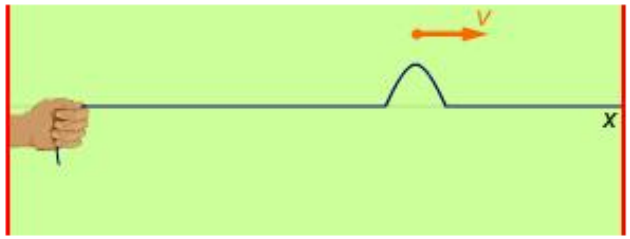
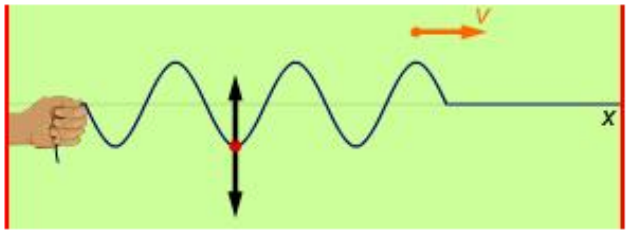
Themed: 02-01

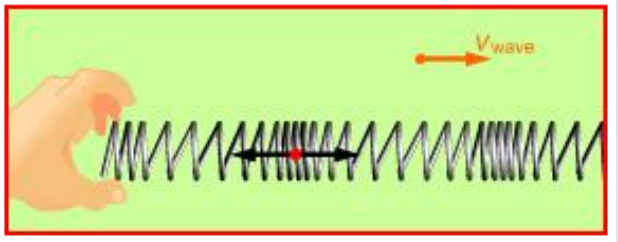
Wave Introduction and Anatomy

Wave Introduction

- Waves move energy through a medium, not mass
- The medium has “restoring force” - water vibrates (bounces up and down), springs bounce too
- Single waves are pulse waves…we’re more interested in continuous, repeating waves
- Time for a single vibration cycle is period (T)
- Frequency is the inverse of period (f = 1/T, T = 1/f)
- Frequency = cycles/second in Hertz (Hz); 1 Hz is sec^{-1}
- Pitch is human perception of sound frequency





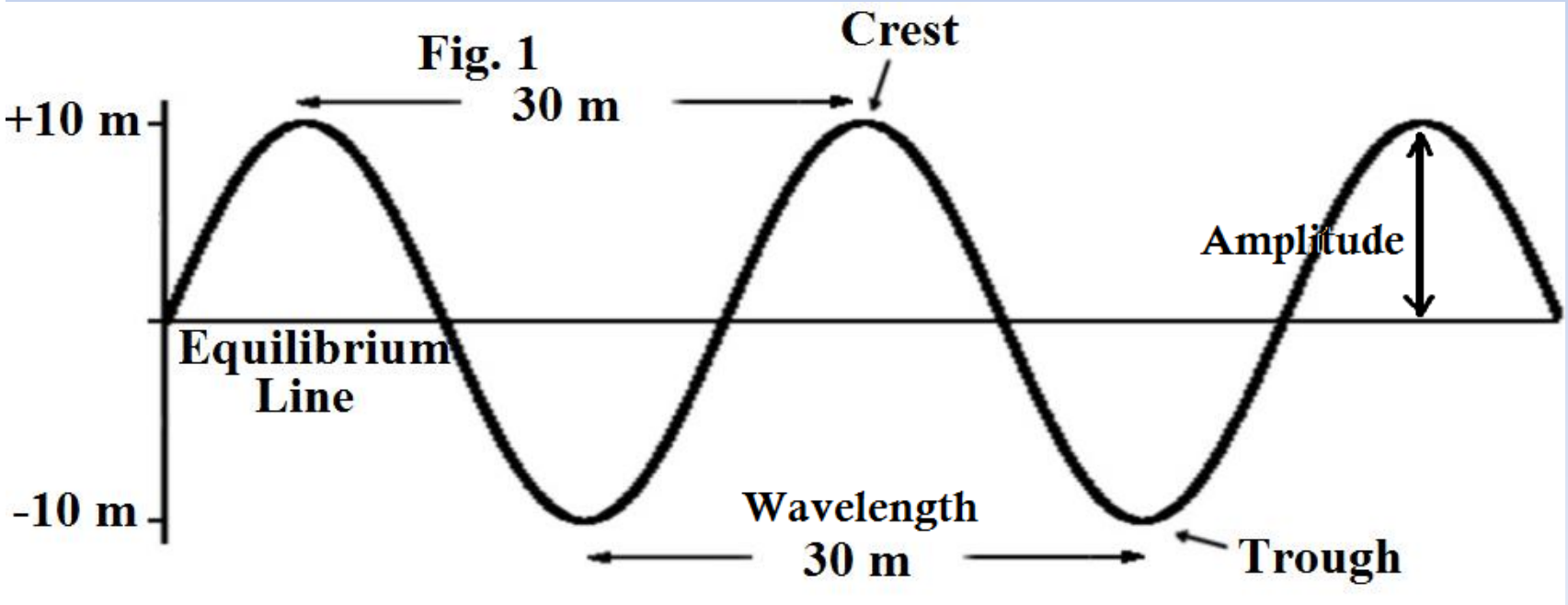


Mechanical waves (vs. EM waves)

- Mechanical waves have something that **physically** vibrates (sound in air, sound in water, a slinky, etc.)
- EM waves self perpetuate (nothing physical actually vibrates)
  - *If you're curious…electrical waves induce magnetic waves which in turn induce electrical waves….cycle goes on forever (we mention this in December in magnetism)*

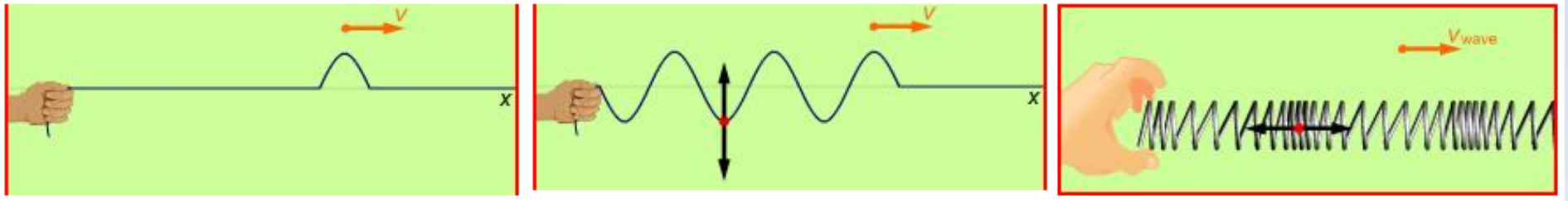
Wave anatomy and wave speed equation

- Recognize the following wave parts:
  - Medium: what the wave travels in (water, etc.)
  - Equilibrium line: “No energy” position of medium
  - Amplitude: displacement (meters) from Eq. line
  - Crest: highest point on wave
  - Trough: lowest point on wave
  - Wavelength: distance between adjacent crests or troughs (meters)



More Wave Properties

- Waves are either Transverse or Longitudinal
  - Direction of vibration compared to wave motion (perpendicular or parallel)
  - Sound is longitudinal, light (EM) is transverse
  - Sound is a mechanical wave, EM isn't (no physical vibrating)
- How fast a wave moves is wave speed: $V = f \lambda$
  - Wave speed only depends on the medium (NOT frequency or amplitude (sound volume))
    - Shouting? Whispering? Little girl's voice? Deep baritone voice?
  - Waves tend to travel faster in more dense medium (air< water<aluminum)
  - Hot air waves travel faster than cold ones



Wave speed equation, echoes, lightning and fireworks

- Wave speed
  - How fast wave moves (mph or m/s)
  - Symbol we use is v (like in "velocity")
- Speed = distance / time
  - $v = d/t$
  - $v = \lambda/t$, but $f = 1/t$, so $v = \lambda f$, but we usually like
  - $\underline{\mathbf{v = f \lambda}}$ (don't ask me why we do, we just do!)
  - Do you see that $v = f \lambda$ and $v = d/t$ are same eqn.?

Wave speed – what determines how fast?

- Sound waves travel
  - faster in warm air than cold;
  - faster in water than air, and
  - faster in metal than water
- GENERAL RULE (KNOW THIS): The more dense a material is, the faster the speed of sound through it
- Speed of sound depends on properties of the medium
- Speed of sound in air:
  - V = 331 m/s + 0.6(T), where T is Celsius temperature
  - **No temperature given? Assume 340 m/s**
  - Note: V is about 5x higher in water and 10x to 20
- Do high frequency sounds move faster than low frequency? Loud (high amplitude) sounds travel faster than quiet sounds…do you think a whisper travels slow? Girl's voices travel faster than boys?

Wave speed – echoes

- Echoes travel to some reflection point (canyon wall, etc.) and bounce back
- Distance sound travels is TWICE the distance to the reflecting wall ($d = 2x$, where x is the distance to the wall)
- Or, think of it as taking half to time to get to the canyon wall (and the other half for the return trip)

Wave speed – lightning and fireworks (Life Skill)

- A mile is 1609 m
- It takes about 5 seconds for sound to go 1 mile (you need to MEMORIZE this number)
- If you see a lightning flash and hear thunder, seek shelter (building, or car with windows up)
- If the two are almost simultaneous, seek shelter urgently
- You can use timing method to determine distance of fireworks too!

Wave speed – Mach number

- Mach speed is ratio of source speed (plane) compared to speed of sound

$$M = V_0/v_{sound}$$

- Example: How fast does a plane moving Mach 3 go? (assume speed of sound is 340 m/s)
  - Answer: 1020 m/s

Example Questions

1. The distance between crests is 12 m and 7 crests pass by each minute. What's the wave speed? (1.4 m/s)
2. What is the speed of sound in 40° C hot air? (355 m/s)
3. While hiking in a canyon, you yodel and hear the echo 2.4 seconds later. How far is the canyon wall from you? (408 m)
4. A military jet claims it can reach speeds of Mach 2.4. How fast is this? (816 m/s)

More sample problems

- How long does it take a marching band member at the back to hear the front, 80 m away when it's 41° F (5° C)?
- On a warm summer day (30° C), you yodel and hear your yodel reflect from a canyon wall 1.4 sec later. How far is the wall from you?
- You see lightning and hear thunder 7 seconds later. How many miles is the lightning from you (approximately, using memorized rule)
- Approximately how far is fireworks from you when there is a 9 second delay from seeing them to hearing their boom?

Slinky Summary/Sound Analogy

Slinky

1. Wave energy moves along the medium (coils)
2. Tight slinky = fast wave speed
3. Wave speed has “nothing to do” with frequency or amplitude (independent)
4. Only specific frequencies form standing waves, these are the harmonics
5. A large number of tiles tall for a wave is a big amplitude

Sound

1. Wave energy moves along the medium (air)
2. Warm air = fast wave speed
3. Same: High pitched voice or shouting doesn’t change wave speed
4. Same: Explains pitch of voice and simultaneous harmonic make rich sounds: timbre
5. A big amplitude is a loud sound