Unified Quiz 4F
March 31, 2004

- Put your name on each page of the exam.
- Read all questions carefully.
- Do all work for each problem on the two pages provided.
- Show intermediate results.
- Explain your work --- don’t just write equations.
- Partial credit will be given, but only when the intermediate results and explanations are clear.
- Please be neat. It will be easier to identify correct or partially correct responses when the response is neat.
- Show appropriate units with your final answers.
- Calculators and a 2-sided sheet of paper are allowed
- Box your final answers.

Exam Scoring

<table>
<thead>
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<th>#1 (40%)</th>
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<tr>
<td>#2 (30%)</td>
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<td>#3 (30%)</td>
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<td><strong>Total</strong></td>
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1. (40 %) Air flows at low speed in a duct of constant area $A = 0.1 \text{ m}^2$, through a resistive heater delivering $\dot{Q} = 5000\text{W}$. The heater is a grid of very fine wires which have negligible frictional resistance. The upstream flow has

$$V_1 = 1 \text{ m/s}$$
$$\rho_1 = 1 \text{ kg/m}^3$$
$$T_1 = 250 \text{ K}$$

Also, $c_p = 1000 \text{ J/kg K}$ everywhere.

a) Using a control volume spanning the heater, determine the enthalpy equation relating stations 1 and 2.

b) Assuming $V^2 \ll h$ (low speed flow), determine the air temperature $T_2$ behind the heater.

Since this is a low speed flow, you can also assume that the pressure changes are very small relative to ambient pressure, i.e. $p_2/p_1 \approx 1$.

c) Determine the density ratio $\rho_2/\rho_1$, and the velocity ratio $V_2/V_1$.

d) Determine the pressure change $p_2 - p_1$ across the heater.
Problem #1 (continued)
2. (30 \%) A thin supersonic airfoil has a pitot tube mounted on top. The freestream Mach number is $M_\infty = 1.3$, and the freestream pressure is some known $p_\infty$.

a) Determine the pitot pressure $p_a$ with the airfoil at $\alpha = 0^\circ$.

b) Determine the pitot pressure $p_b$ with the airfoil at $\alpha = 10^\circ$. 
Problem #2 (continued)
3. (30 %) A duct with air flow has a constant area $A = 1 \text{ m}^2$, except for two throats. The front throat area is $A_{t_1} = 0.8 \text{ m}^2$.

a) The front throat is choked, and has a shock behind it. If the Mach number into the shock is $M_1 = 1.5$, what is the duct area $A_1$ at the shock location?

b) The adjustable area of the second throat is now closed down until the flow there just barely reaches $M = 1$. What is this resulting throat area $A_{t_2}$?
Problem #3 (continued)