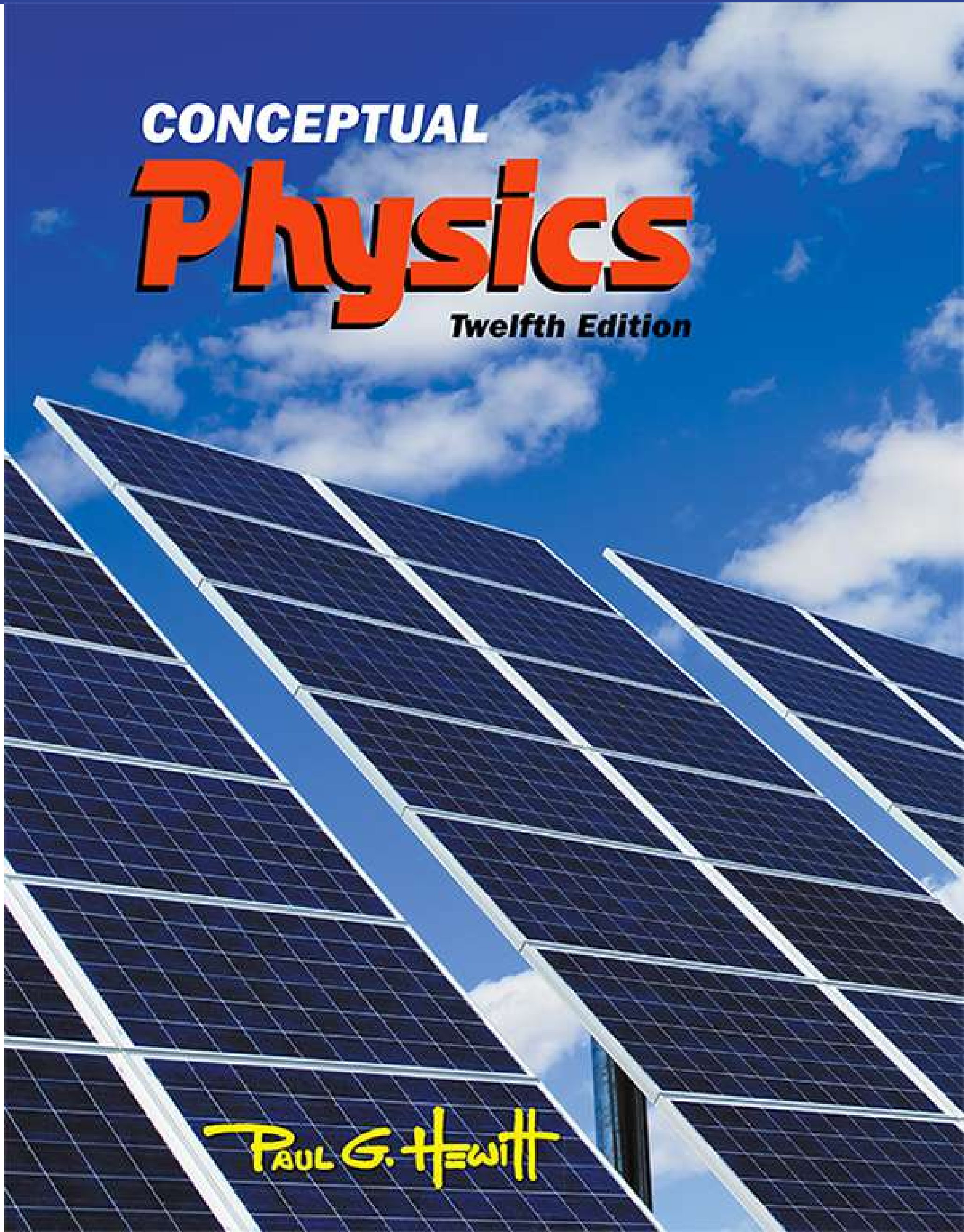
Chapter 25: Electromagnetic Induction

Part 3



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Self-Induction

- Current-carrying loops in a coil interact not only with loops of other coils but also with loops of the same coil.
- Each loop in a coil interacts with the magnetic field around the current in other loops of the same coil.
- This is *self-induction*.

- When the switch is opened, the magnetic field of the coil collapses. This sudden change in the field can induce a huge voltage.
- This can cause big sparks when you disconnect.
- Turn off by the switch, not by pulling out the plug.

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Classwork: page 481

23. When the magnetic field changes in a coil of wire, voltage in each loop of the coil is induced. Will voltage be induced in a loop if the source of the magnetic field is the coil itself?

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Power Transmission

- Almost all electric energy sold today is ac because of the ease with which it can be transformed from one voltage to another.
- Power is generated at 25,000 V or less and is stepped up near the power station to as much as 750,000 V for long-distance transmission.

- It is then stepped down in stages at substations and distribution points to voltages needed in industrial applications (often 440 V or more) and for the home (240 and 120 V).

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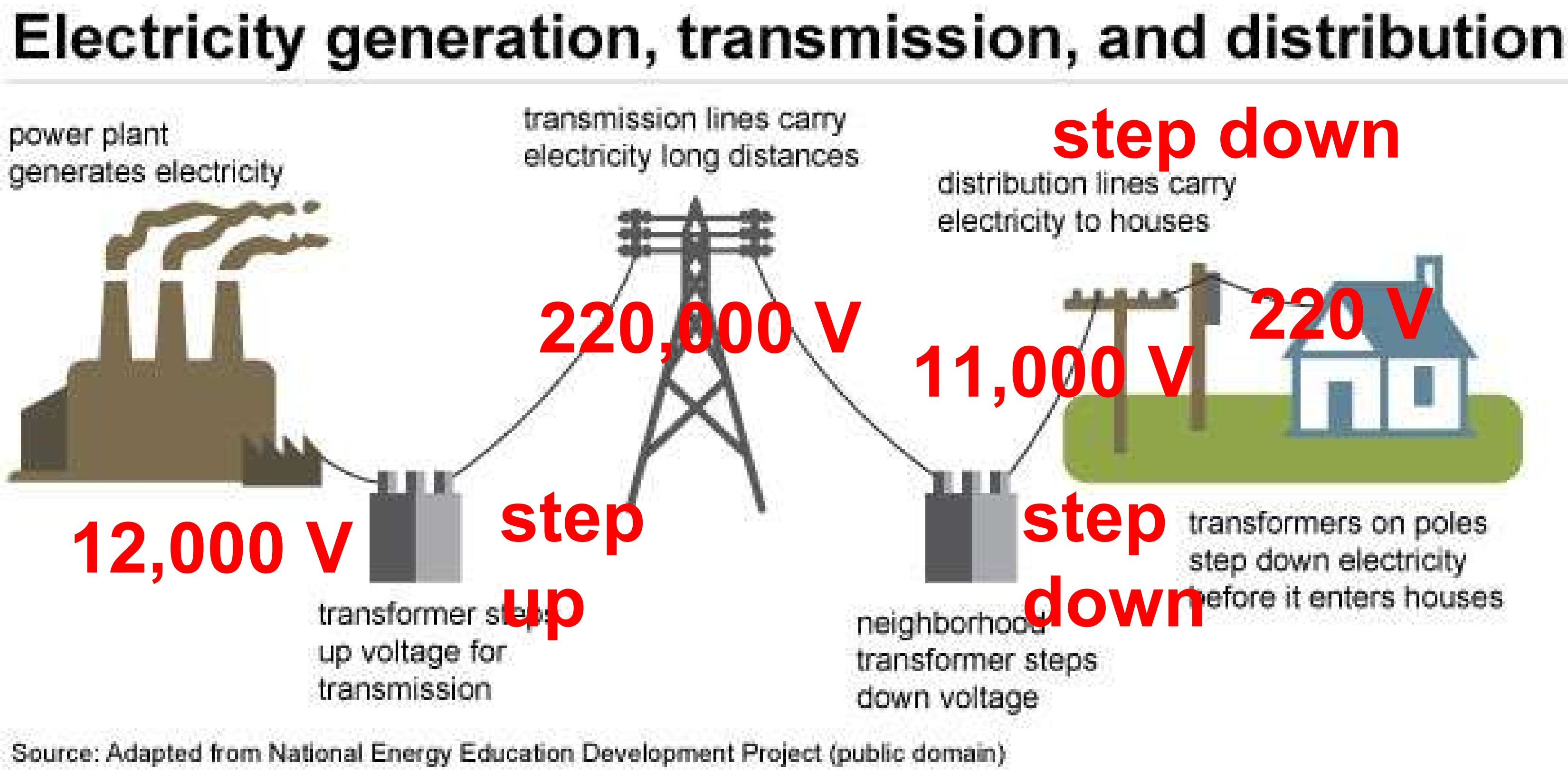

Electrical power = voltage · current = V·I

If V is made high at a transformer, I can be low.

Less I means less heat → less wasted energy.

European outlets have 220 V for the same reason.

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Classwork:

24. What is the purpose of transmitting power at high voltages over long distances?

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Why do high voltage lines crackle and hiss?

- Air is normally a poor conductor of electricity. But if a sufficiently high voltage is applied across a small distance, electrons from the air molecules are stripped off and start to form a current.

- This in turn causes intense heating of the air – resulting in crackle and hiss.
- It's most common during damp weather, when the air becomes a better electrical conductor.

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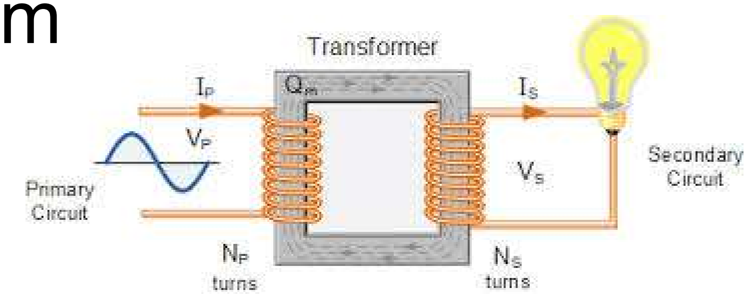
- Transformer transfers energy from one coil to another without being directly connect to each other.



- Example:
  - voltage **stepped up** before leaving power station

  - voltage **stepped down** for distribution near cities by cables that feed power to the grid

  - voltage **stepped down** again at substations and utility poles before going to businesses and consumers/

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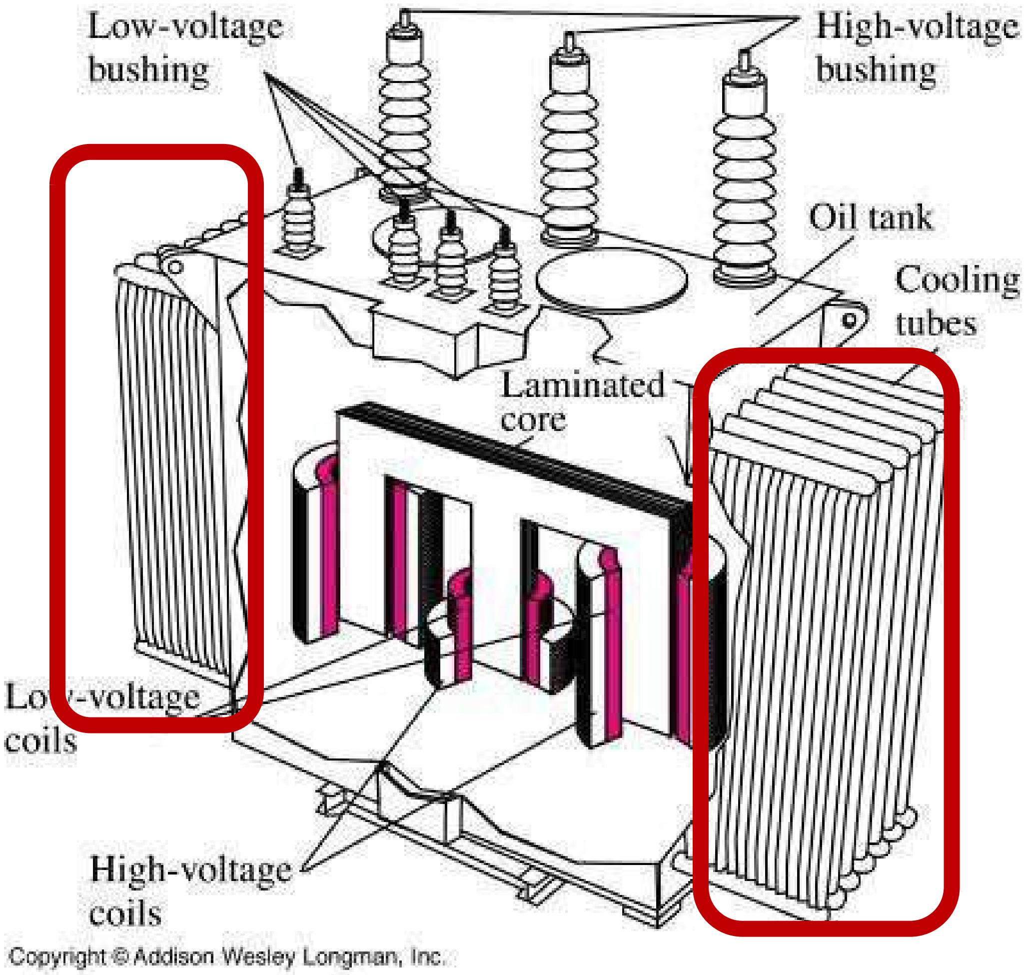
Substation transformers:

The transformers are not totally efficient.

Wasted heat is absorbed by oil, then circulated in cooling tube to be air cooled.



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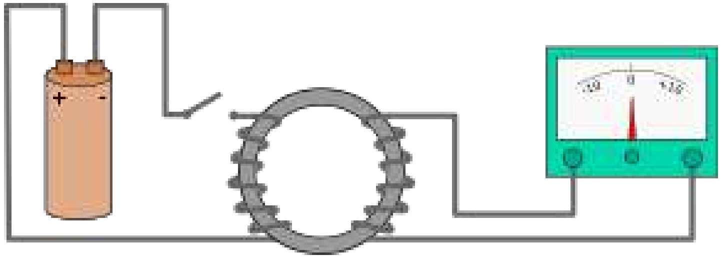
Field Induction

- Electromagnetic induction is a "two-way street."

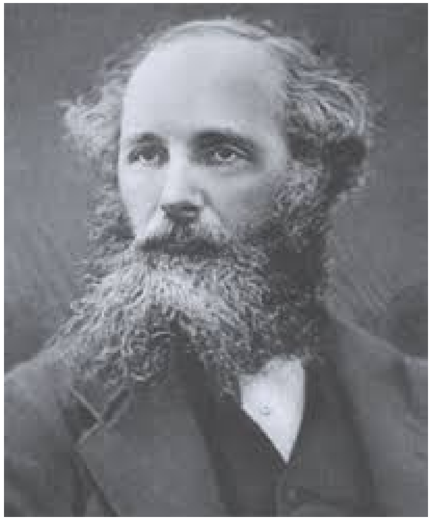
Faraday's law

- A changing magnetic field induces an electric field



Maxwell's counterpart to Faraday's law

- A changing electric field induces a magnetic field.



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Classwork:

26. Who extended Faraday's law to changing electric fields?

27. What is induced by the rapid alternation of a magnetic field?

28. What is induced by the rapid alternation of an electric field?

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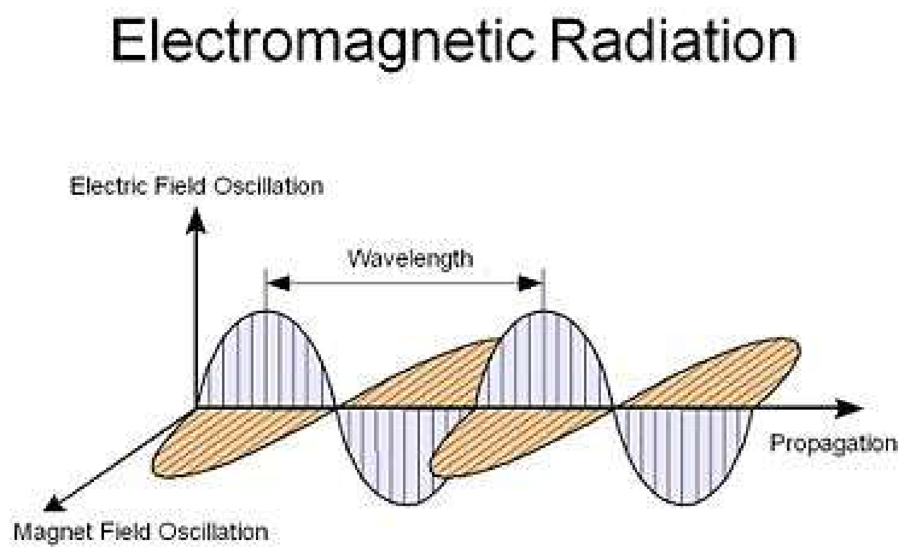
Field Induction



- Light is produced by the *mutual induction* of electric and magnetic fields.

The electric and magnetic fields induce each other.

- Too slow, the regenerating fields die out.
- Too fast, fields build up in a crescendo of ever-increasing energy.
- At the speed of light *c*, just right!
- And, there is light!

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Field Induction
CHECK YOUR NEIGHBOR

The mutual induction of electric and magnetic fields can produce

A. light.
B. energy.
C. sound.
D. None of the above.

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Field Induction
CHECK YOUR ANSWER

The mutual induction of electric and magnetic fields can produce

A. **light.**

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Maxwell (Scottish) is to *electromagnetism*, what **Newton** (British) is to *mechanics*, and what **Einstein** (German) is to *relativity*.

Maxwell's combined all knowledge of electromagnetism into 4 equations:

$\nabla \cdot \mathbf{D} = \rho$	(1)	Gauss' Law
$\nabla \cdot \mathbf{B} = 0$	(2)	Gauss' Law for magnetism
$\nabla \times \mathbf{E} = -\dfrac{\partial \mathbf{B}}{\partial t}$	(3)	Faraday's Law
$\nabla \times \mathbf{H} = \dfrac{\partial \mathbf{D}}{\partial t} + \mathbf{J}$	(4)	Ampère-Maxwell Law

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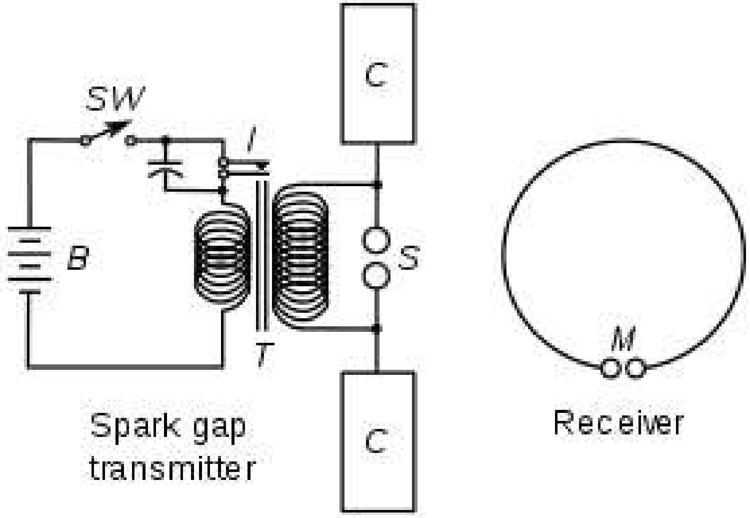
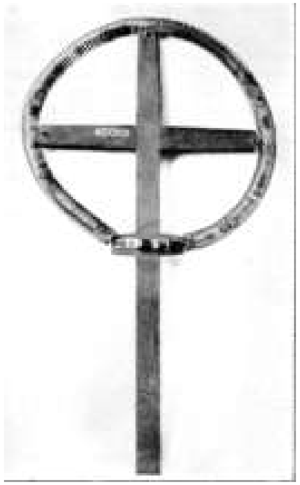
Heinrich Hertz

- German physicist who first conclusively proved the existence of the electromagnetic waves predicted by Maxwell.
- The unit of frequency, cycle per second, was named the "hertz" in his honor.

his radio:



his antenna:



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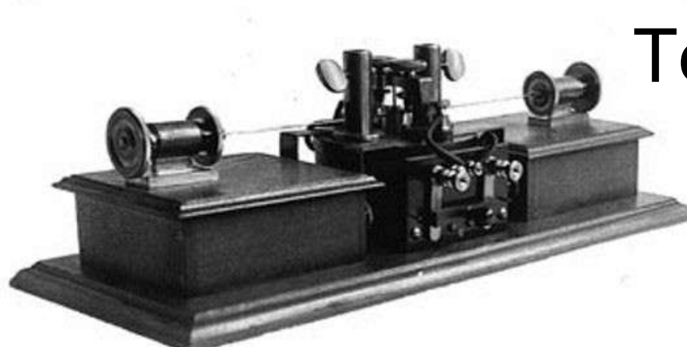
Marconi and Tesla built the first radios….

Electrical power (and information) could now be transmitted over long distances without direct connection!

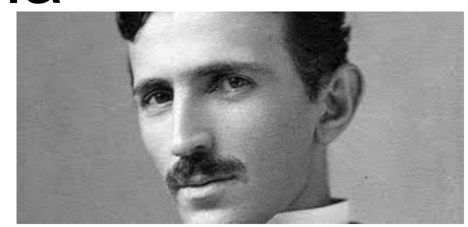
Hertz's radio

Marconi



EARLY TESLA COIL SPARK GAP TRANSMITTER

Tesla



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25. Does the transmission of electric energy require electric conductors between the source and receiver? Cite an example to defend your answer.

29. Are wires needed in Maxwell's view of Faraday's law?

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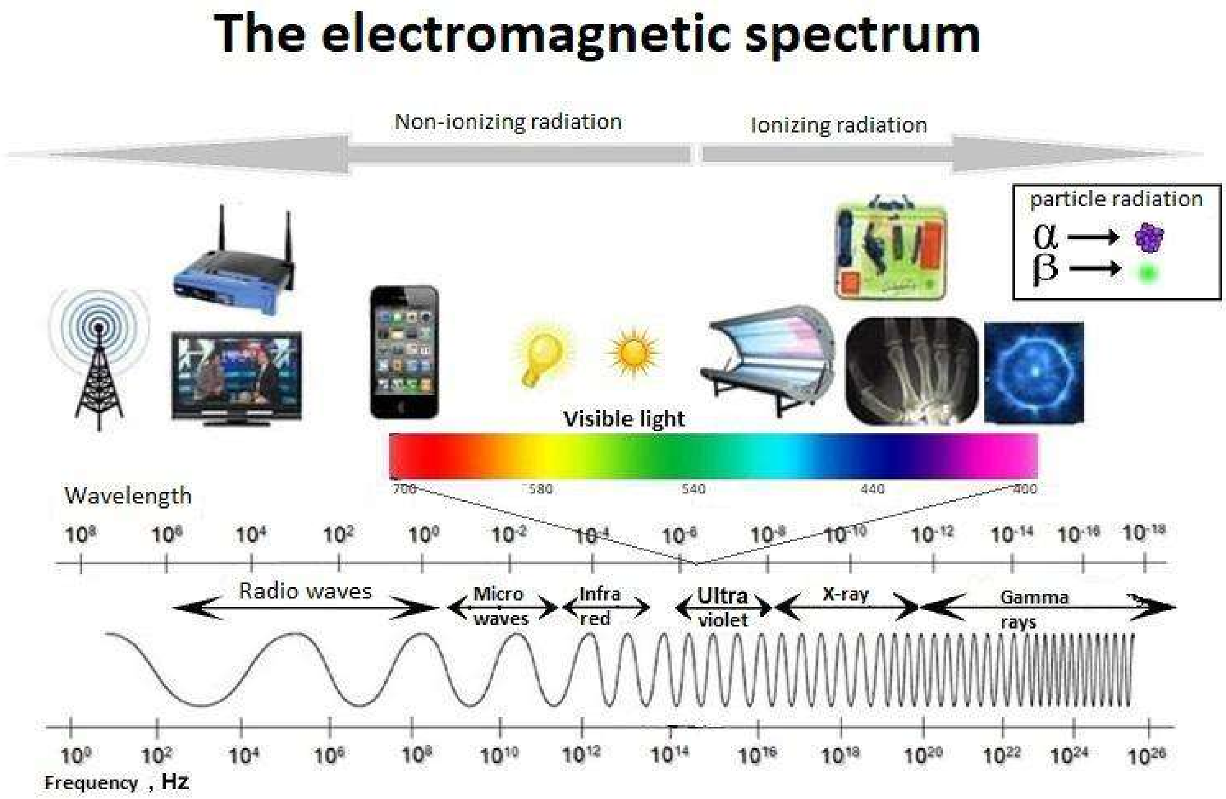
Light is the type of electromagnetic radiation that we can see:



All travel at same speed: ***c*** (speed of light)

Only difference is frequency or wavelength.

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30. What do we call electromagnetic waves in the range of frequencies that match what our eyes can see?

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Test Thursday or Friday.

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