Unified Engineering:

Exam Q4F

Wednesday, March 30, 2005

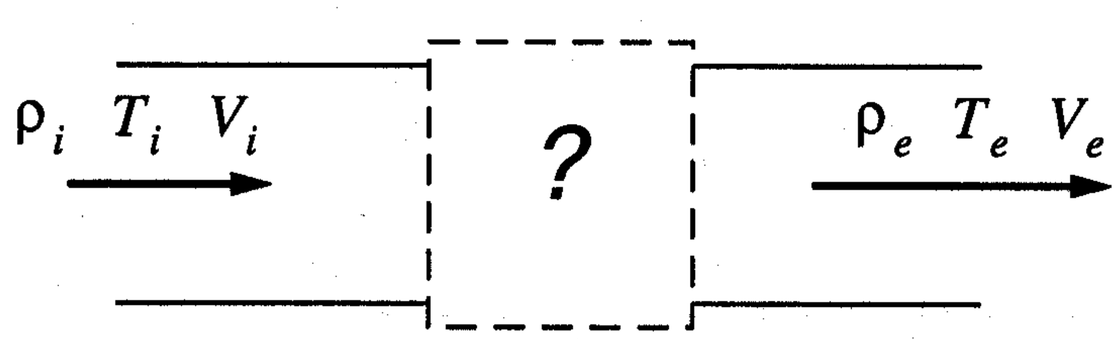
- Please write the last 4 digits of your student ID on every page.

1. (30 %) Air flows into a box where it undergoes some process, and comes out again, as sketched. The following flow properties are measured at the inlet and exit:

$$\rho_i = 1.0\,\text{kg/m}^3 \qquad \rho_e = 0.528\,\text{kg/m}^3$$
$$T_i = 300\,\text{K} \qquad T_e = 240\,\text{K}$$
$$V_i = 200\,\text{kg/m}^3 \qquad V_e = 400\,\text{kg/m}^3$$

The flow areas are not necessarily equal at inlet and exit. The properties of the air are:

$$c_p = 1000\,\text{J/kg}\cdot\text{K} \qquad \gamma = 1.4$$



Circle all words that describe the process inside the box:

i) adiabatic

ii) non-adiabatic

iii) isentropic

iv) non-isentropic

2. (40 %) A thin supersonic airfoil has a pitot tube mounted on top. The freestream Mach number is $M_\infty = 1.6$, and the freestream pressure is some known p_∞.

a) Determine the pitot pressure pressure ratio p_a/p_∞ with the airfoil at $\alpha = 0°$.

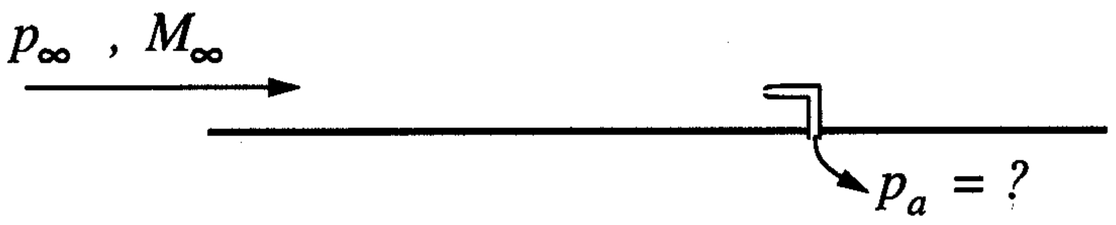
b) Determine the wave angle β and Mach number M_2 with the airfoil at $\alpha = -8°$.

c) Which is true for p_c relative to p_a?

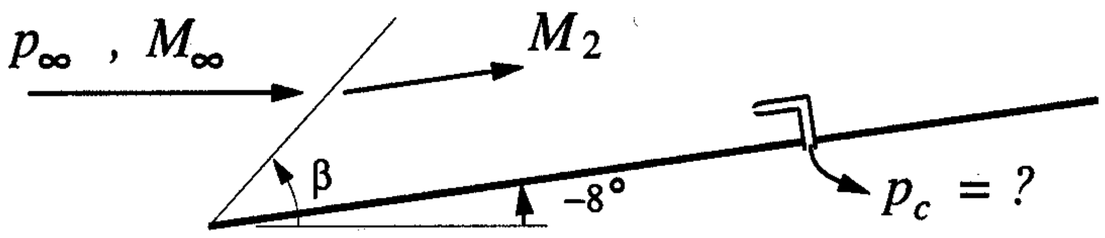
i) $p_c < p_a$

ii) $p_c = p_a$

iii) $p_c > p_a$



a)



b, c)

3. (40 %) A duct has an exit area $A_e = 1\,\mathrm{m}^2$, and an adjustable throat of some arbitrary area A_t. The upstream reservoir has a total pressure of $p_r = 1.0 \times 10^5\,\mathrm{Pa}$, and total enthalpy of $h_r = 2.0 \times 10^5\,\mathrm{m}^2/\mathrm{s}^2$.

a) The exit back pressure is held at $p_B = 0.25 \times 10^5\,\mathrm{Pa}$. What must A_t be set to so that no shocks appear anywhere?

With the throat area held fixed at the shock-free value from a), the total enthalpy of the reservoir air is now increased by 10%, to $h_r' = 1.1 h_r = 2.2 \times 10^5\,\mathrm{m}^2/\mathrm{s}^2$. Both p_r and p_B are left unchanged.

b) Does the flow remain shock-free everywhere?

c) By how much does the mass flow change (percentagewise) relative to the case in a)?

Everything is returned again to the situation in a). The throat area is then increased by 1%, to $A_t' = 1.01 A_t$.

d) Sketch the resulting flow pattern on the diagram below.