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Submarines

Two submarines are approaching each other on a collision course, the first with a speed v_1 and the second with a speed v_2. The speed of sound in sea water is v_{sea}.

a) The first submarine emits a sonar pulse of frequency f_1. What is the frequency, f_2, of this pulse as measured by the second submarine?

$f_2 = \left(\frac{v_{\text{sea}}+v_2}{v_{\text{sea}}-v_1}\right) \cdot f_1$

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b) The sonar pulse is reflected by the second submarine and detected by the first submarine at a frequency f_3. In terms of the first submarine's speed, v_1, the speed of sound in seawater, v_{sea}, and the original frequency, f_1, find the speed of the second submarine, v_2.

$f_3 = \left(\frac{v_{\text{sea}}+v_1}{v_{\text{sea}}-v_2}\right) \cdot \left(\frac{v_{\text{sea}}+v_2}{v_{\text{sea}}-v_1}\right) \cdot f_1$ or $f_2 = \frac{v_{\text{sea}}}{v_{\text{sea}}-(v_1+v_2)} f_1$, $f_3 = \frac{v_{\text{sea}}}{v_{\text{sea}}-(v_1+v_2)} f_2$
$f_3 = \frac{v_{\text{sea}}}{v_{\text{sea}}-(v_1+v_2)} \frac{v_{\text{sea}}}{v_{\text{sea}}-(v_1+v_2)} f_1$

solving for v_2, we get: $v_2 = v_{\text{sea}}\left(1-\sqrt{\frac{f_1}{f_3}}\right) - v_1$

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c) What is the $v_1 \to 0$ limit to your answer to part (b)?

$\lim_{v_1 \to 0} v_2 = v_{\text{sea}}\left(1-\sqrt{\frac{f_1}{f_3}}\right)$

d) What is the $f_3 \to f_1$ limit to your answer to part (b)?

$\lim_{f_1' \to f_1} v_2 = -v_1$