Doppler Effect

Physics 204: Martens Yaverbaum, Kitayama & Walters
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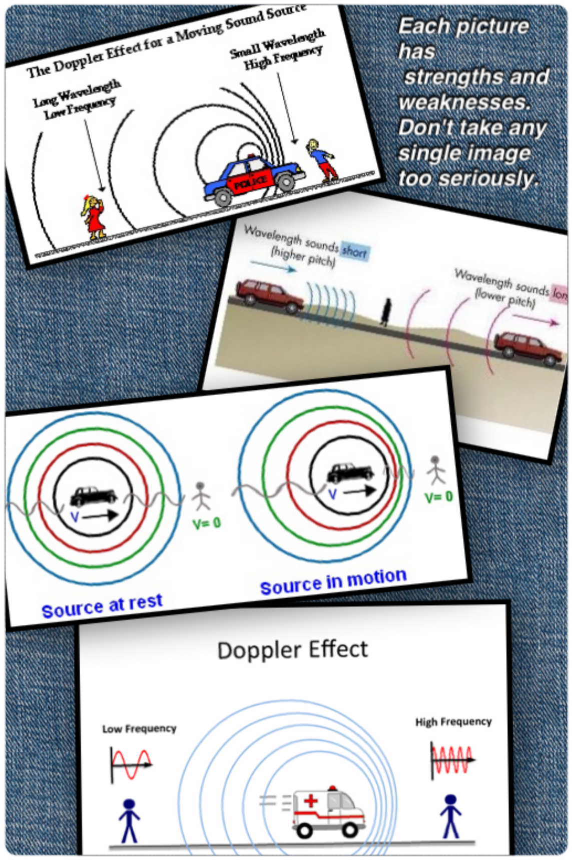

The facts: A car is traveling on a non-windy day. It blares a horn. The car driver hears and MEASURES a frequency of 500 Hz. ***The car moves away*** from you at 44 m/s relative to air. Assume that sound travels at 340 m/s relative to air.

a. According to the car's measurements, what is the wavelength of the horn sound?

b. You also make measurements. Your equipment happens to be technologically advanced to precisely the same extent as that of the car. According to your measurements, what is the wavelength of the horn sound?

c. **According to your perspective, then, w**hat FREQUENCY is observed (heard) and measured in your frame of reference?

d. **Whose reference frame – yours or the car's -- is actually finding the truly correct numbers and Doppler realities? Which reference frame is the flawed one – the one getting tricked into frequency numbers that aren't really the ones which were sent?**

Is this a trick question?!
Does something actually 'CHANGE' on the way from one object ('source') toward the other? Or does some circumstance for a receiver at the end of the trip change?

e. **Receiver Approaching.**

f. Find the frequency you would observe if instead ***you*** were moving away from the car while ***the car was stationary*** relative to air (all above magnitudes held constant)

g. **Source Approaching**
Find the frequency you would observe if instead ***the car were moving toward you*** while ***you remained stationary*** relative to air (all above magnitudes held constant).

SOLUTIONS ON FOLLOWING PAGES . . . !

DOPPLER

B.

Let anything that travels in the direction of the WAVE be designated POSITIVE $(+)$; *opposite direction is NEGATIVE* $(-)$.

$a.\ v = \lambda f$

$$\lambda = \frac{v}{f}$$

We want wavelength according to (relative to, in reference frame of) SOURCE.

$\lambda_s = \frac{v_{ws}}{f_s}$ *where* $v_{ws} \equiv$ *velocity of WAVE relative to SOURCE.*

Recall GPR #4:

$$v_{ws} = v_{wm} + v_{ms}$$

$$v_{ws} = 340\ m/s + 44\ m/s = 384\ m/s$$

$(\text{because } v_{sm} = -44 \text{ and } v_{ms} \equiv -v_{sm})$.

$$\lambda_s = \frac{v_{ws}}{f_s} = \frac{v_{wm} + v_{ms}}{f_s}$$

$$\lambda_s = \frac{384\ m/s}{500\ Hz}$$

$\boxed{\lambda_s \approx .768 \text{ meters.}}$

b. Necessarily and always:

$$\lambda_r = \lambda_s$$

(One crest cannot catch up to nor recede from the next crest while traveling; WAVELENGTH is therefore the one quantity which for which both SOURCE and RECEIVER must measure to be THE SAME. So....

$\boxed{\lambda_r \approx .768 \text{ meters.}}$

c.

$$f_r = \frac{v_{wr}}{\lambda_r} = \frac{v_{wm} + \cancel{v_{mr}}^{\to 0}}{\lambda_r}$$

$$f_r = \frac{340\ m/s}{.768\ m}$$

$\boxed{f_r = 443\ Hz}$

d.

Both reference frames are correct. The laws of physics hold in all uniform reference frames!

Nothing changes on the way from source to receiver:

Two different reference reference frames simply measure two different CONSTANT frequencies.

e. Receiver Approaching

$f.$

$$v = \lambda f$$

$$\lambda = \frac{v}{f}$$

We want wavelength according to (relative to, in reference frame of) SOURCE.

$$\lambda_s = \frac{v_{ws}}{f_s} \text{ where } v_{ws} \equiv \text{velocity of WAVE relative to SOURCE.}$$

Recall GPR #4:

$$v_{ws} = v_{wm} + \cancel{v_{ms}}^{\to 0}$$

$$v_{ws} = 340\ m/s + 0 = 340\ m/s$$

$$\lambda_s = \frac{v_{ws}}{f_s} = \frac{v_{wm} + \cancel{v_{ms}}^{\to 0}}{f_s}$$

$$\lambda_s = \frac{340\ m/s}{500\ Hz}$$

$$\lambda_s = .68\ m$$

. . . -- > . . . (cont'd)

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$$\lambda_r = \lambda_s$$

(One crest cannot catch up to nor recede from the next crest while traveling; WAVELENGTH is therefore the one quantity which for which both SOURCE and RECEIVER must measure to be THE SAME. So....

$$\lambda_s = .68\ m$$

$$f_r = \frac{v_{wr}}{\lambda_r} = \frac{v_{wm} + v_{mr}}{\lambda_r}$$

$$f_r = \frac{340\ m/s - 44\ m/s}{.68\ m}$$

$$\boxed{f_r = 435\ Hz}$$

g.

$$\lambda_s = \frac{v_{ws}}{f_s} = \frac{v_{wm} + v_{ms}}{f_s}$$

$$\lambda_s = \frac{296\ m/s}{500\ Hz}$$

$$\lambda_s = \frac{v_{ws}}{f_s} = \frac{v_{wm} + v_{ms}}{f_s}$$

$$\lambda_s = \frac{296\ m/s}{500\ Hz}$$

$$\lambda_s = .592\ m$$

$$f_r = \frac{340\ m/s}{.592\ m}$$

$$\boxed{f_r = 574\ Hz}$$

f.

$v = \lambda f$

$\lambda = \frac{v}{f}$

We want wavelength according to (relative to,
in reference frame of) SOURCE.

$\lambda_s = \frac{v_{ws}}{f_s}$ *where* $v_{ws} \equiv$ *velocity of WAVE relative to SOURCE.*

Recall GPR #4:

$v_{ws} = v_{wm} + \cancel{v_{ms}}^{\to 0}$

$v_{ws} = 340\ m/s + 0 = 340\ m/s$

$\lambda_s = \frac{v_{ws}}{f_s} = \frac{v_{wm} + \cancel{v_{ms}}^{\to 0}}{f_s}$

$\lambda_s = \frac{340\ m/s}{500\ Hz}$

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$f_r = \frac{340\ m/s - 44\ m/s}{.68\ m}$

$\boxed{f_r = 435\ Hz}$

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$\lambda_s = \frac{v_{ws}}{f_s} = \frac{v_{wm} + v_{ms}}{f_s}$

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$f_r = \frac{340\ m/s}{.592\ m}$

$\boxed{f_r = 574\ Hz}$