CM3110
Transport I
Part II: Heat Transfer

Exam 4 Review:
Some Heat Transfer Problems

Professor Faith Morrison

Department of Chemical Engineering
Michigan Technological University

1

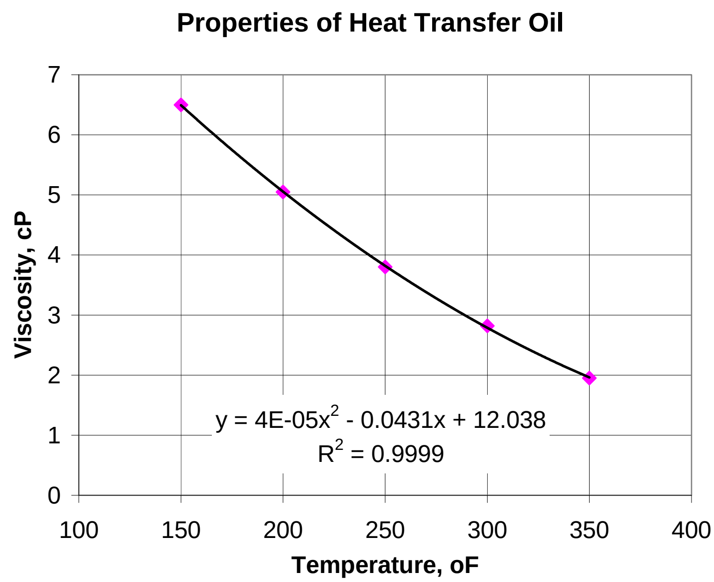
Example 1:

A hydrocarbon oil (mean heat capacity = 0.50 BTU/(lb_m °F); mean thermal conductivity=0.083 BTU/(h ft °F)) is to be heated by flowing through a hot pipe. The pipe is heated in such a way that the inside surface of the pipe (the surface in contact with the oil) is held at a constant temperature of 325°F. The oil is to be heated to 250°F in the pipe, which is 15 ft long and has an inside diameter of 0.0303 ft. The inlet oil temperature is 175°F. What should the flow rate of the oil be (in units of lb_m/h) such that the oil exits at the desired temperature of 250°C?

The viscosity of the oil varies with temperature as follows:

150°F, 6.50 cP
200°F, 5.05 cP
250°F, 3.80 cP
300°F, 2.82 cP
350°F, 1.95 cP

2



3

Geankoplis 4.10-3 (HW6)

Example 2:

A horizontal oxidized steel pipe carrying steam and having an OD of 0.1683m has a surface temperature of 374.9 K and is exposed to air at 297.1 K in a large enclosure. Calculate the heat loss for 0.305 m of pipe.

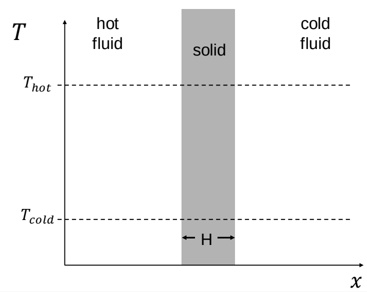
4

(Exam 4 2016)

Example 3:

As shown in the diagram below, hot fluid at T_{hot} is in contact with a tall, deep slab of thickness H. On the other side of the slab is cold fluid at temperature T_{cold}. Sketch the temperature profiles $T(x)$ in both fluids and in the slab for the following two cases:

a. The heat transfer coefficients on the hot side and the cold side are both finite. Label your answer "a".
b. The heat transfer coefficients on both sides are very, very large. Label your answer "b".



5

(Exam 4 2016)

Example 4:

Water enters a horizontal pipe at 35^oC and is heated by an electrical heater blowing hot air around the pipe (for the air, Re $= 5.0 \times 10^3$; $T_{air} = 95^oC$, and the pipe is steel (physical properties given n page 1), with inner diameter of $0.032m$ and wall thickness of $0.0031m$). The exit water temperature is 45^oC and the water flows at $2.8 \times 10^{-1}\ kg/s$. How much heat (in kilowatts) is needed to heat the water stream?

Physical properties of steel:
thermal conductivity = $16.3\ W/mK$
heat capacity = $0.49\ kJ/kg\ K$
density = $8050\ kg/m^3$

6

(Exam 4 2016)

Example 5:

A container has walls made of steel that are $2.5\ cm$ thick (physical properties given below). To prevent vapor condensation on the inside walls of the container, the atmosphere inside the container is heated so that the inside wall temperature never drop below $+10.0^o\ C$. The air temperature outside the container varies between -22^oC and $+30^{oC}$. What is the heat flux through the container wall on the coldest, windiest days? Please give your answer in kW/m^2 .

Physical properties of steel:
- **thermal conductivity = $16.3\ W/mK$**
- **heat capacity = $0.49\ kJ/kg\ K$**
- **density = $8050\ kg/m^3$**

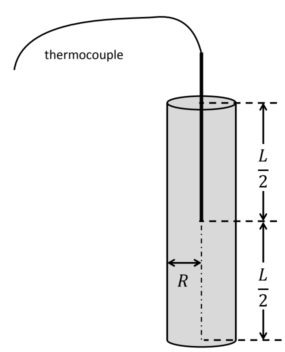
7

(Exam 4 2016)

Example 6:

What are the partial differential equation and the boundary/initial conditions (express in a coordinate system) that must be solved in order to obtain the time-dependent temperature at the center of a steel rod subjected to the following experiment (indicate all your assumptions):

A very long cylindrical steel rod of length L and radius R is initially equilibrated in a bath of temperature T_{bath}. Suddenly, the rod is submerged in a rapidly flowing bath of water of higher temperature T_{new}. The rod has a thermocouple embedded down its axis, with the thermocouple tip lodged exactly halfway down the length of the rod, positioned to read the temperature at that point. The heat transfer coefficient from the fluid to the rod is essentially infinite.



8

(Exam 4 2016)

Example 7:

Water flows at 0.0522 kg/s (turbulent) in the inside of a double pipe heat exchanger (inside steel pipe, inner diameter=0.545 inches, length unknown, physical properties given below); the water enters at 30.0^oC and exits at 65.6^oC. In the shell of the heat exchanger, steam condenses at an unknown saturation pressure. What is the heat transfer coefficient, h_{lm} (based on log mean temperature driving force) in the water flowing in the pipe? You may neglect the effect on heat-transfer coefficient of the temperature-dependence of viscosity. Please give your answer in W/m^2K.

Physical properties of steel:
- **thermal conductivity** $= \mathbf{16.3}\ W/mK$
- **heat capacity** $= \mathbf{0.49}\ kJ/kg\ K$
- **density** $= \mathbf{8050}\ kg/m^3$

9