1. Power vs. Intensity
2. Absolute Intensity vs. Decibels
3. Doppler Effect

- Power $P = \frac{\text{Energy}}{\text{Time}}$
- Intensity $I = \frac{\text{Power}}{\text{Area}}$

Asphere $= 4\pi r^2$

* Intensity of eyeball $I_{\text{eye}} = \frac{P_{\text{bulb}}}{4\pi r^2}$

* Pentaery eye $= (I_{\text{eye}}) \pi r^2$
A satellite radio station puts out 10 kw of cool jazz for an hour at 99.3 MHZ on your radio dial. How much energy per unit time goes through a sphere 50 kilometers in diameter that is centered on the satellite. The drawing below is not to scale.

1. \((10 \text{ kw})/(25 \text{ km})^2\)
2. 10 kw
3. \((10 \text{ kw})(4\pi)(25 \text{ km})^2\)
4. \((10 \text{ kw})(4\pi)(25 \text{ km})^2(\text{time})\)
5. None of the above

Now, the sphere enclosing the satellite that is broadcasting at 10 kw for an hour is way off center, as shown. The total power going through the sphere is now:

1. \((10 \text{ kw})/(25 \text{ km})^2\)
2. 10 kw
3. \((10 \text{ kw})(4\pi)(25 \text{ km})^2\)
4. \((10 \text{ kw})(4\pi)(25 \text{ km})^2(1 \text{ hour})\)
5. None of the above
A ground-based radio station puts out 50 kw, and your radio needs to receive at least $1 \times 10^{-6}$ w/m$^2$ of power per unit area in order to faithfully reproduce the sound of cool jazz. What is the maximum distance that you can be from the broadcast antenna?

1. 1000 km
2. 630 km
3. 316 km
4. 0
5. 32 km
6. 63 km

\[
I = \frac{P}{4\pi r^2}
\]

\[
10^{-6} \text{ W/m}^2 = \frac{50 \times 10^3 \text{ W}}{4\pi r^2}
\]

\[
r^2 = \left(\frac{50}{4\pi \times 10^9}\right) \text{ m}^2
\]

\[
\approx 4 \times 10^9 \text{ m}^2
\]

\[
r \approx 2 \times 10^{4.5} \text{ m}
\]

\[
\approx 6 \times 10^4 \text{ m}
\]
### Decibels

<table>
<thead>
<tr>
<th>Absolute Intensity I</th>
<th>Decibels B</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10^{-12} \frac{W}{m^2}$</td>
<td>0 dB</td>
</tr>
<tr>
<td>$10^{-11} \frac{W}{m^2}$</td>
<td>10 dB</td>
</tr>
<tr>
<td>$10^{-10} \frac{W}{m^2}$</td>
<td>20 dB</td>
</tr>
<tr>
<td>$10^{-9} \frac{W}{m^2}$</td>
<td>30 dB</td>
</tr>
<tr>
<td>$10^{-8} \frac{W}{m^2}$</td>
<td>40 dB</td>
</tr>
<tr>
<td>$10^{-7} \frac{W}{m^2}$</td>
<td>50 dB</td>
</tr>
<tr>
<td>$1 \frac{W}{m^2}$</td>
<td>120 dB</td>
</tr>
</tbody>
</table>

Threshold of hearing $I_0 = 10^{-12} \frac{W}{m^2}$

$B = (10 \times \log_{10} \left( \frac{I}{I_0} \right))$

Convert 77 dB to $I_0$: half of 80 dB is $\frac{1}{2} \times 10^{-4} \frac{W}{m^2} = 5 \times 10^{-5} \frac{W}{m^2}$
Doppler Effect

Observer (receiver moving w/ speed \( V_r \))

*(book \( V_0 \))*

\[
f' = f \left( \frac{V \pm V_r}{V \pm V_s} \right)
\]

Source freq.

Speed of sound: \( V = 343 \text{ m/s} \)

**Key Fact**

If two objects are moving towards each other, \( f' > f \)

If two objects are moving away from each other, \( f' < f \)
Case 1

\[ f' = f \left( \frac{V + \delta Vr}{\sqrt{V}} \right) \]

\[ f' > f \]

(A) +

(B) -

Case 2

\[ f' = f \left( \frac{V + \delta Vr}{V + \delta Vr} \right) \]

(A) + top, + bottom

(B) + top, - bottom

(C) - top, + bottom

(D) - top, - bottom

Which are?

Pretend

\[ \frac{Vs}{\square} \]

\[ f' > f \text{ or } f' = f? \]
A speaker broadcasting at a frequency of 2 MHz is moving with a velocity of 200 m/s toward a stationary detector. What is the frequency that the detector will hear? The speed of sound is 343 m/s and the Doppler formula is:

\[ f' = f \left( \frac{v \pm v_{\text{DETECTOR}}}{v \pm v_{\text{SOURCE}}} \right) \]

1. 0.83 MHz
2. 4.8 MHz
3. 3.2 MHz
4. 1.3 MHz
5. 2 MHz

ANS: 2

A detector is moving 200 m/s toward a stationary speaker broadcasting at a frequency of 2 MHz. What frequency will the detector hear? The speed of sound is 343 m/s and the Doppler formula is:

\[ f' = f \left( \frac{v \pm v_{\text{DETECTOR}}}{v \pm v_{\text{SOURCE}}} \right) \]

1. 0.83 MHz
2. 4.8 MHz
3. 3.2 MHz
4. 1.3 MHz
5. 2 MHz

ANS: 3
A speaker is moving with a velocity of 200 m/s toward a detector, and the detector is moving with a velocity of 100 m/s away from the speaker. The speaker's frequency is 2 MHz, what is the frequency that the detector will hear? (The speed of sound is 343 m/s, and all speeds are relative to the ground.)

**Method 1:** According to the detector, the speaker is approaching at 200-100=100 m/s, so the frequency is

\[ 2 \times \frac{1}{1-\frac{100}{343}} = 2.82 \text{ MHz} \]

**Method 2:** The speaker is moving 200 m/s towards the detector, and the detector is moving 100 m/s away. So the frequency is

\[ 2 \times \frac{1-\frac{100}{343}}{1-\frac{200}{343}} = 3.40 \text{ MHz} \]

1. Both methods are right
2. Both methods are wrong.
3. Only method 1 is right.
4. Only method 2 is right.

A **combined** speaker and detector system is moving at 100 m/s toward a wall. The speaker's frequency is 2 MHz and the detector will hear the wave **reflected** by the wall. What frequency will the detector hear? The speed of sound is 343 m/s and the doppler formula is:

\[ f' = f \frac{v \pm v_{DETECTOR}}{v \pm v_{SOURCE}} \]

1. 2.82 MHz
2. 2.58 MHz
3. 3.65 MHz
4. 1.10 MHz
5. 2.00 MHz
**Figure 1.** The principle of measuring the radial velocity by means of the Doppler effect. The star and the orbiting planet move around their common centre of mass, causing Doppler shifts due to stellar wobble. Stellar absorption lines that arise when radiation from the interior passes the stellar atmosphere will be red- and blue-shifted depending on whether the star is moving away or towards Earth. These Doppler shifts give information about the planet's orbital period around the star and also set a lower mass limit. (Reproduced from Las Cumbres Observatory, a worldwide network of telescopes.)