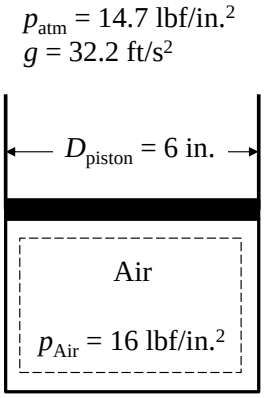
1.34 As shown in Figure P1.34, air is contained in a vertical piston-cylinder assembly such that the piston is in static equilibrium. The atmosphere exerts a pressure of 14.7 lbf/in.^{2} on top of the 6-in.-diameter piston. The absolute pressure of the air inside the cylinder is 16 lbf/in.^{2} The local acceleration of gravity is g = 32.2 ft/s^2. Determine (a) the mass of the piston, in lb, and (b) the gage pressure of the air in the cylinder, in psig.

KNOWN: A piston-cylinder assembly contains air such that the piston is in static equilibrium.

FIND: (a) The mass of the piston, in lb, and (b) the gage pressure of the air in the cylinder, in psig.

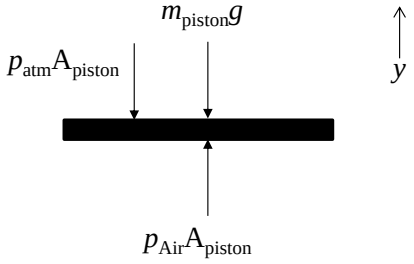
SCHEMATIC AND GIVEN DATA:



ENGINEERING MODEL:
1. The air is a closed system.
2. The piston is in static equilibrium.
3. Atmospheric pressure is exerted on the top of the piston.
4. Local gravitational acceleration is 32.2 ft/s^2.

ANALYSIS:
(a) Draw a free body diagram indicating all forces acting on the piston. Taking upward as the positive y-direction, the sum of the forces acting on the piston in the y-direction must equal zero for static equilibrium of the piston.

Free Body Diagram



$$\uparrow \sum F_y = 0$$

$$p_{Air}A_{piston} - p_{atm}A_{piston} - m_{piston}g = 0$$

Solving for the mass of the piston,

$$m_{piston} = \frac{p_{Air}A_{piston} - p_{atm}A_{piston}}{g}$$

$$m_{\text{piston}} = \frac{(p_{\text{Air}} - p_{\text{atm}})\text{A}_{\text{piston}}}{g}$$

The area of the piston is determined from the piston diameter

$$\text{A}_{\text{piston}} = \frac{\pi}{4}D^2 = \frac{\pi}{4}(6\,\text{in.})^2 = 28.3\ \text{in.}^2$$

Substituting values and solving for the mass of the piston,

$$m_{\text{piston}} = \frac{\left(16\frac{\text{lbf}}{\text{in.}^2} - 14.7\frac{\text{lbf}}{\text{in.}^2}\right)\left(28.3\,\text{in.}^2\right)}{32.2\frac{\text{ft}}{\text{s}^2}}\left|\frac{32.2\frac{\text{lb}\cdot\text{ft}}{\text{s}^2}}{1\,\text{lbf}}\right| = \mathbf{36.8\ lb}$$

(b) Gage pressure of the air is given by Eq. 1.14

$$p(\text{gage}) = p(\text{absolute}) - p_{\text{atm}}(\text{absolute}) = 16.0\ \text{psia} - 14.7\ \text{psia} = \mathbf{1.3\ psig}$$