Module #11: Waves

* Waves
  + Wave = a disturbance that propagates (moves) in a medium
  + A wave must have a medium in which to travel (ex: water)
  + Figure 11.1
    - Wavelength (λ) = the distance between the crests (or the distance between the troughs)
    - Amplitude (A)= the height of the wave; maximum distance away from equilibrium
  + Frequency (f)= how many waves hit a certain point every second
    - f = v / λ
    - (v = wave speed)
    - (Unit = Hz)
  + Frequency and wavelength are inversely proportional
  + Transverse wave = a wave whose propagation is perpendicular to its oscillation
    - Propagation: direction of travel
    - Oscillation: how its medium moves
  + Longitudinal wave = a waves whose propagation is parallel to its oscillation
  + Figure 11.2
    - Compressions = the sections of a longitudinal wave that are bunched up, which correspond to the crests of the wave
    - Rarefactions = the sections of a longitudinal wave that are spread out, which correspond to the troughs of the wave
  + White light is considered a transverse wave and sound is a longitudinal wave
* The Physical Nature of Sound
  + In order for something to make a sound, air must be pushed outwards from the source.
  + The compressions and rarefactions in a sound wave cause the ear drum to vibrate and these vibrations are interpreted by the brain
    - The frequency of the sound wave is the primary factor in determining the pitch
      * The higher the frequency the higher the pitch
    - The volume of the sound is determined by the amplitude of the wave
      * The larger the amplitude the louder the sound
  + Since a sound wave is made by moving clumps of air around, the warmer the air, the faster these clumps move.
    - v = (331.5 + 0.606 \* T) m/s
      * T is the temperature of air in °C
  + Ex 11.1 p.358
  + OYO #11.1-11.2 p.358-359
* The Doppler Effect
  + Doppler Effect = the change in pitch caused by relative motion between the source of a sound and the observer of the sound.
  + Named after Austrian physicist Christian Doppler
  + When a sound-emitting object is moving towards you, the crests and trough of the sound wave get pushed closer to one another
    - Results in a pitch that is higher than when stationary
  + When a sound-emitting object is moving away from you, the crests and trough of the sound wave get pulled farther away from one another
    - Results in a pitch that is lower than when stationary
  + You can produce the same effect by moving towards or away from a fixed object which is emitting a sound wave.
  + To calculate the Doppler Effect:
    - fobserved = (vsound ± vobserver) \* ftrue

(vsound ± vsource )

* + - fobserved is the frequency the observer actually hears
    - ftrue is the frequency that the observer would hear is the source were stationary
    - vsound is the speed of sound[v = (331.5 + 0.606 \* T) m/s]
    - vobserver is the speed of the observer
    - vsource is the speed of the source that is emitting the sound
    - ± means either add or subtract
      * When the observer is stationary (v=0)
        + If the object is moving away from the observer use a + in the denominator
        + If the object is moving towards the observer use a – in the denominator
      * When the source is stationary (v=0)
        + If the observer is moving away from the object use a – in the numerator
        + If the observer is moving towards the object use a + in the numerator
  + Example 11.2 p.362
  + OYO 311.3-11.4 p.363
* Sound Waves in Substances Other Than Air
  + Speed of sound decreases with increasing density of a substance
  + The easier it is to compress the substance, the slower sound travels in it
  + Sound generally travels slowest in gases, more quickly in liquids, and even more quickly in solids.
* Sound Waves Beyond the Ear’s Ability to Hear
  + In general, human ears are sensitive to waves whose frequency is between 20Hz and 20,000Hz.
    - These are called sonic waves
  + Waves with frequencies higher than 20,000Hz are called ultrasonic waves
  + Waves with frequencies below 20Hz are called infrasonic waves
* The Speed of Light
  + The speed of light in air is 3.0 x 108 m/s
  + The speed of light waves changes depending on the medium through which they travel.
    - Generally speaking, as the medium gets more dense, light waves slow down.
  + Example 11.3 p.366
  + OYO p.367 #11.5-11.6
* Light as a Wave
  + In the early 1800s, Thomas Young demonstrated that light is a wave through an experiment:
    - A beam of light hit a screen with a tiny slit in it and produced a thin beam of light
    - That beam of light hit another screen with two tiny slits in it very close together.
    - The light that passed through these slits then hit a screen with no slits in it
    - On the last screen, there was a whole series of bright spots separated by dark spots
    - Figure 11.7 p.368
  + Diffraction = the spreading of waves around an obstacle
  + In the experiment, diffraction makes the slit act like an individual light source whose light radiates outward from the slit
  + The light from the two slits is **coherent**, which means that the spatial relationship between the crests and troughs of one wave compared to those of the other wave does not change.
  + Wave interference occurs whenever two waves overlap with one another
    - When the waves overlap so that their crests and troughs add together to make larger crests and troughs, it is called constructive interference.
    - When the waves overlap so that their crests and troughs cancel one another out, it is called destructive interference.
  + In Young’s experiment, when constructive interference occurred and a wave of large amplitude was produced, a bright spot appeared. When destructive interference occurred and there was no wave, a dark spot appeared.
  + What does light oscillate?
    - All waves must oscillate a medium
    - For a long time, physicists thought that there was a substance called the ether which permeated space, the earth, and anywhere else light traveled.
      * In 1887, two physicists disproved the existence of ether
    - In 1837, James Clerk Maxwell had derived a series of equations which today we call Maxwell’s Equations.
      * Described in mathematical detail the relationship between electric and magnetic phenomena
      * Unify electric and magnetic forces into a single electromagnetic force
      * Specify that this force is mediated by a wave whose speed is a direct result of the mathematics = speed of light (c)
      * Tell us that light is an electromagnetic wave
        + Light waves are oscillating electric and magnetic fields
  + An electromagnetic wave can have a wide range of wavelengths: electromagnetic spectrum
    - Visible light is only a tiny range of the wavelengths (400-700nm)
    - Figure 11.9: Electromagnetic Spectrum
    - Figure 11.10: Visible spectrum
    - Nm = nanometer (10-9)
  + OYO #11.7-11.8 p.372
* Light as a Particle
  + Photoelectric effect refers to the fact that when light is shone on certain metals, electrons can be liberated from the metal
    - These electrons are called photoelectrons
    - Electrons in the metal absorb energy and break free
    - Work function refers to the energy with which a metal holds on to its electrons
  + Observations of the photoelectric effect not consistent with the idea that light is a wave:
    1. Electrons were ejected within a few billionths of a second after the light was turned on
    2. The intensity of the light has no effect on the energy of the electrons after they left the metal. The more intense the light, the greater number of electrons, but the energy of the electrons was independent of the light intensity.
    3. Each metal had a unique “cutoff” frequency. If the light used was below this frequency, electrons would not be emitted.
    4. The maximum kinetic energy of the emitted electrons was directly proportional to the frequency of the light used.
  + Albert Einstein assumed that a beam of light was like a stream of particles
    - Called these particles photons
    - Stated that the energy of each photon was proportional to the frequency of the light:
      * E= hf
        + E: energy of the light
        + F: frequency
        + H: Planck’s constant = 6.63 x 10-34 J\*sec
    - Explained that collisions between photons and the electrons in the metal transferred energy, which would occur almost as soon as the light was turned on (explains observation #1)
    - The intensity of the light would not mean more energy, it would mean more photons, which would mean more collisions (explains observation #2)
    - Since the energy of the photons depends on the frequency, there would be a frequency under which the photons would not provide enough energy to liberate electrons from the metal (explains observation #3)
    - Since the photon energy depends on the frequency, the maximum kinetic energy of the electrons should depend on the light frequency as well (explains observation #4)
  + When dealing with individual photons of light, the energy unit of a Joule is too big, a more convenient unit is called the electron volt (eV)
    - 1.000 eV = 1.602 x 10-19 J
  + Example 11.4 p.374
  + Light experienced particle-wave duality: has both wave-like characteristics and particle-like characteristics
  + OYO #11.9-11.10 p.376
* Biographies of Two Important Physicists (group presentations)
  + James Clerk Maxwell
    - Born in Edinburgh, Scotland in 1831
    - Several contributions to science
    - Devote Christian
  + Albert Einstein
    - Born in Ulm, Germany in 1879
    - Best known for his special and general theories of relativity
    - Nobel Prize winner 1921