National Exams December 2014

04-Agric-A3, Heat Engineering

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. This is an OPEN BOOK EXAM.
   Any non-communicating calculator is permitted.

3. Four (4) questions constitute a complete exam paper.
   The first four questions as they appear in the answer book will be marked.

4. Each question is of equal value.

5. All questions require calculation.
Problem 1 (25 points)

The front of a slab of lead (k=35 W/m.K) is kept at 110°C and the back is kept at 50°C. If the area of the slab is 0.4 m² and it is 0.03 m thick, compute the heat flux, q, and the heat transfer rate, Q.
Problem 2 (25 points)

A house wall consists of an outer layer of common brick 10.16 cm thick having a conductivity of $k=0.0069 \text{W/cm.K}$, followed by a 1.27 cm layer of Celotex sheathing having a conductivity $k=0.00048 \text{W/cm.K}$. A 1.27 cm layer of sheetrock having a conductivity $k=0.0074 \text{ W/cm.K}$ forms the inner surface and is separated from the sheathing by 9.53 cm of air space-as provided by the wall studs. The air space has a conductance of $6.25 \times 10^{-4} \text{ W/cm}^2 \text{.K}$. The outside brick surface temperature is 4.44°C; the inner wall surface is maintained at 21.1°C. What is the rate of heat loss from the house per centimetre square of wall area?
Problem 3 (25 points)

A physics experiment uses liquid nitrogen as a coolant. Saturated liquid nitrogen at 80K flows through 6.35 mm O.D stainless steel line (emissivity $\varepsilon_l=0.2$) inside a vacuum chamber. The chamber walls are at $T_c=230K$ and are at some distance from the line.

**Determine the heat gain of the line per unit length.**
If a second stainless steel tube, 12.7 mm in diameter, is placed around the line to act as radiation shield

**Determine the revised heat gain per unit length.**
Hint: Assume that the chamber area is large compared to the shielded line.
Problem 4 (25 points)

A thin-walled metal tank containing fluid at 40°C cools in air at 14°C(β=0.00348 K⁻¹); the average natural convection heat transfer coefficient h is very large inside the tank. If the sides are 0.4 m high, compute h, the average heat flux q, and the thermal boundary layer thickness δ at the top.

(Air properties at 27°C, α=2.203x10⁻⁵ m²/s, ν=1.556x10⁻⁵ m²/s, Pr=0.711)