solid, k, ρ, and C. Determine the stability criterion for this scheme. Assume $\Delta x = \Delta y$, and the unit depth. (10 points)



3. Consider the metal link on a fire sprinkler head. It is a rectangular parallelepiped of thickness L, length *a* and width *a* . Assume and then justify that it can be treated as a lumped system. If the link, at an initial temperature, T_i = 20 ^{o}C, is suddenly exposed to the fire gas at T_∞ = 300 ^{o}C, with a constant convective heat transfer coefficient, *h* = 30 W/(m^{2}K), how long will it take for the link to reach 297 ^{o}C. Neglect radiation. The thermal conductivity of the metal link *k*= 400 W/(m.K). L = 2 cm, *a* = 0.6 m. ρC = 3 x 10^6 J/m^3-K. (10 points)