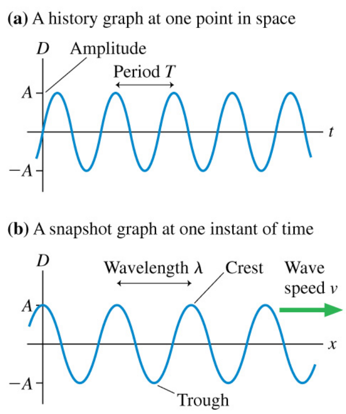
LIGHT

Light

Light has wave-like characteristics.
Light has particle-like characteristics.
Light can identify the elements present.
The motion of a light source affects wavelengths.
Emitted light depends upon the object's temperature.

Wave-like Characteristics



Wavelength: Distance between successive crests (λ).

$1\ \text{nm} = 10^{-9}\ \text{m}$

$1\ \text{Å} = 0.1\ \text{nm} = 10^{-10}\ \text{m}$

Frequency: Number of crests that pass a specific point in one second (ν *or* f).

Speed: Frequency times Wavelength (c)

$c = \lambda\,\nu = 3 \times 10^5\ \text{km/s}$

$= 3 \times 10^8\ \text{m/s}$

Example

Yellow Light

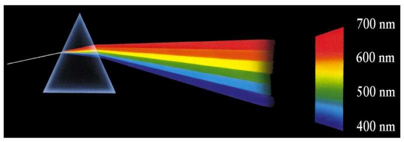
$\nu = 6.0 \times 10^{14}\ /\text{s}$

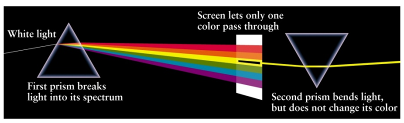
$c = \nu\,\lambda$ so $\lambda = c / \nu$

$= (3 \times 10^8\ \text{m/s}) \;/\; (6.0 \times 10^{14}\ /\text{s})$

$= 5.0 \times 10^{-7}\ \text{m} = 540\ \text{nm}$

Visible Light



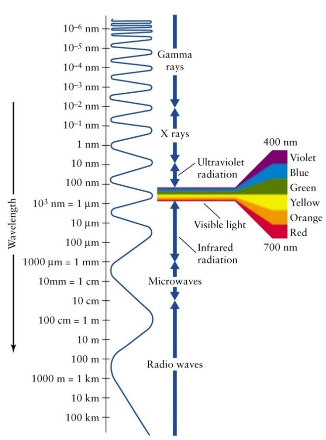


Visible or Optical Light

Range from 700 nm (Red) to
400 nm (Violet)

White light is a combination of these colors. Newton's experiment proved that prisms do not add color.

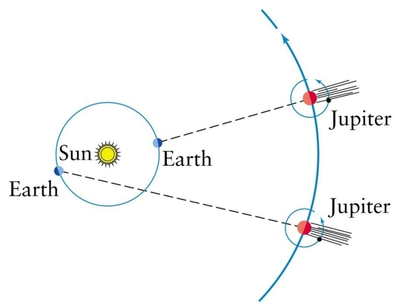
Electromagnetic Spectrum



Wavelength Ranges

Gamma	0.01 nm
X-rays	0.01 to 20 nm
Ultraviolet	20 to 400 nm
Visible	400 to 700 nm
Infrared	700 nm to mm
Microwave	mm to cm
Radio wave	cm to km

Measuring the Speed of Light



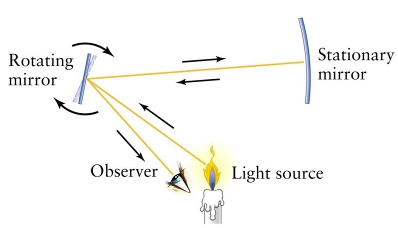
Olaus Roemer (1675) timed when moons disappeared into Jupiter's shadow.

Eclipses were retarded when Earth was far away.

Showed light did not travel infinitely fast.

Did not know the Earth-Sun distance, so he could not compute the speed of light.

Measuring the Speed of Light



Jean Foucault (1850) used a rapidly rotating mirror.

One must measure the deflection angle and know the speed of the rotating mirror.

Accuracy was better than 1%.

Modern Value

c = 299,792.458 km/s

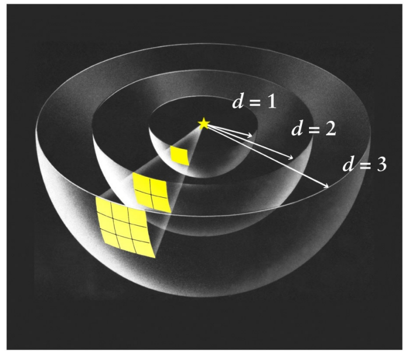
Propagation of Light

Apparent Brightness

Flux = Luminosity / $4 \pi d^2$

Inverse Square Law

$$\frac{Flux_1}{Flux_2} = \frac{4 \pi d_2^2}{4 \pi d_1^2} = \frac{d_2^2}{d_1^2}$$



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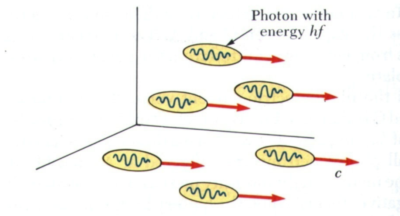
Photoelectric Effect

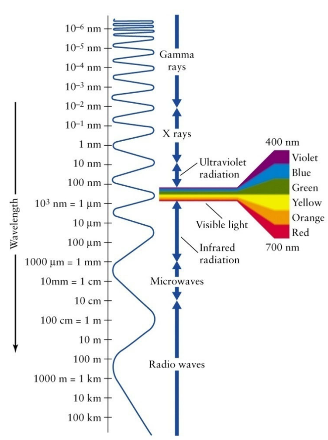


Einstein (1905) analyzed the Photoelectric Effect. He assumed that light can be considered a stream of photons. Each photon has an energy equal to:

$$E = h\nu = hc/\lambda$$

$$h = 6.625 \times 10^{-34} \text{ J s}$$

Electromagnetic Spectrum



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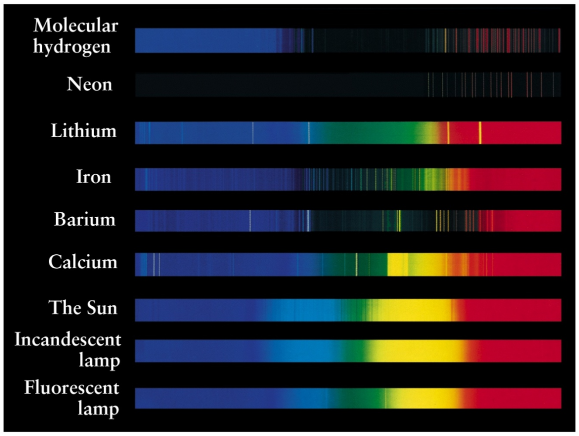
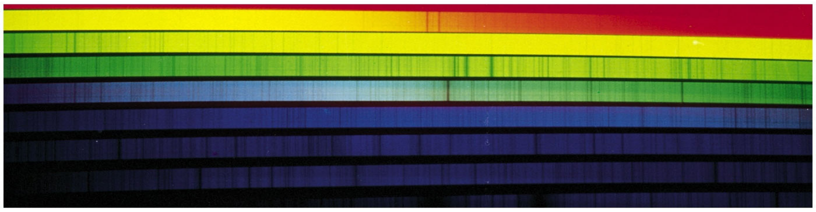
Spectra of Different Elements



Each element has its own unique set of spectral lines.

Solar Spectrum



Fraunhofer (1814)   Shined sunlight through a prism and highly magnified the spectrum. He saw 600 dark lines.

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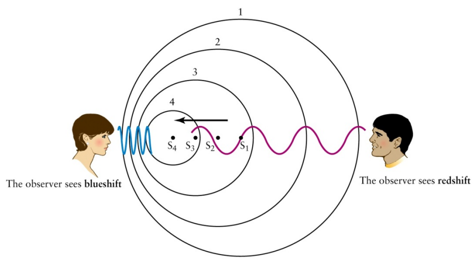
Doppler Shift



If a light source is approaching or receding from the observer, the light waves will be, respectively, crowded closer together or spread out. The Doppler effect is only produced by **radial velocities**.

$$\Delta\lambda / \lambda = v / c$$

$$(\lambda_{obs} - \lambda_{rest}) / \lambda_{rest} = v / c$$

$$v = c\ \Delta\lambda / \lambda$$

Example

The motion of the Earth in its orbit produces a Doppler Shift. Assume one is observing a star while moving directly at it. Therefore, the Earth's v = -30 km/s. Let's use λ_{rest} = 600 nm. Calculate $\Delta\lambda$ and the observed λ.

$$\Delta\ \lambda / \lambda = v / c$$

$$\Delta\lambda = (600\ \text{nm})\ (-30\ \text{km/s}) / (3 \times 10^5\ \text{km/s})$$

$$\Delta\lambda = -0.06\ \text{nm} = \lambda_{observed} - \lambda_{rest}$$

$$\lambda_{observed} = -0.06\ \text{nm} + \lambda_{rest} = 599.94\ \text{nm}$$

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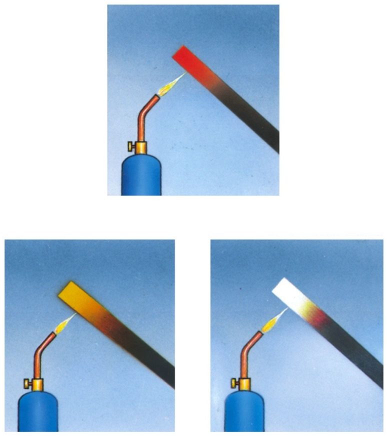
Color Indicates Temperature

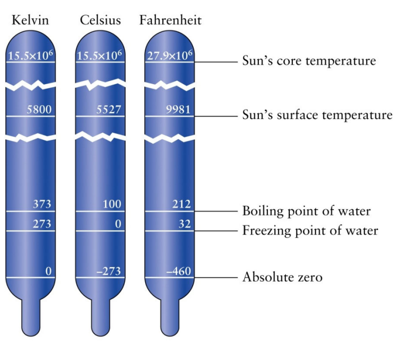
Temperature Effects



Temperature determines the type of electromagnetic radiation emitted. Temperature is a measure of the average motion of the gas molecules.

Electromagnetic radiation is emitted when electric charges accelerate – that is, whenever they change either the speed or the direction of their motion. Each collision results in the emission of radiation.

Temperature Scales



Kelvin Temperature Scale

Coldest Temperature = 0 K (no atomic motion)

No negative temperatures

No degree symbol – just K