Phys 1402 2017-07-26 Lec 14

# From Oscillations to Waves

Review oscillations $x = x_{max} \sin(2\pi f t)$

$x_{max} = X_0$ = amplitude
$f$ = frequency
Also $T$ = period $T = 1/f$ $f = 1/T$

Waves are formed by many oscillators that are coupled (connected)

The speed of a wave is how fast the energy or disturbance travels.

Examples:

String Wave $v = \sqrt{F_T/\mu}$ ← mass per $l$

Sound $v \approx 334$ m/s

Radio, Light $v = c = 3 \times 10^8$ m/s

Water $v$ = variable, depends on $\lambda$, depth

Repetition in time leads to repetition in space.

The wavelength ($\lambda$) is the repeat distance.

$$v = \frac{\text{Dist of one cycle}}{\text{Time of one cycle}} = \frac{\lambda}{T}$$

$$v = f\lambda$$

Ex: Sound wave $\quad v = 340 \text{ m/s}$
$\quad f = 680 \text{ Hz}$

$$\lambda = \frac{v}{f} = \frac{340}{680} = 0.5 \text{ m}$$

Generally for sound $f = 20 \text{ Hz} \ldots 20000 \text{ Hz}$

## Electromagnetic Waves

Radio
Microwaves
Infrared (IR)
Visible Light
Ultraviolet (UV)
X-rays
Gamma Rays

$f = 400$ THz Red
⋮
$f = 750$ THz Violet

v of light ↘

$$\lambda_{red} = \frac{c}{f_{red}} = \frac{3\times10^8 \text{ m/s}}{400\times10^{12} \text{ Hz}} = 7.5\times10^{-7} \text{ m} = 750 \text{ nm}$$

Light ranges from 400 to 750 THz

or from 400 to 750 nm

Generally, when oscillations of one kind stimulate different oscillations, the frequency is copied to the new oscillations or waves.

<u>Exception</u>: Doppler Shift

- A shift in frequency between a source and observer, caused by relative motion.

$$\frac{\Delta f}{f_s} = \frac{v_{rel}}{v_{wave}}$$

$\Delta f$ = freq. shift
$f_s$ = source freq
$v_{wave}$ = wave speed
$v_{rel}$ = relative velocity,
⊕ = toward
⊖ = away.

$$f_o = f_s + \Delta f$$

Ex: Sound Source is 4705 Hz
Observed freq is 4897 Hz } 192 Hz
What is the relative speed?

$\Delta f$ = 192 Hz

$$\frac{192\ \text{Hz}}{4705\ \text{Hz}} = \frac{v_{rel}}{340\ \text{m/s}}$$

$v_{rel}$ = 13.9 m/s
= 31 MPH

④

Doppler Radar involves <u>two</u> doppler shifts. So...

$$\frac{\Delta f}{f} = \frac{2\,V_{rel}}{V_{wave}}$$

Ex: Police radar @ 5 GHz

Car driving ~~away~~ toward @ 30 m/s = 65 MPH

$$\frac{\Delta f}{5\times10^9\ \text{Hz}} = 2\,\frac{30\ \text{m/s}}{3\times10^8\ \text{m/s}}$$

$$\Delta f = 1000\ \text{Hz}$$

Received freq is 5000001000 Hz

# Energy, Intensity, and Decibels

Continuous flow of energy usually described as power = rate of energy flow.

$$P = \frac{\text{Energy}}{\Delta t}$$

Often, a wave spreads out but has an even spread. This changes the Intensity. It is directly related to <u>loudness</u> or <u>brightness</u>.

$$I = \frac{P}{A}$$

P = power going thru surface
A = area of surface

Ex: Solar Flux at surface ~ 1 kW/m²

Ex: Point Source - power of source spreads out in spherical "shells".

$$I = \frac{P}{4\pi R^2}$$

Solar Flux in space ~ 1368 W/m²

$$P_{sun} = (1368\ W/m^2)\,4\pi\,(150\times10^9\ m)^2$$
$$= 3.9\times10^{26}\ W$$

US Elec Demand $786\times10^9$ W

Cell Phone Signal -113 dBm

$P = 5 \times 10^{-15}$ W (milli)

LED Light

P = 1 W (of light)

Decibels – Relative units of energy, power, or intensity.

- Huge range of values
- Dynamic Range – loud vs. Quiet
- Attenuation is "by a factor of ___"
- Turns mult & div into ⊕ and ⊖.

How? Decibels are exponents.

-113 dB means $10^{-11.3} = 5 \times 10^{-12}$

$(x^2)(x^3) = (x \cdot x)(x \cdot x \cdot x) = x^5$

Multiply values = Add exponents

Rules to remember for decibels:

- Add or Subtract dB values
- dB value corresponds to a <u>factor</u>. (aka ratio)

$$\text{Ratio} = 10^{\beta/10}$$

$\beta$ = "level" measured in dB.

Ex: Moving 5 times further from a point source does what to the dB level?

$I \propto \frac{1}{R^2}$

I decreases by 25 times.

$$\text{Ratio} = 10^{\beta/10}$$

$$\log(\text{Ratio}) = \beta/10$$

$$\log(25) \approx 1.4 = \beta/10$$

$$14 = \beta$$

This is a 14 dB decrease.