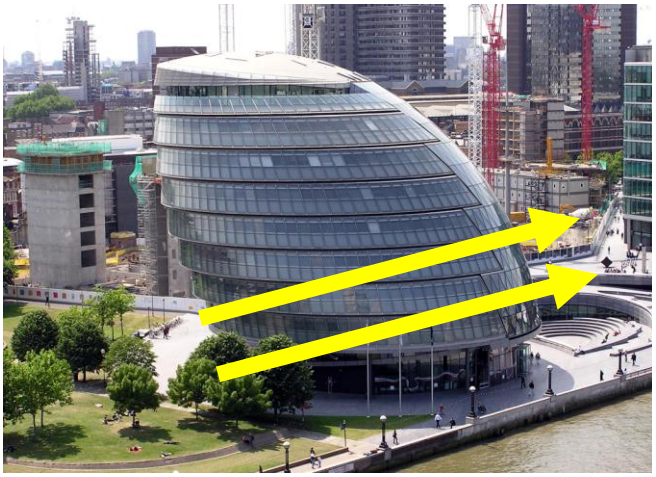
MEAM 333
MIDTERM 3
Spring 2011

- Closed book. You may use a calculator and one 8.5 x 11 cheat sheet.
- Use the properties given below/in the problems for your calculations.
- Assume all properties are constant (i.e. no variation with time, position, or temperature).
- Show all key steps used to solve the problem (this is much more important than the correctness of the final numerical answer).
- Neglect radiation in all problems.
- **Air properties**: ρ=1.1614 kg/m^3, c_p=1007 J/kg K, k=26.3x10^{-3} W/m-K, ν=15.89x10^{-6} m^2/s, Pr=0.707.
- **Water properties**: ρ_f=997 kg/m^3, ρ_g=2.56x10^{-2} kg/m^3, c_p=4179 J/kg K, k=613x10^{-3} W/m-K, ν=8.55x10^{-7} m^2/s, Pr=5.83, h_{fg}=2.438x10^6 J/kg, D_{AB}=0.26x10^{-4} m^2/s.

ALL STUDENTS MUST SIGN THE HONOR PLEDGE IN THE EXAM BOOKLET

1. **[34]**
   - **a.** **[16]** Air blows across a horizontal tube of diameter 10 mm and surface temperature 320 K. If the ambient temperature is 300 K and the air speed is 10 m/s, what is the heat transfer rate per unit length added to the tube (q')?
   - **b.** **[18]** The same tube is now coated with a thin layer of water that is at the same surface temperature as the tube. Calculate the net heat transfer rate per unit length added to the tube (q') for this situation, assuming that the air is dry. Do not assume that the tube is at steady state.
2. **[38]**
   - a. **[26]** A long boron carbide control rod of diameter 2.96 cm initially at 300 K is inserted into a pressurized water nuclear reactor to slow down the reaction. The control rod properties are k=37 W/m-K, ρ=2520 kg/m^3, and c_p=1060 J/kg-K. If the pressurized water has a heat transfer coefficient h = 1000 W/m^2–K and a temperature T_∞ of 950 K, find the temperature of the center of the control rod 1 minute after insertion.
   - b. **[12]** A long uranium dioxide nuclear fuel rod of 1.2 cm diameter generates 10^8 W/m^3 of heat in the same nuclear reactor. The fuel rod properties are k=3.3 W/m-K, ρ=10733 kg/m^3, and c_p=311.4 J/kg-K. An earthquake occurring at time t=0 destroys the cooling system and immediately results in loss of coolant such that the convective cooling rate of the fuel rod becomes negligible compared to the energy generation rate. If the initial temperature of the fuel rod at t=0 is 1073 K and the melting temperature of the rod is 3000 K, how long does it take for meltdown to occur? You may assume the temperature is uniform across the fuel rod for this calculation.
3. **[28]** Air flows across London City Hall parallel to the Thames river in the direction shown by the two arrows. The characteristic length of the building in the airflow direction is 40 m, the building surface temperature is 300 K, the air temperature is 280 K, and the air speed is 2 m/s.



   - a. **[4]** If 3 W/m^2 of heat is lost from the building, calculate the average heat transfer coefficient of the building.
   - b. **[9]** Before City Hall was constructed, the architects built a 1/100th size scale model (all length dimensions are scaled by 100) to evaluate the building energy efficiency. What numerical value of the average Nusselt number for the scale model is required in order to use scale model test data to predict the behavior of the actual building?
   - c. **[8]** If the wind tunnel used for the scale model tests uses air with the same properties as given above, what wind speed must be used in the wind tunnel experiment?
   - d. **[7]** What is the average heat transfer coefficient observed in the scale model tests?