Closed book. Formula sheet and calculator allowed
Part 1: Multiple choice questions

Attempt all of these questions. Do not give random answers, as wrong answers have negative value.
1. Consider a situation where we want to bring water to a fire some distance away. What is the closest analog to the mechanism of heat conduction?
   (a) using a fire hose to spray water at the fire
   (b) using a wheelbarrow to cart buckets of water to the fire
   (c) a chain gang of people to move buckets of water to the fire

Answer:

2. An object initially at uniform room temperature is placed in an environment at a different temperature. In which case do you expect a uniform temperature distribution in the object, independently of time?
   (a) a potato in boiling water
   (b) a block of wood tossed in a fire
   (c) A copper kettle in an oven

Answer:

3. What parameters does the temperature distribution across a brick wall at steady state depend on?
   (a) the conductivity of the brick, \( k \)
   (b) the surface temperatures, \( T_1 \) and \( T_2 \)
   (c) the initial temperature of the wall

Answer:

4. What parameters does the heat flux across a brick wall at steady state depend on?
   (a) the conductivity of the brick, \( k \)
   (b) the surface temperatures, \( T_1 \) and \( T_2 \)
   (c) the initial temperature of the wall
   (d) (a) and (b)
   (e) (a), (b) and (c)

Answer:

5. What parameters does the transient temperature distribution across a brick wall depend on?
   (a) the conductivity of the brick, \( k \)
   (b) the surface temperatures, \( T_1 \) and \( T_2 \)
   (c) the initial temperature of the wall
   (d) all of the above
   (e) none of the above

Answer:
6. The cooking instructions for turkeys always tell us to measure temperature deep inside the turkey. From this, we can infer that, for the typical baking conditions:

(a) the Biot number is low
(b) the Biot number is high
(c) the thermometer will fall off unless we stick it in deep enough

Answer:

7. Why do old un-airconditioned buildings with thick adobe walls feel cool during hot summer days, even though the thermal resistance of uninsulated adobe walls is lousy?

(a) the thermal mass of the building delays the diffusion of heat to the inner wall surfaces until night-time, when the walls cool down again
(b) The walls get cold in the winter and it takes a long time to heat them up
(c) adobe reflects solar radiation

Answer:

8. Why does one use a wooden spoon rather than a metal one for cooking soups and sauces?

(a) metal spoons heat up very quickly and become too hot to touch
(b) it is more traditional to cook with wooden spoons
(c) the wooden spoon does not scratch the surface of the pan

Answer:

9. Why is it acceptable to use only one term in the infinite series solution for transient problems with large Biot numbers, if the Fourier number is large?

(a) the high-frequency terms in the solution decay quickly with time
(b) the low-frequency terms in the solution decay quickly with time
(c) the Krylov space of the higher terms is range-deficient and therefore does not contribute to the solution

Answer:

10. The Biot number and the Nusselt numbers have the same physical parameters in their definition, namely characteristic dimension, convection coefficient and thermal conductivity. What is the difference between the two?

(a) the biot number describes the ratio of convective to conductive thermal resistance, the Nusselt number is a dimensionless temperature gradient in the fluid near a surface
(b) the conductivity in the Biot number is for the solid, the conductivity in the Nusselt number is for the fluid
(c) They are the same thing, there are two groups because Nusselt and Biot both claimed to have invented the dimensionless parameter in question
(d) (a) and (b)
(e) (a) and (c)

Answer:
Part 2: Problems

Choose one of the two problems. If you attempt both, clearly identify the one you do not wish graded.
Problem 1
The thermal storage tanks in the mechanical engineering building at UNM can be considered as a single tank, with dimension 8 m × 16 m × 4 m tall. The walls are concrete, with a thermal conductivity of 1.28 W/mK and a thickness of 0.3 m. Assuming convection coefficients of 4 W/m²K and 50 W/m²K for the air outside the tanks and the water inside the tanks respectively, estimate the total heat loss for the case where the tanks contain hot water at 50°C, while the air outside of the tanks is at 15°C. What is the thickness of polystyrene foam insulation (k = 0.03 W/mK) required to reduce the heat loss by a factor of 10? Assume that heat loss is only through the perimeter walls.
Problem 2
Show that the Biot number is equivalent to the ratio of the conductive thermal resistance of an object in the direction of heat flow and the convective thermal resistance of the boundary layer surrounding the same object. Explain the physical significance of each quantity in your derivation.