FACULTY: ENGINEERING
FIRST SEMESTER EXAMINATIONS
2016/2017 ACADEMIC SESSION

HOD'S SIGNATURE

COURSE CODE: MEE305
COURSE TITLE: HEAT TRANSFER
DURATION: 2 HOURS

INSTRUCTIONS

1. ATTEMPT ANY THREE QUESTIONS OF YOUR CHOICE
2. SEVERE PENALTIES APPLY FOR MISCONDUCT, CHEATING, POSSESSION OF UNAUTHORIZED MATERIALS DURING EXAM
3. YOU ARE NOT ALLOWED TO BORROW CALCULATORS AND ANY OTHER WRITING MATERIALS
4. PLEASE TURN OVER FOR A LIST OF SELECTED RELEVANT FORMULAS AND THE TABLE ON ONE-DIMENSIONAL TRANSIENT HEAT CONDUCTION

1. i) Elias Ibrahim engaged in an early morning jogging exercise when the temperature of the environment was 25 °C at a low relative humidity. After about 2 $mins$ of jogging, he began to sweat profusely and felt cooler.

(a) Explain why was he perspiring so profusely? **(6 marks)**

(b) Discuss the energy exchange occurrences taking place between Elias' body and the environment. **(6 marks)**

ii) A certain material has a thickness of 30 cm and a thermal conductivity of 0.04 $W/m.°C$. At a particular instant in time, the temperature distance with x, the distance from the left face, is $T = 150x^2 - 30x$, where x is in meters.

(a) Calculate the heat flow rates at $x = 0$ and $x = 30cm$.

(b) Is the solid heating up or cooling down?

(8 marks)

2. i) Benz and Daniel bought two roasted plantains "boli" with OD of 25 cm on their way to Omotosho power plant, Okitipupa. Benz's and Daniel's "boli" respectively, had a thermal conductivity of 0.13 $W/m.C$ (15% moisture content) and 0.45 $W/m\ C$ (57% moisture content). The inner core of the "boli", with an ID of 0.2 cm, was at a temperature of 65 °C. The snacks lost heat by free convection with $h = 2.1\ W/m^2.°C$ to the surroundings at 24 °C.

a. Calculate the heat loss per metre for both Benz's and Daniel's "boli" **(7 marks)**

b. Which one gets cooler faster? Explain why, particularly with reference to the respective moisture content?

(3 marks)

ii) What do you understand by thermal contact resistance? **(6 marks)**

Derive the expressions for thermal resistance due to convection and conduction based on the electrical analogy? (4 **marks)**

3. i) (a) Consider heat transfer between two identical hot solid bodies and the air surrounding them. The first solid is being cooled by a fan while the second one is allowed to cool naturally. For which solid is the lumped system analysis more likely to be applicable? Why?

(4 marks)

(b) In what medium is the lumped system analysis more likely to be applicable: in water or in air? Why?

(4 marks)

ii) To warm up some milk for a baby, a mother pours milk into a thin-walled glass whose diameter is 5 cm. The height of the milk in the glass is 7.5 cm. She then places the glass into a large pan filled with hot water at 60°C. **The milk is stirred constantly, so that its temperature is uniform at all times.** If the heat transfer coefficient between the water and the glass is 120 $W/m^2 \cdot °C$, determine how long it will take for the milk to warm up from 3°C to 38°C. Take the properties of the milk to be the same as those of water [The thermal conductivity, density, and specific heat of the milk at 20°C are $k = 0.607$ W/m.°C, ρ = 998 kg/m³, and $C_p = 4.182$ kJ/kg.C]. Can the milk in this case be treated as a lumped system? Why?

(12 marks)

(i) (a) What is the physical significance of the Fourier number? **(5 marks)**

(b) Consider two similar materials A and B. If the thickness of B is twice of A, how will the Fourier number be affected in a specified heat transfer problem for this materials and what is the implication? **(3 marks)**

(ii) An ordinary egg can be approximated as a 5.0-cm diameter sphere whose properties are roughly $k = 0.6\ W/m\ {}^\circ C$ and $\alpha = 0.14 \times 10^{-6} m^2/s$. The egg is initially at a uniform temperature of 9.5°C and is dropped into boiling water at 98.5°C. Taking the convection heat transfer coefficient to be $h = 1200\ W/m^2.{}^\circ C$, determine how long it will take for the center of the egg to reach 71.5°C. **(12 marks)**

LIST OF RELEVANT FORMULAS

(i) $q'' = \frac{q}{A} = -k\frac{dT}{dx}$

(ii) $q = hA(T_s - T_f)$

(iii) $q'' = \varepsilon\sigma T s^4$

(iv) $\nabla^2 T + \frac{\dot{Q}}{k} = \frac{1}{\alpha}\frac{\partial T}{\partial t}$

(v) $\alpha = \frac{k}{\rho c_p}$

(vi) $R_{cond} = \frac{L}{kA} = \frac{(T_1 - T_2)}{q}$

(vii) $q = \frac{\Delta T_{overall}}{[\sum R_{th}]}$

(viii) $U = \frac{1}{\frac{1}{h_{hf}} + \frac{L}{K} + \frac{1}{h_{cf}}}$

(ix) $Q = \frac{2\pi L(T_1 - T_{air})}{\frac{\ln(r_2/r_1)}{k} + \frac{1}{h_o r_2}}$

(x) $r_2 (= r_c) = \frac{k}{h_o}$

(xi) $r_2 (= r_c) = \frac{2k}{h_o}$

(xii) $Bi = \frac{hL_c}{k}$