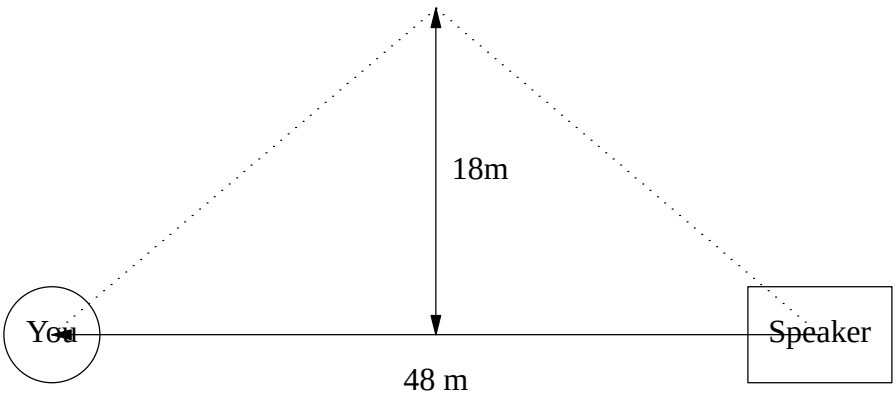
4. (20 pts.) You are seated in a concert hall a distance of 48 m from the stage, as shown in the figure. Some sound reaches you directly, but additional sound is reflected off the ceiling of the concert hall, so interference is possible. The ceiling is 18 m high. (Assume for the sake of this problem that the sound does not undergo any phase change or inversion when it reflects.) What are the two lowest frequencies for which the intensity is a minimum? The speed of sound in air is 340 m/s.



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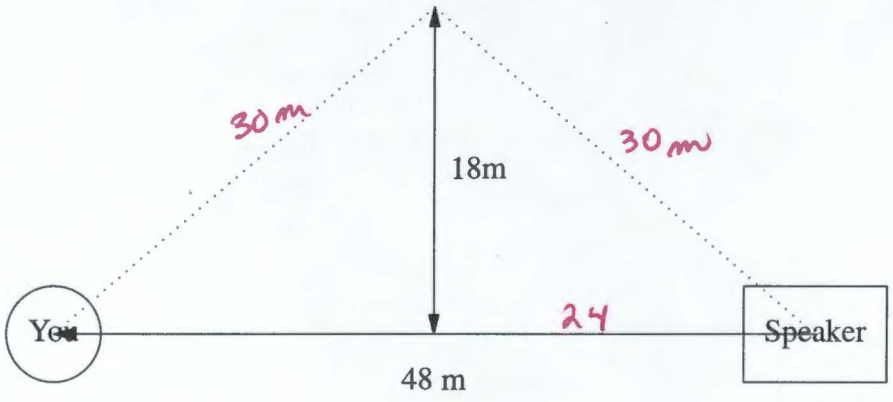

r_1 = direct = 48m

r_2 = reflected distance = 60m

Destructive Interference: $r_2 - r_1 = \frac{1}{2}\lambda$

$12m = \frac{1}{2}\lambda$

$24m = \lambda$

$f_1 = \frac{v}{\lambda} = 14.17\ Hz$

Next lowest: $r_2 - r_1 = \frac{3}{2}\lambda$

$12m = \frac{3}{2}\lambda$

$8m = \lambda$

$f_3 = \frac{v}{\lambda} = 42.5\ Hz$

(or $f_3 = 3f_1$).