



INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

Mid-Autumn Semester Examination 2022-23

Gaurav Patidar

Date of Examination:

Subject No.: AG31005

Department/Center/School:

AGRICULTURAL AND FOOD ENGINEERING

Session: (FN/AN)

Subject:

PRINCIPLES OF FOOD ENGINEERING

Duration: 2 hrs Full Marks:

15

30

Specific charts, graph paper, log book etc., required

NO

Special Instructions (if any):

Students are advised to use 1st half of the answerscript for Part A
and rest part for Part B, or vice versa

PART-A

Q1. Consider a steam pipe of length $L = 20 \text{ m}$, inner radius $r_1 = 6 \text{ cm}$, outer radius $r_2 = 8 \text{ cm}$, and thermal conductivity $k = 20 \text{ W/m}^\circ\text{C}$. The inner and outer surfaces of the pipe are maintained at average temperatures of $T_1 = 150^\circ\text{C}$ and $T_2 = 60^\circ\text{C}$, 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. (9) [5]

Q2. A cold-storage room is constructed of an inner layer of 12.7 mm of pine, a middle layer of 101.6 mm of cork board, and an outer layer of 76.2 mm of concrete. The wall surface temperature is 255.4 K inside the cold room and 297.1 K at the outside surface of the concrete. Use conductivities for pine, 0.151; for cork board, 0.0433; and for concrete, 0.762 W/m.K. Calculate the heat loss in W for 1 m^2 (9) [4]

Q3. Figure 1 shows a thermocouple for measuring temperature. The junction that produces a voltage due to changes in temperature has a spherical lead 'bead' of diameter 1 mm. The thermocouple is exposed to airflow that leads to an h value of $10 \text{ W/m}^2\text{K}$ for the bead. For lead, the thermal conductivity is 35 W/m.K, density is 11340 kg/m^3 and the specific heat is 12 J/kg.K. (5) [5]

- Determine if you can use a lumped parameter approximation for the bead.
- If the bead is suddenly inserted into the air at 200°C from an initial temperature of 20°C , calculate the time it takes to reach 99.9% of the air temperature.
- How long does it take for the bead to reach the exact air temperature?

[1+3+2]



Thermocouple

Figure 1

PART-B

Q4. A 15 cm diameter outlet is used to collect milk from a large cylindrical storage vessel of 1.5 m diameter. The storage vessel is open at atmosphere. The discharge jet is located at the side-bottom of the tank. Initially, the vessel contained 5300 litres of milk. How long will it take to take out 4416 litres milk from the tank? Draw the representative figure of the system. Assume, the height of milk within the vessel is from the centre of the outlet. What would be the maximum attainable velocity of milk through the outlet? Please mention whether it is an open or closed system? (9) [1.5+0.5]

Q5. Consider a steady, incompressible, three-dimensional flow field. The y and z components of the flow field are given as: $v = 2axy^2 + byz$ and $w = 2axyz - bz^2$ where a , b , and c are constants. Calculate the velocity component along x . (9) [2]

①

Q6. A liquid is placed between two plates having a gap of 1.75 cm. If the upper plate has a displacement rate 1.5 m/s, calculate the shear stress and apparent viscosity. The liquid has consistency index, $K=60.0 \text{ Pa}\cdot\text{s}^{0.25}$ [3]

Q7. A dilute sucrose solution flowing through the circular pipe as shown below. The diameter of the large and narrow section of the pipe is 3 m and 0.6 m, respectively. Calculate the average velocity of sucrose solution in the 0.6-m pipe? [4]

The velocity profile in the large section is: $v = 10[1-(r^2/25)]$

④

