**Example Problem**: 3.55 kg of air at a pressure of 101.3 kPa (abs) is confined by a piston/cylinder device with a volume of 3 $m^3$. The piston radius is 0.9 m and atmospheric pressure, $P_{atm}$ = 101.3 kPa (abs), acts on the external surfaces of the piston/cylinder. Determine the following:

a) The density in kg/$m^3$ and temperature in K of the air.

b) The density in kg/$m^3$ and pressure in kPa (abs) of the air if it is isothermally compressed by the piston to a volume of 1.5 $m^3$.

c) The force in N applied to the piston to maintain the 1.5 $m^3$ volume of compressed air.

**Given**: 3.55 kg of air is isothermally compressed from state 1 to state 2 by a piston/cylinder.

$m_1 := 3.55kg$ $\quad$ $kPa := 1000Pa$

$V_1 := 3m^3$ $\quad$ $V_2 := 1.5m^3$

$P_1 := 101.3kPa$ $\quad$ $T_2 = T_1$ (isothermal)

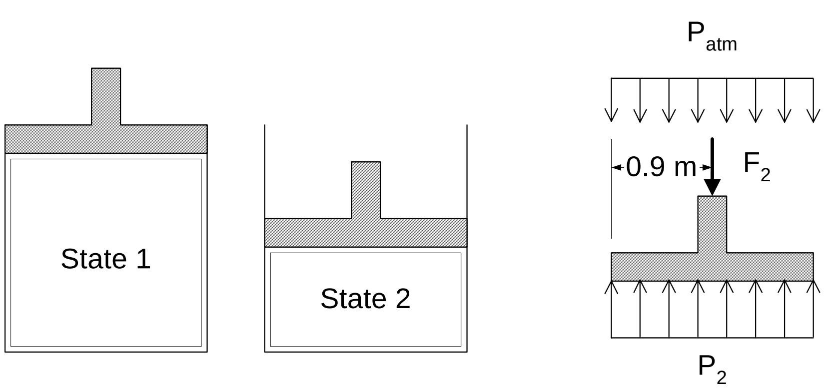
$r_p := 0.9m$ (piston radius) $\quad$ $P_{atm} := 101.3kPa$

**Find**: a) $\rho_1$ in kg/$m^3$, $T_1$ in K

b) $\rho_2$ in kg/$m^3$, $P_2$ in kPa (abs)

c) $F_2$ (force applied to piston at state 2 in N)

**Schematic**:



**Assumptions**:

1. No air leakage from piston/cylinder, therefore $m_1 = m_2$
2. Air is an Ideal Gas
3. No friction between piston and cylinder
4. Piston is "weightless"

**Properties**:

$$R_{air} := 286.9 \frac{J}{kg \cdot K}$$

from Table 1.8 front cover

$$k_{air} := 1.4$$

**Solution**:

a) density = mass/volume, $\rho := \frac{mass}{volume}$

$$\rho_1 := \frac{m_1}{V_1} \qquad \rho_1 = 1.183 \frac{kg}{m^3}$$

Ideal Gas, eqn 1.8, p. 14

$$P := \rho \cdot R \cdot T$$

therefore

$$T := \frac{P}{\rho \cdot R}$$

$$T_1 := \frac{P_1}{\rho_1 \cdot R_{air}} \qquad T_1 = 298.38 \ K$$

b) isothermal compression of an ideal gas

Eqn 1.14, p. 23

$$\frac{P}{\rho} := constant$$

$m_2 := m_1$ $m_1 = 3.55\ \text{kg}$

$\rho_2 := \dfrac{m_2}{V_2}$ $\rho_2 = 2.367\ \dfrac{\text{kg}}{\text{m}^3}$

$\dfrac{P_2}{\rho_2} := \dfrac{P_1}{\rho_1}$ therefore $P_2 := P_1 \cdot \dfrac{\rho_2}{\rho_1}$

$P_2 = 202.6\ \text{kPa}$

c) $\sum F := 0$ $0 := P_2 \cdot A - P_{atm} \cdot A - F_2$

$A := \pi \cdot r_p^{\,2}$ Area of piston

therefore $F_2 := \left(P_2 - P_{atm}\right) \cdot \pi \cdot r_p^{\,2}$ $F_2 = 2.578 \times 10^5\ \text{N}$