88. • Using a ruler, we find the diameter of the period $D$ to be roughly 0.5 mm. Therefore, its area is $A = \pi D^2/4 \approx 2 \times 10^{-7}\,\mathrm{m}^2$. Meanwhile, we estimate the diameter $d$ of an air molecule to be roughly $2 \times 10^{-10}\,\mathrm{m}$ (this is "in the ballpark" of the value used in Sample Problem 20-4). So the area an air molecule covers is $a = \pi d^2/4 \approx 3 \times 10^{-20}\,\mathrm{m}^2$. Thus

$$\frac{A}{a} \approx \frac{2 \times 10^{-7}}{3 \times 10^{-20}} \approx 10^{13} \ .$$

This tells us that rouhgly $10^{13}$ air molecules are needed to cover the period.

• Assume that every second there are $N$ air molecules which collide with the period. If each one of them bounces back elastically after the collision then the change in linear momentum per molecule per collision is $2mv_x$, where $m$ is the molecular mass and $v_x$ is the component of the molecular velocity in the direction perpendicular to the surface of the paper containing the period. We take $v_x$ to mean the *average* velocity $x$-component. Thus, the pressure exerted by the air molecules on the period is

$$p = \frac{2mNv_x}{A\Delta t} \qquad \text{where} \quad \Delta t = 1\,\mathrm{s}$$

and $v_x \approx v_{\mathrm{rms}}/\sqrt{3}$ (see the discussion immediately preceding Eq. 20-20). Also we have $m = M/N_A$, where $M$ is the average molar mass of the air molecules. We solve for $N$:

$$\begin{aligned} N &= \frac{\sqrt{3}pAN_{\mathrm{A}}\Delta t}{2Mv_{\mathrm{rms}}} = \frac{pAN_{\mathrm{A}}\Delta t}{2\sqrt{MRT}} \\ &= \frac{(1.01 \times 10^5\,\mathrm{Pa})(2 \times 10^{-7}\,\mathrm{m}^2)(6.02 \times 10^{23}/\mathrm{mol})(1\,\mathrm{s})}{2\sqrt{(0.028\,\mathrm{kg/mol})\left(8.31\,\frac{\mathrm{J}}{\mathrm{mol{\cdot}K}}\right)(300\,\mathrm{K})}} \approx 7 \times 10^{20} \ . \end{aligned}$$