Wave Properties

Waves

- ***Waves*** transfer energy without
- It is a
- ***Medium*** – matter that
- There are three types of waves:
  1.
  2.
  3.

Electromagnetic waves

- No medium – energy is transmitted
- Ray of energy –
- All E.M. waves travel at the same speed : speed of light :
- We will use ***c*** =
- Examples: radio, micro-waves, infra-red,

Matter waves

- Tiny particles (electrons) show wave-like behaviors under certain
- Follow the Laws

Mechanical Waves

- Require a medium;
- Follow
- Examples: sound,
- Three types of mechanical waves:
  - ***Transverse waves*** : Particles vibrate **perpendicular** to the motion of
  - ***Longitudinal waves*** – particles move **parallel** to the motion of
  - ***Surface waves*** – a **mixture** of transverse and longitudinal

Wave Properties

- Waves are produced when work is done to the
- ***Wave pulse*** – single disturbance
  - A rock drops into the water sends a wave pulse
- ***Traveling wave*** – a simple harmonic motion produces
  - The

- ***Period*** : time interval during
  - Symbol is
  - Unit is
- ***Frequency*** : number of complete
  - How often a
  - Symbol is
  - Unit is
  - 60 Hz =
  - Hz =
  - f =
  - T =
- ***Wavelength*** : distance from one point on a wave to
  - Crest to crest or
  - Symbol is
  - Unit is
- ***Crest*** : max point above
- ***Trough*** : max point below
- ***Amplitude*** : maximum displacement
  - Measured in
  - Amount of energy that is transferred ONLY for
  - Loud sound waves have a high amplitude and
  - Large ocean waves have a high
  - Quadratic relationship between amplitude and energy : double the amplitude,
  - Frequency, wavelength, and wave velocity are
- ***Wave Velocity*** :
  - v =

- v =

- v =
- velocity of wave =

- The velocity of a wave depends on the properties of the
-
-
- Inverse relationship between

Earthquake waves:

- P waves are longitudinal waves ; travel
- S waves are transverse waves ; travel
- Surface waves travel along the
- Concentric waves have the

Change in Medium

- ***Incident wave*** – a wave that strikes the
- ***Reflected wave*** – returning wave that is either inverted or
- ***Transmitted wave*** – the wave that passes through
- How a wave is reflected or transmitted depends on the difference in the
- If there is ***little difference*** in the
  - ***Most of the energy is***
  - Amplitude of incident wave ≈
  - Amplitude of the

- If there is a ***great difference*** in the
  - Wave is reflected depends on the

- ***Less dense to more dense***
  - Most of the energy is
  - ***Reflected wave is***
  - Small transmitted
    - Velocity
    - Wavelength
    - Frequency stays the
- ***More dense to less dense***
  - Most of the energy is
  - ***Reflected wave is***
  - Small transmitted
    - Velocity
    - Wavelength
    - Frequency remains the

1. A periodic transverse wave, that has a frequency of 10.0 Hz, travels along a string. The distance between a crest and either adjacent trough is 2.50 m. What is its wavelength?

2. A wave generator produces 16.0 pulses in 4.00 sec. What is its period? What is its frequency?

3. What is the speed of a periodic wave disturbance that has a frequency of 2.50 Hz and a wavelength of 0.600 m?

4. One pulse is generated every 0.100 sec in a tank of water. What is the speed of propagation of the wave if the wavelength of the surface wave is 3.30 cm?

5. The speed of a transverse wave on a string is 15.0 m/s. If a source produces a disturbance that has a frequency of 5.00 Hz, what is its wavelength?

Wave Behavior

Interactions of Waves

- ***Principle of Superposition*** – when two or more waves meet, the resulting wave (displacement of the medium) is
- Resulting displacement is
- Two types of interference:
    1.
    2.
- Constructive Interference
    - Occurs when wave displacements are
    - Resulting displacement has a
    - ***A is the antinode*** – point of maximum
    - The two waves are not
- Destructive Interference
    - When two waves with equal but opposite amplitudes meet, they overlap
    - ***N is the node*** – point where two waves meet and ***displacement***
    - If the waves have unequal amplitudes, the destructive
    - The interference is the difference of the amplitude
    - The waves pass

Standing Waves

- A ***standing wave*** is created when a traveling wave is reflected and inverted
- A standing wave has nodes and appears to have
- Standing waves result from identical waves (same amplitude and wavelength) traveling in
- If the frequency increases, then the
- Forms
- Energy stays
- As you increase the frequency, the number of

Frequency f	Nodes	Antinodes	Wavelength λ	Velocity $v=\lambda f$	Harmonic	Draw the wave!

Notice that the velocity is constant! 2L = 1 wave, so $v = \lambda f$

Reflection of Waves

- Waves are reflected when they hits a barrier that is the boundary of the
- ***Normal*** : imaginary line drawn
- ***Angle of Incidence,*** θ_i angle between the
- ***Angle of Reflection,*** θ_r angle between the
- Law of Reflection – angle of incidence is equal
- Application – fiber optics, mirrors

Refraction of Waves

- Bending of the path of a wave as it passes

- Caused by the change in
- White light is bent and separated into the different
- Applications: rainbows, corrects our vision, microscopes, binoculars
- Waves refract ***towards*** the normal as it enters a ***more dense***
- Waves refract ***away*** from the normal as it enters a ***less dense***

Diffraction

- Change in direction of waves as they pass through an opening or around a
- The barrier bends the
- The amount of diffraction depends on the
    - Long λ, low f : =
    - Short λ, high f =
- Creates gray areas in shadows, allows you to hear someone in the
- AM radio has longer wavelengths so they diffract over mountains. FM radio has shorter wavelengths, so they
- Owl's produce long wavelength "hoots" that are able to diffract around the forest trees and carry farther than song bird's short-wavelength
- Light does not diffract around corners because the wavelength is too small (4×10^{-7} m). Light can only diffract through
- Interference of waves causes nodes and
- Diffraction grating – many tiny slits or grooves diffract the
- A CD has many extremely small grooves. The grooves diffract the light and then it is reflected showing the

Sound

Sound waves

- Sound waves are made by
- Vibration causes air molecules
- Sound waves are
    - Consist of areas of compression (high pressure) and
- A medium is required to
- Note that radio waves are electromagnetic waves and are transformed into sound

Sound Frequency

- We hear frequency of sound
    - High pitch,
    - Low pitch,
- The frequency of a sound wave is the number of oscillations in pressure each
- Measured in

- Sound waves can
- Constructive interference increases the
- Destructive interference decreases the
- Noise reduction products produce waves that create
- Beats – interference of two sound waves causing a change in
- Calculate the beat frequency (number of beats per second) by the difference in the
- f_b =
- This is how piano's are tuned – the string is adjusted until the frequencies are the same and
- Wave interference gives us
- Octave – two notes with frequencies related by a
- Musical Fifth Interval – two notes with frequencies related by a
- Music is defined as any sounds wave that have a clear whole number ratio between
- Music is sound waves with a regular
- Noise does not have a whole number ratio and does

Harmonics

- You can determine the harmonic that a string is producing by the length of the string, and the
- Each end is a
- The string length is always

- v =
-
- v =
- f_1 =

- The velocity depends on the mass of the string and the
- f_n =

- Harmonics are just a whole number multiple of the
- Air in a tube can create standing waves causing the
- This called resonance. This is how musical
- If the ***air column is open*** – the wave reaches the end and is
- Each end has
- Just like a string, the wavelength is $\frac{1}{2}$ the length of the column.
- f_1=

- f_n = n = harmonic number
- All harmonics are

- If the ***air column is closed*** – the wave reaches the end and is reflected
- The open end has an antinode and the closed
- The wavelength is four tines the length
- v =

- v =
- f_1 =
- Only the odd harmonics can be
- f_n =

- Instruments produce more than one harmonic. The combination of the harmonics produced give each instrument it's unique

Speed of Sound

- Sound travels at 343 m/s in
  - The velocity changes with
  - v_{sound} =
  - At 20°C,
    v_{sound}=

- Speed of sound depends on
  - Sound travels at 1490 m/s in water at
  - Sound travels at 5200 m/s in steel at
  -
  - Particles are closer together in solids, so the vibrations are
- Sound travels at 0 m/s in outer space –

- Echoes are reflection of
- Velocity =
- Velocity does not depend on frequency or
- Echolocation – perception of time delays between the production of sound and the time it returns. Used by

- Sonar and ultrasound use this property to determine the distance between the source
  - If you measure the time it takes for the echo to go and return, you can calculate the distance it traveled.
  - You can divide distance OR
- Sonar is used by cameras, and

Doppler Shift

- Doppler shift is the ***apparent change*** in
  - the sound source is
  - the receiver is
  - both are
- Not how loud or soft of a
- Explains why the pitch of a siren changes as an ambulance approaches and
- Velocity of the wave is
- Dolphins and bats use Doppler shift to determine if the "food" is moving towards or
- Doppler shift works for all waves
-

- Source approaching you –
- Source leaving you –

-
- f_d = frequency of the
- f_s = frequency of the
- v = speed of
- v_d = velocity of
  - +v moving
  - -v moving
- v_s = velocity of
  - +v moving
  - -v moving
- When the source is moving faster than speed of sound, it produces
- The source is ahead of the
- The compressions and
- The compressions and rarefactions reach you all at once creating a very large noise –

Sound Intensity

- Sound waves that are loud have a large amplitude. The air molecules vibrate with a
- ***Amplitude*** = loudness =
- Intensity is the amount of energy

- Intensity =

- I =

- Inverse square between

- We compare the intensity of a sound (I) to the faintest sound you can

- I_0 =

- Use the decibel

-
- Logarithmic scale (multiples of 10) of the ratio of intensity to the intensity of the

- An 10 dB increase

6. The echo of a ship's fog horn, reflected from an iceberg, is heard 5.0 s after the horn is sounded. How far away is the iceberg?

7. What is the speed of sound that has a frequency of 250 Hz and a wavelength of 0.600 m?

8. A sound wave has a frequency of 2000 Hz and travels along a steel rod. If the distance between successive compressions is 0.400 m, what is the speed of the wave?

9. A stone is dropped into a mine shaft 250.0 m deep. How many seconds pass before the stone is heard to strike the bottom of the shaft?

10. Sam, a train engineer, blows a whistle that has a frequency of 400.0 Hz as the train approaches a station. If the speed of the train is 25 m/s, what frequency will be heard at the station?

11. In the previous problem, what frequency will be heard at the station if the train is leaving at 25 m/s?

12. What is the distance from a sound with 5.88×10^{-5} W power if it has a decibel level of 66 dB? What is the intensity?

13. What is a vacuum cleaner's sound power output if the sound's intensity is 4.5×10^{-4} W/m^2 at 1.5 m away?

14. Waves travel at 499 m/s on a 0.850 m long cello string. Find the string's fundamental frequency.

15. A 1.53 m long pipe that is closed on one end has a seventh harmonic frequency of 466.2 Hz. What is the speed of the waves in the pipe?

16. Two train whistles have identical frequencies of 180 Hz. When one train is at rest in the station, sounding its whistle, a beat frequency of 2 Hz is heard from a training coming into the station. What is the velocity of the incoming train?

Electromagnetic Waves

- Light is an
- Magnetic field vibrating at
- Packets of quanta called
- Have no mass –
- Produced by
- Electromagnetic Waves are classified by their
- The ***energy*** of an EM is defined by the
  - Frequency
- Electromagnetic spectrum is a list of the

Electromagnetic Spectrum

- Radio/TV, Microwave, Infrared (IR), Visible,
- Gamma has the highest energy
- Radio has the lowest energy
- Visible spectrum : red,
  - Red light : longest λ
  - Violet light : shortest λ
- Light waves require no
- Travel in straight lines, but radiates from the
- Light has a
  - Light acts a wave by reflecting,
  - Light acts as a particle – photons
- Light travels in a straight line

- Albert Michelson measured the speed of light in the early 1900s.
    - o c =
    - o c = 3.00 x 10^8 m/s in a
    - o c =

Measuring Light

- Sun emits light. Sun is a
- Moon reflects light. Moon is an
- Describe light by
- **Luminous intensity** –
    - o Symbol :
    - o Unit :
    - o SI base unit –
    - o 40 w incandescent =
    - o 40 w fluorescent =
    - o 100 w incandescent =
- **Luminous flux** – "light flow"
    - o Rate of
    - o Symbol :
    - o Unit :
    - o If a source with an intensity of 1 cd emits light in a spherical pattern
    - o P =
    - o lm =
- **Illuminance** –
    - o Luminous flux
    - o depends on:
        - o luminous
        - o Distance
- o Symbol :
- o Units :
- o lux =
- o Luminous flux goes out in a
- o

-
-
- Radius is the
-
- Inverse square law
- Application: determine

17. The wavelength of blue light is about 4.5×10^{-7} m. Convert this to nm.

18. As a spaceship passed directly over Cape Kennedy, radar pulses are transmitted toward the craft and then reflected back toward the ground. If the total time interval was 0.00300 sec, how far above the ground was the space craft when it passed over Cape Kennedy?

19. The distance from Earth to the moon is about 3.8×10^{8} m. A beam of light is sent to the moon and after it reflects, returns to Earth. How long did it take to make the round trip?

20. A radio station, emits radio waves on the AM band and has an assigned frequency of 825 kHz. What is the wavelength of the signal?

21. A short wave HAM radio operator used the 6.0 m band. On what frequency does the HAM operate?

COLOR

Properties of Matter

- ***Transparent*** – object that
- ***Translucent*** – transmits light but you
- ***Opaque*** – objects that absorb or
- ***Spectrum*** – arrangement of

Light Colors

- ***Primary light colors*** –
  - Mix all these colors and get
  -
  - red + green =
  - blue + green =
  - red + blue =
  - red + green + blue =
- ***Secondary light colors*** –
  - Light colors formed by mixing

- ***Complimentary light colors***
    - Two light colors (1 secondary + 1 primary) added
    - yellow + blue =
    - cyan + red =
    - magenta + green =
- Opaque objects reflect the color you see and absorb the
    - red (absorbs green + blue)
    - blue (absorbs green + red)
    - green (absorbs red + blue)
- Absence of light is black
- **Examples**
- Green Light on Red Apple =
- Yellow light on Red apple =
- Green light on Cyan apple =
- Green + Blue light on Yellow apple =
- Red light on Magenta apple =
- Cyan + Magenta lights on Yellow apple =

Filters

- Transparent objects that selectively
- Filters are the color they transmit. They absorb
    - Red Filter transmits red : absorbs
    - Blue Filter transmits blue : absorbs
    - Green Filter transmits green : absorbs
    - Cyan Filter transmits
    - Magenta Filter transmits
    - Yellow Filter transmits
    - Magenta + Cyan + Yellow filters –

- **Examples:**
- Magenta light + Yellow object + Red filter =

- Yellow light + Magenta filter + Cyan filter =

- Blue light + Red object + Green filter =

- Yellow light + Cyan object + Green filter =

Pigments and Dyes

- ***Dyes*** – chemicals that absorb certain colors and
- ***Pigment*** – like a dye, but a
- ***Primary pigments*** –
    - o Absorbs only one color from white light and
    - o This is a
    - o Yellow pigment – absorbs
    - o Cyan pigment – absorbs
    - o Magenta pigment – absorbs
- ***Secondary Pigments*** –
    - o Absorbs two primary colors –
    - o Red pigment – absorbs
    - o Green pigment – absorbs
    - o Blue pigment – absorbs
- ***Complimentary Pigments***
    - o Two pigments (1 primary + 1 secondary) mixed to
    - o yellow + blue =
    - o cyan + red =
    - o magenta + green =
- **Examples – White light on mixed pigments**
- White light on yellow + cyan =

- White light on magenta + cyan =

- White light on yellow + magenta =

- Application: This is how printers work – they have yellow, magenta, and cyan dyes and when they are mixed

Polarization

- Polarizared Light – light consisting of waves that vibrate
- Light can be polarized using a
- Light that vibrates
- Light is also polarized when it is reflected off a smooth, flat
- This light causes
- Glare from a horizontal surface is horizontally polarized. Use a polarized filter that is