Name: _____

ID #: _____

University of Saskatchewan
Department of Mechanical Engineering
ME 327 – Heat Transfer

December 14, 2007	Final Exam	180 minutes

120 Points Total

Open Book Exam – students are permitted to bring into the exams their course notes, assignments and the course text (**or** one other heat transfer book of their choice). Other materials are not permitted. Programmable calculators are permitted in exams.

Cell phones, PDA's, computers, and tape, CD and digital music players are not permitted.

For numerical questions – please show all work in the space provided.

For descriptive questions – please answer each question in a concise and clear fashion in the space provided.

Question	Total Marks	Score
1	15	
2	15	
3	15	
4	15	
5	15	
6	15	
7	15	
8	15	
TOTAL	**120**	

I declare that I am the person named, and that I am formally registered as a student in ME 327.

_____ _____

Signature **Date**

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Question 1 (3 points each, 15 points total)

a) What are the three modes of heat transfer? For each mode, provide a practical example of where this mode of heat transfer would be important.

b) What is the difference between forced and natural convection? What is an example of a situation in which you would expect to see mixed convection (i.e., both forced and natural convection)?

c) An opaque solid has an absorptivity of 0.3. What are the values of reflectivity and transmissivity for this solid?

d) Sketch the boiling curve for water at 1 atm. and indicate the point on the curve where the convection heat transfer coefficient would be a maximum. Estimate this maximum value.

e) In your opinion, what are the three most important things you learned during this course?

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Question 2 (5 points each, 15 points total)

For each part write the appropriate form of the Fourier field equation, and the boundary and initial conditions that you would use to solve the Fourier field equation. Clearly state the assumptions that you have made. Do not solve the differential equation.

a) After writing your ME 327 final you decide to run home to cook a hot dog for lunch before studying for your next exam. Rather than cooking the hot dog in a sauce pan on the stove, as you did after the midterm exam, you decide to use the microwave oven. Determine the temperature distribution within the hot dog as it cooks in the microwave.

b) A hollow sphere with inner and outer radii, r_i and r_o, respectively is exposed to a fluid that is at a temperature of T_∞. The convection heat transfer coefficient on the outside surface is h, and the inner surface of the sphere is perfectly insulated. Determine the steady-state temperature distribution in the sphere.

c) The upper layers of human skin can be treated as a semi-infinite solid for short exposures. In order to determine the time to produce second degree skin burn damage for a particular constant heat flux exposure on the skin surface (q_0"), you must first determine the time-dependent temperature distribution in the skin.

At one location on the forearm, the thickness of the upper layers of skin is L. It is also known that prior to the exposure, the temperature in the skin varies linearly from 37°C at x = L to 32.5°C at the skin surface. The thermal properties of skin vary with temperature. Determine the time-dependent temperature distribution in the upper layers of skin for the first 60 s of this high heat flux exposure.

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Question 3

To celebrate the end of exams, you decide this is the year that you will cook the Christmas turkey. Before inviting your friends over, you want to estimate how long it will take to cook the turkey that you have purchased, which after being thawed overnight, is at a temperature of 20°C. According to your cookbook, you should set your oven to 175°C, and that the turkey is done when the temperature at its centre reaches 85°C. Assume that the convection heat transfer coefficient on the outside surface of the turkey is 10 $W/m^2 \cdot K$ and that the turkey can be treated as a 0.2 m diameter sphere with the following thermal properties: thermal conductivity of 0.5 $W/m \cdot K$, specific heat of 3400 $J/kg \cdot K$ and density of 980 kg/m^3.

a) Estimate the time required to cook this turkey. (10 points)

b) Briefly comment on the assumptions that you made in your estimate in part (a) and how you might increase the accuracy of this estimate. (5 points)

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Question 4

a) Air at 20°C flows at 1 m/s between two large, parallel flat plates spaced 5 cm apart, which are at a temperature of 35°C. Estimate the distance from the entrance to the point at which the thermal boundary layers from the two plates meet. (10 points)

b) What is the local convection heat transfer coefficient at this location on each of the plates? (5 points)

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Question 5

a) The Grinch is looking out over Who-ville on a cold winter's evening where there is no wind and the ambient temperature is -20°C. Assume that the Grinch is 1.8 m tall, and that you can represent him as a vertical cylinder with a 30 cm diameter. Assume that the temperature on the outside of the Grinch's skin is 20°C (this is colder than your skin temperature, because his heart is two sizes too small). What is the rate of heat loss from the Grinch under these conditions? (10 points)

b) Double pane windows are used in Canada to reduce heat losses in buildings. What limits the size of the air gap between the panes in a double pane window? (5 points)

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Question 6

There is a 5 m long, 150 mm diameter uninsulated heating duct in the basement of Mr. Potter's bank in Bedford Falls. Air enters this duct at 75°C and 0.05 kg/s. The duct surface temperature is approximately constant at 15°C. Estimate the rate of heat transfer from the air to the duct.

(15 points)

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Question 7

Santa Claus decides to look into upgrading the mechanical systems in his workshop. He has been thinking of preheating water for a boiler using flue gases from the boiler stack. The flue gases (c_p = 1000 J/kg·K) are available at a rate of 0.25 kg/s at 150°C. Water enters the heat exchanger at 15°C at a rate of 0.05 kg/s, and must be heated to a temperature of 90°C.

Santa would like to use a shell and tube heat exchanger that has one shell pass and four tube passes. Water flows inside a copper tube, which has an inside and outside diameter of 2.5 and 3.0 cm. He estimates that the convection heat transfer coefficients on the gas and water sides are 115 and 1150 W/m^2·K, respectively. He also estimates that scale on the water side of the exchanger will offer an additional thermal resistance of 0.002 m^2·K/W.

a) Estimate the overall heat transfer coefficient based on the outer tube diameter. (5 points)

b) Estimate the outlet temperature of the flue gases. (5 points)

c) Estimate the required tube length. (5 points)

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Question 8

After eating leftover turkey for several days, you decide that you will barbeque a hamburger. You throw a single burger, 12 cm in diameter and 1.5 cm thick, on the centre of the grill of the barbeque, which is located 20 cm above the coals. The coals can be treated as a 40 cm diameter disk at a temperature of 700°C, while the hamburger is initially at a temperature of 20°C throughout.

a) Assuming that the coals and hamburger can be treated as blackbodies, estimate the net rate of thermal radiation heat transfer between the coals and the burger at the moment the burger is put on the grill. (10 points)

b) Another technique is used to cook the hamburger. Estimate the exposed surface temperature of this hamburger patty if it was subjected to a constant heat flux of 20 kW/m^2 for 30 s. Assume the thermal properties of the patty are the same as water at 20°C. (5 points)