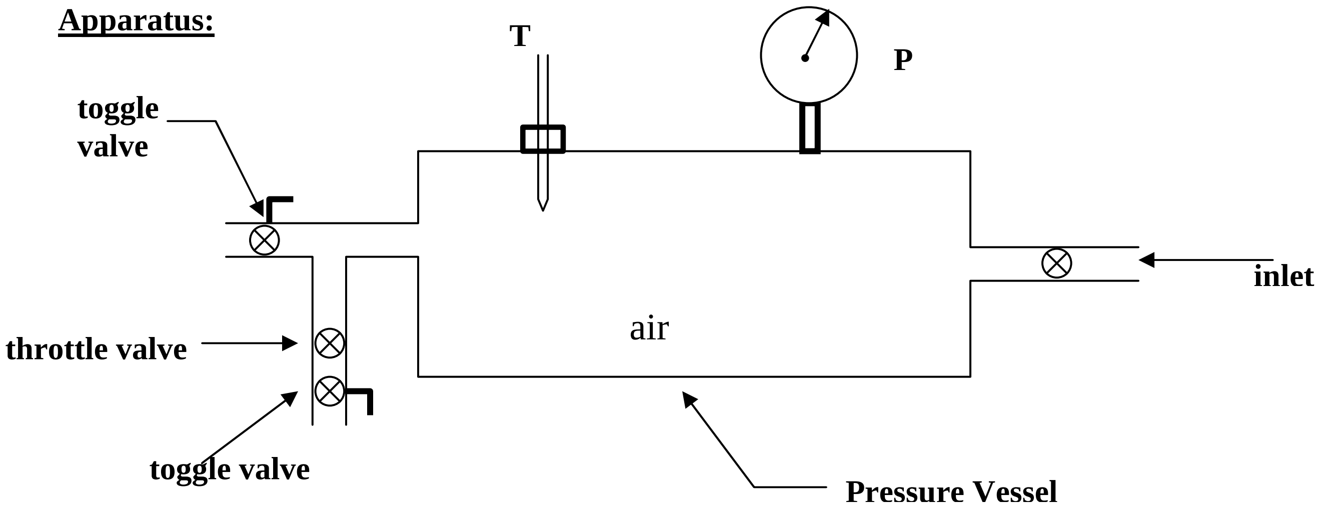
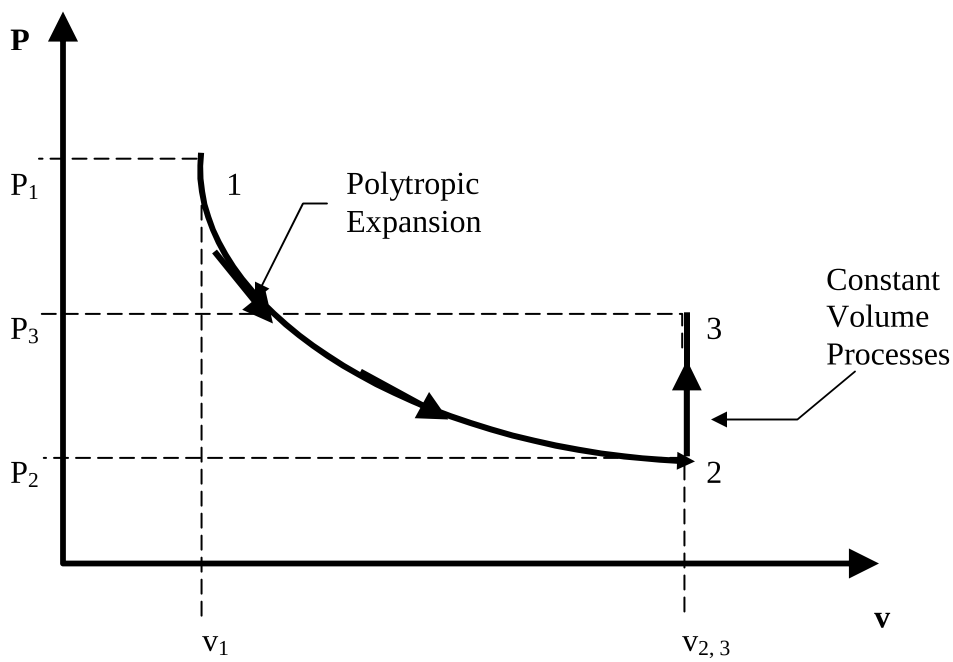
Mechanical Engineering Department MEC1405
Polytropic Processes

Object:
To determine the polytropic index, n, of expansion for air.

Apparatus:



Theory:
Consider the apparatus shown above. By charging the tank with air to some initial pressure and temperature, P_1 and T_1, one can produce a polytropic expansion of the air in the tank by discharging some of the air to the surrounding atmosphere. The value of the polytropic exponent, **n**, will depend upon the discharge rate. Consider the two processes shown on the P-v diagram below. The process 1-2 is a polytropic expansion, from P_1 to P_2, which would take place as the air is discharged from the tank. The process 2-3 is a constant volume process, and takes place immediately after the discharge valve has been shut off.



Procedure:

1. It is possible to relate the three pressures, in the above two processes, by means of the following expression:

$$\frac{p_3}{P_2} = \left(\frac{p_1}{P_2}\right)^{\frac{n-1}{n}} \qquad (1)$$

The constant, n, can be determined from equation (1), and is expressed by:

$$n = \frac{1}{1 - \dfrac{\ln\left(\mathrm{P}_3 / \mathrm{P}_2\right)}{\ln\left(\mathrm{P}_1 / \mathrm{P}_2\right)}} \qquad (2)$$

Starting with the ideal gas equation of state and the polytropic process model, derive equations (1) and (2).

2. Conduct experiments to determine the maximum, minimum, and intermediate value for n. Within limits, the value of the constant, **n**, depends upon discharge rate, which maybe controlled by the throttling valve. Charge the tank to an initial pressure, P_1, of 4 bar (gauge). Wait for thermodynamic equilibrium and noted the pressure P_1 after thermal equilibrium. Discharge air until the tank pressure is equal to 0.8 bar gauge (P_2), and immediately record T_2. Then, wait until equilibrium is again reached and record the final pressure and temperature, P_3 and T_3. Be sure to record T_1, T_2 and T_3. Note that the pressures read from gauges are gauge pressures and the atmospheric pressure read from the barometer has to be added to obtain absolute pressures.

Analysis:

3. Sketch the processes for your three experiments in a single P-v diagram; show the **actual** processes for **n** equal to its maximum, minimum and intermediate value. Physically, what is taking place that would cause the value of **n** to vary?

4. Using the ideal gas model and the polytropic process model, show that the temperature at state point 2 can be predicted by :

$$T_2 = T_1\left(\frac{\mathrm{P}_2}{\mathrm{P}_1}\right)^{\frac{\mathrm{n-1}}{\mathrm{n}}} \qquad (3)$$

Use equation (3) to predict the value of T_2 for the three tests you plotted. Label those state points with the temperatures so calculated.

Conclusion:

Compare the calculated temperatures to the measured values. Can you explain any differences?