Section 4.2

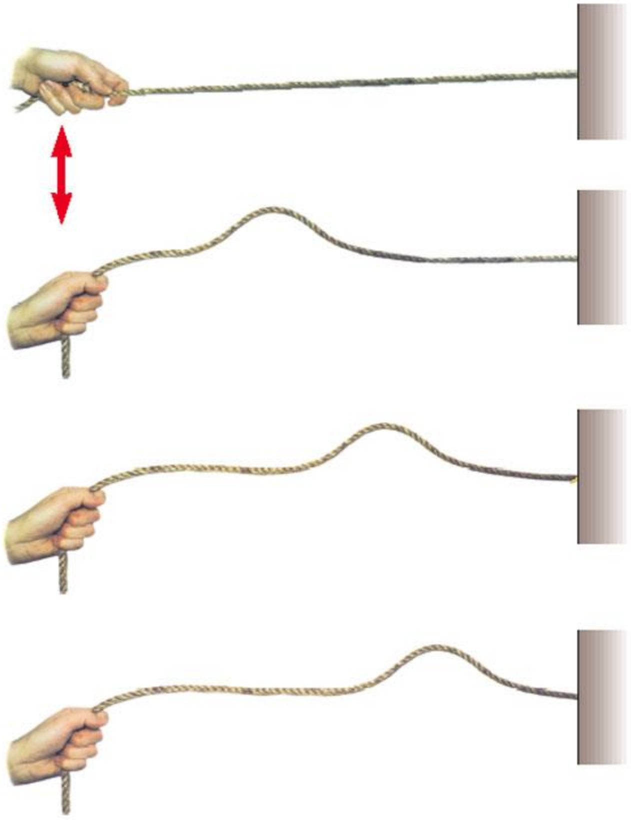
Travelling Waves

Wave Motion

- A wave is the motion of a disturbance
- Mechanical waves require
  - Some source of disturbance
  - A medium that can be disturbed
  - Some physical connection between or mechanism though which adjacent portions of the medium influence each other
- All waves carry energy and momentum

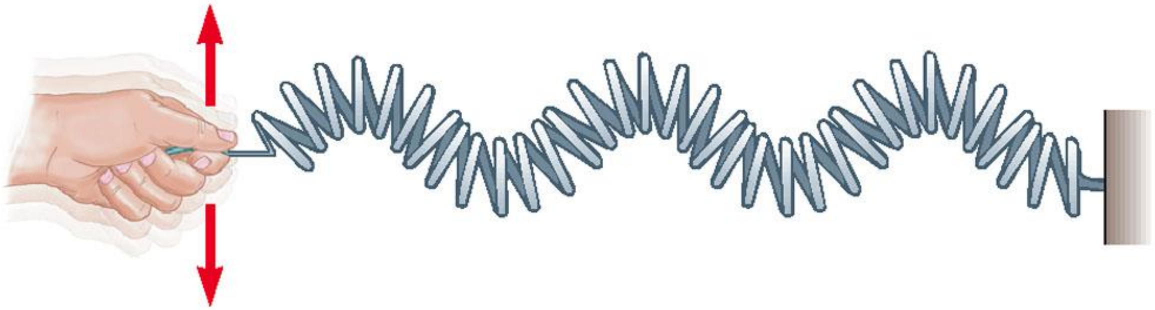
Types of Waves – Traveling Waves

- Flip one end of a long rope that is under tension and fixed at one end
- The pulse travels to the right with a definite speed
- A disturbance of this type is called a *traveling wave*



Types of Waves – Transverse

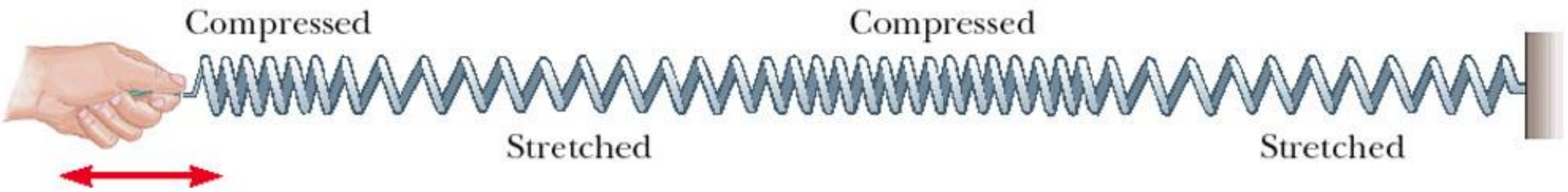
- In a transverse wave, each element that is disturbed moves in a direction perpendicular to the wave motion



(a) Transverse wave

Types of Waves – Longitudinal

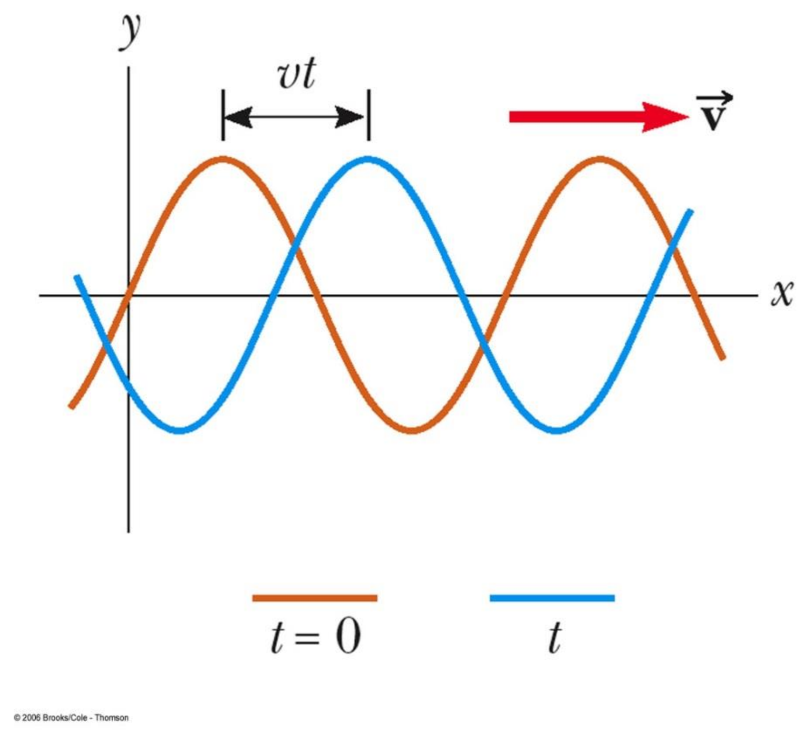
- In a longitudinal wave, the elements of the medium undergo displacements parallel to the motion of the wave
- A longitudinal wave is also called a compression wave



(b) Longitudinal wave

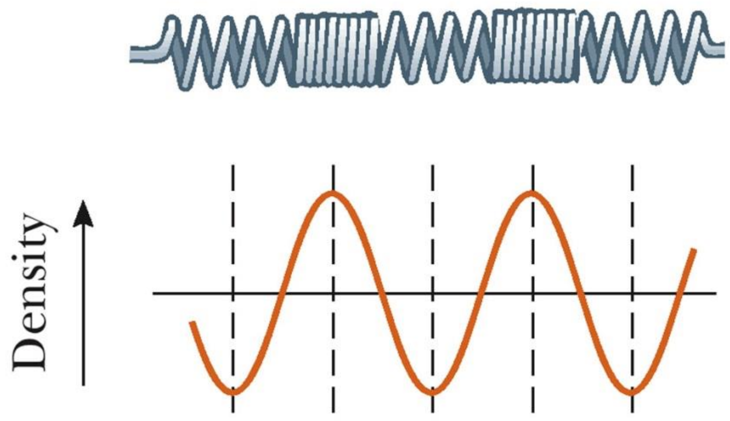
Waveform – A Picture of a Wave

- The brown curve is a “snapshot” of the wave at some instant in time
- The blue curve is later in time
- The high points are *crests* of the wave
- The low points are *troughs* of the wave



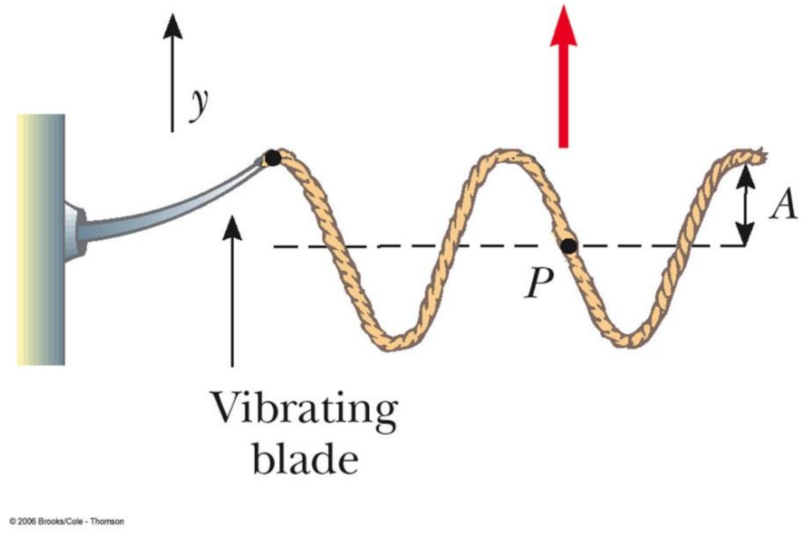
Longitudinal Wave Represented as a Sine Curve

- A longitudinal wave can also be represented as a sine curve
- Compressions correspond to crests and stretches correspond to troughs
- Also called density waves or pressure waves



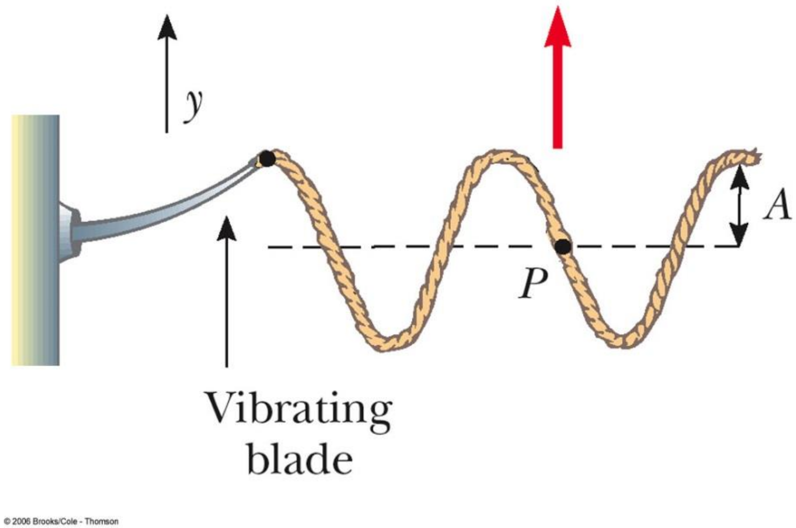
Description of a Wave

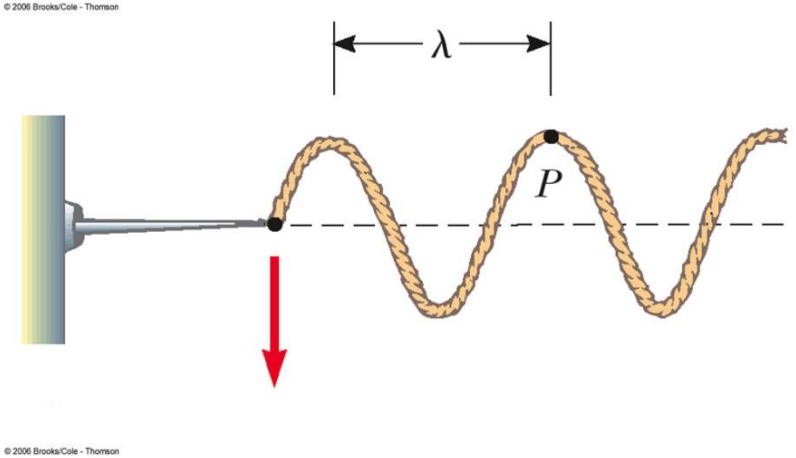
- A steady stream of pulses on a very long string produces a continuous wave
- The blade oscillates in simple harmonic motion
- Each small segment of the string, such as P, oscillates with simple harmonic motion



Amplitude and Wavelength

- Amplitude is the maximum displacement of string above the equilibrium position
- Wavelength, λ, is the distance between two successive points that behave identically





The wavelength of a progressive transverse wave is defined as

A. the distance between a crest and its neighbouring trough.

B. the distance between any two crests of the wave.

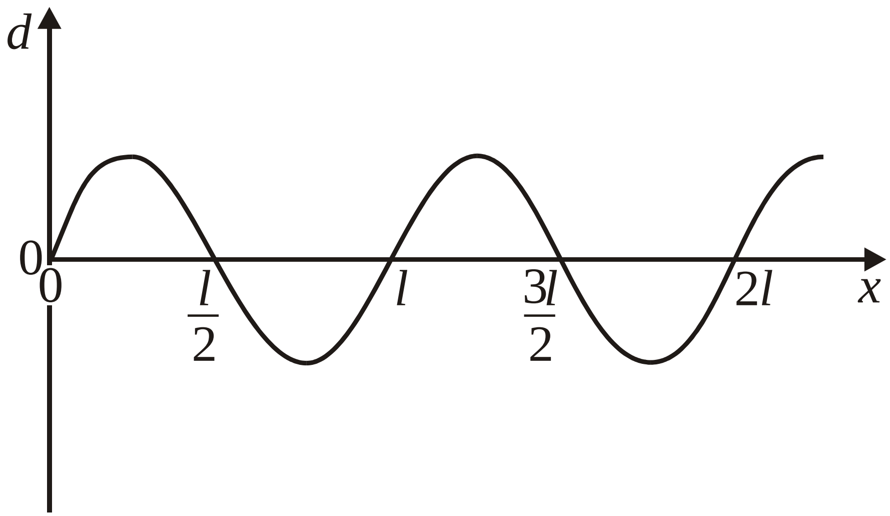
C. the distance moved by a wavefront during one oscillation of the source.

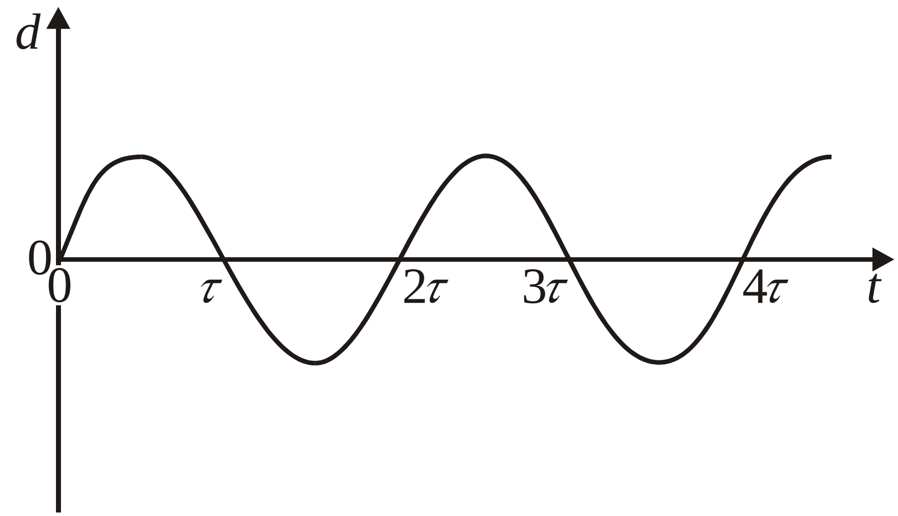
D. the distance moved by a particle in the wave during one oscillation of the source.

Speed of a Wave

- $v = f\,\lambda$
  - Is derived from the basic speed equation of distance/time
- This is a general equation that can be applied to many types of waves

The displacement *d* of a particle in a wave varies with distance *x* along a wave and with time *t* as shown below.





Which expression gives the speed of the wave?

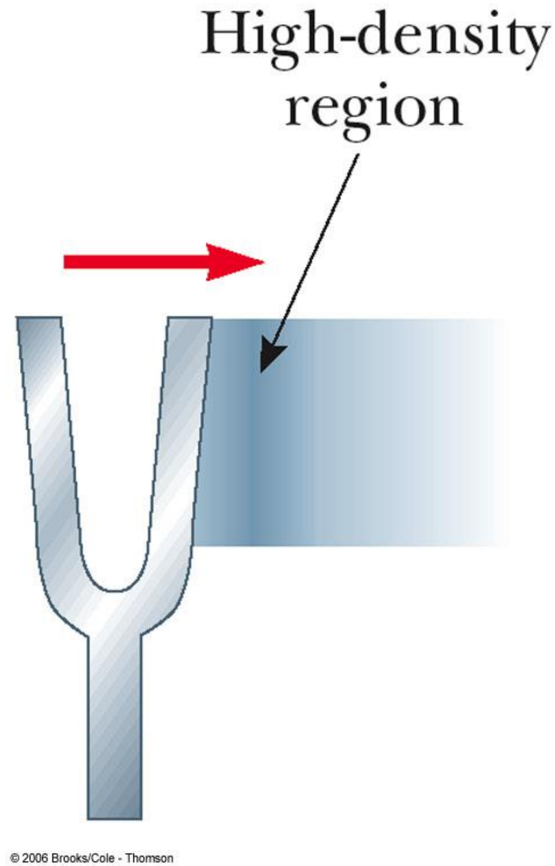
A. $l / 4\tau$ B. $l / 2\tau$ C. l / τ D. $2l / \tau$

Producing a Sound Wave

- Sound waves are longitudinal waves traveling through a medium
- A tuning fork can be used as an example of producing a sound wave

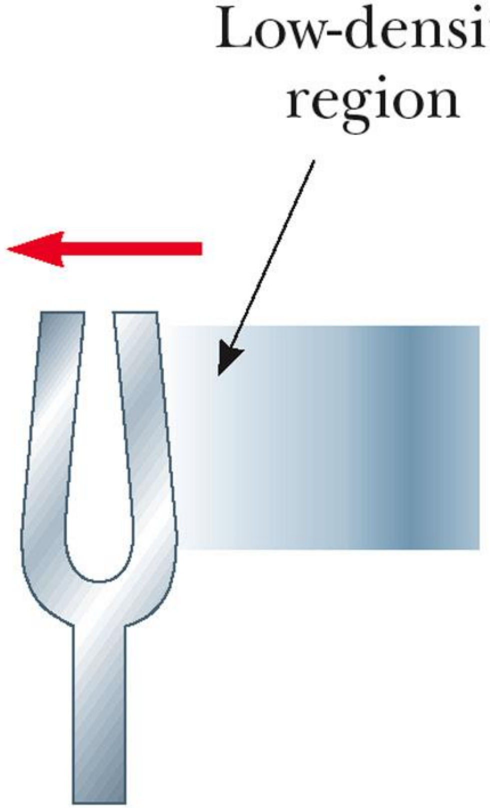
Using a Tuning Fork to Produce a Sound Wave

- A tuning fork will produce a pure musical note
- As the tines vibrate, they disturb the air near them
- As the tine swings to the right, it forces the air molecules near it closer together
- This produces a high density area in the air
  - This is an area of compression

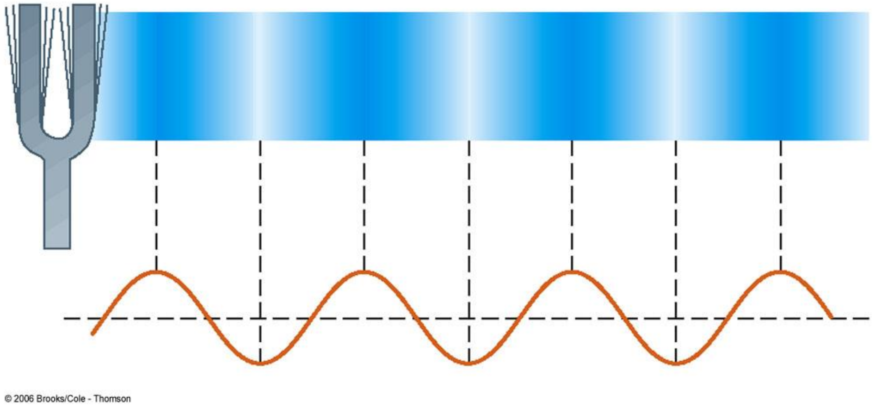


Using a Tuning Fork, cont.

- As the tine moves toward the left, the air molecules to the right of the tine spread out
- This produces an area of low density
  - This area is called a *rarefaction*



Using a Tuning Fork, final



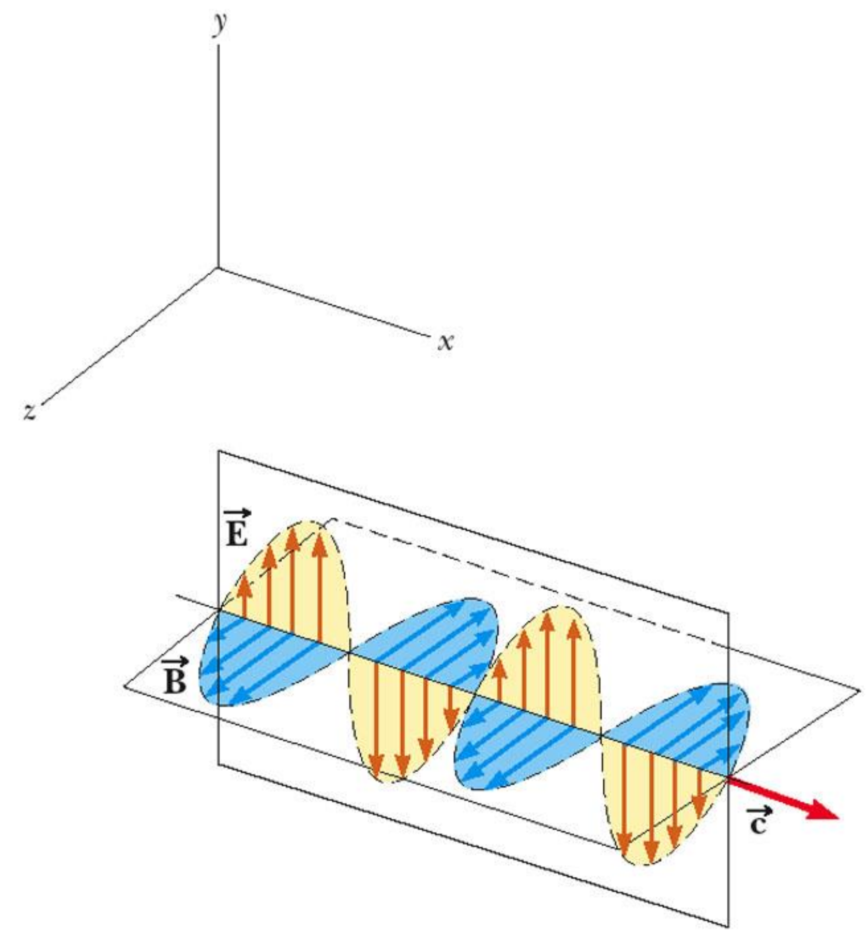
- As the tuning fork continues to vibrate, a succession of compressions and rarefactions spread out from the fork
- A sinusoidal curve can be used to represent the longitudinal wave
  - Crests correspond to compressions and troughs to rarefactions

Electromagnetic Waves, Summary

- A changing magnetic field produces an electric field
- A changing electric field produces a magnetic field
- These fields are *in phase*
  - At any point, both fields reach their maximum value at the same time

Electromagnetic Waves are Transverse Waves

- The $\vec{\mathbf{E}}$ and $\vec{\mathbf{B}}$ fields are perpendicular to each other
- Both fields are perpendicular to the direction of motion
  - **Therefore, em waves are transverse waves**



Properties of EM Waves

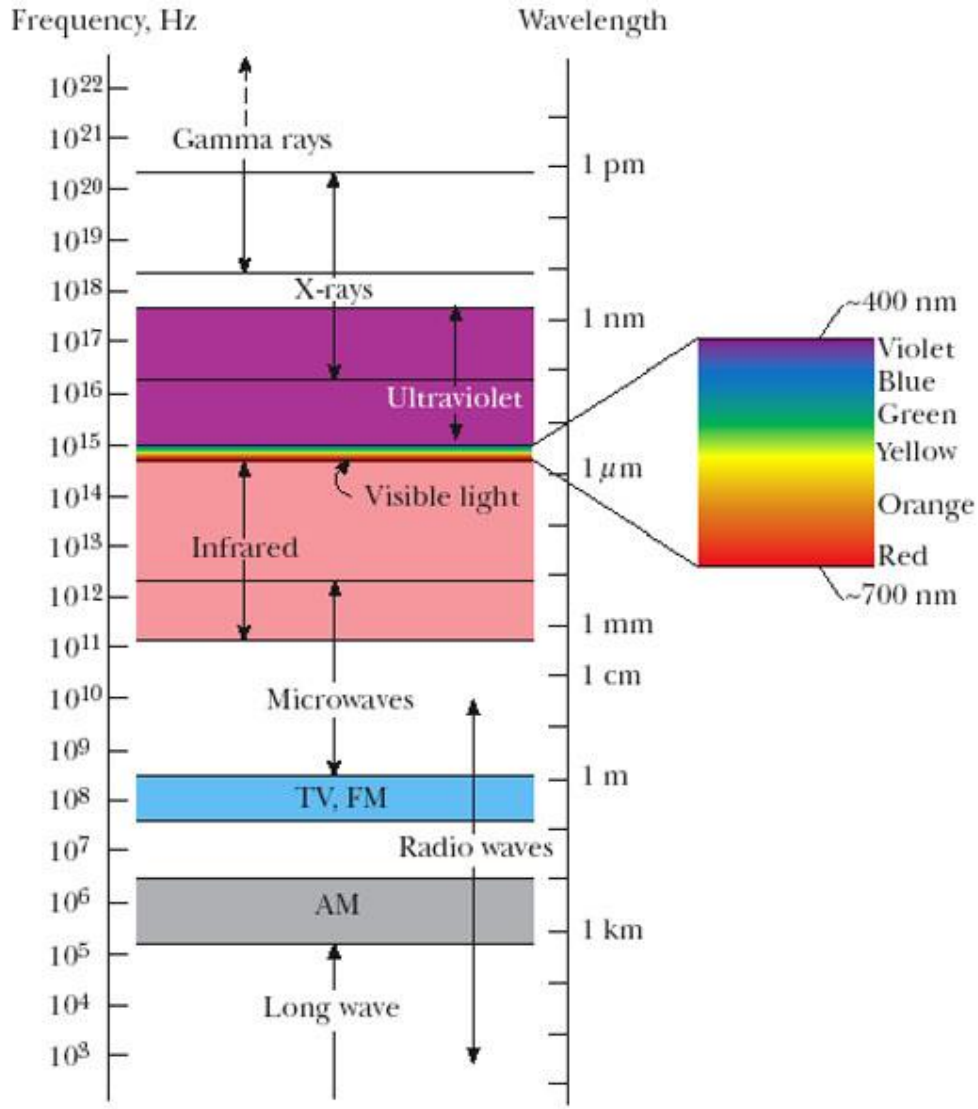
- Electromagnetic waves are transverse waves
- Electromagnetic waves travel at the speed of light
- Because em waves travel at a speed that is precisely the speed of light, *light is an electromagnetic wave*
- Electromagnetic waves carry energy as they travel through space, and this energy can be transferred to objects placed in their path

The Spectrum of EM Waves

- Forms of electromagnetic waves exist that are distinguished by their frequencies and wavelengths
  - $c = f\lambda$
- Wavelengths for visible light range from 400 nm to 700 nm
- There is no sharp division between one kind of em wave and the next

The EM Spectrum

- Note the overlap between types of waves
- Visible light is a small portion of the spectrum
- Types are distinguished by frequency or wavelength



1 micrometer (μm) = 10^{-6} m

1 nanometer (nm) = 10^{-9} m

1 angstrom (Å) = 10^{-10} m

Notes on The EM Spectrum

- Radio Waves
  - Used in radio and television communication systems
- Microwaves
  - Wavelengths from about 1 mm to 30 cm
  - Well suited for radar systems
  - Microwave ovens are an application

Notes on the EM Spectrum, 2

- Infrared waves
  - Incorrectly called “heat waves”
  - Produced by hot objects and molecules
  - Readily absorbed by most materials
- Visible light
  - Part of the spectrum detected by the human eye
  - Most sensitive at about 560 nm (yellow-green)

Notes on the EM Spectrum, 3

- Ultraviolet light
  - Covers about 400 nm to 0.6 nm
  - Sun is an important source of uv light
  - Most uv light from the sun is absorbed in the stratosphere by ozone
- X-rays
  - Most common source is acceleration of high-energy electrons striking a metal target
  - Used as a diagnostic tool in medicine

Notes on the EM Spectrum, final

- Gamma rays
  - Emitted by radioactive nuclei
  - Highly penetrating and cause serious damage when absorbed by living tissue
- Looking at objects in different portions of the spectrum can produce different information

The Particle Nature of Light

- "Particles" of light are called *photons*
- Each photon has a particular energy
  - $E = h f$
  - h is *Planck's constant*
    - $h = 6.63 \times 10^{-34}$ J s
  - Encompasses both natures of light
    - Interacts like a particle
    - Has a given frequency like a wave

Dual Nature of Light

- Experiments can be devised that will display either the wave nature or the particle nature of light
  - In some experiments light acts as a wave and in others it acts as a particle
- Nature prevents testing both qualities at the same time