Optional Extra Credit Problems

• You will be assigned a group with three problems.
• For maximum credit you would need to submit all three problems correctly.
• You are allowed to use any resources except another student.
• They are to typed so they are easily read, all illegible papers will not be looked at.
• They are due Tuesday, November 26th CoB,
• No late papers will be accepted after that date.
• You may want to take copies before submission since they probably will not be returned.

• Groups A, B, and C.

A normal shock wave moves at 600 m/s down a tube into a gas with static conditions of 50 kPa and 300 K. At the end of the tube, a piston is moving with a velocity of 50 m/s, as illustrated in Figure 2-19. Find the velocity of the reflected shock wave and the static and stagnation conditions behind the reflected shock wave. Choose any gas for which $R$ and the ratio of specific heats are known.
**B2.** Air at a stagnation temperature 365 K and a stagnation pressure 760 kPa flows through a convergent-divergent nozzle to a back pressure of 550 kPa. The throat diameter of the nozzle is 2.5 cm. A shock occurs at a location where the pressure is 200 kPa \((p_x)\). Find:
(a) The exit area, temperature, and exit Mach number.
(b) The area and the strength of the shock.
(c) The exit pressure if shock is to be avoided.

**A3.** Air at a stagnation state of 100 kPa and 470 K expands steadily and isentropically to a Mach number of 2.0, where the cross-sectional area is 30 cm\(^2\). Determine:
(a) The mass rate of flow.
(b) The exit pressure for the design conditions.
(c) The back pressure for maximum flow rate if the diverging portion of the duct acts as an isentropic diffuser.
(d) The back pressure if a shock occurs at an area equal to \((A_t + A_{exit})/2\).

**C2.** Air flows through a convergent-divergent nozzle with an exit-to-throat area \(A_{exit}/A_t = 4.0\). If a normal shock occurs at a location where \(A_x/A_t = 2.5\), determine:
(a) The Mach number at the exit.
(b) The increase in entropy in the nozzle.
(c) What would be the relative decrease in the back pressure in order to locate the shock at the exit plane of the nozzle?
(d) What would be the relative decrease in the back pressure if the flow is isentropic and supersonic at the exit?

**A2.** An impact (stagnation) tube in an air stream reads 186 kPa. If the local temperature is 293 K and the local Mach number is 0.8, determine:
(a) The local pressure.
(b) The mass rate of flow per unit area.

**EXTRA**
A Pitot tube and a thermocouple give the following measurements pertaining to air flow in a duct:
\[
p_0 = 180 \text{ kPa}, \quad p = 157 \text{ kPa}, \quad T_0 = 1250 \text{ K}
\]
Estimate the velocity of the stream if:
(a) The flow is subsonic.
(b) The flow is supersonic and there is a shock in front of the instruments.
C3 A normal shock wave moves through a constant-area tube into air at rest at 25 C. The velocity of the air behind the wave is measured to be 175 m/s. Find the shock wave velocity and the stagnation temperature in the pipe after passage of the shock wave. If the end of the duct is suddenly closed, find the velocity of the reflected shock wave and the properties after passage of the reflected shock wave.

B1 A blunt reentry vehicle enters the atmosphere at a Mach number of 15. As shown in Figure 2-16, in the region near the blunt nose the shock wave can be approximated as a normal shock wave. If the vehicle is at 30,000 m altitude, determine the stagnation pressure to which the nose is subjected assuming the air acts as a calorically perfect gas. What are the stagnation pressure and temperature if the vehicle is at sea level?

C1 A normal shock wave traveling at 1250 m/s moves into still air at sea level conditions and reflects from a plane wall. Compare the pressure ratio across the reflected shock with that across the incident shock. Explain why the pressure ratios are different. What are the stagnation conditions after passage of the reflected shock wave?

B3 Engine knock can be modeled as a moving normal shock wave in the cylinder of an automobile engine. Consider, as in Figure 2-18, a piston moving upward at 30 m/s and a normal shock wave moving downward at 2500 ft/s into a mixture of unburned air and gas at 70 psia and 400 R. Assuming that the properties of the unburned mixture are similar to those of air, find the pressure acting on the piston face after the reflection of the shock wave.