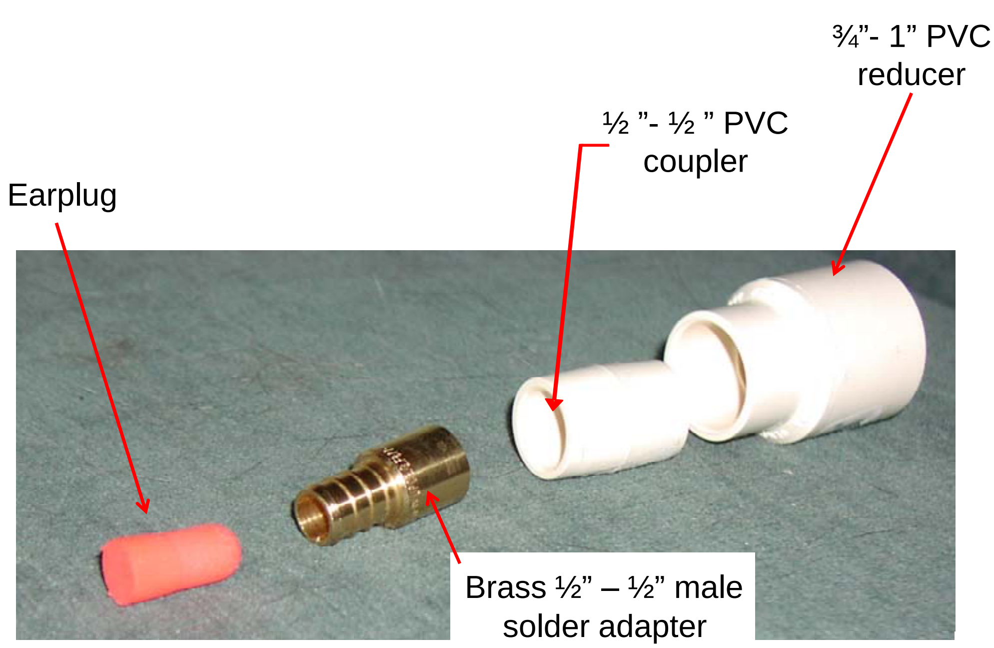
Race Gear: Sound Meters

Measuring Sound

A ***sound level meter*** is used to measure sound intensity levels. Since we're concerned mostly with human hearing, it is handy to rig the sound level meter to mimic the ear canal. The photo below shows one possible setup.

The attachment is shown in more detail below:



Most sound-level meters have a microphone that extends a short distance beyond the end of the meter. The meter shown is a Radio Shack model #: 33-2055, which has a microphone that extends about 0.5" beyond the meter and is just less than 1" in diameter. A series of PVC plumbing parts from the hardware store serves to make an "ear canal" as shown in the picture. Duct tape was used to attach the rig to the sound-level meter and to make the ½"-½" PVC coupler fit snugly in the ¾"-1" PVC reducer. It is important that the sound is being measured coming through your simulated ear canal. If there are gaps, you'll measure sound coming through those openings.

Most sound-level meters use units of decibels or "dBs " (pronounced "dee-bees") to measure sound intensity level. The decibel is named after Alexander Graham Bell, the inventor of the telephone and a scientist who studied sound and human hearing in the 1800s.

> ***Read your sound-level meter instruction manual to find out what weighting settings your meters have. For the purposes of activities within Building SPEED, have the students use the so-called "C-weighting", which gives a uniform frequency response.***

What is a dB?

The human ear can hear a broad range of ***sound intensities*** – from $10^{-12}\ \frac{W}{m^2}$ to $1\ \frac{W}{m^2}$; however, the relationship between how loud we perceive a sound to be and its actual amplitude is not linear. To produce a sound that is perceived to be twice as loud as another sound requires the louder sound to have an amplitude about 10 times larger than the first sound. This experimental observation indicates that what humans characterize as loudness is not the same thing as intensity. For this reason, we use a quantity called an ***intensity level*** or a ***sound intensity level***, β, which is more consistent with what we call loudness.[1] β is defined as:

$$\beta(in\ dB) = 10\log\left(\frac{I}{I_o}\right)$$

where I_o is a constant reference intensity, taken to be $1.0\times10^{-12}\ \frac{W}{m^2}$. This value theoretically is the lowest intensity sound we can hear. The decibel scale is a compressed scale that allows loudness to be specified using numbers, varying from 0 dB (for the threshold of hearing) to about 140 dB, where the sound can damage your ears permanently.

The smallest possible value of β, which we will call β_{min}, occurs when $I = I_o$:

$$\begin{aligned}\beta_{\min}(in\ dB) &= 10\log\left(\frac{I_o}{I_o}\right)\\ &= 10\log(1)\\ \beta_{\min} &= 0\ dB\end{aligned}$$

[1] β is the lower-case Greek letter 'beta'

Every time you add ten to a sound intensity level, it means that the sound intensity increases by a multiplicative factor of 10.

To go from sound intensity level (in dB) to sound intensity, use:

$$I = I_0 10^{\frac{\beta}{10}}$$

The following table gives some examples:

Sound Intensity Level (in dB)	Sound intensity (in terms of I_o)	Sound intensity (in W/m^2)
0	I_0	1×10^{-12}
10	$10\ I_0$	1×10^{-11}
20	$10^2 I_o = 100\ I_0$	1×10^{-10}
60	$10^6 I_o = 1{,}000{,}000\ I_0$	1×10^{-6}
90	$10^9 I_o = 1{,}000{,}000{,}000\ I_0$	1×10^{-3}

The table below gives some approximate sound levels for different situations. Your measurements may not agree exactly with those in the table. Sound intensity level depends on where the meter is relative to the sound source and the space in which the sound source is located, as you may have (for example) reflections of the sound from nearby walls or other objects.

Situation	Approximate sound level (in dB)	OSHA-mandated maximum exposure per day
threshold of hearing	0 dB	
Whisper	15 dB	
quiet room	30 dB	
normal conversation	60 dB	
city traffic, heard from inside the car	85 dB	**16 hours**
power drill, shop tools, diesel trucks	90 dB	**8 hours**
clarinet or oboe at 10 feet	95 dB	**4 hours**
jet takeoff at 1000 feet; outboard motor, farm tractor, garbage truck	100 dB	**2 hours**
power mower	105 dB	**1 hour**
chain saw, rock concert, riveting, auto horn at 3 feet	110 dB	**0.5 hours**
iPod at full volume with earbud; jackhammer	115 dB*	**0.25 hours**
jet engine or rock concert	120 dB	
threshold of pain	130 dB	**Ear drum distortion**
gun shot or fire cracker	140 dB	
jet takeoff at 75 feet	150 dB	**Ear drum rupture**
Shot from a 38-caliber handgun at 1 foot	155 dB	
jet aircraft taking off from 30 feet	160 dB	
jet engine at 1 foot	**180 dB**	**Immediate tissue death**

Sources: Wikipedia ; How Stuff Works; OSHA; *http://blogs.zdnet.com/Apple/?p=95

Noise Reduction Ratio

Measure a noisy sound (like a Dremel tool, a hair dryer or a shop vac) with nothing in the measuring tube. Then make the same measurement with your finger over the opening in the tube or an earplug in the ear canal. The difference between the two readings is called the Noise Reduction Ratio or NRR.

The Environmental Protection Agency requires that earplugs carry a label showing the **hearing protection** NRR. If you use earplugs with an NRR of 33, the noise entering your ears should be reduced by 33 dB. In reality, it's probably more accurate to decrease that measurement by about 25% because you have to account for earplugs not fitting quite right, not being worn correctly, etc. In practice, we find that a nominal 30 dB ear plug gives about 25 dB sound reduction for the rig shown in the photo. The actual sound level reduction level may depend on how tightly the ear plug is compressed in the tube and whether there is any sound "leaking in" through the walls of the tubes.

The NRR should be independent of the loudness of the original sound. For example, an ear plug with a 20 dB sound reduction level should reduce the reading of a 95 dB to 75 dB. If the original sound level is 87 dB, the reading with the 20 dB ear plug in place should be 67 dB.

Other Transmission

This sound meter set up (like your ear) is not perfect. Sounds can reach your inner ear (and then induce signals that go on to the brain) even if your ear canal is fully blocked. Sound vibrations can be transmitted by the bones in your head. Try scratching your head. The sound will be much louder to you than to someone else even if that person's ear is close to where you are scratching. Or hold a wooden Popsicle stick tightly between your teeth and then scratch the wood. The sound vibrations are transmitted through your teeth and skull bones to your inner ear. Bone conduction means that even if your ear drums are broken, you can still hear some loud sounds.