# **Wave Motion**

Types of Waves:

* Electromagnetic Waves
  + (Not covered in this class... example is light)
* Mechanical Waves
  + Transverse waves
    - disturbance moves **perpendicular** to wave propagation
    - cannot travel through fluids (no restoring force)
    - up/down (e.g. ocean waves)
  + Longitudinal waves
    - disturbance moves **parallel** to wave propagation
    - compression (e.g. sound waves)

Waves:

* waves are disturbances that travel through space *and time*
* move through a medium (oscillations don’t move)
* oscillate *as they move*
* are started by vibrations/oscillations
* only transport energy; do not transport the medium
* are sinusoidal
* have a **wavelength** in space,
  + distance along axis from crest to trough; like period, but through space
* have a **wave velocity** ()
  + Note: velocity *only* depends on the medium; this equation is only a relation
  + Look at velocity has change in distance over change in time...
* have an equation where ( is called the **wave number**)
  + phase is where the wave starts (i.e. the phase of cos vs sin is , so sin and cos are interchangeable. The phase is

Conditions for waves:

1. Wave medium must be **elastic** (can store energy and has a restoring force)
   1. i.e. there must be a restoring/tension force:
2. There must be an initial disturbance
3. There must be **inertia**/mass that can store energy
   1. linear mass density:

Wave velocity:

* General form:
* For a transverse wave:

Energy in Waves:

* The maximum potential energy is where is the wave “height” (similar to amplitude)
  + so the actual
  + So the energy is **proportional to the amplitude and frequency squared!**
  + Energy shifts between kinetic and potential at every point on the string
* and
* **Every** point on the wave has energy (even kinetic)

Wave Reflection:

* Waves always reflect back when they come to an end (unless they are absorbed)
* The reflection is *inversed* (phase shift of ) when the end is attached to a solid wall (the wall pushes down as the wave tries to move it up)
* The reflection is *the same* when the end is attached to something flexible/moving

Superposition Principle:

* Waves cancel/add with each other
* the resultant amplitude is the sum of the heights
* When a wave going along one string encounters a bigger string, it will:
  + send a smaller-amplitude wave backwards (with no phase shift)
  + send a smaller-amplitude wave forwards through the bigger string
  + reflect off the wall (where the big string is attached) and send a wave backwards *with* a phase shift
* Remember: and the wavelength () will be smaller in a thicker string

Standing Waves:

* If a string has boundaries, only certain wavelengths can form in it
* This is called a “standing wave”
* Appropriate wavelengths are:
  + where is the string length
  + and
  + i.e. the smallest part of a wave that can exist is *half* of a wavelength
* , where is the original magnitude of each wave. This equation models the total displacement of a two, same-height standing waves
* Boundary Conditions:
  + at the end of a standing wave, the amplitude is zero
  + This is only the case when . This leads to the quantized wavelengths (above, )
  + for , “First Harmonic. for , “Second Harmonic”, etc.
* Nodes:
  + there are nodes in a standing wave. There is *no* energy at the nodes
* Every complex wave is made of simple sines and cosines

Real Waves:

* Most real waves are not 1D. They can
  + be 2D like ocean waves,
  + or emit from a point source, like dropping a rock in water
* The **velocity is still only determined by the material**,
* but the frequency and wavelength are determined by the oscillator
* **Defraction:** if a 2D waves encounters a wall with an opening, it will change into a radial wave with the same frequency, velocity, and wavelength
* **Interference Patterns:** Waves will make a pattern (two crests make it high, two troughs make it low. a crest and a trough make a node)
* **Refraction:** When ocean waves move onto shallow land, the *velocity* changes and so does the angle!
  + where is the speed of the wave
  + the wavelength decreases because the speed decreases, but the frequency stays the same
  + think of marching soldiers slowing down at a line