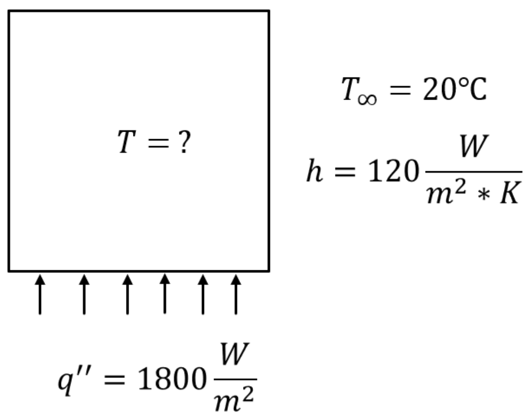
Heat Transfer Ch En 3453 | Homework 1 | Due Friday Sept. 3 at 5 PM

Scan as pdf and submit through Canvas

Note: Problems with a star* may be covered during scheduled lectures.
Note 2: Approximate solutions are the actual solution, but rounded to only 1 significant figure.

Problem 1

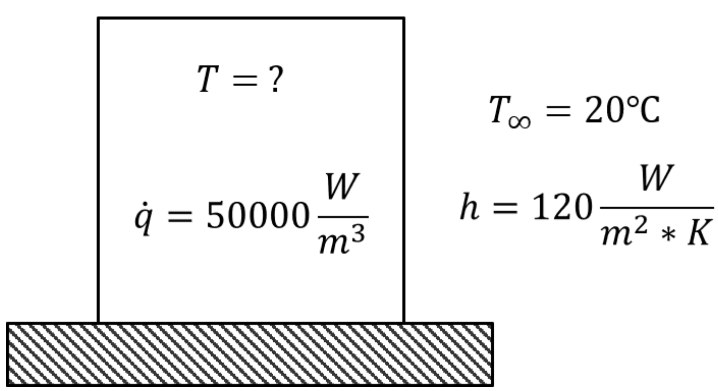
A cube with an area (***A = 0.1 m²***) on each side is heated from the bottom with a uniform heat flux (q''). The cube is at temperature ***T*** and is assumed to be isothermal. The cube loses heat to the environment by convection, which is assumed to be uniform over the exposed faces of the cube. The process is at steady state. What is the temperature of the cube?



Approximate solution[1]: 20°C

Problem 2

A cube with that is 10 cm on each side is insulated on the bottom with a uniform volumetric generation ($\dot{q}$). The cube is at temperature ***T*** and is assumed to be isothermal. The cube loses heat to the environment by convection, which is assumed to be uniform over the exposed faces of the cube. The process is at steady state. What is the temperature of the cube?



Approximate solution: 30°C

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[1] Note that approximate solutions are generally the actual solution rounded to 1 or 2 significant figures.

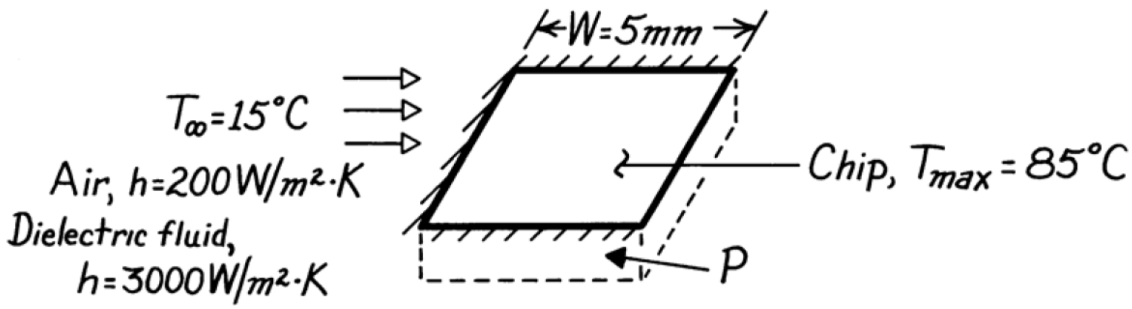
Problem 3

a. A glass window of width W = 1 m and height H = 2 m is 5 mm thick and has a thermal conductivity of k_g = 1.4 W/(m K). If the inner and outer surface temperatures of the glass are 15 °C and -20 °C, respectively, on a cold winter day, what is the rate of heat loss through the glass?
b. To reduce heat loss through windows, it is customary to use a double pane construction in which adjoining panes are separated by an air space. If the spacing is 10 mm and the glass surfaces in contact with the air have temperatures of 10 °C and -15 °C, what is the rate of heat loss from a 1 m x 2 m window? The thermal conductivity of air is k_a = 0.024 W/(m K). Hint… the air between the window panes can be treated as a stationary fluid.

Approximate solutions: 20,000 W & 100 W

Problem 4

A square isothermal microchip is of width w = 5 mm on a side and is mounted in a substrate such that its side and back surfaces are well insulated; the front surface is exposed to the flow of a coolant at T_∞ = 15 °C. From reliability considerations, the chip temperature must not exceed T = 85 °C.



a. If the coolant is air and the corresponding convection coefficient is h = 200 W/(m^2 K), what is the maximum allowable chip power?
b. If the coolant is a dielectric liquid for which h = 3000 W/(m^2 K), what is the maximum allowable power?

Approximate solutions: 0.4 W, 5 W

Problem 5

The free convection heat transfer coefficient on a thin hot vertical plate suspended in still air can be determined from observations of the change in plate temperature with time as it cools. Assuming the plate isothermal and radiation exchange with its surroundings is negligible, evaluate the convection coefficient at the instant of time when the plate temperature is 225 °C and the change in plate temperature with time (dT/dt) is -0.022 K/s. The ambient air temperature is 25 °C and the plate measures 0.3 x 0.3 m with a mass of 3.75 kg and a specific heat of 2770 J/(kg K).

Approximate solution: 6 W/m^2*K

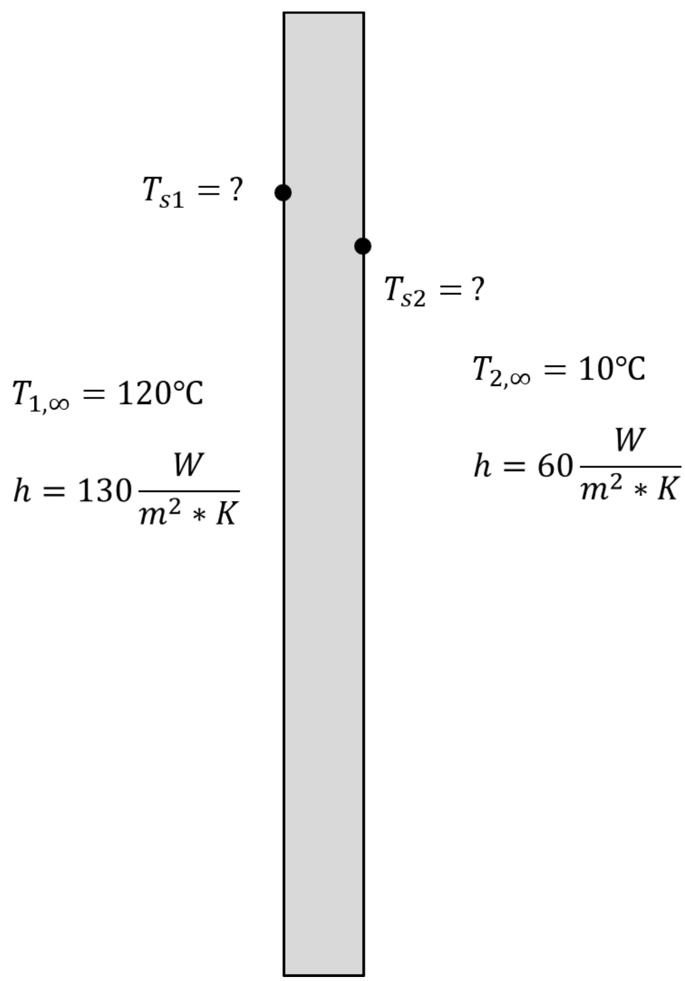
Problem 6

Consider the conditions of Problem 5. However, now the plate is in a vacuum with a surrounding temperature of 25 °C. What is the emissivity of the plate? What is the rate at which radiation is emitted by the surface?

Approximate solution: 0.4, 300 W

Problem 7*

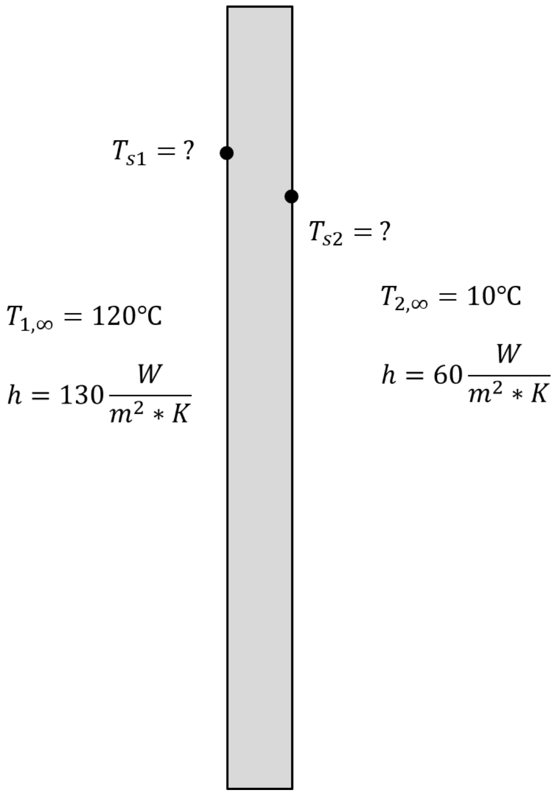
A plane wall that is 20 cm thick and has constant thermal conductivity k = 3 W/m*K undergoes one-dimensional, steady conduction. The wall is exposed to air and convective heat transfer on each side. What are the temperatures at the interface between the wall and the air on each side (T_{s1} and T_{s2})?



Approximate solutions: 100 °C and 30 °C

Problem 8

A plane wall that is 30 cm thick and has constant thermal conductivity k = 25 W/m*K undergoes one-dimensional, steady conduction and has the properties shown in the figure.



a. What is the rate of heat flux through the wall by convection on the left side?
b. What is the rate of heat flux through the wall by conduction?
c. What is the rate of heat flux through the wall by convection on the right side?
d. Which direction is heat flowing (i.e., from left to right or from right to left)?
e. If the wall is 2.5 m tall and 6 m wide, what is the total heat rate through the wall?

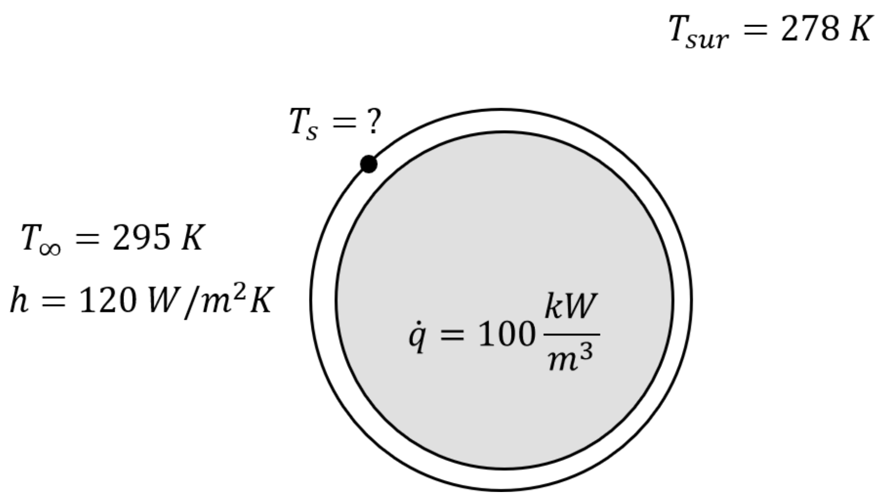
Approximate solutions: (a) 3000 W/m2, (b) 3000 W/m2, (c) 3000 W/m2, (e) 50,000 W

Problem 9*

A spherical reaction vessel contains an exothermic reaction that generates heat at the volumetric rate shown in the figure. Assume that the vessel is exposed to large surroundings at a uniform temperature, that the vessel radiates energy uniformly, and that the system is at steady-state. Do not neglect convection.

a. What is the outer surface temperature of the vessel (T_s)?
b. How much heat is generated?
c. How much heat is lost via radiation?
d. How much heat is lost via convection?

The outer surface has an emissivity of ($\varepsilon = 0.78$), an inner radius of 1 m and an outer radius of 1.1 m.

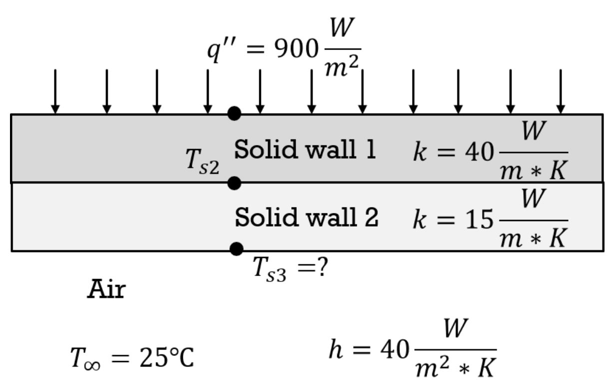


Approximate solution: (a) 500 K, (b) 400,000 W, (c) 40,000 W, (d) 400,000 W

Problem 10

Sunlight hitting a horizontal composite wall with two layers creates a constant and uniform flux going into the top of the wall. Each wall layer is 10 cm thick. On the bottom of the lower wall layer, there is contact with air, which circulates and causes convection to occur. If the process is steady, what is the temperature at the bottom of the wall (T_{s3})?

Treat the wall as a "plane wall" (i.e., temperature only varies in one direction).



Approximate solution: 50 °C

Extra Credit

In the Ed Discussion App, in the HW1 Folder, there is a post that says "Reply to this post with your name to receive extra credit for Homework 1". Go ahead and reply with your name to receive extra credit.