Doppler Effect: Example Problem

The siren of a police car emits a pure tone at a frequency of 1125 Hz.

Find the frequency that you would perceive under the following circumstances:

(a) Your car is at rest, the police car moves toward you at 29 m/s

Known: $f = 1125\ Hz$; $v_{source} = 29\ \frac{m}{s}$; $v = v_{sound} = 340\ \frac{m}{s}$

unknown: f' = perceived frequency by stationary observer

Equation: $f' = f\ \frac{v \pm v_o}{v \mp v_s}$

car (observer) at rest $\Rightarrow$ $v_o = 0\ \frac{m}{s}$

source moves toward observer $\Rightarrow$ upper sign (-) in denominator

$$f' = f\ \frac{v}{v - v_s} = 1125\ Hz\ \frac{340\ m/s}{340\ m/s - 29\ m/s}$$

$$= 1229.9\ Hz$$

Cross check: Do you expect a higher frequency in this case?

(b) the police car is at rest, your car moves toward it at 29 m/s

Known: $f = 1125\ Hz$; $v_{observer} = 29\ \frac{m}{s}$; $v = v_{sound} = 340\ \frac{m}{s}$

$v_{source} = 0\ \frac{m}{s}$

unknown: f' = perceived frequency by stationary observer

Equation: $f' = f\ \frac{v \pm v_o}{v \mp v_s}$

observer moves towards source ⇒ upper sign (+) in numerator

$$f' = f\ \frac{v + v_o}{v} = 1125\ Hz\ \frac{340\ \frac{m}{s} + 29\ \frac{m}{s}}{340\ \frac{m}{s}}$$

$$= 1220.96\ Hz$$

Cross check: Do you expect a higher frequency in this case?

(c) You and the police car are moving toward each other at 14.5 m/s.

Known: $f = 1125\,Hz$; $v_{source} = v_s = 14.5\,\frac{m}{s}$ $\quad v = v_{sound}$

$v_{observer} = v_o = 14.5\,\frac{m}{s}$ $\quad = 340\,\frac{m}{s}$

unknown: f' ≡ perceived frequency by stationary observer

Equation: $f' = f\,\frac{v \pm v_o}{v \mp v_s}$

You and the police car are moving toward each other ⇒ choose the upper sign in numerator and denominator:

$$f' = f\,\frac{v + v_o}{v - v_s} = 1125\,Hz\,\frac{340\,\frac{m}{s} + 14.5\,\frac{m}{s}}{340\,\frac{m}{s} - 14.5\,\frac{m}{s}}$$

$$= 1225.23\,\frac{m}{s}$$

Cross check: Do you expect a higher frequency in this case?

(d) You are moving at 9 m/s.
The police car is chasing behind you at 38 m/s.

Known: $f = 1125\ Hz$; $v_{source} = v_s = 38\ \frac{m}{s}$ $\quad v = v_{sound}$

$v_{observer} = v_o = 9\ \frac{m}{s}$ $\quad = 340\ \frac{m}{s}$

unknown: $f' \equiv$ perceived frequency by stationary observer

Equation: $f' = f\ \frac{v \pm v_o}{v \mp v_s}$

you are moving away from the police car $\Rightarrow$
choose the lower (-) sign in numerator.

the police car is moving toward you $\Rightarrow$
choose the upper (-) sign in denominator.

$$f' = f\ \frac{v - v_o}{v - v_s} = 1125\ Hz\ \frac{340\ \frac{m}{s} - 9\ \frac{m}{s}}{340\ \frac{m}{s} - 38\ \frac{m}{s}}$$

$$= 1233.03\ Hz$$

Cross check: Do you expect a higher frequency in this case?