Lesson 17

Problem 17.1 (from E.O. Doebelin, *Measurement Systems*, 4/e, McGraw Hill, 1990.)

A sensor for measuring radiant power can be constructed from a pyroelectric crystal with thin-metal film electrodes as shown in Figure (a). In its linear operating region, the sensor current output i_s is related to the temperature T of the sensor by

$$i_s = K_p \frac{dT}{dt},$$

where K_p is a known constant.

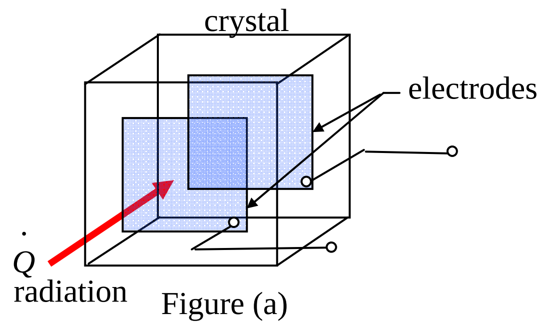

Figure (a)

A model of the system is shown in Figure (b). The op-amp circuit produces a voltage output e_o. C_s is the sensor capacitance and current i_s is generated by the sensor in response to $\dot{Q}$. The conservation of energy applied to the sensor yields

$$R_{th} C_{th} \dot{T} + T = R_{th} \dot{Q},$$

where R_{th} represents the sensor's thermal resistance, C_{th} its thermal capacitance, and T its temperature.

(a) Sketch a block diagram relating the circuit output e_o to radiant power input $\dot{Q}$.

(b) Obtain the transfer function relating e_o to $\dot{Q}$.

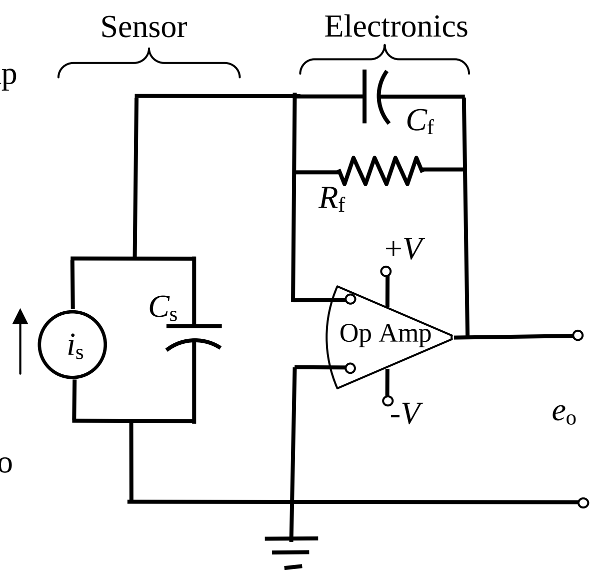

Figure (b)

Problem 17.2

Hot gas flows in a duct instrumented with two thermocouples. The thermocouple embedded in the duct wall indicates a temperature T_w = 760ºF. The thermocouple immersed in the center of the hot gas stream has emissivity ε = 0.5, a convection coefficient of 20 btu/(hr·ft^2·F), and indicates a temperature T_t = 1000ºF. The Stefan-Boltzman constant in USCS units is $\sigma = 0.1714 \times 10^{-8}$ btu/(hr·ft^2·R^4). Assuming that the thermocouples have negligible thermal capacitance, estimate the true temperature of the hot gas.

(Hint: The thermocouple in the stream radiates to the wall. Don't forget to convert temperatures to Rankine.)

Answer: approximately 1100ºF