Heat Transfer - 1

A mineral insulated thermocouple has a junction point which is approximated as a sphere with a diameter of 2.50 mm, and is suddenly inserted in a cross flow just upstream of a turbine vane. The initial temperature at the junction is 300 K, the density is $19.97\ {}^{g}/_{cm^3}$, and the specific heat is $0.13\ {}^{kJ}/_{kg\ K}$. The two insulated wires connected to the junction point are both 1 mm in diameter, have thermal conductivities of $38\ {}^{W}/_{m\ K}$, and are 1 m to a known temperature of 300 K. The spherical junction point has the same thermal conductivity as the wires. The cross flow of the gas generates a heat transfer coefficient of $1000\ {}^{W}/_{m^2\ K}$. Blackbody radiation ($\sigma = 5.67 \times 10^{-8}\ {}^{W}/_{m^2 K^4}$) heat transfer occurs between the thermocouple junction and the combustor walls, which are at a temperature of 1250 °C. Assuming lumped capacitance, perfectly insulated thermocouple wires, and all the thermal radiation emanating from the thermocouple junction is incident on the combustor walls solve the following:

a. **(25 points)** Sketch a control volume and setup an equation to solve for the temperature of the thermocouple junction as a function of time. Clearly label all variables and forms of energy transfer.
b. **(15 points)** The thermocouple is allowed to reach a steady state temperature reading of 1500 °C. Determine the temperature of the crossflow.
c. **(15 points)** Repeat part (b), neglecting radiation effects.
d. **(15 points)** Repeat part (b), neglecting effects of conduction through the thermocouple wires.
e. **(10 points)** Discuss the implications of neglecting radiation and conduction effects. Will neglecting conduction induce more error than neglecting radiation? Should radiation and/or conduction be neglected?
f. **(20 points)** Neglecting radiation, neglecting conduction, and using the crossflow temperature calculated in part b, calculate the time it takes for the thermocouple junction to reach 95% of the steady state absolute temperature, sketch a plot of temperature as a function of time, and sketch the temperature as a function of time if radiation wasn't neglected (Do not have to solve this case, just sketch the expected effect of including radiation).