

# MECH 375: Heat Transfer

## Final Examination

December 5, 2014

This exam is **closed book**. You are permitted only the provided formula booklet. Note that the exam will be marked out of 100; the additional 20 marks available will be treated as bonus marks.

Time allowed: 2.5 hours.

1. Indicate in your exam booklet whether the following statements are True or False. Also provide a short (one sentence) justification of your answer. **(3 marks each)**
  - (a) The transmissivity of a black body is zero.
  - (b) Adding a fin to a surface increases the surface area available for heat transfer without affecting the convective heat transfer coefficient.
  - (c) The one-term approximations to the series solutions for transient conduction provided in Table 5.1 become inaccurate for a Fourier number greater than 1.
  - (d) The Biot and Nusselt numbers are both non-dimensional forms of the convective heat transfer coefficient.
  - (e) The efficiency of a fin can never be greater than 1.
2. In approximately 150 words, explain the physical significance of the Number of Transfer Units ( $NTU = UA/C_{\min}$ ), the dimensionless parameter used in heat exchanger analysis. Specifically, what would it mean for this number to be larger, rather than smaller? **(15 marks)**
3. A double boiler is used to heat materials on a stove gently without burning or scorching them; it consists of a flat-bottomed insert pan that fits into a lower pan of boiling water such that the bottom surface of the insert pan is well above the surface of the boiling water. I plan to use a double boiler to melt some chocolate chips over the holidays to make a chocolate fondue. My pan is 30 cm in diameter; the “insert” is a second pan of the same size that fits on top of the first pan. The pans have a thermal conductivity of 60 W/m·K and are 3 mm thick on their bottoms. My double boiler is at sea level, so the pressure is 1.01 bar. The pots are stainless steel so that  $C_{s,f} = 0.0133$  and  $n = 1$ . The lower pan has water in it and I want it to boil vigorously, but not so fast as to jump into film boiling, so I want to provide a significant fraction of the critical heat flux.
  - (a) What would 80% of the critical heat flux be (treating the problem as one-dimensional, such that we treat the sides of the boiler as being adiabatic)? **(10 marks)**
  - (b) If I choose to change the setting on the stove such that I am now delivering 60 kW, what will the temperature on the bottom of the lower pan (that is, the bit that actually touches the stove) be? **(20 marks)**
  - (c) The melting point of my chocolate is 45°C; we will assume that the top surface of the flat-bottomed insert pan (which has the same dimensions as the lower pan) has that temperature. I put too little water in the lower pan so that it all boils off. Now there is only water vapour between the two pans, but I’m still delivering the same 60 kW on my stove. How would you estimate the temperature on the bottom surface of the lower pan under these new circumstances? Specifically, what additional assumptions would you make, what correlations would you need and what equation(s) would you end up trying to solve? (Hint: don’t try to get an actual number here! That would be very difficult in the time available!) **(15 marks)**

4. We have an evacuated oven with a uniform inner wall temperature  $T_{\text{oven}}$  which we will treat as a black enclosure. There is a square channel running through the enclosure that is 2 cm on each side with a wall thickness of 5 mm; the channel is 2 m long and its outer surface can be treated as grey with an emissivity of 0.8. The channel material has a thermal conductivity of 170 W/m·K. Inside of the channel, there is a flow of water which enters at 290 K and 10 m/s – for the purpose of this analysis, assume that the temperature of the water does not change sufficiently for the properties of the water to be affected and use the properties of saturated liquid at the inflow temperature. What must the temperature of the inner surface of the oven be for the outer wall of the channel to be maintained at 300 K? **(25 marks)**
5. A large panel heater is used to heat a surface, as depicted below, where the rectangular panel 1 (which is treated as grey with an emissivity of 0.9) is kept at 500 K and the rectangular surface to be heated, 2 (also treated as grey with an emissivity of 0.6), has a temperature of 300 K. The dimensions of the panels are as indicated. What is the rate of heat transfer between the two surfaces? **(20 marks)**

