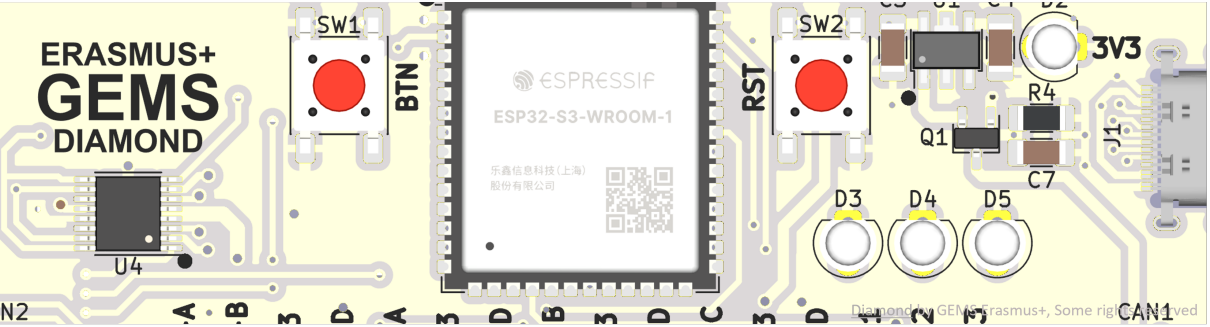

Tutorial 1

Laws of Electromagnetism for Electrical Machines

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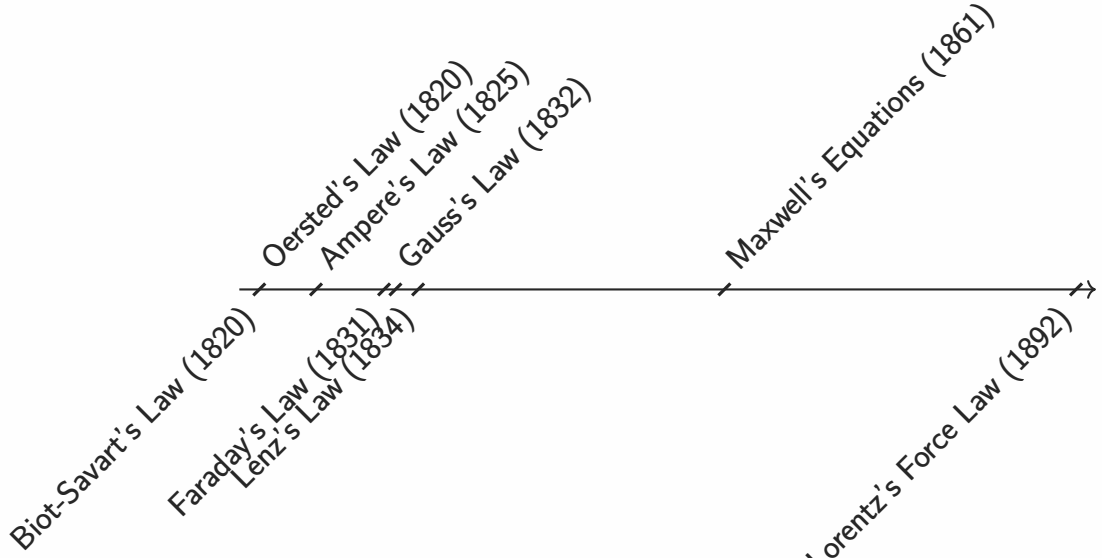
Historical Timeline



Oersted's Law

- Hans Christian Oersted (1777 – 1851)
- Electric current produces a magnetic field.
- Compass needle deflects near a current-carrying wire.
- Linked electricity and magnetism.

Biot-Savarts Law

$$\vec{B} = \frac{\mu_0}{4\pi} \int \frac{I \, d\vec{l} \times \hat{r}}{r^2} \tag{1}$$

- Quantitatively relates magnetic field to current and geometry of conductors.

1820

Ampère's Law

- Investigated forces between current-carrying wires.
- Formulated that magnetic fields circulate around electric currents.

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 I \tag{2}$$

- Fundamental to magnetic field calculations.
- Forms the basis of electromagnet design and motor field theory.

Faraday's Law

- Michael Faraday (1791 – 1867)
- Discovered electromagnetic induction — the principle behind electric generators.
- Demonstrated that a changing magnetic field induces an electromotive force (EMF).

$$\mathcal{E} = -\frac{d\Phi_B}{dt} \tag{3}$$

Significance:

- Foundation of generators, transformers, and induction motors.

Gauss's Law

- Carl Friedrich Gauss (1777–1855) and Wilhelm Eduard Weber (1804–1891) together made magnetism measurable.
- Developed methods to measure magnetic field strength and magnetic dipoles.
- Formulated early quantitative relations between electricity and magnetism.
- Laid the groundwork for Gauss' Law in Maxwell's field theory.

$$\nabla \cdot \vec{B} = 0 \tag{4}$$

Lenz's Law

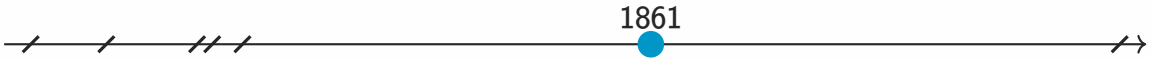
- Heinrich Lenz (1804 – 1865)
- Defined the direction of induced currents.
- Stated that induced currents oppose the change that caused them.

$$\mathcal{E} = -\frac{d\Phi_B}{dt} \tag{5}$$

- The negative sign represents opposition to change.
- Ensures conservation of energy in electromagnetic systems.

Maxwell's Equations

- James Clerk Maxwell (1831 – 1879)
- Unified electricity and magnetism into four elegant equations.
  - Gauss's Law for Electricity
  - Gauss's Law for Magnetism
  - Faraday's Law of Induction
  - Ampère-Maxwell Law
- Predicted electromagnetic waves and established field theory.



Lorentz Force Law

- Hendrik Antoon Lorentz (1853 – 1928)
- Defined the total force on a moving charge in electric and magnetic fields.

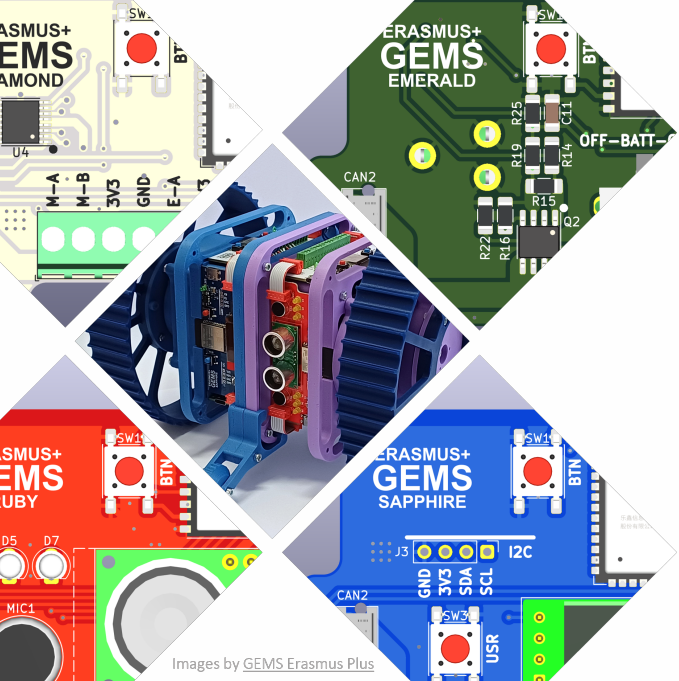
$$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B}) \tag{6}$$

Importance:

- Explains the motion of charges in magnetic fields.
- Core to understanding torque in electric motors.

Conclusion

- These discoveries built the foundation for electric motor technology.
- Each step connected electricity, magnetism, and motion more deeply.
- From Oersted's compass to Lorentz's force — a century of innovation.



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