

Electromagnetic Theory

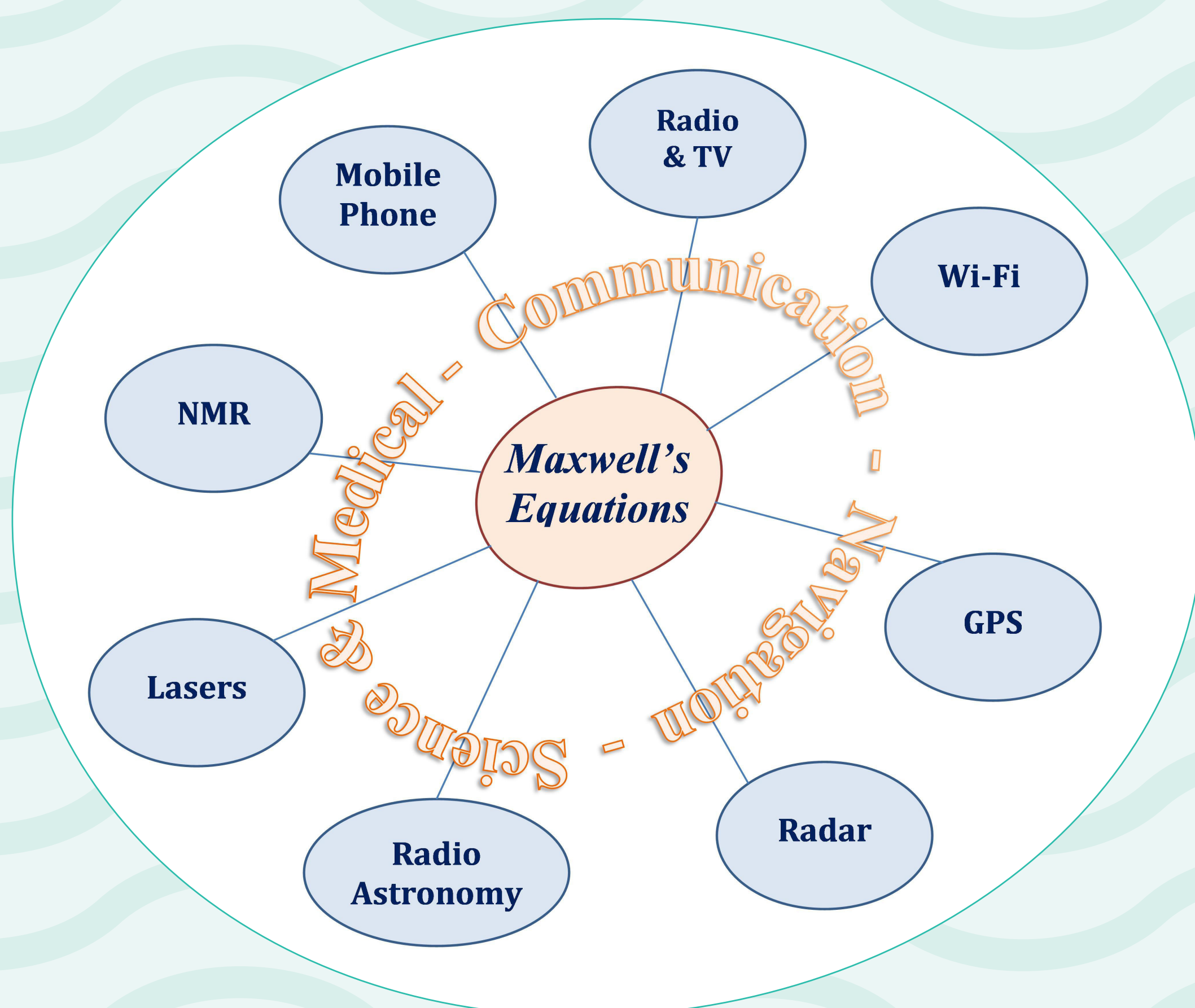
Electromagnetic Waves come in many varieties, including radio waves, from the 'long-wave' band through VHF, UHF and beyond; microwaves; infrared, visible and ultraviolet light; X-rays, gamma rays etc.

About 1860, **James Clerk Maxwell** brought together all the known laws of electricity and magnetism:

- **Gauss' law** gives the electric field produced by electric charges $\nabla \cdot \mathbf{D} = \rho$
- **Faraday's law** gives the electric field produced by a changing magnetic field $\nabla \times \mathbf{E} = -\partial \mathbf{B} / \partial t$
- **Ampère's law** gave the magnetic field produced by an electric current $\nabla \times \mathbf{H} = \mathbf{J}$
- **A fourth law** states that individual magnetic charges cannot exist $\nabla \cdot \mathbf{B} = 0$

In a metal wire electric charges flow round as a continuous current, while in an insulator they are only *displaced* by a small distance. Maxwell reasoned that this displacement could still make a current, $\partial \mathbf{D} / \partial t$, and so he reformulated Ampère's law as $\nabla \times \mathbf{H} = \mathbf{J} + \partial \mathbf{D} / \partial t$.

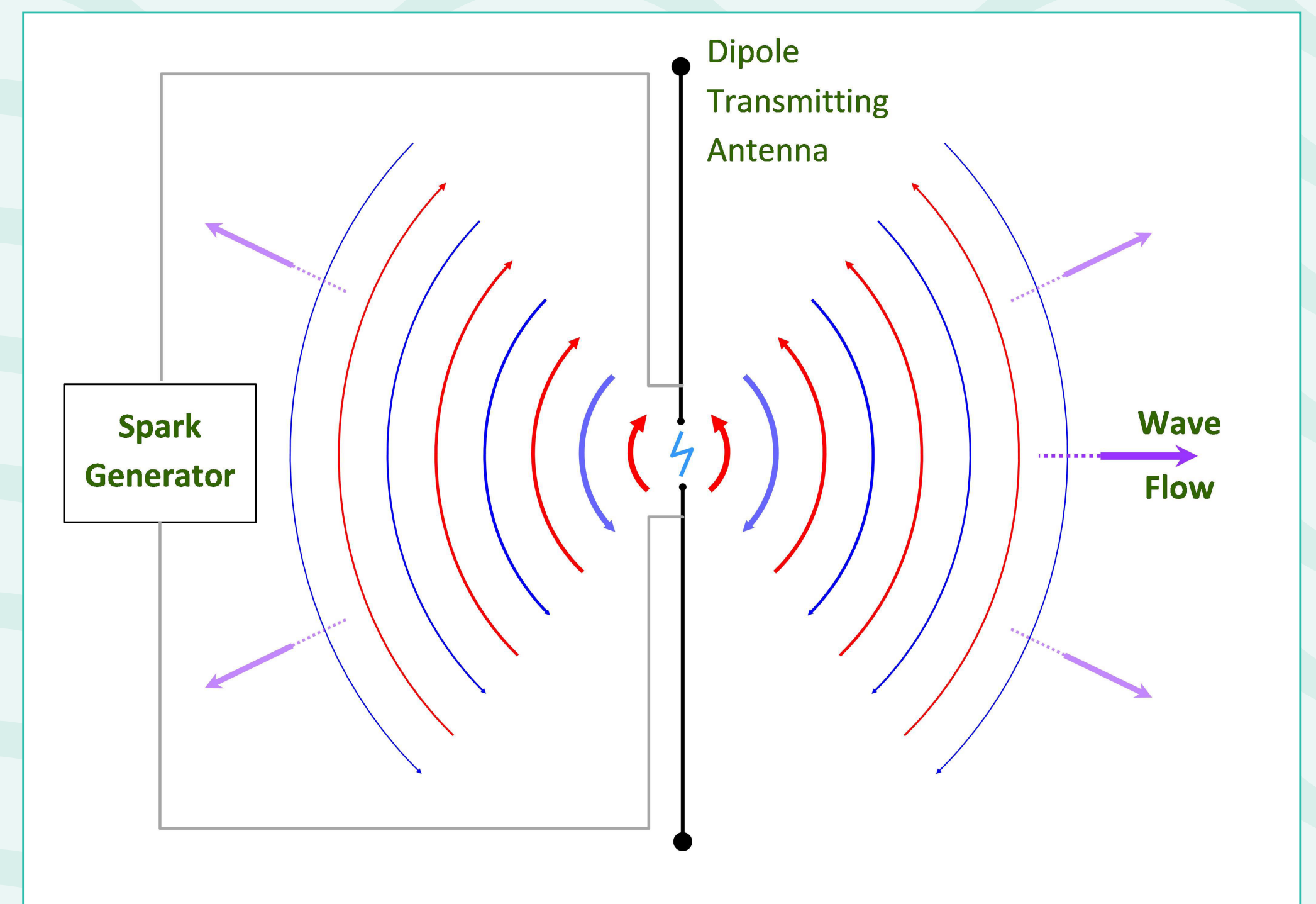
Maxwell's equations are essential to the understanding of such things as the electrical and optical properties of matter, the ionosphere, 'space weather', solar dynamics and pulsars. New advances, the Large Hadron Collider, also depend on them.



Some Key Applications that Depend on Maxwell's Equations and Electromagnetic Waves.

What difference did it make? Maxwell's new law and Faraday's law give a wave equation, implying that any disturbance in the electric and magnetic fields will be self sustaining and travel out in space at the speed of light as an 'electro-magnetic' wave.

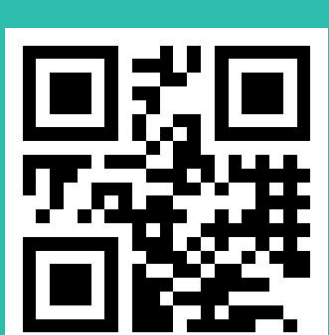
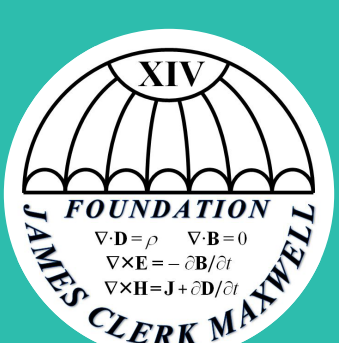
What happened next? In 1887 Heinrich Hertz used a spark-gap transmitter and receiver to demonstrate that these waves actually existed:



The spark generator causes a current spike across the gap in the central antenna. The transient pulse of electric field travels outwards at the speed of light. It alternates in direction (red for up, blue for down) making a wave, and carries with it a magnetic field and electromagnetic energy. The wave can be detected when it passes through a loop receiving antenna incorporating a small gap where a feeble spark can be seen.

Milestones from Maxwell to the Wireless Communications of Today

- 1885 - Oliver Heaviside reduces Maxwell's original equations into the form used today.
- 1897 - Guglielmo Marconi employs electromagnetic waves for radio communications.
- 1905 - Albert Einstein uses Maxwell's equations to start his theory of special relativity.
- 1920 - households begin listening to music and voice broadcast on crystal and valve radios.
- 1957 - Sony begins mass producing affordable portable transistor radios.
- 1973 - the first hand-held or personal cellular mobile telephone networks roll out.
- 2000 - WiFi expands connectivity of mobile devices to networks and the internet.



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