BENG 37303 Transport Phenomena in Biological Systems

Homework #1

Assigned: August 28, 2024

Due: September 4, 2024

1. A Stanley tumbler (Yeti is so yesterday, and don’t get me started on Tervis) is used to hold hot coffee and does so very well. Does it make sense to preheat the Stanley before adding the coffee? Or, in other words, does pouring hot coffee into a cold Stanley significantly reduce the temperature of the coffee?

Assume the Stanley is composed of two stainless steel cylinders (sides and bottom, no top) with insulation between the two cylinders. Assume the insulation layer between the cylinders completely blocks heat exchange between the outside surrounding air and inner cylinder. Therefore, when coffee is added to the Stanley, only the inner cylinder is heated (this is why your hand doesn’t get hot holding a Stanley full of hot coffee). The dimensions of the inside cylinder are inside diameter of 5.5 cm (touching the coffee), wall thickness of 0.48 mm (including the bottom circle), and height of 23 cm. Stainless steel properties are Cp = 0.5 kJ/kg-K; density = 8000 kg/m3. Also assume the coffee at the top surface does not lose any heat to the surroundings because of the lid. If the Stanley is removed from your backpack after walking in the cold and is at an initial temperature of 30 °F and filled with coffee at 170 °F (ideal temperature) to the top, estimate the resulting steady-state temperature of the coffee assuming the Stanley is perfectly insulated. Should the Stanley be preheated?

5.5 cm

23 cm

Inside diameter

Insulation

1. A heat rate q of 6.2 kW is conducted through a wall section of a solar dryer. The cross-sectional area of the wall section is 10 and thickness is 2.5 cm. If the inner (hot) surface temperature is 105 °C and the thermal conductivity of the wall material is 0.2 , what is the outer surface temperature?
2. You want to create a new structural wall using an advanced material and you need to figure out how thick to make it. The new material of wall has a conductivity of k = 0.25 . You want to improve the insulating ability of the new wall by reducing the heat flow rate by at least 20% over the existing brick (k = 0.75 ) wall. The existing brick wall is 100 mm thick and both walls are subjected to the same surface temperature difference between inside and outside of the wall. How thick should the structure wall made from the new material be?
3. The top of the roof of a car absorbs a solar radiant flux of 800 , the underside is perfectly insulated (q” = 0 exiting the bottom of the roof). Assume the roof is a surface for purposes of setting up an energy balance equation. The convection coefficient between the roof and the ambient air is 12 .
   1. Neglecting radiation given off from the roof to the surroundings, calculate the temperature of the roof surface under steady-state conditions if the ambient air temperature is 20°C. Steady state conditions means the rate of heat flow into the roof equals rate of heat flow out (as conduction down only since radiation to the surroundings is neglected).
   2. For the same ambient air temperature of 20°C, calculate the temperature of the roof including convection and radiation if its surface emissivity if 0.8 and radiation leaving the roof to the surroundings is no longer neglected.
4. You are working for a major snack food manufacturer intending to install a new fried pie line. The fryer is 20 m long, 1 m wide, and 0.5 m tall. You are using a special blend of oil with a density of 0.935 g/mL and a specific heat of the oil is 3.2 KJ/kg°C. How much heat is required to bring the room temperature (25 °C) oil to 350 °F for frying. If the fryer oil needs to be ready in 1 hour, what size heater is needed (assume complete efficiency and no other losses).