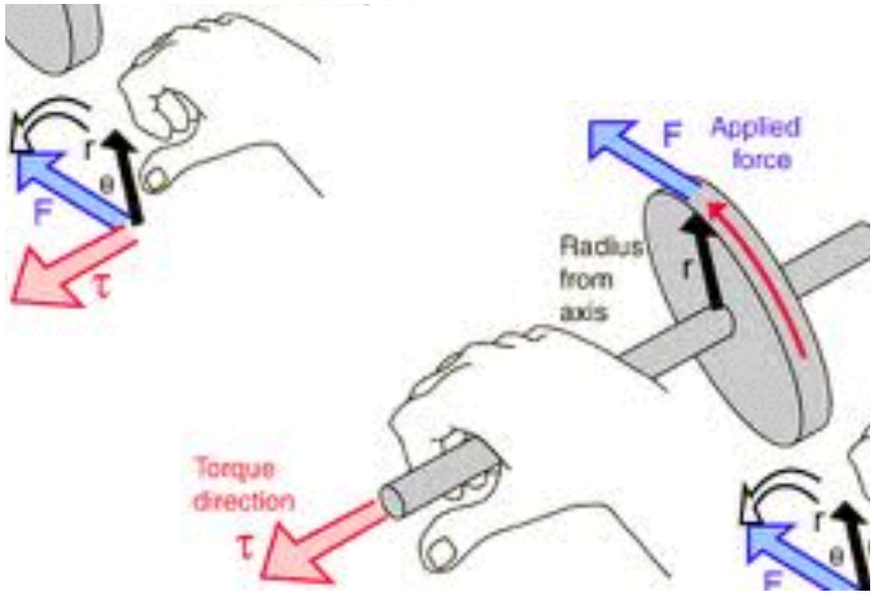
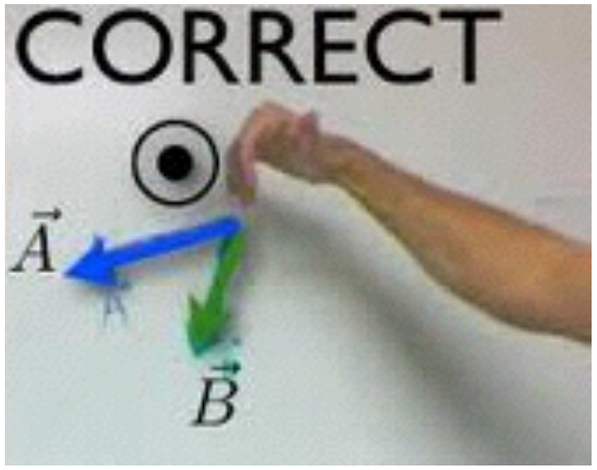
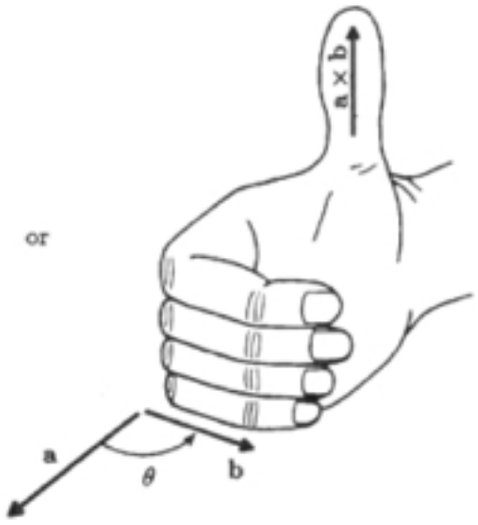
Forces and torques generated by the B field

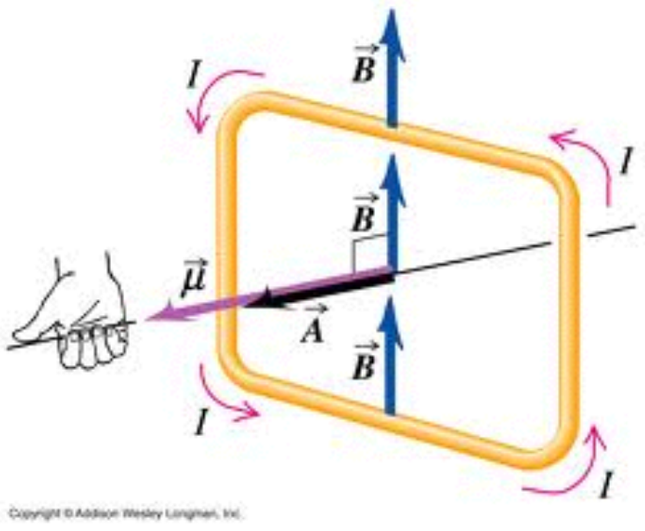
Lecture 18

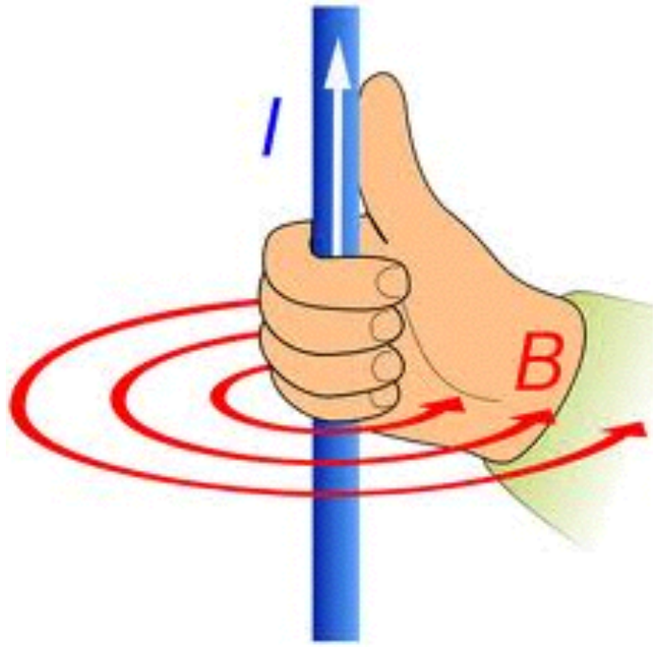
Review: Right Hand Rules

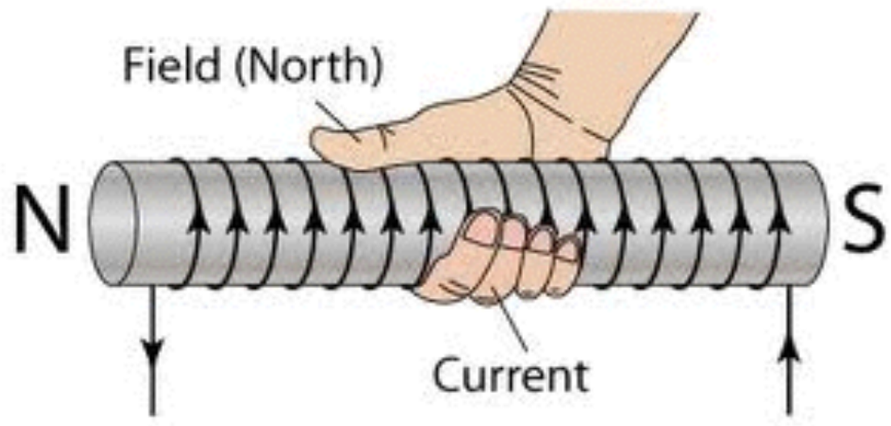












From last time: Unification

- **Electricity** and **Magnetism** were **unified** into a single theory!

- Current **generates** B and B **applies forces** on currents.

- Lorentz Force Law (J.J. Thomson ++):

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

- Ampère Law (w/o Maxwell correction):

$$\vec{\nabla} \times \vec{B} = \mu_0 \vec{j} \qquad \oint \vec{d\ell} \cdot \vec{B} = \mu_0 \, I_{\text{inside}}$$

Lorentz Force Law

- Force on moving charges:

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

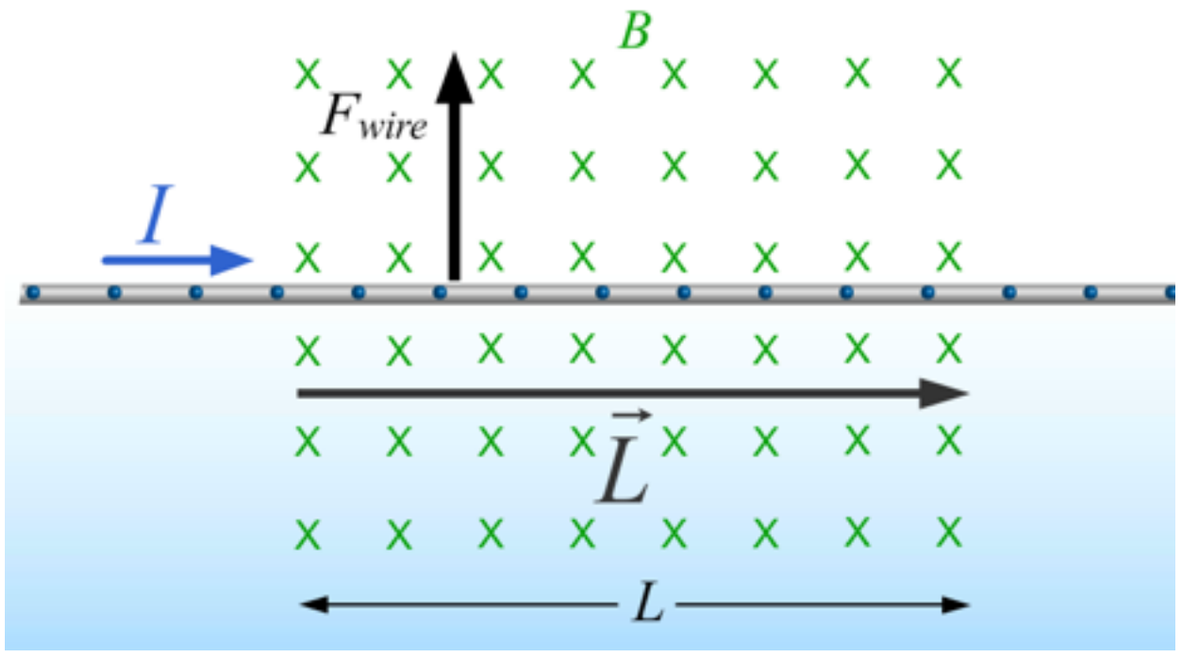
- Derive a force on wires carrying current (overhead):

- Result:

$$\vec{F} = I\vec{L} \times \vec{B}$$

Demo: Jumping Wire

$$\vec{F} = I\vec{L} \times \vec{B}$$



- Work out the direction of the force…

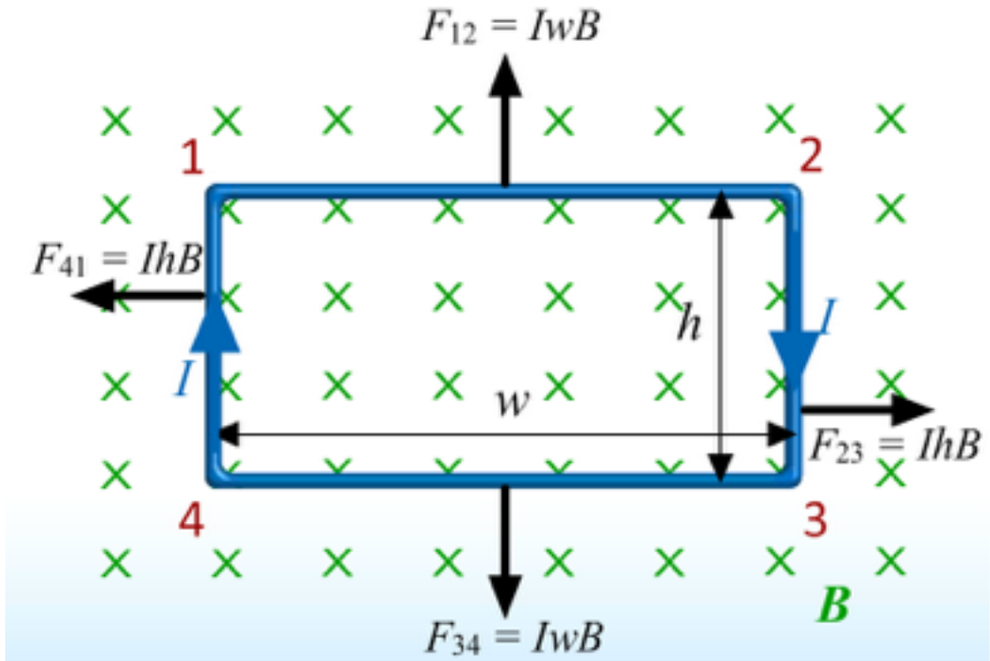
Compute the force on a closed loop

- L is the end-to-end displacement of the loop

$$\vec{F} = I\vec{L} \times \vec{B}$$

- Closed loops have L = 0

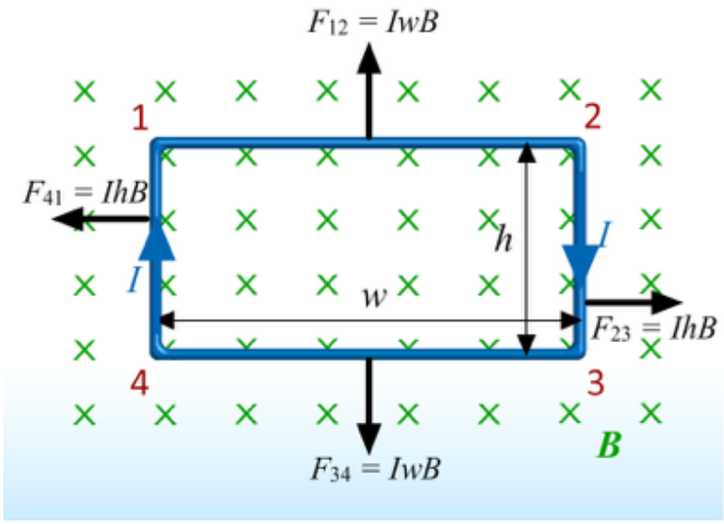
- **Physical intuition**: Cancelation between opposing sides.



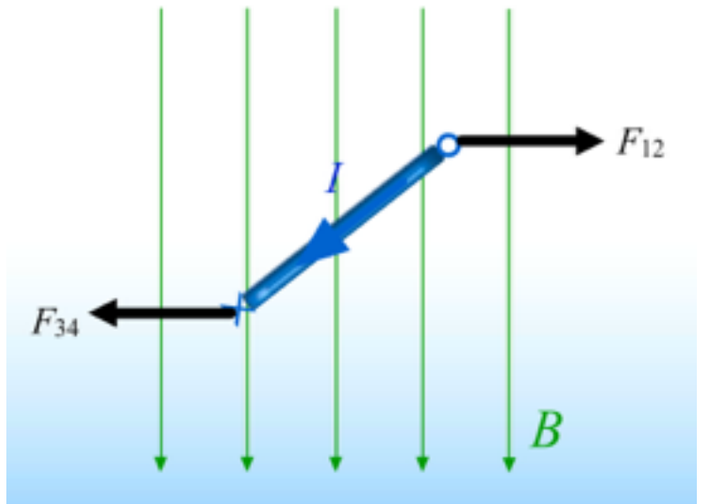
Torque on a closed loop

- Compute the torque on a closed loop.

$$\vec{F} = I\vec{L} \times \vec{B} \qquad \vec{\tau} = \vec{r} \times \vec{F}$$



- (Overhead)



- Result:

$$\vec{\tau} = N\, I\, A\, \hat{n} \times \vec{B}$$

Magnetic Dipole Moment

- Define the Magnetic Dipole Moment:

$$\vec{\mu} \equiv N\, I\, A\, \hat{n}$$

- Torque is now:

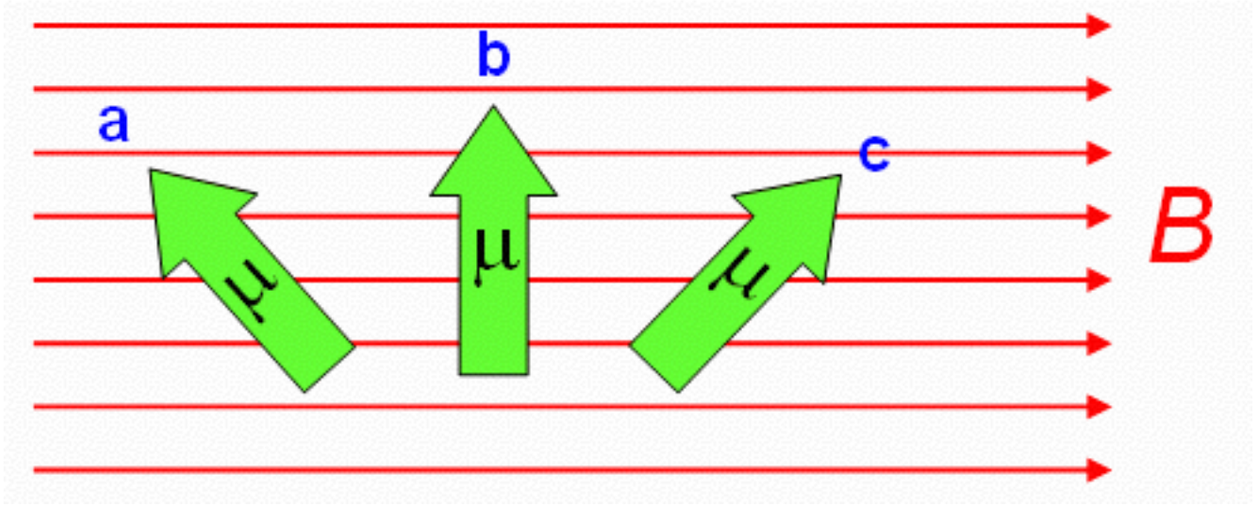
$$\vec{\tau} = \vec{\mu} \times \vec{B} \qquad\qquad \vec{\tau} = \vec{p} \times \vec{E}$$

- Compute the Potential Energy:
(Overhead)

Potential energy for MDM

- Potential energy for a magnetic dipole moment
  Result:

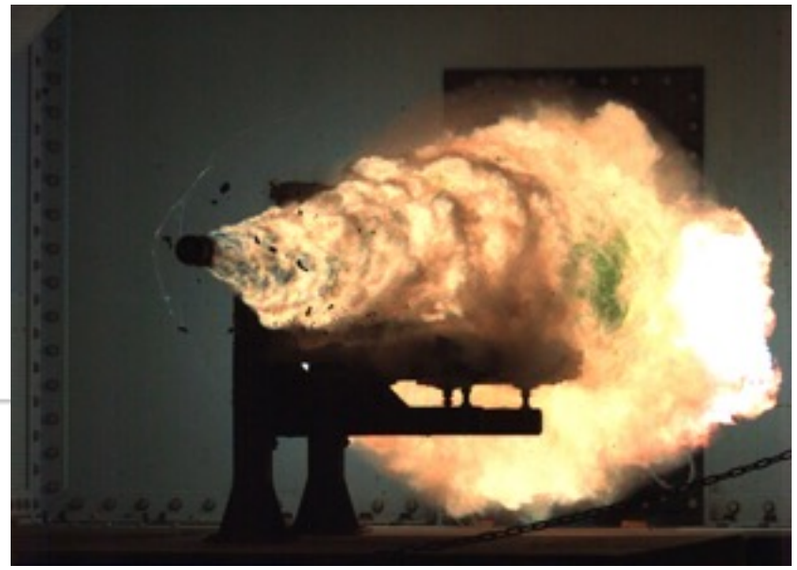
$$U = -\vec{\mu} \cdot \vec{B} \qquad\qquad U = -\vec{p} \cdot \vec{E}$$



- Lowest energy configuration: Aligned

Demo: Electric motor

Just for fun clicker…



Railgun

From Wikipedia, the free encyclopedia

For railroad artillery, see Railway gun. For other uses, see Rail-gun (disambiguation).
See also: Coilgun

A **railgun** is an electrically powered electromagnetic projectile launcher based on similar principles to the homopolar motor. A railgun comprises a pair of parallel conducting rails, along which a sliding armature is accelerated by the electromagnetic effects of a current that flows down one rail, into the armature and then back along the other rail.[2]

Railguns are being researched as a weapon with a projectile that would not use explosives nor propellant, but rather rely on electromagnetic forces to achieve a very high kinetic energy, somewhat similar to a kinetic energy penetrator. While current kinetic energy penetrators such as an armour-piercing fin-stabilized discarding-sabot can achieve a muzzle velocity on the order of Mach 5, railguns can potentially exceed Mach 10, and thus far exceed conventionally delivered munitions in range and destructive force, with the absence of explosives to store and handle as an additional advantage. Railguns have long existed as experimental technology but the mass, size and cost of the required power supplies have prevented railguns from becoming practical military weapons. However, in recent years, significant efforts have been made towards their development as feasible military technology. For example, in the late 2000s, the U.S. Navy tested a railgun that accelerates a 3.2 kg (7 pound) projectile to hypersonic velocities of approximately 2.4 kilometres per gave the project the Latin motto "Velocitas Eradico", Latin for "I, [who am] speed, eradicate".

In addition to military applications, NASA has proposed to use a railgun from a high-altitude aircraft to fire a small forces involved would necessarily restrict the usage to only the sturdiest of payloads.

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