Kafrelsheikh University
Faculty of Engineering
Dept. Mech. Engineering
Year: 2nd Year Mechanical
Subject: Heat & Mass Transfer (MEP2206)

Semester: 2nd Semester
Final Examination
Date: 13/06/ 2021
Time allowed: 3 hours
Full Mark: 100

This course must be able to satisfy the General Competencies of engineering graduate (Level A): A1 and Competencies of basic mechanical engineering (Level B): B1 and B2

يسمح باستخدام جداول وخرائط انتقال الحرارة

Answer the following questions and assume any missing dada
Important note: Use suitable illustrations (drawing) as much as you can.

Question: 1 [15 Marks]

a) Starting with an energy balance on a rectangular volume element, derive the one-dimensional steady heat conduction equation for a plane wall with constant thermal conductivity and with heat generation.

b) Consider a large plane wall of furnace has thickness $L = 0.25$ m, thermal conductivity $k = 1.5$ W/m · °C, and surface area $A = 20$ m^2. The temperature of inside gas is 450 °C with heat transfer coefficient 45 W/m^2 °C. The outside air temperature is 25 °C with heat transfer coefficient 10 W/m^2 °C. Determine the following:

(*i*) The rate of heat conduction through the wall under steady conditions.
(*ii*) The surface temperature of inside and outside wall respectively.
(iii) If insulation material with 0.25 W/ m °C is used to insulate the wall, calculate its thickness to reduce the heat transfer rate by 40%.

Question: 2 [15 Marks]

a) Derive relation of critical radius of insulation for tubes and mention the conditions of non-effective insulation is required.

b) A steam flows inside a steel pipe with 5 cm inner diameter and 2.5 mm thickness with $k = 15$ W/m .°C. The pipe is insulated by covered with 3 cm thick glass wool with $k = 0.038$ W/m. °C. The steam temperature is 320 °C and the surrounding air is 5 °C. The inside and outside heat transfer coefficients are 80 W/m^2 .°C and 15 W/m^2 °C respectively. Calculate the following:

(i) The rate of heat transfer per unit length (L= 1m) and the temperature drops across the pipe and the insulation.
(ii) If the glass wool is replaced by insulation with 0.15 W/m. °C thermal conductivity, is the insulation is effect or not?

Question: 3 [30 Marks]

a) Explain the effect of fins on heat transfer rate and define the fin efficiency and the fin effectiveness, *also* discuss the difference between infinite fin and insulated fin.

b) Steam in a heating system flows through tubes whose outer diameter is $D_1 = 3$ cm and whose walls are maintained at a temperature of 120 ° C. Circular aluminum fins ($k = 180$ W/m · C) of outer diameter $D_2 = 6$ cm and constant thickness $t = 2$ mm are attached to the tube. The space between the fins is 3 mm, and thus there are 200 fins per meter length of the tube. Heat is transferred to the surrounding air at $T = 25$ ° C, with a combined heat transfer coefficient of $h = 60$ W/m^2 · ° C. Determine the increase in heat transfer from the tube per meter of its length as a result of adding fins. The efficiency of fin 0.95.

c) In a production facility, large brass plates of 4 cm thickness that are initially at a uniform temperature of 20 °C are heated by passing them through an oven that is maintained at 500 °C. The plates remain in the oven for a period of 7 min. Taking the combined convection and radiation heat transfer coefficient to be h= 120 W/m^2. °C. Determine the surface temperature of the plates when they come out of the oven using Analytical and Heisler charts solutions. Not, the properties of brass at room temperature are K =110 W/m.°C, ρ= 8530 kg/m^3 and C_p= 380 J/kg. °C and $\alpha = 33.9 \times 10^{-6}$ m^2/s.

Question:4 [25 Marks]

a) Air at a pressure of 6 kN/m^2 and a temperature of 300°C flows with a velocity of 10 m/s over a flat plate 0.5 m long. Estimate the cooling rate per unit width of the plate needed to maintain it at a surface temperature of 27°C.

b) Pressurized water is often available at elevated temperatures and may be used for space heating or industrial process applications. In such cases it is customary to use a tube bundle in which the water is passed through the tubes, while air is passed in cross flow over the tubes. Consider a staggered arrangement for which the tube outside diameter is 16.4 mm and the longitudinal and transverse pitches are SL = 34.3 mm and ST = 31.3 mm. There are seven rows of tubes in the airflow direction and eight tubes per row. Under typical operating conditions the cylinder surface temperature is at 70 C, while the air upstream temperature and velocity are 15 C and 6 m/s, respectively. Determine the air-side convection coefficient and the rate of heat transfer for the tube bundle. What is the air-side pressure drop?

Question:5 [15 Marks]

Consider the flow of oil at 20°C in a 30-cm-diameter pipeline at an average velocity of 2 m/s. A 200-m-long section of the horizontal pipeline passes through icy waters of a lake at 0°C. Measurements indicate that the surface temperature of the pipe is very nearly 0°C. Disregarding the thermal resistance of the pipe material, determine (*a*) the temperature of the oil when the pipe leaves the lake, (*b*) the rate of heat transfer from the oil, and (*c*) the pumping power required to overcome the pressure losses and to maintain the flow of the oil in the pipe.

$\rho = 888.1$ kg/m³ $\quad \nu = 9.429 \times 10^{-4}$ m²/s

$k = 0.145$ W/m · °C $\quad c_p = 1880$ J/kg · °C $\quad \Pr = 10{,}863$