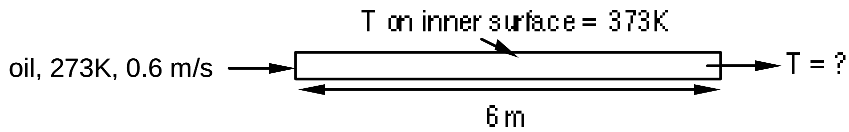
ta3220 - Fluid Flow, Heat and Mass Transfer
Heat transfer in tubes

1. An operator wants to heat oil by pumping it through a heat exchanger. In the heat exchanger, the oil flows at a velocity of 0.6 m/s through cylindrical tubes 6 m long and of 0.025 m inside diameter. Steam outside the tubes maintains the temperature of the <u>inside</u> surfaces of the tubes at 373 K throughout the tube length. The oil enters the heat exchanger at 273 K. What is the temperature of the oil <u>leaving</u> the heat exchanger? You may assume that the oil properties are independent of temperature.

<u>Properties of Oil</u>

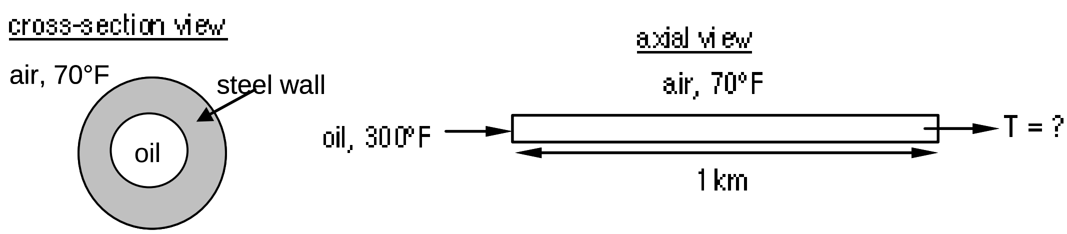
μ = 0.002 Pa s ρ = 1,200 kg/m^3 $\hat{C}_p$ = 2,050 J/(kg K)
k = 0.14 W/(m K)



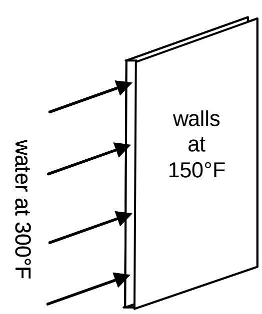
2. A 1 km length of 6-inch I.D. steel pipe, with 1-inch-thick walls, has hot oil flowing through it. The outside air temperature is 70°F, and the heat-transfer coefficient on the outer pipe wall is h_{outer}= 100 W/(m^2 K). For the steel pipe itself, k = 16.3 W/(m K). The oil enters the pipe at 300°F at a flow rate of 100 bbl/hr. The properties of the oil are given below, and can be assumed to be independent of temperature. What is the temperature of the oil 1 km from the pipe inlet? **<u>Please do your calculations in SI units.</u>**

<u>Properties of Oil</u>

μ = 100 cp ρ = 0.95 g/cc $\hat{C}_p$ = 1.5 cal/(g °C)   k = 0.10 Btu/(hr ft °F)



3. Water at 300°F (liquid, under pressure) is injected into a fracture 2 mm wide with a velocity of 10 m/s. Assuming the walls of the fracture are uniform at 150°F, how far does the water travel before its temperature drops to 200°F? Assume the water properties are those given below and are independent of temperature.



<u>properties of water</u>

ρ = 1000 kg/m^3 μ = 0.001 Pa s   k = .680 W/(m K) $\hat{C}_p$ = 4190 J/(kg K)

4. A tube heat exchanger is used to heat oil before injection into a well to dissolve asphaltenes. Hot water inside the tubes is used to heat the oil, which is on the outside of the tubes. The geometry of a tube is shown below. The tubes are of inner diameter 1 inch (2.54 cm) and outer diameter 1.5 inch (3.81 cm). In addition, each tube has a layer of solid scum on the outside, with outer diameter 5 cm. The thermal conductivities of the tube material and the scum are 16.3 W/(m K) and 1 W/(m K), respectively. At the outer surface of the scum, the heat-transfer coefficient is 50 W/(m^2 K). Inside the tube, water flows at velocity 1 m/s; the properties of water are given below.

The heat exchanger is not efficient enough. There are several things the operator could do to improve the rate of heat-transfer through the tubes; he could

(a) eliminate the scum (leaving the same value of h at the outer surface of the pipe),
(b) replace the material of the pipe with a new material with k = 100 W/(m K) (thereby <u>also</u> eliminating the scum, but leaving the same value of h at the outer surface),
(c) increase turbulence in the oil flow past the tubes, increasing h at the outer tube surface from 50 to 500 W/(m^2 K) (leaving the scum in place), or
(d) increase the rate of water flow <u>inside</u> the tube by a factor of 10 (leaving everything else the same).

By what factor much would each strategy, **<u>if</u> <u>used</u> <u>alone</u>**, increase the rate of heat transfer through each tube?

<u>properties of water</u>

ρ = 1000 kg/m^3 μ = 0.001 Pa s   k = .680 W/(m K) $\hat{C}_p$ = 4190 J/(kg K)