

Name: \_\_\_\_\_.

# Final Exam

CM 3110

19 December 2007

Note:

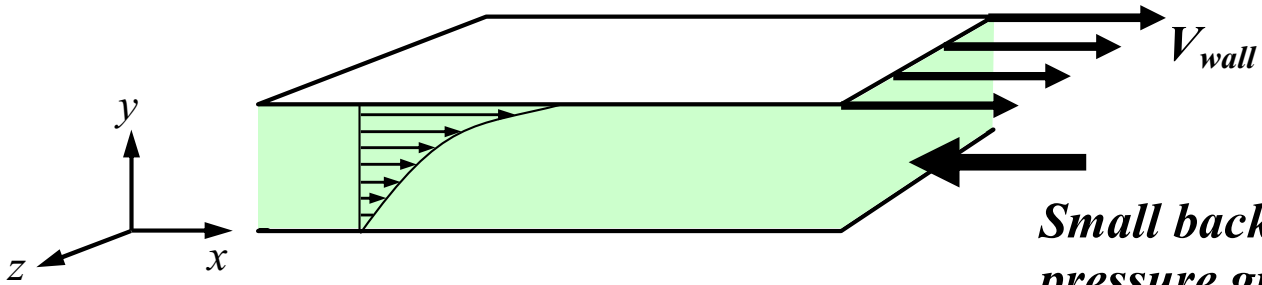
Significant figures count.

Please box your final answers.

Please be neat.

1. (20 points)
  - a. Forced convection heat transfer coefficients are principally a function of what two dimensionless numbers?
  - b. Natural convection heat transfer coefficients are principally a function of what two dimensionless numbers?
  - c. What is the equation for the pressure-drop/flow rate relationship for laminar flow of a Newtonian fluid in a smooth tube?
  - d. What is the equation for the pressure-drop/flow rate relationship for turbulent flow of a Newtonian fluid in a smooth tube?
2. (20 points) Water at  $43^{\circ}\text{C}$  (heat capacity =  $4.102 \text{ kJ/kg }^{\circ}\text{C}$ ; density =  $994.7 \text{ kg/m}^3$ ; thermal conductivity =  $0.6283 \text{ W/mK}$ ; viscosity =  $0.616 \times 10^{-3} \text{ Pa s}$ , Prandtl number = 4.05) flows in a long,  $0.070 \text{ m}$  inner-diameter pipe at a Reynolds number of 6050. The temperature of the inner surface of the pipe is a uniform  $56^{\circ}\text{C}$ . What is the heat transfer coefficient between the water and the pipe wall? The effect of temperature on fluid properties may be neglected.
3. (20 points) A single heat shield protects the bottom of a car from the heat of the exhaust. The exhaust pipe is at  $250.0^{\circ}\text{C}$  and the maximum temperature of the bottom of the car is  $50.0^{\circ}\text{C}$ . What is the heat flux from the exhaust system to the car? Please give your answer in  $\text{W/m}^2$ . The steel in the car has the following properties: thermal conductivity =  $55.0 \text{ W/mK}$ , density =  $7800 \text{ kg/m}^3$ , heat capacity =  $420 \text{ J/kg }^{\circ}\text{C}$ , absorptivity 0.79.
4. (20 points) Hot oil at a flow rate of  $4.00 \text{ kg/s}$  (heat capacity  $C_p = 12.92 \text{ kJ/(kg K)}$ ) enters an existing counterflow heat exchanger at  $400. \text{K}$  and is cooled by water entering at  $325 \text{ K}$  (under pressure) and flowing at a rate of  $0.820 \text{ kg/s}$  ( $C_p = 4.201 \text{ kJ/(kg K)}$ ). The overall heat-transfer coefficient is  $350. \text{ W/(m}^2 \text{ K)}$  and the heat-transfer area is  $11.9 \text{ m}^2$ . Calculate the heat-transfer rate and the exit oil temperature.

5. (20 points) A constant-density, Newtonian fluid is subjected to a steady flow in a parallel-plate apparatus as sketched below. The two long, wide parallel plates are separated by a distance  $H$ . The top plate is moving with a velocity  $V_{wall}$  to the right, as shown. There is a small backwards pressure gradient  $-\Delta p/L$  in the  $x$ -direction. You may neglect gravity. Calculate the velocity profile.



***Small backwards  
pressure gradient,***  

$$\frac{\partial p}{\partial x} = \frac{-\Delta p}{L} = \text{constant}$$