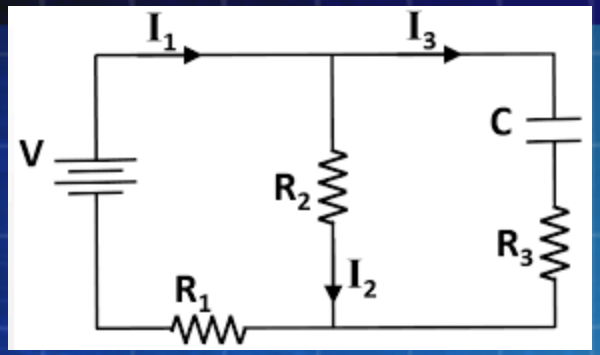
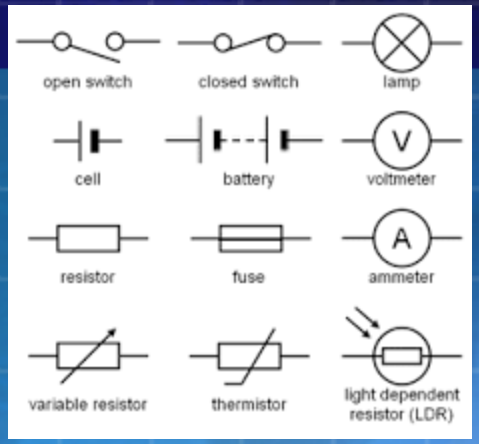
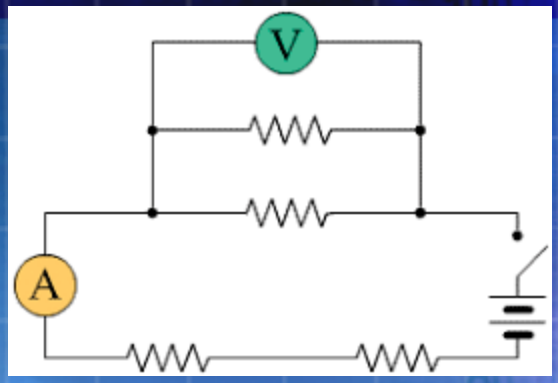






Circuit Lab

North Carolina Coaches Workshop

October 4-5, 2019

Russ Burleson

geaux15@hotmail.com

Agenda

- Purpose
- Rules and Scoring
- Circuit Lab Topics
- General Coaching Tips
- Open Discussion

THIS EVENT IS SPONSORED BY IEEE

Purpose

- New Coaches? – Welcome!
- Returning Coaches – Thanks for continued involvement
- Purpose of this session:
  - NOT to teach you how to compete in the event
  - IS to help you guide and coach your students for the event
  - NOT reprint every little detail in rules
  - IS to provide you with resources you can refer to

- Do:
  - Ask questions
  - Share suggestions
- Don't:
  - Seek competitive advantage by keeping secrets
  - Assume rules are the same as last time (many changes)

Circuit Lab Rules and Scoring

- Allowed to use notes and/or calculators
- Scoring is 50-75% for Theoretical Portion (Test) and 25-50% for Hands On (Lab) Portion
- Historical perspective of the discoveries of electricity and the key people involved
- Properties of electrical charge, sources/hazards of static electricity, Coulomb's Law and capacitance
- Direct current(DC) characteristics, sources, uses, simple circuit diagrams, DC hazards
- Alternating current(AC) characteristics, sources, uses, AC hazards
- Concepts and units of current, voltage, resistance, power and energy and using Ohm's law
- Magnetic poles/fields, electromagnets, transformers, motors/generators, right-hand rule for torque
- Electrical controls devices including 3 way light switch circuit
- Simple measurements, constructions, and configurations of a circuit and individual components
- Basic characteristics and operation of a light emitting diode (LED)
- Simple circuit analysis using Kirchhoff's Voltage & Current Laws (now for B and C)
- Basic digital logic and digital logic operations
- Electrical characteristics of a silicon PN junction (now includes BJT transistors)
- Basics and application of Operational Amplifiers (OpAmps)

*Underlined bullets are Division C only

Practice Recommendations

- Recommend practicing at least once a week with studying between practices. Most practices would be approximately 1 to 1.5 hours.
  - 15 minutes—Grading homework.
  - 30 minutes—Learning Lesson of the Day
  - 15 minutes—In Practice quick test on Lesson of the Day
  - 25 minutes—Practical testing
  - 5 minutes—Sending out homework
- If the student misses a Practice, the student is responsible to get the notes and homework to be ready for the next Practice.

Resources

- Every file at the National Website.
- Text books especially those focused on electricity and magnetism
- Wikipedia pages are great places to start your investigation, but you will need more
- Khan academy, Hyper Science, Bozeman Science, and electronics tutorials have some great resources and videos
- Just find the resource that works best for you, sometimes a different way of explaining a topic just makes sense
- Remember that www.soinc.org is the official website and the rules/clarifications there are the official rules
- www.scioly.org is an alumni run website that has lots of great resources and old tests, but it is NOT official. Everything there is just opinion.
  - Do not get caught up into arguments online

https://www.youtube.com/watch?v=F_vLWkkOETI
https://www.youtube.com/watch?v=0YOGrTNgGhE
https://www.youtube.com/watch?v=NXMgvrS8Gr8
https://www.youtube.com/watch?v=ZRLXDiiUv8Q
https://www.youtube.com/watch?v=8Y4JSp5U82I
https://ibphysicsnotes.wordpress.com/topic5/
https://www.youtube.com/watch?v=mc979OhitAg
https://en.wikipedia.org/wiki/Electricity
https://en.wikipedia.org/wiki/Magnetism
http://www.bozemanscience.com/
https://www.electronics-tutorials.ws/
http://hyperphysics.phy-astr.gsu.edu/hbase/emcon.html#emcon

Ground Rules If Using Online Coaching

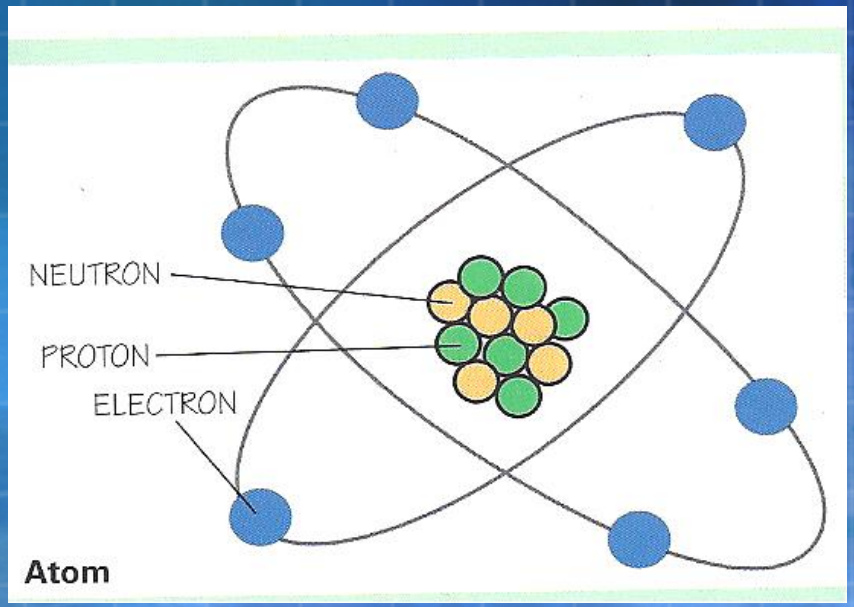
- The narration will not read all bullets, but the slides are available in the dropbox.
- This is provided to augment and not replace your team's coaching, so always go with your own coaches advice or training first
- National Science Olympiad rules, clarifications, and FAQs take precedence, so always go with what is on the official website www.soinc.org
- Each student is responsible for their own learning of this topic, so be prepared to learn more using other resources including the internet
- Follow all safety rules and use low voltage (12VDC or less) for hands on activities, we are developing a full guide of safety rules to be put in the drop box
- Put any questions in the comments section and be respectful and helpful to others.
- Always come prepared to practices with completed homework and all your questions
- Listen, participate, and always follow your coaches

Your Binder is Your Lifeline

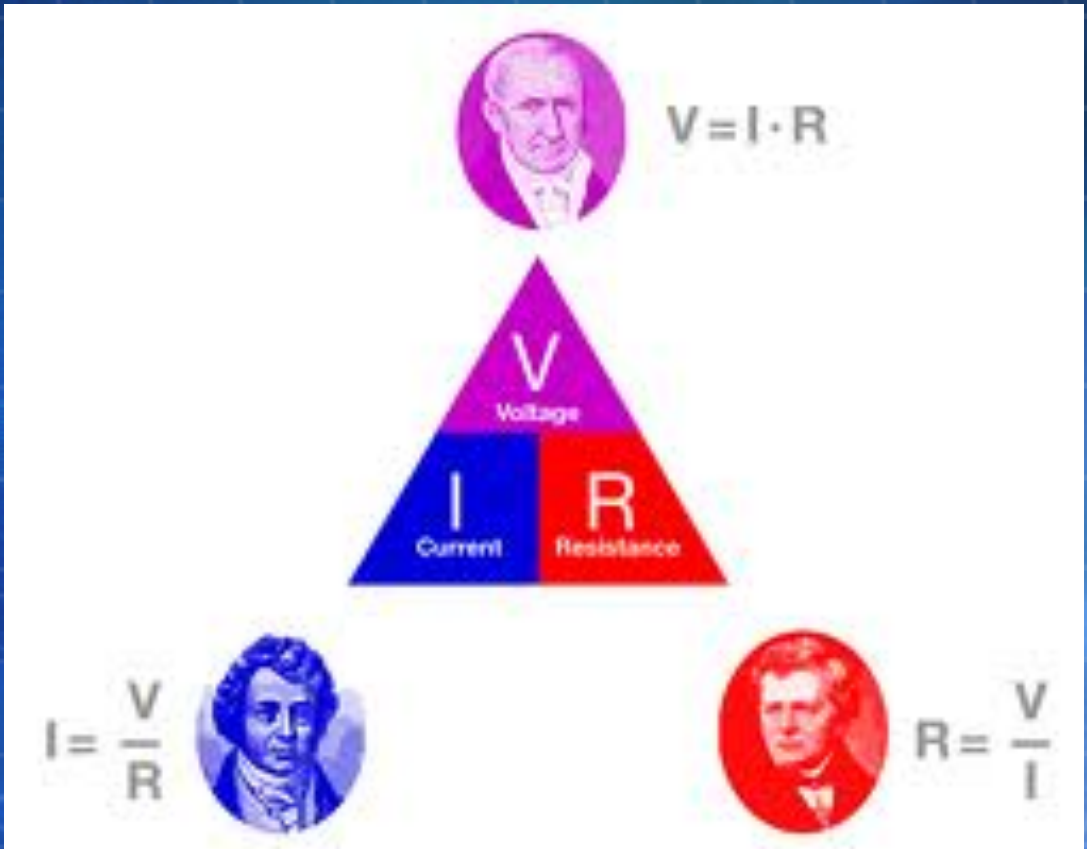
- A good binder is like having an open book test
- Use your binder in all studying, practices, and at tournaments
- Always build your own binder in case something happens to your partner's
- First page should be the rules, so you can find them quickly
- Always have easy to read tables for constants, materials, and equations
- Organize into sections that work for you and your teammate with tabs for easy finding
- Focus on the things you have to look up or don't understand
- Include other tests with keys and work shown
- When you have two or more pictures of the same thing, include ALL of them (often Event Supervisors will get diagrams and samples from the internet)
- When you solve a difficult problem, show all your work and put that in the binder to help remind you how you solved that difficult problem
- Keep the binder small enough to be useful, but big enough to be comprehensive
- Test you skills at finding things in the binder each practice so that it takes no more than 10 seconds to find anything
- Make sure you can read it (good fonts)
- Use sheet protectors when possible

Basics of Electricity

- Atoms
- Protons
- Neutrons
- Electrons
- Electrical current



The Big Three—Volta, Ampere, and Ohm



*historical questions can be for Ampere, Coulomb, Kirchhoff, Volta, Ohm, Tesla, and Faraday

Important Terms

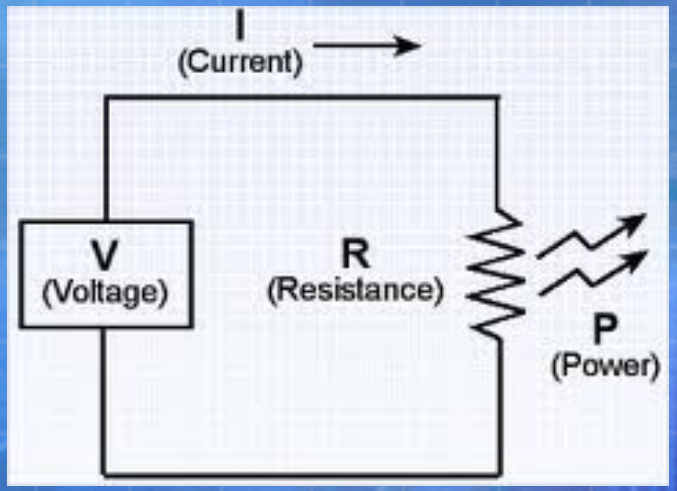
- Volt (V)—unit of electric potential or how much strength the charge is "pushed"
  - Batteries are 1.5-24 V
  - Home electricity 110-220 V
  - Lightning can be millions of volts
  - Also called Potential Difference
  - Is the force behind the electrons
- Ampere (A)—unit of electric current or how many electrons go past a given point in a second.
  - Also called an "Amp"
  - Amperage can heat up a wire and too much can melt a wire or start a fire. That is why we have breakers and fuses.

Important Terms

- Direct Current (DC) is an electric current of constant direction.
  - All batteries are DC
  - Most electronics need DC, so you have special transformers and rectifiers to convert house AC voltage to DC.
  - Most of the problems in Circuit Lab are DC.
- Alternating Current (AC) is electric current that regularly reverses direction.
  - House electricity and power lines are AC
  - AC is even more dangerous than DC
  - AC has less power loss to heat during transmission so it is used for generation and transmission
  - AC is transmitted at very high voltages and stepped down using a transformer for home usage (normally around 220V AC in the US)
  - 3 Phase Power questions are NOT allowed

Important Terms

- Resistance is the opposition against the free transfer of electrons in a conductor.
  - Copper, Silver, and other conductors have low resistance
  - Glass, wood, rubber, plastic, and other insulators have high resistance.
  - Transfer (or current) is usually due to some force like the EMF from the Voltage of a battery
- Ohms (Ω)—unit of electric resistance which is equal to the ratio of voltage to amperage.



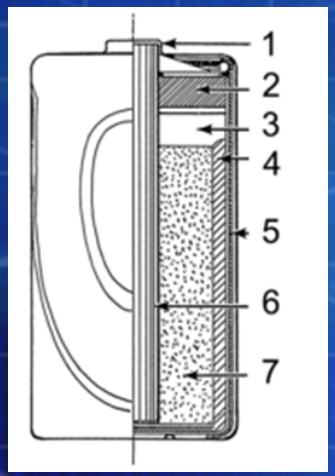
How to identify batteries?

- All batteries are Direct Current (DC)
- They are usually denoted by their Voltage
  - Normally 1.5V, 3V, 6V, 9V, 12V, and 24V
  - This is because most cells produce 1.5V and then are put in series.
- **POSITIVE (+)** terminals are either marked or painted **RED**, sometimes with a cover to reduce chance of a SHORT CIRCUIT
- **NEGATIVE (-)** terminals are normally marked or painted **BLACK** or **BLUE**.

Batteries

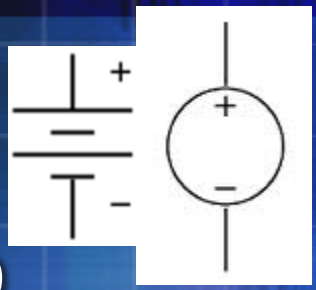
Dry CELL

- Electrolyte is immobilized as a paste
- Zinc-carbon
- Alkaline batteries
- Most small batteries

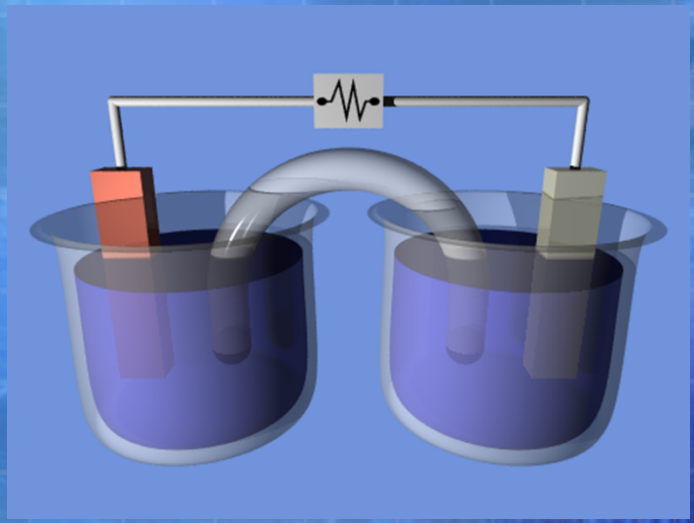


Line art drawing of a dry cell:
1. brass cap,
2. plastic seal,
3. expansion space,
4. porous cardboard,
5. zinc can,
6. carbon rod,
7. chemical mixture
(wikipedia.org)

WET CELL

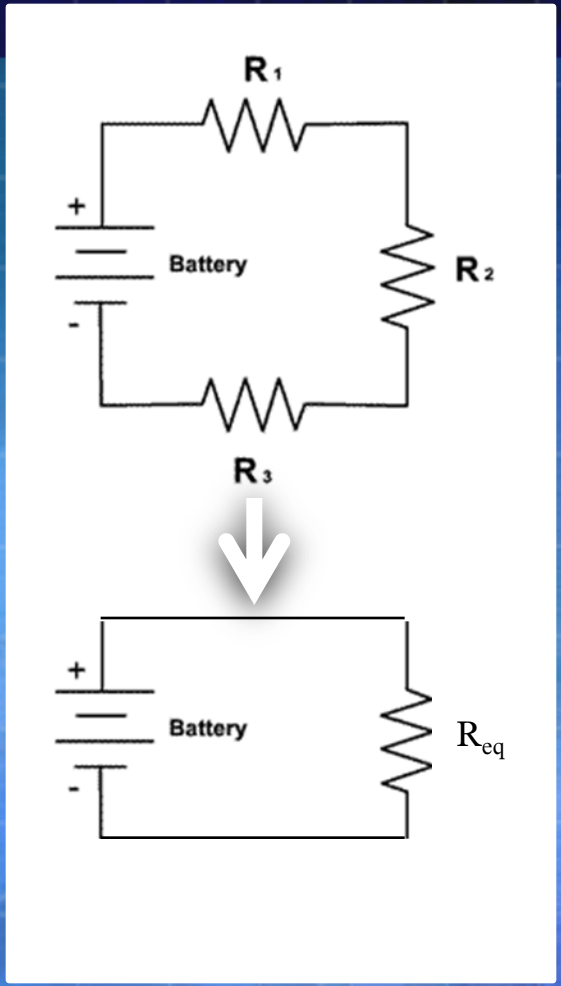


- Has a liquid electrolyte
- Lead-acid (car batteries)
- Nickel-Cadmium



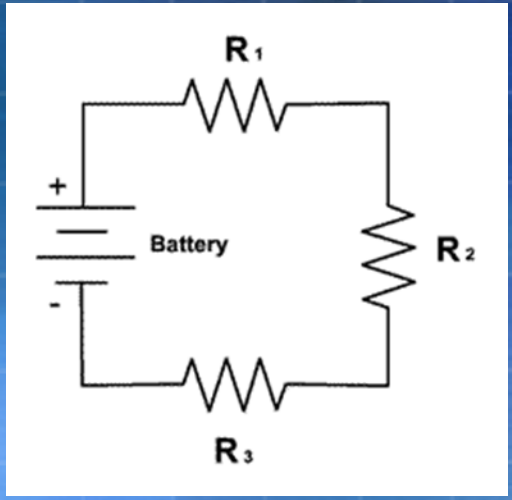
Equivalent Resistance

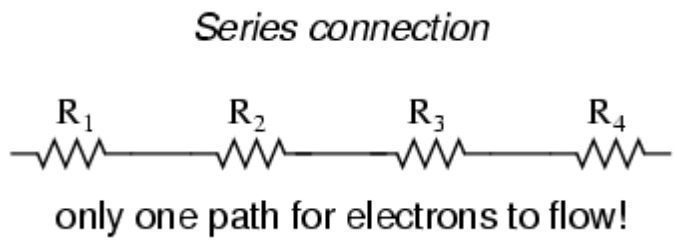
- Multiple resistors can be combined into a single resistance to represent all of them called an Equivalent Resistance or R_{eq}
- The current flowing through both of the circuits on the right is exactly the same



Series Circuit

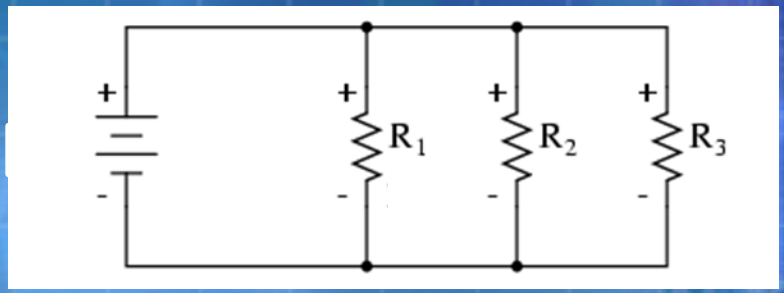
- Two or more resistors in series
- Current is the same through all resistors (electrons have no other path)
- Voltage is split between resistors
- $R_{eq} = R_1 + R_2 + R_3$
- R_{eq} is always greater than the largest single resistance
- Current = Voltage / R_{eq}





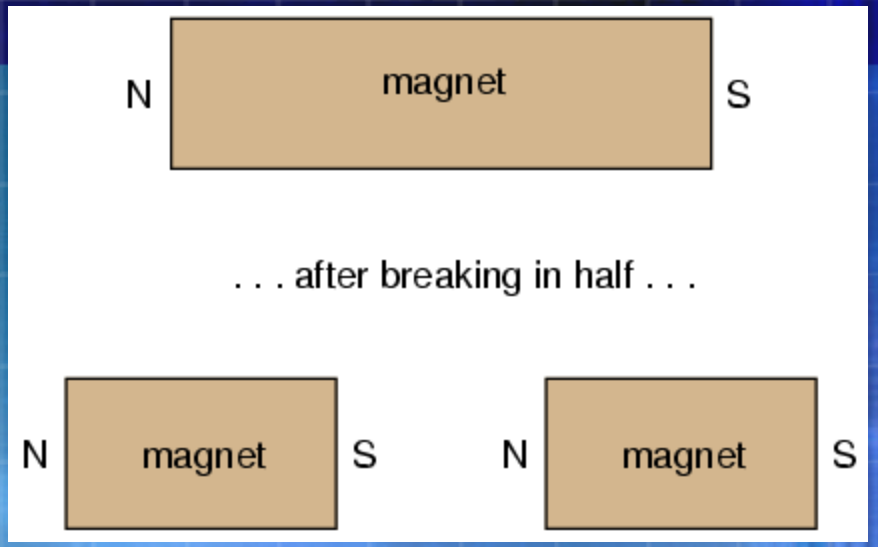
Parallel Circuit

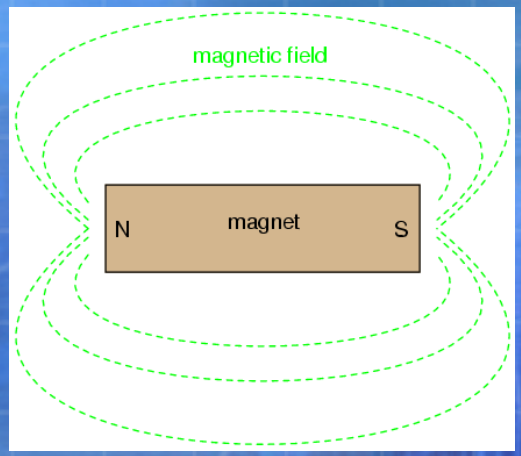
- Two or more resistors in parallel
- Voltage is the same through all resistors
- Current is split between resistors (electrons are split between all branches)
- $1/R_{eq} = 1/R_1 + 1/R_2 + 1/R_3$
- R_{eq} is always less than the smallest single resistance
- Current (from battery) = Voltage / R_{eq} ,which is then split among the three branches



North and South Poles

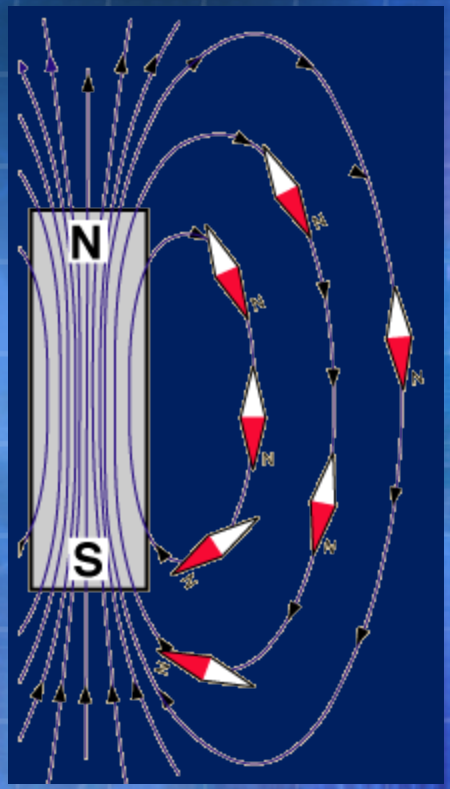
- If you break a magnet in half, it forms two magnets—each with a North and South Pole
- The magnetic field can be displayed by lines drawn from the North Pole to the South Pole





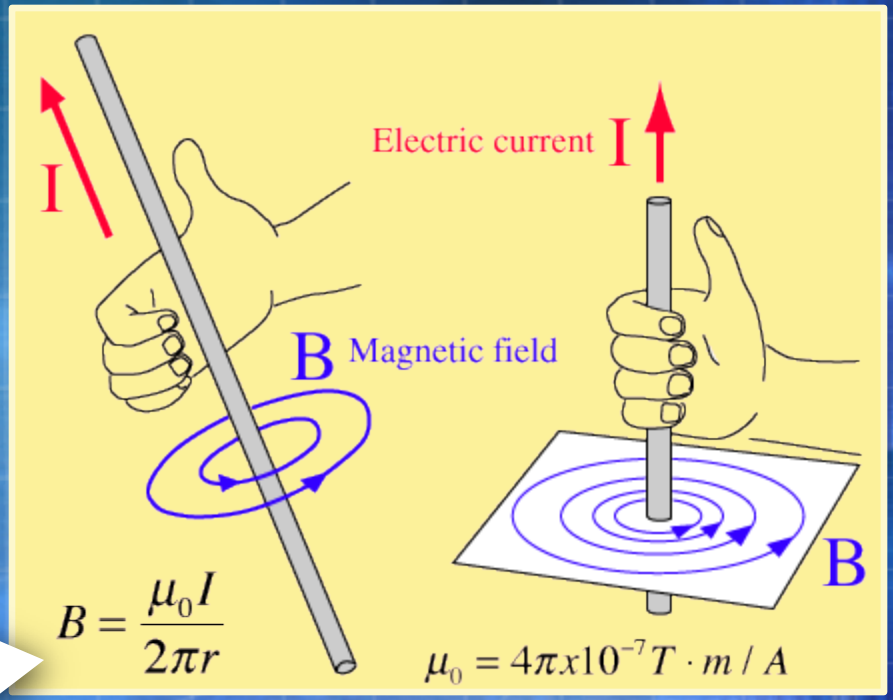
Magnetic Compass

- A compass is a navigational instrument that measures directions using a free floating magnetic and the Earth's magnetic field to point towards the Magnetic North Pole.
  - Magnetic North Pole is not quite at the geographical North Pole and it moves
  - Magnetic North Pole is actually a South Pole of Earth's magnetic field—allowing the North Pole of the compass to be attracted.
  - Compasses become useless near the Poles
- Invented first by the Chinese during the Han Dynasty. Europe invented the dry compass around 1300.



Magnetic Field of Current

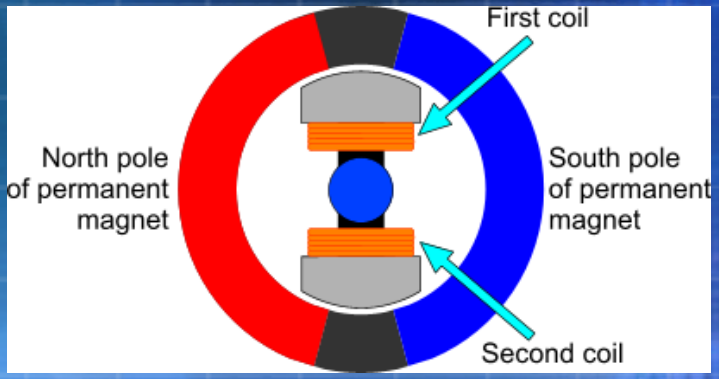
- Current going through a wire causes a magnetic field going around it in a "right hand rule"
  - Point your right thumb in the direction of the current.
  - The magnetic field (B) goes around the wire like your right hand fingers
  - See the formula for B

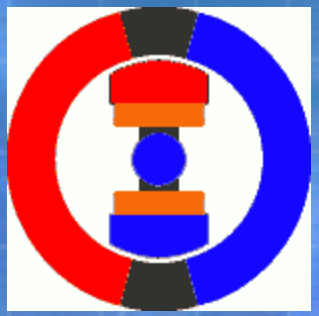


Permeability of free space

How does a motor work?

- DC motor has two windings and two permanent magnets
- Coils are powered from the Commutator and the Brushes
- The current that runs through each windings changes direction at the halfway point (caused by the connection of the commutator)
- Magnets are wound such that when one is North, the other is South
  - Please note this is colored differently than we normally used



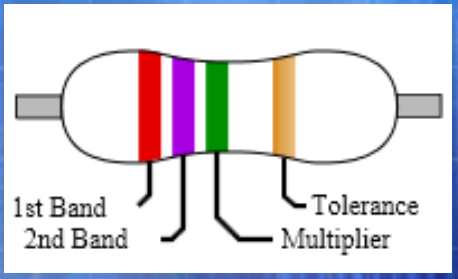


Resistor Marking

- Electronic Color Code Developed in early 1920's.
  - Sometimes the resistance is printed directly on the resistor to avoid confusion, esp. for colorblind people.
  - If you are colorblind, let your event supervisor know at start of test.

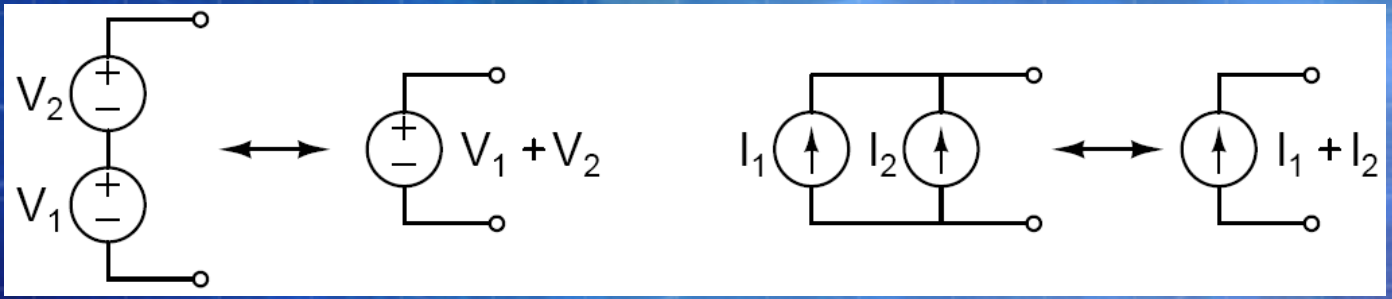
A is the first significant digit of the component
B is the second significant digit
C is the decimal multiplier
D (if present) indicates the tolerance—no D means 20%

This example is the following:
A=Red=2; B=Violet=7; C=Green=10^5; D=Gold=5%
Or 2.7MΩ +/- 5%



Multiple Sources

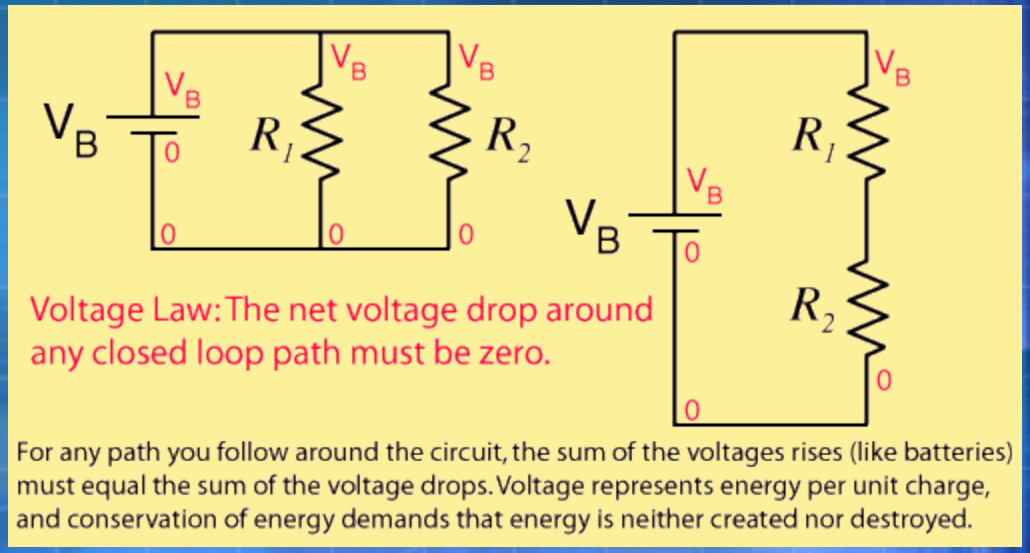
- Sometimes a circuit has more than one source
- Voltage Sources should be added in series
- Current Sources should be added in parallel
- You shouldn't put voltage sources in parallel or current sources in series, as it can create a situation that violates circuit rules.



Kirchhoff's Voltage Law (KVL)

(Now both Divisions)

- The directed sum of the electrical potential differences (voltage) around any closed network is zero
- or: the sum of the voltage in any closed loop is equivalent to the sum of the potential drops in that loop

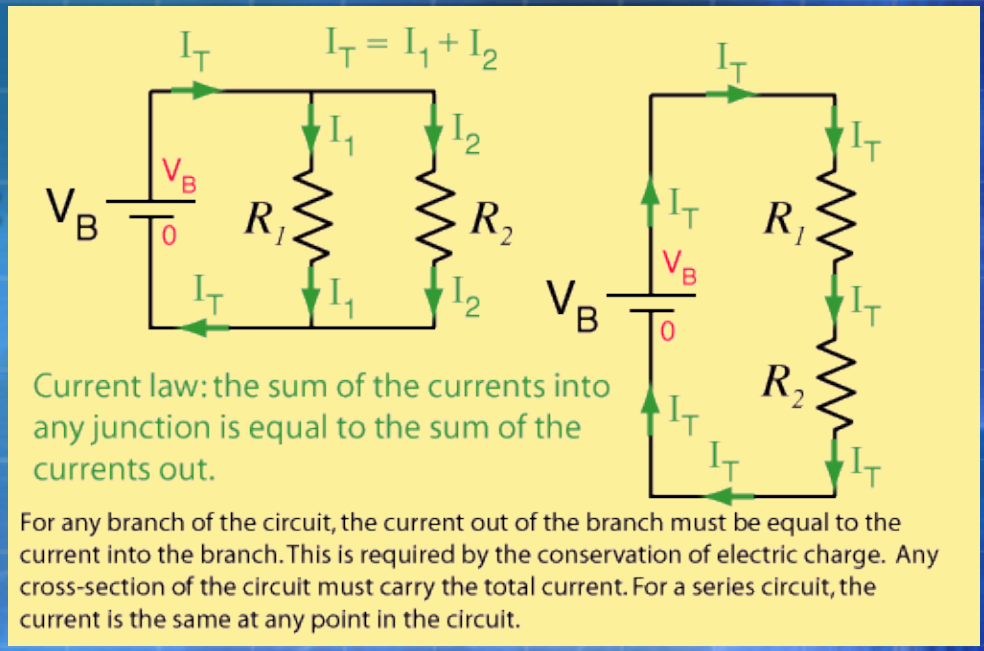


For any path you follow around the circuit, the sum of the voltages rises (like batteries) must equal the sum of the voltage drops. Voltage represents energy per unit charge, and conservation of energy demands that energy is neither created nor destroyed.

Kirchhoff's Current Law (KCL)

(Now both Divisions)

- At any node (junction) in an electrical circuit, the sum of currents flowing into that node is equal to the sum of currents flowing out of that node
- or: The algebraic sum of currents in a network of conductors meeting at a point is zero.
- or: All current into a node equals all current out!

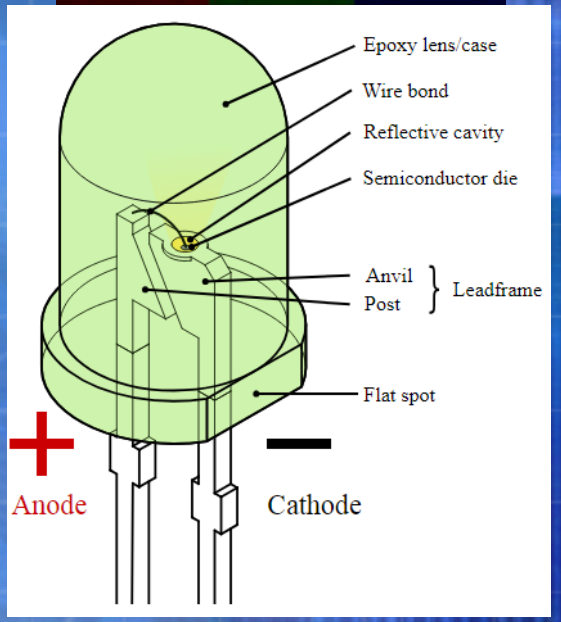


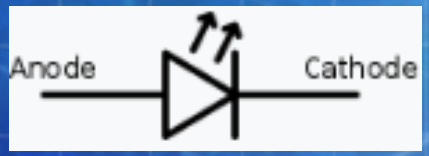
For any branch of the circuit, the current out of the branch must be equal to the current into the branch. This is required by the conservation of electric charge. Any cross-section of the circuit must carry the total current. For a series circuit, the current is the same at any point in the circuit.

Light Emitting Diodes (LEDs)

Exploring the World of Science

- A light-emitting diode (LED) is a two-lead semiconductor light source. It is a p–n junction diode that emits light when activated
- Color is determined by the energy band gap of the semiconductor, which also affects the voltage drop
  - Full table has been put in the Homework Generator, LED Datasheet tab
  - https://en.wikipedia.org/wiki/Light-emitting_diode#cite_note-79

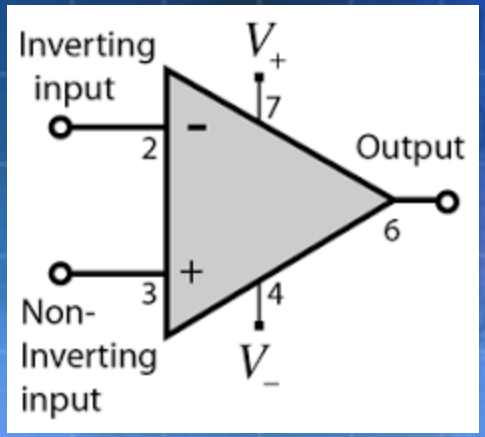




https://en.wikipedia.org/wiki/Light-emitting_diode

Operational Amplifiers
(Division C Only)

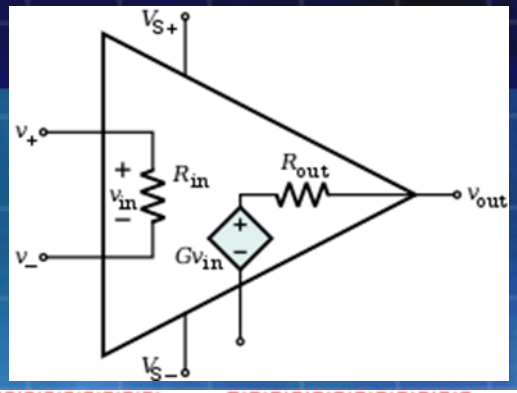
- An operational amplifier (often op-amp or opamp) is a DC-coupled high-gain electronic voltage amplifier with a differential input and, usually, a single-ended output
- Very popular due to its versatility as a differential amplifier.
- Can be set up easily as a comparator, inverting amplifier, or non-inverting amplifier
- NEVER, EVER use a KCL at the output of an Op-Amp

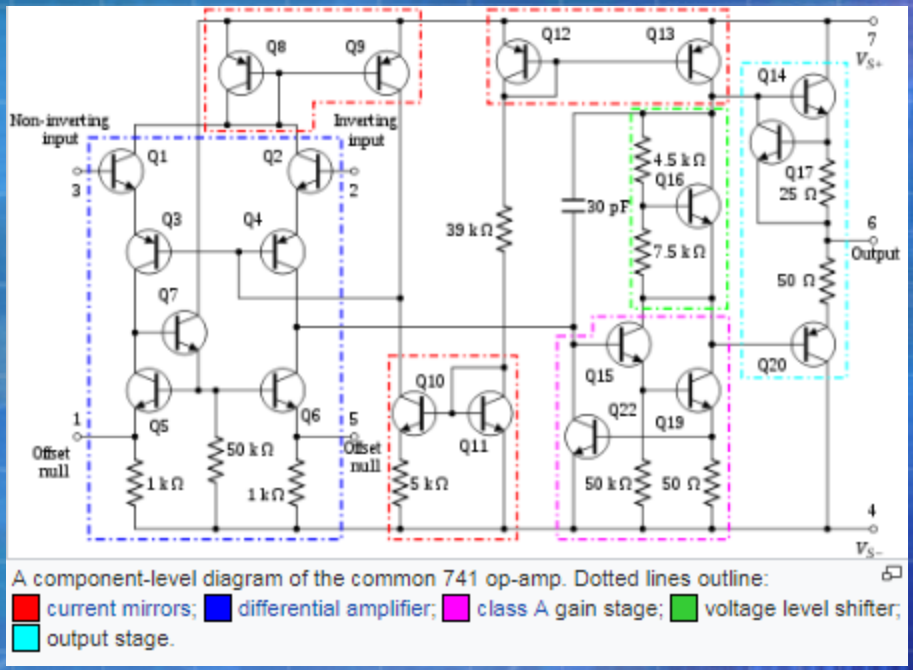


https://en.wikipedia.org/wiki/Operational_amplifier

Ideal Op-Amps

- Full List for Ideal Op-Amps
  - Infinite Open-Loop Gain (G)
  - Infinite Input Impedance (R_{in})
  - Infinite Out Voltage Range (v_{out} max)
  - Infinite Common-Mode Rejection Ratio
  - Infinite Power Supply Reject Ratio
  - Zero Input Offset Voltage
  - Zero Output Impedance (R_{out})
  - Zero Noise
  - Zero Input Current (v_{in}/R_{in})
  - None of these are actual





A component-level diagram of the common 741 op-amp. Dotted lines outline: current mirrors; differential amplifier; class A gain stage; voltage level shifter; output stage.

- Two Golden Rules
  - $V_+ = V_-$
  - Current is zero at V_+ and V_-

https://en.wikipedia.org/wiki/Operational_amplifier

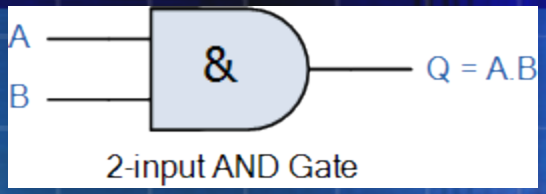
Digital or Boolean Logic

- Boolean Algebra deals mainly with the theory that both logic and set operations are either "TRUE" or "FALSE" but not both at the same time
  - All inputs and outputs are either "TRUE" or "FALSE"
  - Inputs and Outputs are normally shown in a Truth Table
  - There are multiple electronic logic circuits and devices including relays, switches, diodes, discrete electronics, etc.
  - Basic Logic Functions include
    - AND (all inputs must be True for the output to be True, otherwise output is False)
    - OR (all inputs must be False for the output to be False, otherwise output is True)
    - NOT (the output is always the opposite of input, so if the input is True then the output is False and if the input is False the output is True)

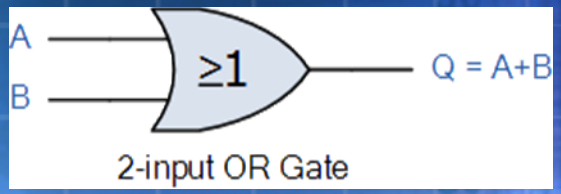
https://en.wikipedia.org/wiki/Boolean_algebra
https://en.wikipedia.org/wiki/Logic_gate
https://www.electronics-tutorials.ws/boolean/bool_1.html

AND, OR, and NOT

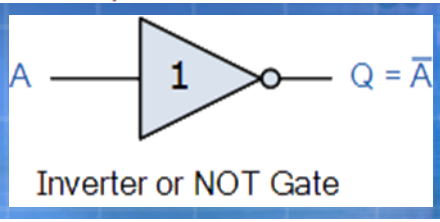
- Three most common and basic
- NOT is also called an Inverter
- 0 means False and 1 means True
- You can also show a NOT by a Bar over an Input or Function
  - NOT X can also be shown by $\overline{X}$
  - NOT A & B can be shown by $\overline{A \& B}$



2-input AND Gate



2-input OR Gate



Inverter or NOT Gate

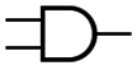
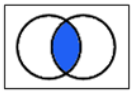
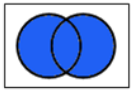
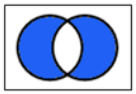
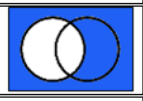
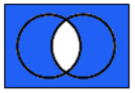
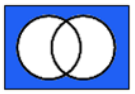
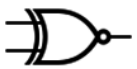
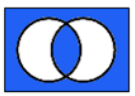
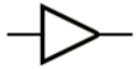
x	y	$x \wedge y$	$x \vee y$
0	0	0	0
1	0	0	1
0	1	0	1
1	1	1	1

x	$\neg x$
0	1
1	0

https://en.wikipedia.org/wiki/Boolean_algebra
https://en.wikipedia.org/wiki/Logic_gate
https://www.electronics-tutorials.ws/boolean/bool_1.html

Common Logic Expressions

- These are the most common expressions, symbols, and values for one or two input logic gates
- Note all the ways you can show the functions
- Please note that in addition
  - X AND Y can be shown as X ∧ Y
  - X AND Y can be shown as X ∨ Y
  - NOT X can be shown as ¬X

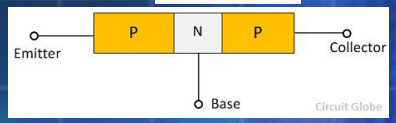
Expression	Symbol	Venn diagram	Boolean algebra	Values
AND			$A \cdot B$	A B Output 0 0 0 0 1 0 1 0 0 1 1 1
OR			$A + B$	A B Output 0 0 0 0 1 1 1 0 1 1 1 1
XOR			$A \oplus B$	A B Output 0 0 0 0 1 1 1 0 1 1 1 0
NOT			$\overline{A}$	A Output 0 1 1 0
NAND			$\overline{A \cdot B}$	A B Output 0 0 1 0 1 1 1 0 1 1 1 0
NOR			$\overline{A + B}$	A B Output 0 0 1 0 1 0 1 0 0 1 1 0
XNOR			$\overline{A \oplus B}$	A B Output 0 0 1 0 1 0 1 0 0 1 1 1
BUF			A	IN Output 0 0 1 1

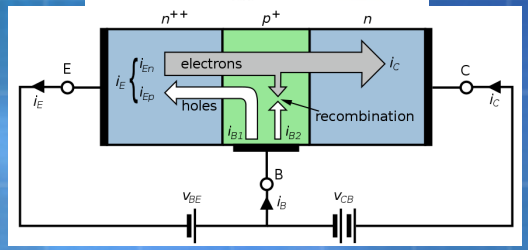
Venn Diagram for logic gates is a schematic representation of A and B overlapping each other inside a rectangle area, the diagram shows the relation of the boolean operators.

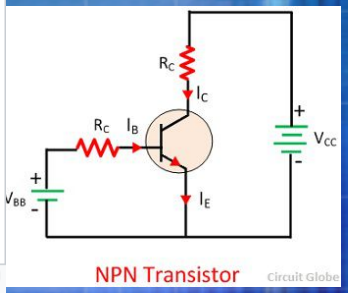
http://www.ambrsoft.com/Equations/LogicalGates/LogicalGates.htm

PNP and NPN Transistors

- Bipolar Junction Transistors (BJTs) are either set up as a PNP or an NPN configuration.
- Know at least the following:
  - General Characteristics
  - Four Operation Modes
  - DC Biasing
  - Gain calculation and amplification
  - Transistor as a switch applications
  - Band Diagrams
  - Simple models
  - Etc……





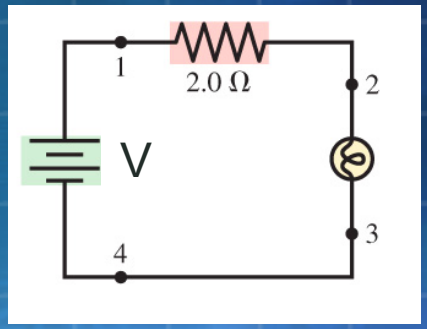


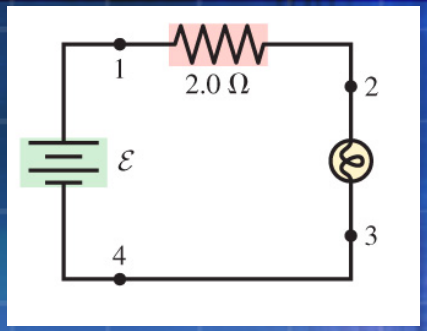
https://en.wikipedia.org/wiki/Transistor
https://en.wikipedia.org/wiki/Bipolar_junction_transistor
https://circuitglobe.com/npn-transistor.html
https://circuitglobe.com/difference-between-npn-and-pnp-transistor.html
https://www.electronics-tutorials.ws/amplifier/transistor-biasing.html

General Coaching Tips

Physics Teachers versus Engineers

- Physicists and Engineers look at circuit problems differently and sometimes put focus on different areas
- Both are right, but you should be prepared because you don't know who writes your test
- Always look at lots of different sample tests to get a flavor for all the ways a question may be asked
- The diagrams to the right are equivalent, one uses a Voltage Source and one an Electromotor Force source (EMF)—same thing





- Conventional current (which is what is mainly used) flows from the positive terminal of a battery or EMF source and would be clockwise in the diagrams above
  - This is the direction of positive charges, but not electrons which flow the opposite way
- Physicists often prefer to use "Real Current" which flows the opposite direction to match electron flow (counter clockwise or out of negative to positive)

https://en.wikipedia.org/wiki/Circuit_diagram

General Coaching Tips

- Always send max # competitors to event. 'Warm bodies' can:
  - Look for general / safety mistakes
  - Gain valuable experience in competitive setting
  - Help with 'administrative' tasks during event
- Event supervisors make mistakes sometimes
  - Counsel students on appropriate way to point them out
  - Document to extent possible
  - Don't be afraid to use the appeals process
- Put extra effort into logistical issues
  - Have lots of backup supplies, safety apparatus
  - Preplan transportation, food, communications

- Know the **Updated** General Rules / Spirit of the Problem
- SO is as much about the preparation as it is the competition

Things to consider

- Winners prepare
  - No one knows this material naturally, those that prepare the best will do better.
  - Study and do homework before practice, use practice for asking questions
  - Plan on doing work on this a few times a week in addition to practice
- Winners work together
  - Be a good partner
  - Work off each other strengths
  - Practice together
- Event Supervisors are volunteers
  - They have given up their time to prepare for the competition, run the event, score, etc.
  - Some are more experienced than others
  - Some know the rules more than others
  - Be respectful and work with them
  - Always listen to instructions and read the test before you ask your questions
  - Different Event Supervisors ask the same question differently

Arguing an Illegal Question

- Always make sure you read the question again to ensure it really is illegal.
  - Event supervisor might have old rules, but double check your rules first.
- Ask for how to implement the question within the rules.
  - Remove the illegal items like capacitors/inductors/LEDs/etc.
  - Operate it as DC instead of AC.
- Reference the specific rule, normally in sections 3.I.c or 3.I.d
- Semiconductors include diodes, LEDs, transistors, OpAmps, and integrated circuits. LEDs, Diodes and OpAmps are now allowed in certain circumstances.
- AC circuit theory includes frequency analysis, two or three phase power, capacitor/inductor reactance. But they can sometimes be made legal by switching to a DC system.
- AC devices include transformers, rectifiers, others. Most will not work with DC.
- Several items are only available for Division C and not for B

Coaching Tips for Science Olympiad

Exploring the World of Science

- Always send max # competitors to event. 'Warm bodies' can:
  - Look for general / safety mistakes
  - Gain valuable experience in competitive setting
  - Help with 'administrative' tasks during event
- Event supervisors make mistakes sometimes
  - Counsel students on appropriate way to point them out
  - Document to extent possible
  - Don't be afraid to use the appeals process
- Put extra effort into logistical issues
  - Have lots of backup supplies, safety apparatus
  - Preplan transportation, food, communications

- Know the **Updated** General Rules / Spirit of the Problem
- SO is as much about the preparation as it is the competition

Coaching Tips for Science Olympiad (cont.)

- Check the national website often.
- Coaches should be familiar with the material, but the work should be done by the students
- Practices are for covering material, sample tests, and practicing measurements—studying should be done as homework
- Coaches and students should know the rules better than anyone
- Start early and practice at least one a week
- More practice will lead to better results

Coaching Tips for Science Olympiad (cont.)

- Be ready for people to focus on different aspects on the written test.
- Always look for good pairs of students who work well together and complement each other.
- Students should:
  - Come prepared to practices with completed homework and all questions
  - Listen and participate.
  - Be willing to study on their own and do more work than assigned

Final Random Thoughts

- Moderation in all things!
- Regularly check www.soinc.org
  - Clarifications
  - FAQs
  - Policies (Lasers, Safety, Building, etc)
- Use free tools if running event / tournament
  - Checklists / scoresheets for select events: soinc.org event pages
  - Complete tournament scoring system: sourceforge.net/projects/soscoring/
  - Event sign up system: sciolyeventsignup.com
- Large invitational tournaments
  - Opportunity to have 'National experience'
- Please publicize SO and recruit new participants
- Keep SO mission in mind
  - Create an interest and passion for science
  - Improve STEM education and workforce skills
  - Recognize and celebrate achievements by students and teachers