Program: B. Sc. in IPE (3rd)
Semester: Winter

Date: 05 December, 2023
Time: 9:00 am – 12:00 pm

ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)
ORGANISATION OF ISLAMIC COOPERATION (OIC)
DEPARTMENT OF MECHANICAL AND PRODUCTION ENGINEERING

Semester Final Examination
Course Number: ME 4353
Course Title: Thermodynamics and Heat Transfer

Winter Semester: 2022 - 2023
Full Marks: 150
Time: 3.0 Hours

There are **06 (six)** questions. Answer all of them. The symbols have their usual meanings. Marks of each question and corresponding CO and PO are written in parenthesis. Assume any reasonable value for the missing data (Property tables are attached at page – 04)

---

1. a) Discuss in brief about different 'macroscopic' forms of energy. **(04) (CO1) (PO1)**

b) For a stationary and closed system show that the general form of "first law equation for control mass" is: **(06) (CO1) (PO2)**

$$\Delta Q - \Delta W = \Delta E$$

c) A gas in a piston–cylinder assembly undergoes an expansion process for which the relationship between pressure and volume is given by $PV^n = C$. The initial pressure is 4.5 bar, the initial volume is 0.16 m^3, and the final volume is 0.32 m^3. Determine the work done for the process in kJ, if (a) $n = 1.8$, (b) $n = 1.0$, and (c) $n = 0$ and show that the work done is minimum for case "a". **(15) (CO1) (PO2)**

2. a) A 4-stroke V12 engine has a bore-stroke ratio of 0.95. The linear distance travelled from TDC to BDC is 90 mm and the clearance volume of a single cylinder is 0.07 L. **(02+04 +04 = 10) (CO2) (PO2)**
Determine:
i. The crank radius.
ii. The ideal mass of air swept by the piston.
iii. Mathematically whether the engine is a Gasoline engine.

b) Explain why we cannot use diesel in a spark ignition engine. **(04) (CO2) (PO1)**

c) Write the valve actuation sequence for: **(02x03 = 06) (CO2) (PO1)**
i. In-block Cam
ii. Overhead Cam

3. a) Consider a steam pipe (see Fig. 1) of length L = 15 m, inner radius r_1 = 5 cm, outer radius r_2 = 8 cm, and thermal conductivity k = 20 W/m·K, as shown in Fig. 1. The inner and outer surfaces of the pipe are maintained at average temperatures of T_1 = 140°C and T_2 = 60°C, respectively. **(15+03 = 18) (CO3) (PO2)**

   i. Obtain a general relation for the temperature distribution inside the pipe under steady conditions.

   ii. Determine the rate of heat loss from the steam through the pipe.

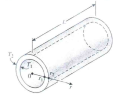


Figure 1: Steam Pipe

b) Construct the resistance networking and find the expression for rate of heat transfer for the following combined resistance network (see Fig. 2). All symbols are provided in the figure. **(06) (CO3) (PO2)**

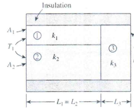


Figure 2: A combined resistance network

c) Describe the following in brief: **(03x02 = 06) (CO3) (PO1)**

   i. Thermal diffusivity, α

   ii. Convection heat transfer co-efficient, h

   iii. Thermal conductivity, k

4. a) Using necessary assumptions for a "rectangular fin" show that the general differential equation is, **(13) (CO3) (PO2)**

$$\frac{d^2\theta}{dx^2} - m^2\theta = 0.$$

OR,

Using necessary assumptions for a "large plane wall" show that the general differential equation for one-dimensional heat transfer is,

$$\frac{\partial^2 T}{\partial x^2} + \frac{\dot{e}_{gen}}{k} = \frac{1}{\alpha}\frac{\partial T}{\partial t}.$$

b) Draw the boiling curve and identify the different boiling regimes. Define the following from the curve: **(06+03 = 09)** **(CO3)** **(PO1)**

i. ONB
ii. CHF
iii. Liedenfrost point

c) A Newtonian fluid with a dynamic viscosity of 0.45 $N.s.m^{-2}$ and a specific gravity of 0.86 forms a condensate of 20 mm thick over a 300 mm dia. vertical pipe with a velocity of 2.0 $m.s^{-1}$. Determine the Reynolds number and hence identify the flow regime. **(08)** **(CO3)** **(PO2)**

5. a) A test is conducted to determine the overall heat transfer coefficient in an automotive radiator that is a compact Cross-flow water-to-air heat exchanger with both fluids (air and water) unmixed. The radiator has 50 tubes of internal diameter 0.4 cm and length 60 cm in a closely spaced plate-finned matrix. Hot water enters the tubes at 90°C at a rate of 0.5 kg/s and leaves at 60°C. Air flows across the radiator through the inter fin spaces and is heated from 20°C to 40°C. Determine: **(15)** **(CO4)** **(PO3)**

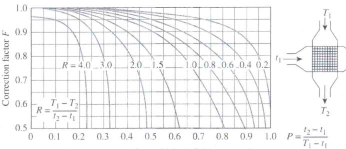
i. The overall heat transfer coefficient U_i of this radiator based on the inner surface area of the tubes.
ii. The rate of heat transfer from water to air.

b) In a 'parallel-flow DPHX', water (C_{pc}) at a rate of $\dot{m}_c$ is heated from $T_{c,i}$ to $T_{c,o}$ by an oil (hot fluid) having a specific heat of C_{ph}. Oil enters the exchanger at $T_{h,i}$ and leaves at $T_{h,o}$ with a rate of $\dot{m}_h$. If the overall heat transfer co-efficient and surface area are denoted by U and A_s respectively then justify that the log mean temperature difference for this HX is: **(10)** **(CO4)** **(PO2)**

$$\Delta T_{lm} = \frac{\Delta T_1 - \Delta T_2}{ln\left(\frac{\Delta T_1}{\Delta T_2}\right)}$$

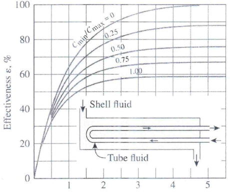
6. a) A one-shell pass, four-tube pass heat exchanger ($A = 27.8$ m^2) is used to cool oil ($C_p = 2100$ J/kgK) at 1.5 kg/s and 90°C with water entering at 19°C and at 1.0 kg/s. The HX involves the use of a 1 hp pump and 0.3 hp pump at 7h a day and 5 days a week. If $U = 250 W/m^2K$, Estimate: **(20)** **(CO4)** **(PO3)**

i. Rate of heat transfer.
ii. Outlet temperatures of the fluids.
iii. The annual operating cost if the cost of electricity is 15 cents/kWh.



(c) Single-pass cross-flow with both fluids *unmixed*

Figure 3. Use of Correction factor, F



(c) One-shell pass and 2, 4, 6, … tube passes

Figure 4. ε-NTU method