RoboJackets

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THE ARTHUR M. BLANK
FAMILY FOUNDATION

TE Sessions - Electrical Power
November 6, 2007

Electrolmagnetism

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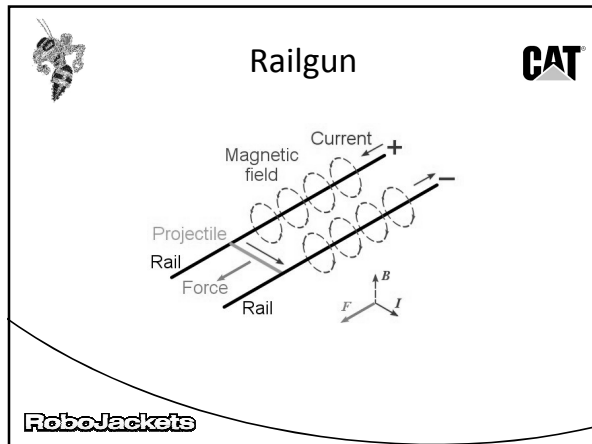| Name	Differential form	Integral form
Gauss's law:	$\nabla \cdot \mathbf{E} = \dfrac{\rho}{\epsilon_0}$	$\oint_S \mathbf{E} \cdot d\mathbf{A} = \dfrac{\mathbf{Q}_S}{\epsilon_0}$
Gauss' law for magnetism (absence of magnetic monopoles):	$\nabla \cdot \mathbf{B} = 0$	$\oint_S \mathbf{B} \cdot d\mathbf{A} = 0$
Faraday's law of induction:	$\nabla \times \mathbf{E} = -\dfrac{\partial \mathbf{B}}{\partial t}$	$\oint_{\partial S} \mathbf{E} \cdot d\mathbf{l} = -\dfrac{d\mathbf{\Phi}_{B,S}}{dt}$
Ampère's Circuital Law (with Maxwell's correction):	$\nabla \times \mathbf{B} = \mu_0 \mathbf{J} + \mu_0 \epsilon_0 \dfrac{\partial \mathbf{E}}{\partial t}$	$\oint_{\partial S} \mathbf{B} \cdot d\mathbf{l} = \mu_0 \mathbf{I}_S + \mu_0 \epsilon_0 \dfrac{d\mathbf{\Phi}_{E,S}}{dt}$

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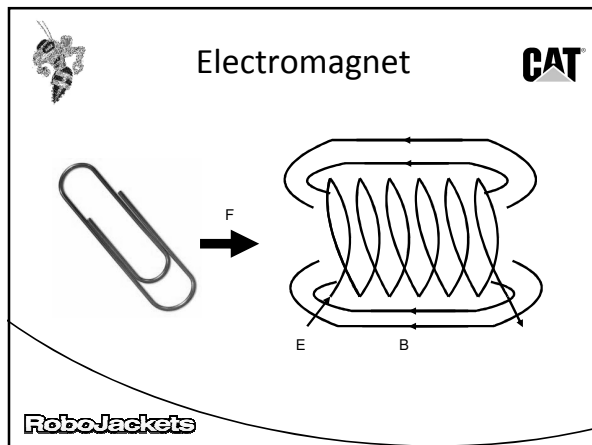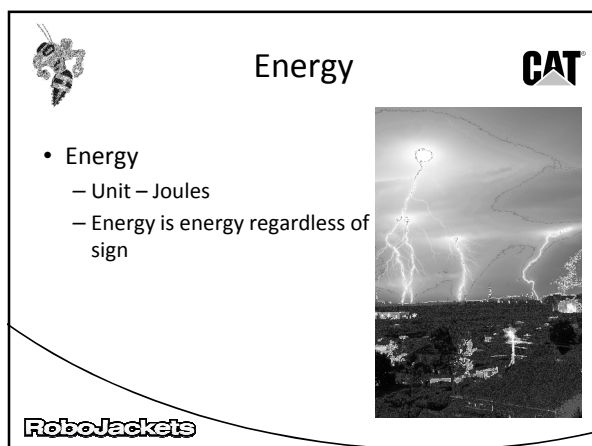

Electromagnetism

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- Duality – electricity and magnetism are the same "thing"
  - Aside: QED relates EM and nuclear
- Maxwell's Equations
- Mechanical force can be applied by electromagnetism (Lorentz Force)

$$F = q \quad E \quad v \times B$$

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Railgun

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Electromagnet

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Energy

- Energy
  - Unit – Joules
  - Energy is energy regardless of sign

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Power

- Rate of electrical energy transfer
- Power is converted to work
  - Heat (heaters)
  - Force (motors and solenoids)
  - Sound (speakers)
- Signs
  - Negative => Absorption
  - Positive => Supply

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Circuit Elements

- Wire – Connects circuit elements
- Switch – Interrupts current flow
- Resistor – Resists current flow
- Capacitor – Resists change in voltage
- Inductor – Resists change in current
- Fuse/Breaker – interrupts *excessive* current flow
  - Battery – Stores electrical energy chemically
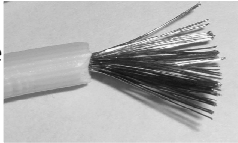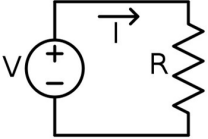
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Wire

- Connects circuit elements with (ideal) zero resistance
- Strict rules in FIRST
  - Gauge (ga, awg)
  - Color
- Activity
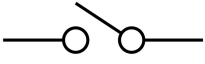
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Switch

- Interrupts the flow of current
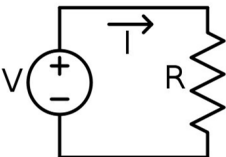- Electronic switches
  - FETs
  - Relays (SPIKEs)
- Activity

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Resistor

- Resists current flow
- By producing a voltage
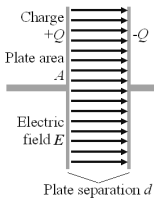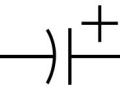- V = IR (Ohm's Law)

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Capacitor

- Stores energy as charge
- Resists change in voltage
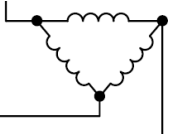 - Fast changes imply filtering
  - Slow changes imply energy storage

Charge
$+Q$ $-Q$
Plate area
A
Electric
field E
Plate separation d

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Inductor

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- Resists change in current
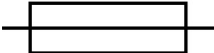- Through *magnetism*
- Motors
- Solenoids
- Filtering

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Fuse/Breaker

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- Interrupt *excessive* current flow
- Strict FIRST rules
- ESSIENTIAL SAFETY DEVICE

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Battery

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- Stores electrical energy chemically
- Strict FIRST rules
- Lead Acid
- Use the charger they give you
- Charge at 2.4 V / Cell

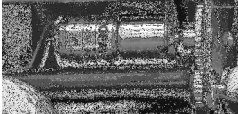RoboJackets

Energy Conversion

- Heat – resistive coils
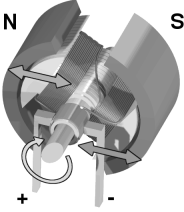- Mechanical force
  - Motors
  - Solenoids
- Sound – speakers

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How DC Motors Work

N   S

+   -

- DC voltage in coil turns armature into an electromagnet
- This magnetic field interacts with the stators
- Producing a rotational force on the armature
- Commutation changes and process repeats

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Electrical Properties

- FORCE VARIES WITH APPLIED VOLTAGE!!!
  - See Lorentz Force
- DC motors have inductance and resistance
- Coil -> Inductance
- Wire -> Resistance
- Other properties: Rotor Inertia, Speed Constant, Torque Constant

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Motor Control

- Voltage Control
  - Resistor – Don't actually do this!
  - Amplifier (Class A) – Don't actually do this!
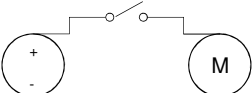 - H Bridge (Class D) – Do this!
  - Switch
  - Relay

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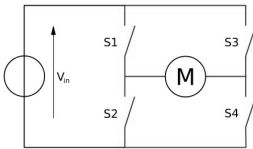## Switch/Relay

- Easy
- Unidirectional
- (Bidirectional)
- Slow (relatively)
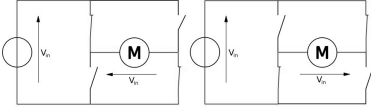- Mechanical (possibly)

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H Bridge

- Vary speed
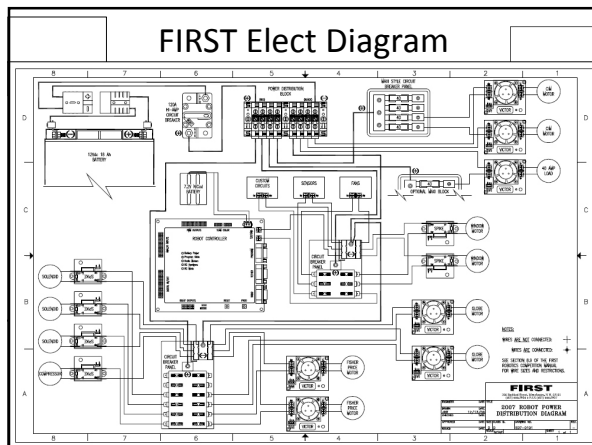- Direction change
- Solid state

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FIRST Electronics

- Strict rules
  - SAFETY
- Most parts supplied
- External Circuit – area of innovation
- Additional sensors

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FIRST Elect Diagram

Activity

Build an electromagnet!

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