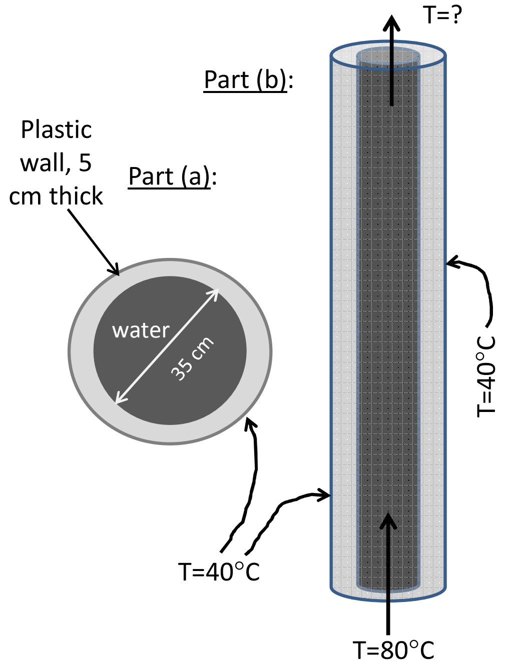
AESB2320, 2018-19

Part 2 Examination - 18 April 2019

Write your solutions *on your answer sheet*, not here. In all cases ***show your work***.
To avoid any possible confusion,
state the equation numbers and figure numbers of equations and figures you use
along with the text you are using (BSL1, BSL2 or BSLK).
Beware of unnecessary information in the problem statement.

1. A geothermal well has inner diameter 35 cm and pumps water (properties listed below) at a velocity of 0.2 m/s. Water enters the well at 80°C at the bottom. Water leaves the well 2 km above the entrance. The well has a wall of plastic, with properties listed below, 5 cm thick. For this problem, assume that the outer surface of the wall is maintained at a uniform, constant temperature of 40°C.
   a. What is the overall heat-transfer coefficient U_o between the fluid and the outer surface of the wall?
   b. What is the temperature of the water leaving the well at the top? If you weren't able to complete part (a), assume for this part that $U_o = 50$ W/(m^2 k).

   (40 points)



<u>Properties of Water</u>

k = 0.60 W/(m K) ρ = 1000 kg/m^3 C_p = 4180 J/(kg K) μ = 0.001 Pa s

<u>Properties of plastic</u>

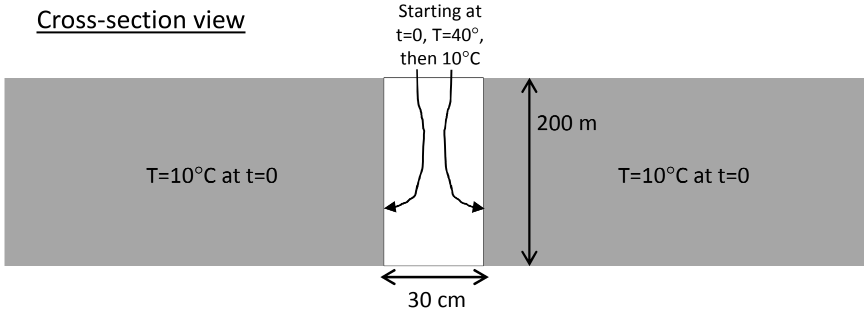
k = 0.16 W/(m K) ρ = 1300 kg/m^3 C_p = 1950 J/(kg K)

2. A scheme for heat storage into the subsurface involves pumping hot water through a loop of piping underground during the summer and then cold water in the winter, to extract the heat that was stored in the surrounding ground during the summer. For the purposes of this problem, simplify the description as follows:
   A solid (the subsurface) with properties below extends very far (infinitely) in the radial direction, and is 200 m thick. It is perfectly insulated on top and bottom surfaces. Assume a cylindrical, vertical pipe penetrates the subsurface; the pipe has a diameter of 30 cm. The subsurface is initially at a temperature of 10°C. Starting at time t = 0, we pump hot water through the pipe, such that the inner surface of the formation around the pipe is brought to and maintained at 40°C. Starting 180 days later, the surface of the pipe is brought to and maintained at 10°C.
   a. What is the temperature of the formation at a distance of 1 m from the center of the well at day 179, just before the temperature is reduced on day 180?
   b. What is the temperature of the formation at a distance of 1 m from the center of the well at day 210, 30 days after the temperature is reduced on day 180?

   (30 points)

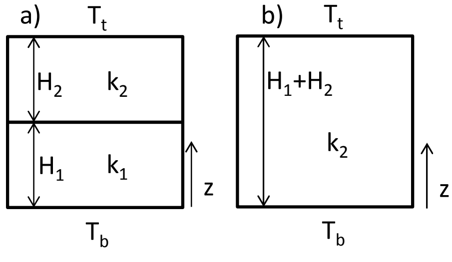
Properties of formation

ρ = 2270 kg/m^3 C_p = 1000 J/(kg K) k = 2.61 W/(m K)



3. Mining prospectors can tell if there's a metals or salt deposit underground from the steady-state vertical temperature gradient (dT/dz) near the surface. Consider this simplified problem.
   a. A layer of thickness H_1 of thermal conductivity k_1 (give other props?) lies underneath layer 2 of thickness H_2 and thermal conductivity k_2. At the bottom of layer 1, T = T_b; at the top of layer 2, T = T_t. What is the steady-state vertical heat flux q near the top of layer 2? What is the steady-state temperature gradient there?
   b. Suppose instead there is a single layer, of thickness (H_1+H_2), of thermal conductivity k_2. What is the steady-state temperature gradient near the top of layer 2?
   c. Suppose $H_1 = H_2$, but $k_1 = 1.5\ k_2$. By what factor is the heat flux in case (a) greater than that in case (b)? By what factor is the temperature gradient (dT/dz) greater in case (a) than in case (b)?

   (15 points)



4. Rocky wants to determine the thermal diffusivity α of a rectangular slab of metal by measuring its response to heating from one end. He perfectly insulates five sides of the solid. The solid is initially at a temperature T_0. Starting at time t = 0 Rocky heats the sixth side of the solid by exposing it to vigorously stirred water at temperature T_1.

   Rocky assumes that the heated side of the solid is instantaneously raised in temperature to T_1. Then, from the change in temperature on the far side of the solid over time, he determines the thermal diffusivity of the solid using the chart for unsteady conduction for this geometry.

   a) What chart should he use? State the figure number and text he should use.
   b) Of course it is not physically possible to instantaneously change the surface temperature of the solid. In reality, Rocky is exposing this surface to a stirred fluid at the hotter temperature T_1. By ignoring the process of convective heat transfer to the exposed surface, Rocky has introduced an error (perhaps a small error) into his calculations. Is the true value of α that he calculates from the data greater or less than true value? Briefly justify your answer.

   (15 points)