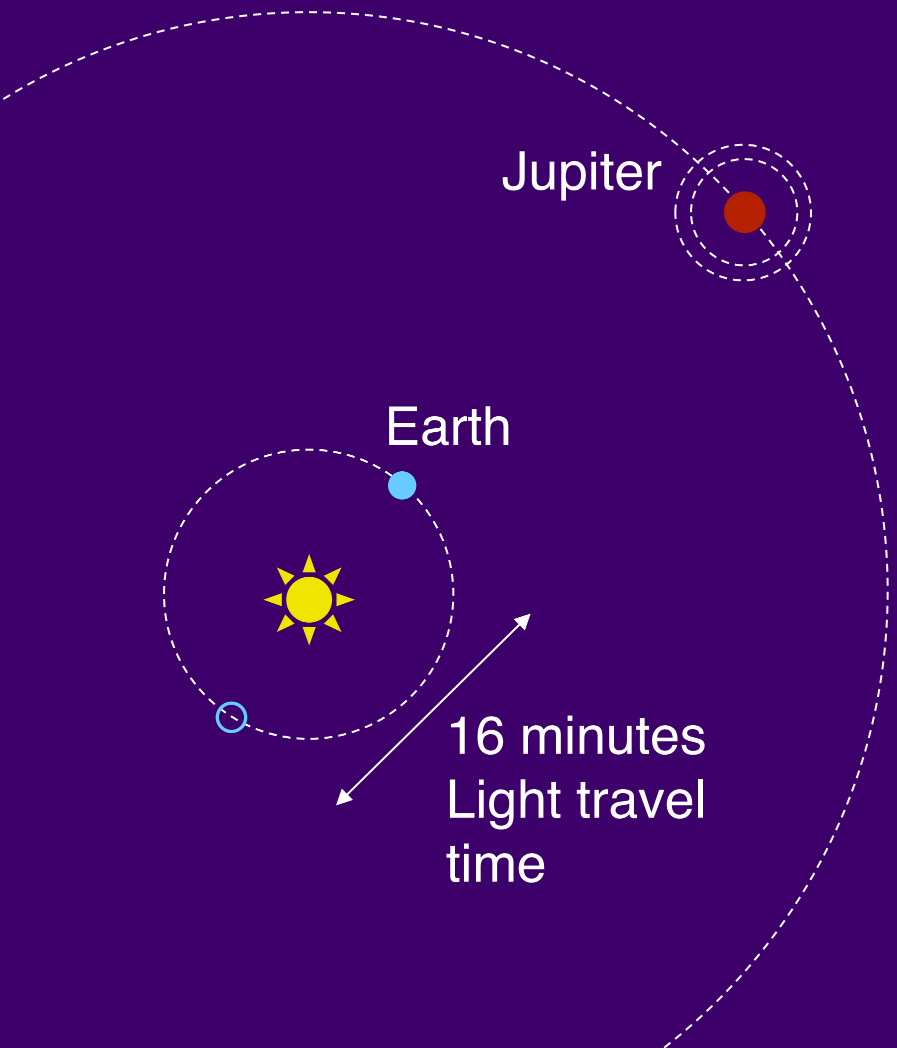
The Physics of Light

How fast does light travel?

- With today’s fast electronics, it’s easy to measure the time for a pulse of light to cross an ordinary room (billionths of a second).
- First measurement of the speed of light was by an astronomer: Olaus Roemer, 1675.

Jupiter’s moons seem to orbit faster when earth is moving toward Jupiter, slower when earth is moving away.

How fast does light travel?



Jupiter’s moons appear to get 8 minutes ahead of schedule when we’re close, 8 minutes behind schedule when we’re on the far side.

So light must take 8 minutes to travel 1 AU.

(Size of 1 AU was measured around 1700, by triangulating Mars, Venus from 2 locations on earth, with aid of telescopes.)

Speed of Light

300,000,000 meters per second (m/s)

or 3×10^8 m/s or 300,000 km/s

Example: How long does it take light to reach you from the screen/dome?

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

$$\rightarrow \quad \text{time} = \frac{\text{distance}}{\text{speed}} = \frac{6\ \text{m}}{3 \times 10^8\ \text{m/s}} = 2 \times 10^{-8}\ \text{s}$$

$$= 0.00000002\ \text{s}$$

(Be sure that you know how to use your calculator!)

How to quantify brightness?

Light carries ENERGY.

What *is* energy?

I don't know.

Types of energy

Motion ("kinetic")

Gravitational

Elastic

Thermal

Chemical

Nuclear

Electrical

Radiant (light)

Energy can be *converted* from one type to another, but cannot be created or destroyed. The total amount of energy in the universe never changes.

Units of energy

1 joule (official scientific unit; apple lifted 1 meter)

1 Calorie (food) = 4200 joules (1 kg water, up 1°C)

1 Jelly Donut = 250 Calories = 10^6 joules ($0.59)

1 BTU = 1050 joules (1 lb water, up 1°F)

1 kilowatt-hour = 3.6 million joules (7 cents)

1 gallon of gasoline provides 30,000 Calories ($3.00)

Typical American diet per day = 10 J.D.

Power = Rate of energy conversion

= energy / time

Power is measured in *watts*:

1 watt = 1 joule / second

(1 kilowatt = 1000 watts; 1 horsepower = 750 watts; *you* convert energy at a rate of about 100 watts.)

The "brightness" of a light source is really its power, measured in watts. The "intensity" of light striking a surface is measured in watts per square meter.

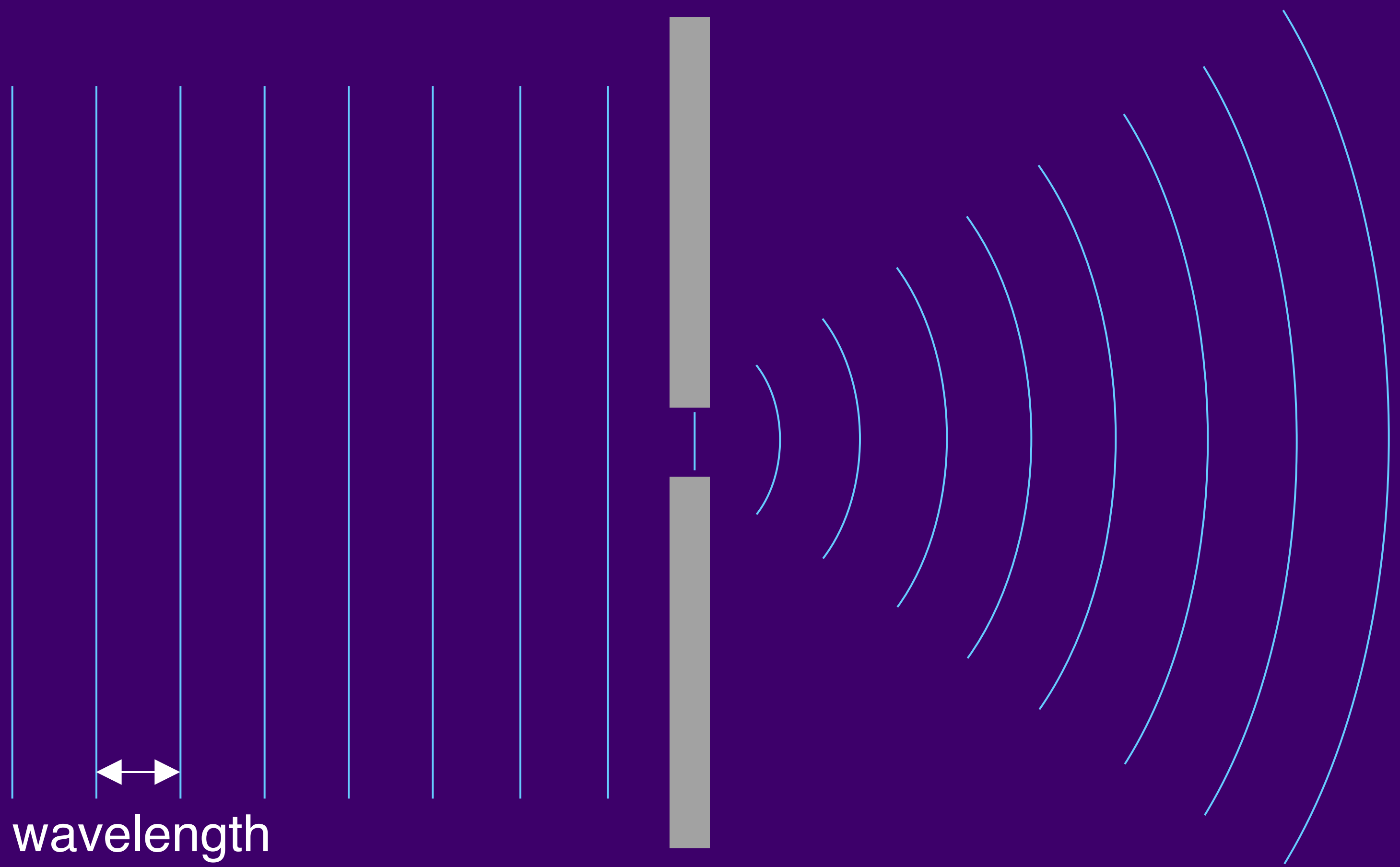
Example: The power of our sun is about 4×10^{26} watts; the intensity of direct sunlight at earth's surface is about 1000 watts per square meter.

Light as a Wave

What *is* light (particles or waves?)

It behaves like both!

Water waves:

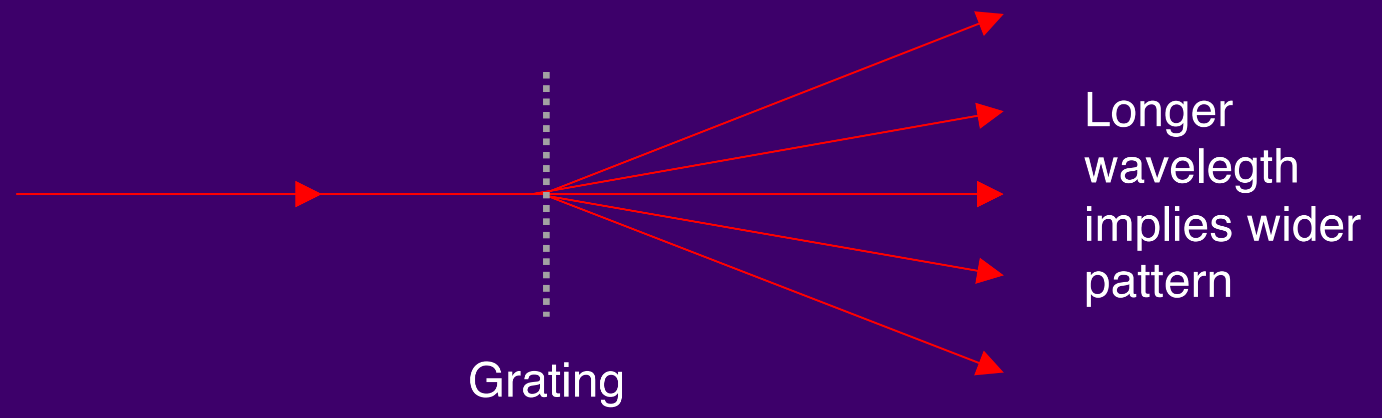


“Diffraction”

Waves can spread out, bend around barriers, and cancel each other out.

Light does all these things, so we say it’s a wave, even though we don’t see the waves themselves.

To measure wavelength, use a “diffraction grating”:



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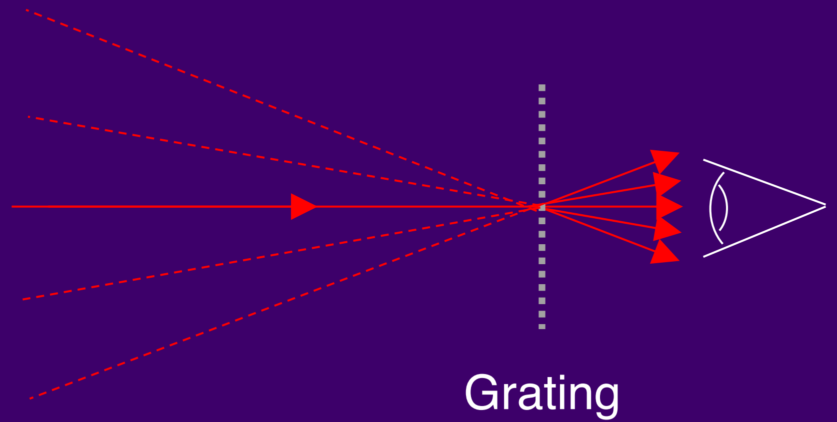
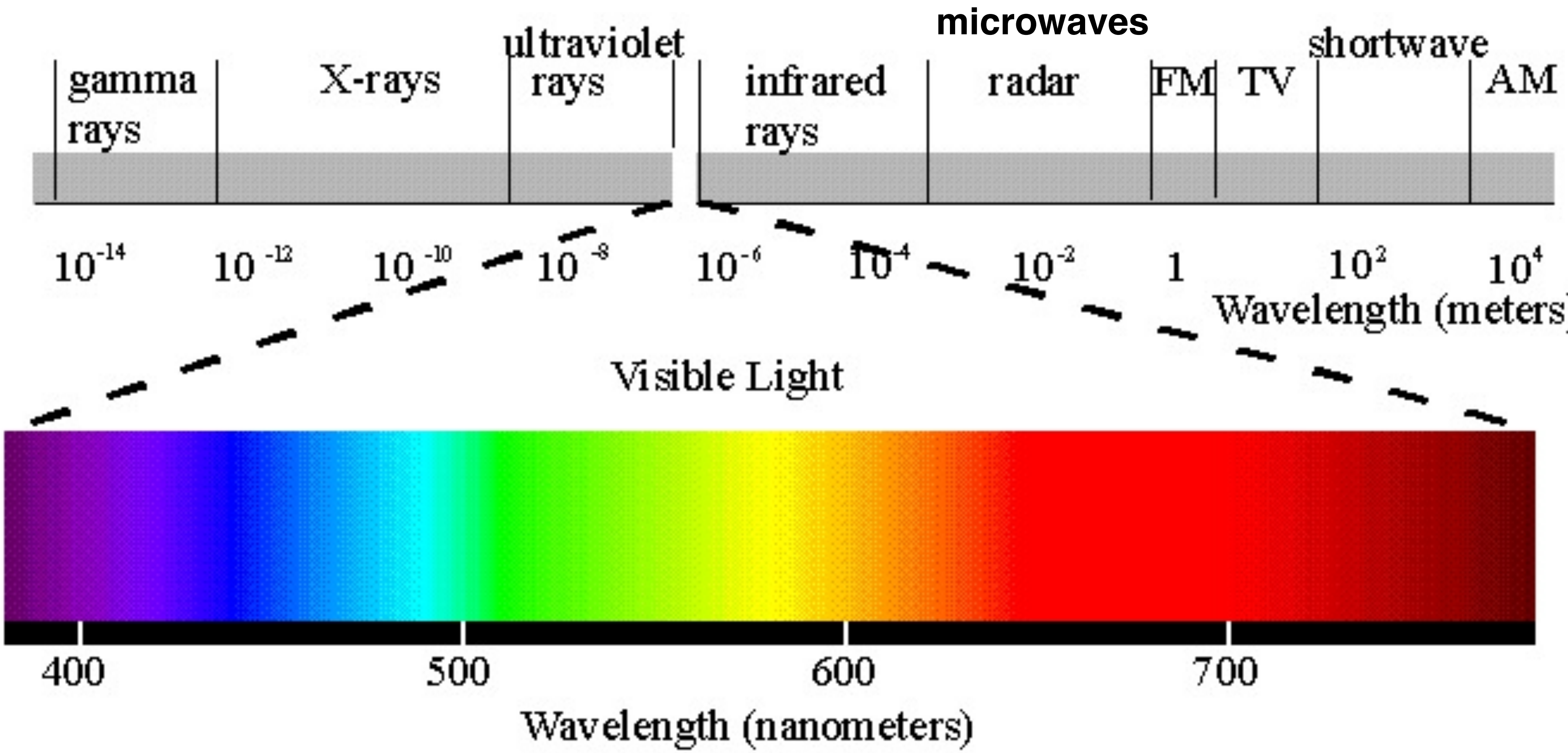
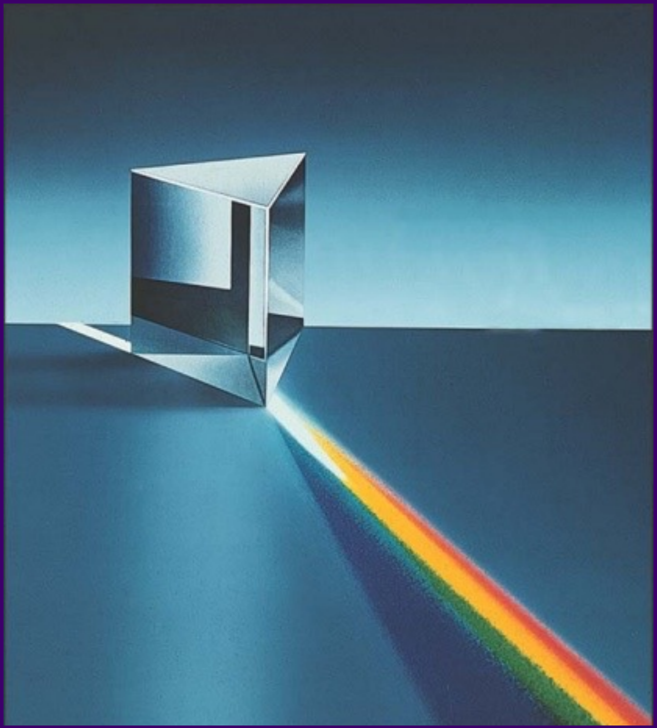


With light, wavelength determines *color*



Most “colors” are invisible to our eyes!

White light is a *mixture* of the visible colors



Visible range: 400 nanometers (violet)
to 700 nanometers (red)

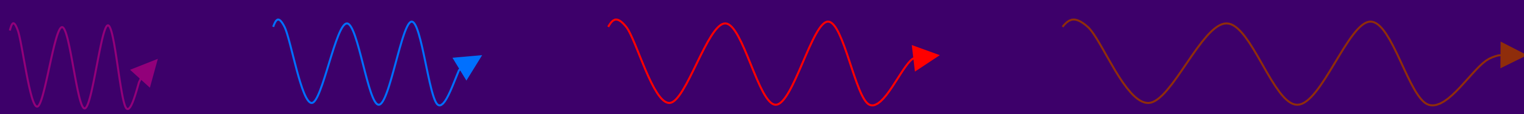
(1 nanometer (nm) = 10^{-9} meters)

Light also behaves like particles ("photons")

A 100-watt bulb emits 3×10^{20} photons per second

The energy *per photon* depends on the wavelength of the light: shorter wavelength (faster "wiggling") implies *higher* energy per photon.

So a blue photon packs more punch than a red photon; an ultraviolet photon can break molecules apart, and an x-ray photon is still more energetic.



ultraviolet | blue | red | infrared

highest energy | lowest energy