Analog assignment (11.15.21)

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Question:

A train, standing in a station yard, blows a whistle of frequency 400 Hz in still air. The wind starts blowing in the direction from the yard to the station with a speed of 10 m/s. What are the frequency, wavelength, and the speed of sound for an observer standing on the station's platform? Is the situation exactly identical to the case when the air is still and the observer runs towards the yard at a speed of 10 m/s? The speed of sound in still air can be taken as 340 m/s.

Solution:

Table 1: Summary of Parameters

Parameter	Description	Value
f	Sound frequency	400 Hz
c	Speed of sound in air	340 m/s
v	Wind velocity	10 m/s
v_e	Effective speed of sound	350 m/s
λ	Wavelength of the sound wave	0.875 m
v_o	Observer's velocity	10 m/s
v'	Frequency change	411.76 Hz

For the stationary observer:

As there is no relative motion between the source and the observer, the frequency of the sound heard by the observer will be the same as that produced by the source, i.e., $f = 400\,\text{Hz}$.

The wind is blowing toward the observer. Hence, the effective speed of the sound increases by 10 units, i.e.,

$$v_e = c + v = 340 + 10 = 350\,\text{m/s} \tag{1}$$

The wavelength (λ) of the sound heard by the observer is given by the relation:

$$\lambda' = \frac{v_e}{f} \tag{2}$$

Equation for the transmitted sound wave:

$$P_{\text{transmitted}}(x,t) = A \sin\left(2\pi f' \left(t - \frac{x}{v_e}\right)\right) \tag{3}$$

where $f' = \frac{v_e}{\lambda'}$

For the running observer:

$$\text{Change in frequency, } v' = \frac{v_e}{c} \cdot v_o + f \tag{4}$$
$$= \frac{350}{340} \cdot 10 + 400 \tag{5}$$
$$\approx 411.76\,\text{Hz} \tag{6}$$

Equation for the received sound wave:

$$P_{\text{received}}(x,t) = A \sin\left(2\pi f \left(t - \frac{x}{c}\right)\right) \tag{7}$$