



ELIZADE UNIVERSITY, ILARA-MOKIN,  
ONDO STATE, NIGERIA  
DEPARTMENT OF  
MECHANICAL, AUTOMOTIVE AND PRODUCTION ENGINEERING

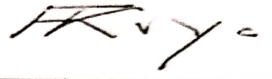
FIRST SEMESTER EXAMINATIONS

2017/2018 ACADEMIC SESSION

**COURSE:** MEE 305 Heat Transfer I (2 Units)  
**CLASS:** 300 Level Mechanical Engineering &  
400 Level Automotive Engineering

**TIME ALLOWED:** 2 hours

**INSTRUCTIONS:** Attempt any three questions of your choice

  
HOD'S SIGNATURE

**Date:** March, 2018

**Question 1**

- (a) What are the mechanisms of heat transfer?  
(b) How are they distinguished from each other?

(7 marks)

- (c) Consider a steam pipe of length  $L = 20$  m, inner radius  $r_1 = 6$  cm, outer radius  $r_2 = 8$  cm, and thermal conductivity  $k = 20$  W/m $\cdot$  $^{\circ}$ C. The inner and outer surfaces of the pipe are maintained at average temperatures of  $T_1 = 150^{\circ}$ C and  $T_2 = 60^{\circ}$ C, respectively. Obtain a **general relation** for the temperature distribution inside the pipe under steady conditions and determine the rate of heat loss from the steam through the pipe.

(13 marks)

**Question 2**

- (a) Consider an insulated pipe exposed to the atmosphere. Will the critical radius of insulation be greater on calm days or on windy days?
- (b) A 3-mm-diameter and 5-m-long electric wire is tightly wrapped with a 2-mm thick plastic cover whose thermal conductivity is  $k = 0.15$  W/m $\cdot$  $^{\circ}$ C. Electrical measurements indicate that a current of 15 A passes through the wire and there is a voltage drop of 6 V along the wire. If the insulated wire is exposed to a medium at  $T = 25^{\circ}$ C with a heat transfer coefficient of  $h = 12$  W/m $^2 \cdot$   $^{\circ}$ C, determine the temperature at the interface of the wire and the plastic cover in steady operation. Also determine whether doubling the thickness of the plastic cover will increase or decrease this interface temperature.

(5 marks)

(15 Marks)

### Question 3

- (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? **(8 Marks)**
- (b) An ordinary egg can be approximated as a 5-cm-diameter sphere, whose properties are roughly  $K = 0.6 \text{ W/m}\cdot^\circ\text{C}$  and  $\alpha = 0.14 \times 10^{-6} \text{ m}^2/\text{s}$ . The egg is initially at a uniform temperature of  $5^\circ\text{C}$  and is dropped into boiling water at  $95^\circ\text{C}$ . Taking the convection heat transfer coefficient to be  $h = 1200 \text{ W/m}^2 \cdot ^\circ\text{C}$ , determine how long it will take for the center of the egg to reach  $70^\circ\text{C}$ . Take thermal diffusivity to be  $0.14 \times 10^{-6} \text{ m}^2/\text{s}^2$ . **(12 marks)**

### Question 4

- (a) What is the physical significance of the Fourier number? Will the Fourier number for a specified heat transfer problem double when the time is doubled? **(8 marks)**
- (b) A person is found dead at 5 PM in a room whose temperature is  $20^\circ\text{C}$ . The temperature of the body is measured to be  $23^\circ\text{C}$  when found, and the heat transfer coefficient is estimated to be  $h = 8 \text{ W/m}^2 \cdot ^\circ\text{C}$ . Modeling the body as a 30-cm-diameter, 1.70-m-long cylinder, estimate the time of death of that person. **(12 marks)**

## LIST OF SELECTED RELEVANT FORMULAS

$$1. \frac{\partial}{\partial x} \left( k \frac{\partial T}{\partial x} \right) + \frac{\partial}{\partial y} \left( k \frac{\partial T}{\partial y} \right) + \frac{\partial}{\partial z} \left( k \frac{\partial T}{\partial z} \right) + \dot{Q} = \rho c_p \frac{\partial T}{\partial t}$$

$$2. r_{cr} = \frac{k}{h}$$

$$3. R_{conv} = \frac{1}{h_1 A}$$

$$4. R_{cond, cyl} = \frac{\ln(r_2/r_1)}{2\pi k L}$$

$$5. Fo = \alpha t / L^2$$

$$6. L_c = \frac{\text{Volume of the solid (V)}}{\text{Surface area of the solid (A_s)}}$$

$$7. R_{cond, sph} = \frac{r_2 - r_1}{4\pi r_1 r_2 k}$$

$$8. R_{cond, rec} = \frac{L}{kA}$$

$$9. Q = \frac{\Delta T}{\Sigma R_T}$$

10.

Center of plane wall ( $x = 0$ ):

$$\theta_{0, wall} = \frac{T_0 - T_\infty}{T_1 - T_\infty} = A_1 e^{-\lambda_1^2 \tau}$$

Center of cylinder ( $r = 0$ ):

$$\theta_{0, cyl} = \frac{T_0 - T_\infty}{T_1 - T_\infty} = A_1 e^{-\lambda_1^2 \tau}$$

11.

$$\frac{1}{r} \frac{\partial}{\partial r} \left( kr \frac{\partial T}{\partial r} \right) + \frac{1}{r^2} \frac{\partial}{\partial \phi} \left( kr \frac{\partial T}{\partial \phi} \right) + \frac{\partial}{\partial z} \left( k \frac{\partial T}{\partial z} \right) + \dot{g} = \rho C \frac{\partial T}{\partial t}$$

Properties of air at 1 atm pressure

Temp. $T, ^\circ\text{C}$	Density $\rho, \text{kg/m}^3$	Specific Heat $c_p, \text{J/kg} \cdot \text{K}$	Thermal Conductivity $k, \text{W/m} \cdot \text{K}$	Thermal Diffusivity $\alpha, \text{m}^2/\text{s}$	Dynamic Viscosity $\mu, \text{kg/m} \cdot \text{s}$	Kinematic Viscosity $\nu, \text{m}^2/\text{s}$	Prandtl Number Pr
-150	2.866	983	0.01171	$4.158 \times 10^{-6}$	$8.636 \times 10^{-5}$	$3.013 \times 10^{-6}$	0.7246
-100	2.038	966	0.01582	$8.036 \times 10^{-6}$	$1.189 \times 10^{-4}$	$5.837 \times 10^{-6}$	0.7263
-50	1.582	999	0.01979	$1.252 \times 10^{-5}$	$1.474 \times 10^{-4}$	$9.319 \times 10^{-6}$	0.7440
-40	1.514	1002	0.02057	$1.356 \times 10^{-5}$	$1.527 \times 10^{-4}$	$1.008 \times 10^{-5}$	0.7436
-30	1.451	1004	0.02134	$1.465 \times 10^{-5}$	$1.579 \times 10^{-4}$	$1.087 \times 10^{-5}$	0.7425
-20	1.394	1005	0.02211	$1.578 \times 10^{-5}$	$1.630 \times 10^{-4}$	$1.169 \times 10^{-5}$	0.7408
-10	1.341	1006	0.02288	$1.696 \times 10^{-5}$	$1.680 \times 10^{-4}$	$1.252 \times 10^{-5}$	0.7387
0	1.292	1006	0.02364	$1.818 \times 10^{-5}$	$1.729 \times 10^{-4}$	$1.338 \times 10^{-5}$	0.7362
5	1.269	1006	0.02401	$1.880 \times 10^{-5}$	$1.754 \times 10^{-4}$	$1.382 \times 10^{-5}$	0.7350
10	1.246	1006	0.02439	$1.944 \times 10^{-5}$	$1.778 \times 10^{-4}$	$1.426 \times 10^{-5}$	0.7336
15	1.225	1007	0.02476	$2.009 \times 10^{-5}$	$1.802 \times 10^{-4}$	$1.470 \times 10^{-5}$	0.7323
20	1.204	1007	0.02514	$2.074 \times 10^{-5}$	$1.825 \times 10^{-4}$	$1.516 \times 10^{-5}$	0.7309
25	1.184	1007	0.02551	$2.141 \times 10^{-5}$	$1.849 \times 10^{-4}$	$1.562 \times 10^{-5}$	0.7296
30	1.164	1007	0.02588	$2.208 \times 10^{-5}$	$1.872 \times 10^{-4}$	$1.608 \times 10^{-5}$	0.7282
35	1.145	1007	0.02625	$2.277 \times 10^{-5}$	$1.895 \times 10^{-4}$	$1.655 \times 10^{-5}$	0.7268
40	1.127	1007	0.02662	$2.346 \times 10^{-5}$	$1.918 \times 10^{-4}$	$1.702 \times 10^{-5}$	0.7255
45	1.109	1007	0.02699	$2.416 \times 10^{-5}$	$1.941 \times 10^{-4}$	$1.750 \times 10^{-5}$	0.7241

Bi	Plane Wall		Cylinder		Sphere	
	$\lambda_1$	$A_1$	$\lambda_1$	$A_1$	$\lambda_1$	$A_1$
0.01	0.0998	1.0017	0.1412	1.0025	0.1730	1.0030
0.02	0.1410	1.0033	0.1995	1.0050	0.2445	1.0060
0.04	0.1987	1.0066	0.2814	1.0099	0.3450	1.0120
0.06	0.2425	1.0098	0.3438	1.0148	0.4217	1.0179
0.08	0.2791	1.0130	0.3960	1.0197	0.4860	1.0239
0.1	0.3111	1.0161	0.4417	1.0246	0.5423	1.0298
0.2	0.4328	1.0311	0.6170	1.0483	0.7593	1.0592
0.3	0.5218	1.0450	0.7465	1.0712	0.9208	1.0880
0.4	0.5932	1.0580	0.8516	1.0931	1.0528	1.1164
0.5	0.6533	1.0701	0.9408	1.1143	1.1656	1.1441
0.6	0.7051	1.0814	1.0184	1.1345	1.2644	1.1713
0.7	0.7506	1.0918	1.0873	1.1539	1.3525	1.1978
0.8	0.7910	1.1016	1.1490	1.1724	1.4320	1.2236
0.9	0.8274	1.1107	1.2048	1.1902	1.5044	1.2488
1.0	0.8603	1.1191	1.2558	1.2071	1.5708	1.2732
2.0	1.0769	1.1785	1.5995	1.3384	2.0288	1.4793
3.0	1.1925	1.2102	1.7887	1.4191	2.2889	1.6227
4.0	1.2646	1.2287	1.9081	1.4698	2.4556	1.7202
5.0	1.3138	1.2403	1.9898	1.5029	2.5704	1.7870
6.0	1.3496	1.2479	2.0490	1.5253	2.6537	1.8338
7.0	1.3766	1.2532	2.0937	1.5411	2.7165	1.8673
8.0	1.3978	1.2570	2.1286	1.5526	2.7654	1.8920
9.0	1.4149	1.2598	2.1566	1.5611	2.8044	1.9106
10.0	1.4289	1.2620	2.1795	1.5677	2.8363	1.9249
20.0	1.4961	1.2699	2.2880	1.5919	2.9857	1.9781
30.0	1.5202	1.2717	2.3261	1.5973	3.0372	1.9898
40.0	1.5325	1.2723	2.3455	1.5993	3.0632	1.9942
50.0	1.5400	1.2727	2.3572	1.6002	3.0788	1.9962
100.0	1.5552	1.2731	2.3809	1.6015	3.1102	1.9990
$\infty$	1.5708	1.2732	2.4048	1.6021	3.1416	2.0000