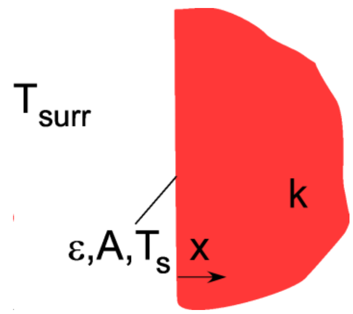
MEAM 333
MIDTERM 1
Spring 2011

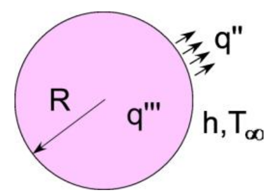
- Closed book and closed notes. You may use a calculator.
- Assume all properties are constant (i.e. no variation with time, position, or temperature).
- Use the properties given in the problems for your calculations.
- Show all key steps used to solve the problem.
- Stefan-Boltzmann constant: $\sigma = 5.67\text{x}10^{-8}$ W/m^2-K^4

ALL STUDENTS MUST SIGN THE HONOR PLEDGE IN THE EXAM BOOKLET

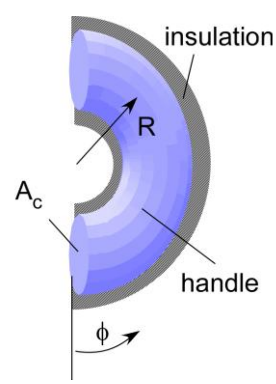
1. **[26]** The left side of a wall with thermal conductivity k is exposed to a surroundings with temperature T_{surr}. The surroundings may be treated as a blackbody and the surface may be assumed to be gray. The wall has a surface area A, thermal conductivity k, surface temperature T_s, and surface emissivity ε.
   a. **[7]** Write an expression for the net radiative heat rate q_{rad} flowing *into* the surface at x=0 (i.e. in the positive x direction).
   b. **[7]** Write an expression for the conductive heat rate q_{cond} flowing *out of* the surface at x=0 (i.e. in the positive x direction)
   c. **[12]** If dT/dx at x=0 is equal to 1000 C/m, k = 10 W/m^2-K, A = 1 cm^2, ε = 0.4, and T_{surr} = 25° C, calculate the surface temperature of the wall.



2. **[20]** The spherical nuclear fuel pellet at right generates heat at a volumetric rate q''' and is immersed in a fluid coolant of temperature T_∞ and heat transfer coefficient h. The radius of the pellet is R and the heat flux leaving the surface of the pellet is q''.
   a. **[10]** If q'''= 400 kW/m^3, h = 10 W/m^2-K, and R = 2 cm, calculate q''.
   b. **[10]** To avoid nuclear meltdown, the pellet temperature must remain below 1100 K. Assuming the entire pellet is at the same temperature, and using the above parameters, calculate the maximum allowable coolant temperature for safe operation.



3. **[54]** A glass mug is partially filled with hot cocoa such that the lower end of the handle contacts the mug below the 'fill line' (i.e. contacts the part of the mug filled with cocoa) and the upper end of the handle contacts the mug above the fill line (i.e. contacts the mug above the cocoa level). The temperature of the handle at the lower contact T_1 is greater than the temperature the upper contact T_2 and heat flows through the handle from the bottom end to the top end. Assume that the handle is a semicircle with radius R, that the handle cross section is A_c, that there is no volumetric heating in the handle, and that the handle temperature varies over time. Note that the handle outer surfaces are well insulated.



   a. **[5]** By what heat transfer mechanism does heat enter and leave the handle?
   b. Taking a differential slice of the handle (between the dashed lines shown in the figure), do the following. *NOTE: the answers for parts i-iv should be expressed in terms of the following variables only: k, ρ, C_p, A_c, R, T, ϕ, t. Not every variable will appear in every answer.*
      i. **[20]** Write an expression for $\dot{E}_{in}$-$\dot{E}_{out}$ for the slice.
      ii. **[5]** Write an expression for $\dot{E}_{gen}$ for the slice.
      iii. **[10]** Write an expression for $\dot{E}_{stored}$ for the slice.
      iv. **[8]** Write the heat equation for the handle (do not try to solve it).
      v. **[6]** If you were to solve the heat equation, which boundary conditions should be applied?