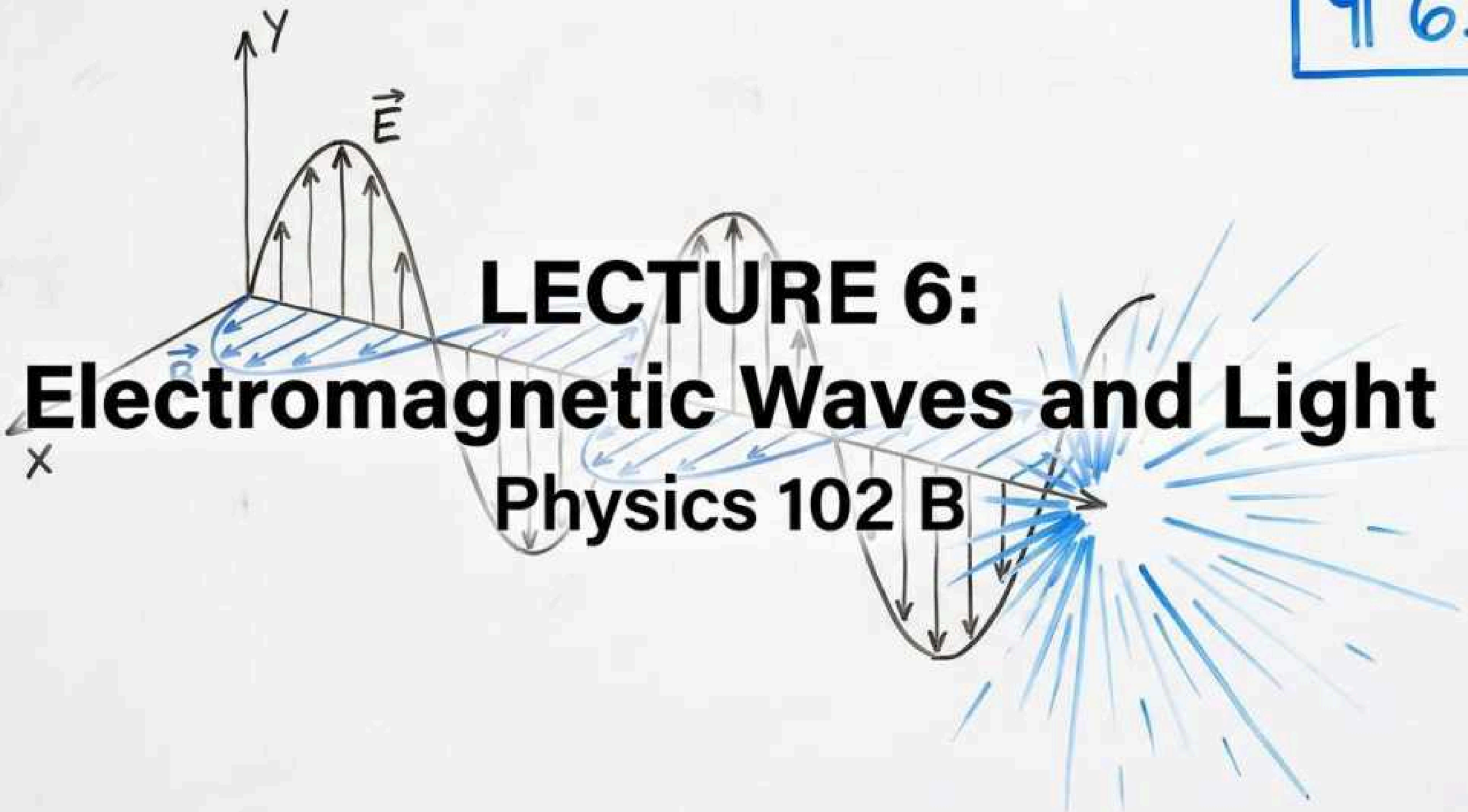
¶ 6.1



LECTURE 6:
Electromagnetic Waves and Light
Physics 102 B

Gemini Notebook

¶ 6.2

The Great Unification

Maxwell's Equations

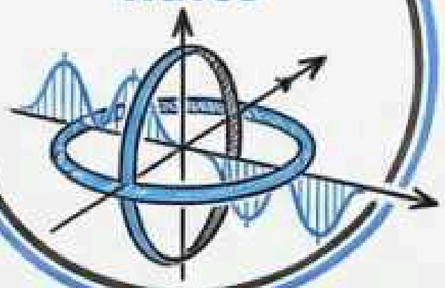
$$\left[\vec{\nabla}\cdot\vec{E}=\frac{\rho}{\varepsilon_0}\right] \quad \left[\vec{\nabla}\cdot\vec{B}=0\right]$$

$$\left[\vec{\nabla}\times\vec{E}=-\frac{\partial\vec{B}}{\partial t}\right] \quad \left[\vec{\nabla}\times\vec{B}=\mu_0\vec{J}+\mu_0\varepsilon_0\frac{\partial\vec{E}}{\partial t}\right]$$

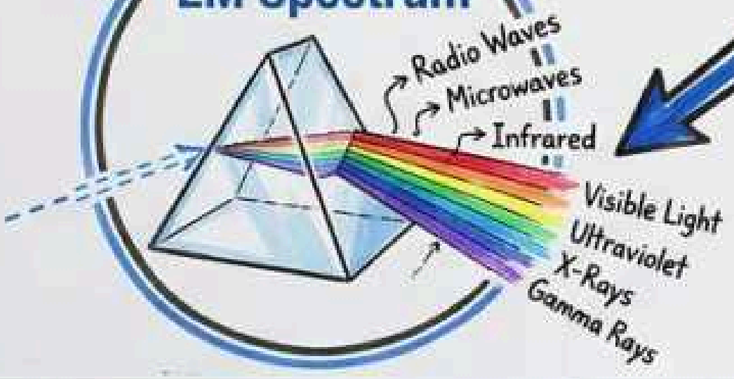
Photons



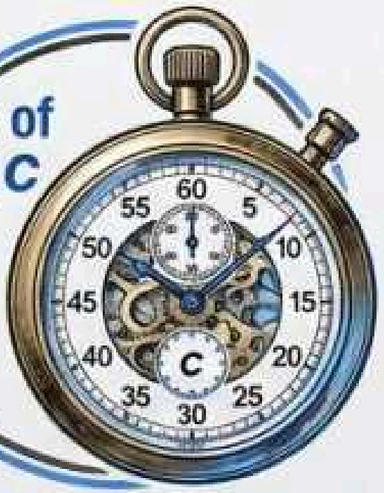
Self-Sustaining Waves



EM Spectrum



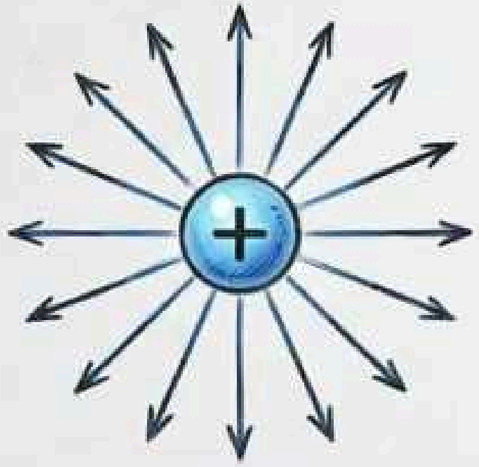
Speed of Light, *C*



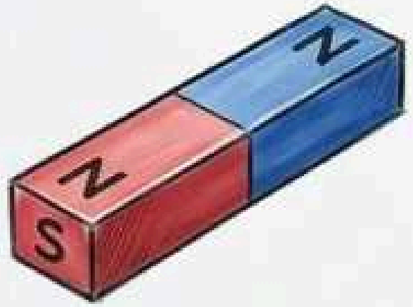
Gemini Notebook

¶ 6.3

Electric charges –> Electric fields (Gauss)



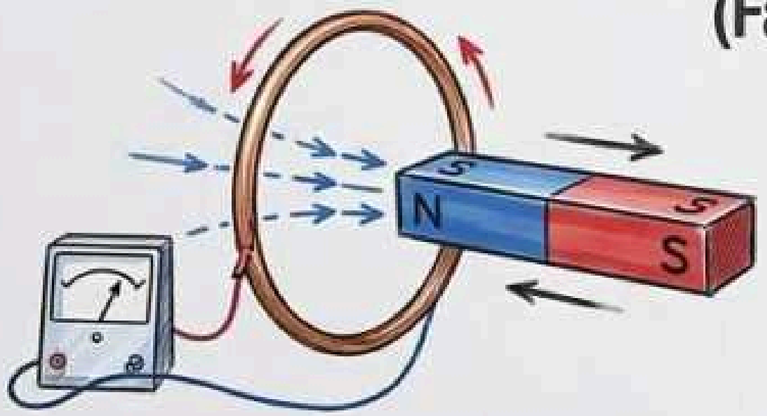
No magnetic monopoles (Gauss)



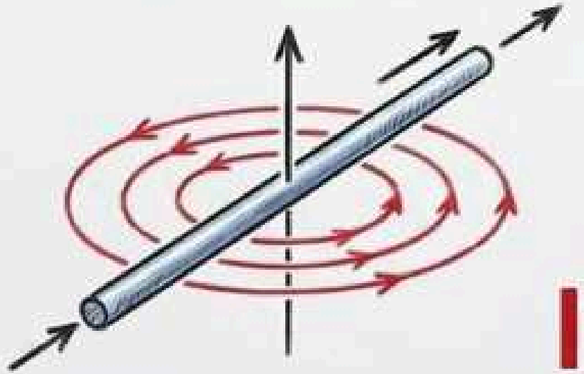


isolated North pole

Changing magnetic field → Electric field (Faraday)



Current → Magnetic field (Ampere)





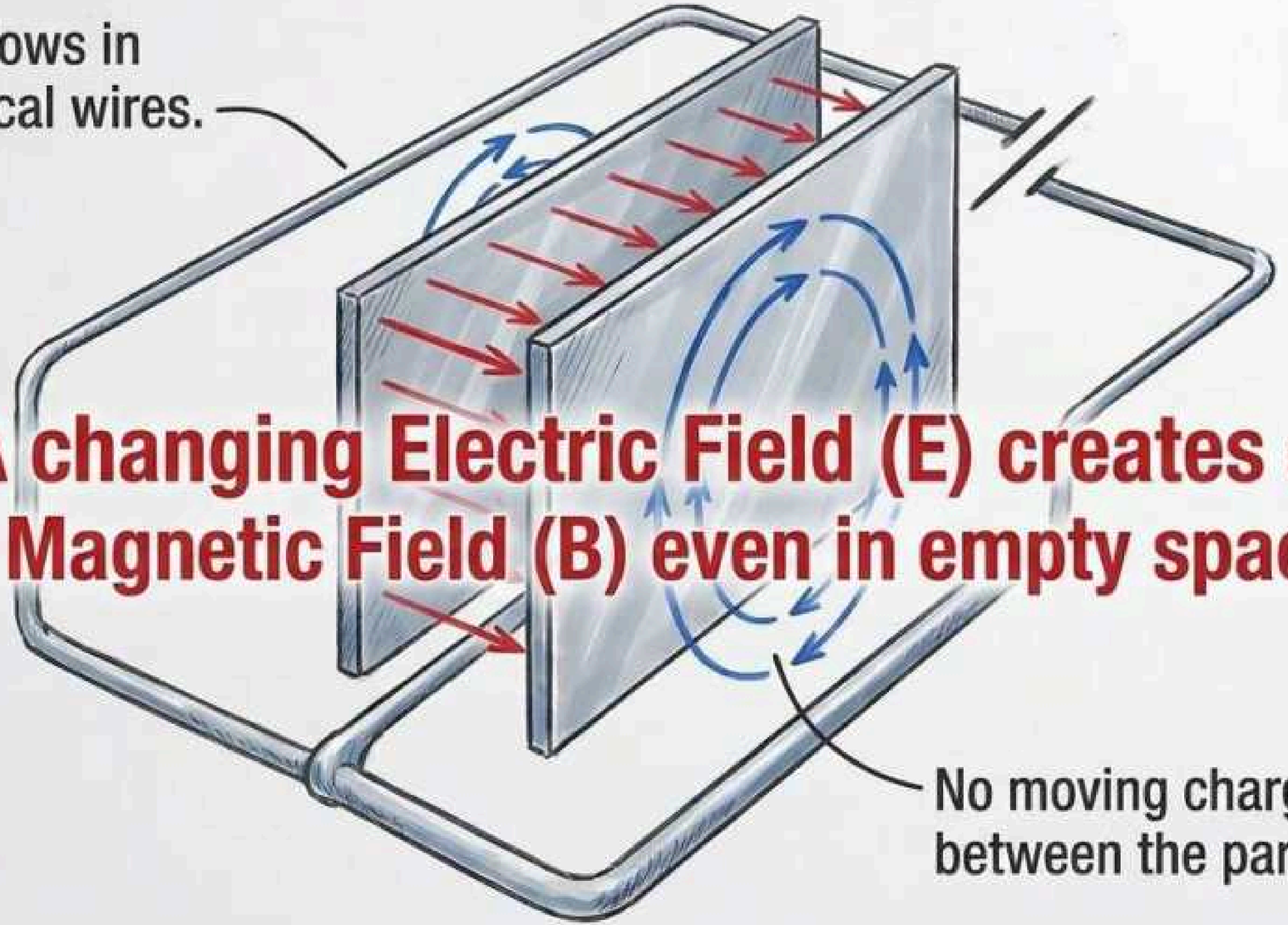
Incomplete

James Clerk Maxwell noticed a fatal asymmetry in these four facts.

Gemini Notebook

¶ 6.4

Current flows in the physical wires.



A changing Electric Field (E) creates a Magnetic Field (B) even in empty space.

No moving charge exists between the parallel plates.

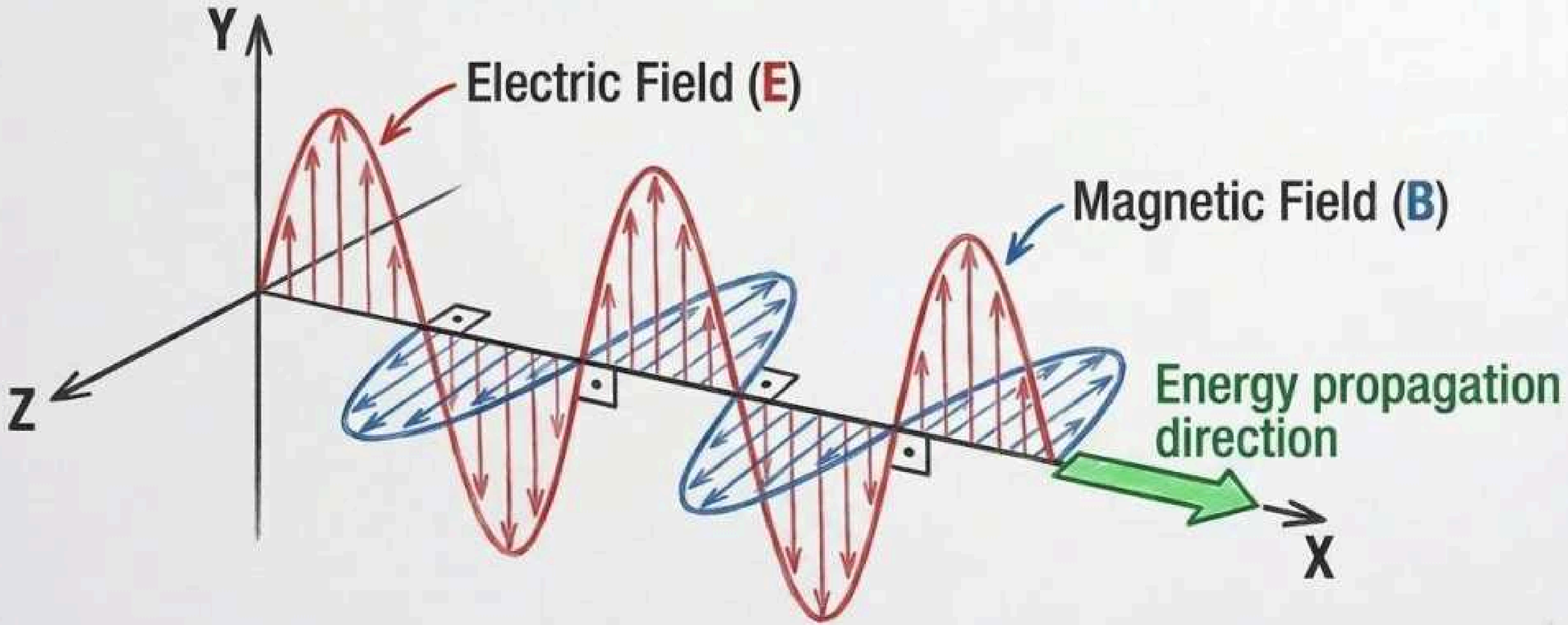
The equations are now symmetric.

Gemini Notebook

Sustaining the Wave

¶ 6.5

Shake a charge -> Disturbance spreads outward.



Gemini Notebook

¶ 6.6

$$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$$

$c = 2.998 \times 10^8$ m/s

Magnetic constant (derived from measuring magnets).

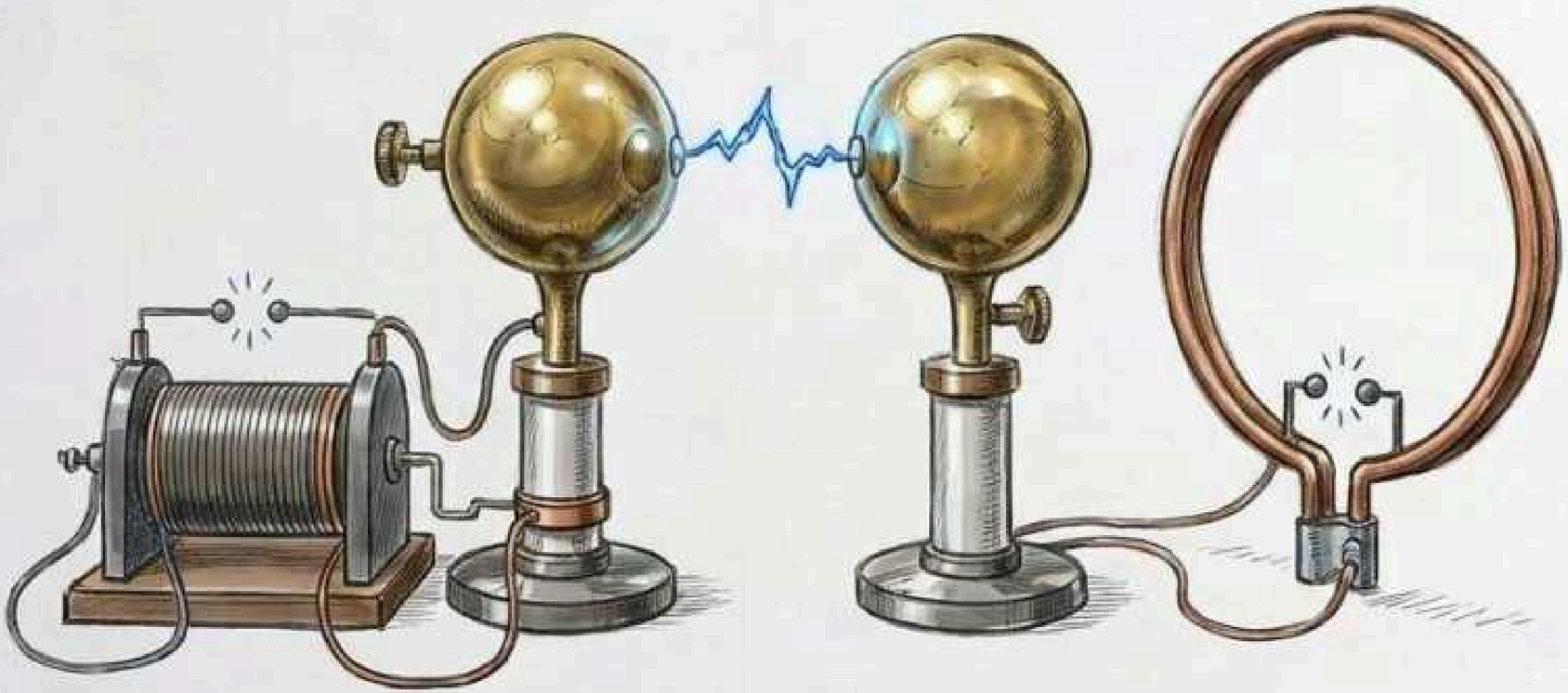
Electric constant (derived from measuring capacitors).

This purely theoretical calculation perfectly matched the known, measured speed of light.

Gemini Notebook

1888 — Heinrich Hertz experimentally generates radio waves (proving light is an EM wave).

¶ 6.7



- EM waves reflect, refract, and travel at c.

Unit of frequency named in his honor: 1 Hertz (Hz) = 1 cycle/second.

Gemini Notebook

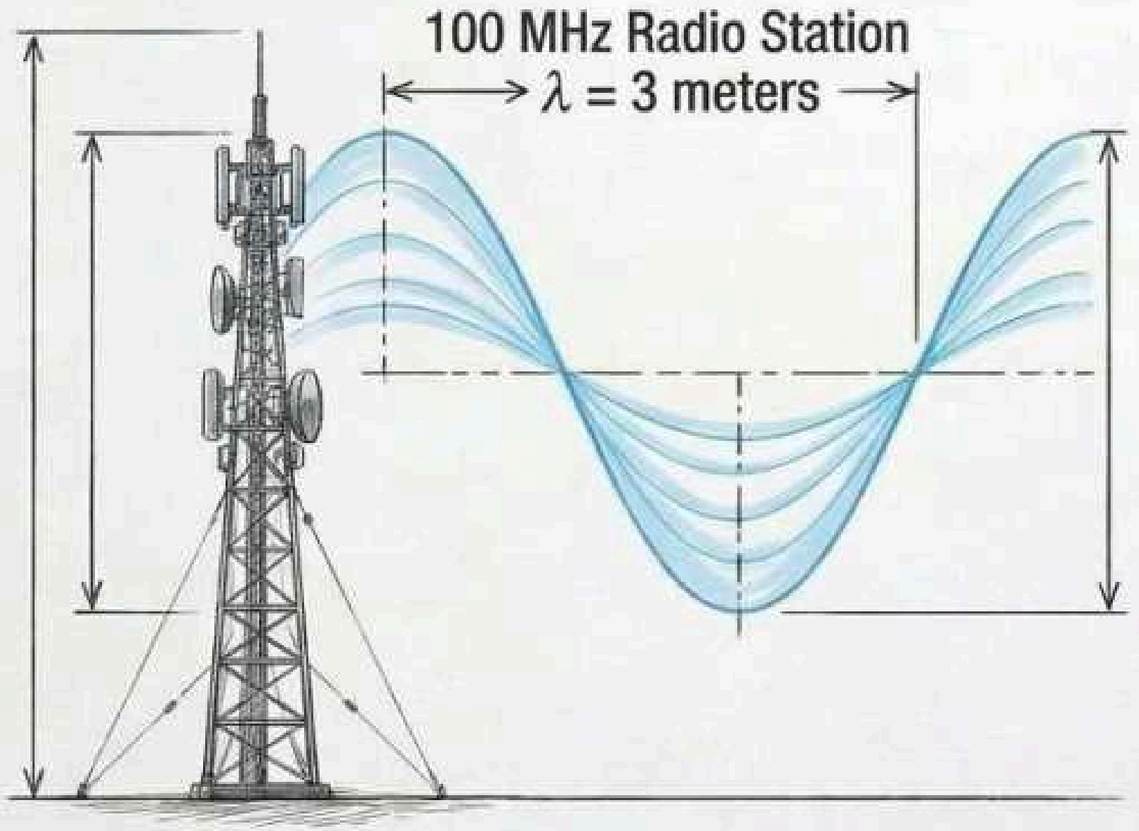
¶ 6.8

Universal Rule:

Speed = Frequency x Wavelength

$$(c = f\,\lambda)$$

Constant: $c = 3.00 \times 10^8$ m/s

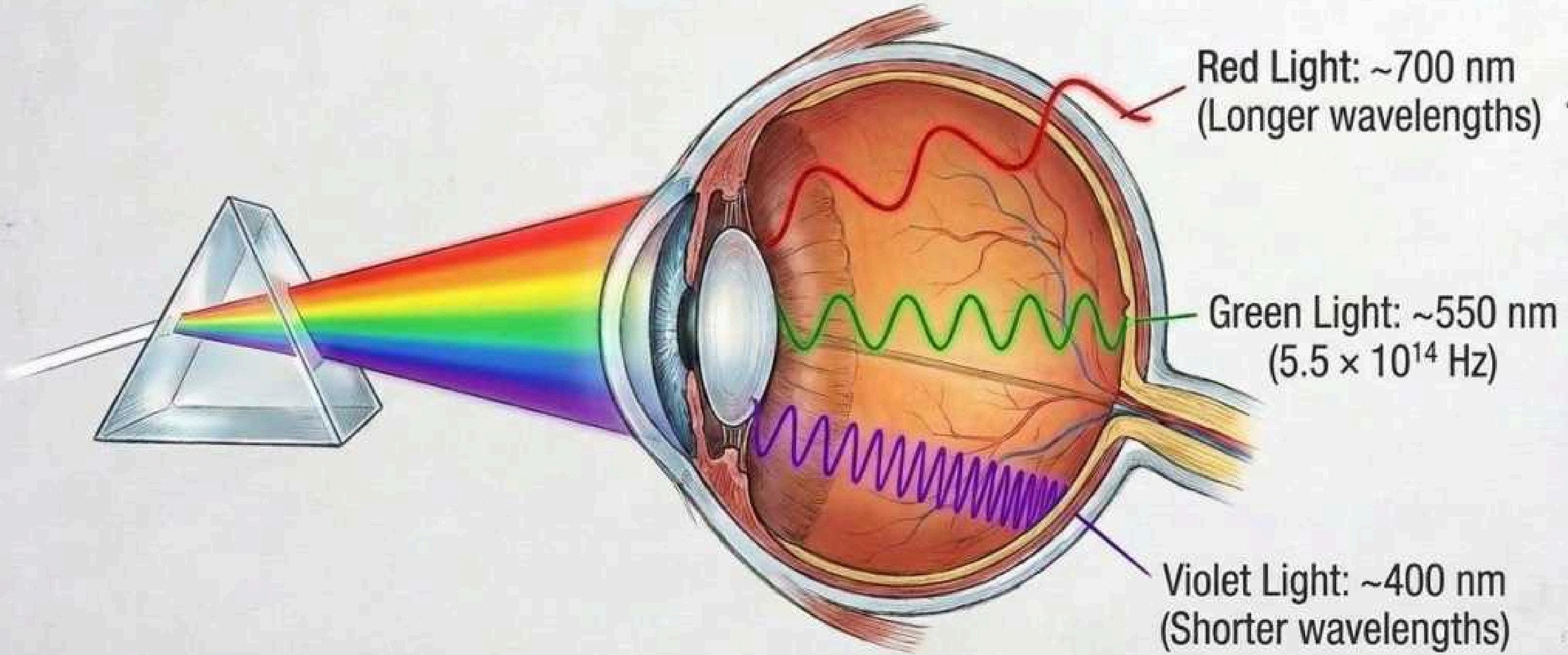


↑ Higher Frequency = ↓ Shorter Wavelength (Always)

Gemini Notebook

Visible light is a narrow band. Our eyes evolved specifically to detect the sun's strongest emitted colors.

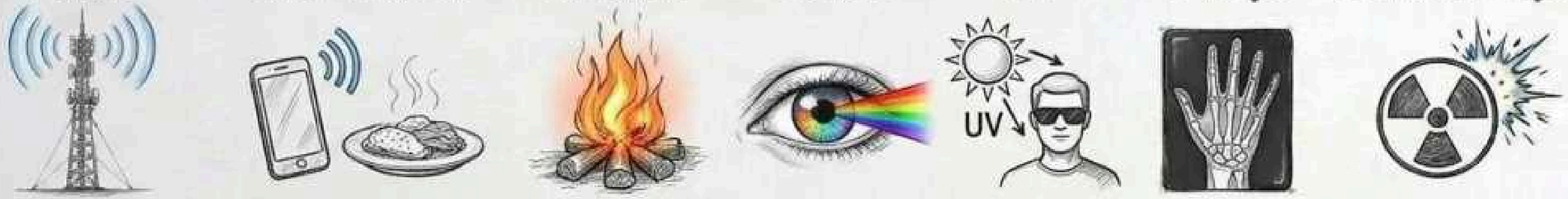
¶ 6.9



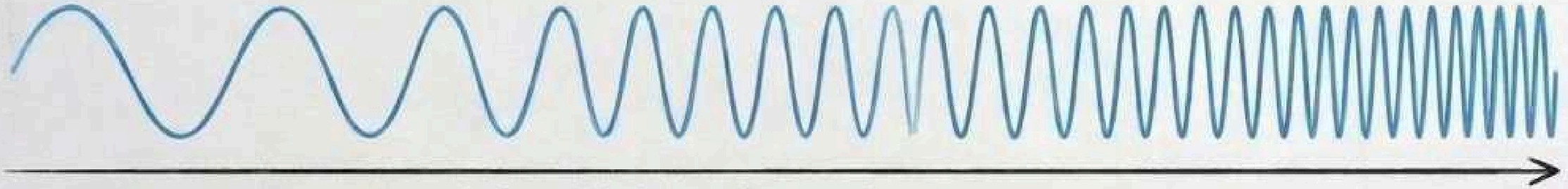
Gemini Notebook

¶ 6.10

Radio | Microwaves | Infrared | Visible | UV | X-Rays | Gamma Rays



Radio | Microwaves | Infrared | Visible | UV | X-Rays | Gamma Rays



Left to Right → Increasing Frequency

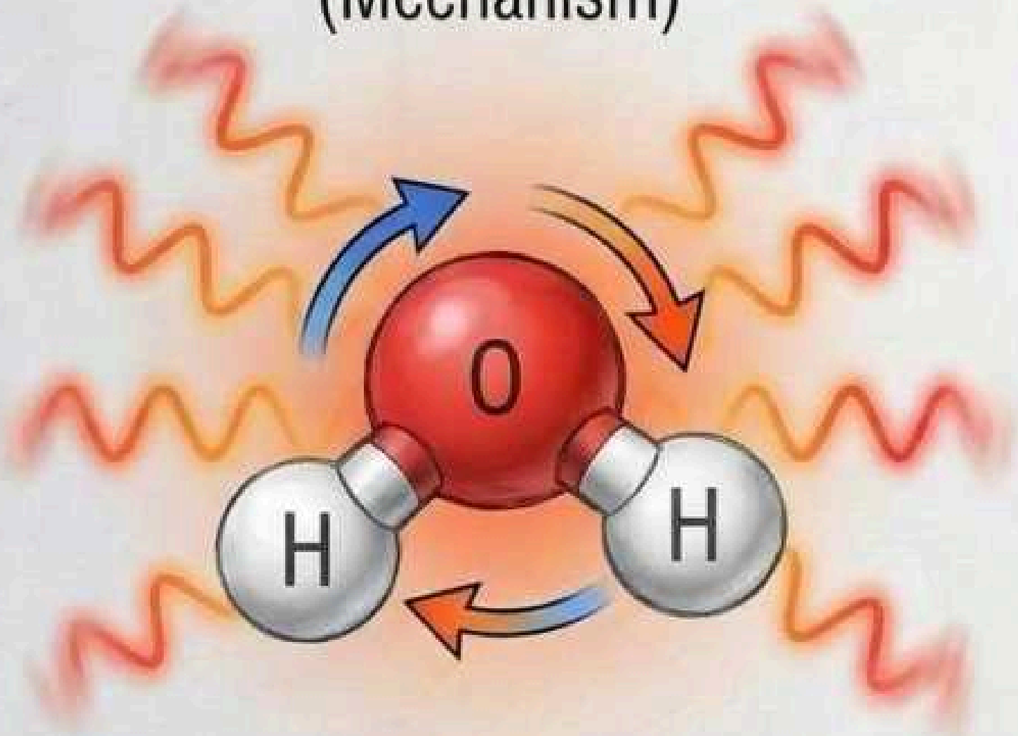
They differ only in frequency and wavelength.
In a vacuum, all travel at the same speed (c).

Gemini Notebook

~2.4 GHz = 12.5 cm wavelength (Shares frequency with Wi-Fi).

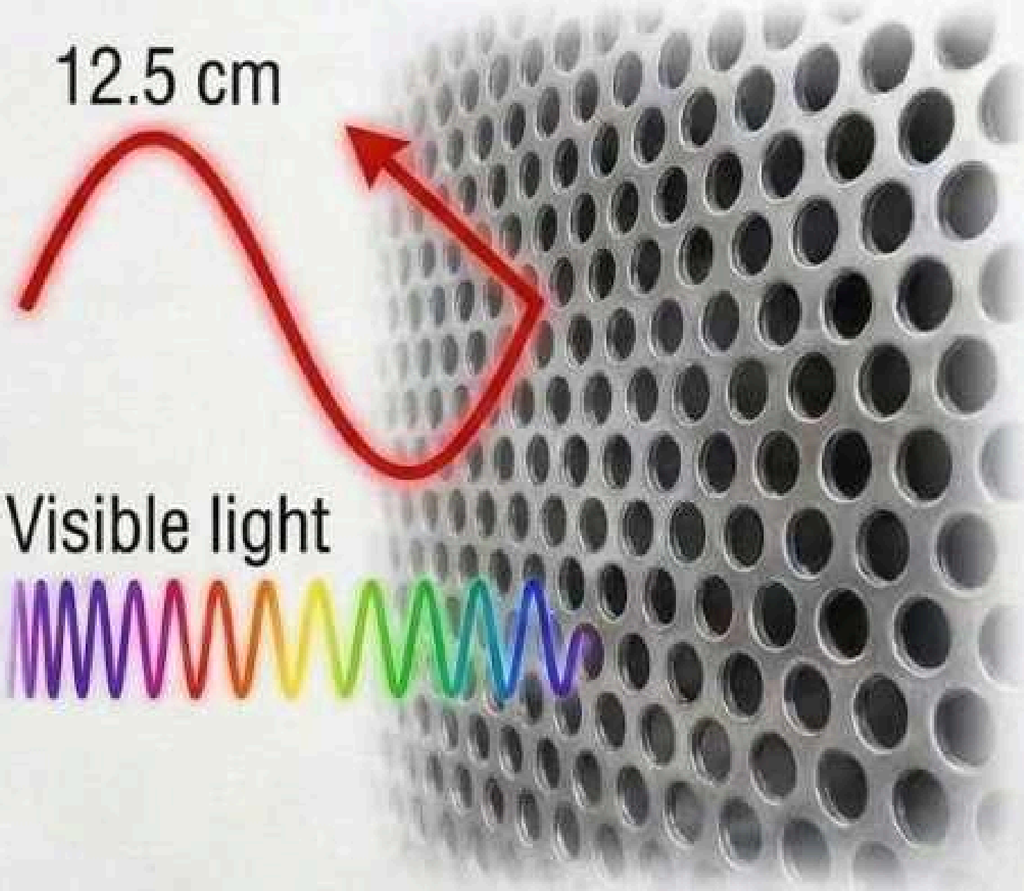
¶ 6.11

(Mechanism)



Waves rotate water molecules
→ Friction → Heat

(Containment)



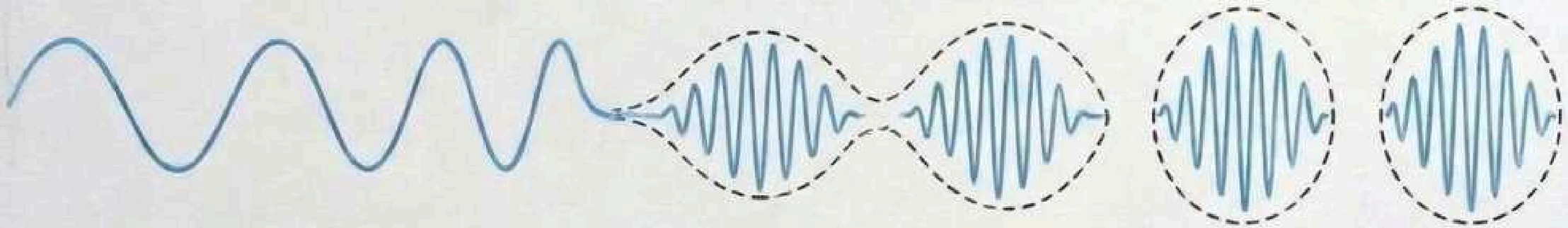
Gemini Notebook

Light also behaves as discrete particles called Photons.

¶ 6.12

$E = hf$ (Energy = Planck's constant x frequency).

A green photon carries 3.6×10^{-19} Joules (or ~2.25 eV).



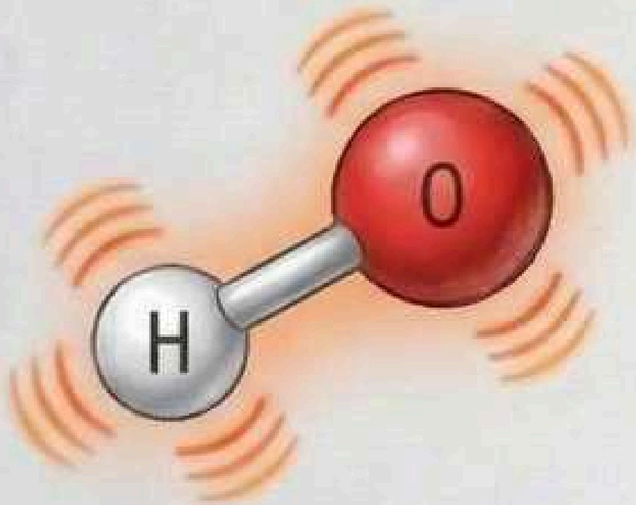
Radio — Gamma

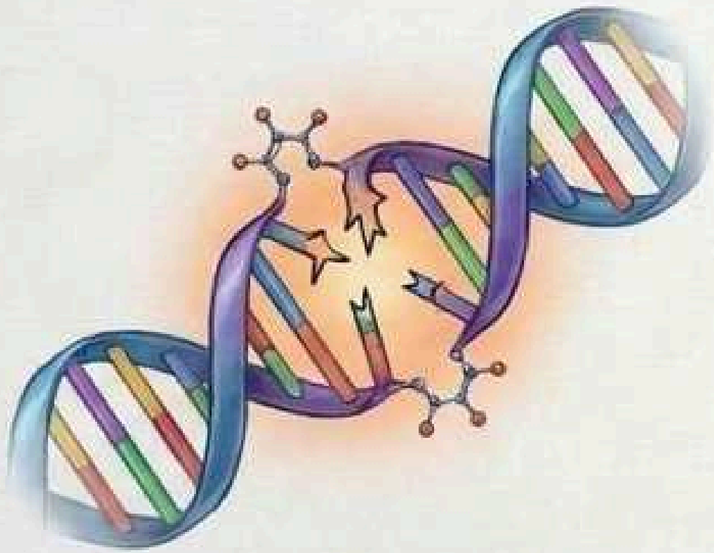
tiny energy packets — wave packets — enormous energy packets

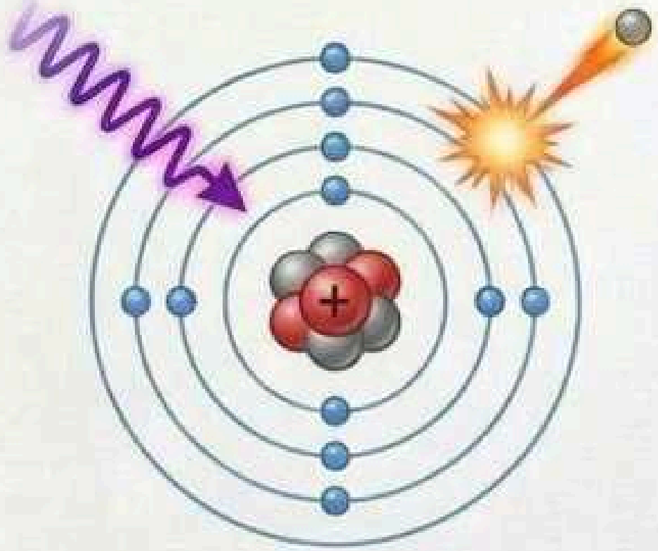
Gemini Notebook

¶ 6.13

Radio / Microwave	Ultraviolet	X-Ray / Gamma
Weak. Heats matter, cannot break bonds.	Moderate. Damages skin molecules (causes sunburn).	Extreme. Ionizes atoms; requires strict exposure limits.





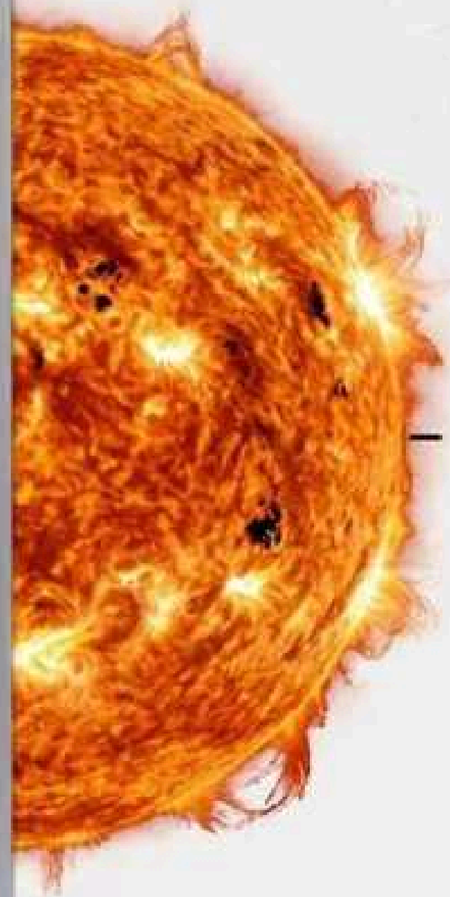


The frequency of the light matters more than its brightness.

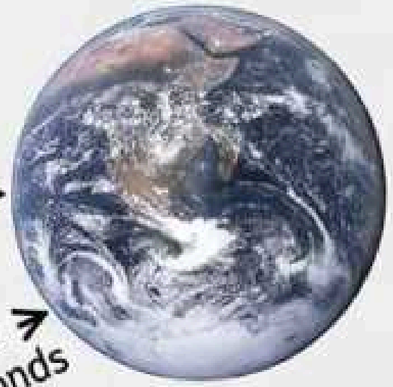
Gemini Notebook

Baseline Speed: 300,000,000 m/s.

¶ 6.14



1.5×10^{11} meters = 8 minutes, 20 seconds



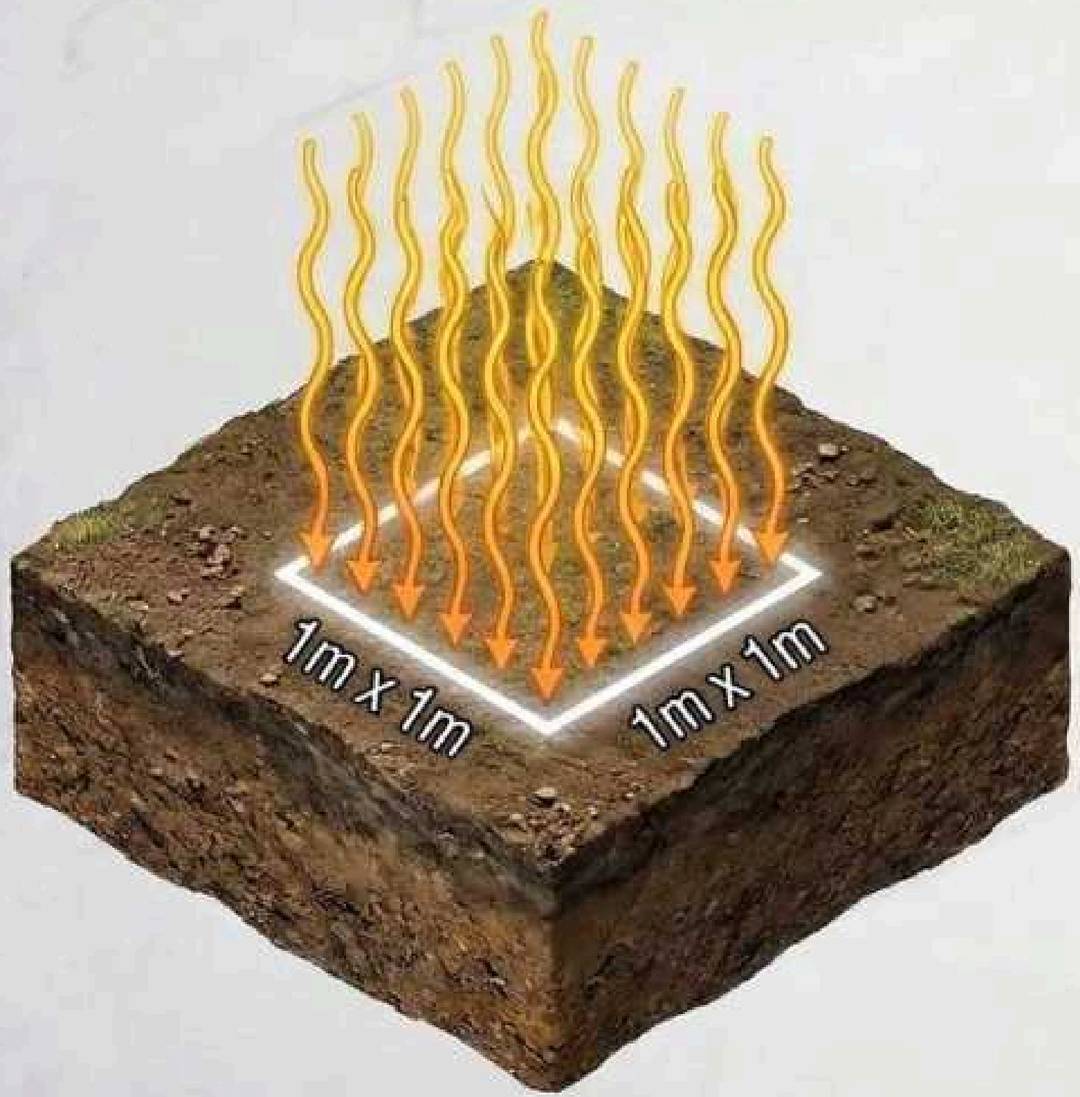


1.3 seconds

We see the sun as it was 8 minutes ago.

Gemini Notebook

¶ 6.15



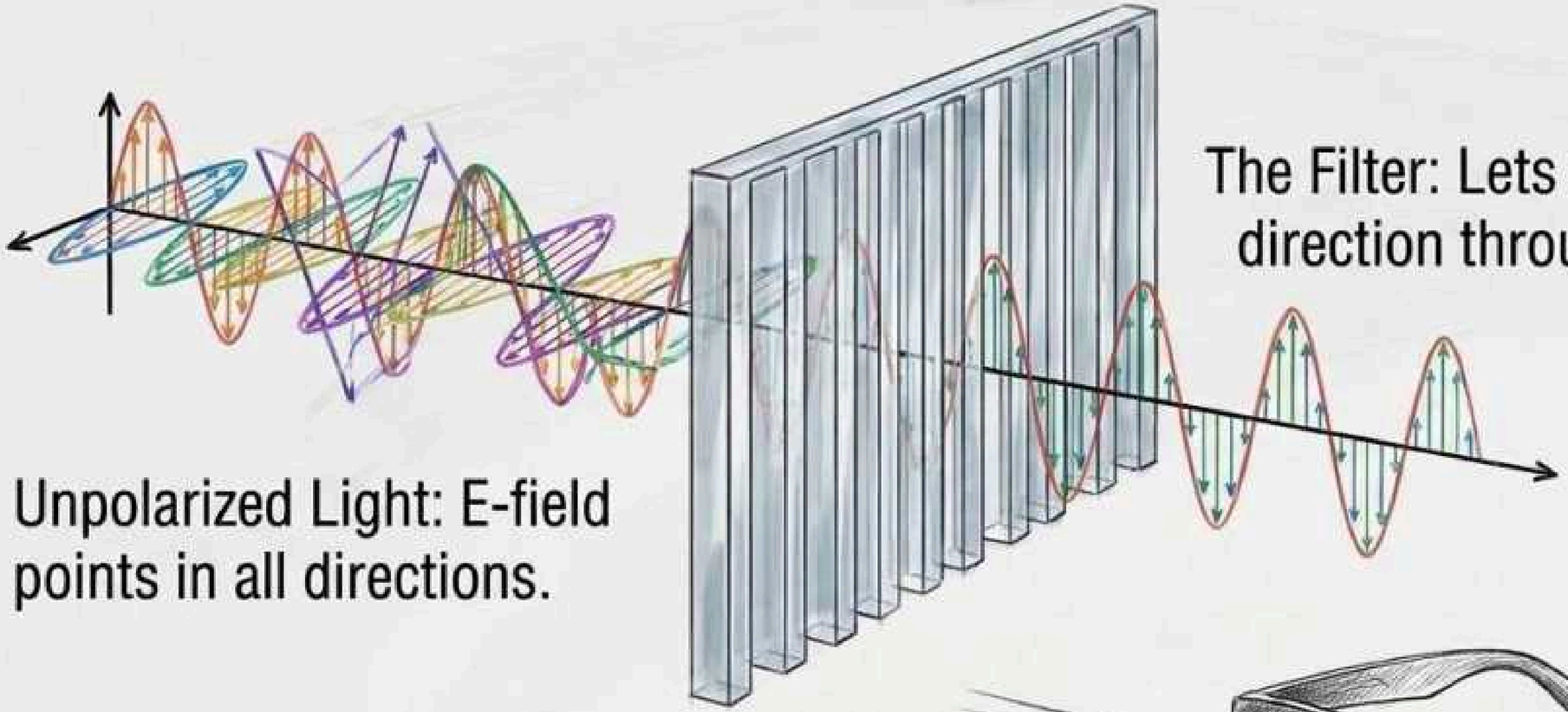
- Direct sunlight = 1,000 Watts / m^2
- Electric Field (**E**): ~600 V/m
- Magnetic Field (**B**): ~2 μT

$$E / B = c$$

(The ratio equals the speed of light)

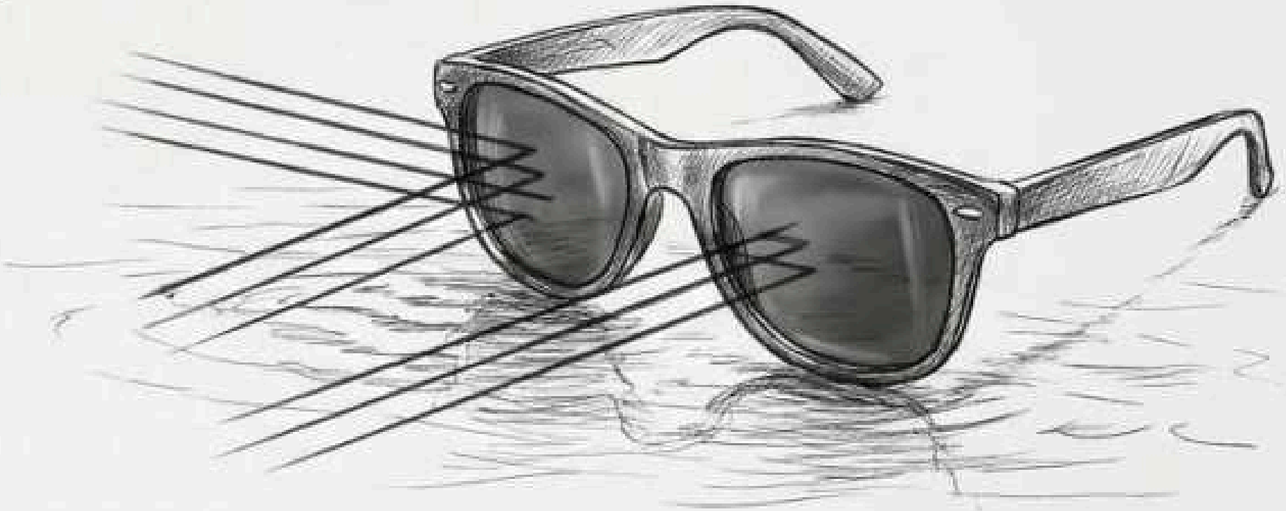
Gemini Notebook

¶ 6.16



The Filter: Lets only one direction through.

Unpolarized Light: E-field points in all directions.

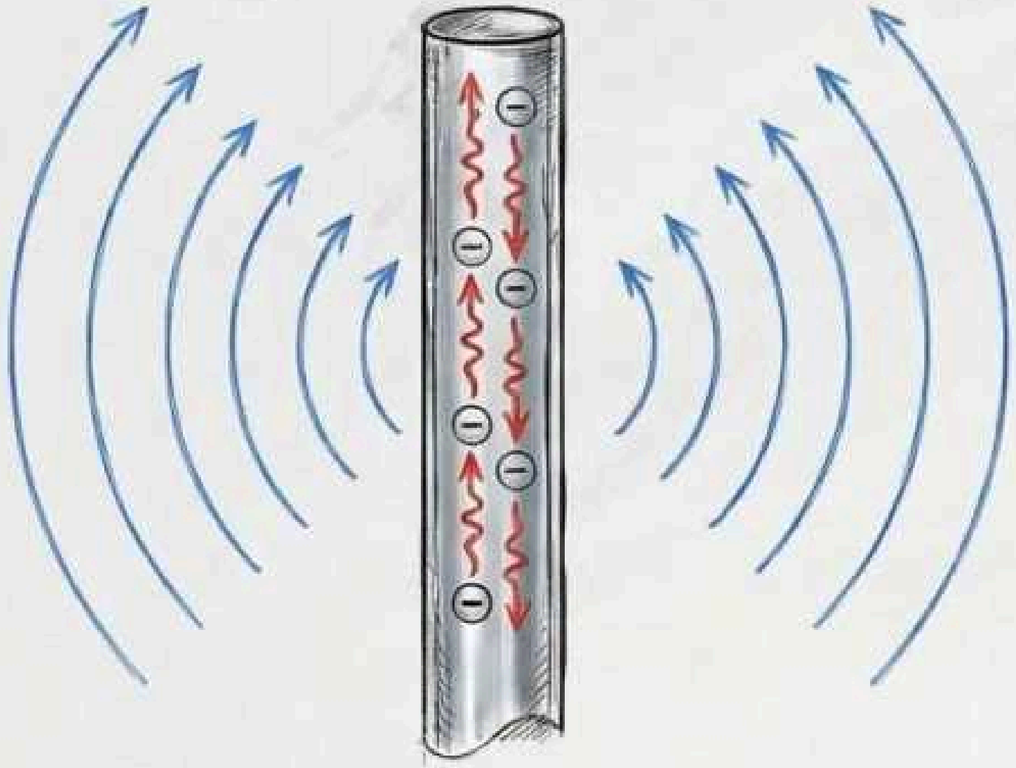


Application: Polarized sunglasses block horizontally polarized glare.

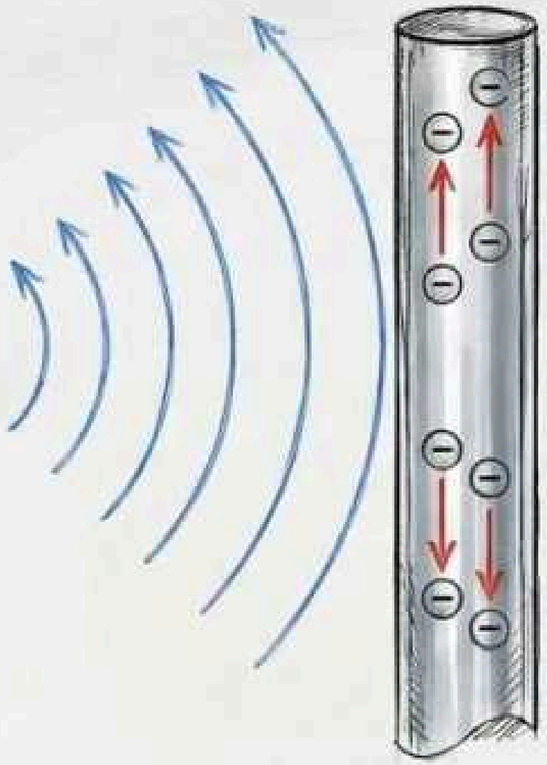
Gemini Notebook

¶ 6.17

Transmit: Accelerating electrons back & forth -> Radiates waves.



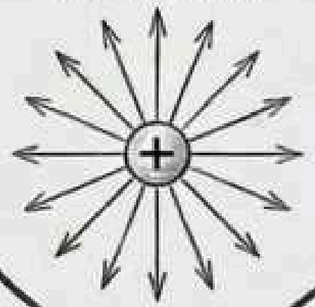
Receive: Passing wave -> Pushes electrons up & down.



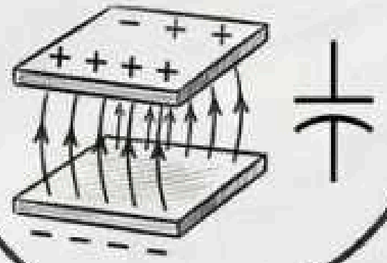
Optimal Design Rule: Antenna length ≈ ½ λ. (Example: Wi-Fi antenna is a few centimeters long).

¶ 6.18

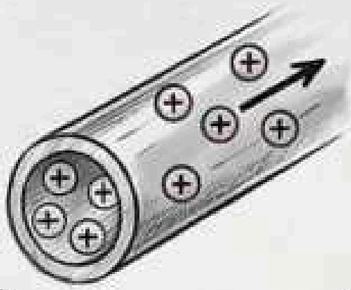
L1: Charges & Fields



L2: Energy & Capacitors



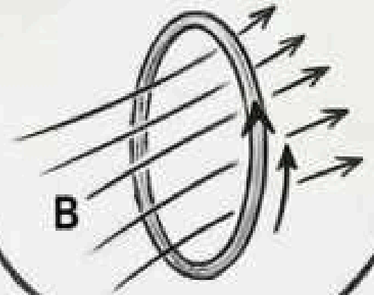
L3: Current



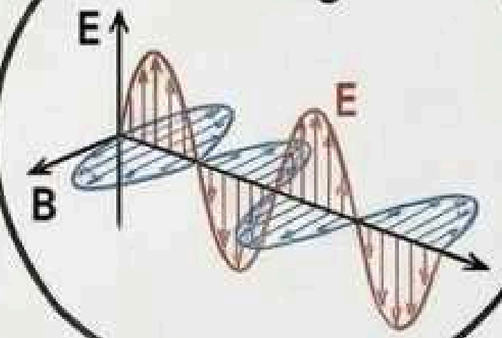
L4: Magnetic Fields



L5: Induction



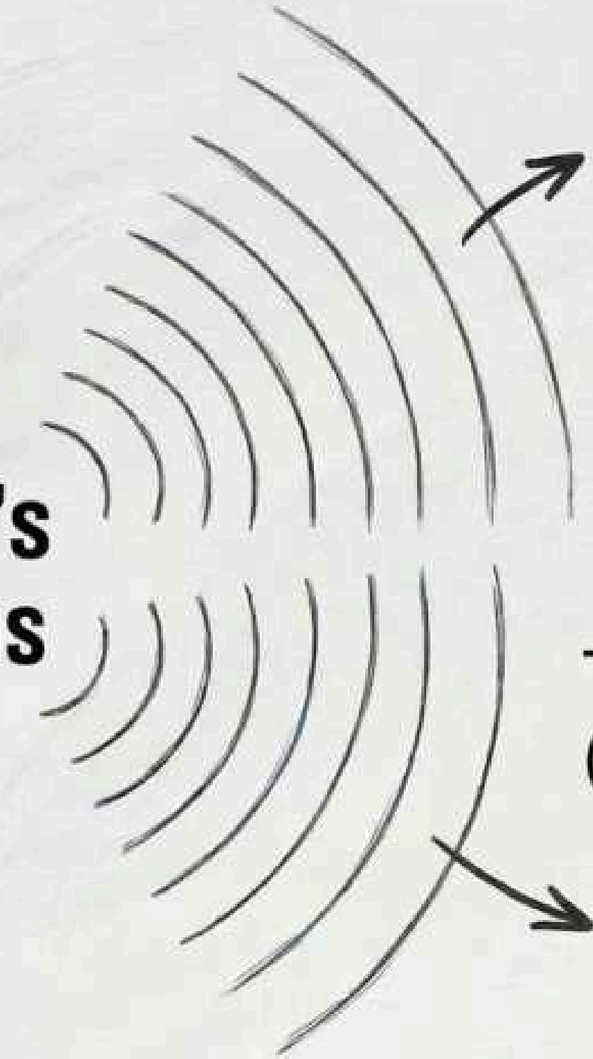
L6: Light



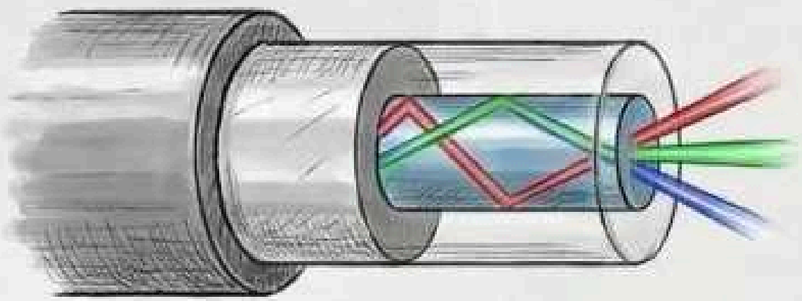
Gemini Notebook

¶ 6.19

Maxwell's Equations



Technological Applications:
Radio, Television, Radar,
Fiber Optics.



The Clue: The math showed the speed of light (c) does not depend on the observer's motion.

The Result: Following this clue, **Albert Einstein** developed **Special Relativity** (1905).

A good theory points beyond itself.

¶ 6.20





The Problem: Your phone uses Wi-Fi (5 GHz) & Cellular (~1.9 GHz).

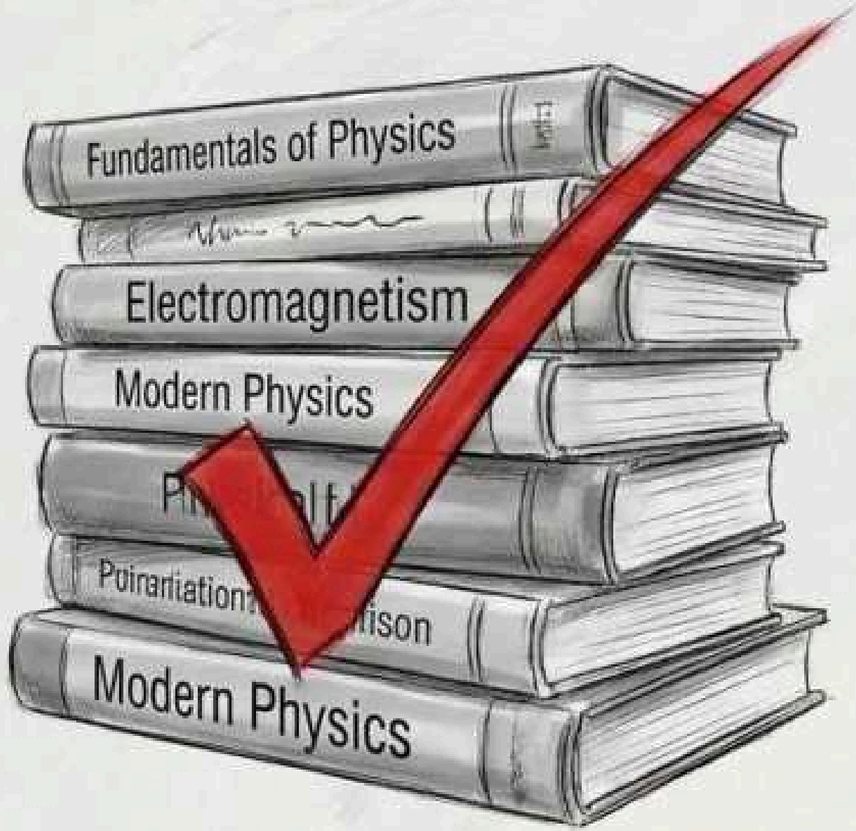
Question 1: Calculate the wavelength of each.

Question 2: Which would you expect to pass through a wall more easily?

Question 3: Why do engineers care about **antenna size** when choosing a frequency?

¶ 6.21

Physics 102 B Complete.



(Covered: charge, fields, voltage, current, magnetism, induction, light).

Next Steps: AC circuits, optics, and modern physics. Keep practicing!

Email: garyanderson@mail.grokbot.com **X: @garyanderson**

Thank you for taking **Physics 102 B.**