Due: In class, Friday **September 02, 2022**	**Name(s)** (*Each* student must submit; list anyone you worked with) **PSU ID (abc123)** Student submitting: Worked with: Worked with:

ME 420
Fall Semester, 2022
Homework Set # 1

Professor J. M. Cimbala

For instructor or TA use only:		
Problem	**Score**	**Points**
1		20
2		15
3		20
4		20
5		25
Total:		**100**

1. (20 pts) We wrote two *Tds* equations in class for *any* gas, and then used one of them to show that for the special case of an ***ideal gas***, $s_2 - s_1 = c_\upsilon \ln\frac{T_2}{T_1} + R\ln\frac{\upsilon_2}{\upsilon_1}$.

(**a**) Use the *other Tds* equation to show that for an ideal gas, $s_2 - s_1 = c_p \ln\frac{T_2}{T_1} - R\ln\frac{P_2}{P_1}$. Show all your work for full credit.

(**b**) Manipulate the above equation for the special case of an ***isentropic process*** involving an ideal gas. Specifically, show that $\frac{P_2}{P_1} = \left(\frac{T_2}{T_1}\right)^{\text{exponent}}$. Find the exponent, and manipulate it so that it is a function of γ only.

(**c**) We also showed in class that $\frac{\rho_2}{\rho_1} = \left(\frac{T_2}{T_1}\right)^{\frac{1}{\gamma-1}}$ for isentropic flow of an ideal gas. Combine this equation with your result of Part (b) above to show that $\frac{P_2}{P_1} = \left(\frac{\rho_2}{\rho_1}\right)^{\gamma}$ for isentropic flow of an ideal gas. For full credit, show all your work.

2. (15 pts) Air flows adiabatically and nearly isentropically through a duct from location 1 to location 2. At 1, P_1 = 357.4 kPa and T_1 = 86.7°C. At 2, the only property measured is P_2 = 209.5 kPa.

(**a**) Calculate temperature T_2 at location 2 in °C.

(**b**) The average air speed at location 1 is also measured: V_1 = 435 m/s. Calculate Mach number M_1 at location 1. Is the flow at location 1 subsonic, sonic, or supersonic?

3. (20 pts) Air flows adiabatically and nearly isentropically through a duct from location 1 to location 2. At 1, P_1 = 427.6 kPa and T_1 = 193.2°C. At 2, the only property measured is T_2 = 150.8°C.

(**a**) Calculate pressure P_2 at location 2 in kPa.

(**b**) The average air speed at location 1 is also measured: V_1 = 234 m/s. Calculate Mach numbers M_1 and M_2 at locations 1 and 2, respectively. Also calculate V_2. Is this flow subsonic, sonic, or supersonic?

Note: There is another page. →

4. (20 pts) We normally consider liquids (like water) to be incompressible and in this course, we limit our discussion to compressible *gases* (like air). Do some Internet searching about compressible flow in liquids. Do liquids ever behave like compressible fluids? Give some examples and discuss. You may copy portions of websites, but if you do so, say so, and **always show your references**.

5. (25 pts) We deal mostly with air in this course. However, there are times when gases other than air need to be analyzed.

(**a**) Look up (or calculate) and list the specific heats c_p and c_υ, the ratio of specific heats (γ or k), and the specific gas constant R for the following ideal gases: nitrogen, carbon dioxide, helium, hydrogen, and methane. Use standard SI units and be careful to use the *molecule* of the substance, not just the element. For example, nitrogen gas is N_2, not just N.

(**b**) For a temperature range from -10 to 40°C, calculate and plot (on the same plot) the speed of sound for each of the above gases. Make sure you include a legend so that someone looking at your plot knows which curve corresponds to which gas.

(**c**) Which gas has the highest speed of sound? Compared to the other gases, is it primarily the specific gas constant or the ratio of specific heats that gives this particular gas a higher speed of sound than the other gases at the same temperature?