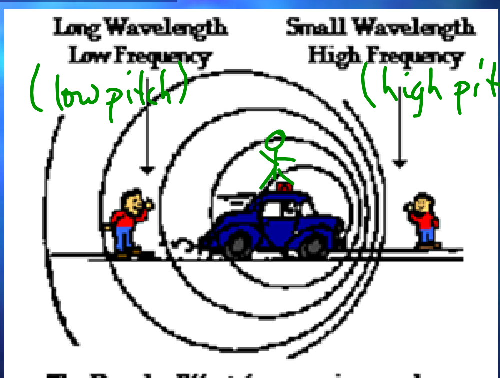
## THE DOPPLER EFFECT

- The motion of the source of a sound wave or the observer can affect the frequency of the sound perceived by the observer.
- The frequency of sound is higher when the source is moving toward the observer and lower when the source is moving away from the observer. or the observer is moving away from the sound (the gap is getting wider)
- The Doppler Shift occurs in all waves.

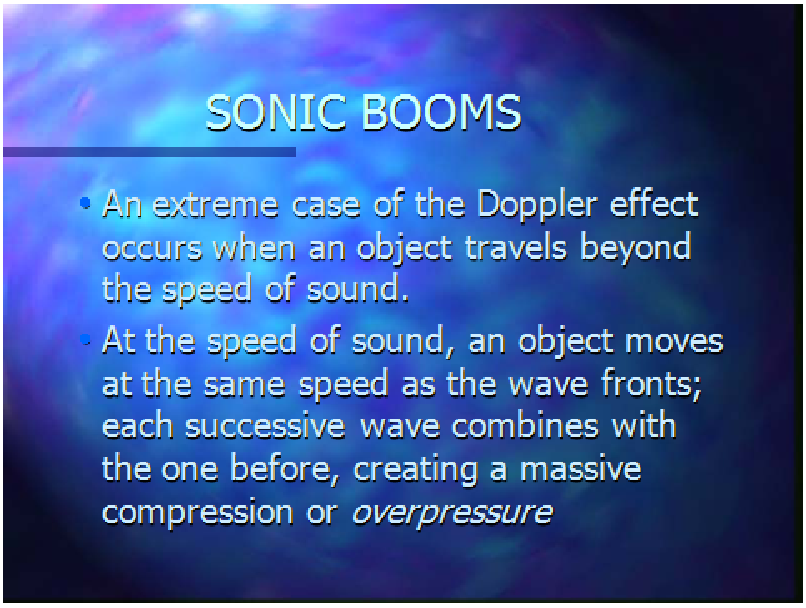
or the observer is moving towards the sound: (the gap between is getting smaller)

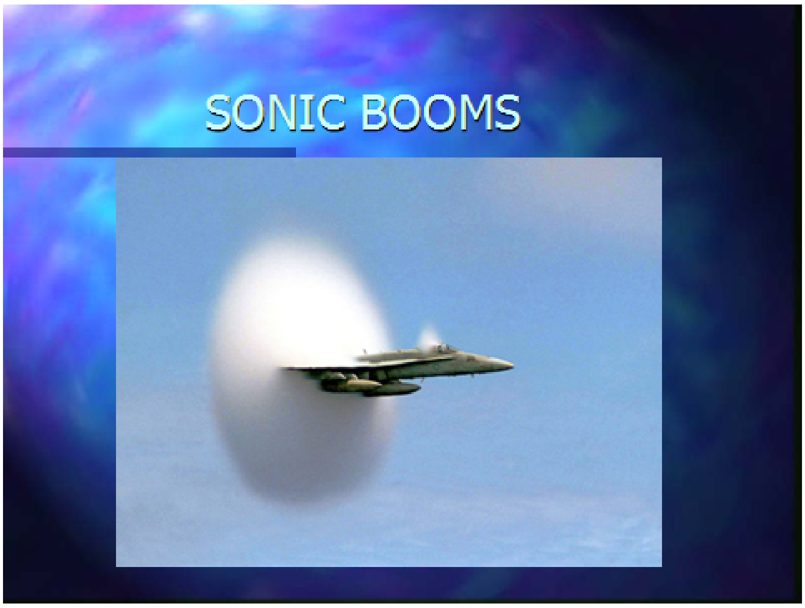
## THE DOPPLER EFFECT

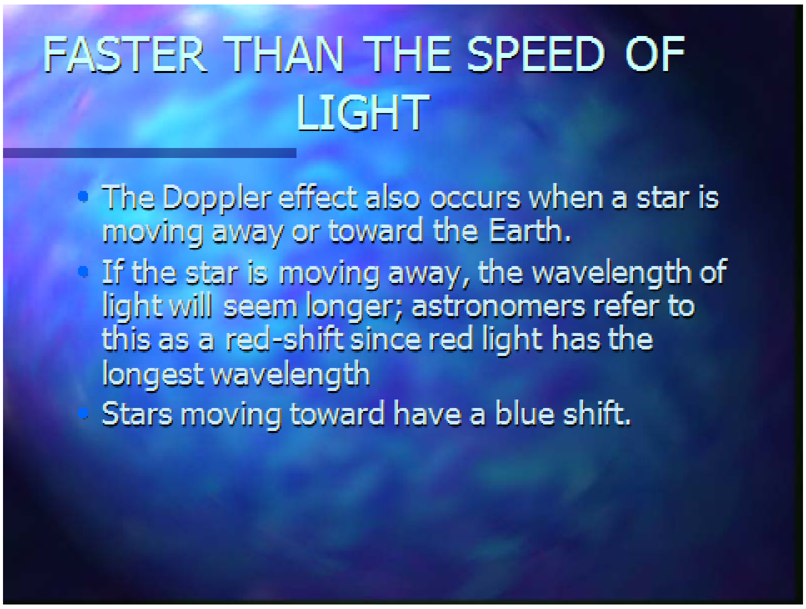


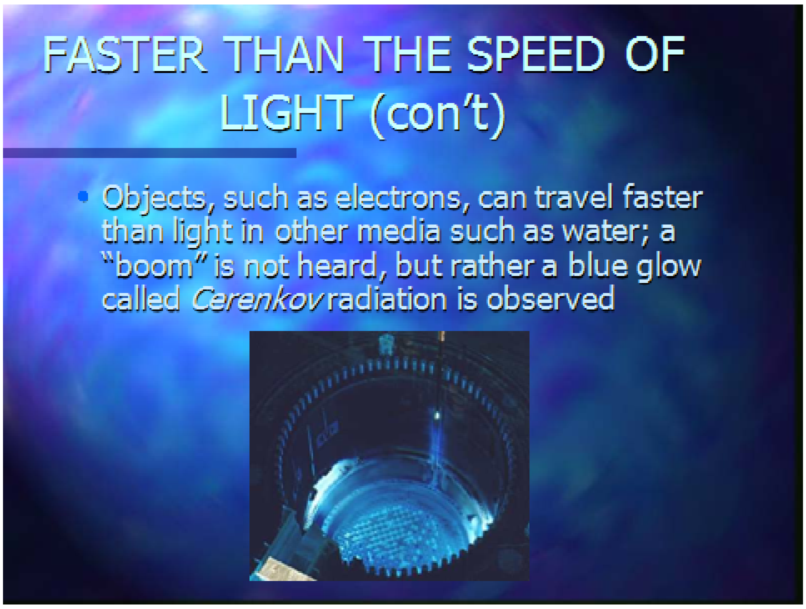

The Doppler Effect for a moving sound source

The Doppler Effect will be more pronounced when the source is moving faster.


SONIC BOOMS
• An extreme case of the Doppler effect occurs when an object travels beyond the speed of sound.
• At the speed of sound, an object moves at the same speed as the wave fronts; each successive wave combines with the one before, creating a massive compression or *overpressure*


SONIC BOOMS


FASTER THAN THE SPEED OF LIGHT
The Doppler effect also occurs when a star is moving away or toward the Earth.
If the star is moving away, the wavelength of light will seem longer; astronomers refer to this as a red-shift since red light has the longest wavelength
Stars moving toward have a blue shift.


FASTER THAN THE SPEED OF LIGHT (con't)
Objects, such as electrons, can travel faster than light in other media such as water; a "boom" is not heard, but rather a blue glow called *Cerenkov* radiation is observed

## Calculating the perceived frequency due to the Doppler Effect:

for a sound source moving toward a stationary observer

$$f' = f\left(\frac{v}{v - u_s}\right) \qquad v = 331 + 0.59T$$

where $f'$ is the perceived frequency (Hz)

$f$ is the actual frequency of the source (Hz)

$v$ is the speed of sound (m/s)

$u_s$ is the speed of the source (m/s)

If the source is moving away from the stationary observer

$$f' = f\left(\frac{v}{v + u_s}\right)$$

Note: $$f' = f\left(\frac{v}{v \pm u_s}\right)$$ ← for a moving source (− if coming towards, + if going away)

For a moving observer (i.e. stationary source)

$$f' = f\left(\frac{v \pm u_o}{v}\right)$$

observer goes towards the source (+)

observer goes away from the source (−)

Example

Car travels at $30\,ms^{-1}$ and emits a sound of frequency of 500Hz. What is the frequency perceived by a stationary observer?

$V = 330\,ms^{-1}$

$$f' = f\left(\frac{V}{V \pm u_s}\right)$$

↳ use the − for a higher frequency (ie. coming toward)

$$f' = 500Hz\left(\frac{330\,ms^{-1}}{330\,ms^{-1} - 30\,ms^{-1}}\right)$$

$$f' = 500Hz\left(\frac{330\,ms^{-1}}{300\,ms^{-1}}\right)$$

$$f' = 550Hz$$

Example

A stationary observer hears a frequency of 560Hz from an approaching car. After the car passes, the observed frequency is 460Hz. What is the speed of the car? $V = 343\,m/s$

toward

$$f' = f\left(\frac{V}{V - u_s}\right)$$

$$560Hz = f\left(\frac{343}{343 - u_s}\right)$$

$$f = 560Hz\left(\frac{343 - u_s}{343}\right)$$

away

$$f' = f\left(\frac{V}{V + u_s}\right)$$

$$460Hz = f\left(\frac{343}{343 + u_s}\right)$$

$$f = 460Hz\left(\frac{343 + u_s}{343}\right)$$

$$560Hz\left(\frac{343 - u_s}{343}\right) = 460Hz\left(\frac{343 + u_s}{343}\right)$$

$$\frac{560Hz}{460Hz} = \left(\frac{343 + u_s}{343}\right)\left(\frac{343}{343 - u_s}\right)$$

$$\frac{560}{460} = \frac{343 + u_s}{343 - u_s}$$

$$560(343 - u_s) = 460(343 + u_s)$$

$$192080 - 560u_s = 157780 + 460u_s$$

$$34300 = 1020u_s$$

$$u_s = \frac{34300}{1020}$$

$$u_s = 33.6\,ms^{-1}$$

$$f' = f\left(\frac{V}{V - u_s}\right)$$

$$560Hz = f\left(\frac{343}{343 - 33.6}\right)$$

$$560Hz = f(1.10)$$

$$f = 505\,Hz$$