Code Number :.....

HEAT TRANSFER QUALIFYING EXAM

January 2016

One book allowed

Answer all questions

All questions have equal weight

TIME: 3.0 hrs

Prepared by : Profs. J. Yeom and A. Bénard

Problem 1. A 3 m by 3 m plate made of carbon steel (AISI 1010) with 100 mm in thickness is heat treated in a gas-fired furnace whose gases are at 1000 K and provide a convection heat transfer coefficient of 100 $W/m^2 \cdot K$. Use k = 63.9 W/m·K, $\alpha = 18.8 \times 10^{-6}$ m^2/s for carbon steel (AISI 1010).

a) If the plate enters the furnace at 300 K, how long must it remain in the furnace to achieve a centerline temperature of 800K? Justify your approach.

b) How accurate is the answer obtained in (a) when compared to the 1-term approximate solution?

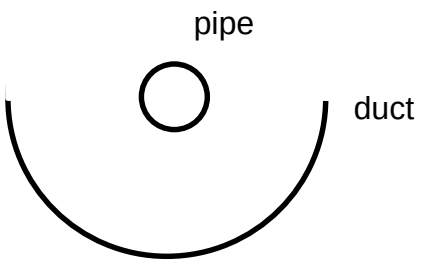
Problem #2. An engineer designs an experimental setup for exhaust analysis of some combustion byproduct on a summer day. A thin-walled tube with a diameter of 6 mm and length of 20 m is used to carry the exhaust gas from the combustion chamber to the nearby gas analysis facility. Wind at a temperature of 27°C is blowing directly across the tube at a constant velocity of 6 m/s. If the gas enters the tube at 250°C and with a flow rate of 0.005 kg/s, calculate the temperature of the exhaust gas when it reaches the facility.

Problem #3) An electric burner is modeled as a black surface and has a diameter of 15 cm and has a surface temperature of 230 ^{o}C. Only the top surface of the burner is exposed to air and its surface is modeled as a black body; the unexposed surfaces are insulated. The burner is rated has having an efficiency of 0.9 and it sits in still air at 25°C. You are asked to find the radiation and convection heat transfer rates and the electric power needed to maintain this temperature. To achieve this, please answer the following questions.

a. State below what properties of air you are using and at what temperature
b. Compute the convective heat transfer rate
c. Compute the radiant heat transfer rate if the surrounding is treated as a large enclosure at 25°C.
d. What is the rate of heat transfer from the surrounding to the burner? Is is significant?
e. What is the electrical power required? Recall the that the efficiency is 0.9.
f. At what wavelength is the peak radiant emissive power found?

Problem #4) A diagram of the pipe and duct acting as a heat shield are shown below. The pipe is located at the center of the duct.

a. Find the view factors between the cylinder and the duct, labeling surface 1 as the pipe located at the center of the duct. The pipe has a radius of 10 cm and the duct as a radius of 40 cm.



b. If the pipe is at 500K and the duct is at 450K, estimate the rate of radiation heat transfer between the two surfaces. The surrounding is at 300K. Both surfaces are gray and diffuse with an emissivity of 0.9.