In Astronomy the most common unit to measure distances is----

Light Year:

It is the distance traveled by light in one year.

Speed of light ~ 300,000 kilometers/sec

So in one hour lights travels = 300,000 x 3600 Km
in one day = 300,000 x 3600 x 24 Km
in one year = 300,000 x 3600 x 24 X 365
= 9.5 x 10^{12} Km

How do we get information about heavenly bodies when they are so far??

It's light.
What is light and its Nature

Light is an (or part of) electromagnetic radiation and shows dual nature

Wave (radiation) (transfer of energy without physical movement)

Particle (photon) (energy packets “photons” interact physically)

Wave Motion

Wave is a pattern of up-and-down motion
Examples of waves

- Sound waves, water waves, light waves, radio waves, TV waves etc.
- The fundamental difference between radiation and other waves is that radiation needs no medium to travel.
- E.g. sound and water waves need medium to travel but light, radio and TV waves don’t.

Wave Properties

- **Wavelength**: distance between two adjacent crests or troughs. (Meters)
- **Amplitude**: maximum departure from the undisturbed state.
- **Wave period**: number of seconds needed for the wave to repeat itself.
- **Wave frequency**: number of crests passing any given point per unit time. (cycles per sec: Hertz -- Hz)

\[
\text{frequency} = \frac{1}{\text{period}}
\]

\[
wavelength \times \text{frequency} = \text{velocity}
\]
Formation of radiation

- Radiation is produced by an accelerated electrical charged particles.

Electrical charge is a fundamental property of matter.

- Electrons and protons are elementary particles that carry equal and opposite electrical charges ---- *building blocks.*

An electrically charged particle exerts an *electrical force* on every other charged particle in the universe.

But unlike the gravitational force, which is always attractive, electrical forces can be either attractive or repulsive.

- The *electrical force* exerted by the particle on other charged particles is determined by an *electric field* that extends outward in all directions from the particle.

- Vibrations in the particle (due to heat or collision) cause the electric field to change which in turn causes the electric force exerted on other particles to change.

- By measuring the change in force on these other charges, we learn about our original particle.

- Magnetic field must accompany every changing electric field.
**Electromagnetic Radiation**

Electric and magnetic fields vibrate perpendicular to each other and move perpendicular to the direction of motion with the speed of light.

**Speed of electromagnetic waves**

- All electromagnetic waves move at a very specific speed called *speed of light* \((c)\) \(\sim 300,000\) km/s. *Speed of light (EM waves) is the fastest speed possible, known by now.*
- The speed of light does not depend upon direction or frequency.
- In a vacuum: A CONSTANT OF NATURE. \((V = c)\)
- In matter (air or water etc.): SOMEWHAT LESS \((V < c)\)
The Electromagnetic Spectrum

- Visible light is the particular type of electromagnetic radiation --- to which our eyes happen to be sensitive.

- There is also invisible EM radiation, which goes undetected by our eyes. These are radio, infrared, ultraviolet, x rays and gamma rays.

- The only characteristic distinguishing one from another is wavelength or frequency.

- All these radiation including visible light collectively make electromagnetic spectrum.

Electromagnetic Spectrum

Water vapor & oxygen

Water vapor & carbon dioxide. **Ozone layer**

- Opacity is just the opposite of transparency.

- The more opaque an object is, the less radiation gets through it.

- In our case, object is --Earth’s atmosphere.
White (visible) light is composed of many colors (6 major hues).

Example: each drop of water acts like a prism to create a rainbow.

Distribution of Radiation

- **Intensity**: amount or strength of radiation. This is a basic property of radiation.
- The characteristic distribution of intensity versus frequencies is called **blackbody curve**.
- **Blackbody**: is an ideal body which reemit the same amount of energy it absorbs.
- **Temperature**: is the direct measure of heat or motion of constituent particles.
• *Gabriel Daniel Fahrenheit*, a German-born scientist, invented the mercury thermometer in 1714 in Holland, where he lived most of his life. He introduced a scale on which the freezing point of water was 32 degrees and the boiling point was 212 degrees. Zero Fahrenheit was the coldest temperature that he could create with a mixture of ice and ordinary salt.

• *Anders Celsius*, a Swedish astronomer, introduced his scale is 1742. For it, he used the freezing point of water as zero and the boiling point as 100. For a long time, the Celsius scale was called "centigrade".

• *William Thomson, Lord Kelvin*, a British scientist determined that the coldest we can go (theoretically) is minus 273.15 degrees Celsius. The value, minus 273.15 degrees Celsius, is called "absolute zero". At this temperature scientists believe that molecular motion would stop. You can't get any colder than that. The Kelvin scale uses this number as zero. To get other temperatures in the Kelvin scale, you add 273 degrees to the Celsius temperature.

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**Conversions between temperature scales**

**kelvin / degree Celsius conversions:**

- kelvins = degrees Celsius + 273.15
- degrees Celsius = kelvins - 273.15

**degree Fahrenheit / degree Celsius conversions:**

- degrees F = degrees C x 1.8 + 32
- degrees C = (degrees F - 32) / 1.8
Radiation laws

Wien’s law
wavelength of peak emission \( \lambda_{\text{max}} \) \( \propto \frac{1}{T} \)

Stenfan’s law
total energy emission \( F \) \( \propto T^4 \)

Doppler Effect
An observed wavelength or frequency will differ from the emitted one if there is a relative motion between the emitter and the observer.

- Recession \( \rightarrow \) the observed wavelength is longer, or frequency is lower \( \rightarrow \) redshift
- Approach \( \rightarrow \) the observed wavelength is shorter, or frequency is higher \( \rightarrow \) blueshift
The Doppler Effect
• e.g. Sound - Pitch of train whistle drops as it passes - this also happens with light.
• An observed wavelength or frequency will differ from the emitted one if there is a relative motion between the emitter and the observer.

- Sees shorter wavelength ("blueshifted")
- Sees longer wavelength ("redshifted")
- No shift

Formula using Doppler Effect
\[
\frac{\text{apparent wavelength}}{\text{true wavelength}} = \frac{\text{true frequency}}{\text{apparent frequency}} = 1 + \frac{\text{recession velocity}}{\text{wave speed}}
\]

• Apparent wavelength and frequency are measured by the observer.
• True wavelength and frequency are true/real quantities emitted by the source.
• The wave speed is the speed of light c in the case of EM radiation.
• A positive recession velocity means that the source and the observer are moving apart; a negative value means that they are approaching.