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Thermodynamics, Wave Motion and Optics (PHYS201)
Participation 1

Suppose a speaker is mounted to a stand and attached to a spring having spring constant $k = 10.0$ N/m (so it moves in a SHM). The total mass of the stand and speaker is 2.5 kg, and the amplitude of this unit's motion is 0.500 m.

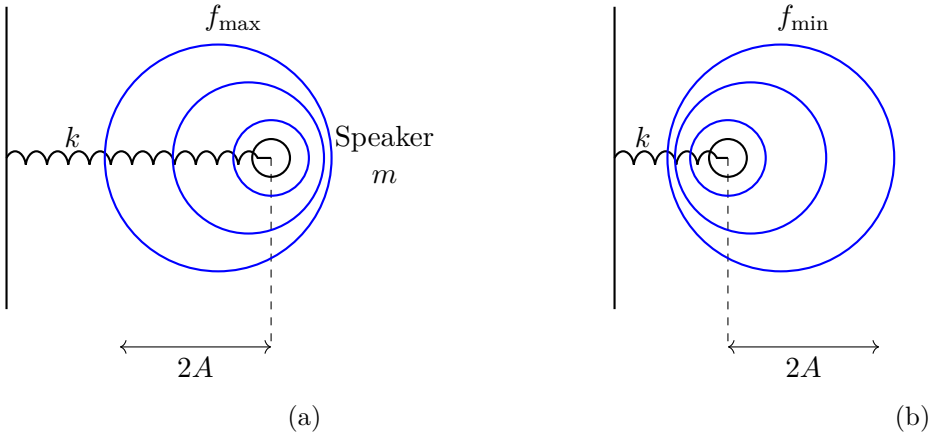

Figure 1

(a) If the speaker emits sound waves of frequency 450 Hz, determine the highest and lowest frequencies heard by the person to the right of the speaker.

$$k = 10.0 \text{ N/m} \quad m = 2.5 \text{ kg} \quad A = 0.500 \text{ m} \quad f = 450 \text{ Hz}. \tag{1}$$

$$f' = f\left(\frac{v \pm v_s}{v \pm v_o}\right) \tag{2}$$

$$f_{\max} = f\left(\frac{v + v_s}{v}\right) \tag{3}$$

$$f_{\min} = f\left(\frac{v - v_s}{v}\right). \tag{4}$$

$$v_{\max} = -v_{\min} = A\sqrt{\frac{k}{m}} \tag{5}$$

$$= 0.500\sqrt{\frac{10.0}{2.5}} \tag{6}$$

$$= 1 \text{ m/s} \tag{7}$$

$$. \tag{8}$$

$$f_{\max} = 450\left(\frac{343+1}{343}\right) \tag{9}$$
$$= 451 \text{ Hz} \tag{10}$$
$$f_{\min} = 450\left(\frac{343-1}{343}\right) \tag{11}$$
$$= 449 \text{ Hz}. \tag{12}$$

(b) If the maximum sound level heard by the person is 60.0 dB when he is closest to the speaker, 1.00 m away, what is the minimum sound level heard by the observer? Assume that the speed of sound is 343 m/s.

$$\beta_{\max} = 60.0 \text{ dB} \quad \beta = 10\log_{10}\left(\frac{I}{I_0}\right) \quad I = \frac{P}{4\pi r^2}. \tag{13}$$

$$\beta_{\max} - \beta_{\min} = 10\log_{10}\left(\frac{I_{\max}}{I_0}\right) - 10\log_{10}\left(\frac{I_{\min}}{I_0}\right) \tag{14}$$
$$= 10\log_{10}\left(\frac{I_{\max}}{I_{\min}}\right) \tag{15}$$
$$= 10\log_{10}\left(\frac{r_{\min}}{r_{\max}}\right)^2 \tag{16}$$
$$= 20\log_{10}\left(\frac{r_{\min}}{r_{\max}}\right) \tag{17}$$
$$= 20\log_{10}\left(\frac{d+2A}{d}\right) \tag{18}$$
$$= 20\log_{10}\left(\frac{1+2(0.500)}{1}\right) \tag{19}$$
$$= 6.02 \text{ dB}. \tag{20}$$

$$\beta_{\min} = 60.0 - 6.02 \tag{21}$$
$$= 53.98 \text{ dB}. \tag{22}$$