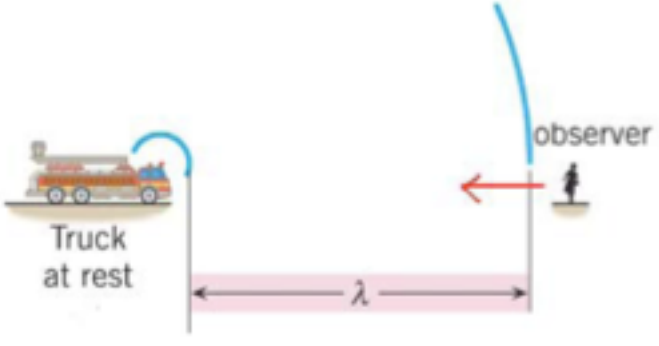
An observer runs at 10 m/s toward a stationary fire truck. The frequency of the sound the observer experiences when running is 350 Hz. If the speed of the sound in the air is 340 m/s, what is the frequency of the sound the observer experiences when moving away from the truck (after passing it by)? What is the wavelength of the sound wave emitted by the truck?



$$f_o = f_s\left(1 \pm \frac{v_o}{v}\right)$$

After he passes the truck we have to use …

1. + 2. –

to relate frequnacies f_s and f_o.

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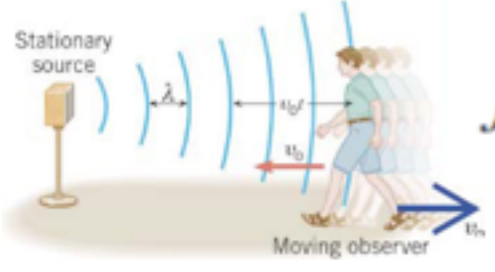

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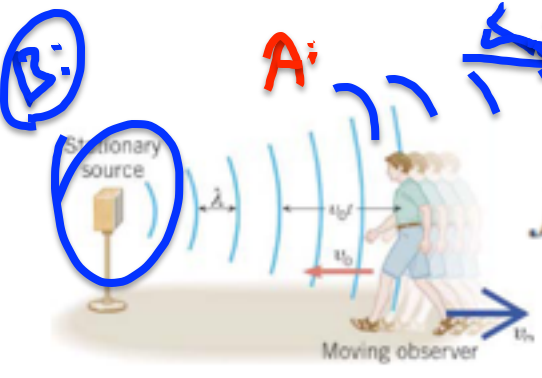
A: $f_o = f_s\left(1 + \frac{v_o}{v}\right) = f_s\left(1 + \frac{10}{340}\right)$

f_o = ? 350 Hz f_s (2)

$350 = f_s \frac{350}{340}$

$f_s = 340\ Hz$?

B: $f_o = f_s\left(1 - \frac{10}{340}\right)$



$$f_o = f_s\left(1 \pm \frac{v_o}{v}\right)$$

(6:

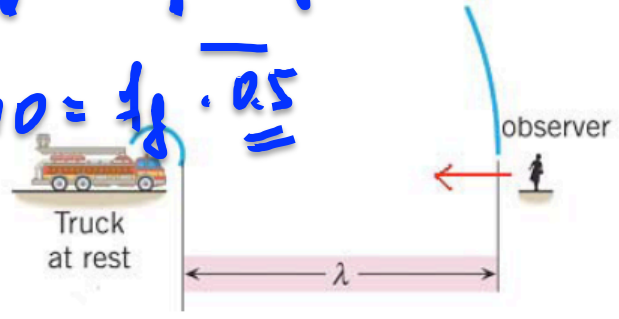
$$f_0 = 340\left(1 - \frac{10}{340}\right) = 340 \cdot \frac{330}{340} =$$

$$= 330\ Hz$$

$V = f \cdot \lambda$

$340 = f_s \cdot 0.5$

PROBLEM



An observer running at 10 m/s towards the stationary fire truck finds that the truck makes a sound of the wavelength of 0.5 m. What are the wavelength and the frequency for the stationary truck?
The speed of the sound is 340 m/s.

When the truck is 700 m away from the observer the truck blows its horn. How long does it take for the sound to get to the observer after it is emitted? How many wavelengths were emitted during this time?

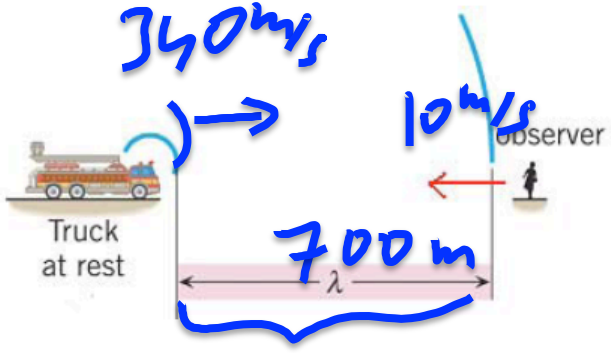
$$350 = V_{so} = f_s \cdot \lambda = f_s \cdot 0.5$$

$$f_o = f_s\left(1 \pm \frac{v_o}{v}\right)$$

$$f_o = 700\,Hz = f_s\left(2 + \frac{10}{340}\right) = f_s \frac{350}{340}$$

$$f_s = 680\,Hz$$

PROBLEM



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When the truck is 700 m away from the observer the truck blows its horn. How long does it take for the sound to get to the observer after it is emitted? How many wavelengths were emitted during this time?

$$V_{so} = 350\ m/s = \frac{700}{t}$$

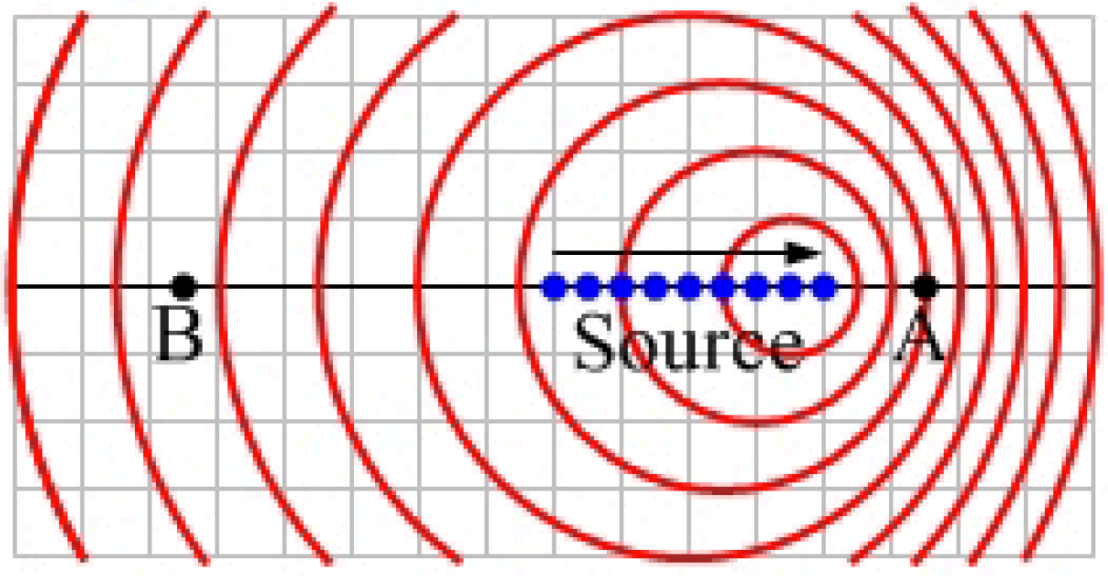
$$t = 2\ s$$

$$f_o = f_s\left(1 \pm \frac{v_o}{v}\right)$$

Doppler effect: a moving source

If the source moves through the medium, the situation looks a little different.

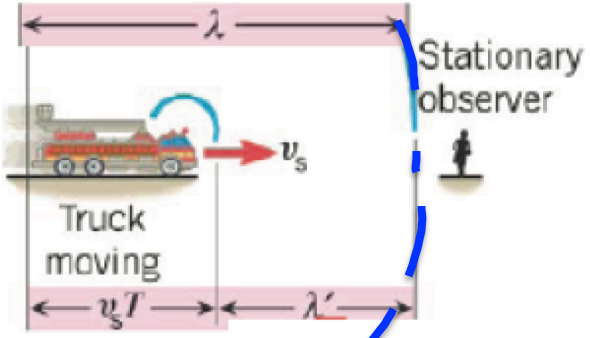
Simulation: (moving source)



A moving source

$$v_{sound\_observer} = v_{sound\_ground} = v$$

λ



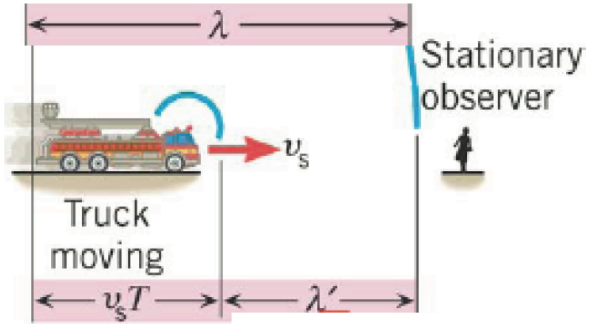
$$\lambda_{observer} = \lambda_{ground} = \lambda_{by\_moving\_source}$$

$$\lambda_{by\_moving\_source} = \lambda_{by\_resting\_source} \mp v_{source} \bullet T_{by\_resting\_source}$$

$$v_{sound\_ground} = \lambda_{by\_resting\_source} \bullet f_{by\_resting\_source}$$

$$v_{sound\_observer} = \lambda_{observer} \bullet f_{observer}$$

A moving source



$$\lambda_{observer} = \lambda_{ground} = \lambda_{by\_moving\_source}$$

$$v_{sound\_ground} = \lambda_{by\_resting\_source} \bullet f_{by\_resting\_source}$$

$$v_{sound\_observer} = \lambda_{observer} \bullet f_{observer}$$

$$\lambda_{by\_moving\_source} = \lambda_{by\_resting\_source} \mp v_{source} \bullet T_{by\_resting\_source}$$

Do the Math

$$v_{sound\_observer} = v_{sound\_ground} = v \quad \Rightarrow$$

$$\frac{v}{f_{observer}} = \frac{v}{f_{by\_resting}} \mp \frac{v_{source}}{f_{by\_resting}} \quad \Rightarrow$$

$$f_{observer} = f_{by\_resting} \frac{1}{1 \mp \frac{v_{source}}{v}}$$

$$\frac{1}{1 \mp M} > 1$$

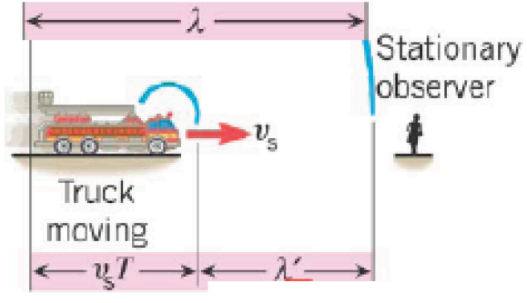
2. + 2. − 3. Both

source moving away from a stationary observer

$$f_o = f_s\left(\frac{1}{1+v_s/v}\right)$$

source moving toward a stationary observer

$$f_o = f_s\left(\frac{1}{1-v_s/v}\right)$$



Only the ratio v_o/v and the direction of relative motion are important!

The Sound of a Passing Train

A high-speed train is traveling at a speed of 44.7 m/s when the engineer sounds the 415-Hz warning horn. The speed of sound is 343 m/s. What are the frequency and wavelength of the sound, as perceived by a person standing at the crossing, when the train is (a) approaching and (b) leaving the crossing?

$$f_o = f_s\left(\frac{1}{1 - v_s/v}\right)$$

$$f_o = f_s\left(\frac{1}{1 + v_s/v}\right)$$

$$\lambda' = \frac{v}{f_o}$$

$\lambda = \frac{343}{415}$

approaching

$$f_o = (415\ \text{Hz})\left(\frac{1}{1-\frac{44.7\text{m/s}}{343\text{m/s}}}\right) = 477\ \text{Hz}$$

$$\lambda' = \frac{v}{f_o} = \frac{343}{477}\,m$$

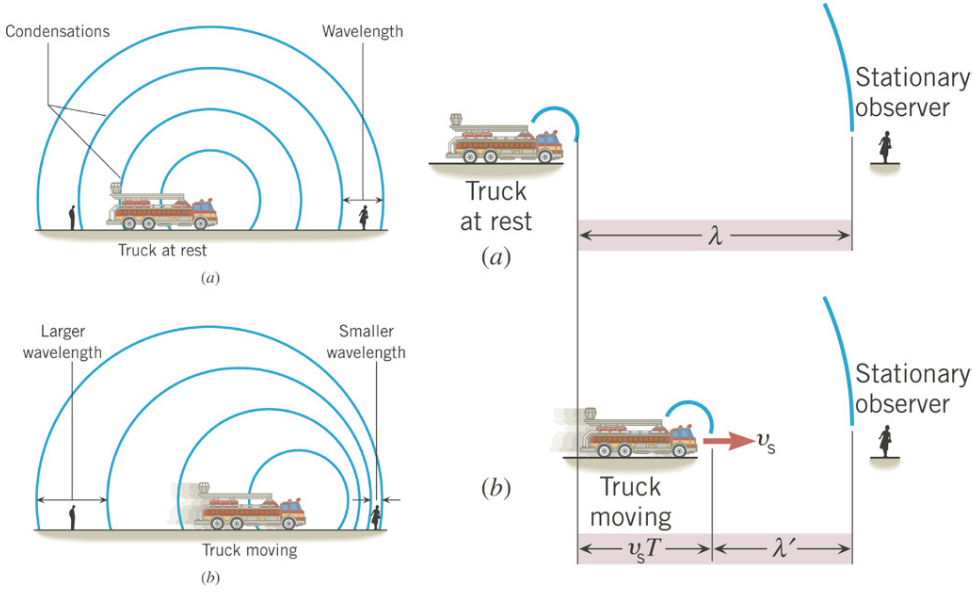
leaving

$$f_o = (415\ \text{Hz})\left(\frac{1}{1+\frac{44.7\text{m/s}}{343\text{m/s}}}\right) = 367\ \text{Hz}$$

$$\lambda' = \frac{v}{f_o} = \frac{343}{367}\,m$$

PROBLEM

$$f_0 = f_s \frac{1}{1 \pm \frac{v_s}{v}}$$



A stationary observer finds that the fire truck makes a sound of the wavelength of 0.5 m in the air when approaching at the speed of 10 m/s. What are the wavelength and the frequency for the stationary truck? The speed of the sound is 340 m/s.

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$$f_0 = f_s \frac{1}{1 \pm \frac{v_s}{v}}$$

$$f_0 = f_s \frac{1}{1 - \frac{10}{340}}$$

$$680 = f_s \cdot \frac{340}{330}$$

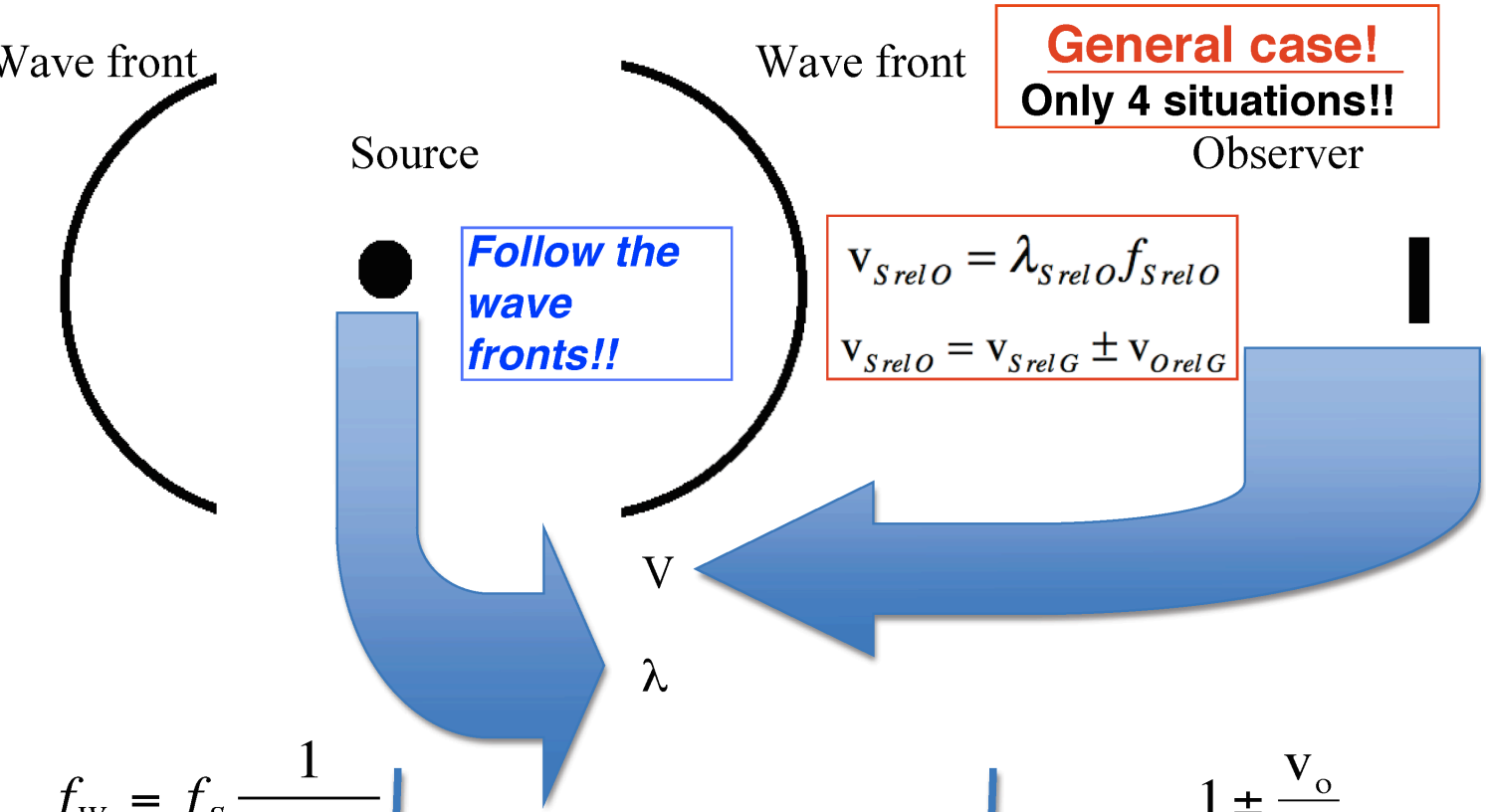
$$v = \lambda \cdot f$$

$$340 = 0{,}5 \cdot f_0 \quad \therefore f_0 = 680\,Hz$$

$$f_s = 660\,Hz \quad ; \quad 340 = \lambda^* \cdot 660$$

$$f_0^* = 660 \frac{1}{1 + \frac{10}{340}}$$

$$\lambda^* \cdot f_0^* = 340$$



General case!
Only 4 situations!!

$$f_W = f_S \frac{1}{1 \mp \frac{v_s}{v}}$$

$- v_S \uparrow\uparrow v$

$+ v_S \uparrow\downarrow v$

Resting observer.

$$f_O = f_S \frac{1 \pm \frac{v_o}{v}}{1 \mp \frac{v_s}{v}}$$

General case!

$$f_O = f_W \frac{1 \pm \frac{v_o}{v}}{1}$$

$+ v_O \uparrow\downarrow v$

$- v_O \uparrow\uparrow v$

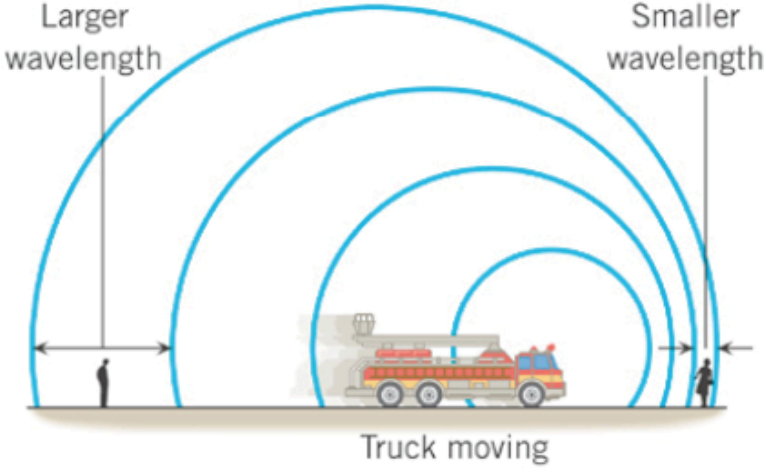
Resting source.

$$f_0 = f_s \frac{1 \pm \frac{v_0}{v}}{1 \mp \frac{v_s}{v}}$$

Only four *special* cases!

		Top sign	Bottom sign
→ Source	→ Observer		−
→ Observer	→ Source		+
← Source	→ Observer		+
→ Observer	← Source		−

$$f_o = f_s \frac{1 \pm \frac{v_o}{v}}{1 \mp \frac{v_s}{v}}$$



As you are riding your bicycle at 10.0 m/s north along a road, an ambulance traveling south approaches you. You observe the ambulance's siren to have a frequency of 322 Hz. However, the siren's frequency is actually 320 Hz, when the ambulance is at rest (relative to the resting observer). (a) How fast is the ambulance traveling? (b) After the ambulance has passed you, what frequency do you observe for the siren? (c) If you were at rest, what frequency would you register for the ambulance approaching/leaving you?

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$$f_o = f_s \frac{1 \pm \frac{v_o}{v}}{1 \mp \frac{v_s}{v}}$$

$v = 340 \text{ m/s}$ ⊙ $f_s = 320 \text{ Hz}$

$322 = 320 \dfrac{1 + \frac{10}{v}}{1 - \frac{v_s}{v}}$

$\uparrow v_o = 10 \text{ m/s}$ $f_o = 322 \text{ Hz}$

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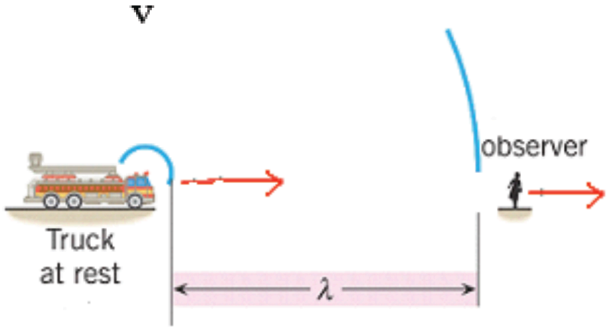

an observer running at 5 m/s away from the fire truck which is moving at 10 m/s towards the observer.

$$f_o = f_s \frac{1 \pm \frac{v_o}{v}}{1 \mp \frac{v_s}{v}}$$

The observer finds that the truck makes a sound of the wavelength of 0.5 m.

What are the wavelength and the frequency for the stationary truck? The speed of the sound is 340 m/s.

$V = f \cdot \lambda$

1340 ~~2.335~~ $335 = f_0 \cdot 0.5$

$f_0 = f_s \dfrac{1 - \frac{5}{340}}{1 - \frac{10}{340}}$