GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Fall Quarter 1997

Heat Transfer
EXAM AREA

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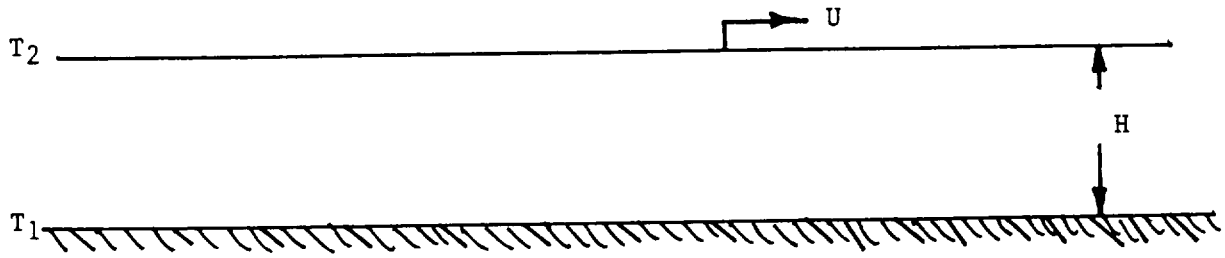
Assigned Number (DO NOT SIGN YOUR NAME)

- **Please sign your name on the back of this page—**

PhD Qualifying Examination in Heat Transfer
Fall 1997

1. Consider steady, planar, laminar, incompressible Couette flow between two very long horizontal plates, spaced a distance H apart, the top one at a uniform temperature T_2 moving at a constant velocity U, and the bottom one at a uniform temperature T_1 remaining stationary. Assume that the thermophysical properties of the fluid are constant.



(a) Write down the simplified forms of the boundary layer equations **(do not neglect viscous dissipation in the energy equation).**

(b) Solve for the velocity distribution $u(y)$ and the temperature distribution $T(y)$.

(c) Find expressions for τ_w and q''_w at each wall.

(d) If the fluid is glycerin, $T_1 = 50°C$, $U=10$ *m/sec*, $H=10^{-2}$*m and* $T_2 = 60°C$, calculate the shear force and heat transfer rate at each wall for a *10 m* long by *1 m* wide channel. Take viscosity of glycerin = 0.1 N-sec/m^2.

2. A person is sitting in a car that is traveling at 40 mph. The person sticks his/her arm and hand out the window straight at an angle of 90° to the side of the car. The outside air temperature is 45°F. Neglecting the circulation of blood and the body's metabolism, estimate the heat loss from the body to the outside air where the convective heat transfer coefficient, h, is of the order of 100 W/m^2-K. The thermal conductivity of body tissue is assumed to be approximately that of water (k = 0.6 W/m-K). Make any other assumptions necessary. Also outline the procedure you would use to refine your estimate of heat loss and also to calculate the person's body temperature at the end of his/her hand.

3. A large steak (assume infinite) of uniform thickness is placed on an open grill over a uniform bed of charcoal. You want to estimate the steady temperatures of the two surfaces of the steak. Assume the temperatures experienced in this case are high enough so that the convective rates from both surfaces of the steak can be neglected compared to the radiative heat transfer rates. Perform a heat transfer analysis to determine the surface temperatures and express your equations in terms of the following symbols:

Charcoal: temperature T_c, emissivity ε_c
Steak: thickness t, thermal conductivity k_s, emissivity ε_s
Distance between the steak and the bed of charcoal: H.
Ambient air surrounding the upper surface of the steak: temperature T_a, emissivity ε_a .