# National Exams December 2004

## 98-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. However candidates are allowed to bring only **ONE** textbook of their choice but no notes.

3. Do SIX out of the following seven questions. Unless otherwise specified on the cover, the first six solutions in the answer booklet will be graded.

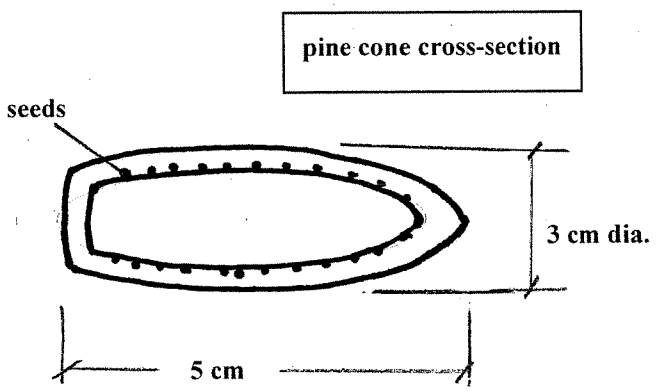
4. All questions have equal value.

5. Candidates may use one of the Casio or Sharp approved calculator models.

1. The ABC Evening News Report in a news segment on hypothermia research studies at the University of Minnesota claimed that heat loss from the human body is 30 times faster in 10°C water than in air at the same temperature. Is that a realistic statement? [Provide a mathematical analysis to support your answer; that is, compare the heat loss from the person in both cases]. Clearly state the assumptions that you made at arriving at your conclusion.

2. The first phase of a proposed seed extraction technique for serotinous seed cones from the lodgepole pine tree is to obtain information on the release of the cone-scale seal. This can be achieved by momentarily plunging the cones in boiling water which causes the serotinous seal to melt. Length of exposure to the fluid temperature is critical as seed viability may be severely reduced by high temperatures. In order to design the prototype continuous flow system for releasing the cone-scale seal, the required cone immersion time must be determined.

   Assuming that the thermal conductivity of all constituents of a seed cone is 0.12 W/m.K, the thermal diffusivity is $1.3 \times 10^{-7}$ m$^2$/s, the seal melts at 46 °C, the cone is stored at 10 °C prior to plunging, estimate the time needed for the seeds to be released and the resulting seed temperature. The heat transfer coefficient can be assumed to be 600 W/m$^2$.K. The seed dimensions are as follows:




   The seeds are located at an average depth of 0.5 cm below the cone surface, while the serotinous seal extends to a depth of 0.2 cm below the surface. Neglect the energy needed to melt the seal.

3. Consider a large plane wall of thickness 2L immersed in a large fluid bath. If the initial temperature of is $T_i$ and the fluid is $T_\infty$, draw the temperature profiles in the solid and fluid at time t = 0, t = finite, and t = ∞ for each of the following three cases when $T_\infty > T_i$:

   a) Bi << 1
   b) Bi ≃ 1
   c) Bi >> 1

4. A procedure for open heart surgery under hypothermic conditions involves cooling the patient's blood before surgery and rewarming it after surgery. It is proposed that a concentric-tube, counterflow heat exchanger of length 1.5 m be used for this purpose with the thin-walled inner tube having a diameter of 55 mm. If water at a temperature of 60 °C and a flow rate of 0.10 kg/s flows through the inner tube to heat the blood entering the heat exchanger with a temperature of 18 °C and a flow rate of 0.05 kg/s, what is the temperature of the blood leaving the exchanger? The specific heat of blood is 3500 J/kg.K and the heat transfer coefficient of the blood-side is 1000 $W/m^2.K$.

5. An opague horizontal plate, which is insulated on its backside, receives irradiation at the rate of 3000 $W/m^2$, of which 500 $W/m^2$ is reflected. The plate is at an equilibrium temperature of 200°C and has an emissive power of 500 $W/m^2$. Air at 25°C flows over the plate and the convective heat transfer coefficient is 20 $W/m^2.K$. Calculate

   1. the emissivity, absorptivity and radiosity of the plate; and
   2. the net heat transfer rate per unit area.

6. A long **horizontal** cast iron pipe 0.3 m diameter is covered with aluminum paint. It is maintained at a temperature of 250 °C in a **large** room where the ambient and wall temperatures are 10 °C. Calculate the <u>total</u> heat loss per meter of pipe.

7. The incandescent bulb in a slide projector is rated at 400 W. A reflector placed behind the filament direct 30% of the energy towards the slide. The slide is assumed to be a gray body with a transmissivity of 0.50 and an emissivity of 0.20. The area of the slide is 8.9 $cm^2$. Assume that any radiative energy that leaves the slide never returns.

   Determine the equilibrium temperature of the slide if a fan blows air at 35°C over both side of the slide with h=500 $W/m^2.K$.