PAPUA NEW GUINEA UNIVERSITY OF TECHNOLOGY

MECHANICAL ENGINEERING DEPARTMENT

2022 SEMESTER ONE – FINAL EXAMINATIONS

ME 313- HEAT TRANSFER

DATE: MONDAY 06 JUNE 2022, MORNING

TIME ALLOWED: TWO (2) HOURS

INSTRUCTION TO STUDENTS:

1. You have 10 minutes to read the paper. **DO NOT** write anything during this time.
2. Answer **ALL** questions.
3. All questions must be answered **neatly** in the ANSWER BOOKLET provided, No other written materials will be accepted.
4. Calculators are permitted in the examination room.
5. Sketches must be neatly drawn and clearly labelled. Use a soft-grade pencil for drawing.
6. Write your name clearly on the front page of the answer booklet using **BLOCK LETTERS – DO IT NOW!**

MARKING SCHEME:

All questions carry equal marks unless specified otherwise

Notes:

i. Steam Table provided
ii. Convection correlations provided on the last page of the question paper

iii. <u>Make a justifiable assumption if not given.</u>
iv. The symbols represent their usual meanings.

<u>Question 1</u>

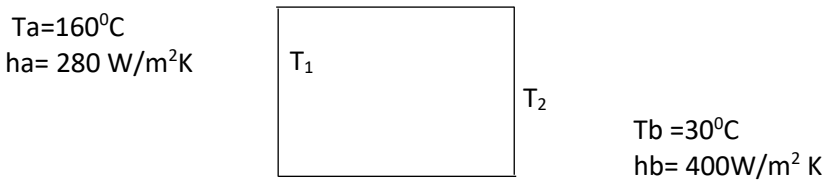
a. Heat Conduction: For a hollow sphere, derive the equation

$$Q = \frac{kAm(t_1 - t_2)}{r_2 - r_1}$$ [4 Marks]

Where

Am is the mean area
r_2 is the external radius
r_1 is the internal radius
t_1 is the inside surface temperature
t_2 is the outside surface temperature

b. Refer the figure as is shown below. The dimension of the surface perpendicular to the heat transfer is 0.3m x 3m and is 3cm thick. Average thermal conductivity of the slab is 15W/mK



Calculate
i. the rate of heat transfer
ii. the overall heat transfer coefficient
iii. the total thermal resistance

[6 Marks]

<u>Question 2</u>

a. Explain the concepts of
i. fully developed flow [1.5 Marks]

ii. Boundary layer-flow over a flat plate; indicating leading edge, behaviour of fluid flow and viscous sub layer [2.5 Marks]

b. Air flows over a flat plate at a velocity of 15 m/s. Air and surface temperature of the plate are 24^0C and 630^0C respectively. Calculate

i. the average heat transfer coefficient
ii. the amount of heat transferred per meter width from both sides of the plate over a distance of 50 cm from the leading edge

[6 Marks]

Question 3

a. Define black body and Gray body [3 Marks]

b. A horizontal pipe of outside diameter 8 cm is maintained at a temperature of 184^0C. It is exposed to atmospheric air. The air temperature is 20^0C. The emissivity of the surface is 0.8. Deduce the heat loss from the pipe. Assume the length of the pipe is 1m. [7 Marks]

Question 4

a. Define the followings:
Kirchhoffs law, Wein's displacement law [2 Marks]

b. Define view factor in relation to radiation heat transfer and obtain the expression $Q_{12} = A_1 F_{12}(E_{b1} - E_{b2})$ for black surfaces, where F_{12} is the view factor from surface 1 to 2.

[4 Marks]

c. The inside surface of a hollow sphere is maintained at a temperature of 600K. A hole of diameter 1.2 cm is made on the sphere. Calculate the radiation energy entering into the sphere through the hole per unit slid angle at an angle of 40^0 with the normal to the surface of the opening [4 Marks]

Use of various correlations used in convection

Forced Convection

Flat Plates

Equation	Condition
Boundary layer thickness, $\delta = 5x\frac{1}{\sqrt{R_e}}$	Laminar
Boundary layer thickness, $\delta = 0.37x\frac{1}{R_e^{0.25}}$	Turbulent
Boundary layer thickness-Thermal, $\delta_{th} = \frac{\delta}{\sqrt[3]{P_r}}$	Laminar
Local Skin Friction Coefficient, $C_x = 0.664\frac{1}{\sqrt{R_e}}$	Laminar
Average Skin Friction Coefficient, $C_{Ave} = 1.328\frac{1}{\sqrt{R_e}}$	Laminar
Local Skin Friction Coefficient, $C_x = 0.0592\frac{1}{R_e^{0.25}}$	Turbulent
Nusselt Number, $N_u = 0.332\ R_e^{0.5} P_r^{0.333}$	Local, Laminar, 0.6<Pr<10
Average Nusselt Number , $N_u\ Ave = 0.664\ R_e^{0.5} P_r^{0.333}$	Laminar, 0.6<Pr<10
Drag Force (F) $\frac{F}{LD} = \frac{C_D \rho u_\infty^2}{2}$ $\frac{F}{A} = \frac{C_{Ave} \rho u^2}{2}$	Cylinder Flat Plate

Natural Convection

Horizontal Cylinders

$(Gr)_L (Pr)$	C	N
10^{-10} to 10^{-2}	0.675	0.058
10^{-2} to 10^{2}	1.02	0.148
10^{2} to 10^{4}	0.85	0.188
10^{4} to 10^{7}	0.48	0.250
10^{7} to 10^{12}	0.125	0.333