**1.22**   As shown in Figure P1.22, a vertical piston-cylinder assembly containing a gas is placed on a hot plate. The piston initially rests on the stops. With the onset of heating, the gas pressure increases. At what pressure, in bar, does the piston start rising? The piston moves smoothly in the cylinder and $g = 9.81$ m/s^2.

KNOWN: A piston-cylinder assembly contains gas that is heated.

FIND: At what pressure the piston starts rising.

SCHEMATIC AND GIVEN DATA:
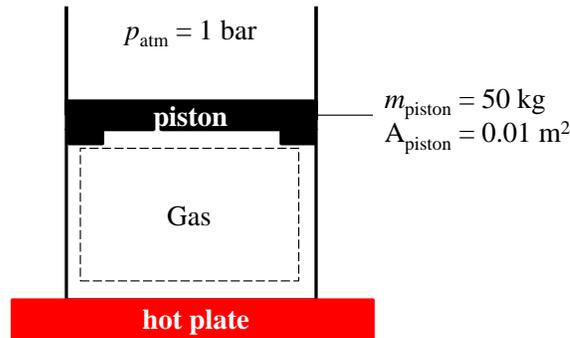
ENGINEERING MODEL:
1. The gas is a closed system.
2. The piston is in static equilibrium.
3. Atmospheric pressure is exerted on the top of the piston.
4. Local gravitational acceleration is 9.81 m/s^2.

ANALYSIS:
Since the piston moves smoothly within the cylinder, the piston begins to rise when the force exerted by the gas exceeds the resisting force comprised of the piston weight and the force exerted by the atmospheric pressure. That is,

$$F_{gas} \geq Weight + F_{atm}$$

$$p_{gas}A_{piston} \geq m_{piston}g + p_{atm}A_{piston}$$

$$p_{gas} \geq \frac{m_{piston}\,g}{A_{piston}} + p_{atm}$$
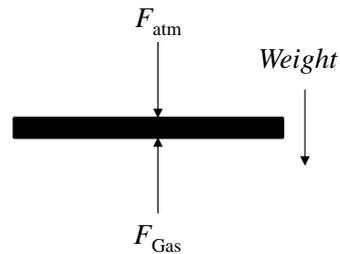
$$p_{gas} \geq \left[\frac{(50\,\text{kg})\left(9.81\dfrac{\text{m}}{\text{s}^2}\right)}{0.01\,\text{m}^2} \right] \left| \frac{1\,\text{bar}}{10^5\,\dfrac{\text{N}}{\text{m}^2}} \right| \left| \frac{1\,\text{N}}{1\dfrac{\text{kg}\cdot\text{m}}{\text{s}^2}} \right| + 1\,\text{bar} \quad \rightarrow \quad p_{gas} \geq \underline{\textbf{1.49 bar}}$$