Due: In class, Friday **October 21, 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 # 7

Professor J. M. Cimbala

For instructor or TA use only:		
Problem	**Score**	**Points**
1		15
2		70
3		15
Total:		**100**

1. (15 pts) In class we derived the ***compressible subsonic Pitot equation***, useful for calculating the velocity of a freestream when stagnation pressure is measured by a Pitot probe in a compressible but subsonic flow. It is assumed that the upstream (static) pressure P_1 and temperature T_1 are also known. We should be able to generate this same equation by starting with the compressible form of the Bernoulli equation derived in an earlier homework (HW Set 4). Work out the algebra and see if you are able to get to the same final equation – the compressible subsonic Pitot equation.

2. (70 pts) We analyze blast waves in this problem. First, we use known experimental bomb data (Bomb 1) to estimate the Π constant of the dimensional analysis we did in class. Then, we use this constant to estimate the energy of a *second* bomb (Bomb 2), and to estimate shock strength and other properties as functions of time as the blast wave from the second bomb expands. For this problem we ignore ground effects and assume that the blast waves from both bombs are spherical. The ambient air is assumed to be the same for both bombs, namely a hot summer day at $T = 35^{\circ}\text{C}$ and $P_{\text{atm}} = 100.4$ kPa. *All* of the energy is assumed to be released at $t = 0$ for both cases.

(**a**) Look up some information about how bomb energy is measured, and about the world's first atomic bomb blast (Alamogordo, NM, July 16, 1945). The energy released from this bomb is estimated to have been about 18.6 kilotons (TNT equivalent). Call this Bomb 1 and convert this energy to Joules.

(**b**) From high-speed camera footage of this bomb, we determine that blast wave radius $R = 210$ m at $t = 0.100$ s. Estimate the Π constant of the dimensional analysis we did in class. Use this Π for the rest of this problem.

(**c**) Now consider a second (larger) bomb (Bomb 2). The *only* available data point is that $R = 482$ m at $t = 0.113$ s. Estimate the energy released by this bomb in units of Joules and in units of megatons equivalent TNT.

(**d**) Plot R, T_{as}, and P_{as} as functions of time from $t = 0.1$ to 3.0 s.

(**e**) Plot moving shock Mach number M_s and Mach number M_{as} following the shock *on the same plot*. M_s starts off as supersonic, of course, but when M_s decays to 1 (it becomes an infinitesimally weak shock, i.e., an isentropic sound wave), set $M_s = 1$ from then on. At what time and radius does blast wave Mach number M_s fall to 1? M_{as} should also start off as supersonic for this bomb. At what time and radius does Mach number M_{as} following the shock go ***below*** 1?

(**f**) Finally, I looked up the survivability of blasts. An average person can survive a blast wave if $P_{as} < 300$ kPa (absolute pressure). [Eardrums can rupture from a blast much of much lower pressure, about 120 kPa absolute.] How far away would the person have to stand in order to survive this blast? [Note that we are not taking into account the heat or *radiation* effects (which may dominate) – just the sudden increase of air pressure from the blast.]

3. (15 pts) For this problem, use the standard atmospheric property website https://www.digitaldutch.com/atmoscalc/ to obtain the pressure and speed of sound of the air at the given altitude. A fighter jet is cruising at supersonic speeds at 37,000 ft altitude. A Pitot probe at the nose of the jet measures a pressure of 52.3 kPa. Assume standard atmospheric conditions. Show all your algebra and equations, etc. [Do not just plug into the Compressible Aerodynamics Calculator; although you are certainly encouraged to use this tool to verify your algebra and calculations.]

(**a**) Calculate the Mach number of the aircraft.

(**b**) Calculate the speed of the aircraft relative to the ground.