Springs obey Hooke’s Law

- the strength of a spring is measured by how much force it provides for a given amount of stretch
- we call this quantity $k$, the spring constant in N/m
- magnitude of spring force $= k \times \text{amount of stretch}$

Some terminology

- the maximum displacement of an object from equilibrium is called the AMPLITUDE $A$
- the time that it takes to complete one full cycle ($A \rightarrow B \rightarrow C \rightarrow B \rightarrow A$) is called the PERIOD $T$ of the motion
- if we count the number of full cycles the oscillator completes in a given time, that is called the FREQUENCY $f$ of the oscillator
- frequency $f = 1 / \text{period} = 1 / T$

follow the mass – position vs. time

http://www.phys.hawaii.edu/~teb/java/ntnujava/shm/shm.html
→ Period of the mass-spring system

\[ T = 2\pi \sqrt{\frac{m}{k}} \]

• This formula is good for a mass on a hanging spring or for a horizontal spring on the air track
• If the mass is quadrupled, the period is doubled

→ Period of a pendulum of length L

\[ T = 2\pi \sqrt{\frac{L}{g}} \]

Energy in the simple harmonic oscillator

• a compressed or stretched spring has elastic potential energy
• this elastic potential energy is what drives the system
• if you pull the mass from equilibrium and let go, this elastic PE changes into kinetic energy.
• when the mass passes the equilibrium point, the KE goes back into PE
• if there is no friction the energy keeps sloshing back and forth but it never decreases

Simple harmonic oscillator

• the period of oscillation is longer (takes more time to complete a cycle) if a bigger mass (m) is used
• the period gets smaller (takes less time to complete a cycle) if a stronger spring (larger k) is used
• Period \( T = 2\pi \sqrt{\frac{m}{k}} \) in seconds
• the time to complete a full cycle does not depend on where the oscillator is started (period is independent of amplitude)

Resonance effects

• all systems have certain natural vibration tendencies
• the mass/spring system oscillates at a certain frequency determined by its mass, m and the spring stiffness constant, k
• When you push a child on a swing you are using resonance to make the child go higher and higher.

How resonance works

• resonance is a way of pumping energy into a system to make it vibrate
• in order to make it work the energy must be pumped in at a rate (frequency) that matches one of the natural frequencies that the system likes to vibrate at.
• you pump energy into the child on the swing by pushing once per cycle
• The Tacoma Narrows bridge was set into resonance by the wind blowing over it

Resonance examples

• mass on spring
• two tuning forks
• shattering the glass
Waves

- **What is a wave?** A *disturbance* that moves (*propagates*) through something
- The “wave” - people stand up then sit down, then the people next to them do the same until the standing and sitting goes all around the stadium.
- the standing and sitting is the disturbance
- notice that the people move up and down but the disturbance goes sideways!

Homer trips and creates a longitudinal wave

- **Mechanical waves**
  - a disturbance that propagates through a medium (e.g. air, water, strings)
  - waves carry energy
  - they provide a means to transport energy from one place to another
  - electromagnetic waves (light, x-rays, UV rays, microwaves, thermal radiation) are disturbances that propagate through the electromagnetic field, even in *vacuum* (e.g. light from the Sun)

How fast does it go?

- The speed of the wave moving to the right is not the same as the speed of the string moving up and down. (it could be, but that would be a coincidence!)
- **The wave speed is determined by:**
  - the tension in the string: more tension → higher speed
  - the mass per unit length of the string (whether it’s a heavy rope or a light rope): thicker rope → lower speed
Harmonic waves – keep jiggling the end of the string up and down

Slinky waves
- you can create a **longitudinal** wave on a slinky
- instead of jiggling the slinky up and down, you jiggle it in and out
- the coils of the slinky move along the same direction (horizontal) as the wave

SOUND WAVES
- longitudinal pressure disturbances in a gas
- the air molecules jiggle back and forth in the same direction as the wave

Sound – a longitudinal wave

The pressure waves make your eardrum vibrate
- we can only hear sounds between 30 Hz and 20,000 Hz
- below 30 Hz is called **infrasound**
- above 20,000 is called **ultrasound**

I can’t hear you!
Since sound is a disturbance in air, without air (that is, in a vacuum) there is no sound.

There is no sound in outer space!