RoboJackets

CAT®

The Arthur M. Blank Family Foundation

# TE Sessions - Electrical Power

November 6, 2007

www.robojackets.org

# Electromagnetism

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

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# Electromagnetism

- 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)

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

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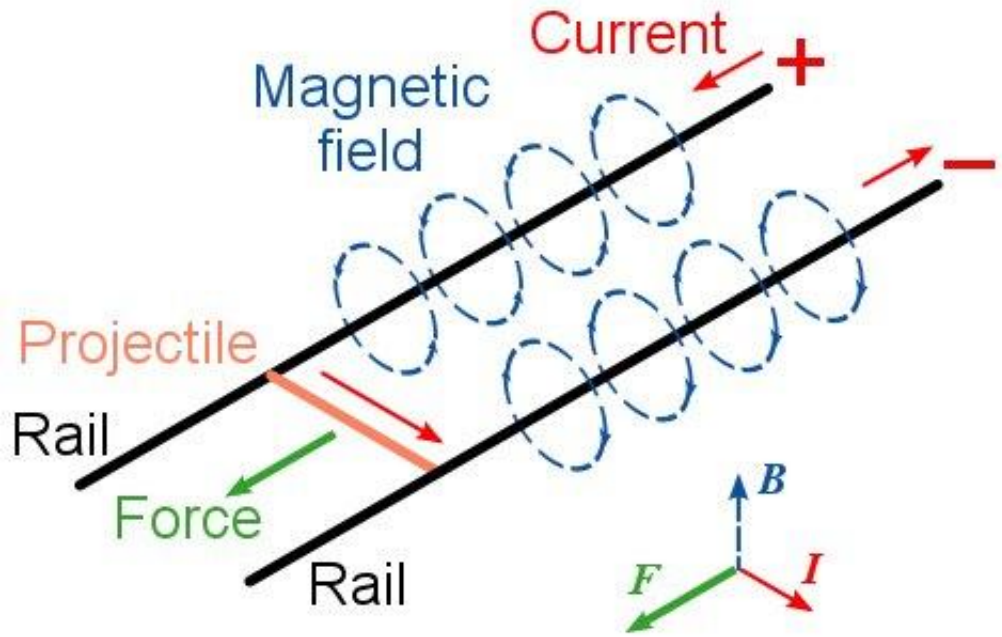
# Railgun

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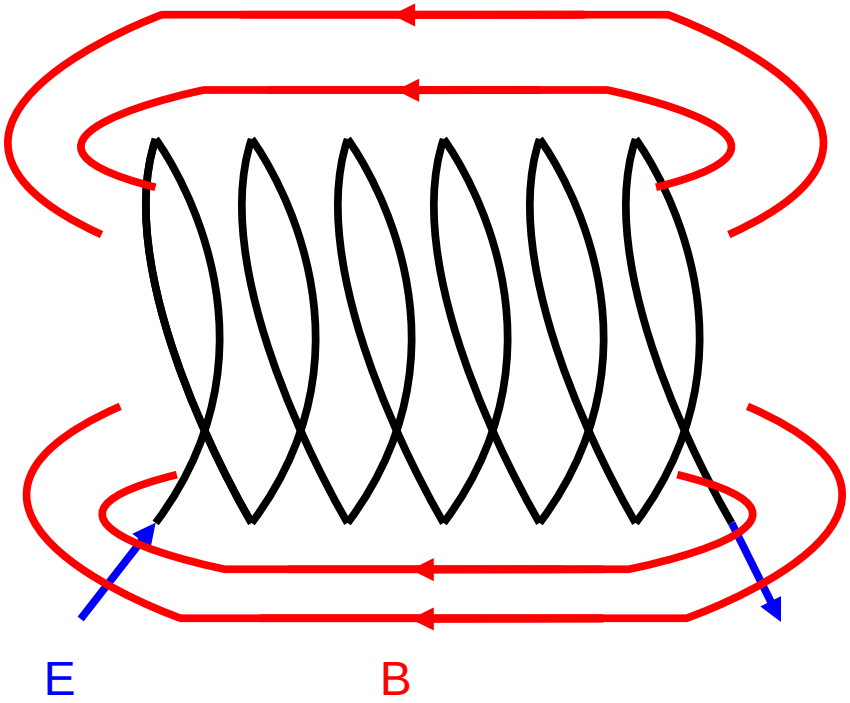
# Electromagnet

F



# Energy

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

# Power

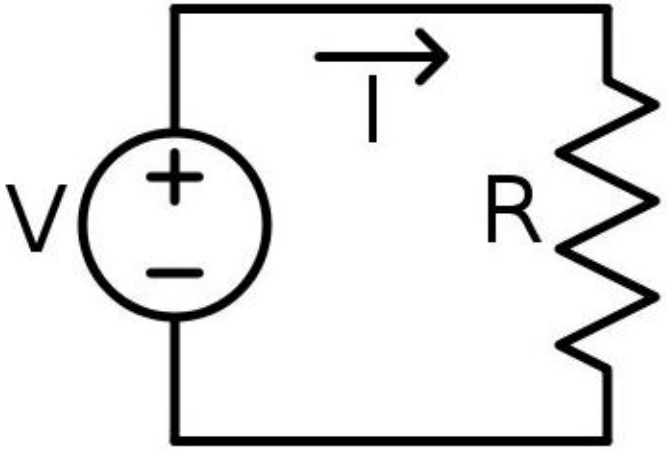
- Rate of electrical energy transfer
- Power is converted to work
  - Heat (heaters)
  - Force (motors and solenoids)
  - Sound (speakers)
- Signs
  - Negative => Absorption
  - Positive => Supply

# 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

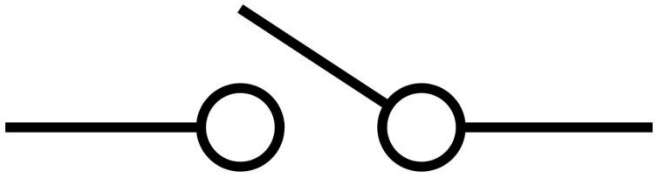
# Wire

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



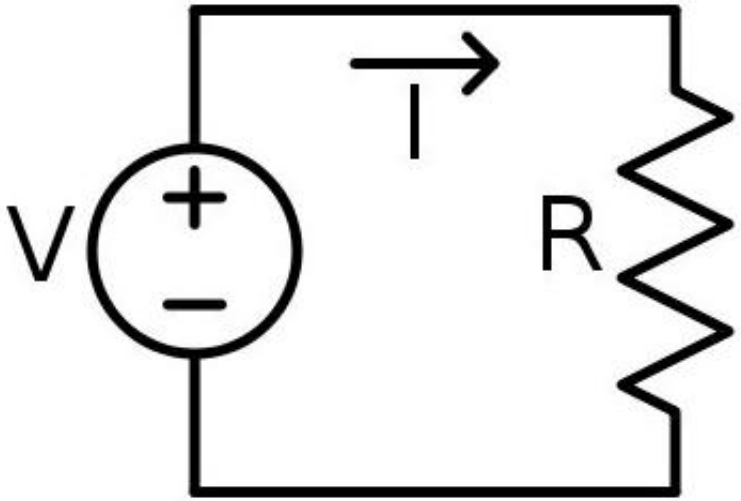
# Switch

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

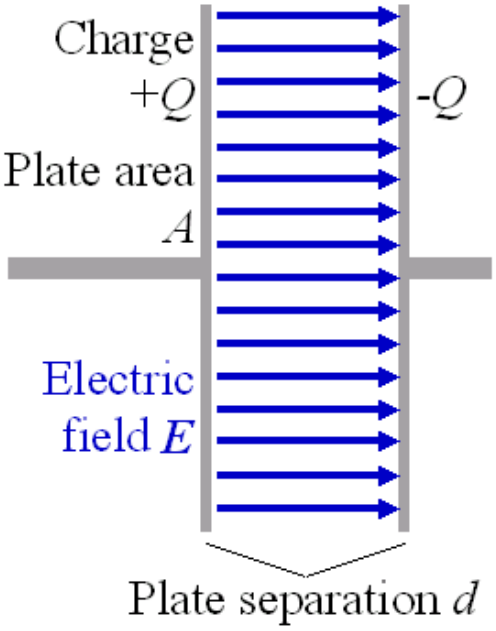


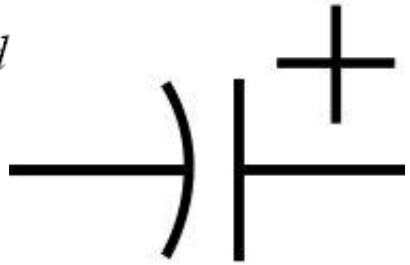
# Resistor

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




# Capacitor

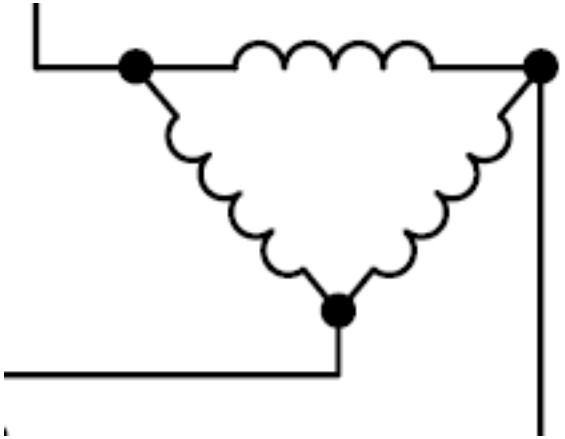


- Stores energy as charge
- Resists change in voltage
  - Fast changes imply filtering
  - Slow changes imply energy storage

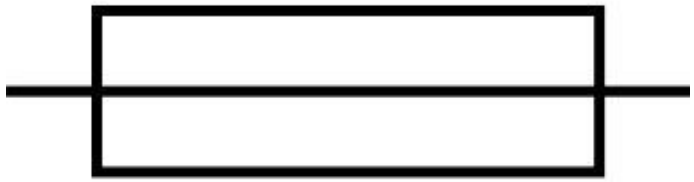
# Inductor

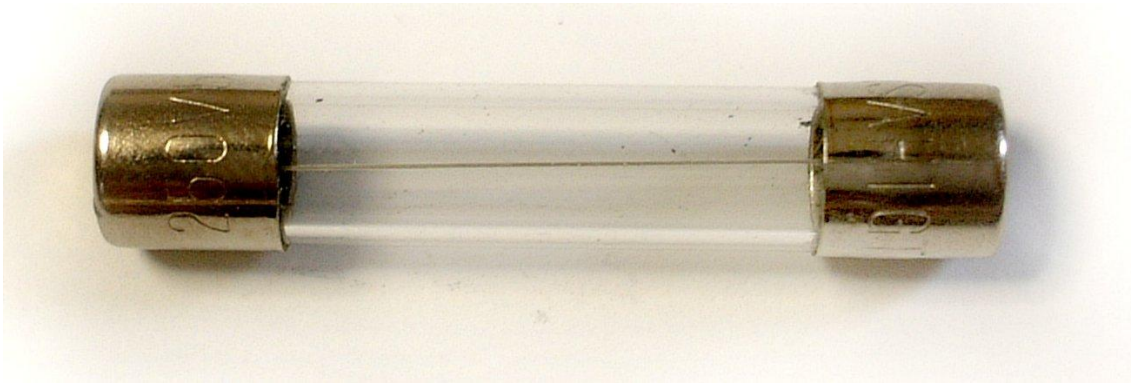
- Resists change in current
- Through *magnetism*
- Motors
- Solenoids
- Filtering



# Fuse/Breaker

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





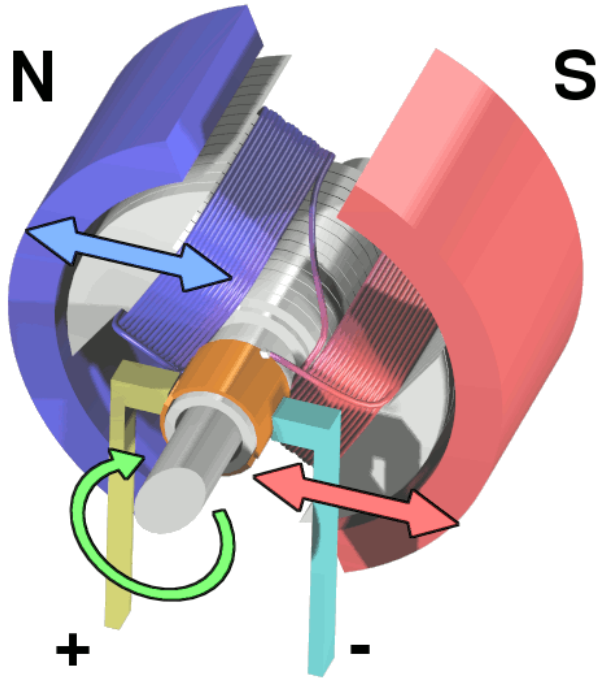
# Battery


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

# Energy Conversion

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


# How DC Motors Work




- 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

# Electrical Properties

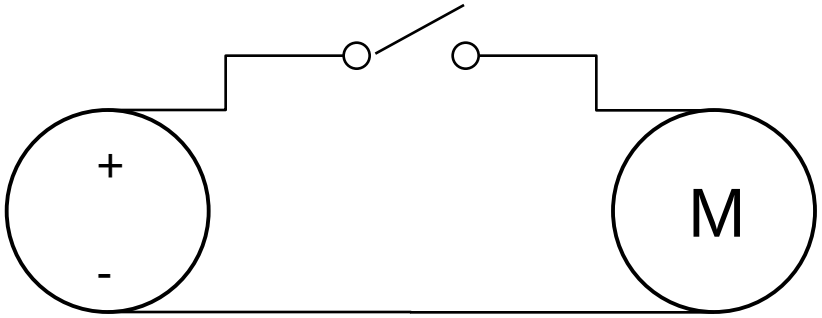
- FORCE VARIES WITH APPLIED VOLTAGE!!!
  - See Lorentz Force
- DC motors have inductance and resistance
- Coil -> Inductance
- Wire -> Resistance
- Other properties: Rotor Inertia, Speed Constant, Torque Constant

# Motor Control

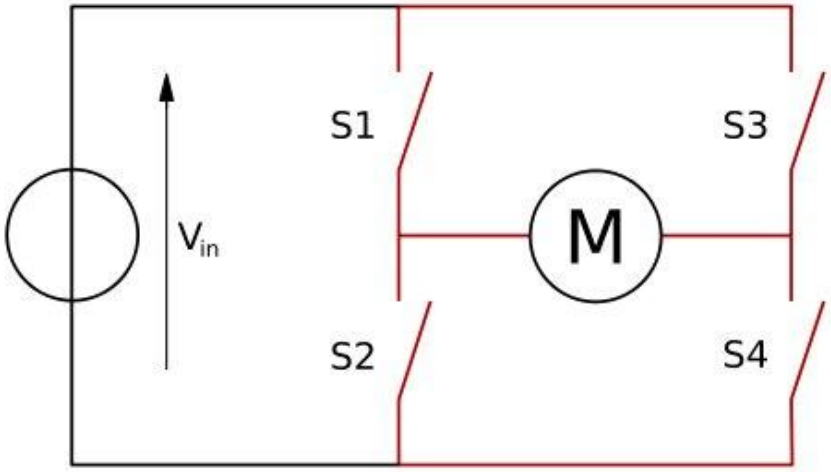
- Voltage Control
  - Resistor – Don't actually do this!
  - Amplifier (Class A) – Don't actually do this!
  - H Bridge (Class D) – Do this!
  - Switch
  - Relay

# Switch/Relay

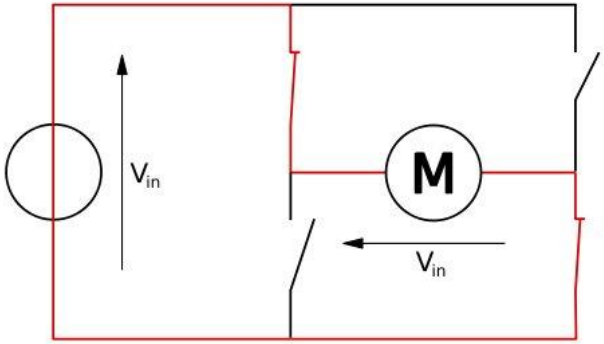
- Easy
- Unidirectional
- (Bidirectional)
- Slow (relatively)
- Mechanical (possibly)

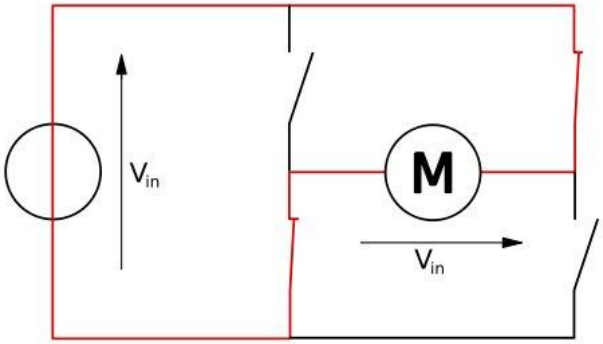



# H Bridge




- Vary speed
- Direction change
- Solid state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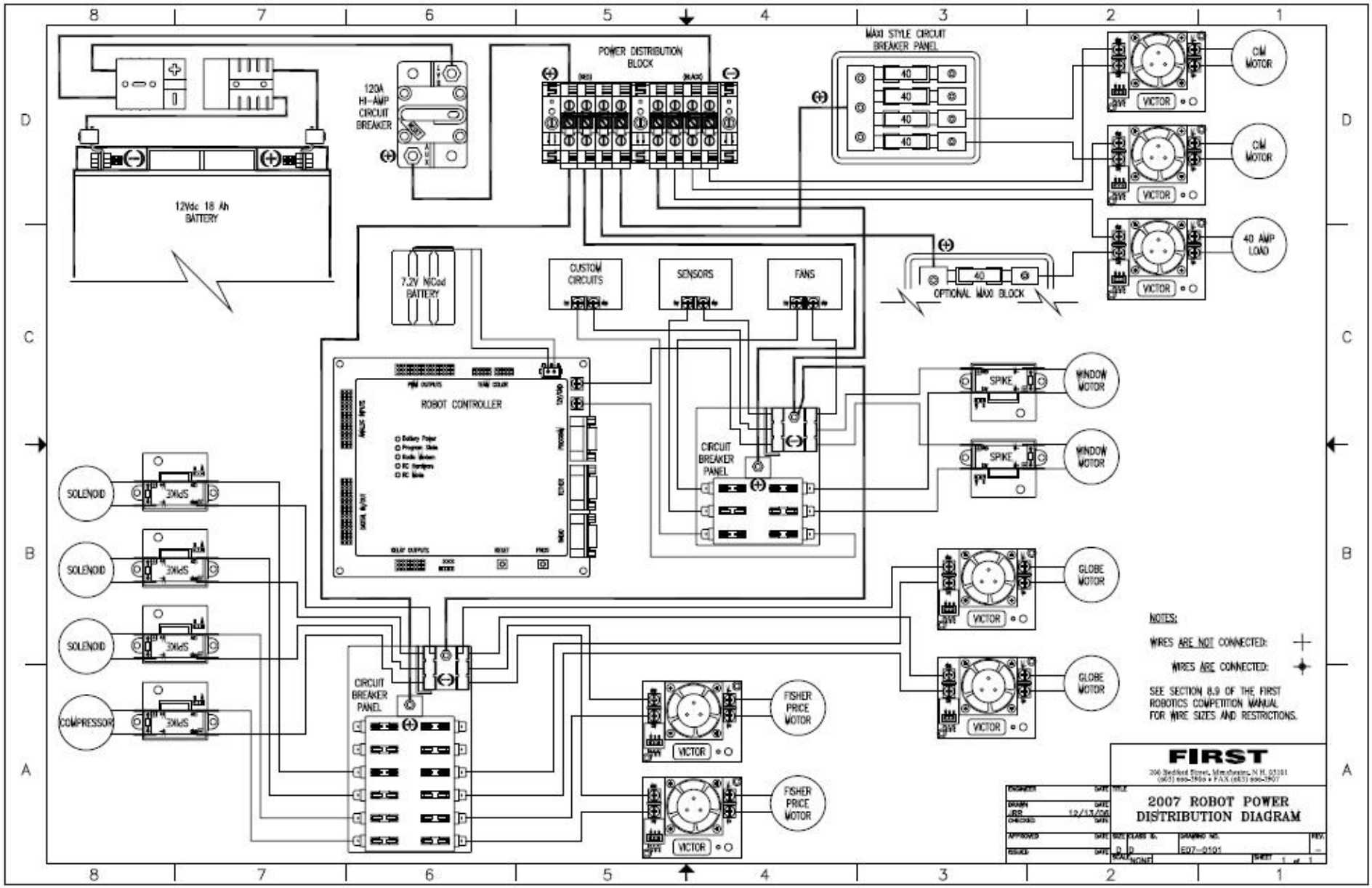
# FIRST Electronics

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

# FIRST Elect Diagram



# Activity

Build an electromagnet!

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