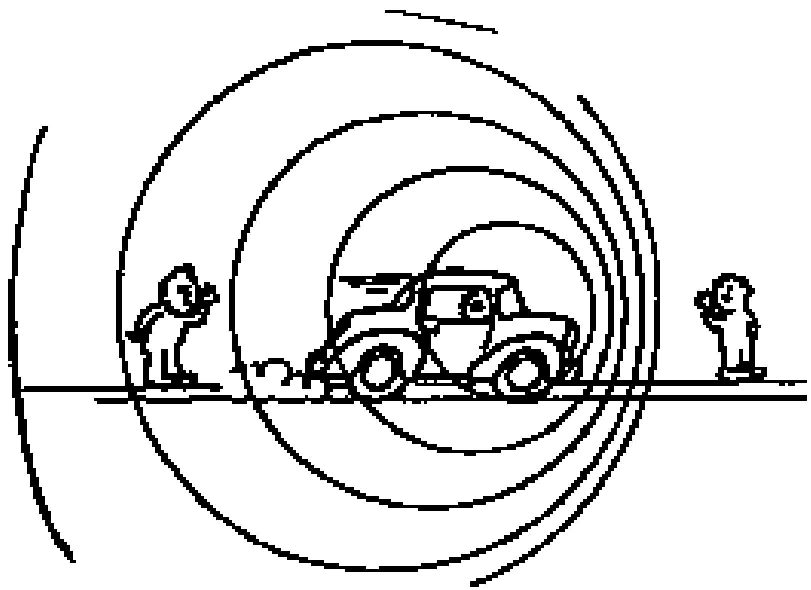
# Doppler Effect



# What is the Doppler Effect?

- Change in observed frequency or wavelength when the source of the waves and the observer are in motion relative to each other
- Occurs for *all* types of waves

http://www.youtube.com/watch?v=Tn35SB1_NYI

# From the Car

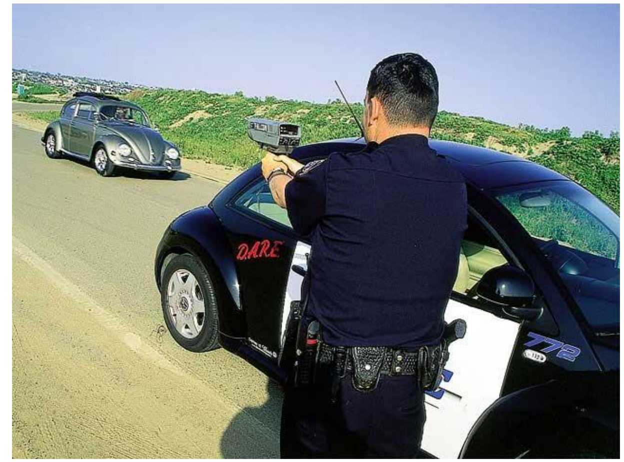
# Car Drives by

# Our Observations

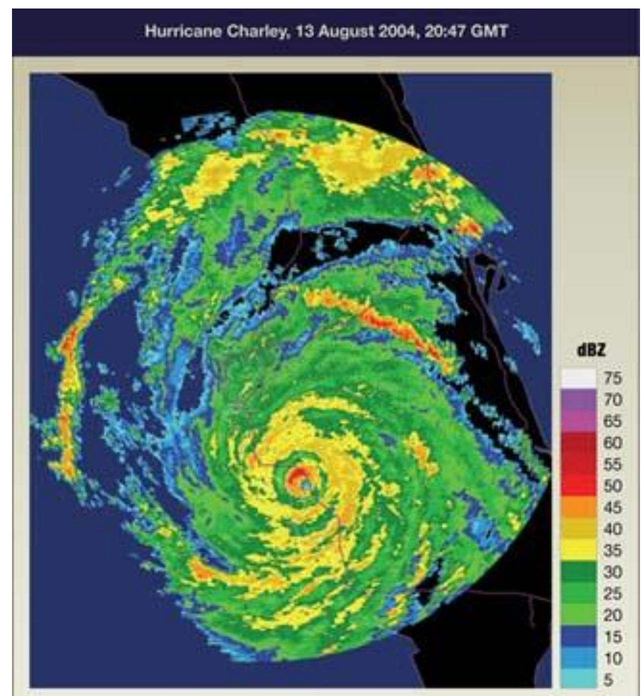
- When a source is moving toward a stationary observer, the apparent frequency is higher than emitted frequency and lower when the source is moving away
- When the source is stationary and the observer moves toward it, the apparent frequency is higher than emitted and lower when the observer moves away

# Uses of the Doppler Effect

- Police speed guns



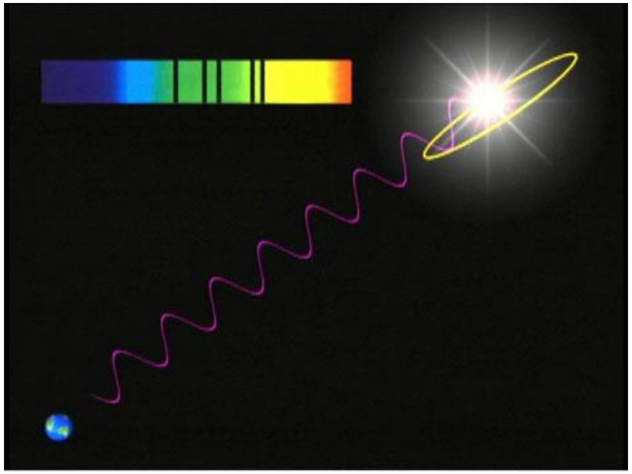

- Doppler weather radar for tracking storms



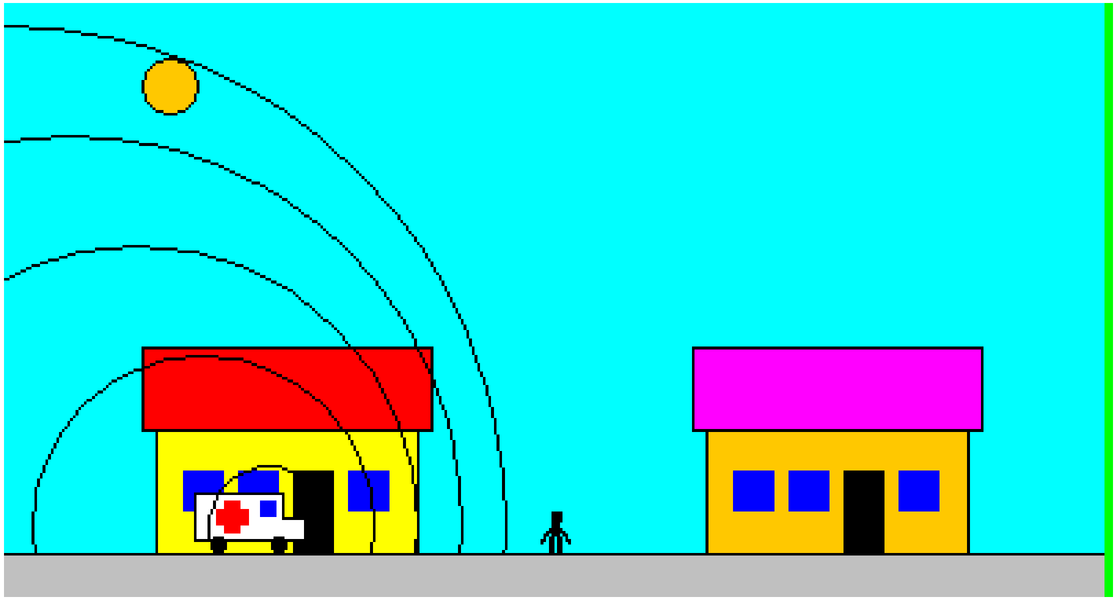
# Uses of Doppler Effect (cont.)

- Measure blood flow

- Determine velocities of distant stars and galaxies

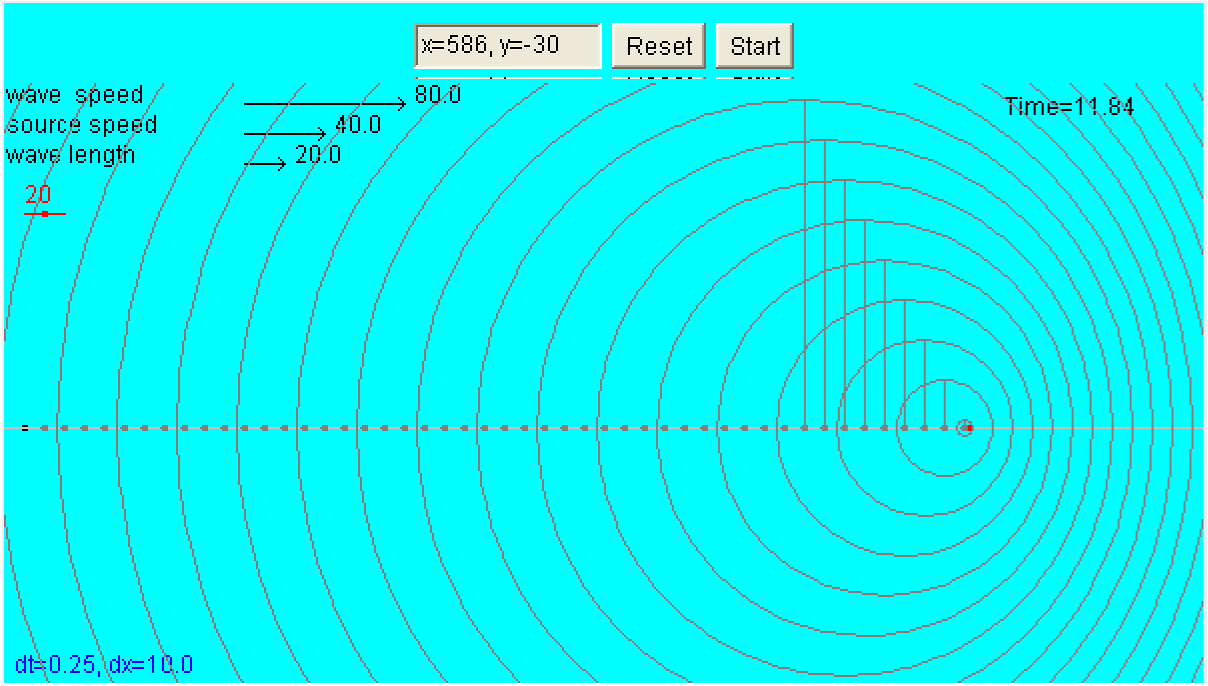


# Doppler Animation



http://www.walter-fendt.de/ph14e/dopplereff.htm

# Doppler Effect Applets



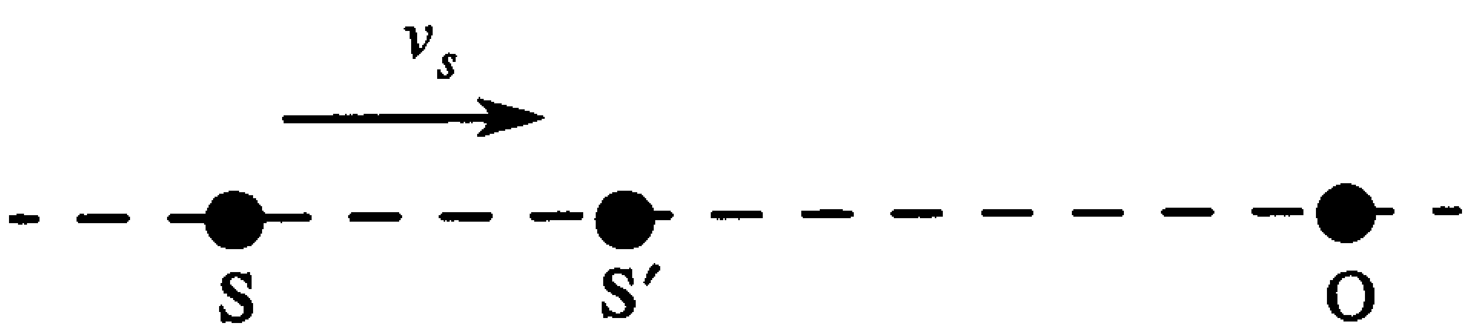

- http://www.phy.ntnu.edu.tw/ntnujava/index.php?topic=21.0
- http://www.lon-capa.org/~mmp/applist/doppler/d.htm

# Some youtube movies

- http://www.youtube.com/watch?v=RsiY8VdDIDQ&feature=related
- http://www.youtube.com/watch?v=Kg9F5pN5tlI&feature=related

# Deriving the formulas

- Simplest case: source velocity in line with observer
- In the diagram the observer o is at rest with respect to the medium and the source is moving with speed $v_s$.



- Source emits note of constant frequency f that travels with speed v in the medium: this wave velocity does not change.
- S' shows the position of the source $\Delta t$ later.
- In a time $\Delta t$ the observer would receive $f\Delta t$ waves and when the source is at rest these waves will occupy a distance $v\Delta t$ .

- The wavelength = distance occupied by the waves ÷ the number of waves
- The wavelength = $v\Delta t$ / $f\Delta t$ = $v/f$
- Because of the motion of the source this number of waves will now occupy a distance $v\Delta t - v_s\Delta t$
- The “new”wavelength = $(v\Delta t - v_s\Delta t) / f\Delta t$
- i.e. $\lambda' = (v - v_s) / f$

- If $f'$ is the new frequency, then
- $\lambda' = v/ f' = (v- v_s) / f$
- Rearranging
- $f' = v / (v- v_s) * f$
- Dividing throughout by v gives
- $$f' = \frac{1}{1- (v_s / v)} f$$

- If source moves away from observer then the expression becomes

$$f' = \frac{1}{1 + (v_s / v)} f$$

# For a moving observer

- Observer moving towards source
- Relative velocity = $v + v_O$
- $f' = (v + v_O)/ \lambda$
- But $\lambda = v/f$
- Therefore $f' = (v + v_O)/ v/f$
- Rearranging gives
- $f' = ((v + v_O)/ v )f$

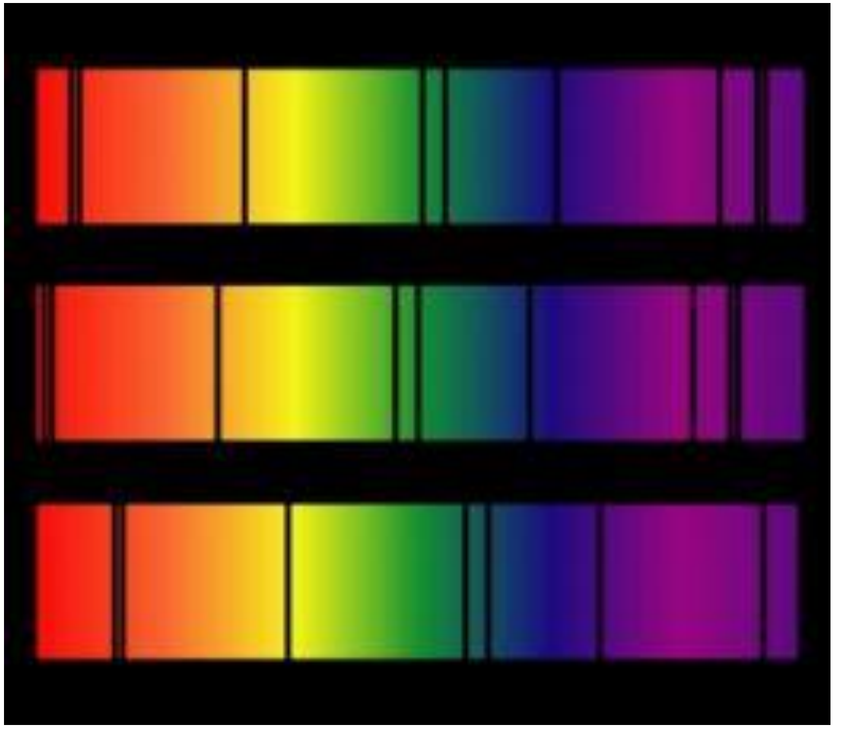
- If the observer is moving towards the source
- $f' = (1 + (v_o / v))\, f$

- If the observer is moving away from the source
- $f' = (1 - (v_o / v))\, f$

# Doppler Effect for Light

- Upper absorption band: no relative velocity
- Middle: red shift – source moving away from viewer
- Lower: blue shift – source moving toward observer
- Equation (v << c):

$$\Delta f = f_s(v/c) \quad \text{-or-} \quad \Delta\lambda = \lambda_s(v/c)$$



http://www.physorg.com/news200044818.html

# Example Problem #1

- A car is moving at a speed of 34 $ms^{-1}$ towards a stationary source of sound emitting a note of frequency 5.0 kHz. What frequency is observed by the people in the car? Use $v = 340\ ms^{-1}$.

- Answer: 5500 Hz

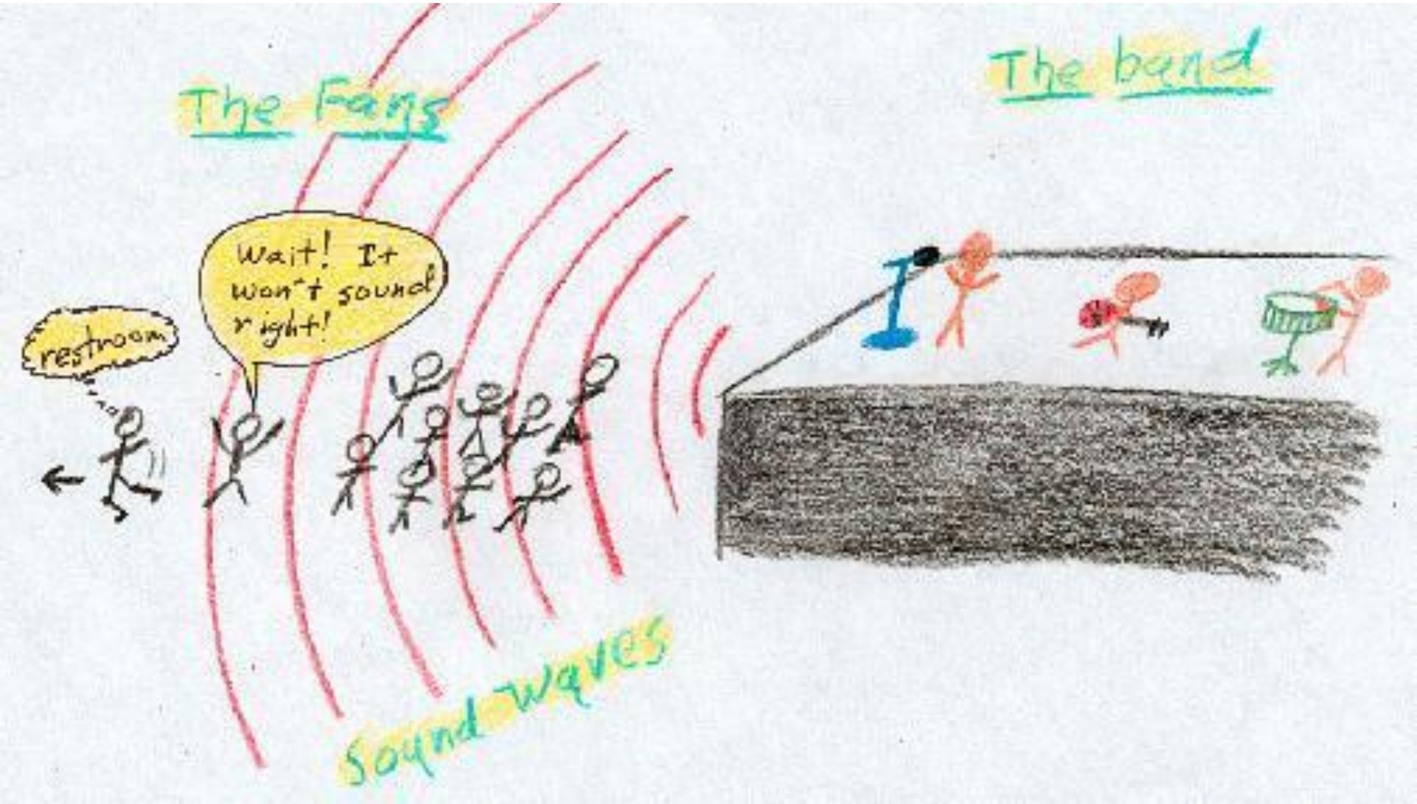
# Example Problem #2

- A star is moving away from the earth at a speed of $3.0 \times 10^5$ $ms^{-1}$. If the light emitted from the star has $f = 6.0 \times 10^{14}$ Hz, find the frequency shift observed on earth.

- Answer: $\Delta f = 6.0 \times 10^{11}$ Hz; earth observer would detect $f = 6.0 \times 10^{14} – 6.0 \times 10^{11} = 5.994 \times 10^{14}$ Hz (red shift)

# More Links

- http://www.school-for-champions.com/SCIENCE/sound_doppler_equations.htm
- http://www.colorado.edu/physics/2000/applets/doppler.html


The Fans
The band
restroom
Wait! It won't sound right!
Sound waves