SCIENCE RIGHT NOW

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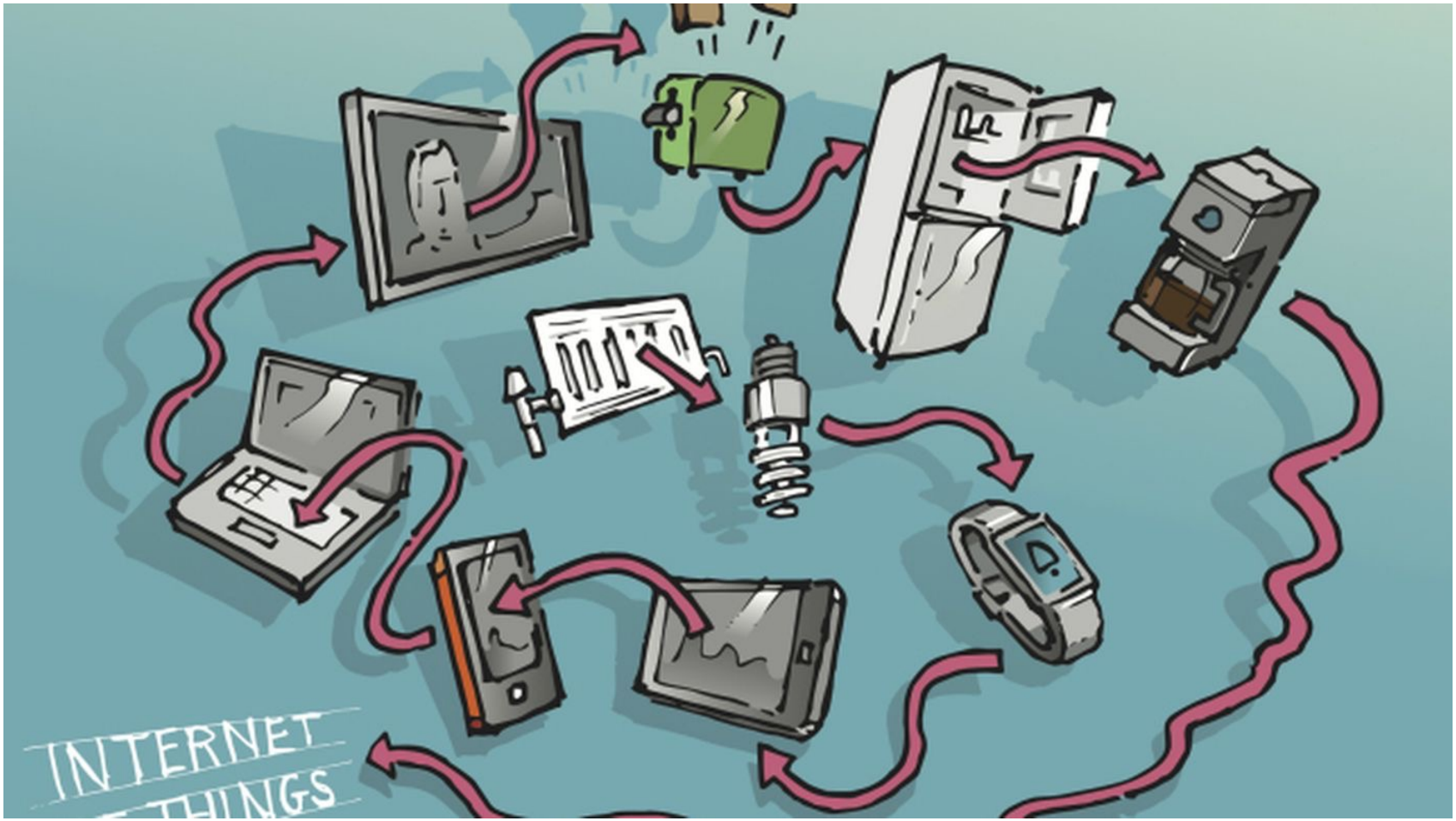
How does the internet work?



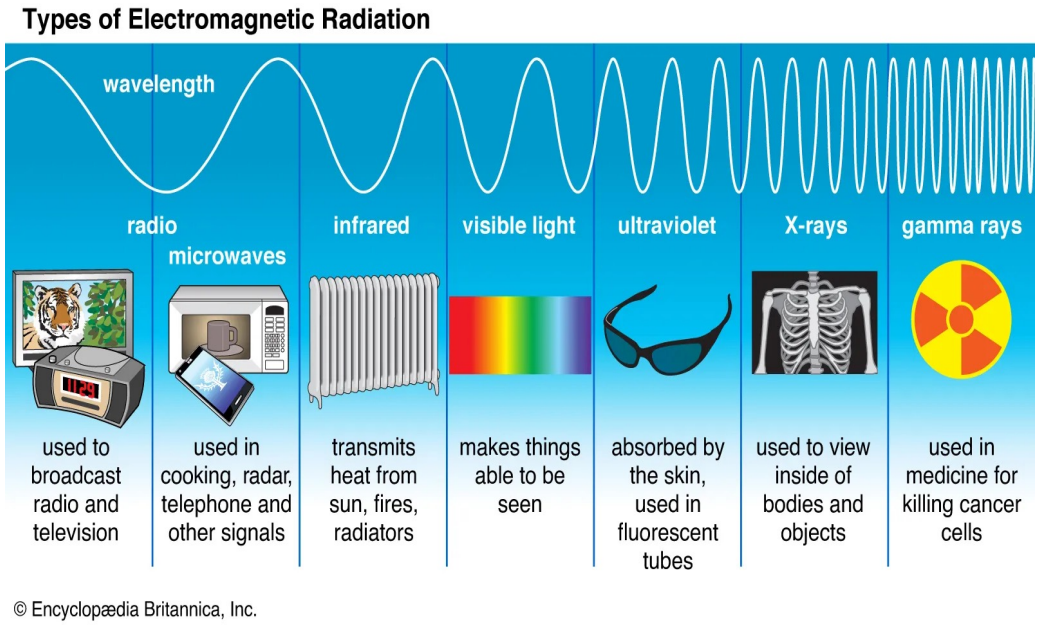
https://www.vox.com/2015/1/15/11557782/a-beginners-guide-to-understanding-the-internet-of-things

Hi, I am Apoorva

- I study electromagnetic waves
- Pursuing my Ph.D. program
- Hobbies: Biking, snowboarding, and Travelling.

How did I get involved in Electromagnetic research?

- Always been curious how invisible phenomena impact our day-to-day lives.
- Particularly interested in how electromagnetic waves interact with different environments.

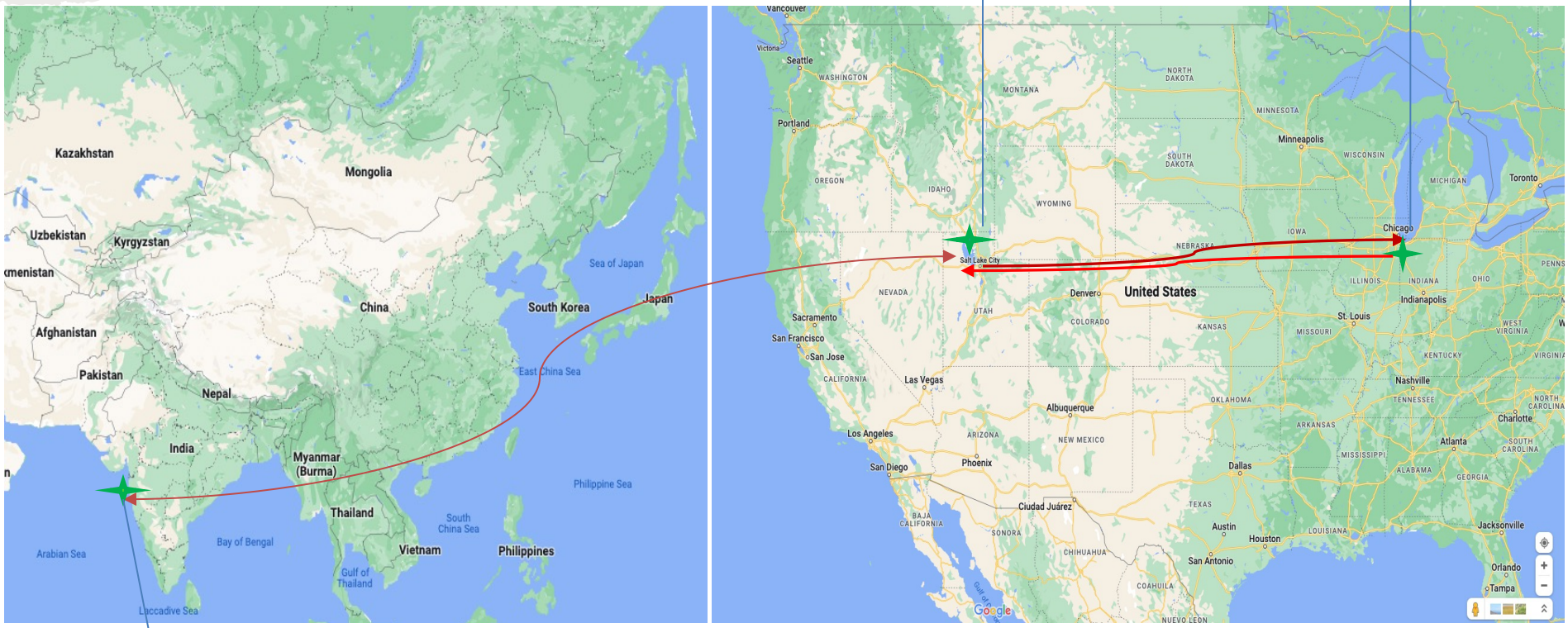


Speed of light = (1/Time) x wavelength

My career path

Graduate student (Masters) and Ph.D.

Lead Systems Engineer

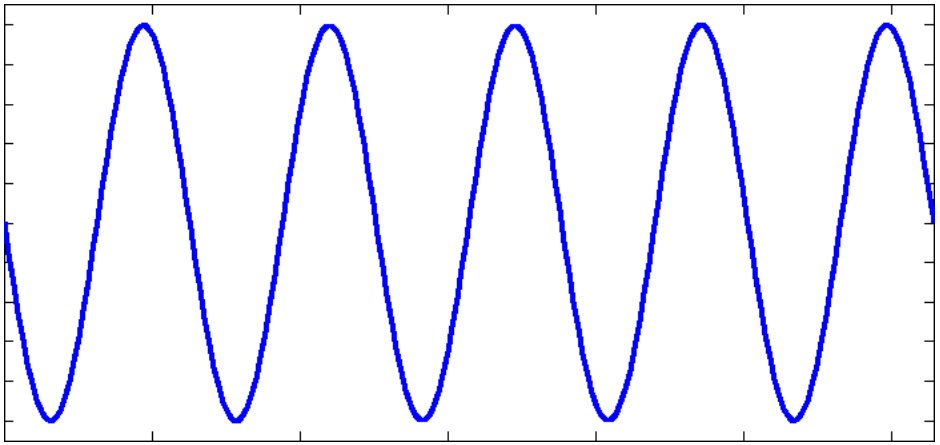


High School and Undergrad

Programs in STEM

Undergraduate degree	Masters degree	Ph.D. Degree
Approx 4 years of full time study	Approx 2 years of full time study without research and a minimum 2.5 years with research	Timeline is dependent on research (4 years min)
• develop particular skills and abilities. • think critically and creatively to solve problems • acquire both breadth of knowledge and depth of knowledge	• Expand knowledge of fields related to their interest/current area of specialization. • Stepping stone for Ph.D. program.	• Extend knowledge about an important topic through research • develop competencies needed to be an effective researcher

What is a wave?



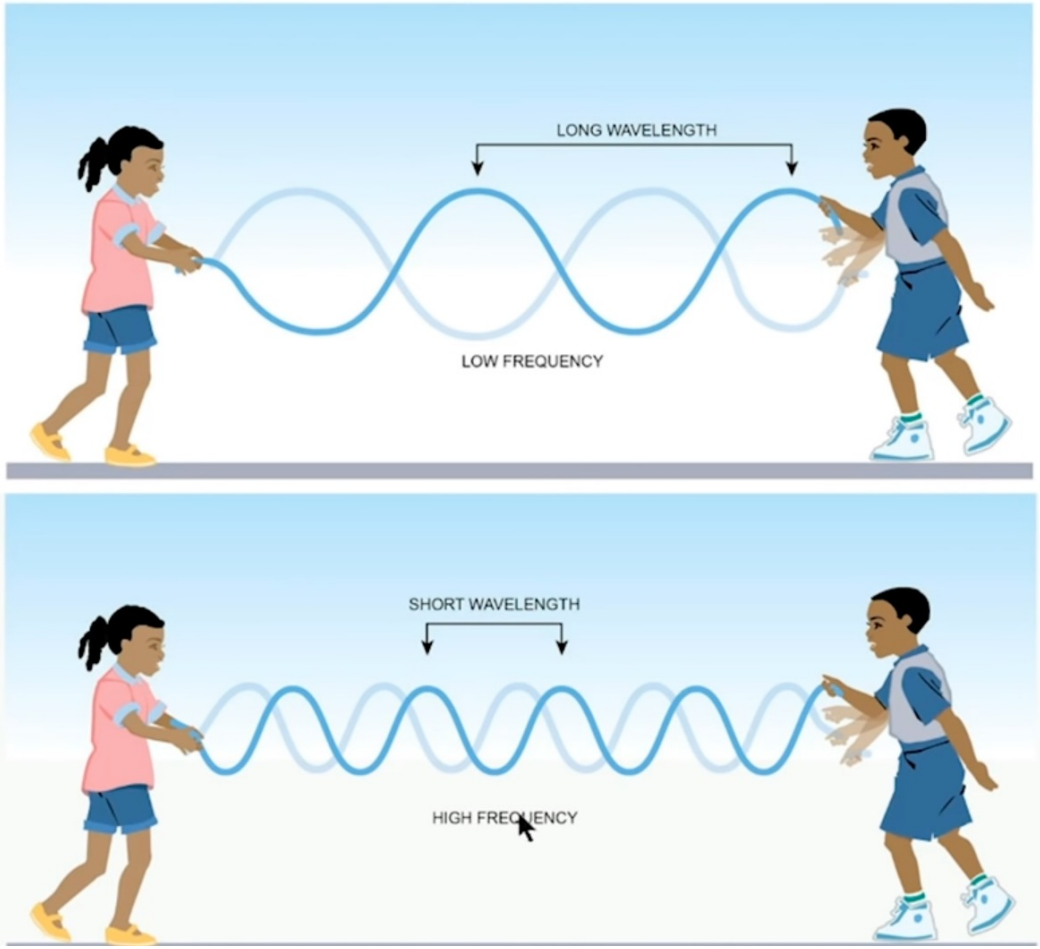
F – frequency
T – Time period
F= $1/T$

$$x(t) = A \sin(\omega t + \phi)$$

This is the angular frequency

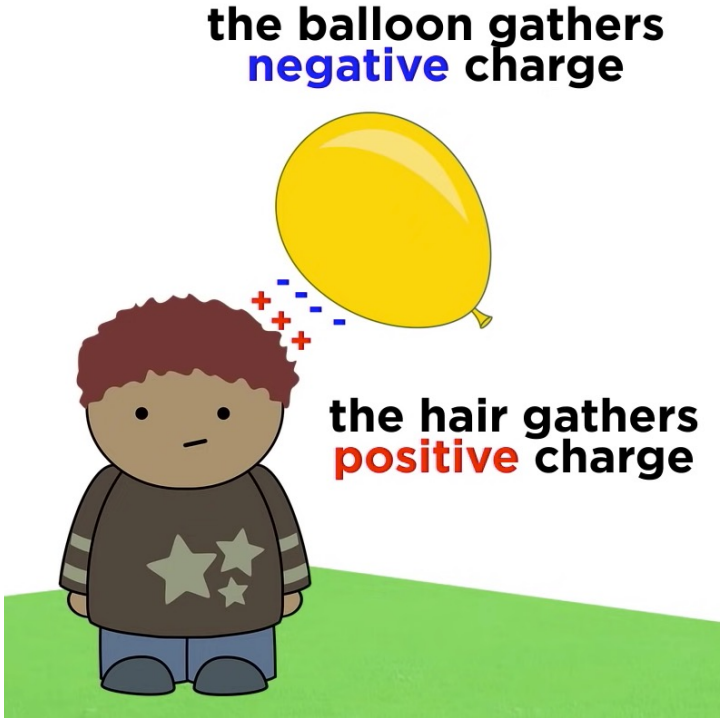
$$\omega = 2\pi f$$

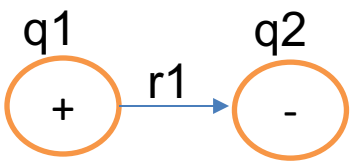
Sine wave and frequency



https://www.youtube.com/watch?v=bwreHReBH2A

Electric field





Attract

Repel

Opposite charges attract because of electric force

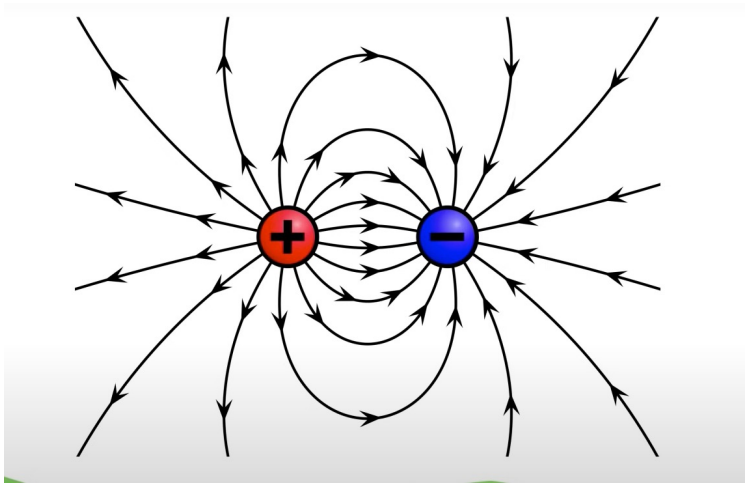
Coulomb's Law

$$F = k \frac{q_1 q_2}{r^2}$$

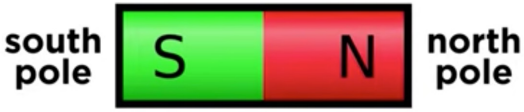
electric field strength

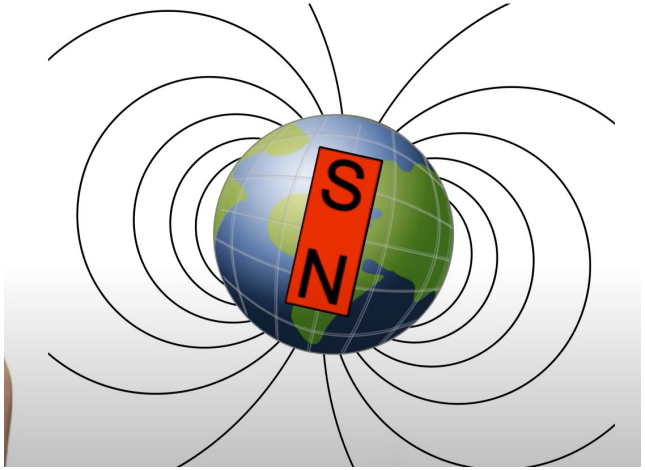
$$E = k_c \frac{q}{r^2}$$

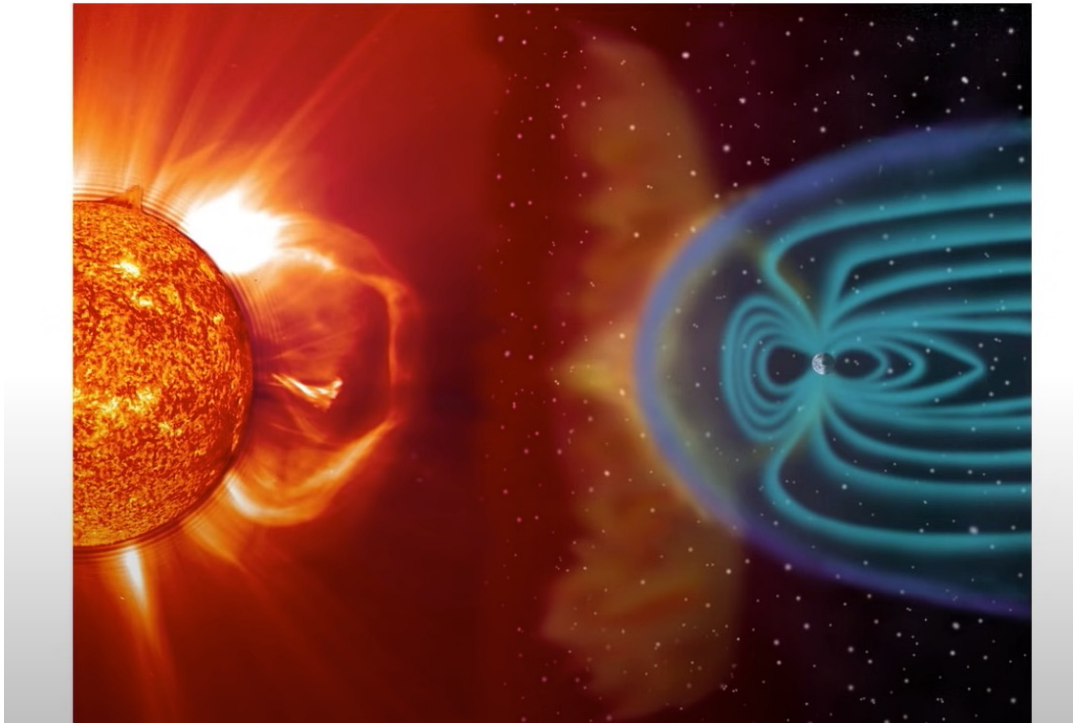
charge on the object



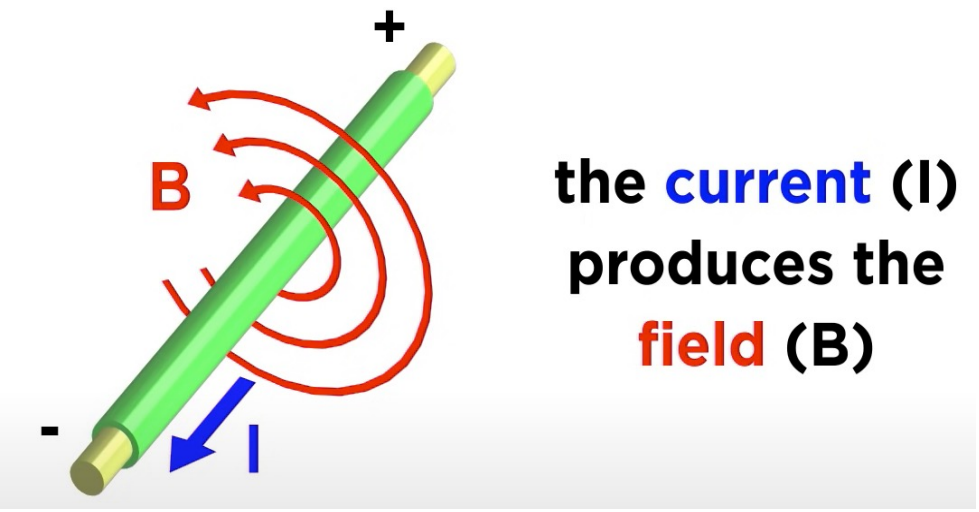
Magnetic field



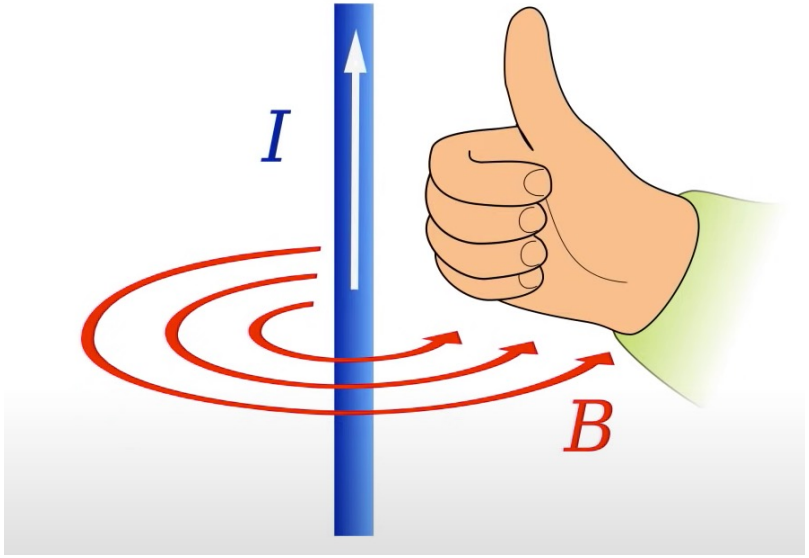




Magnetic field



the current (I) produces the field (B)



Right hand rule

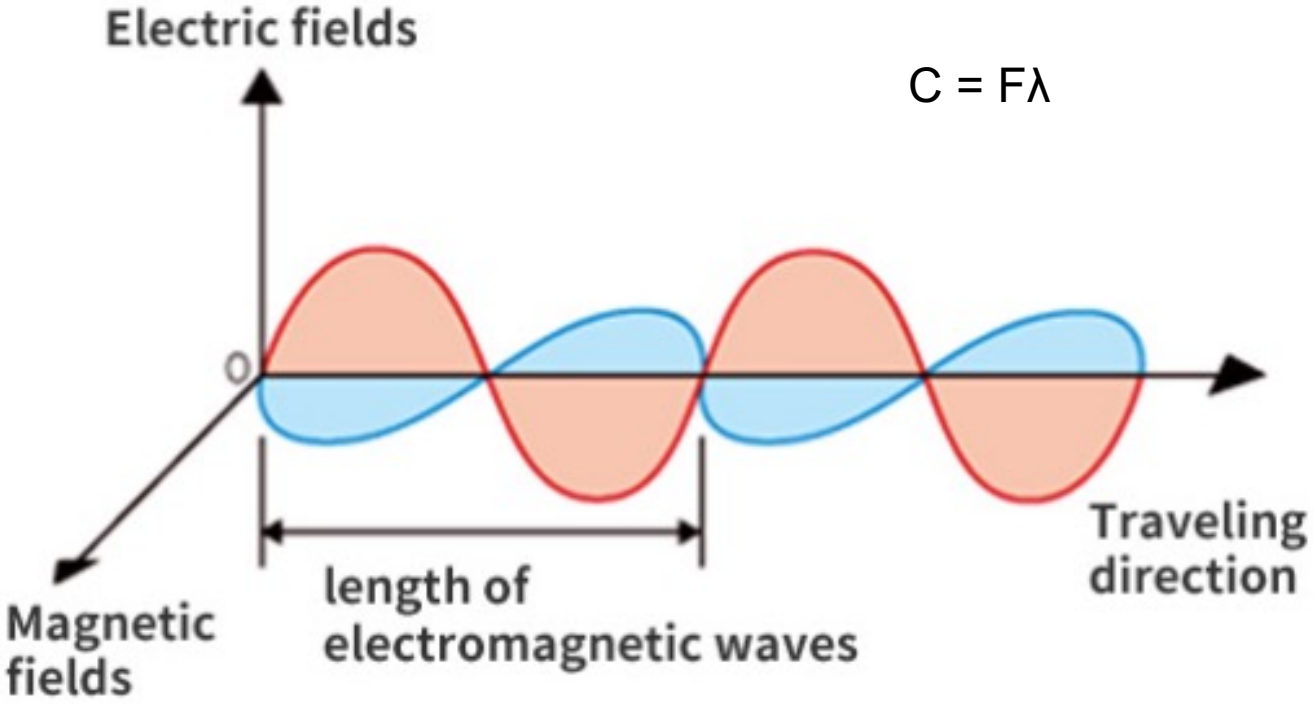
Also Known as Biot-Savart Law

EM wave

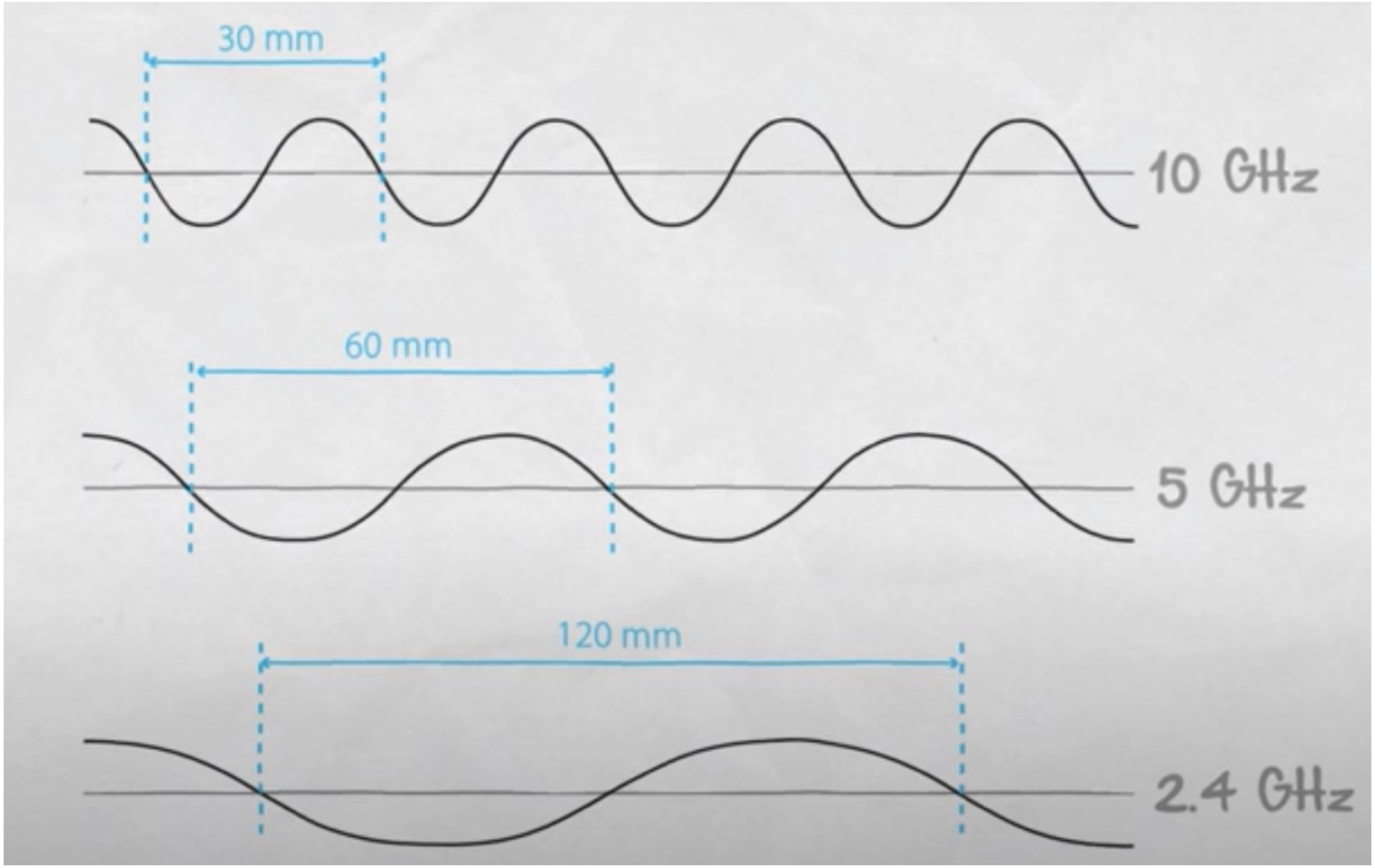
λ = wavelength/distance of EM wave

C = speed of light (3 x 10^8)
F = frequency of wave

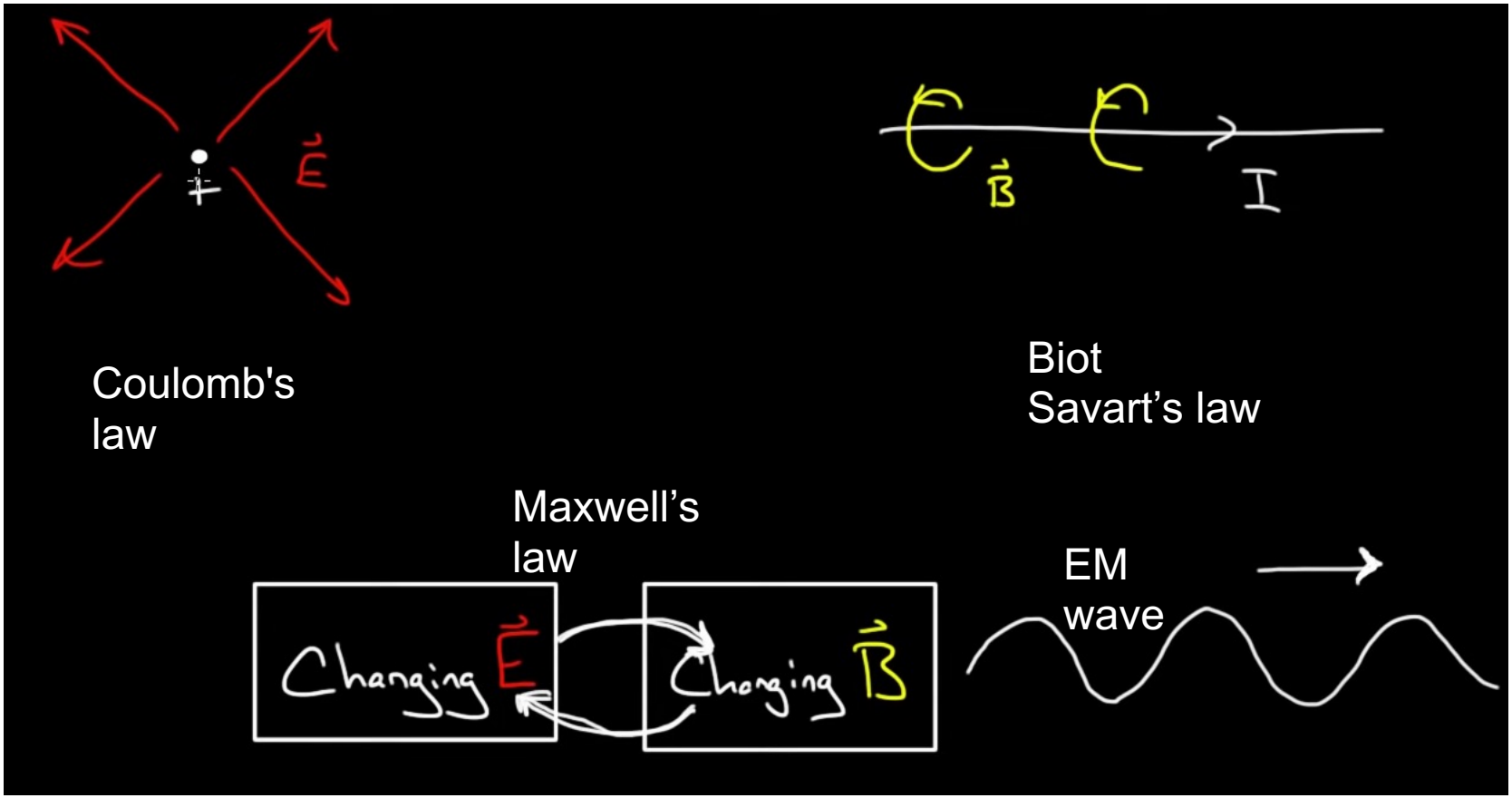
C = Fλ



EM Wave

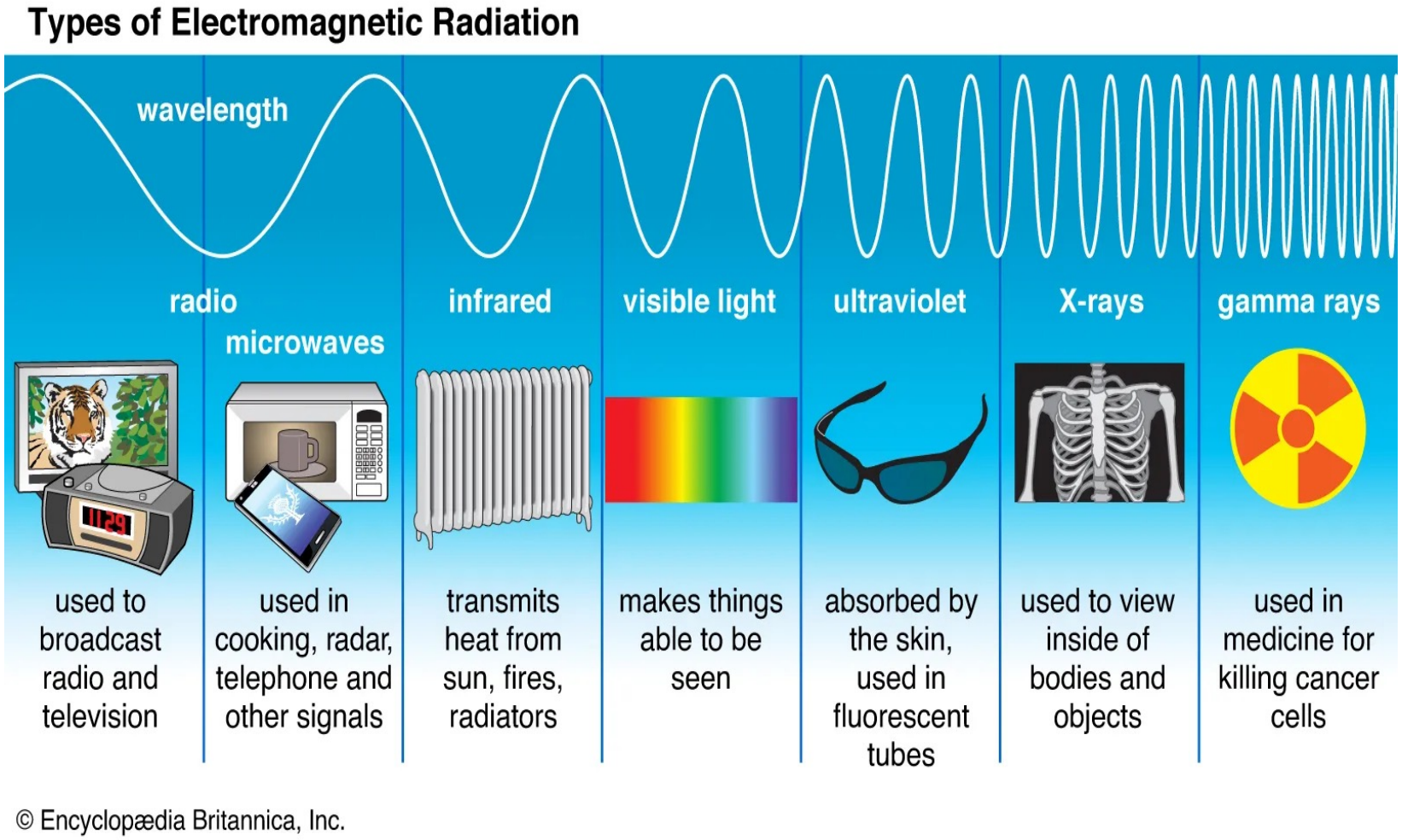


EM waves



Acceleration and deceleration of charged particles makes EM wave

EM spectrum


Types of Electromagnetic Radiation
wavelength
radio
microwaves
infrared
visible light
ultraviolet
X-rays
gamma rays
used to broadcast radio and television
used in cooking, radar, telephone and other signals
transmits heat from sun, fires, radiators
makes things able to be seen
absorbed by the skin, used in fluorescent tubes
used to view inside of bodies and objects
used in medicine for killing cancer cells
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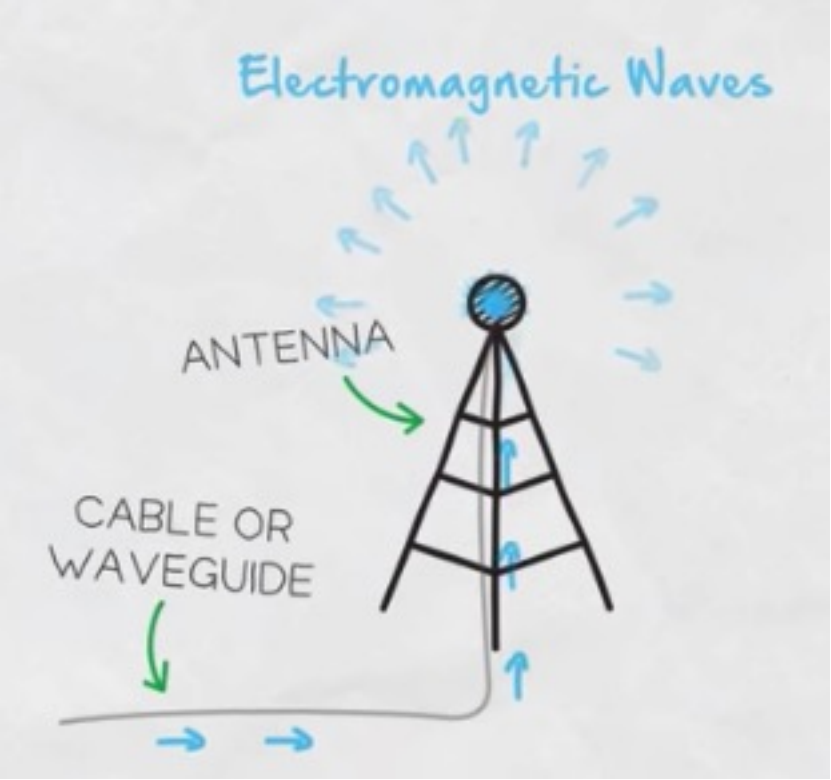
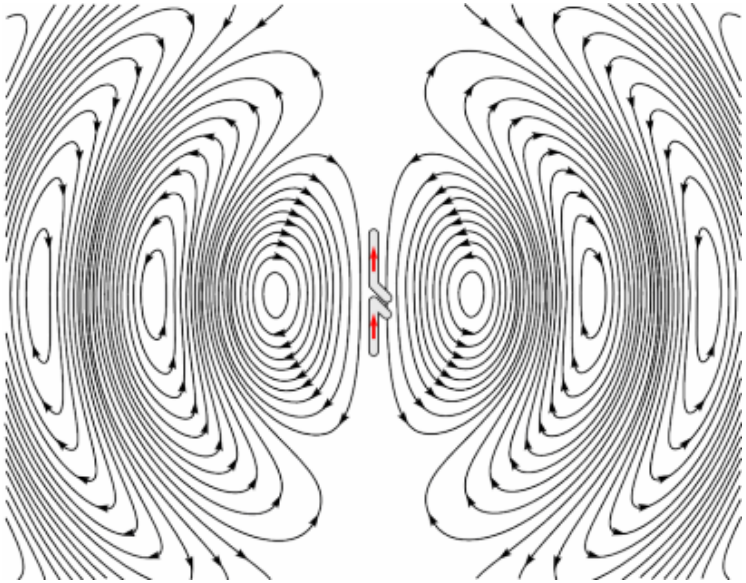
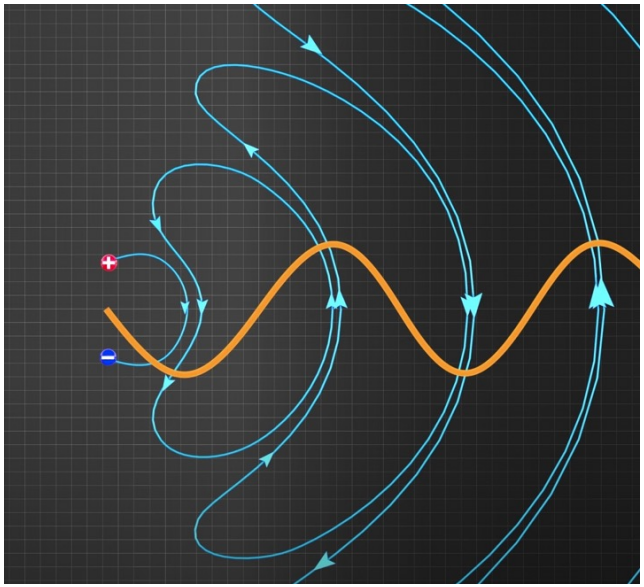
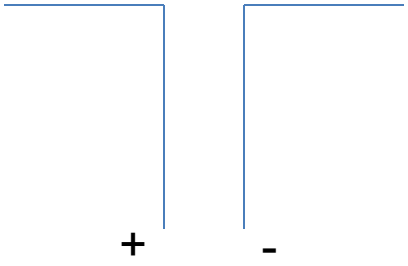
What is an Antenna?



How does an antenna radiate?

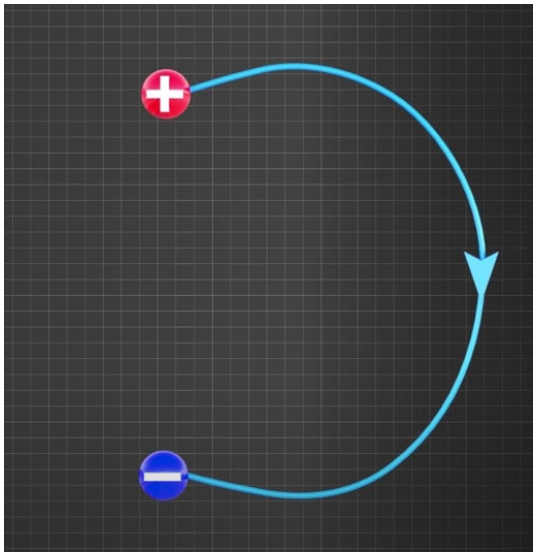


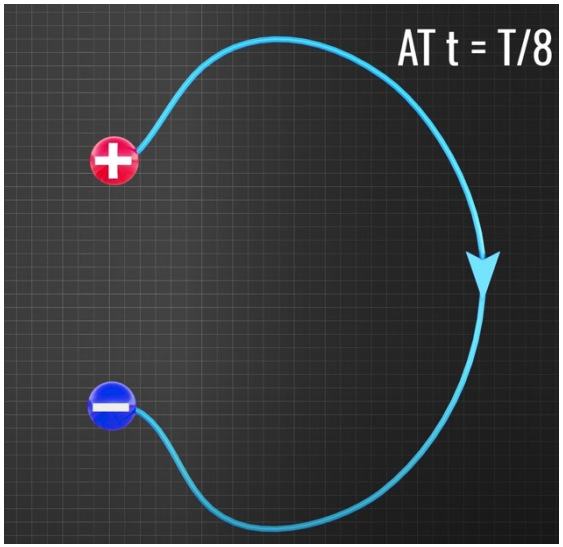


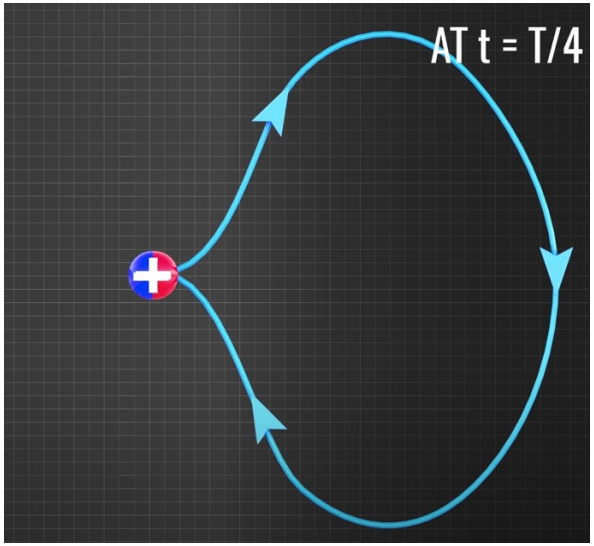


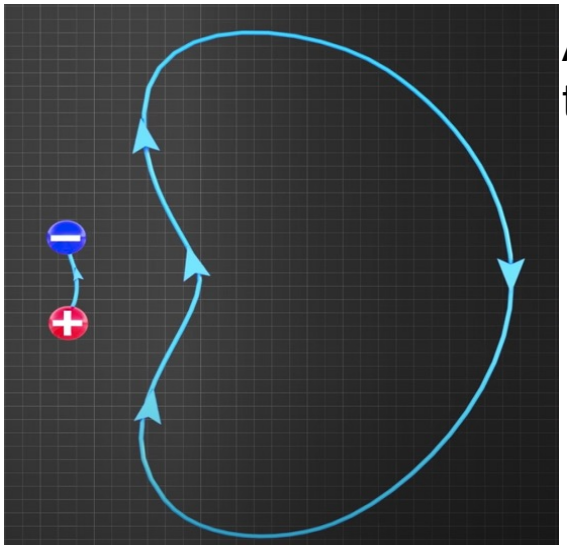
How does an Antenna radiate?

At t=0



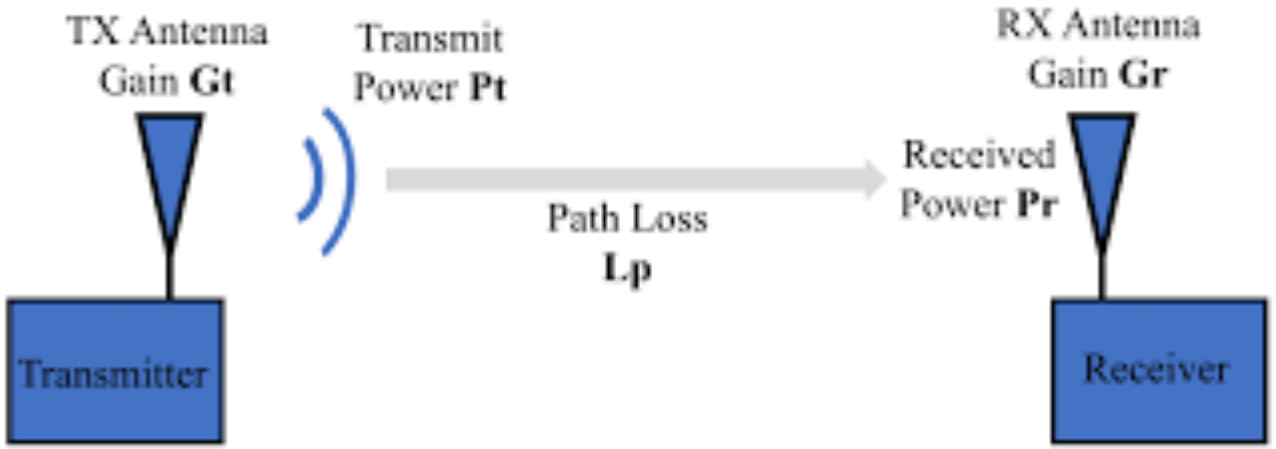




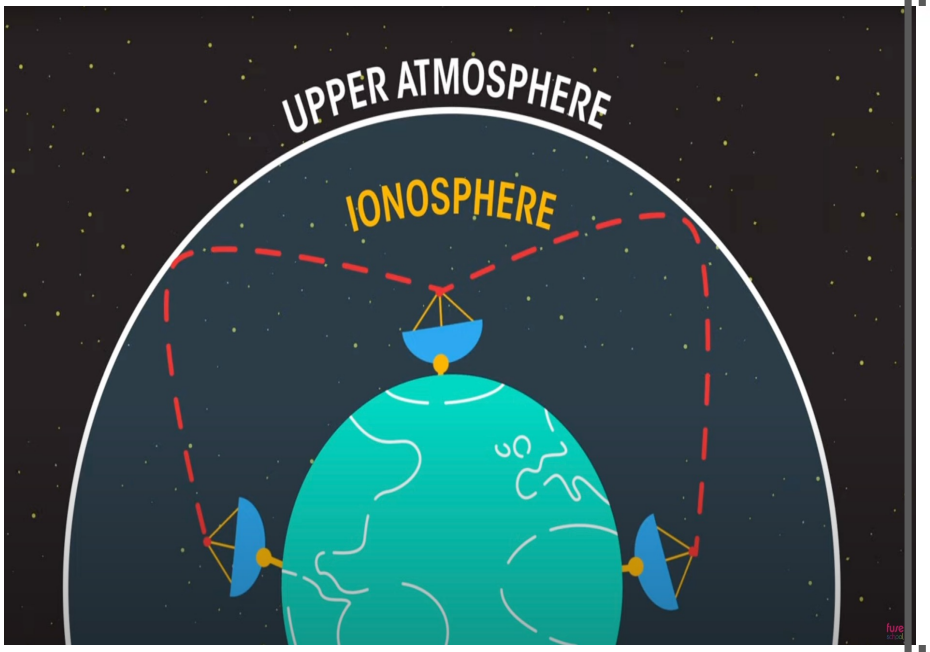


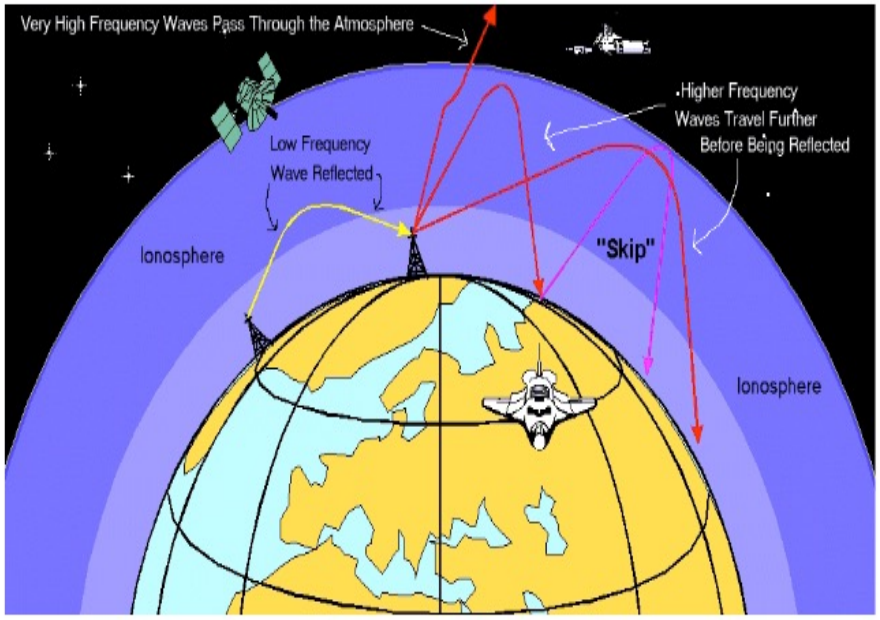
At t=T/2

Radio wave transmission



What does my Lab do?





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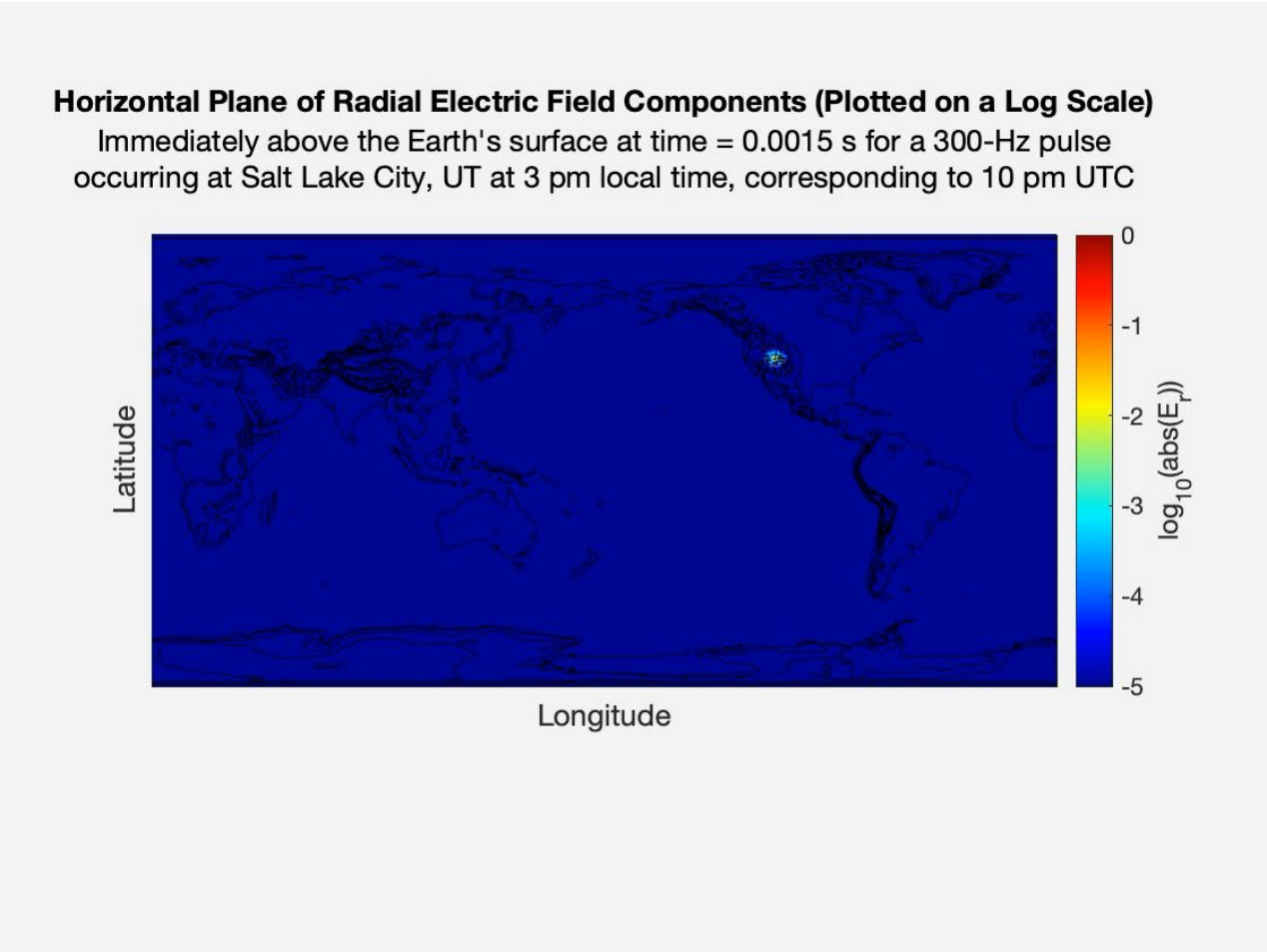
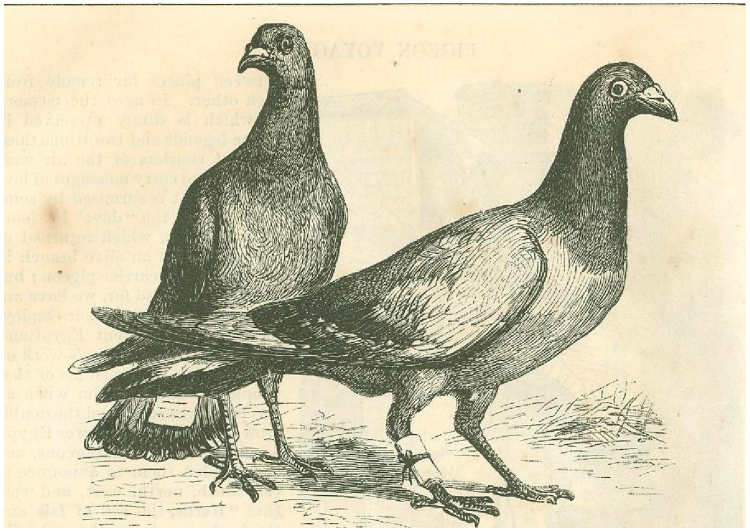


Early Communication Methods over Long Distances

by Jonathan Sprague

Day-Long Runners (Messengers) in Ancient Greece



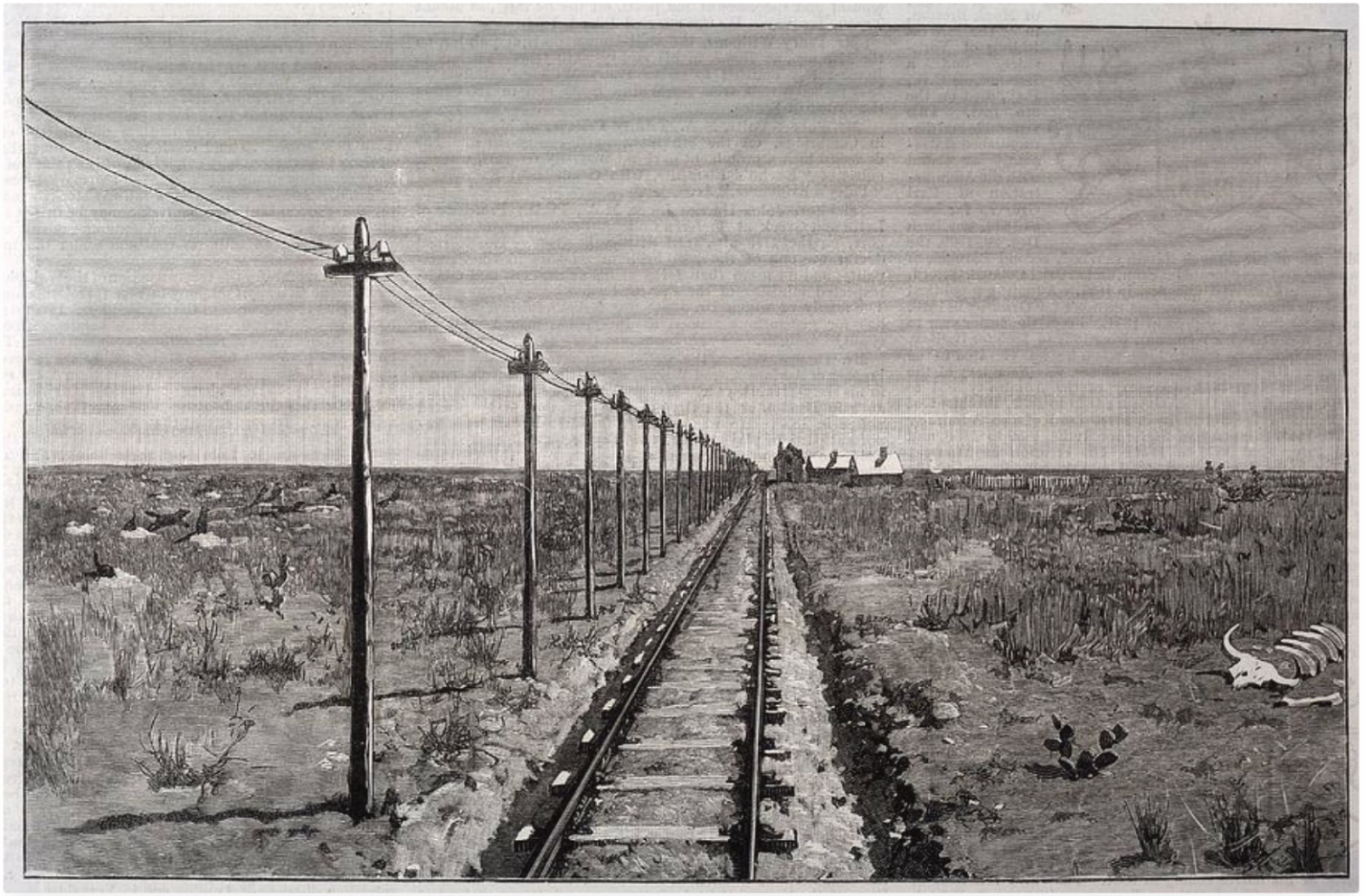
Harper's New Monthly Magazine, April 1873

Carrier Pigeons

Universal History Archive/Getty Images

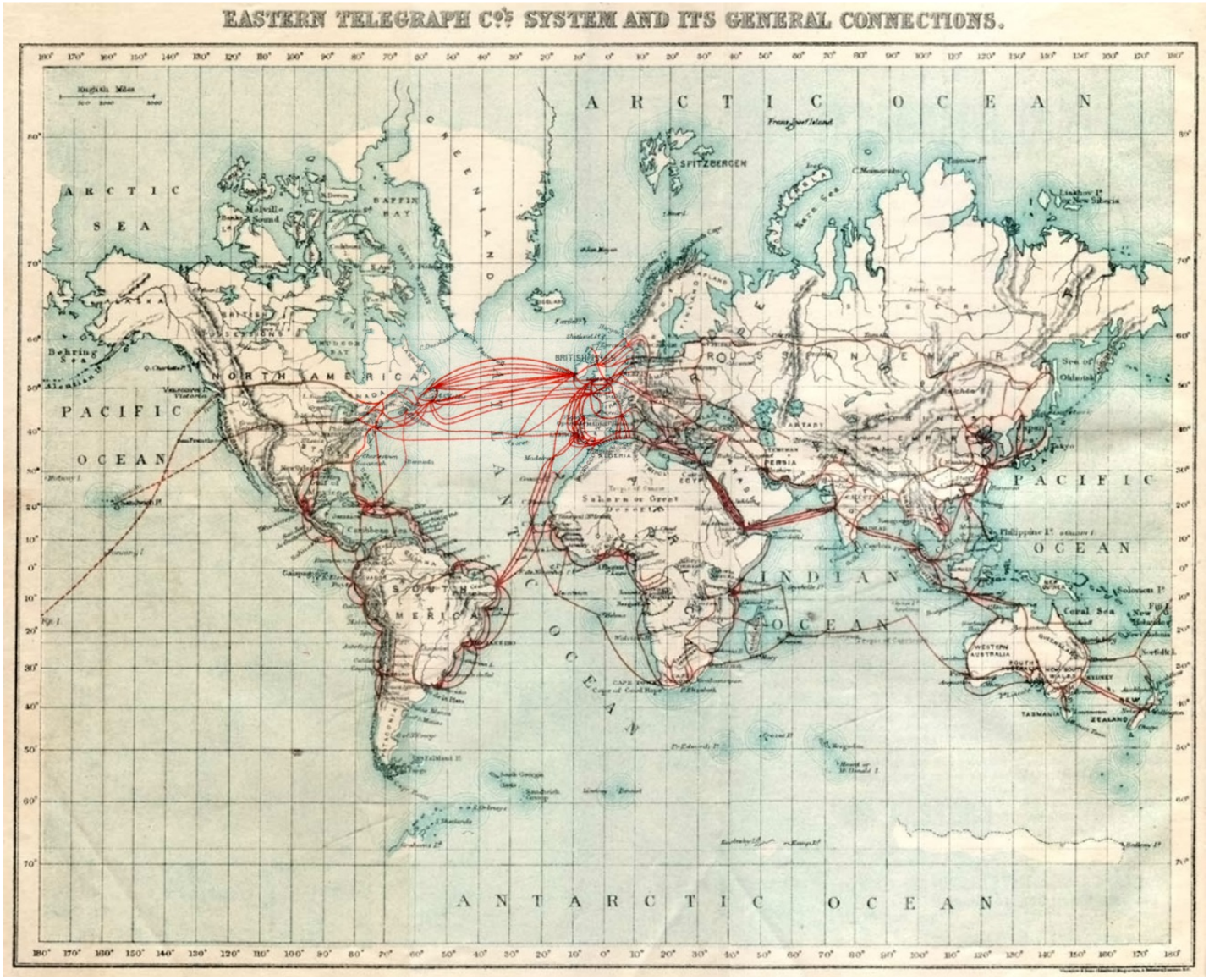
Pony Express

Drawing of Telegraph Lines Running Alongside a Railway Track on the Great Plains of the U.S. (1885)



Illustrated London News Ltd/Mar

British Eastern Telegraph Company Cables in 1901



submarinecablemap.com

Design Challenge

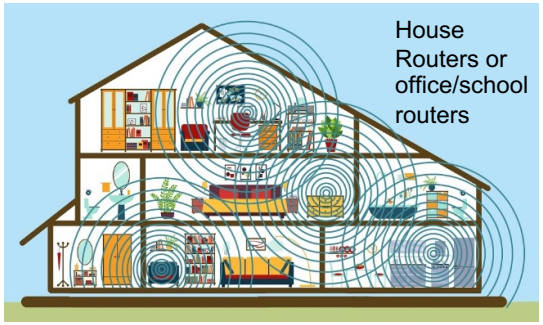
- Say I take a picture of our class today and email it to your teacher via email. How did my email go from my phone to the teacher's phone?

- Assume my phone was connected to the Wifi

Design challenge

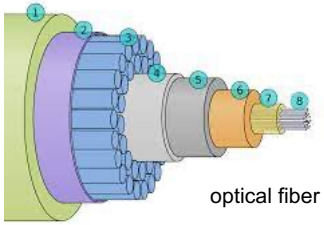
How does the internet or the world of connectivity work?

AT&T Internet network



Internet

Salt lake Youth center
Internet network



optical fiber cable

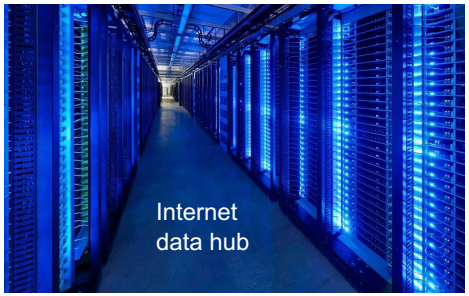


Photo on my cell phone

Apoorva: 24.111.90.24

Teacher: 38.10.110.40

Apoorva: 24.111.90.21

Teacher: 38.10.110.45

Envelopes of address for online mailing system

1 bit

10010010

00100010

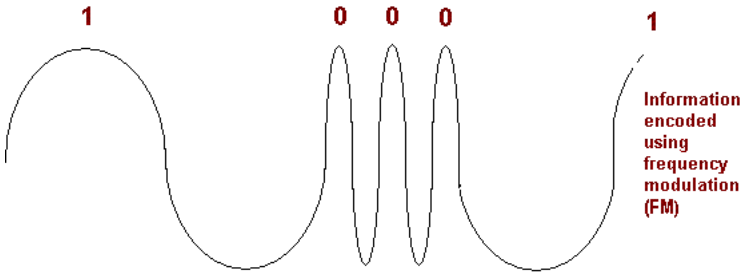
1 byte

How does the binary data go wirelessly?

10010010 →  → ?

Binary information of each packet (part of the photo)

Radio waves

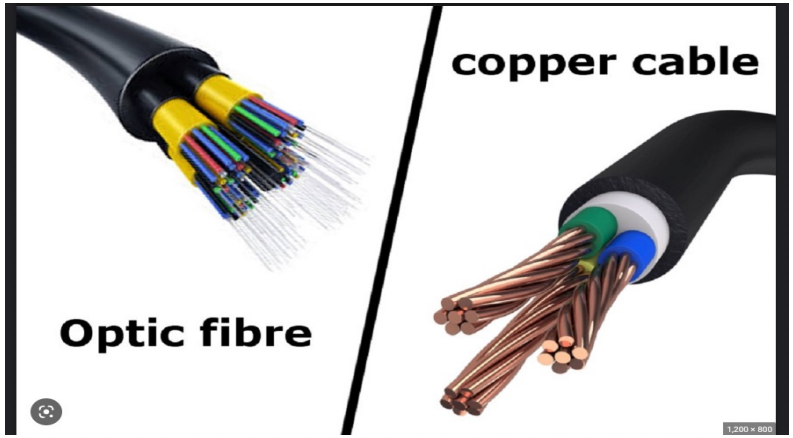


For binary 1 – assign one frequency
For binary 0 – assign one frequency

Cellph one photo → Broken down in packets of binary data → Binary data is encoded on radio waves and travels to a wireless router

How does the information travel from the router?

- Routers are connected to your school's wired network

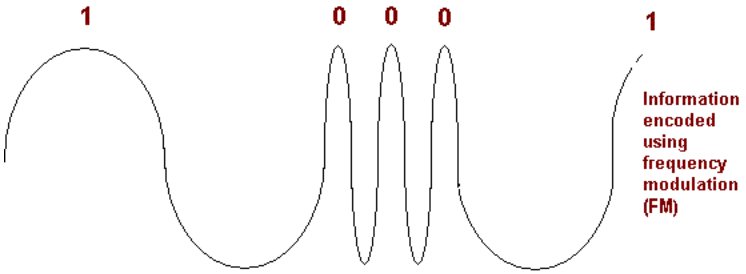


laser pulses

Electric pulses

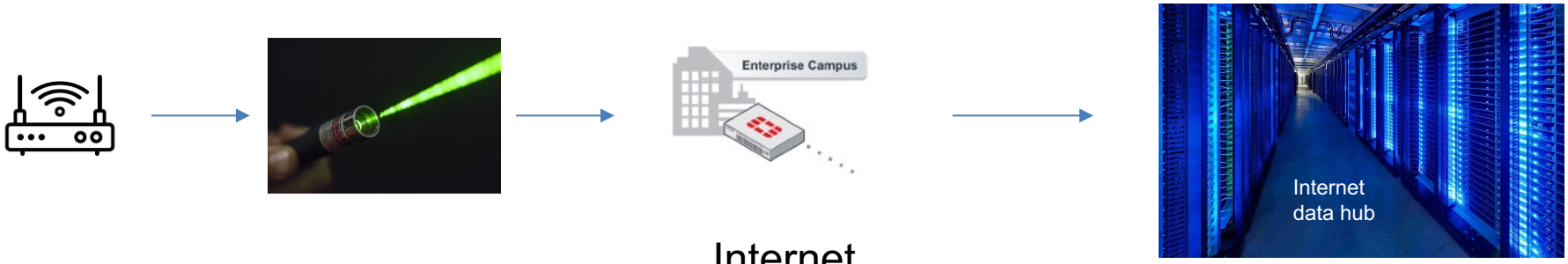
How does the information travel from the router?

- The laser light turns on when 1 and turns off when 0.
- Now information is wired and in cables



What happens next?

- Information traveled from router, along with the envelope information utilizes the internet service provider

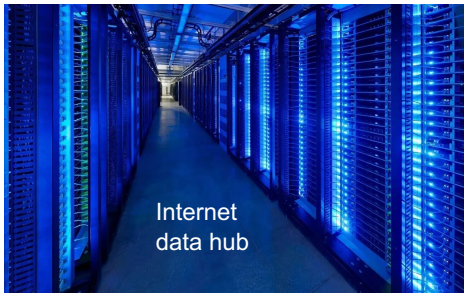


Laser pulses containing binary info packets

Internet service provider network (AT&T)

Finds the most efficient route

Internet data Hub



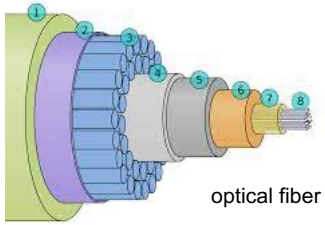
Design challenge

- What if I need to send this photo to someone far away say Australia?

World wide web

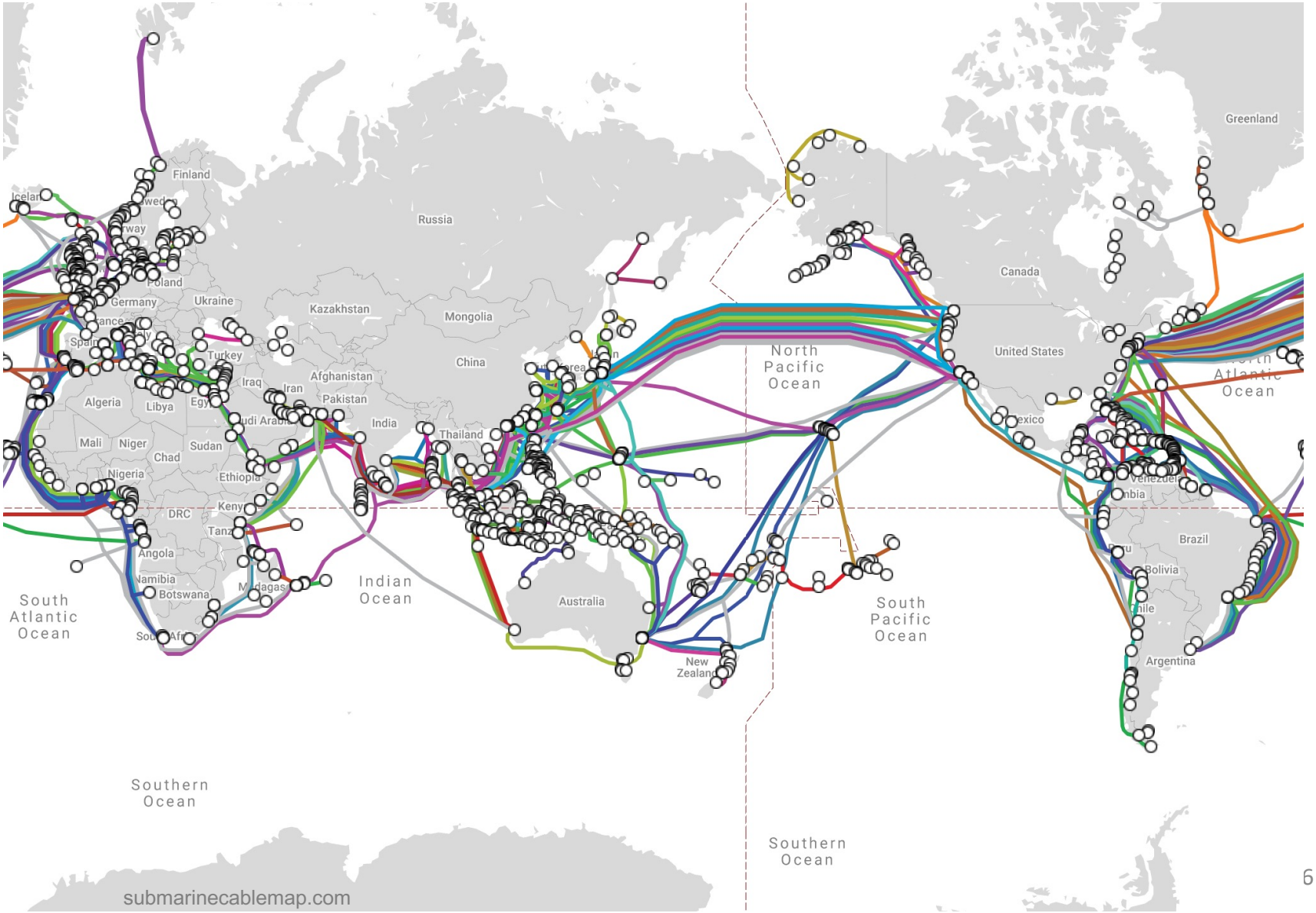
The internet is physically connected to different parts of the world via undersea cables.

World wide web is a physical thing.

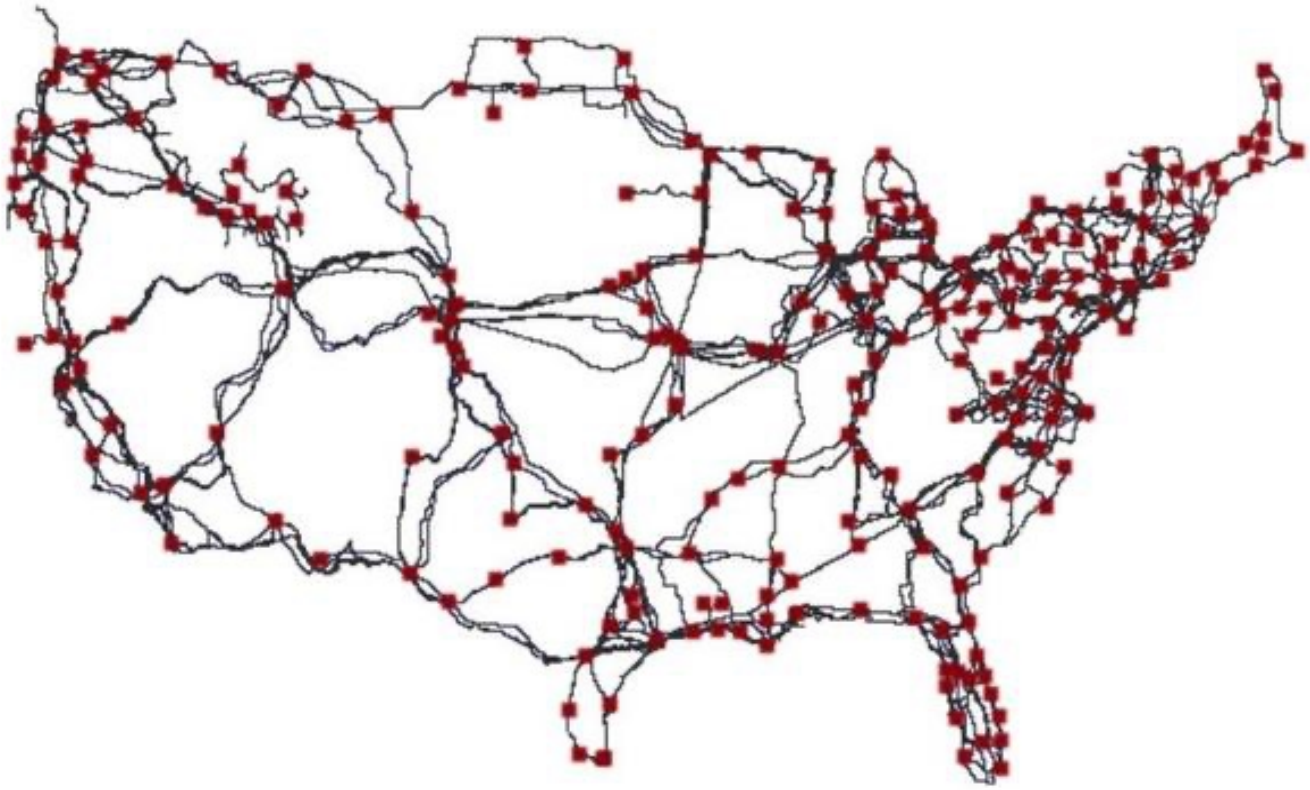


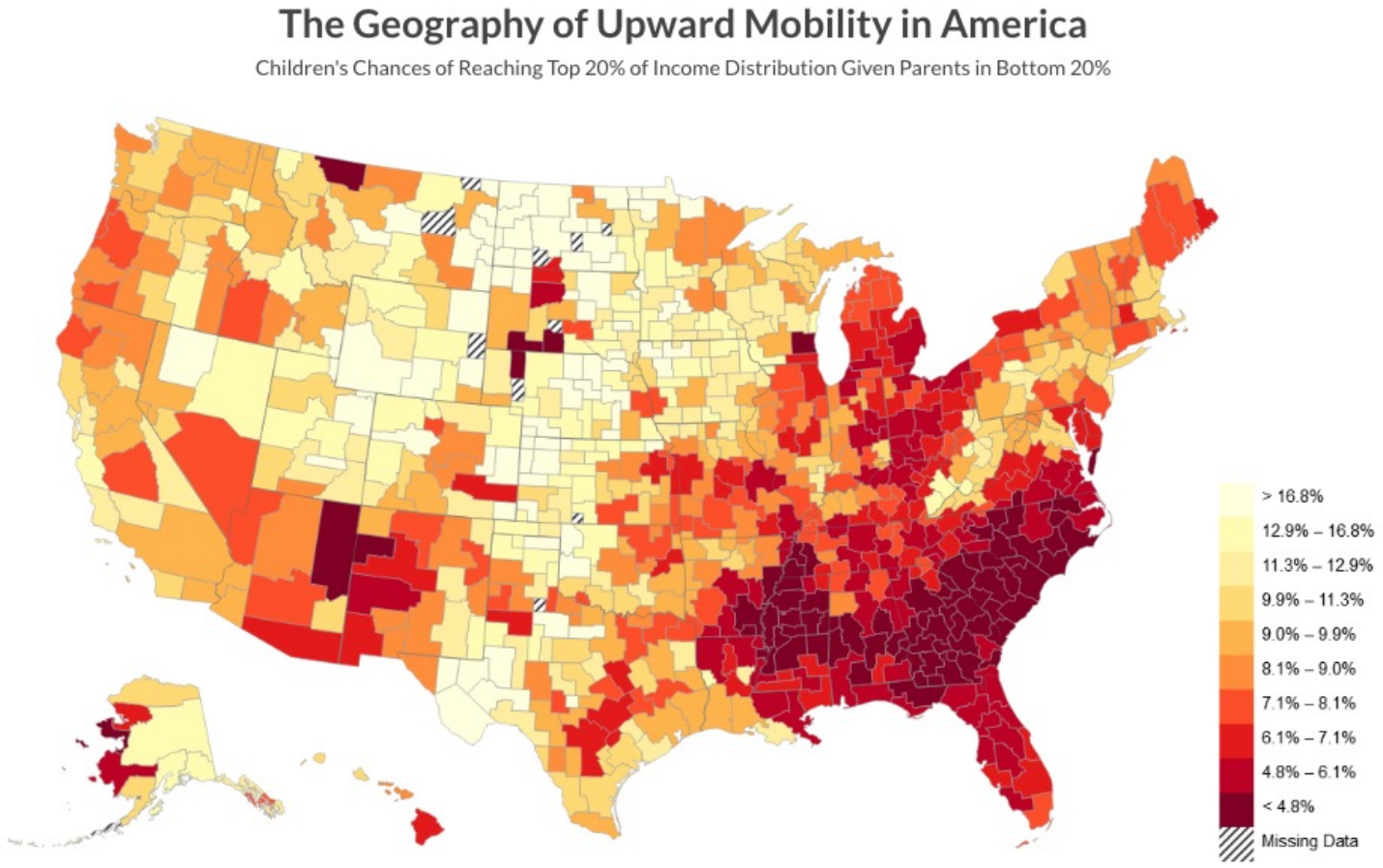
optical fiber cable

Global Submarine Fiber Optic Cables



Internet backbone United States

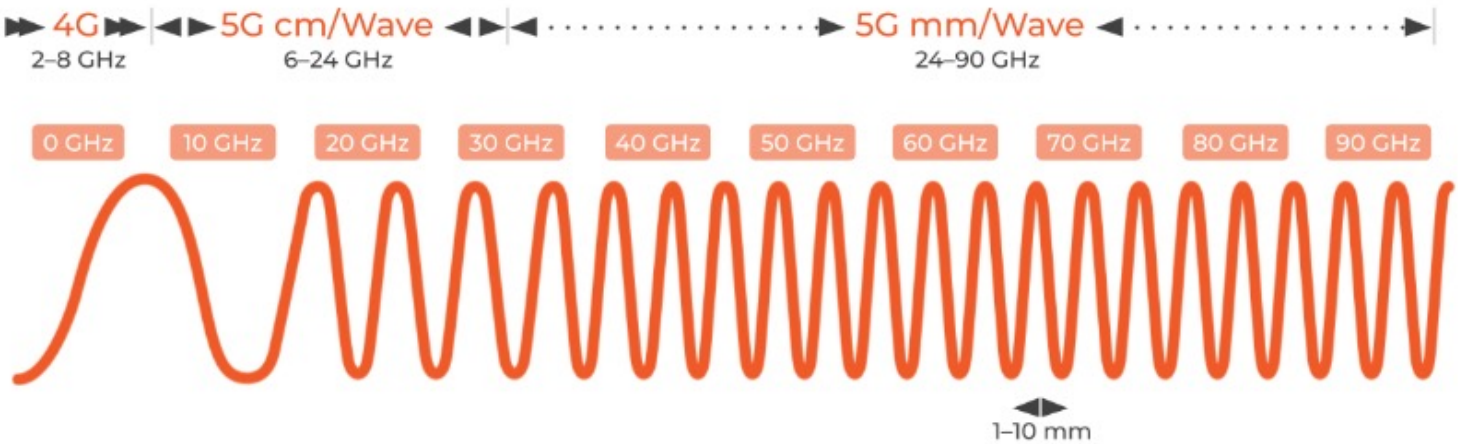




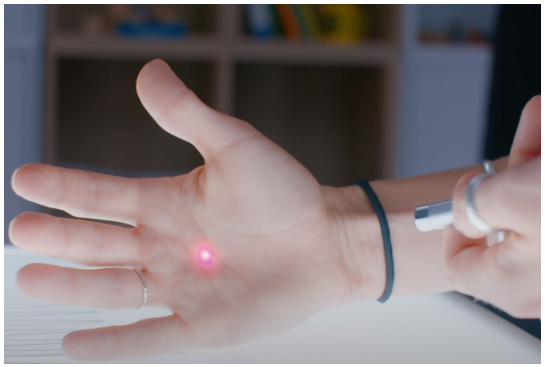
Cost > revenue

Only 1 or 2 options for internet providers

What is 5G?



Higher frequency allows more binary bits to be encoded on the wave

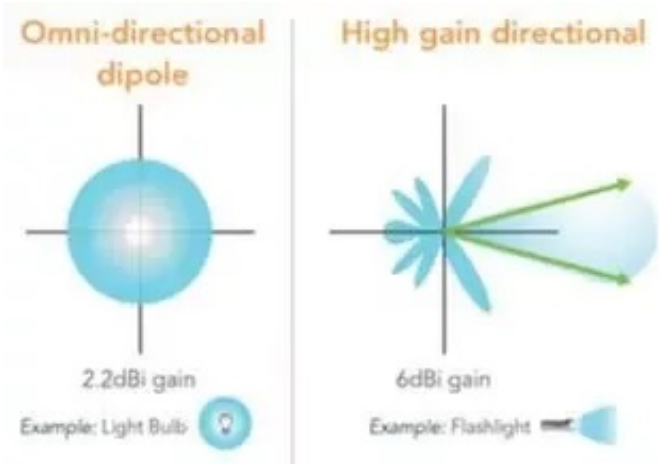


Higher frequency gets blocked easily.
As it reaches wirelessly.

Need more antennas???

Antenna types

- Omnidirectional
  - Dipole
  - Monopole
  - Collinear
  - Slotted Waveguide
- Directional
  - Sectorial
  - Patch
  - Waveguide / Horn
  - Yagi
  - Biquad
  - Dish



Adapted from wndw.net

5G Tech

Multiple directed outputs

- Need for smart, compact multi-output antennas.
- More gain antennas

Wireless/Antenna opportunities to build better internet infrastructure

Many technological reforms are needed to develop intelligent, compact, and flexible antennas with high gain. Skills needed

1) Smart materials and semiconductor devices
2) Advanced manufacturing
3) Complex antenna design (knowledge of EM)
4) Radiofrequency engineering
5) Electromagnetic propagation models
6) Information coding techniques

Design Challenge Project

- Use the drawing paper and the images provided to you to create your understanding of the internet.