1. The equation for finding the epicenter

To calculate the distance to the epicenter for each station, you will use the equation:

\[ \text{Distance} = \text{Rate} \times \text{Time} \]

Table 1 lists the variables that are used in the equation for finding the distance to the epicenter. This table also tells you which values are given to you and which values you need to calculate.

**Table 1: Variables for the equation to calculate the distance to the epicenter**

<table>
<thead>
<tr>
<th>Variable</th>
<th>What it means</th>
<th>Given</th>
<th>Need to calculate</th>
</tr>
</thead>
<tbody>
<tr>
<td>(d_p)</td>
<td>distance traveled by P-waves</td>
<td>(r_p = 5 \text{ km/sec})</td>
<td>(d_p, t_p, \text{ and } d_s)</td>
</tr>
<tr>
<td>(r_p)</td>
<td>speed of P-waves</td>
<td>(r_s = 3 \text{ km/sec})</td>
<td></td>
</tr>
<tr>
<td>(t_p)</td>
<td>travel time of P-waves</td>
<td>(t_s = \text{ travel time of P-waves plus the time between the P- and S-waves})</td>
<td></td>
</tr>
<tr>
<td>(d_s)</td>
<td>distance traveled by S-waves</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(r_s)</td>
<td>speed of S-waves</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(t_s)</td>
<td>travel time of S-waves</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For each of the practice problems, assume that the speed of the P-waves will be 5 km/sec and the speed of the S-waves will be 3 km/sec. Also, because the P- and S-waves come from the same location, we can assume the distance travelled by both waves is the same.

\[
\text{distance traveled by P-waves} = \text{distance traveled by S-waves}
\]

\[
d_p = d_s
\]

\[
r_p \times t_p = r_s \times t_s
\]

Since the travel time for the S-waves is longer, we can say that,

\[
\text{travel time of S-waves} = (\text{travel time of P-waves}) + (\text{extra time})
\]

\[
t_s = t_p + (\text{extra time})
\]

\[
r_p \times t_p = r_s \times (t_p + \text{extra time})
\]
2. Practice problems

For each of the practice problems, assume that the speed of the P-waves is 5 kilometers per second, and the speed of the S-waves is 3 kilometers per second. The first problem is done for you. Show your work for all problems.

1. S-waves arrive to seismographic station A 85 seconds after the P-waves arrive. What is the travel time for the P-waves?

\[
\frac{5 \text{ km}}{\text{sec}} \times t_p = \frac{3 \text{ km}}{\text{sec}} \times (t_p + 85 \text{ sec})
\]

\[
\left(\frac{5 \text{ km}}{\text{sec}}\right)t_p = \left(\frac{3 \text{ km}}{\text{sec}}\right)t_p + 255 \text{ km}
\]

\[
\left(\frac{2 \text{ km}}{\text{sec}}\right)t_p = 255 \text{ km}
\]

\[
t_p = 128 \text{ sec}
\]

2. S-waves arrive to another seismographic station B 80 seconds after the P-waves. What is the travel time for the P-waves to this station?

3. A third seismographic station C records that the S-waves arrive 120 seconds after the P-waves. What is the travel time for the P-waves to this station?

4. From the calculations in questions 1, 2, and 3, you know the travel times for P-waves to three seismographic stations (A, B, and C). Now, calculate the distance from the epicenter to each of the stations using the speed and travel time of the P-waves. Use the equation: distance = speed \times time.

5. **Challenge question:** You know that the travel time for P-waves to a seismographic station is 200 seconds.
   a. What is the difference between the arrival times of the P- and S-waves?
   b. What is the travel time for the S-waves to this station?
3. Practice problems: Locating the epicenter

Table 2 includes data for three seismographic stations. Using this information, to perform the calculations that will help you fill in the rest of the table.

Table 2: Calculating the distance to the epicenter

<table>
<thead>
<tr>
<th>Variables</th>
<th>Station 1</th>
<th>Station 2</th>
<th>Station 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed of P-waves</td>
<td>( r_p )</td>
<td>5 km/sec</td>
<td>5 km/sec</td>
</tr>
<tr>
<td>Speed of S-waves</td>
<td>( r_s )</td>
<td>3 km/sec</td>
<td>3 km/sec</td>
</tr>
<tr>
<td>Time between the arrival of P- and S-waves</td>
<td>( r_s - r_p )</td>
<td>70 seconds</td>
<td>115 seconds</td>
</tr>
<tr>
<td>Total travel time of P-waves</td>
<td>( t_p )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total travel time of S-waves</td>
<td>( t_s )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance to epicenter</td>
<td>( d_p, d_s )</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Once you have calculated distance to the epicenter for three stations, you can use a map to locate the epicenter. The steps are as follows:

**Step 1:** Draw a circle around each seismographic station. The radius of the circle should be proportional to the distance to the epicenter.

**Step 2:** The place where all three circles intersect is the location of the epicenter.

1. In Table 2, you calculate the distance to the epicenter for three seismographic stations. Convert each of these distances in kilometers to centimeters using the scale, 200 kilometers = 1 centimeter. Use proportions to perform the calculation:

\[
\frac{1 \text{ cm}}{200 \text{ km}} = \frac{x}{\text{distance to epicenter in km}}
\]
2. Now, use the values you calculated in question (1), the graphic below, and a geometric compass to make circles around each station. Remember that the radius of each circle is proportional to the distance to the epicenter.