National Exams May 2012
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.
   A Casio or Sharp approved 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

a) Figure below provides the results of a performance test for a single-glazed flat-plate collector. The transmissivity, $\tau$, of the glass is 0.90, and the absorptivity, $\alpha$, of the surface is 0.92. For the collector, find;

a) The collector heat removal factor, $F_R$

b) The overall conductance, $U_L$ in Btu/ft$^2$.°F

c) The rate at which the collector can deliver useful energy when the irradiation incident on the collector per unit area is 200 BTU/ft$^2$.h, the ambient temperature is 30°F, and the inlet water temperature is 60 °F.

d) The collector temperature when the flow rate is zero(collector efficient $\eta$=0).
Problem 2

Water at 20°C flows through a small-bore tube 1 mm in diameter at a uniform speed of 0.2 m/s. The flow is fully developed at a point beyond which a constant heat flux of 6000 W/m² is imposed. How much farther down the tube will the water reach 74°C at its hottest point? (Water at T=47°C, k=0.6367 W/m.K, α=1.541x10⁻⁷ m²/s, ν=0.556x10⁻⁶ m²/s).
Problem 3

A jet of liquid metals at 2000°C pours from a crucible. It is 3mm in diameter. A long cylindrical radiation shield, 5 cm in diameter, surrounds the jet through an angle of 330°, but there is a 30° slit in it. The jet and the shield radiate as black bodies. They sit in a room at 30°C, and the shield has a temperature of 700°C. Calculate the net heat transfer; from the jet to the room through the slit (view factor $F_{\text{jet-room}} = 0.08333$); from the jet to the shield (view factor $F_{\text{jet-shield}} = 0.9167$); and from the inside of the shield to the room (view factor $F_{\text{slit-jet}} = 0.0600$, view factor $F_{\text{shield-room}} = 0.08545$)
Problem 4

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)