# Science Activity/Demo: Hearing a Pin Drop

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| Topic/Concepts Sound, energy, "back-of-the -envelope" physics, estimating |
| Grade Level: mid high school to college |

**Description**
How sensitive are your ears? A very surprising demo can be done with the simplest of materials:

- a simple drum made from plastic wrap and a coffee can
- very small piece of paper
- cm ruler
- accurate lab scale
- large open room (gymnasium is ideal)
- computer interface/microphone (optional)

**Procedure**
Situate your students in a circle around you. Crumple a small piece of paper into a tight ball. Drop the paper onto the drum surface and have students move progressively farther away until they can no longer hear the sound of the paper hitting the drum surface. Measure the height of drop, mass of paper and distance of the students.

**Discussion**
The point of the discussion is to demonstrate the amount of power that a typical ear can respond to. The result is truly remarkable. Here is an actual sample drop and calculation:

- mass of paper = 3 mg
- height of drop = 1 cm
- distance of students = 7 m

Maximum energy available for conversion to sound =

$$\begin{aligned} &\Delta E_p = \text{potential energy} \\ &= mg\Delta h \\ &= (3x10^{-6}\,kg)(9.81m/s^2)(0.01m) \\ &= 3x10^{-7}\,J \end{aligned}$$

The following graph shows the result of "listening" to the sound of the drum surface with a computer-interfaced microphone.
This suggests that the duration of the sound was approximately 0.2 s. Thus, the average power generated was a mere:

$$P = \Delta E/\Delta t = \frac{3x10^{-7}\,J}{0.2s} = 1.5x10^{-6}\,W$$

BUT! that's not the whole story! This sound is spread throughout a hemisphere of radius 7 meters! Thus, the intensity received at the ear is a tiny:

$$I = {}^{P}\!/_{A} = \frac{1.5x10^{-6}\,W}{[illegible]} = \frac{1.5x10^{-6}\,W}{2\pi(7.0m)^2} = 5x10^{-9}\,W/m^2$$

BUT!!! that's not even close to the whole story. Your ear only intercepts a small fraction of this. Thankfully, your ear is not 1 m$^2$ in area! Adopt 10 cm x 10 cm as a "standard ear". Thus, your ear is responding to only:

$$5x10^{-9}\,{}^{W}\!/_{m^2}\; x10^{-4}\,m^2 = 5x10^{-13}\,W$$

This is truly remarkable!

If you want to continue the argument you can demonstrate the average distance of compression of the air molecules via: $I = 2\pi^2 f^2 \rho v X_o^2$ where f is the frequency (about 400 Hz in our test) and ρ is the air density, v the velocity of sound and X the displacement. Plugging in the numbers gives a truly remarkable result- the air molecules are only shifted - *on average* by 1.2 x 10$^{-9}$ m! This is less than an atomic diameter.