Lecture 3

Resistance; Measuring Your DMM; Diodes

Reading For This Lecture:

- A&L 16.1-16.3 – Diodes

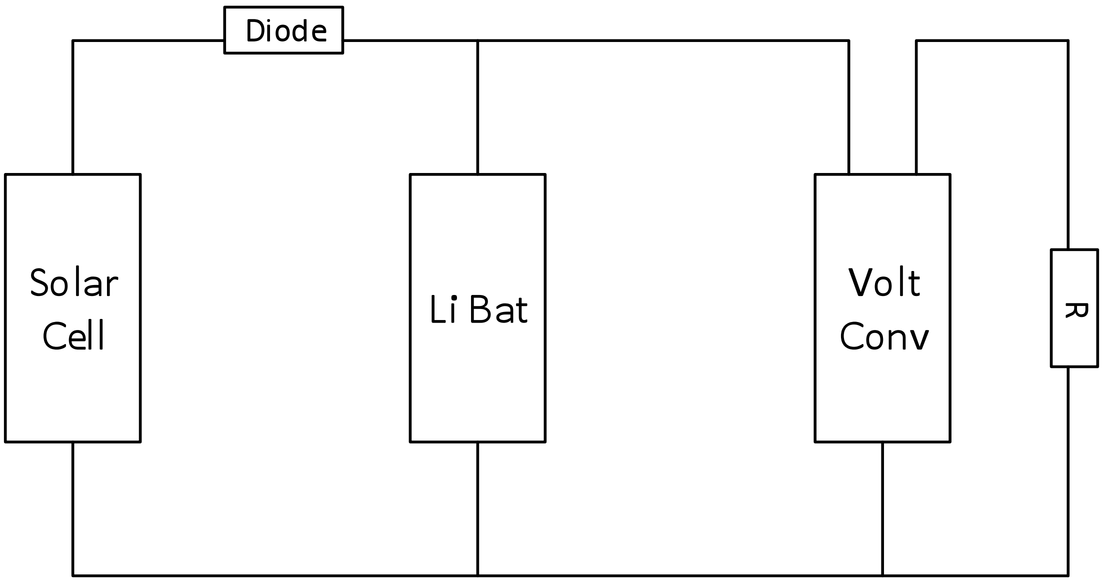
  OR

- Chapter 2 of the course reader

If you want to look at a different take, you can look at:

- Diodes:
  - https://learn.sparkfun.com/tutorials/diodes
  - http://www.allaboutcircuits.com/vol_3/chpt_3/1.html

Roadmap



Today's Topics:

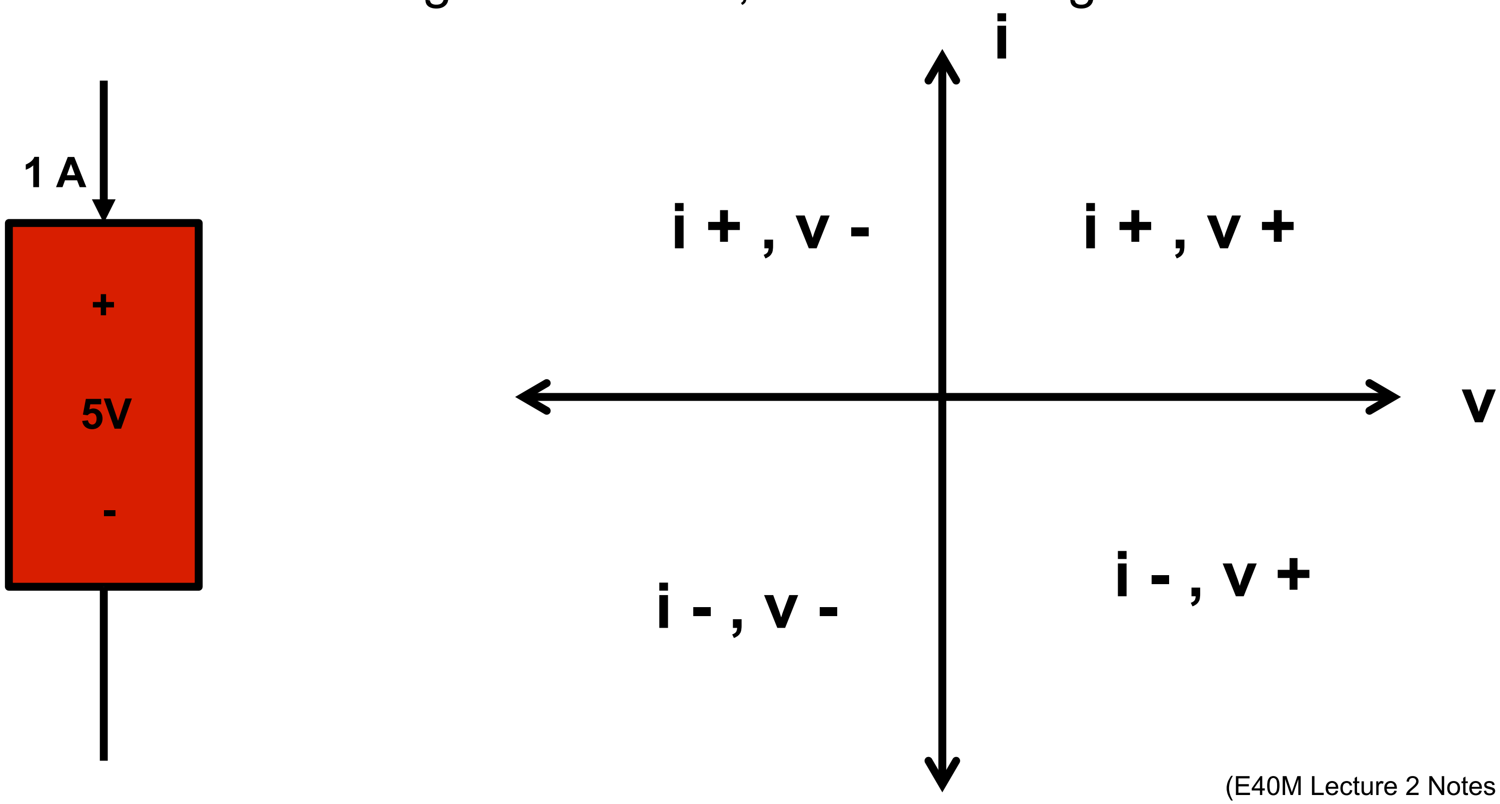
1. Current sources, voltage sources, resistor characteristics.
2. Two new devices – current sources and diodes.
3. How our DMM really works.
4. Soldering fundamentals.

Key Ideas From The Last lecture

- Sum of current into a device or a **node** is always 0 (KCL)
- Sum of voltage drop across any loop of devices is always 0 (KVL)
- Calculating the **power** used by a device or circuit = I*V
- The characteristics of **resistor** (type of device) V = iR, Ohms Law
- Be able to use your **DMM**
- **The next few slides are from the last set of lecture notes since we didn't cover them last time in class.**

Device Models

- It's useful to represent what a "device" does by plotting its characteristics on a plot of i vs. V.
- i is the current through the device, V is the voltage across the device.



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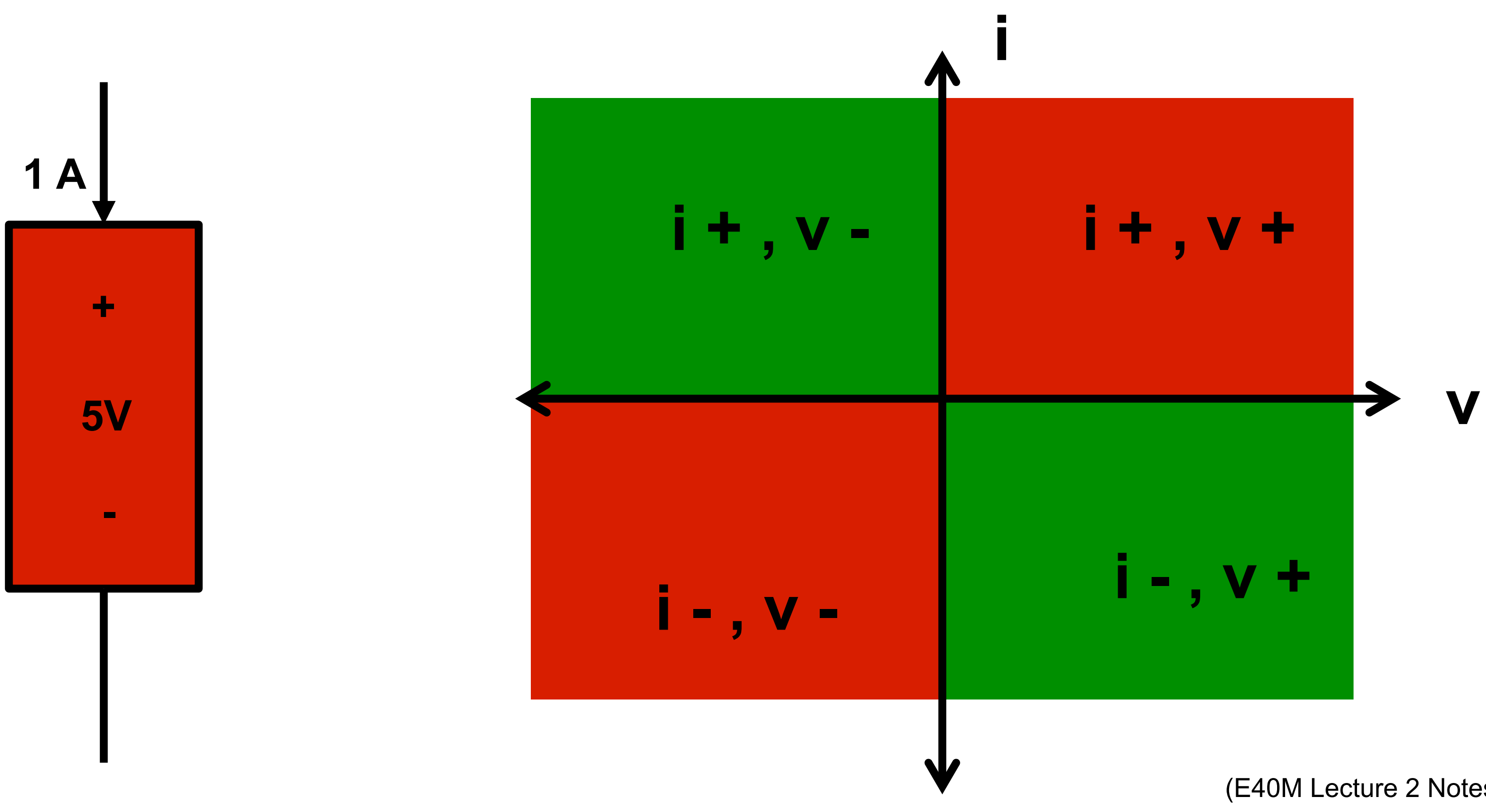
Device Models

- Note that the energy is dissipated by the device in quadrants 1 and 3, and power is generated by the device in quadrants 2 and 4.



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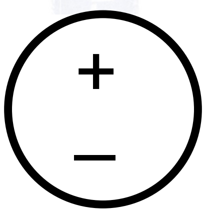
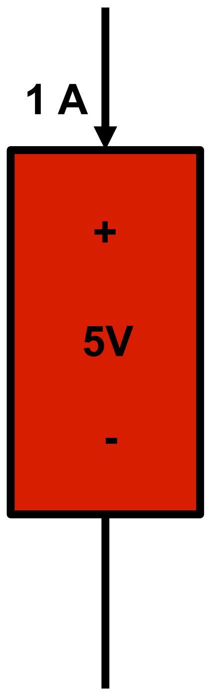
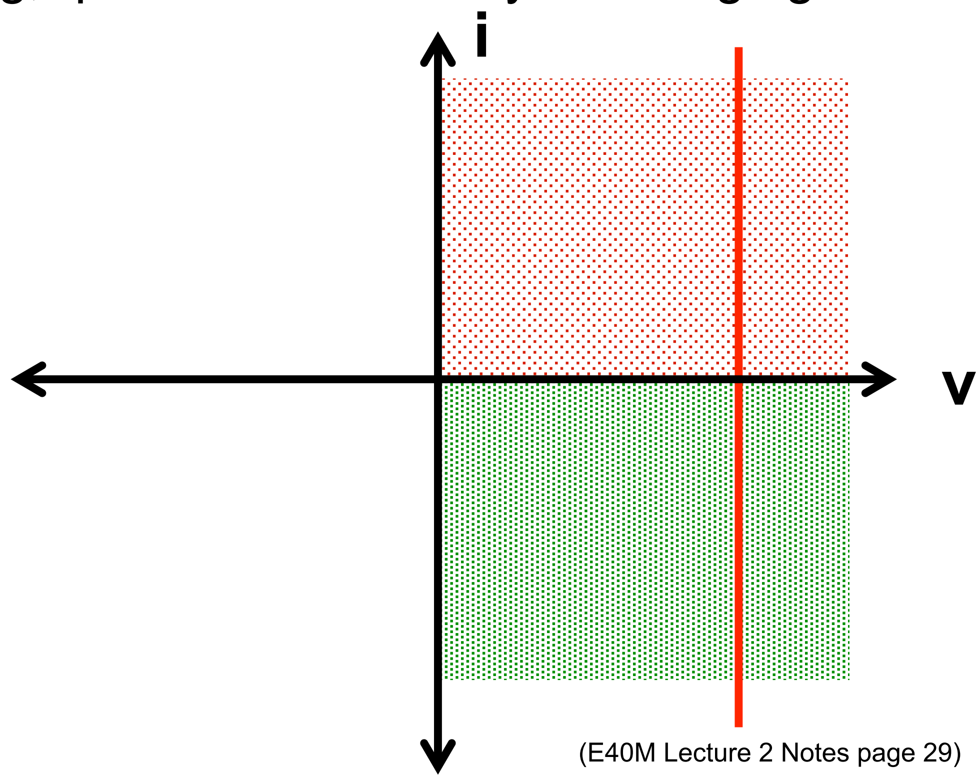
Device Models – Battery, Voltage Source

- A battery or a voltage source provide a fixed out put voltage no matter what current they are asked to provide or consume (“sink”).
- In quadrant 1 energy is consumed, in quadrant 4 energy is provided.
- Quadrant 1 = battery charging, quadrant 4 = battery discharging.







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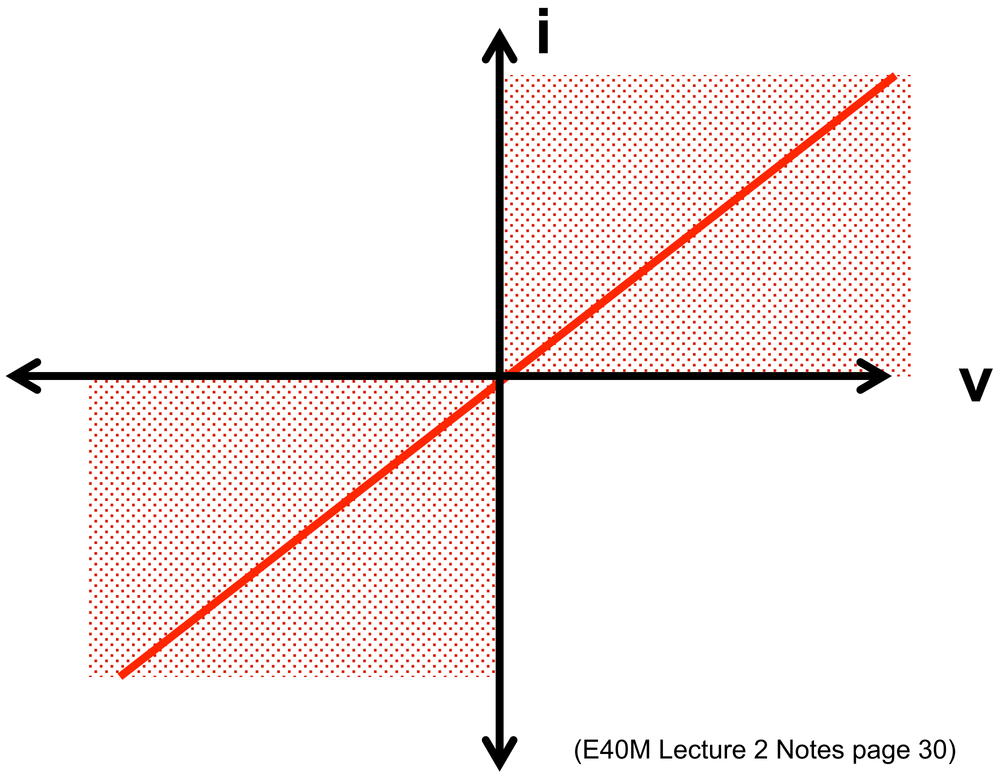
Device Models – Resistors

- Current is proportional to voltage
  - V=iR – Ohm's Law
- Book also uses G
  - Conductance = 1/R
  - i = GV
- Symbol



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Why Does Resistance Exist (What Physical Effect Does it Model)

- Conductors are not perfect
  - They use a little energy to get current to flow through a wire[1]
- Since the energy flow into the wire is ($i\ \Delta V$)
  - There must be a voltage drop along the wire
  - Generally this drop is proportional to the current
    - $V = k * i$
    - Call the constant of proportionality, Resistance
- Make resistors by using material that doesn't conduct well

[1]Well except for superconductors which are magical. They have interesting properties, like current can flow in a loop forever! And this is used in MRI machines to make large magnetic fields.

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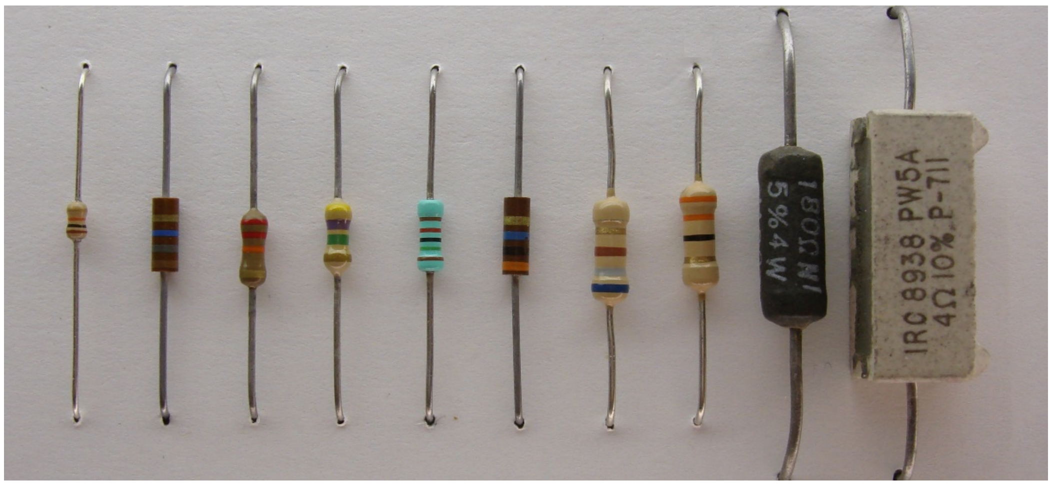
Resistors



http://ecee.colorado.edu/~mathys/ecen1400/labs/resistors.html

http://www.instructables.com/id/Reading-Surface-Mount-Resistor-codes/

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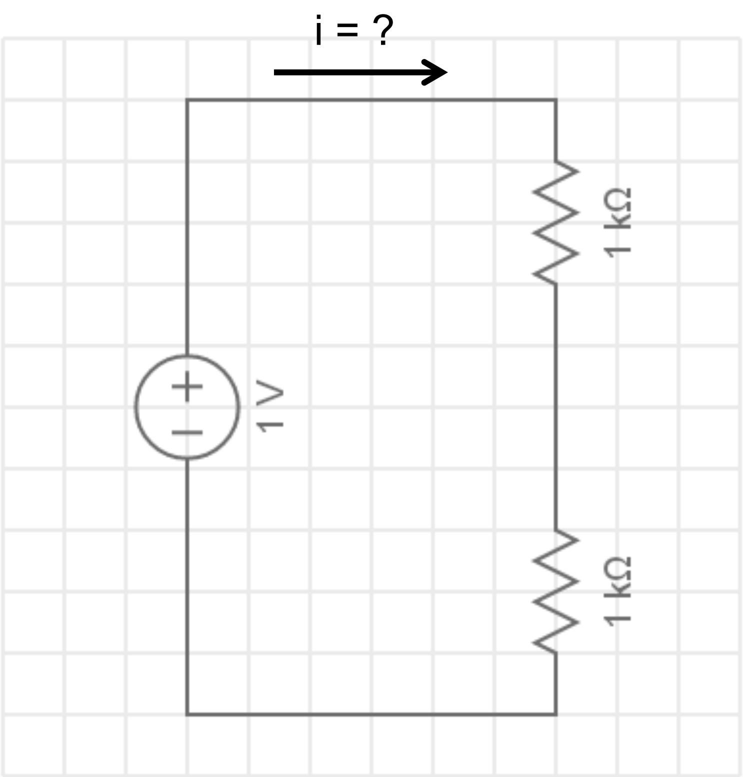
Resistance Problem #1



What current flows in the loop?

What is the voltage across the bottom resistor?

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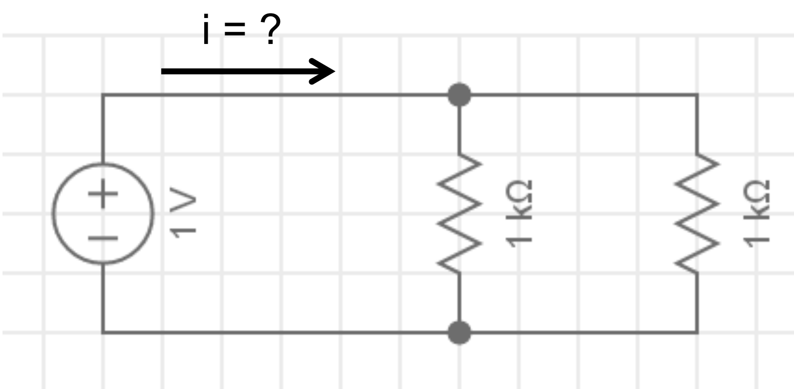
Resistance Problem #2

What is the current i?



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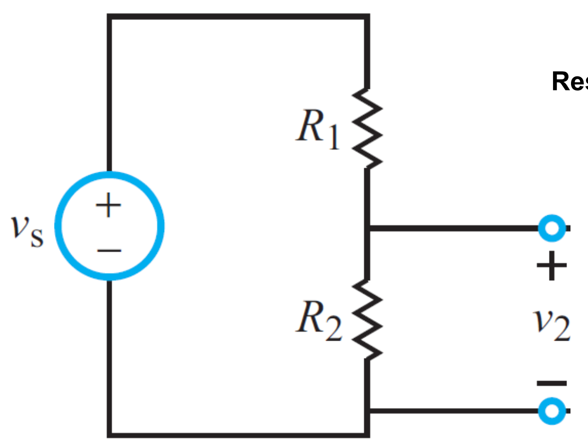
Learning Objectives For Today

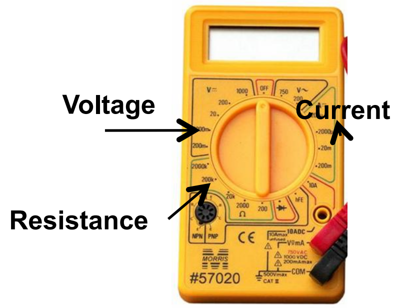
- Understand the device i-V curve of a current source
- Understand the operation of a diode, and its symbol
- Be comfortable using your DMM to measure voltage and current
- Be prepared to solder next week in lab

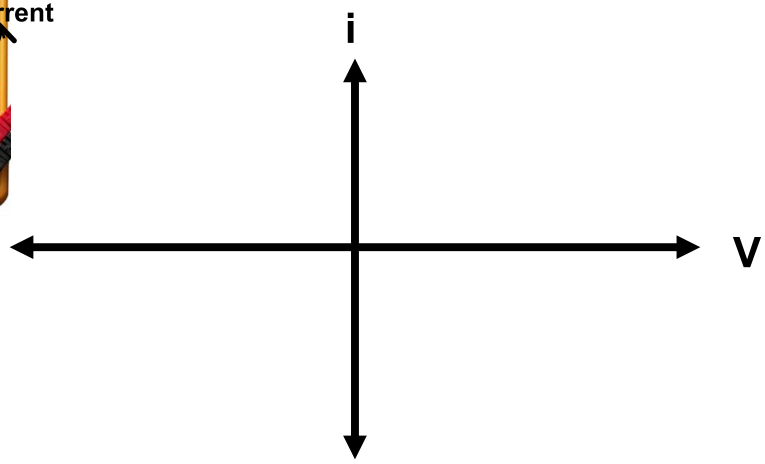
MEASURING W/ DMM

How to Measure Voltage

- Set DMM on a voltage scale
- Remember an ideal voltage meter takes no current
  - Its iV curve is a line on the x-axis (i = 0)
- Put meter in parallel with the device you want to measure
  - Devices in parallel have the same voltage

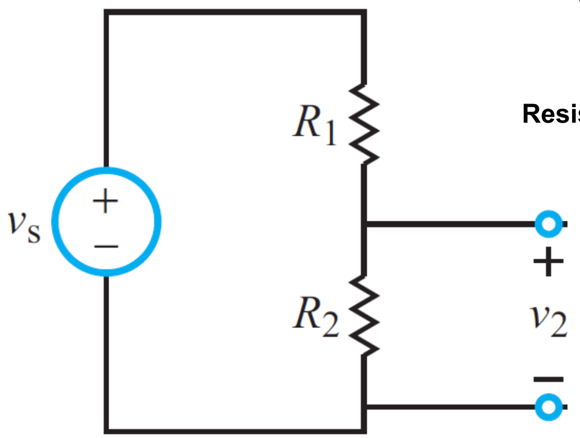


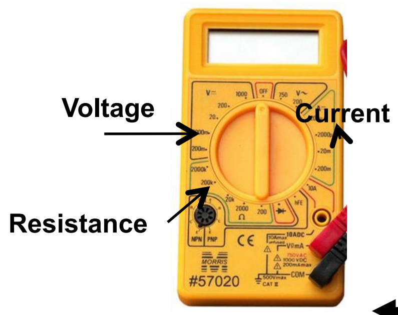


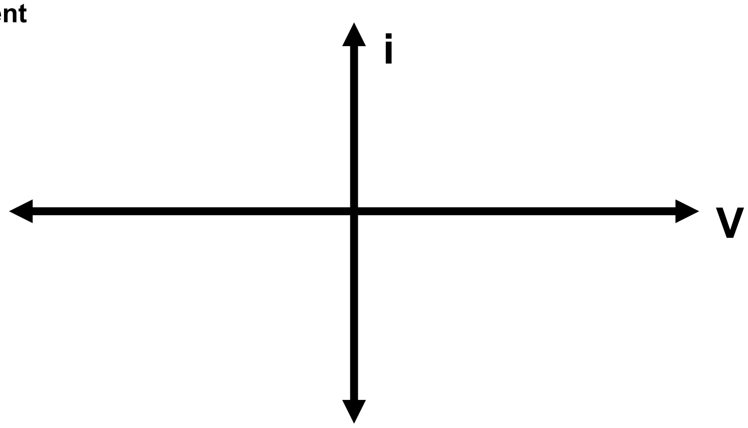


How to Measure Current

- Set DMM on a current scale
- Remember an idea current meter has no voltage drop
  - Its iV curve is a line on the y-axis (V=0)
- Put meter in series with the current you want to measure
  - Devices in series must have the same current flow







Care and Feeding of your DMM

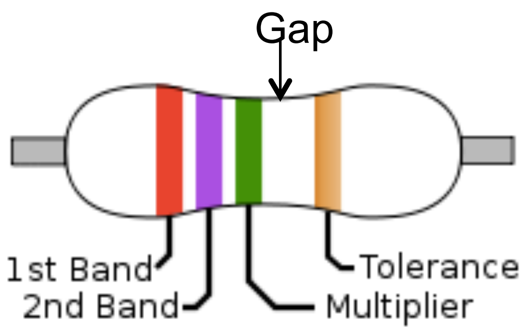
- Do NOT put the current meter in parallel with the device
  - This “shorts” out (creates a low resistance path) the device
  - And might damage your meter
    - Never put the DMM in current mode across your battery

- Do not put the voltage meter in series in your circuit
  - Since this basically breaks the circuit’s connection
  - But it won’t damage your meter

- Do not leave your DMM on
  - It will run out the battery, and you will need to buy another
  - It uses a standard 9V battery

IN CLASS ACTIVITY

Measuring/Reading Resistors



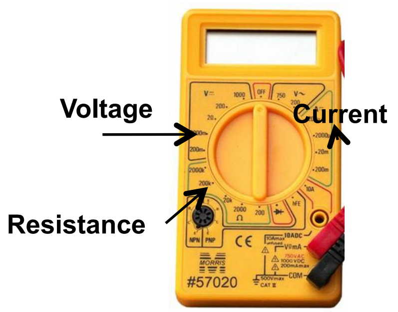
A 100 kΩ, 5% axial-lead resistor

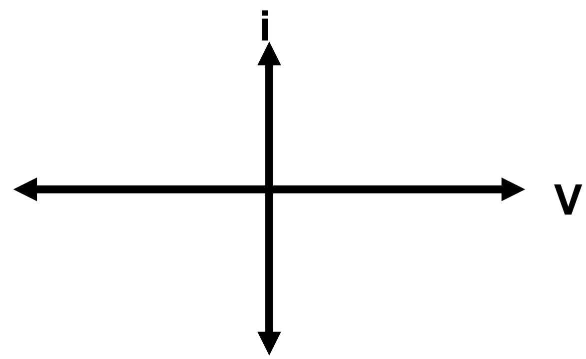
- Measure a resistor
  - Does it match the value printed on it?

Color	First Digit	Second Digit	Third Digit 1% Resistors	Multiplier	Tolerance
Black	0	0	0	1	
Brown	1	1	1	10	±1%
Red	2	2	2	100	±2%
Orange	3	3	3	1000 (=1k)	
Yellow	4	4	4	10k	
Green	5	5	5	100k	
Blue	6	6	6	1000k (=1M)	
Violet	7	7	7	10M	
Gray	8	8	8	100M	
White	9	9	9	1000M (=1G)	
Gold				0.1	±5%
Silver				0.01	±10%

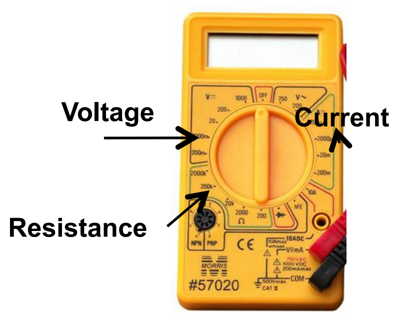
Your DMM is not Ideal (Pre Lab)

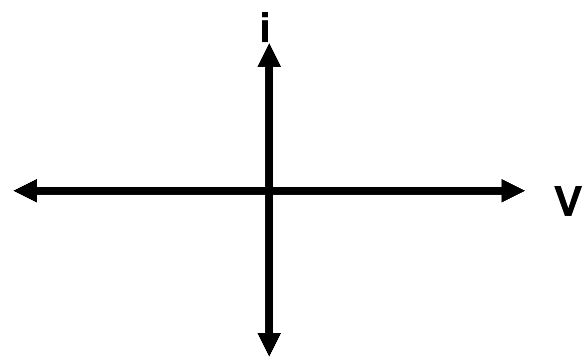
- An ideal voltage meter takes how much power? Why?





- An ideal current meter takes how much power? Why?

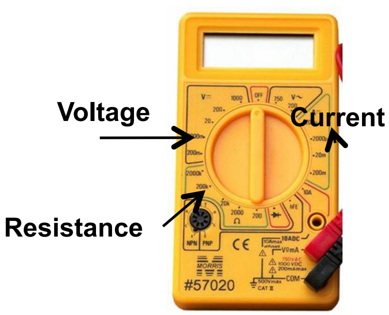




- A real DMM needs to take some power to operate
  - Therefore real DMMs are not ideal

Real Voltage Meter

- Takes some input current
  - Modeled by a resistor in parallel with ideal voltage meter



Actual DMM

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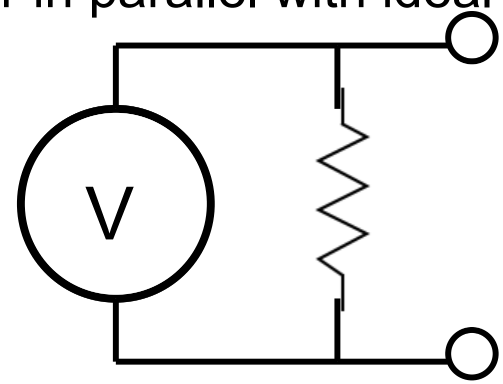
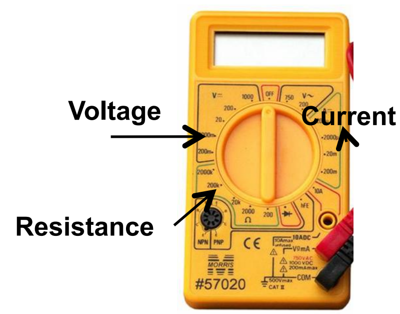


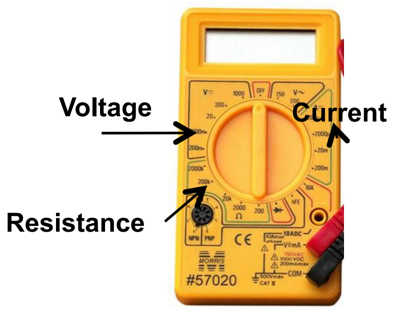
Ideal Voltmeter + R



- Work with a partner. Set one DMM to measure voltage. Use a second DMM to measure the resistance of the first DMM.
- Different groups should try different voltage scales.
- What resistance do you measure?
- Does the voltmeter you're measuring read anything?

Real Current Meter

- Real voltage meters drop a little voltage
  - Modeled by a resistor in series with an ideal current meter



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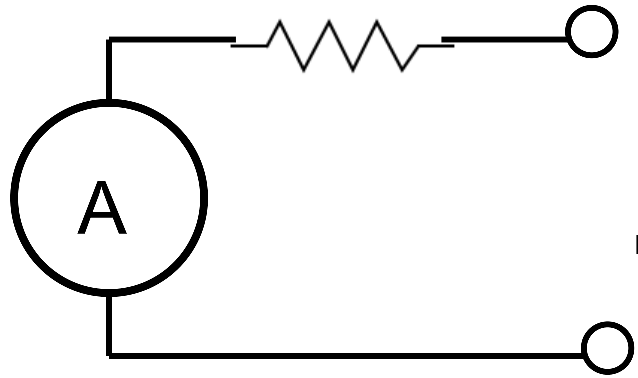
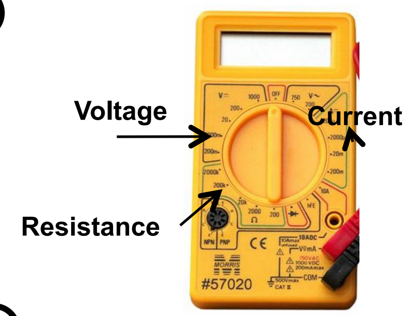




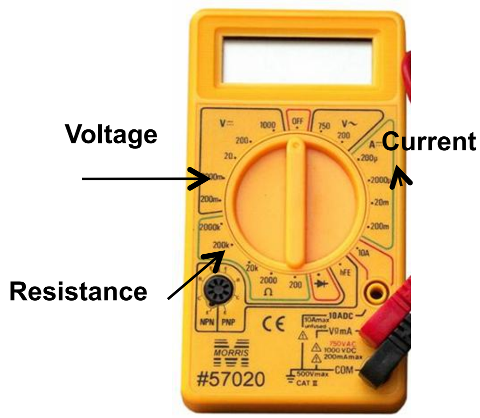
Actual DVM

Ideal Ammeter + R

- Work with a partner. Set one DMM to measure current. Use the 20mA scale. Use a second DMM to measure the resistance of the first DMM.
- What resistance did you measure?
- Does the ammeter display anything?

How Does the DMM Measure Resistance?

- The device doesn't generate any energy
  - There is no energy flow for the DMM to measure, unless …
- How can we tell what it does?



- This is part of your prelab for next week. Hint – look at the last two slides when we were measuring resistance. The DMM we were measuring also displayed a value.

Care and Feeding of you Batteries

- Please do not leave your AA batteries in the battery holders
  - The leads of the battery holder can connect by accident

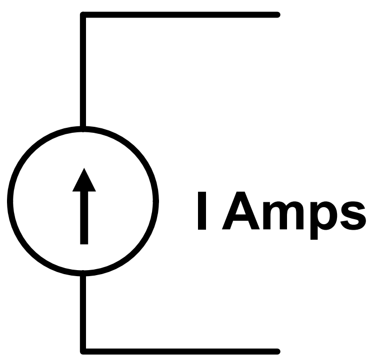
- Also make sure the leads of your LiPo (lithium ion polymer) battery don’t connect.

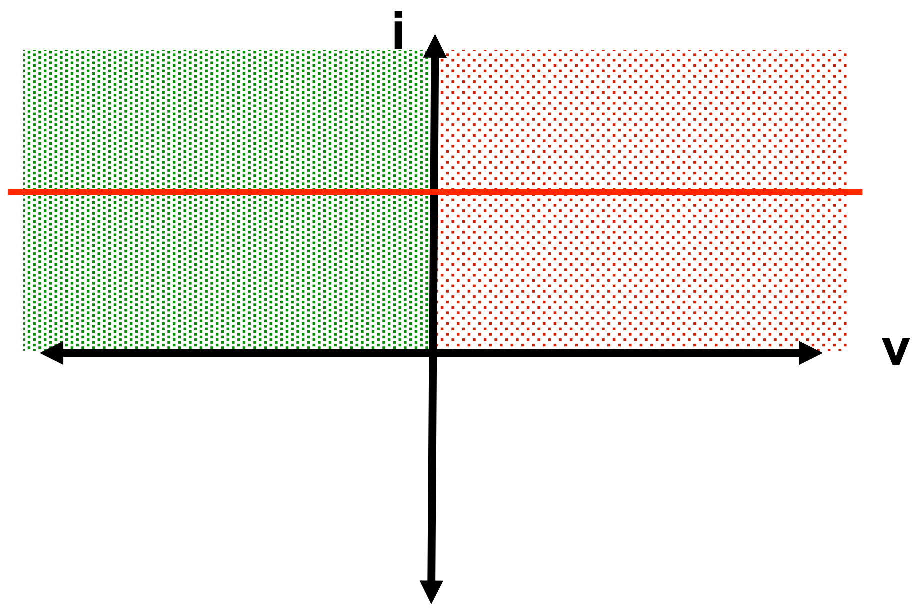
- Why?
  - All wire has some small resistance
  - Power = iV = V^2/R
  - Small R implies high power
    - Many battery holders melted last year

DEVICES: CURRENT SOURCE; DIODE

Current Source

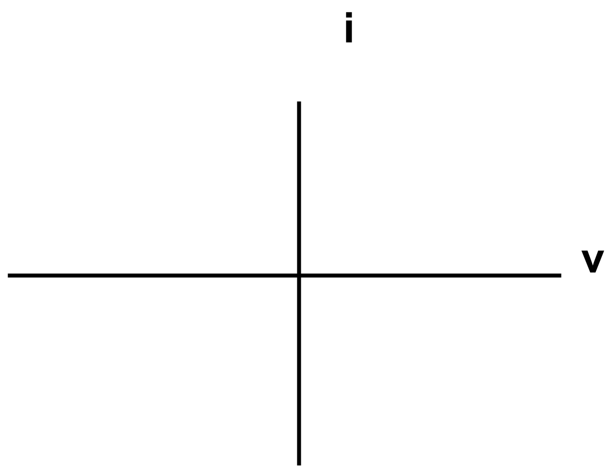
- Current is constant, independent of voltage



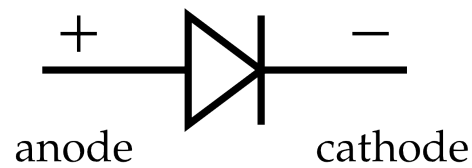


New Element – **Diode**

- Diode is a one-way street for current
  - Current can flow in only one direction

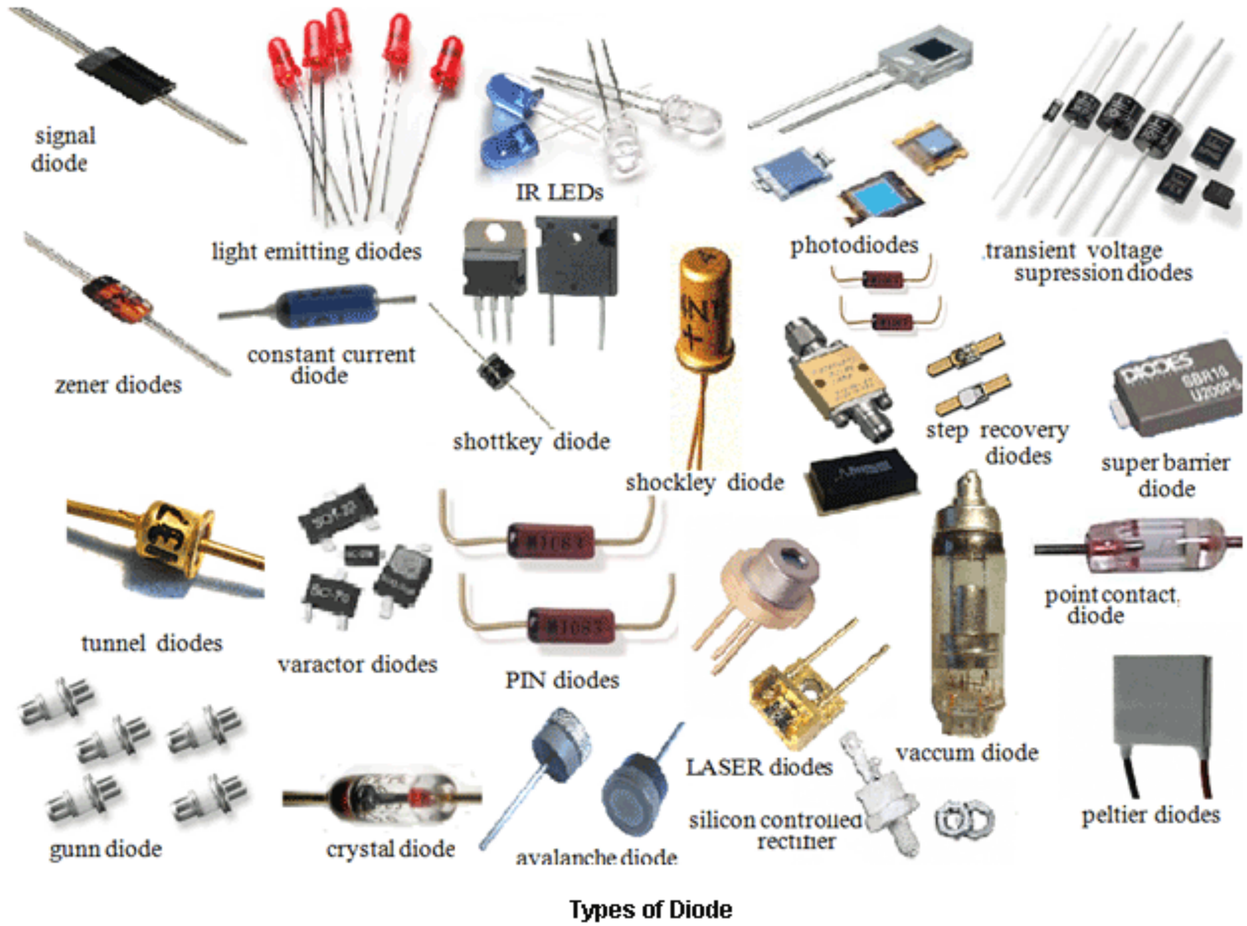


- An idea diode
  - If the current is positive
    - Voltage drop is zero independent of current
    - Looks like a wire (short circuit)
  - If the voltage is negative
    - Current is always zero independent of voltage
    - Looks like the device is not there (open circuit)



- The plus end of the diode is called the anode
  - The minus end of the diode is called the cathode

There Are Many Types of Diodes



http://www.instructables.com/id/Types-of-Diodes/

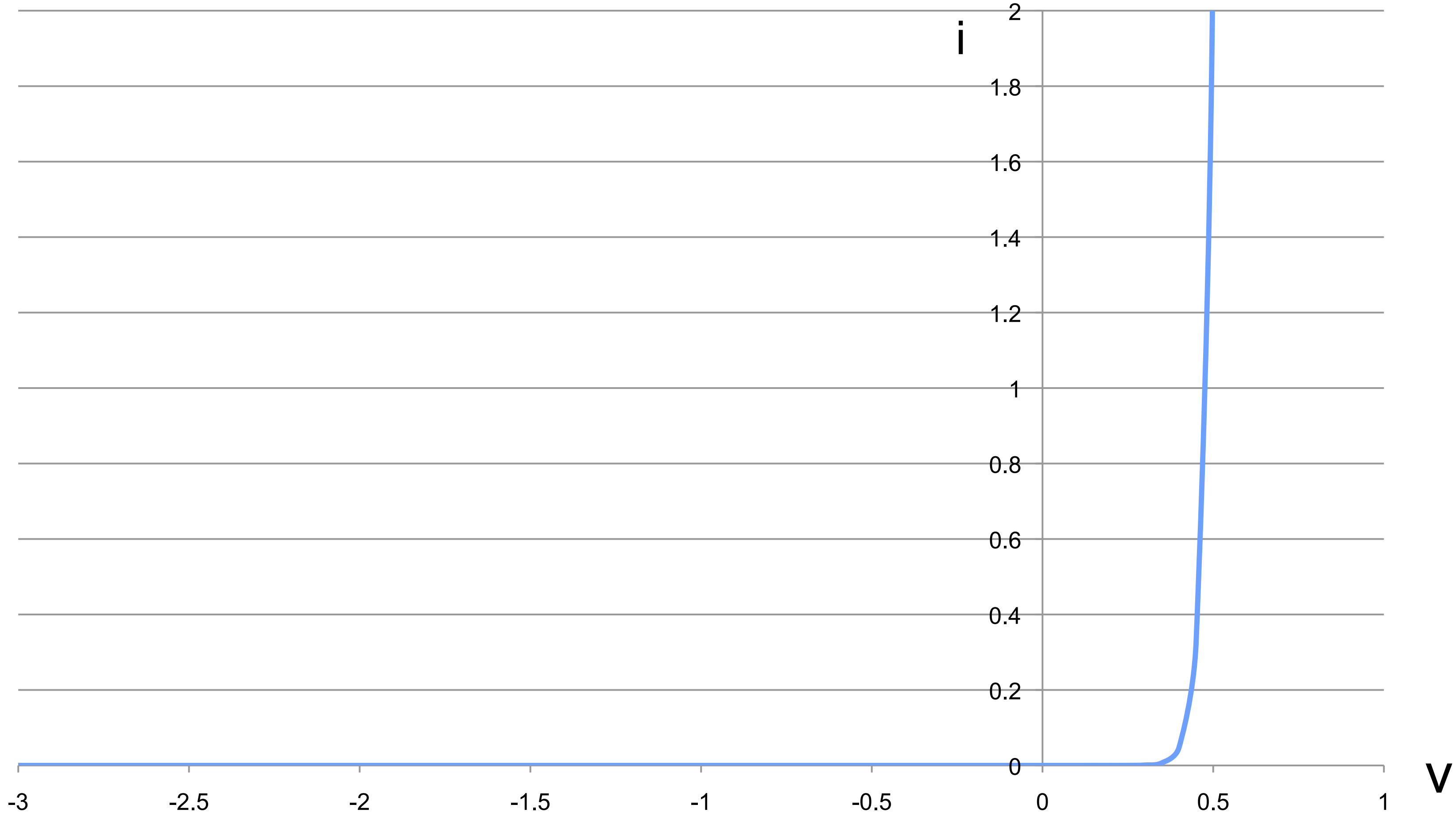
Real Diodes

- Do conduct current in only one direction
  – But they have some forward voltage drop
  – And their voltage does increase with current, but
- Their voltage is logarithmic on current
  – Current is exponential on voltage!
  – So the voltage is not very dependent on current level

$$I = I_o \exp\left(\frac{qV}{kT}\right)$$

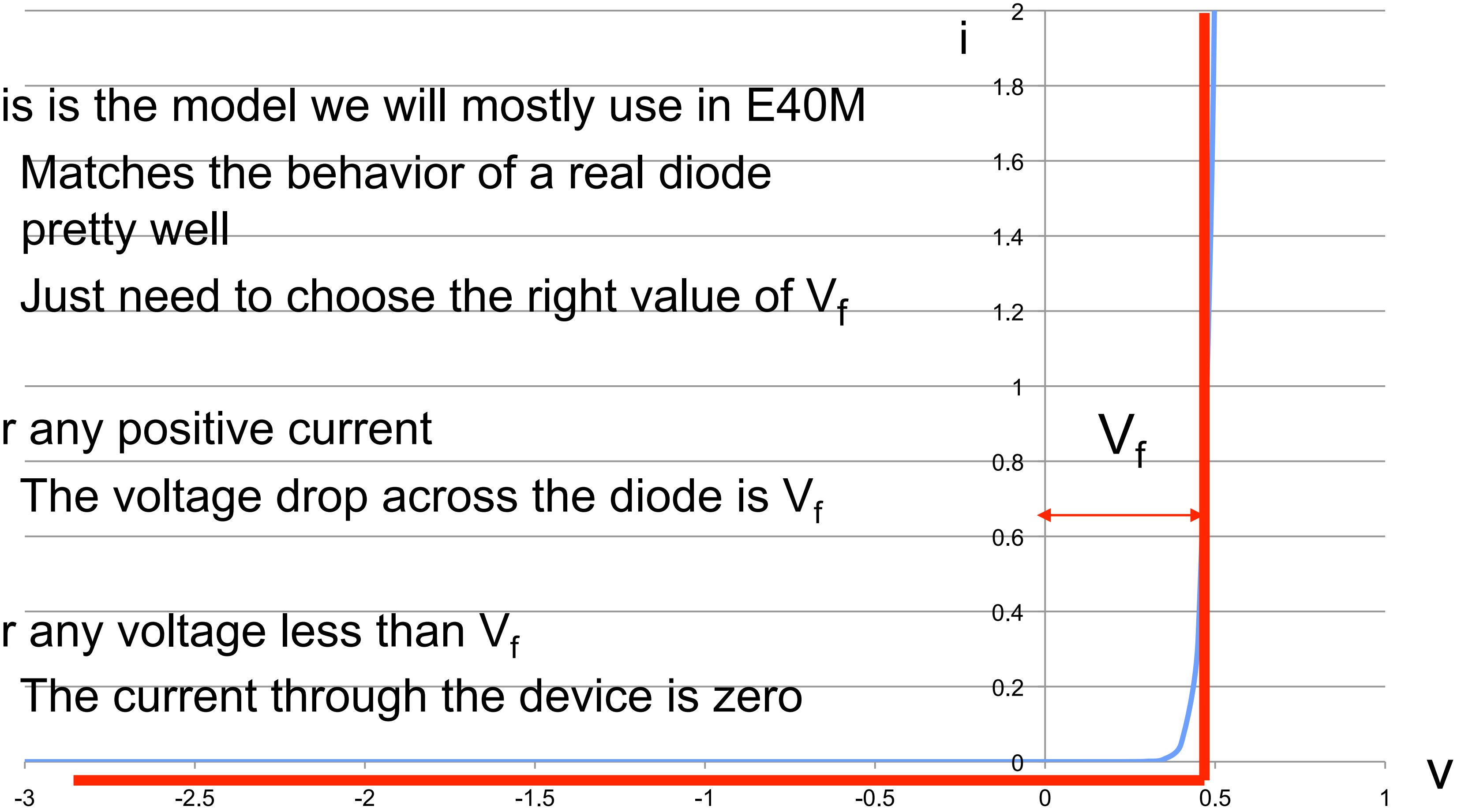
- Their drop depends on the type of diode
  – Schottky diodes are around .3V
  – Normal silicon PN diodes are generally around .6V
  – Other semiconductor materials have larger voltages

Diode iv



Idealized Diode iv

- This is the model we will mostly use in E40M
  - Matches the behavior of a real diode pretty well
  - Just need to choose the right value of V_f
- For any positive current
  - The voltage drop across the diode is V_f
- For any voltage less than V_f
  - The current through the device is zero

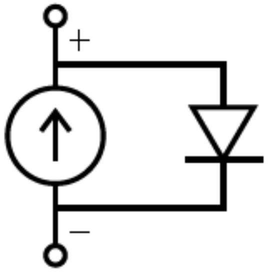


Some Diodes Are Light Sensitive

- These diodes are called **solar cells**

- When you shine light on the cell
  - The light generates a current which runs in parallel to the diode
  - The value of the current is proportional to the light

- This generates electrical energy
  - Actually converts energy in the light to electrical form



- More on this next week.

SOLAR CELL

Some Diodes Are Light Sensitive

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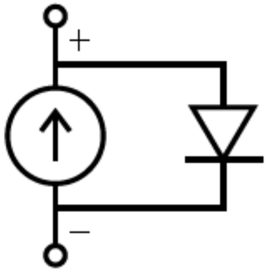
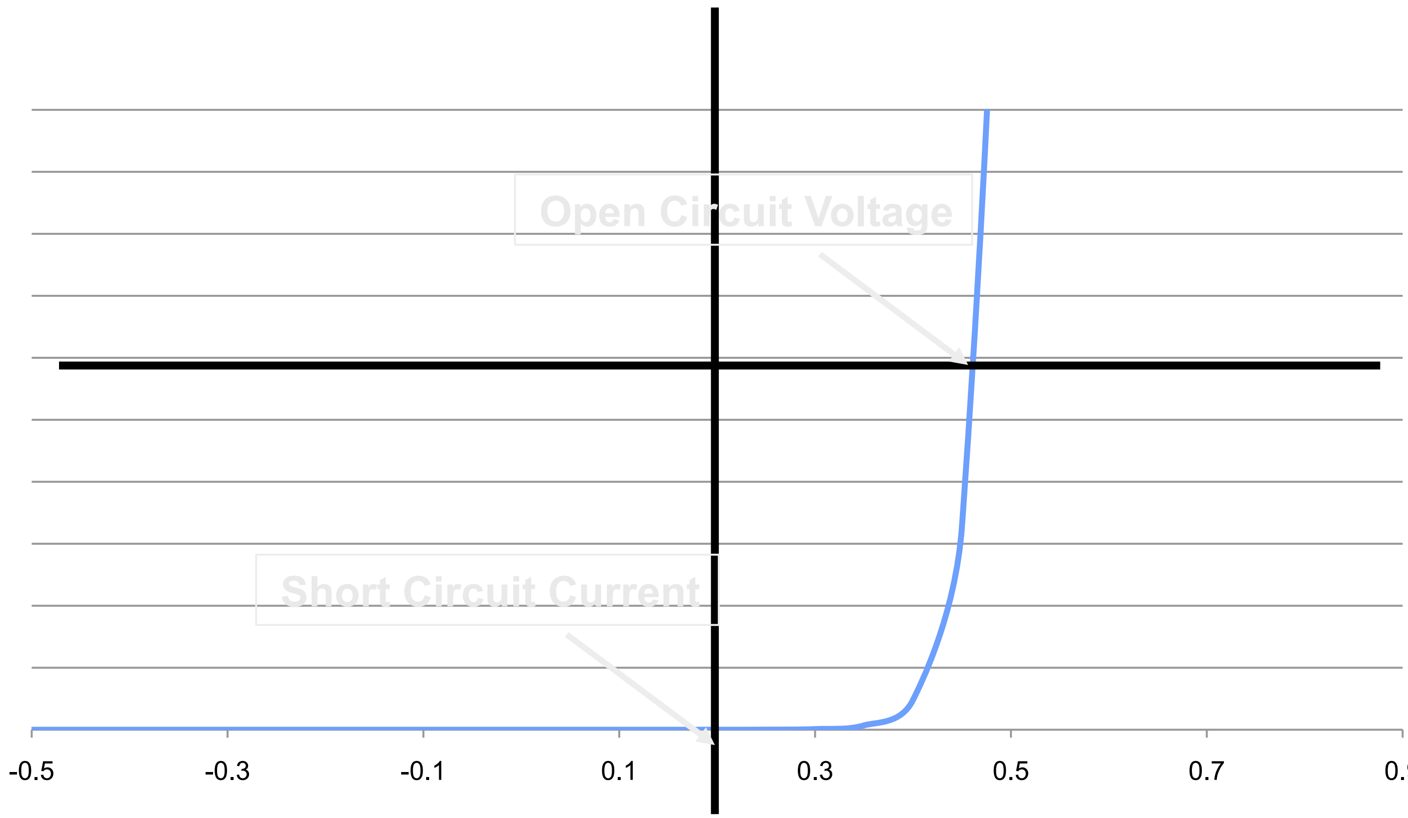
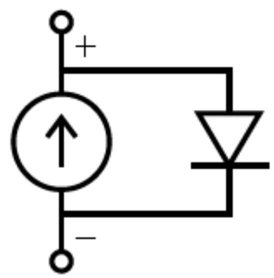


Photo Generated Current

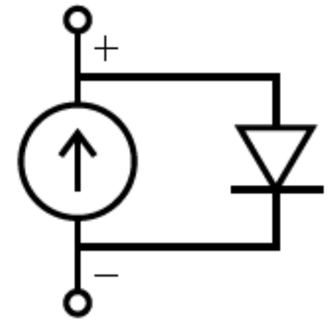
- Using standard reference direction for current
  - What does the i-V curve look like when light is shining?





What Sets the Open Source Voltage and the Short Circuit Current?

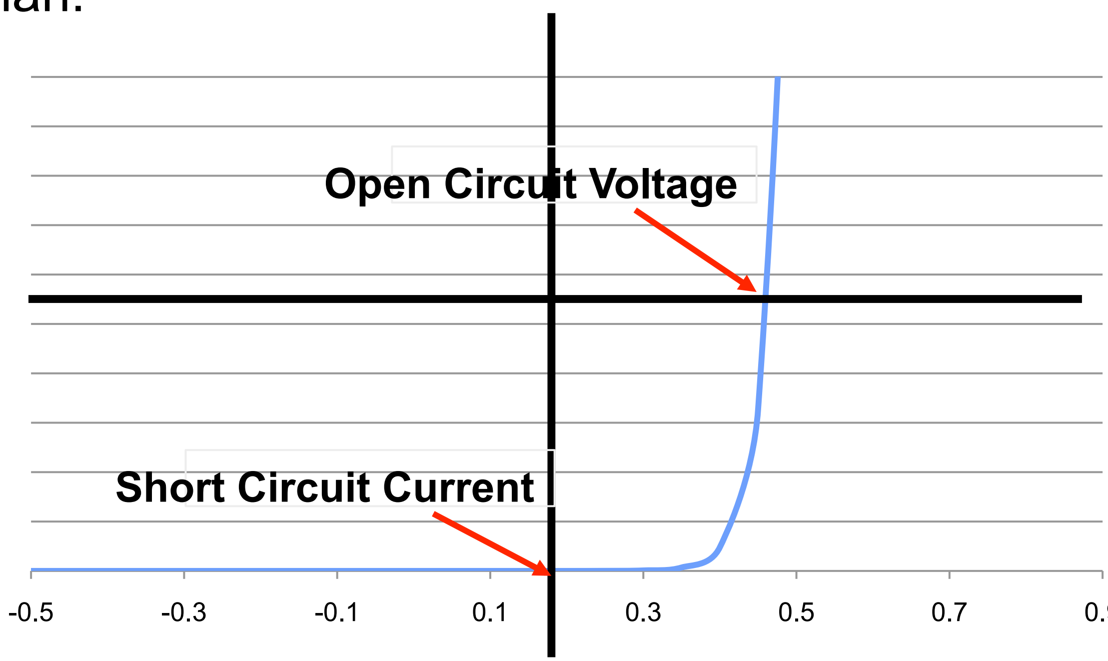
- If there is no path for current (open source voltage case)
  - It will flow into the diode which increases its voltage
    - Why the voltage increases in this case will be explained in a few weeks
  - As the voltage across the diode increases
    - The diode will eventually turn on
    - Now the current can flow in diode



- If you short the diode out (short circuit current)
  - You measure all the optically generated current

Extracting Power from a Diode

- Power is iV
  - So in neither of these cases we get power from diode
- Power will be less than:
  - $V_{open} * i_{short}$



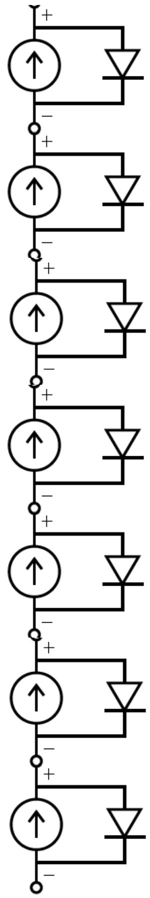
Solar Cell was Spec'd 6V and 1W

- What did you measure?

- How did they get a diode with such a large voltage?
  - They didn't, look closely at the solar cell

Generating Enough Voltage

- There is one weak point for solar cells
  - Each cell provides < 0.5V
  - We need around 5V, bought 6V cells
- To get this voltage put cells in series
  - But this puts the currents sources in series
  - If one of the cells doesn't see light
    - Its current goes to zero
    - What happens to the current through the stack?
    - Try it out on your cell (use you finger)
- This happens in commercial cells too
  - Solar panels produce 40V



Prelab To Do This Weekend

- Wait for a bright sunny day
- Take your solar cell
  - Clip alligator leads to it
  - Go outside and hold it to the sun
    - Try to cast the largest shadow
  - Measure the short circuit current
    - Put the DMM in current mode across the solar cell
  - Measure the open circuit voltage
    - Put the DMM in voltage mode across the solar cell
- We will talk about the results on Monday

Learning Objectives for Today

- Understand the device i-V curve of a resistor
- Understand the device i-V curve of a current source
- Understand the operation of a diode, and its symbol
- Be comfortable using your DMM to measure voltage and current
- Be prepared to solder next week in lab