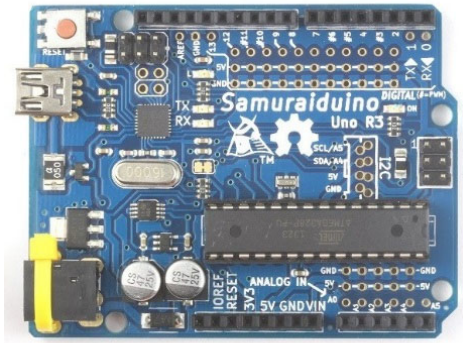
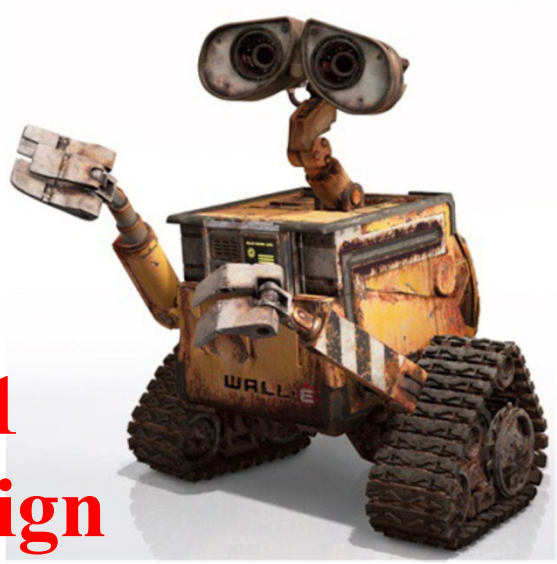
Pratt



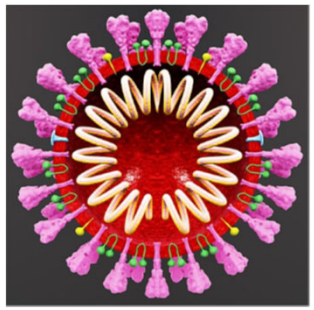


ARDUINO

MSCI 422/522-01
Electronics for Design

Charles Rubenstein, Ph. D.

Professor of Engineering & Information Science

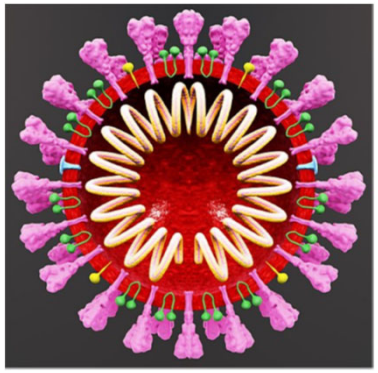


Week 2 - Session 02 - 01/27/21

Lab #01

Revised after ONLINE Zoom meeting - 1

COVID-19 & OUR CLASS



As you know the
Pratt Campus is CLOSED

I will be posting our class materials online
by 12:00pm - Noon the Saturday before class

Lab Assignments will be posted on the Class Website Saturdays
They must be submitted to me via Email by NOON on Tuesdays

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Instructor Contact Information

Dr. Charles Rubenstein <crubenst@pratt.edu>
Professor of Engineering & Information Science

Spring 2021 Office hours

to request a private 30-minute Zoom session on

Wednesdays 3:00 pm – 5:00 pm ET

or another mutually agreeable day/time

Send me an email … crubenst@pratt.edu

Subject line: E4D Talk

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21 Spring E4D Class Roster

MSCI422P-01 = UG

MSCI522P-01 = G

Last Name	First Name	Call Me	UG/ G	Time Zone
Ding	Yiming	**Yiming**	**G**	***+13, China***
Liu	Xiao	**Xiao**	**G**	***ET***
Xu	Xiyun	**Xiyun**	**G**	***ET***
Yang	Haiwen	**Haiwen**	**G**	***+13, China***

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Preliminary Schedule - MSCI 422/522 – Spring 2021

WEDNESDAY	NOTES
20 Jan (1)	Session 1. Intro, Review of Syllabus, Basic Electronics Concepts
27 Jan (2)	Session 2. Signal Conditioning, Sensors, Transducers and Output Devices (Lab #1: Basic Electronics Measurements)
3 Feb (3)	Session 3. Displays and Light-emitting Diode (LED) Devices ***Sensors Paper Proposal Due*** (Lab 2: Circuits 1 and 2; L1 Due)
10 Feb (4)	Session 4. Environmental and Interactive Inputs I: LEDs ***Midterm Project Proposal DUE*** (Lab 3: Circuits 3 and 4; L2 Due)
17 Feb (5)	Session 5. Environmental and Interactive Inputs II: Buttons and Light ***Sensors Paper Due*** (Lab 4: Circuits 5, and 6; L3 due)
24 Feb (6)	Session 6. Temperature Sensing and Electromechanical Devices I: Thermistors and Servos (Lab 5: Circuits 7 and 8; L4 Due)
3 Mar (7)	Session 7. Electromechanical Devices II: Buzzers and DC Motors ***Midterm Project & Presentation DUE*** (Lab 6: Circuits 9 and 10; 37-in-1 Sensor Kit;L5 Due)
10 Mar (8)	Session 8. Relays and Expanding Output Capabilities with Shift Registers (Lab 7: Circuits 11 and 12; L6 Due)
17 Mar (9)	Session 9. Advanced Sensors and Actuators ***Final Project Proposal DUE*** (Lab 8: Stepper Motors; L7 Due)
24 Mar	**Pratt Spring Break – No Classes**
31 Mar (10)	Session 10. Using Sensors and Microcontrollers: 3D Printers & Robotics ***ARM/Claw Redesign Proposal DUE*** (L8 Due)
7 Apr (11)	Session 11. Controlling Robots with Continuous Rotation Servo and Stepper Motors
14 Apr (11)	Session 12. Review of Final Project Design progress
21 Apr (11)	Session 13. ***ARM/Claw Redesign Revue***
28 Apr (11)	Session 14. ***Final Project Design Due***
5 May	Session 15. ***Final Project Presentations***

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MSCI 422/52 – Preliminary - *Readings Schedule*

Session	*Readings – PRELIMINARY*
20 Jan (1)	*Review **EW1** and **EW2** Lab Manuals as necessary*
27 Jan (2)	*Review **EW1** and **EW2** and **Sensors** Lab Manuals as necessary*
3 Feb (3)	***Vilros**: Circuits 1 and 2*
10 Feb (4)	***Vilros**: Circuits 3 and 4*
17 Feb (5)	***Vilros**: Circuits 5 and 6*
24 Feb (6)	***Vilros**: Circuits 7 and 8*
3 Mar (7)	***Vilros**: Circuits 9 and 10*
10 Mar (8)	***Vilros**: Circuits 11 and 12; **Elegoo 37-in-1 Manual** for Final Project ideas*
17 Mar (9)	***LAFVIN Robot ARM Manual***
31 Mar (10)	***LAFVIN Robot ARM Manual***
7 April (11)	***LAFVIN Robot ARM Manual***
14 April (12)	***LAFVIN Robot ARM Manual***
21 April (13)	***LAFVIN Robot ARM Manual, Misc Arduino texts; Elegoo 37-in-1 Manual***

KEY	***TEXTS STORED IN THE ONLINE "_references" Folder***
	EW1 = Mims III, Forrest M.: Basic Electronics: Transistors & Integrated Circuits, Workbook I (ew1.pdf)
	EW2 = Mims III, Forrest M.: Digital Electronic Projects, Workbook II (ew2.pdf)
	Sensors = Mims III, Forrest M. : Radio Shack Electronic Sensors Lab (sensors.pdf)
	Vilros = Basic Arduino Projects in VILROS Ultimate Starter Kit Guide – Revision 1 (vilros.pdf)
	Ref = Arduino Language References (Arduino_Quick_Reference.pdf and CodeBasics_E4D.pdf)
	See also the files that come with the various kits (e.g., folder: _Elegoo_Super_Starter_Kit_for_Uno).

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* Class Session Archives

http://www.CharlesRubenstein.com/E4D/

21sp02.pdf *(Class PowerPoint slides)**

21sp02_h.pdf *(6-slide/page handout format)**

The syllabus and other materials will also be found in this website, as will various "eBooks" and kit manuals and the eight Lab Instruction and Results sheets.
They will be available in time for your need to have them!

**PowerPoints normally available by Saturday 12:00pm week before class*

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In Today's Class: Session #02

Lecture: ***AC/DC conversion, LED Circuit analysis***

Readings: **EW1** *(Basic Electronics: Transistors and Integrated Circuits - Workbook I by Forrest M. Mims, III; ew1.pdf)***;** **EW2** (Digital Electronic Projects - Workbook II by Forrest M. Mims, III; ew2.pdf)**;** Sensors (Sensors Lab Manual by Forrest M. Mims, III; sensors.pdf)

Hands-On: ***Lab #01: Measuring Resistance and Voltage***

Requires Meter/Leads, Breadboard, Power Supply and four 1K resistors

For our next class - Session 3:

DUE: Sensor Research Paper Proposal

DUE: ***Lab #01: Measuring Resistance and Voltage***

Lecture: ***Displays and Light-emitting Diode (LED) Devices; signals, sensors, transducers and output devices; Microcontrollers; Installing the IDE and examples.***

Readings: **Vilros** *(VILROS Ultimate Starter Kit Guide; vilros.pdf); Elegoo and Lavfin "manuals and tutorials"*

Hands-On: ***Lab #02:***

Vilros Circuit 1: Blinking a LED; Vilros Circuit 2: Potentiometer

Requires Arduino UNO R3 Advanced Starter Kit or Equivalent

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MSCI 422/522 Requirements

A. HANDS-ON LAB MODULES: 40%

(Eight required Labs @ 5% each)

B. SENSORS RESEARCH PAPER: 10%

(Proposal: 5%; Paper & presentation: 5%)

C. DESIGN PROJECTS*: (50%)

C.1. Midterm Design Project: 10%

(Proposal: 5%; Formal presentation: 5%)

C.2. ARM/*Claw Redesign Project*: 10%

(Proposal: 5%; Formal presentation: 5%) ***(Required for 522)***

C.3.a. Final Design Proposal: 10%

(Proposal: 5%; Formal presentation: 5%)

C.3.b. Final Design Project: 20%

(Project Design: 15%; Formal presentation: 5%) ***(*Details in the next week…)***

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A. Hands-On Lab Modules

Hands-On Lab Modules: (40%)

Eight (8) Labs, 5% per completed lab

Hands-on projects involving wiring, testing, flow charting, and programming a variety of electronic and Arduino interface circuits.

Students will also assemble and test a robotic arm.

On campus, teams of students will calibrate 3D printer systems. Lab grade is based on completion of all modules.

Note:

Lab work will NOT be accepted after 7 April class session.

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B. Research Paper on Sensors

RESEARCH PAPER: (10%)

Paper Topic: "Research a sensor not included in the normal labs. It does NOT have to be in the 37-in-1 Sensors kit, but that would be nice – especially if you also use it in your Final Design Project."

*(See **SensorPaper.pdf**)*

Topic Due: 2 February*

(You will review your proposed sensor in class)

Final Paper Submission: 16 February*

(* Tuesday day before class @ 12:00pm Noon ET)

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C.1. Midterm Design Project**

Midterm Design Project: (10%)

Proposal: 5% proposal, Design presentation 5%

Design Topic: Students will research a microcontroller design project using either one of the 'advanced' projects provided in the Arduino kits, or an original idea – which might become the basis for their final project.

The project proposal is expected to include possible forms that the project can take in terms of function and physicality.

A one-page overview of the proposed project will be reviewed by the instructor.

Midterm Design Topic Proposal Due: 9 February*

Midterm Design Presentation: 2 March*

(* Tuesday day before class @ 12:00pm Noon ET)

*****Details in the next week…***

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C.2. ARM/Claw Redesign Project

ARM/Claw Redesign Project: (10%) ***REQUIRED for MSCI 522*****

Proposal: 5% proposal, Design presentation 5%

Design Topic: MSCI522P students will research the mechanical design of robot 'claws' and propose an alternate ARM or claw construction design; create the laser cutter drawings for that design; and subject to time (etc.) constraints they will build their design.

A one-page overview of the proposed redesign will be reviewed by the instructor.

ARM/Claw Design Proposal Due: 30 March*

ARM/Claw Design Presentation: 20 April*

(* Tuesday day before class @ 12:00pm Noon ET)

***** Optional for MSCI 422***

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C.3. Final Design Project

Final Design Project: (30%)

C.3.a. Final Design Proposal: 5% proposal, Proposal presentation: 5%

C.3.b. Final Project Design: 15%, Design presentation: 5%

Design Topic:

MSCI422: Undergraduate students

will research a microcontroller design project using either one of the 'advanced' projects provided in the Arduino kits, or an original idea.

MSCI522: Graduate students

must research an original microcontroller design idea.

The project proposal is expected to include possible forms that the project can take in terms of function and physicality.

A three-page overview of the final project design will be required.

Final Design Topic Proposal Due: 16 March*

Final Design Presentation: 27 April*

(* Tuesday day before class @ 12:00pm Noon ET)

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MSCI 422/522 Hands-on Lab Modules

VERY Preliminary… Eight Labs Required

#01: *Measuring Resistance and Voltage*

#02: *Circuit 1: Blinking a LED; Circuit 2: Potentiometer*

#03: *Circuit 3: RGB LED; Circuit 4: Multiple LEDs*

#04: *Circuit 5: Push Buttons; Circuit 6: Photoresistor;*
Circuit 7: Temperature Sensor

#05: *Circuit 8: Single Servo;* ***and ARM Claw construction***

#06: *Circuit 9: Buzzer; Circuit 10: Spinning a Motor;*
Circuit 11: Relays; Continuous Rotation Servos, Stepper Motors

#07: *Circuit 12: Shift Registers; The 37-in-1 Sensor Kit*

#08: *LAFVIN Robot ARM: Joystick and Bluetooth Control*

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Questions?

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Basic Electronics Review

Ohms Law
eMath Calculations
Combining Resistors
Voltage Divider Equation

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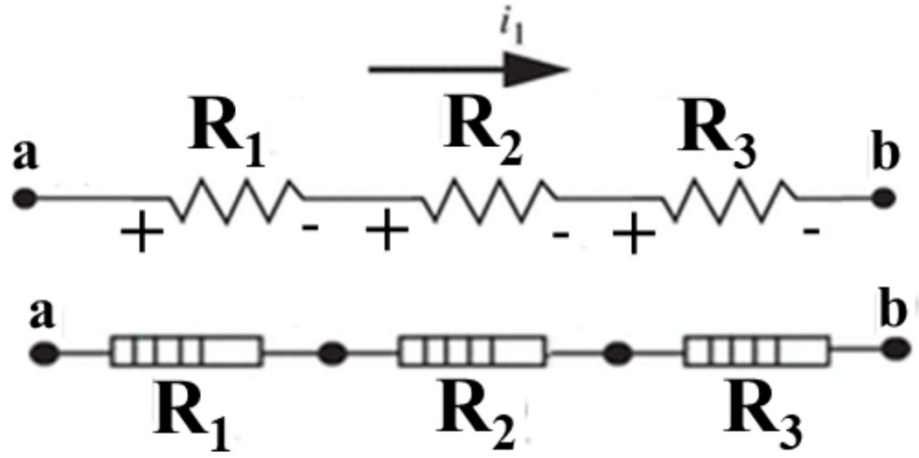
Basic Resistors in Series

SERIES CIRCUITS: ***A series circuit is one in which the same CURRENT flows <u>through</u> each device***



1. ***Resistors in SERIES add***

$$R_{ab} = R_1 + R_2 + \ldots + R_n$$

2. ***For 'n' Like Resistors in SERIES:***

$$R_{ab} = n \cdot R$$

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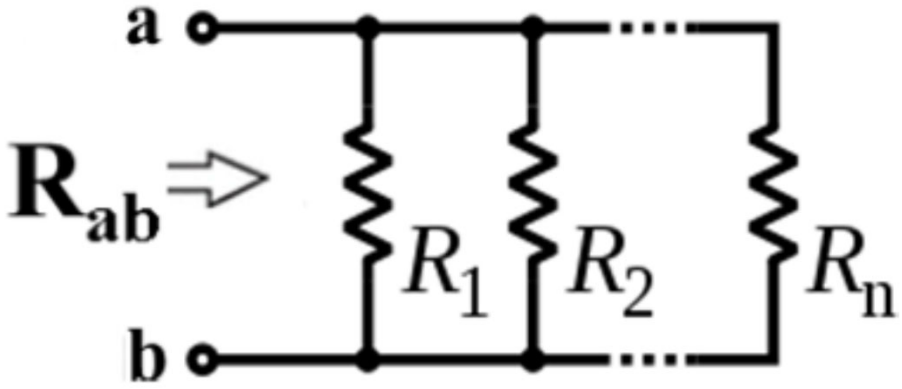
Basic Resistors in Parallel

PARALLEL CIRCUITS

A parallel circuit is one in which the same VOLTAGE is measured <u>across</u> each device

For "N" Resistors in Parallel



$$1/R_{ab} = 1/R_1 + 1/R_2 + 1/R_3 + 1/R_4 + \ldots + 1/R_n$$

BUT, if there are n resistors of the same value, R:

$$R_{ab} = R / n$$

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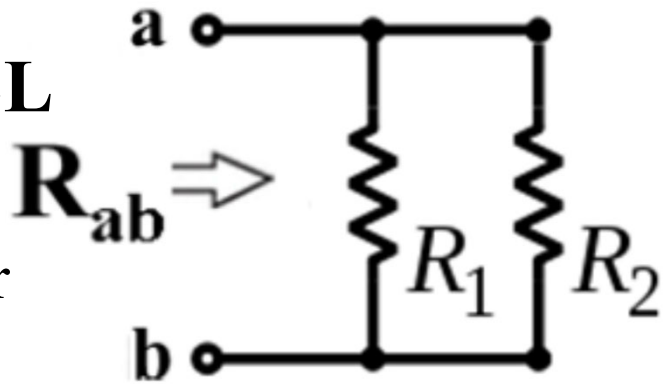
Two Resistors in Parallel

***SPECIAL CASE*:**

TWO RESISTORS IN PARALLEL

(valid for TWO resistors only)



The resistance from **a** to **b** in a **two** resistor parallel circuit is:

$$1/R_{ab} = 1/R_1 + 1/R_2$$

Rearranging: $$R_{ab} = (R_1R_2) / (R_1+R_2)$$

It is stated that the "product of the two resistors over the sum of the two resistors" yields the equivalent value of resistance for the parallel combination of two resistors.

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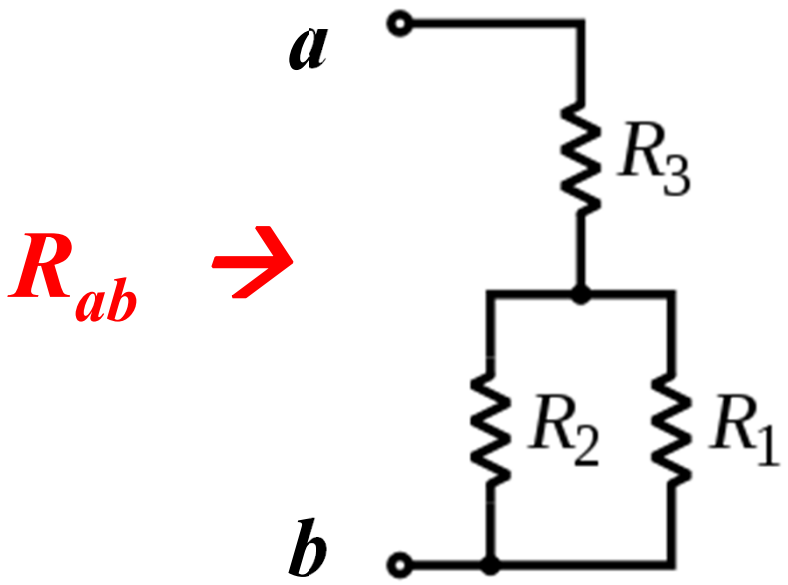
Simple Series/Parallel Resistor Circuits



The Equivalent Resistance of the circuit above:

$$R_{ab} = [\, R_1 R_2 / (R_1 + R_2) \,] + R_3$$

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Ohms Law

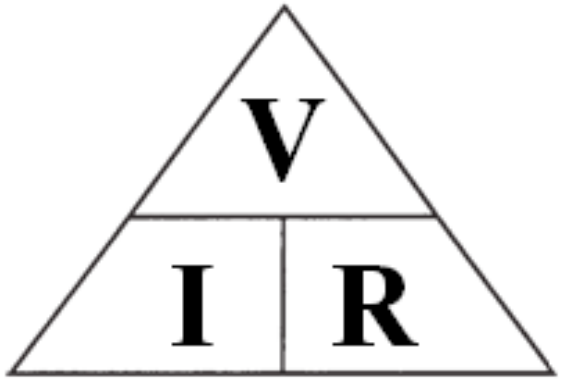
There are three forms for the **Ohms Law** equation:

$$V = I R$$

$$R = V / I$$

$$I = V / R$$

and a convenient figure to remember them by…



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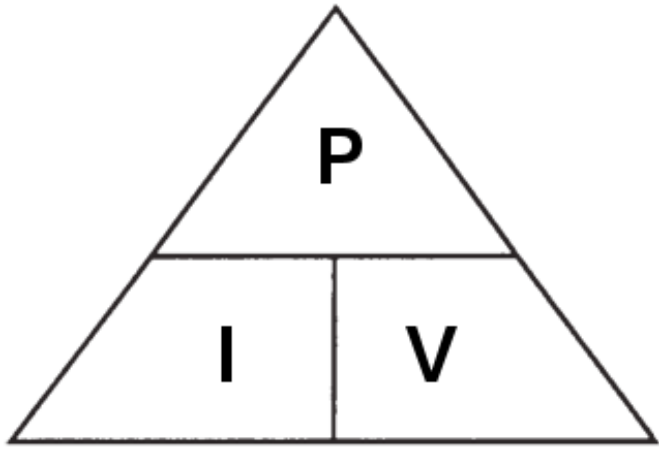
Power and the Power Law

Power (**P**) is the rate of delivering energy or doing work, for electrical work the unit is called the "**watt**"

Practical: The **Power Law**

The definition of electrical power is one volt (**V**) times one ampere (**I**) equals one watt (**P**).



For the DC resistor circuits we work with:

$$P = I\,V$$

From Ohm's Law: $P = I\,(IR) = I^2R$

From Ohm's Law: $P = (V/R)\,V = V^2/R$

(Note: Some texts may use P = IE)

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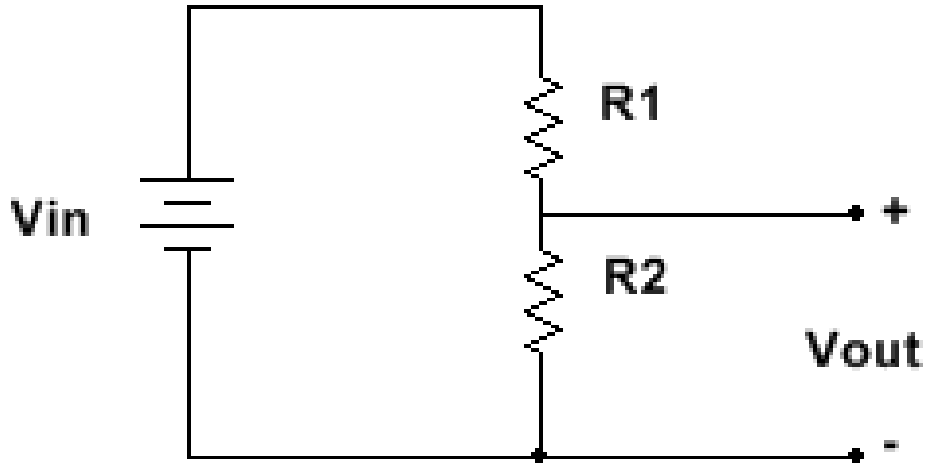
The Voltage Divider Equation



The two-resistor series circuit above can be used to derive:

The Voltage Divider Equation

$$Vout = Vin \left[R_2 / (R_1 + R_2) \right]$$

*When a voltage is applied to **two or more resistors in series**, the voltage across a particular resistor is the applied voltage times a certain fraction and that fraction is the selected resistor divided by the sum of the resistors.*

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Questions?

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Basic Electronics

Calculations:
Resistors in Series & Parallel

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Example 1 - 1

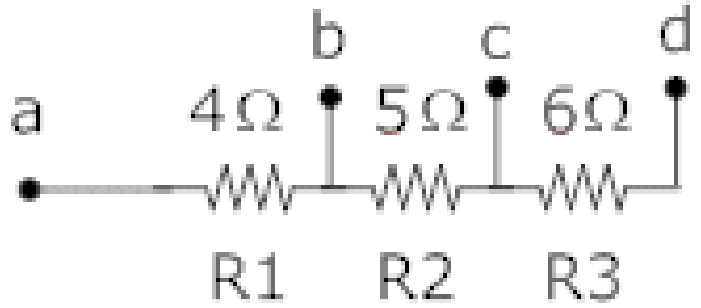

Figure 1. Three Series Resistors

1.1) Find the total resistance

between the various points for the three resistors in Figure 1.

Series Resistor Formula:

$\mathbf{R_{ab}}$ (*betw. points* ***a*** & ***b***) = ***4 ohms***

$\mathbf{R_{ac}}$ (*betw. points* ***a*** & ***c***), $R_t = R_1 + R_2 = 4\ ohms + 5\ ohms = 9\ ohms$

$\mathbf{R_{ad}}$ (*betw. points* ***a*** & ***d***)

$$R_t = R_{ad} = 4\ ohms + 5\ ohms + 6\ ohms = 15\ ohms$$

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Example 1 - 2

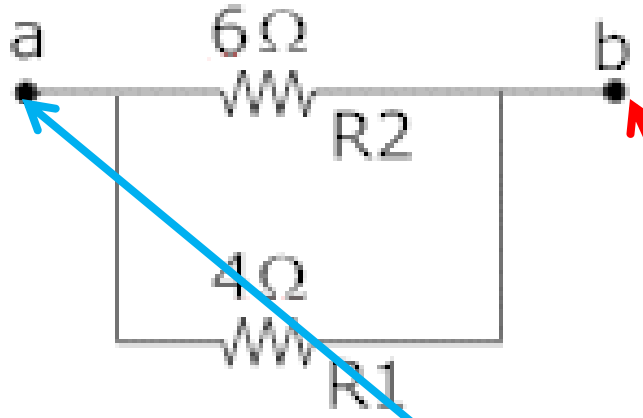

Figure 2. Two Parallel Resistors

1.2)

Find the total resistance between points **a** and **b** for the two resistors in Figure 2.

2 Parallel Resistor Formula: $R_T = [(R_1 \bullet R_2) / (R_1 + R_2)]$

$$R_T = (4 \bullet 6) / (4 + 6)$$

$$R_T = 24 / 10 = 2.4 \text{ ohms}$$

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Example 1 - 3

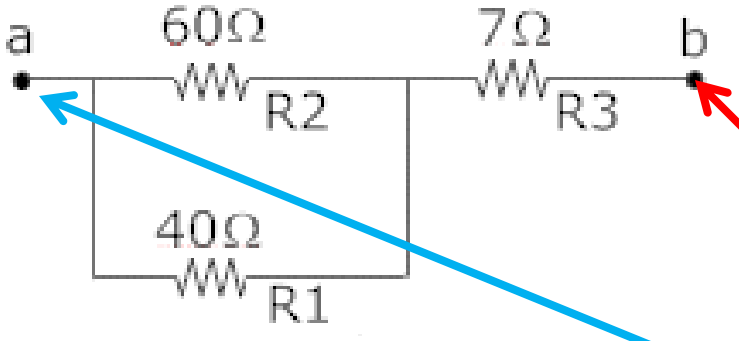

Figure 3. Series and Parallel Resistor Combinations

1.3) Find the resistance between points **a** and **b** for the three resistors in Figure 3.

Parallel/Series Resistor Formula:

$$R_T = [(R_1 \bullet R_2)/(R_1 + R_2)] + R_3$$

$$R_T = [(40 \bullet 60) / (40+60)] + 7$$

$$R_T = [(2400) / (100)] + 7 = [24] + 7$$

$$R_T = 31 \text{ Ohms}$$

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Example 1 - 4

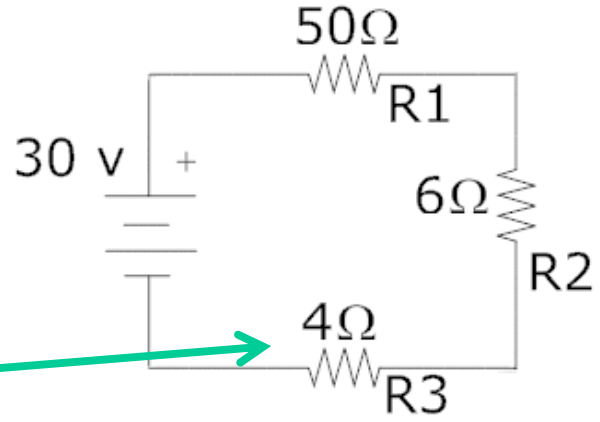

Figure 4. A Complete Series Circuit

1.4) Find the **current *through*** R3, the **4 ohm** resistor, in Figure 4.

a. Calculate the Total Equivalent Resistance in the Circuit:

$$R_T = R_1 + R_2 + R_3 = 50 + 6 + 4 = 60 \text{ ohms}$$

b. KCL for a series circuit 'tells' us $I_T = I_1 = I_2 = I_3$

c. Using Ohm's Law:

$$I_3 = V / R_T$$

$$I_3 = 30 \text{ V} / 60 \text{ Ohms} = 0.5 \text{ Amperes}$$

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Example 1 - 5

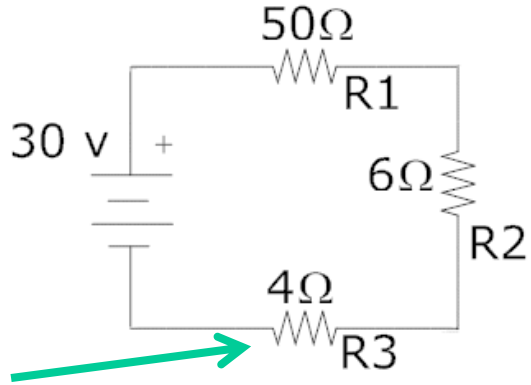

Figure 4. A Complete Series Circuit

1.5) Now find the **voltage *Across*** resistor R3 in Fig 4.

Calculate the Total Equivalent Resistance in the Circuit:

$$R_T = R_1 + R_2 + R_3 = 60 \text{ ohms}$$

b. KCL for a series circuit 'tells' us $I_T = I_1 = I_2 = I_3$

c. Using Ohm's Law: $I_3 = V / R_T = 30/60 = 0.5A$

d. Using Ohm's Law again: $V_3 = I_3 \bullet R_3$

$$V_3 = 0.5A \bullet 4 \text{ Ohms} = 2.0 \text{ Volts}$$

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Questions?

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Basic Electronics

Overview of Semiconductor Diodes and LEDs

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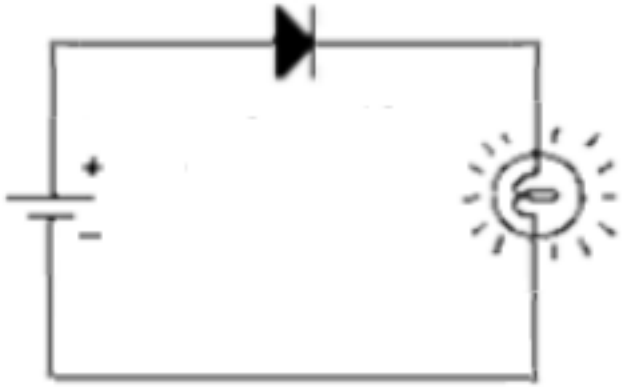
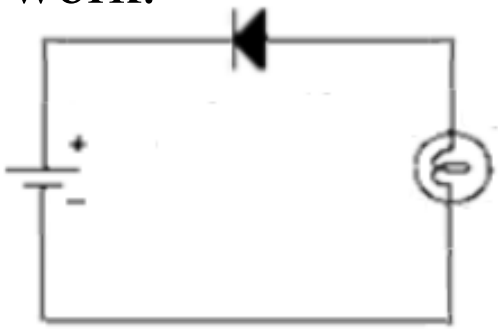
Semiconductor Diodes *(Review)*

Let's review the basic action of diodes under forward and reverse bias conditions.



Forward Biasing

We will see there is a small voltage drop across the **1N4007** diode when forward biased. There is a lot of physics behind it, but let's just agree that ***the PN junction creates a small barrier to forward bias current that is about 0.6 volts for Silicon diodes*** *(about 0.3-0.4 volts for Germanium diodes).* The voltage in the circuit across the diode needs to exceed this voltage for the diode to work.



Reverse Biasing

When ***reverse biased, the diode blocks nearly all current that tries to pass through it***. The small amount of current that does get through is called ***leakage current***.

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Forward/Reverse Biasing of Diodes

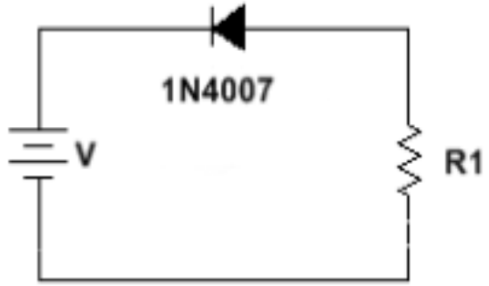
Semiconductor diodes have the ability to pass the flow of current in only one direction. This occurs when the diode is

Forward Biased:

$$I_{R1} \approx V / R1$$

$$I_{R1} = (V - 0.6) / R1$$

Similarly, semiconductor diodes have the ability to block the flow of current in one direction. This occurs when the diode is **Reverse Biased**:



$$I \approx 0$$

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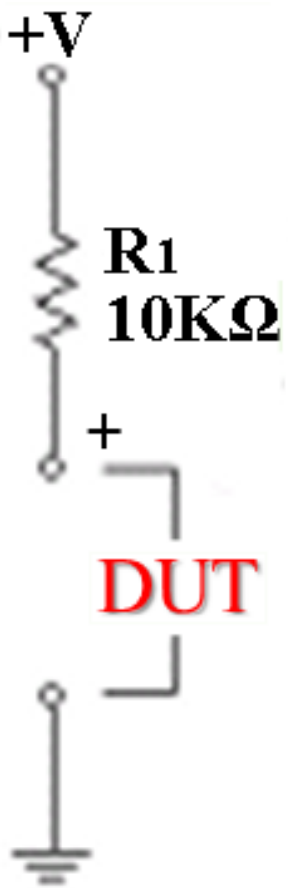
Diode Characteristic Curve

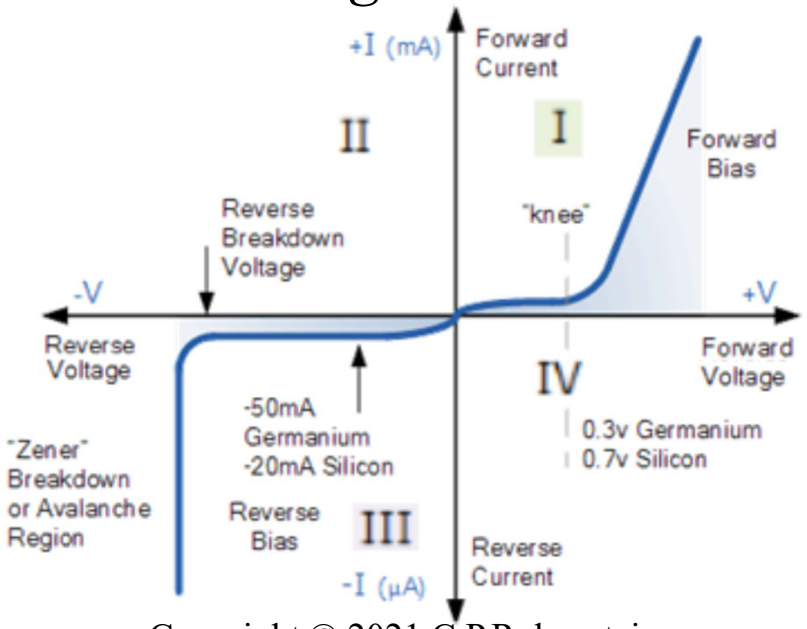
A typical **LED's** test circuit has a DC power supply and a *10KΩ current limiting series resistor* to limit the current to about 10 mA. (*DUT means device under test*).

Recording the voltage across the diode and resistor

We can calculate the resistor's current by Ohm's Law

Then we can plot the IV Characteristic Curve for the Diode which will look something like:





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Questions?

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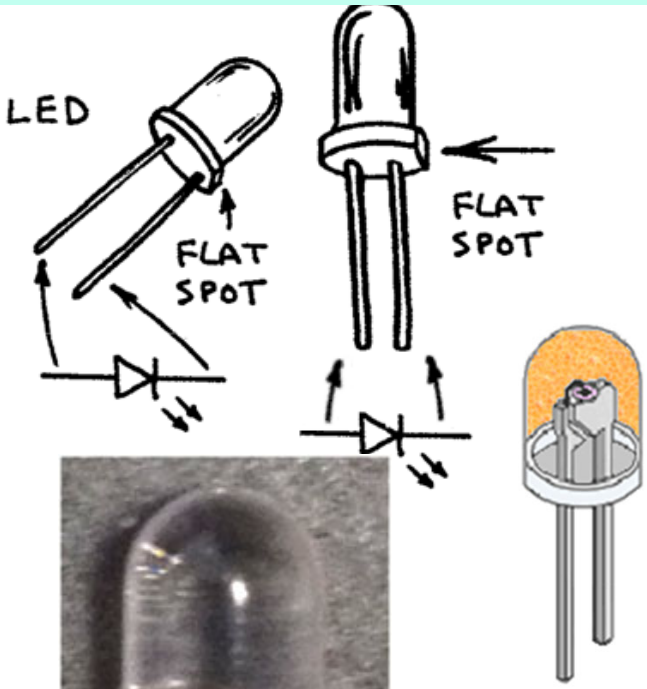
Light Emitting Diodes - 1

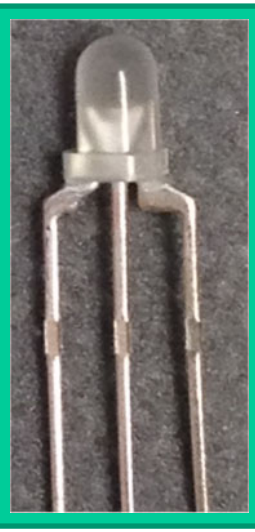


← Flat Side (negative)

The LED's FLAT SIDE corresponds to the lead that holds the actual semiconductor 'die' and is the CATHODE or NEGATIVE lead.

The other POSITIVE lead has a small wire "whisker" that attaches to the center of the semiconductor die.

On special LEDs there can be two wires going to the center die lead from either side. This can be for two color or double Brightness dual LEDs…



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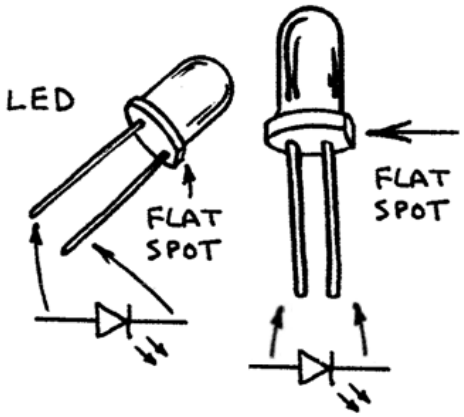
Testing Diodes and LEDs - 1

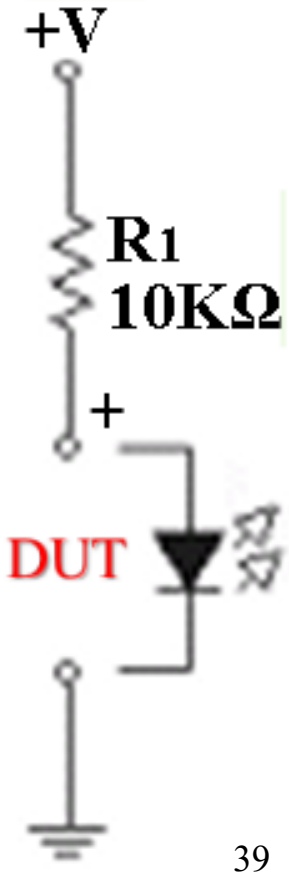


The LED's flat side is normally connected to Ground, or the Negative power supply voltage.

A typical **Silicon signal or rectifier diode** usually has a ***forward voltage drop*** of ***0.5 to 0.8 volts***.

LED diodes usually have a *forward voltage drop* too high to test with most Multimeters, so you should use a test circuit with a 3 volt or higher DC power supply and a current limiting series resistor to limit the current to 1 to 10 mA - enough to light most LEDs.

(*DUT means device under test*)



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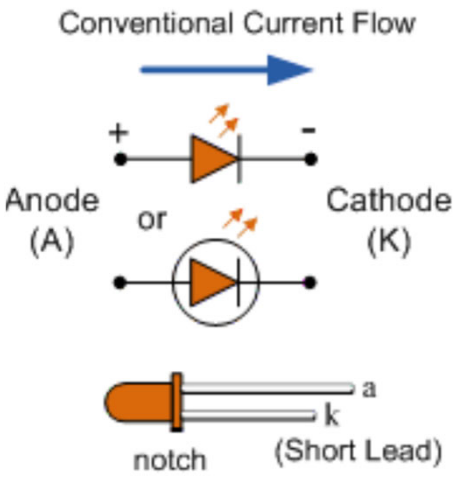
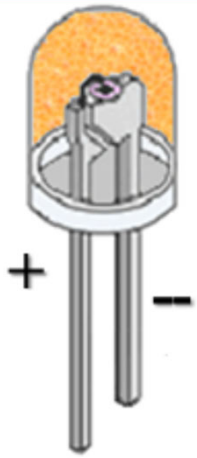
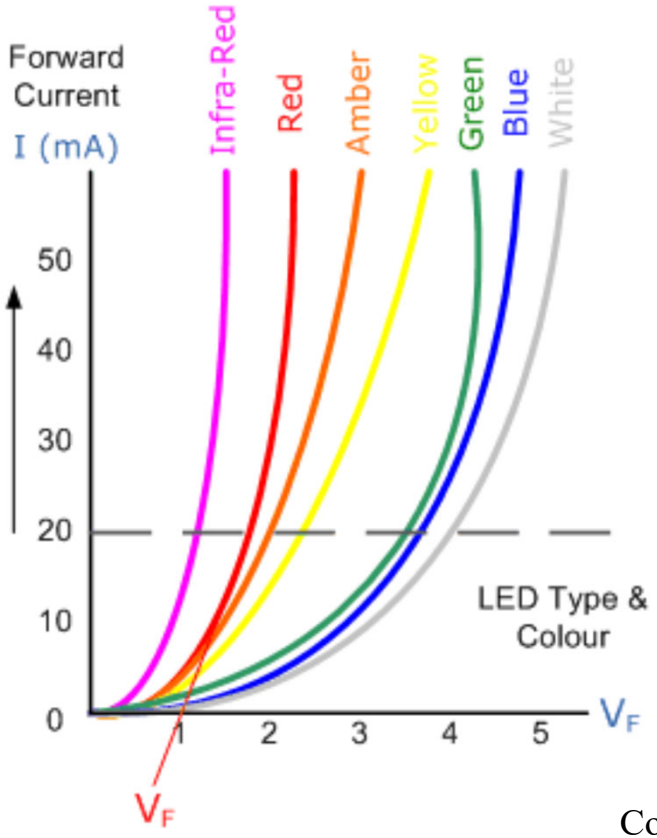
Light Emitting Diodes - 2

As we will see in our hands-on lab, *all* diodes have an IV Characteristic curve.

LEDs have a 'family' of curves – related to their doping and resulting colors







Semiconductor Material	Color	Wavelength in Nanometers (nm)	Vf @ 20mA
GaAs	**Infra-red**	850-940	**1.2 v**
GaAsP	**Red**	630-660	**1.8 v**
GaAsP	**Amber**	605-620	**2.0 v**
GaAsP-N	**Yellow**	585-595	**2.2 v**
AlGaP	**Green**	550-570	**3.5 v**
SC	**Blue**	430-505	**3.6 v**
GaInN	**White**	450	**4.0 v**

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LED Circuit Problems - 1

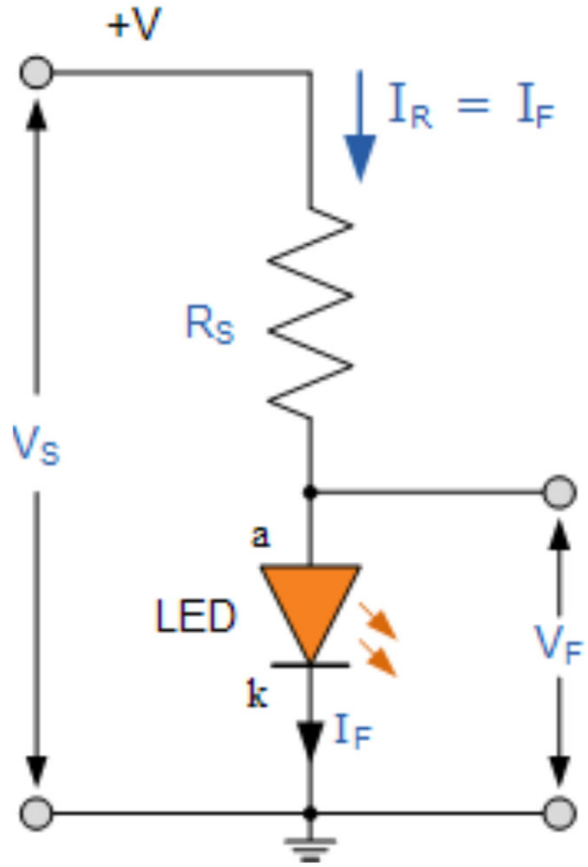
Basic Ohms Law Calculation: $R_S = (V_S - V_F) / I_F$

1. What is R_S if $V_S = 5$ *and* $V_F = 2$ volts @ 10 mA:

$R_S = (V_S - V_F) / I_F$

$R_S = (5v - 2v) / 10mA$

$R_S = 3 / 10 \times 10^{-3} = 3 / 0.010 =$ 300 ohms



2. If $R_S = 100$ ohms, what is I_F :

$R_S = (V_S - V_F) / I_F$ ***and thus,***

$I_F = (V_S - V_F) / R_S$

$I_F = (5v - 2v) / 100 = 0.030A =$ 30mA

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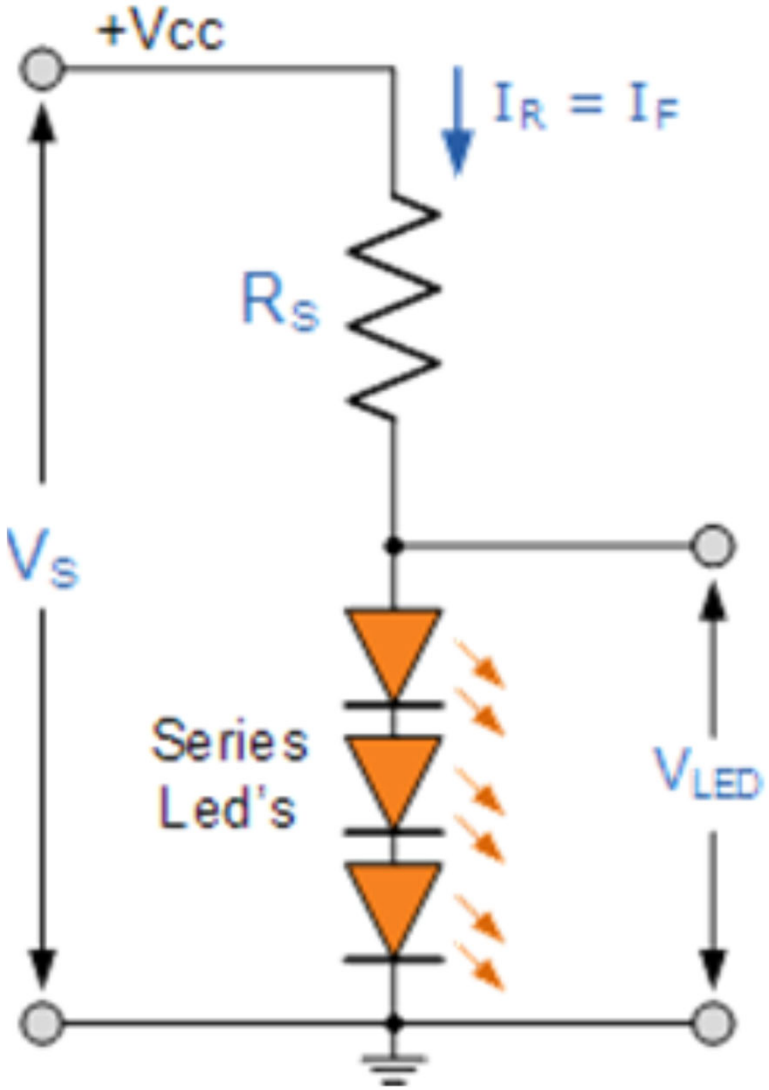
LED Circuit Problems - 2

Now consider a three LED Circuit



Once again, using Ohms Law:

$\mathbf{R_S = (V_S - V_{LED}) / I_F}$

If $V_F = 1.2$ *volts (IR LED)*

then $\mathbf{V_{LED} = [3 \times 1.2v]}$

and therefore

$\mathbf{R_S = (V_S - [3.6]) / I_F}$

If we knew $\mathbf{I_F}$ and $\mathbf{V_S}$

we could calculate $\mathbf{R_S}$

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Basic Electronics

Alternating Current (AC)
Transformers,
Rectifier Bridges,
Filtering and
AC/DC Power Adapters

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DC/AC Basics

When we look at the voltage from a direct current or DC source, like a battery, the 'ideal' voltage output stays constant over time:

When we plug a device into the wall socket, we are connecting it to an Alternating Current power source, specifically one that changes the voltage direction in a *sinusoidal* manner 60 times or 'cycles per second' or 60 Hertz AC:

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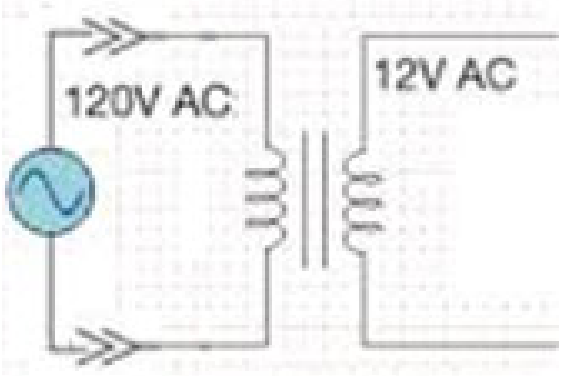
AC and Transformer Basics

A transformer is an electrical component constructed with a Primary and at least one Secondary coil winding usually on an iron core (as shown earlier).



120 VAC Primary:

12 VAC Secondary:

When AC voltages flowing in the Primary winding reverse their polarity they induce an *electromagnetic field* that creates a current in the Secondary winding flowing in the opposite direction – *the Transformer Effect*!

By adjusting the winding ratios a step-up or a step-down of voltage occurs. In our case 120 VAC in becomes about 12 VAC…

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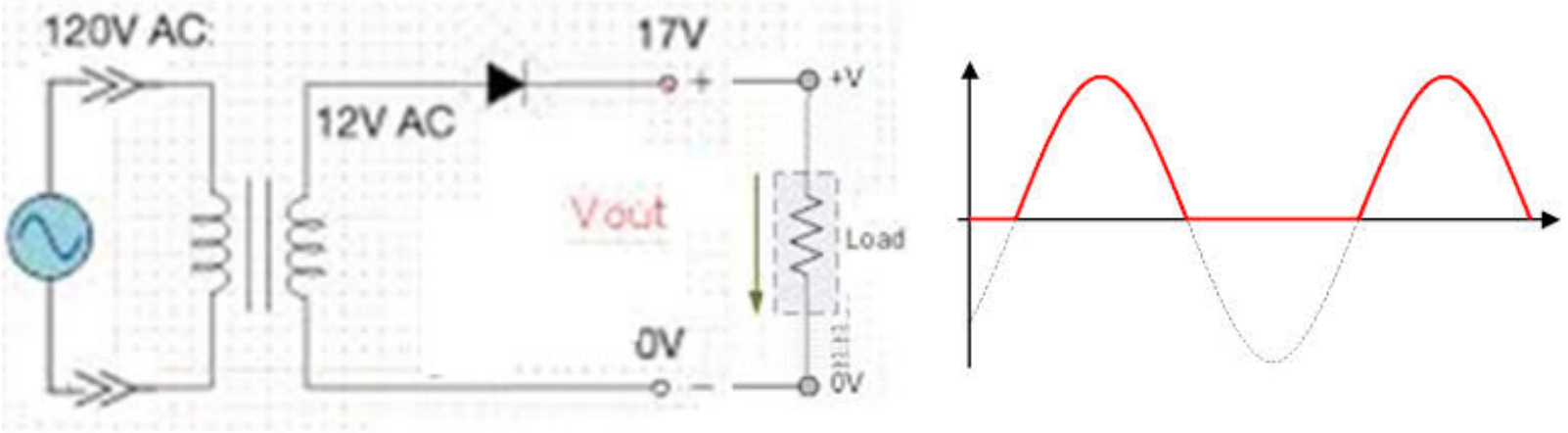
Half Wave Rectifier Basics

Earlier we saw that a device called a diode or rectifier allows current to flow in *ONLY* one direction through it. If we inserted the diode in the transformers secondary circuit such that it blocks the NEGATIVE side of the waveform, we have a circuit that can rectify the AC current into a "*HALF WAVE RECTIFIED*" output:



If we connected the diode to the transformer's 12VAC secondary we would have a voltage of about 16 VAC which we have now 'rectified' somewhat …

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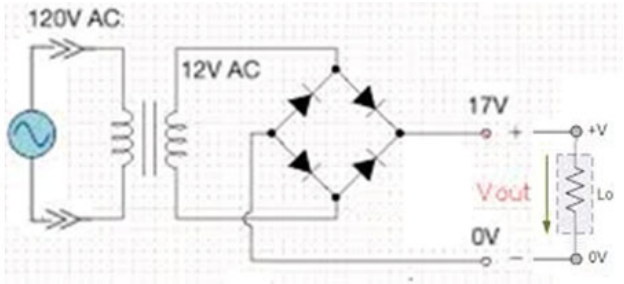
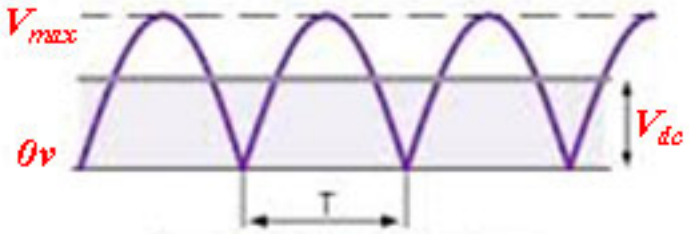
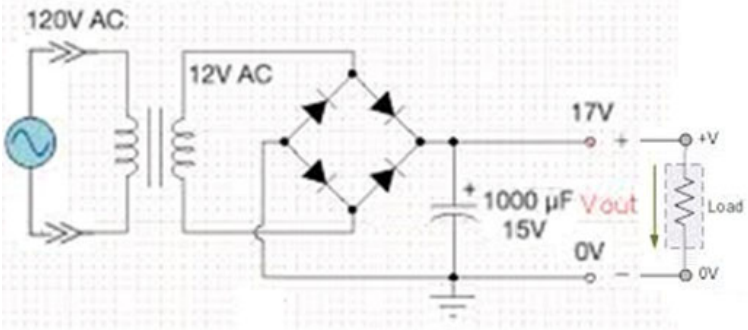
Full Wave Rectification

Using four diodes in a '*full wave bridge*' circuit we can create a more efficient output with the 'negative' side inverted to produce a *FULL WAVE RECTIFIED* output:





We noted that capacitors STORE charge… With very high value capacitors the output becomes smooth or FILTERED resulting in a full wave output that is very much like a direct current waveform with some ripples:



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AC to DC Power Adapters

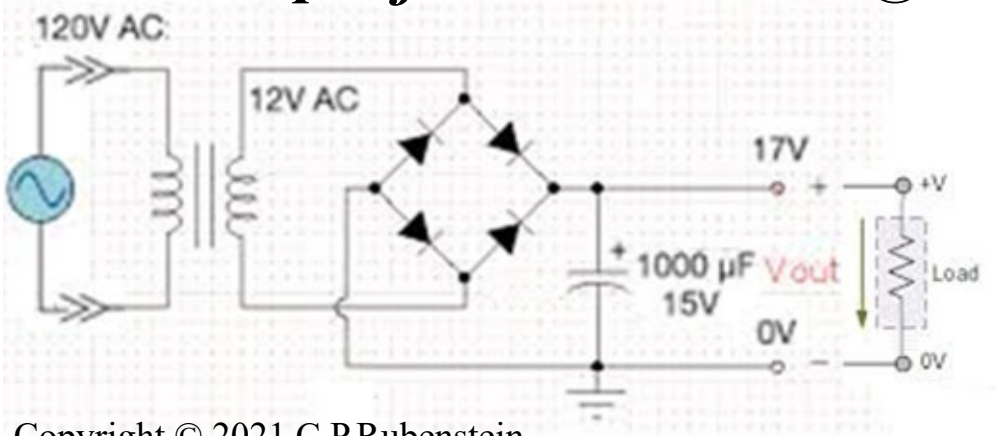
A transformer has an iron core and TWO or more wires wound around that core like an inductor (one is inside the 9V adapter).

The Adapter's primary we use is listed as 120VAC 60Hz 7W input; with a typically 9V @ 150mA – 1 Ampere secondary output.

IF we were to open the adapter's plastic case…

– !!! DO NOT DO THIS !!! –

we would find a power transformer and a circuit board with four 1N4001 rectifier diodes and a 1000 microfarad electrolytic capacitor yielding a 9+ VDC output from this circuit @150mA:



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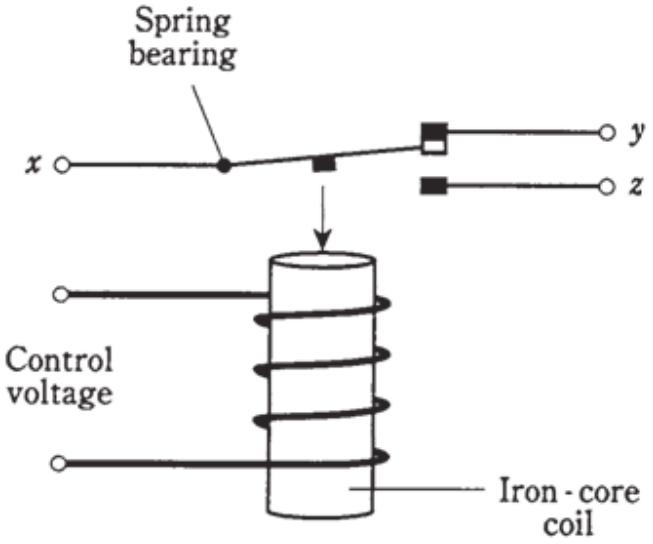
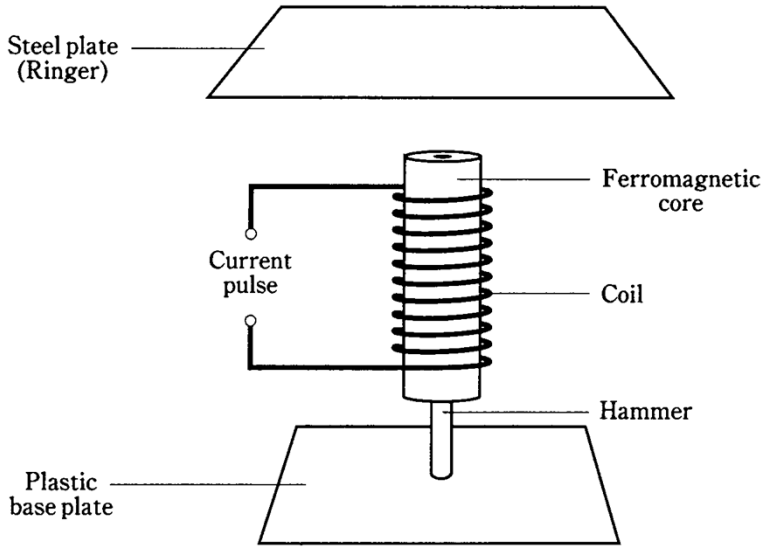
Relays: Electromagnetic Switches

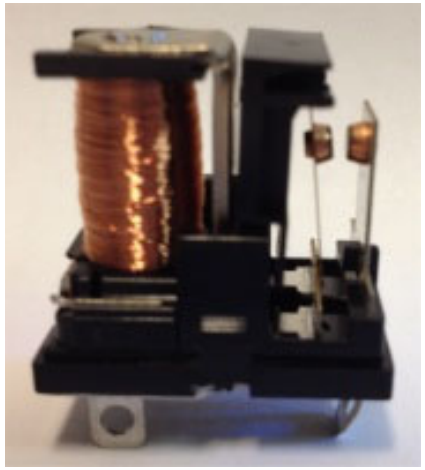
Single Pole, Double Throw (SPDT) RELAY

NC = normally CLOSED; NO = normally OPEN

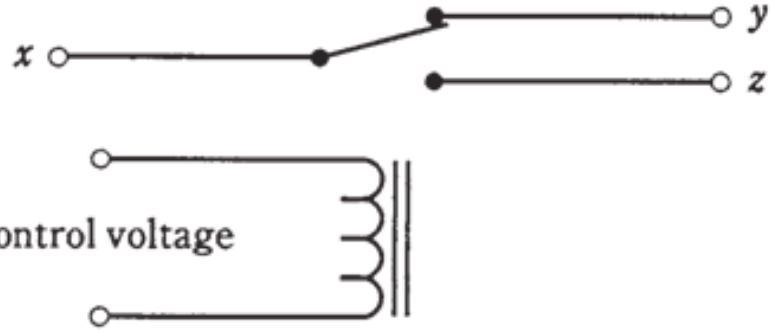
Pictorial *and actual Unit*







Schematic



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Basic Electronics

Example Set 2:
Series/Parallel Resistors, and Power

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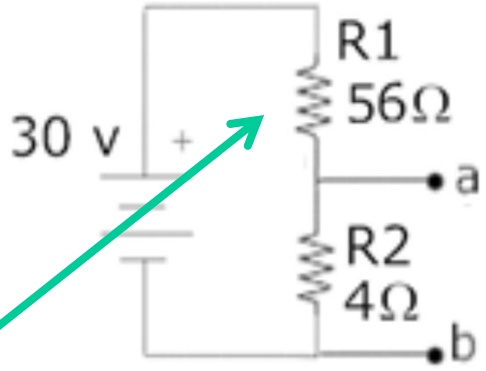
Example 2.1

2.1) Find the voltage from **a** to **b** (across $\mathbf{R_2}$) in Figure 1, *on the right*, using the voltage divider equation.



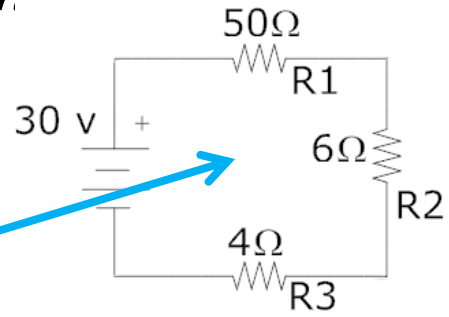
$$\mathbf{V_{R2} = R_2 \bullet (V / [R_t])}$$

$$\mathbf{V_{R2} = 4\ ohms \bullet (\ 30\ volts/\ [56+4]\ ohms)}$$

$$\mathbf{V_{R2} = 4 \bullet (1/2)\ volt\text{-}ohms\ /\ ohms = 2\ Volts}$$

Compare this to Example 1.4 until it is clear to you why the answer to there must be the same as the answer here

Example 1.4 has a 50 ohm and 6 ohm in series with the 4 ohm resistor: 50+6 = 56 ohms !



Thus the circuits are the same with $R_1 + R_2$ of Fig. 4 = R_1 of Fig. 1 above, and R_3 of Fig. 4 = R_2 of Fig. 1

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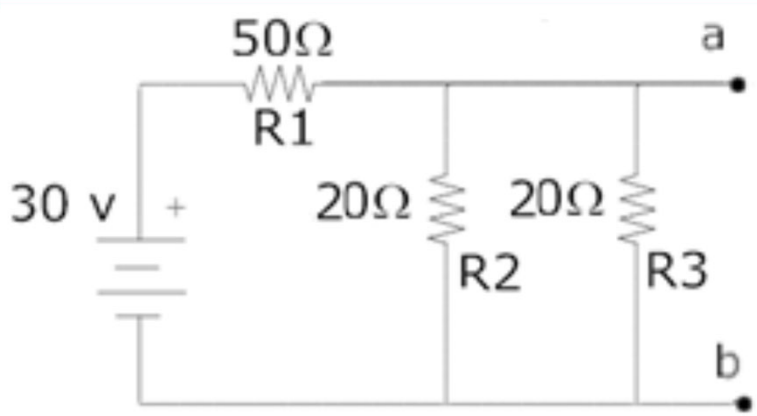
Example 2.2

2.2a) Find the ***current*** leaving the **30V source** in Figure 2, *on the right*.

(Hint-start by combining the two **20 ohm** resistors).



$$R_2 // R_3 = [(R_2 \bullet R_3)/(R_2 + R_3)] = (400/40) = 10 \text{ Ohms}$$

$$R_T = R_1 + [R_2 // R_3] = 50 + 10$$

$$R_T = 60 \text{ Ohms}$$

Using **Ohms Law:**

$$I_t = V / R_t = 30 \text{ volts} / 60 \text{ Ohms} = 0.5A \ (= 500 \text{ mA})$$

2.2b) Now find the voltage from **a** to **b** (across $\mathbf{R_3}$)

$$V_{R3} = I_t \bullet [R_2 // R_3] = 0.5A \bullet 10 \text{ ohms}$$

$$V_{R2} = 5 \text{ Volts}$$

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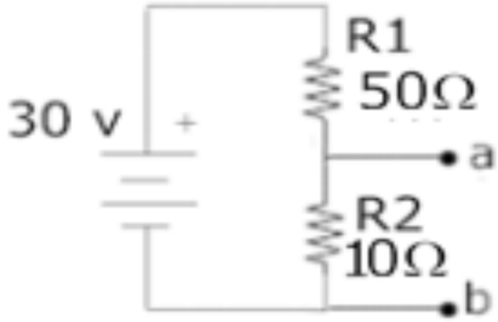
Example 2.3

2.3) Find the voltage from **a** to **b** (across $\mathbf{R_2}$) in Figure 3 using the voltage divider equation.



$$V_{R2} = R_2 \bullet (V/R_t)$$

$$V_{R2} = 10 \text{ ohms} \bullet (30 \text{ volts}/ [50+10] \text{ ohms})$$

$$V_{R2} = 10 \bullet (1/2)$$

$$V_{R2} = 5 \text{ Volts}$$

Then examine & compare Figures 2 and 3 until it is clear to you why the answer to #2b must be the same as the answer to #3.

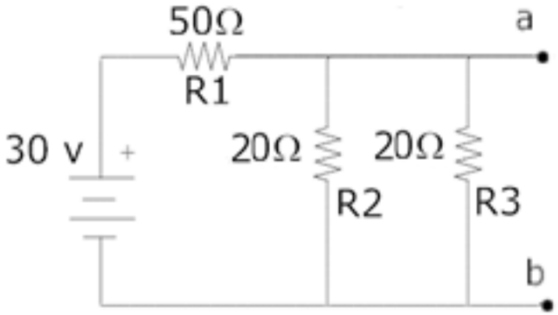


Figure 3 is the same as Figure 4 after we combine the two parallel resistors, $\boldsymbol{R_2}$ and $\boldsymbol{R_3}$.

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Example 2.4

2.4) Find the power dissipated in a **130 ohm** resistor carrying **60mA** (*recall that **1 mA = 0.001 Amp***).

Using the Power Law Formula:

$$P = I^2R$$

$$P = (0.060\ Amps)^2 \times 130\ Ohms$$

$$P = 0.0036 \times 130$$

$$P = 0.468\ Watts\ = 468\ mW$$

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Example 2.5

2.5a) Find the power dissipated in a **100 ohm** resistor carrying **60mA** (*recall that **1 mA = 0.001 Amp***).

$$P = I^2R = (0.060\ Amps)^2 \times 100\ Ohms$$

$$P = 0.0036 \times 100$$

$$P = 0.360\ Watts = 360\ mW$$

2.5b) Is this power level within the ratings of a **1/2 watt** resistor?

(**Yes**, No)

BUT, barely as 50% of power rating = 250 mW, is the preferred maximum value

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About Electronic Devices

Although a primary goal for here is for you to be comfortable using electronic circuits by the end of the course…

NEVER, EVER, EVER

open up an electronic device that is under warrantee!

You will void that warrantee and quite possibly

need to throw the device away if you can not repair it…

Of course, if you do open and damage something electronic,

or if YOU have 'dead' electronic devices …

Please bring them in and we can do some 'dissecting' of them to see what is inside before we throw them out or use them as electronic device examples in future classes.

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Basic Electronics

Lab #01
Measuring Resistance and Voltage

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Parts Needed for Lab Module 1

Meter, Power Sources, Resistors & Lamps

(1) **Digital Multimeter**, *with mini-grabber test leads*

(1) **Jumper Wires**

(1) **Breadboard**

(1) **9V DC Adapter**

(1) **Power Supply Module** *(or Arduino…)*

(4) **1,000 ohms** (***1 kiloOhm or 1KΩ***)

4 Band Code: ***brown-black-red; gold band (5%)***

5 Band Code: ***brown-black-black-brown; brown band (1%)***

Next section shows how to read these color codes…

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Basic Electronics

Lab #01
4-Band and 5-Band Resistor Color Codes

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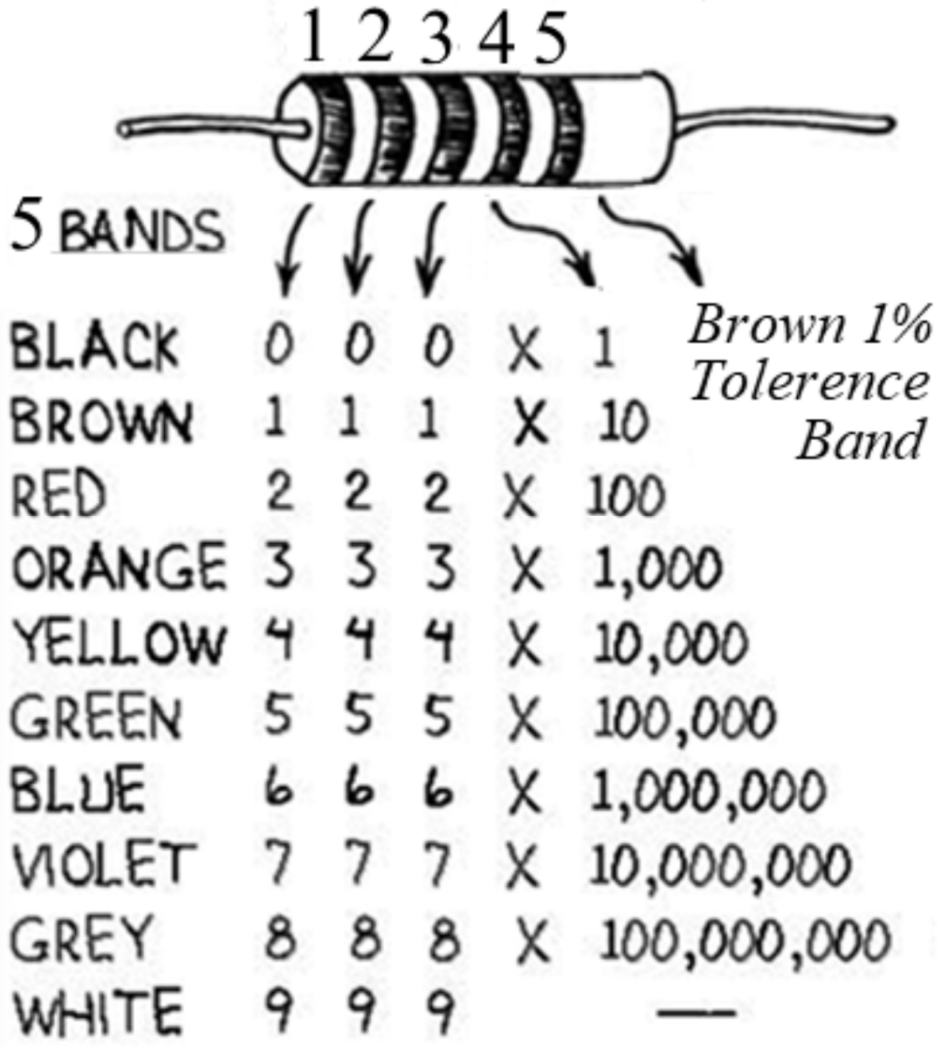
Five Band 1% Color Code



Five-Band

***1%* Resistor**

Color Code

- ***Hold with Band 5 as Brown on right***

(NOTE: GOLD as 4th band = 1/10th)

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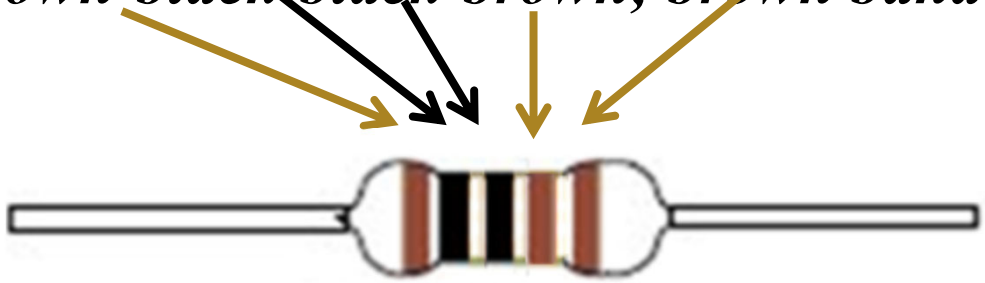
What value is my 5 Band Resistor?

READING COLOR CODES:

With ***BROWN*** **1%** band at your ***right***, we read from

LEFT to RIGHT: **3 numbers and power of ten multiplier**

(***brown-black-black-brown; brown band*** = ***+/- 1%***).



BROWN = 1; BLACK = 0; BLACK = 0; and BROWN = x 10^1

Reads as: 100 x 10^1; and is thus a 1,000 Ohm +/-1% resistor

Note: Some colors (Red, Orange, etc.) may not be easy to 'read'

Other examples:

red-red-black-black-brown: *reads as* ***220 x 10^0*** *or* ***220 Ohms***

brown-black-black-orange-brown *reads as* ***100 x 10^3*** *or* ***100KΩ***

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Five band - 1% Resistor Values

¼ Watt RESISTORS - color code, 1st four digits: ### x $10^{\#}$

10 ohm (brown-black-black-gold-brown : 100G @1%)

100 ohm (brown-black-black-black-brown : 1000 @1%)

220 ohm (red-red-black-black-brown : 2200 @1%)

330 ohm (orange-orange-black-black-brown : 3300 @1%)

1k ohm (brown-black-black-brown-brown : 1001 @1%)

2k ohm (red-black-black-brown-brown : 2001 @1%)

5k1 ohm (green-brown-black-brown-brown : 5101 @1%)

10k ohm (brown-black-black-red-brown : 1002 @1%)

100k ohm (brown-black-black-orange-brown : 1003 @1%)

1M ohm (brown-black-black-yellow-brown : 1004 @1%)

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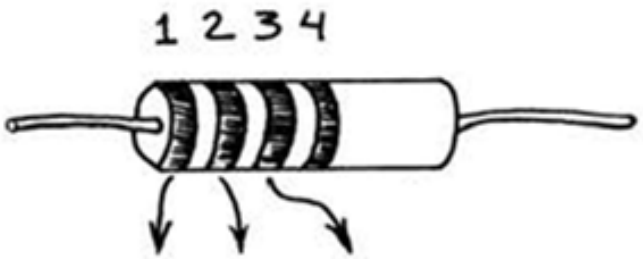
Common Four Band Color Code

1/2-Watt Carbon Film Resistors (±5%)

4 BANDS



BLACK	0	0	X	1
BROWN	1	1	X	10
RED	2	2	X	100
ORANGE	3	3	X	1,000
YELLOW	4	4	X	10,000
GREEN	5	5	X	100,000
BLUE	6	6	X	1,000,000
VIOLET	7	7	X	10,000,000
GREY	8	8	X	100,000,000
WHITE	9	9		—

THE FOURTH BAND GIVES THE TOLERANCE:
GOLD = +/- 5% SILVER = +/- 10%

Four-band

Resistor color code

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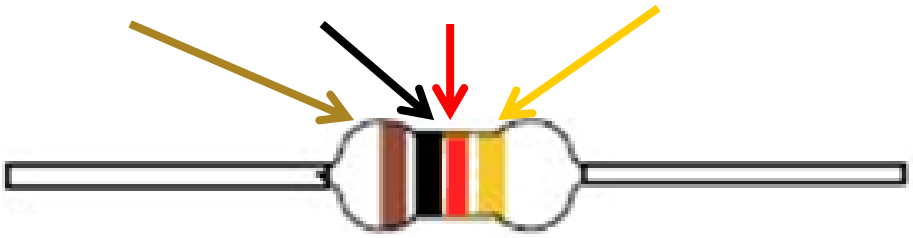
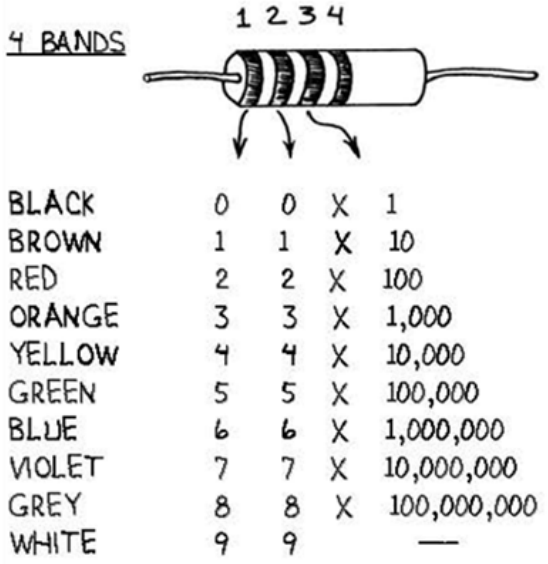
What value is my 4 Band Resistor?

READING COLOR CODES:

With ***GOLD*** **5%** band at your ***right***, we read from ***LEFT to RIGHT***: **2 numbers and power of ten multiplier** (***brown-black-red; gold band = +/- 5%***).





BROWN = 1; BLACK = 0; and RED = x 10^2

Reads as: 10 x 100; and is therefore a 1000 Ohm +/-5% resistor

Note: Some colors (Red, Orange, etc.) may not be easy to 'read'

Other examples:

Yellow-Violet-Red-Gold: *reads as* ***47 x 100*** *or* ***4,700 Ohms***

Brown-Black-Orange-Gold: *reads as* ***10 x 1000*** *or* ***10Kohms***

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Four Band - 5% Resistors

5% Resistors have a fourth *GOLD* band…

RESISTORS - color code, 1st three digits: ## x $10^{\#}$

10 ohm (brown-black-black-gold : 100 @1%)

100 ohm (brown-black-brown-gold : 101 @1%)

220 ohm (red-red-brown-gold : 221 @1%)

330 ohm (orange-orange-brown-gold : 331 @1%)

1k ohm (brown-black-red-gold : 102 @1%)

2k ohm (red-black-red-gold : 202 @1%)

5k1 ohm (green-brown-red-gold : 512 @1%)

10k ohm (brown-black-orange-gold : 103 @1%)

100k ohm (brown-black-yellow-gold : 104 @1%)

1M ohm (brown-black-green-gold : 105 @1%)

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Basic Electronics

Lab #01
Measuring Resistance

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Digital Multimeter

RECOMMENDED:
Harbor Freight
7 Function
Digital Multimeter

Meter is shown in the ON position and set for the 2000 ohms range. With no resistance between leads, we read more than 2000 ohms (infinite resistance) which produces a "1" or "over range" output.
Note: Your meter might look different!

ALWAYS turn your meter off when not in use to conserve the batteries…

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Measuring Resistance

To use a Multimeter as an Ohmmeter

Rotate the knob so that one of the ***resistance ranges (200Ω – 2000KΩ)*** *is selected.*

Here the ***2000Ω (2KΩ) Range*** *is selected.*

Connect the ***BLACK*** *lead to the lower right* ***COM*** *terminal and connect the* ***RED*** *lead to the* ***VΩmA*** *terminal.*

(NOTE: Your meter may look different!)

Turn ON the meter switch if there is one.

*NOTE that the display shows "****1****" - this indicates that with nothing connected to the meter, the resistance between the leads is greater than 2000Ω. (NOTE: Your meter may show* ***OL*** *!)*

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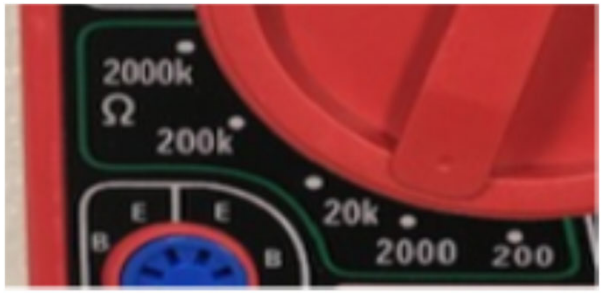
Lab Module 1 –1a

MEASURING THE RESISTANCE OF A RESISTOR



Using the resistance (**ohms**) function on your multimeter - select the **2000Ω** or **2kΩ** range (*or equivalent scales*) to measure the resistance of a **1000 ohms = 1K Ω** resistor (*there are at least ten (10) in the kit*).

We use the meter range that is ***just a bit greater than the result we expect***…

Holding the GOLD band of a 5%, ***4-band***, resistor to the right, and reading from LEFT to RIGHT it is marked

brown-black-red-gold

*If you have a **5-band 1% resistor** it will be coded:*

brown-black-black-brown-brown

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Lab Module 1 –1a

MEASURING THE RESISTANCE OF A RESISTOR

*Using the resistance (ohms) function on your multimeter - select the **2000Ω** range…*

Connect the meter to the resistor using the mini-grabber leads as shown →

NOTES:

1. The Tack digital multimeter here has a 6KΩ range.

*2. Our **resistors are not polarized** so it doesn't matter which lead connects to which end of the resistor!*

3. The meter reading might be in Ohms or KiloOhms as noted here!

If your 5% resistor result is less than 950 Ω or greater than 1050 Ω, or your 1% resistor result is less than 990 Ω or greater than 1010 Ω, CONSULT YOUR INSTRUCTOR!

1.a) What resistance value do you get? _____ ohms

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Basic Electronics

Lab #01
Using the
Solderless Breadboard

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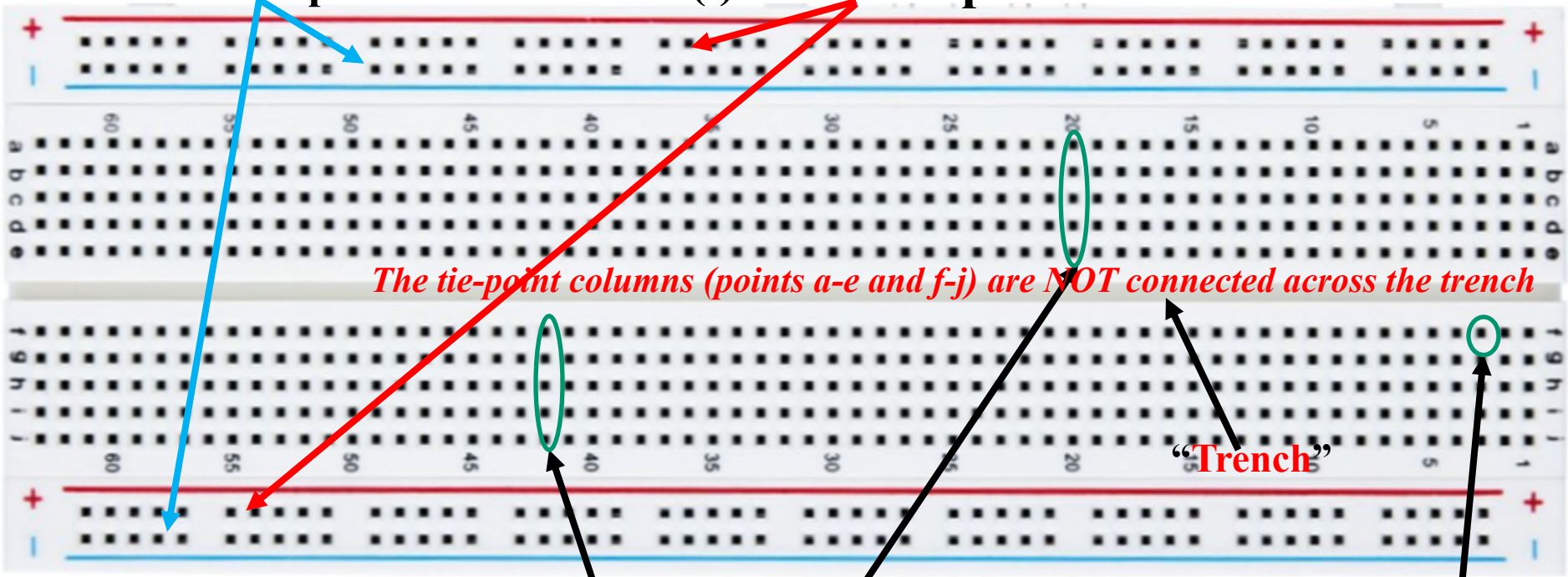
Solderless Breadboard Connections

Connections on a Solderless '830 tie-point' Breadboard

Power tie-points connected across 50 points on top ***or*** *bottom:*

Connect **Blue points** to **GROUND (-)** *and* **Red points** to **+5 volts**



Vertical Columns *numbered* ***1 – 63*** *have two sets of five (5) connected tie-points*

Tie-points **f, g, h, i, and j : f42-j42** are *connected together, and*

Tie-points **a, b, c, d, and e : a20-e20** are *connected together*

Note: Your board might have A, B, C, etc.

*This particular tie-point is "**f 3**"*

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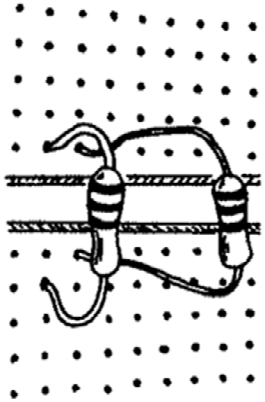
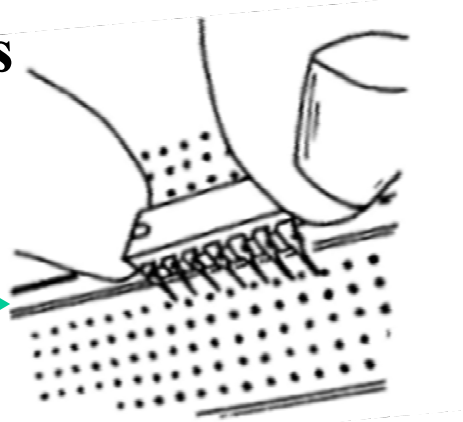
Inserting Components into the Breadboard

Insert ALL Resistors, Capacitors, Diodes, LEDs and ICs

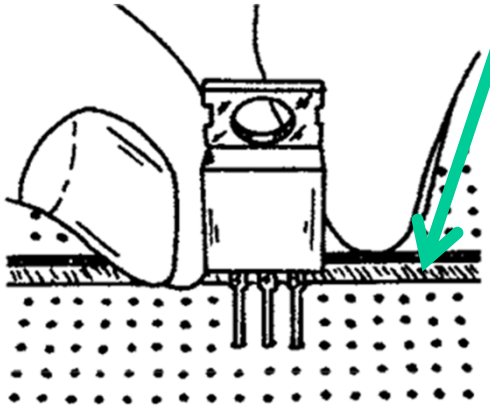


across **the trench**



And/or insert Transistors, LEDs, Diodes, *etc.*

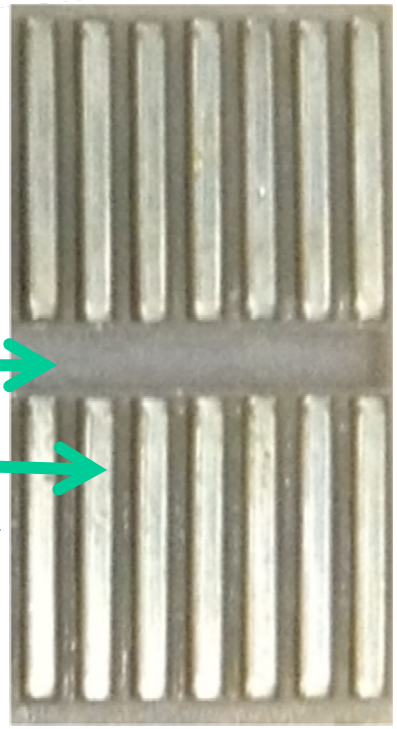
parallel **to the trench**



Trench

and **5 tie-point connections**

seen from underside of breadboard



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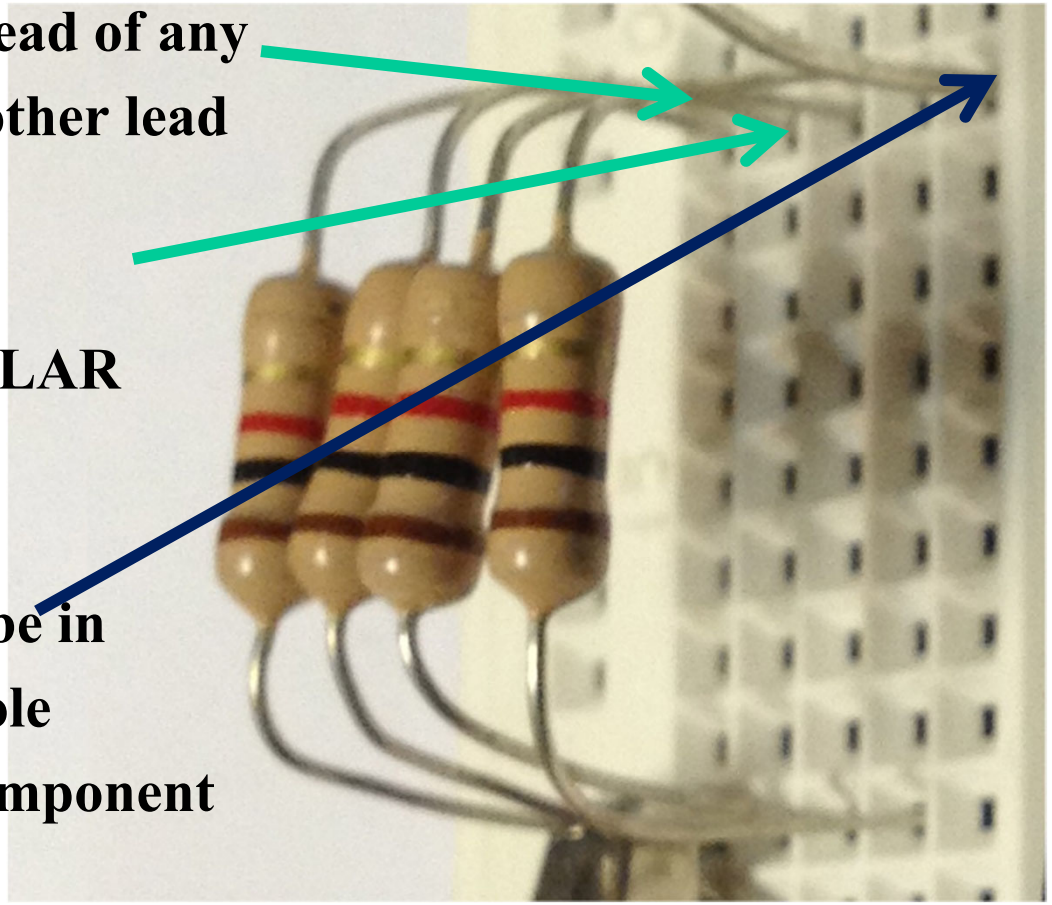
Creating a Circuit on the Breadboard

When inserting several **1K** Resistors ***in parallel*** on the breadboard:
Remember the five holes in each row are connected.

These four 1K Resistors are connected in parallel by inserting one lead of any resistor in any row and the other lead in another row.



Rows are all PERPENDICULAR to the trench.

All four resistor leads must be in the same row, leaving one hole empty for a wire or other component to be inserted.

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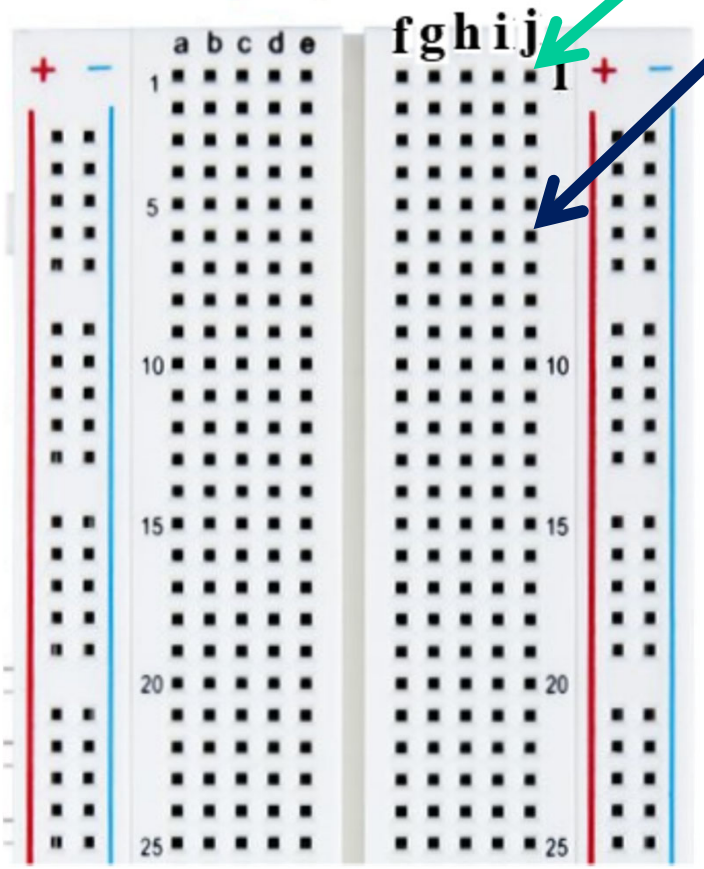
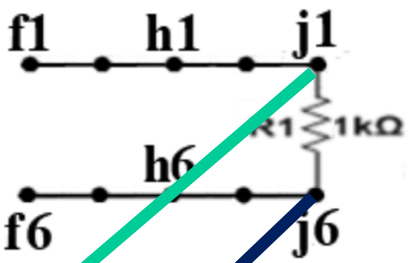
Inserting Resistors on the Breadboard

We will be plugging a voltage regulator module into the bottom of the breadboard, so we will use the tie-points at the top of the board for this portion of the lab.

Insert the first **1K** resistor on the Breadboard between tie-points **j1** and **j6**.

Remember the five holes in each row across are connected, thus, ***f1*** *through* ***j1*** *and* ***f6*** *through* ***j6*** *are all 'shorted' together...*





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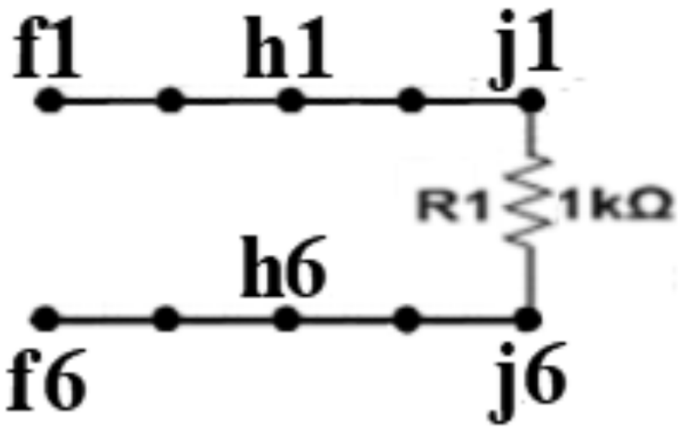
Lab Module 1 –1b

MEASURING THE RESISTANCE OF A RESISTOR

Insert the 1000 ohm resistor just measured

into the Console Breadboard into tie-point connections **j1** and **j6**

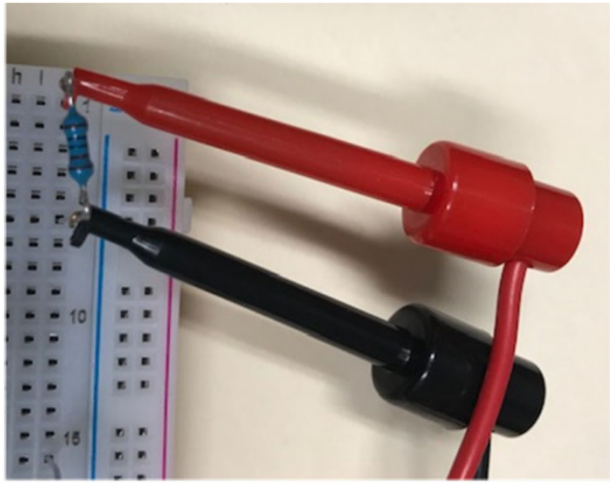


1b.) Repeat your resistance measurement (j1 to j6)

_____ Ohms

Did you read the same value as in 1a?

YES ____ or NO ____ ?



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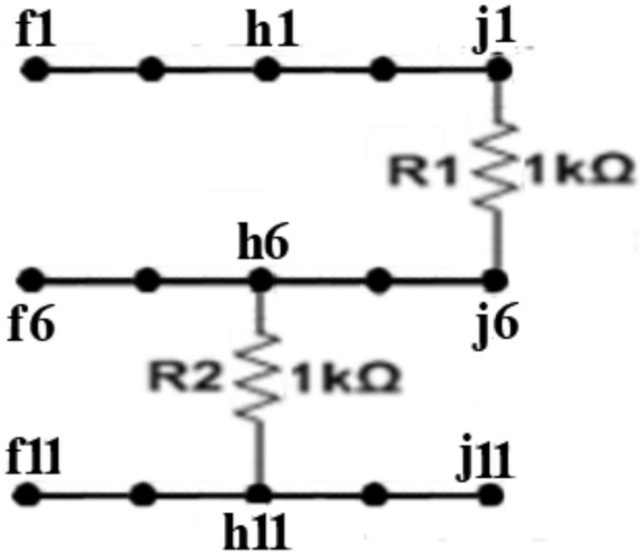
Lab Module 1 –1c

THE RESISTANCE OF TWO RESISTORS IN SERIES

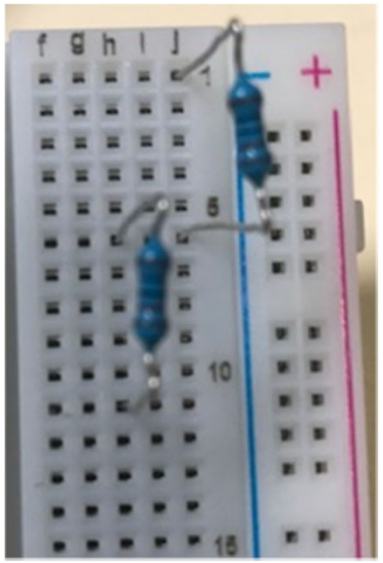
Now insert a second 1000 ohm resistor into the Breadboard into tie point connections **h6** and **h11**



1c.) Resistance of two 1KΩ resistors, in series is: _____ ohms

If the resistance is not nearly 2000 ohms;

Consult your instructor



NOTE: We should be using the '20K' ohm scale and the results should be:

5% resistors: between 1.95 and 2.050 = 1950-2050 ohms

1% resistors: between 1.98 and 2.020 = 1980-2020 ohms

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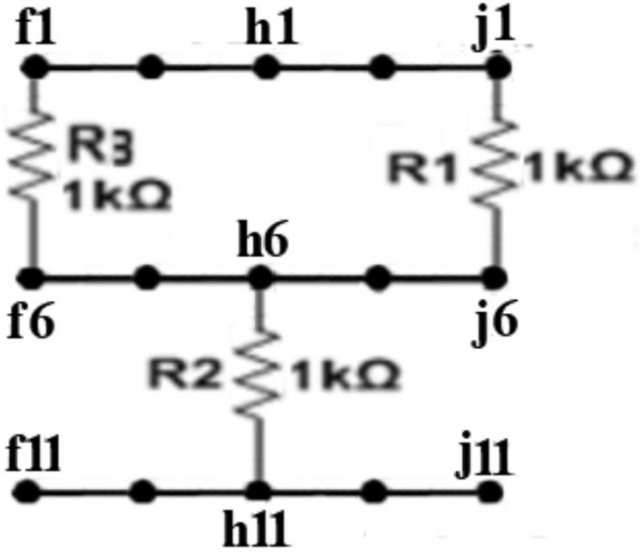
Lab Module 1 –1d

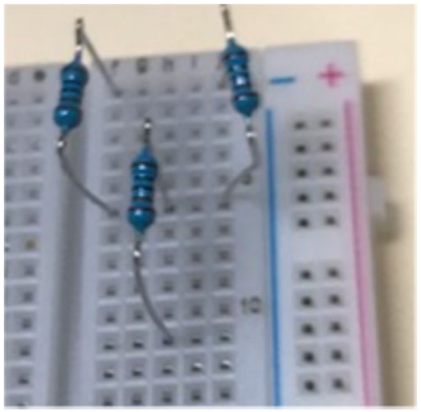
THE RESISTANCE OF TWO RESISTORS IN PARALLEL

Without removing the current two resistor circuit, insert a third 1000 ohm resistor into the Console Breadboard into connections **f1** and **f6.**



This yields two resistors in parallel between the f1-j1 and the f6-j6 rows

1d.) Use the '2000' ohm scale to measure the resistance of two 1KΩ resistors in parallel: _____ ohms



BE CAREFUL!

*Measure only the parallel resistors by ONLY measuring the resistor between **j1** and **j6***

If the resistance is not nearly 500 ohms;

Consult your instructor

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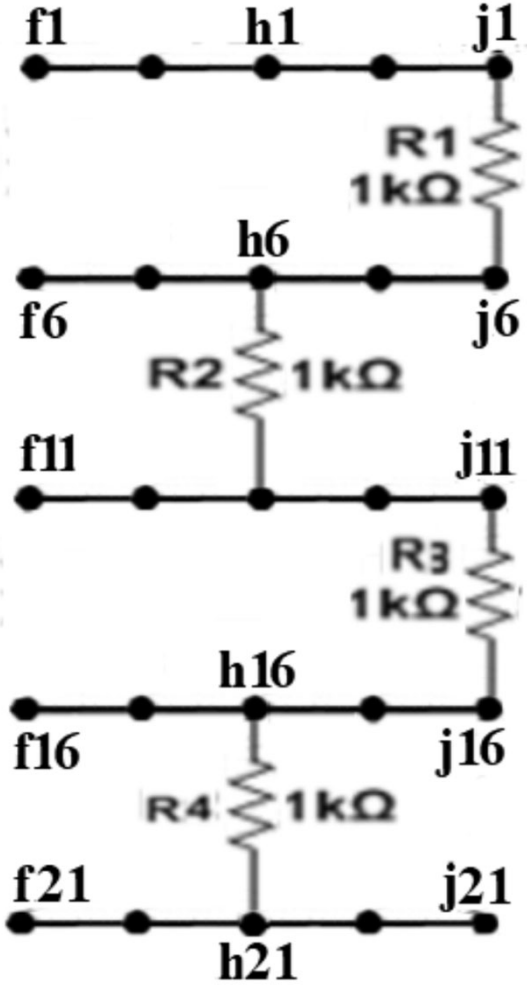
Lab Module 1 –1e

THE RESISTANCE OF FOUR RESISTORS IN SERIES

Remove the parallel resistor between **f1** and **f6** and *insert it in tie points* **j11** and **j16**.

Now insert a fourth 1000 ohm resistor into the Console Breadboard connections **h16** and **h21**

This yields four resistors in series between the f1 – j1 and the f21 – j21 rows



1e.) Resistance of four 1KΩ resistors in series

_____ **ohms**

If the resistance is not nearly 4000 ohms on the 20K scale; ***Consult your instructor***

This is Instructor Check Point 1A

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Questions?

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Basic Electronics

Lab #01

Measuring Voltage

Arduino Board Version

(Use if your kit did NOT contain a Power Supply Module
The Power Supply Module Version follows…)

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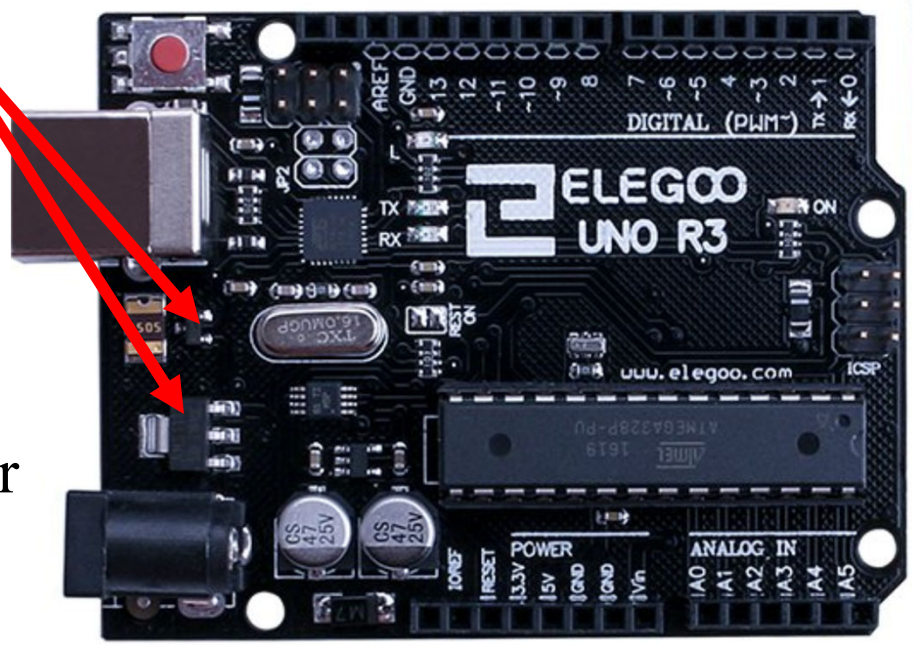
Regulated Power Supply

There are several ways to provide a regulated source of DC power our circuits. We will show here how to use the Arduino Uno R3 board as a regulated power supply to provide **regulated +5 volts** (as well as 3.3 volt) power.

The Arduino has a pair of regulator ICs *on the board* used to reduce the DC adapter input voltage or to regulate the USB power from your computer.

The Arduino can therefore be used as a low current source of regulated +5 volt *as well as regulated 3.3 volt* power for other circuits and components.



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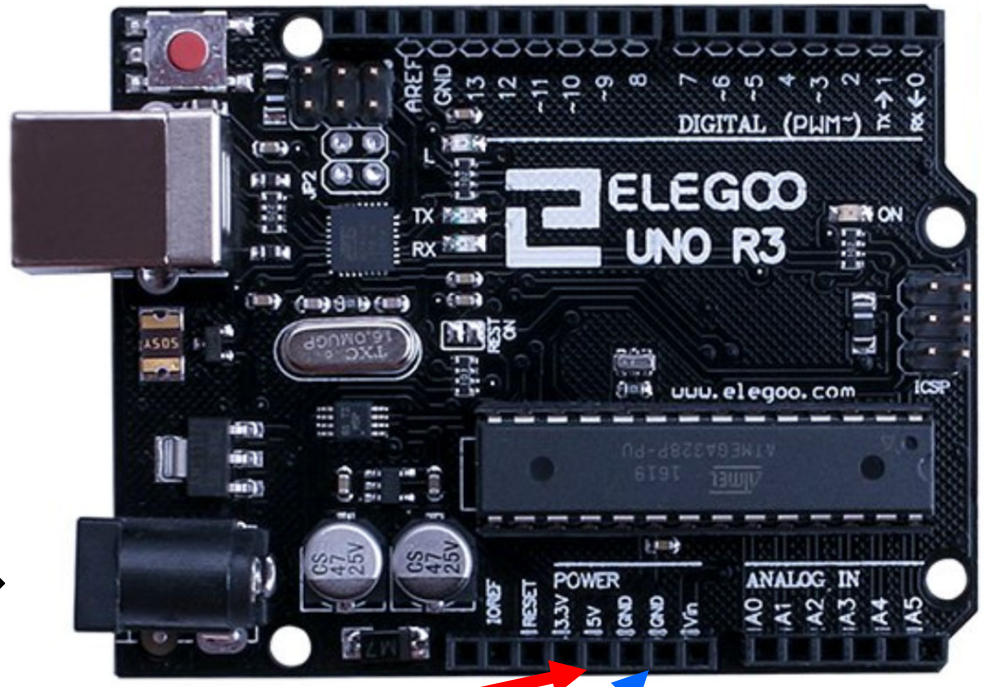
Power From the Arduino

If we connect a **9 volt Adapter (or the USB cable connected to your computer)** to the Arduino Board we can then connect a **RED (+5)** and **BLACK (Ground)** wire from the board to our breadboard without needing a Power Supply Module.

USB cable →

9 volt Adapter →



The Arduino provides a "+5V" and a "GND" connection.

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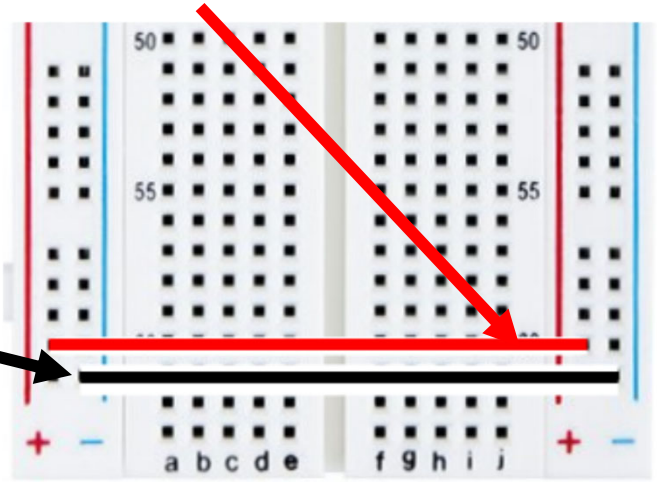
Powering The Breadboard

1. Use a **RED** jumper wire to connect the **RED** lines at the bottom of the breadboard on both sides as shown.



2. Repeat this for power ground using **BLACK** jumper wires connected to the **BLUE** power lines.

3. Use a second (*LONG*) **RED** jumper to connect one of the **RED** power lines to the "**+5V**" tie point on the Arduino Board.

4. Use a second (*LONG*) **BLACK** jumper to connect one of the **BLUE** power lines to the "**GND**" tie point on the Arduino Board. *(See next slide)*

Now **+5** and **GND** are available on either side of the Board.

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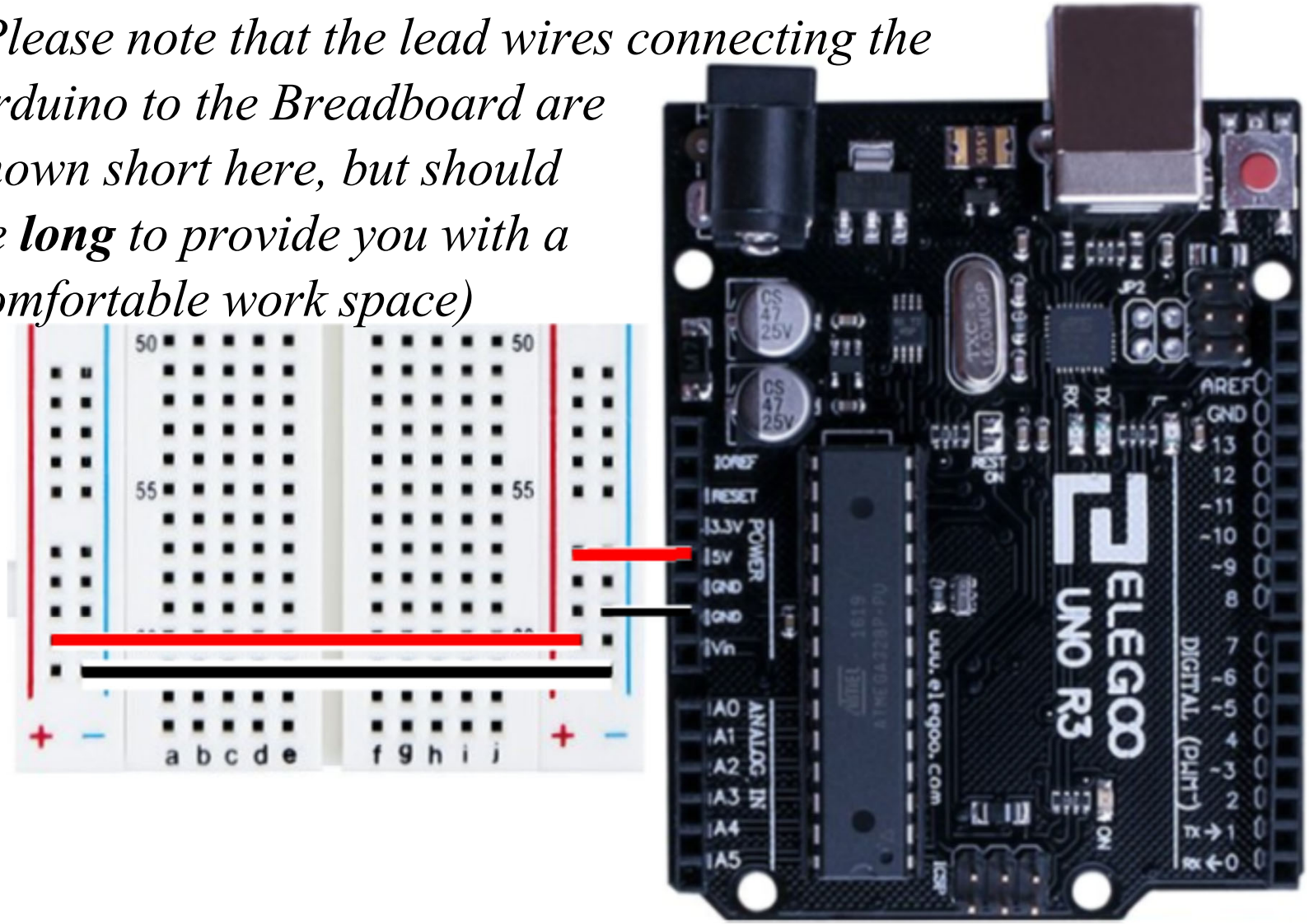
Power from the Arduino

Arduino UNO providing +5 volts to Breadboard

*(Please note that the lead wires connecting the Arduino to the Breadboard are shown short here, but should be **long** to provide you with a comfortable work space)*



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Basic Electronics

Lab #01

Measuring Voltage

(Power Supply Module Version)

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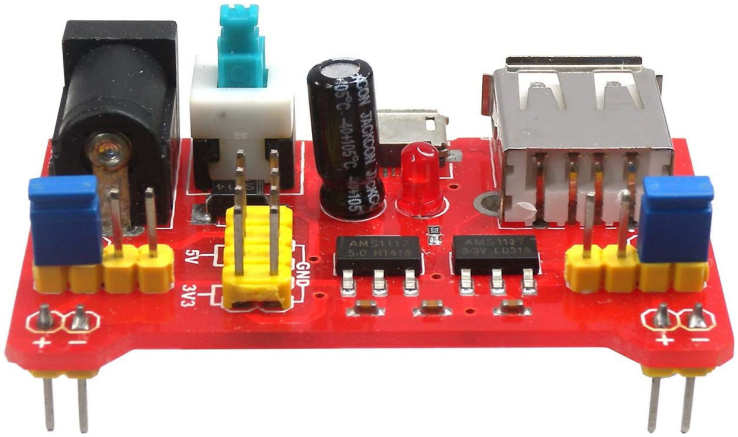
Power Supply Module

As noted previously, there are several ways to power our circuits.

If we are already using the Arduino Uno R3 board, we can connect a **RED (+5)** and **BLACK (Ground)** wire from the Arduino board to our breadboard.

If we are using the **9VDC Power Adapter** we need to reduce the **+9** volts down to a regulated **+5** volts.

*We could design a circuit around the **7805** Voltage Regulator to do this, but the advanced Arduino kits have a "**Power Supply Module**" which we can use to provide either **+5 v, +3.3 v, or Both**!*



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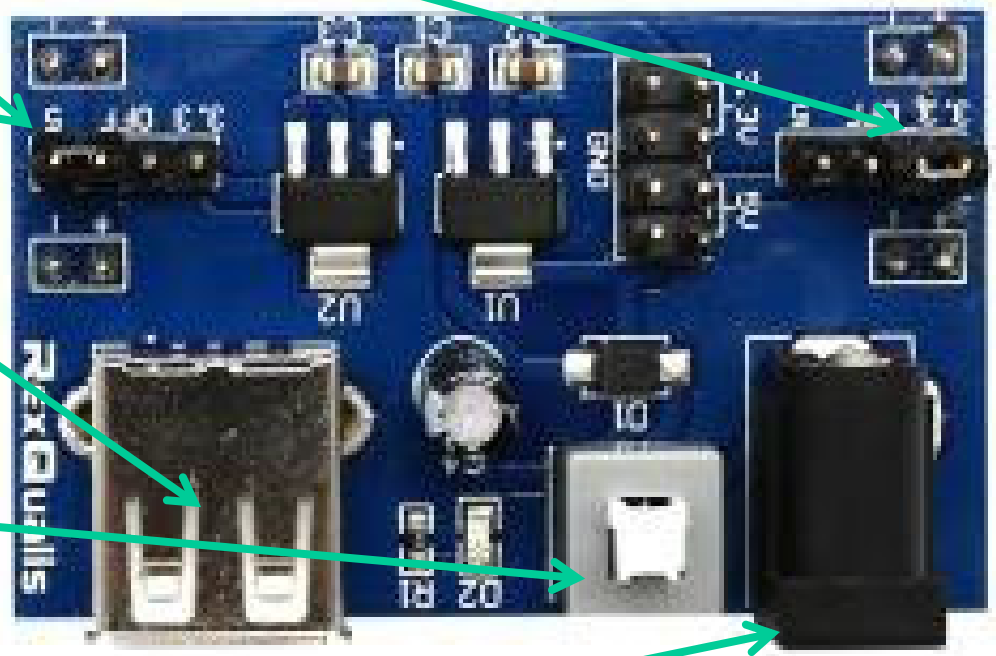
Powering The Breadboard

The Power Supply Module – that plugs into the bottom of the breadboard – normally has the jumpers set for

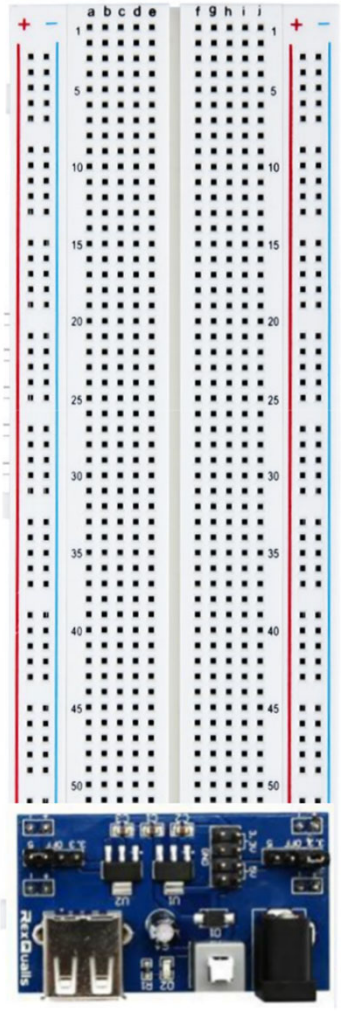
+5 volts and +3.3 volts.



It has a USB port,

An ON/OFF switch

and the 9volt Adapter Input



Plug it into the Breadboard *bottom* as shown here

With *a51* through *j51* tie points with line 51 visible.

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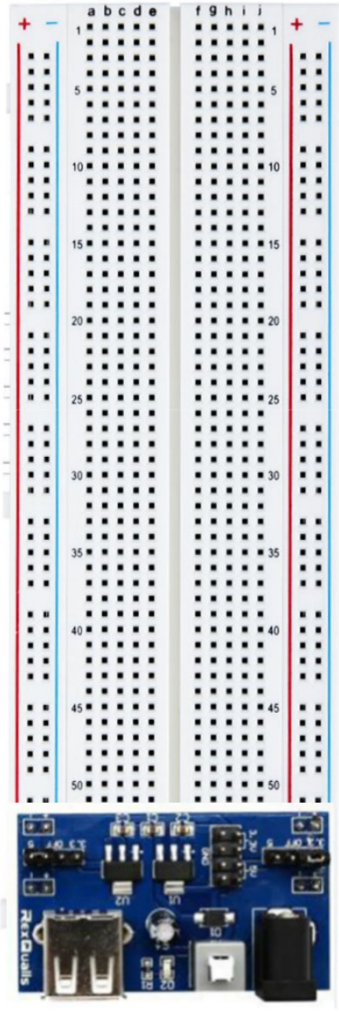
+5 Volts for the Breadboard

The Power Supply Module normally has the right hand jumper set for +3.3 volts. We can move that jumper to the left to make BOTH power outputs +5 volts.



Plug the 9volt Adapter into the Power Supply Module and continue with the voltage measurement portion of this lab.

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Measuring DC Voltage

To use the Multimeter as an DC Voltmeter

Rotate the knob so that one of the
DC voltage ranges (200m – 250) *are selected.*
Please select the ***20 volt Range****.*

There is no need to remove the RED and BLACK mini-grabber leads as they are where they need to be to measure voltage.
Turn ***ON*** *the meter and* ***NOTE that the display shows 0.00***
This indicates that with nothing connected to the meter, the voltage is 0.00 volts.

In this mode,
If the display shows "1 ." it means that the voltage being measured exceeds 20.00 volts*.*
(As noted previously, turn the unit OFF when not in use to conserve battery power.)

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Lab Module 1 – Part 1f

Measuring The +5 volt Power Module Output.

Plug the AC Adapter into the Power Module.

Using the DC volts function on your Multimeter

select the "**20**" range *(your meter might look different):*

Turn **ON** the Module's power by pressing the button

to the left of the power connector – *jumper on +5v!*

Plug a **RED** jumper wire into one of the **RED** tie-point sets on the right or the left of the breadboard, and a **BLACK** jumper wire into one of the **BLUE** tie-point sets.

Connect the meter leads to those jumpers

1f. What is the UNLOADED voltage on the breadboard?

_____ **volts**

If your result is more than 6 volts or less than 4 volts: Consult your instructor

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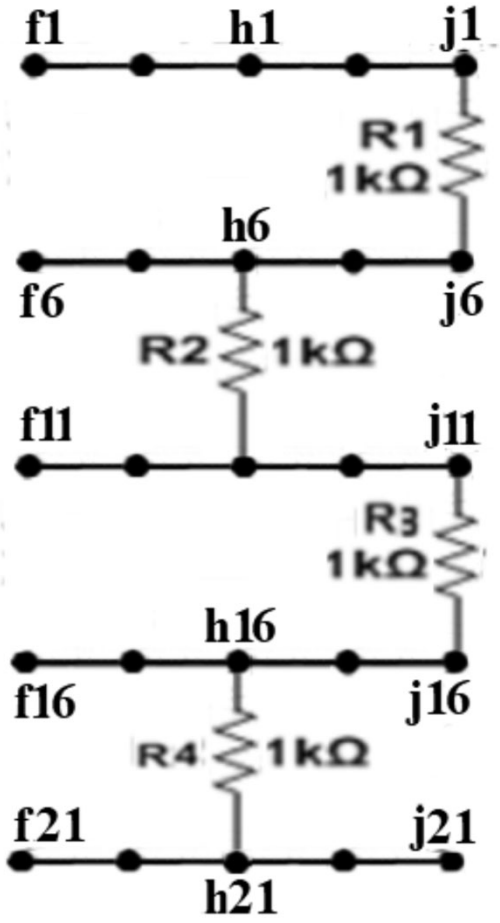
Lab Module 1 –1g-j

VOLTAGE DROPS ACROSS FOUR RESISTORS IN SERIES

1. Press the power module switch to turn OFF power.
2. Connect a **RED** jumper wire from the **RED** side **power tie-points** to the resistor network at **h1**
3. Connect a **BLACK** lead from the **BLUE** side **power tie-points** to the resistor network at **f21**
4. Turn the switch **ON** and connect the meter to the network – e.g., try leads at tie-points **j1** and **h21**. There should be ***+5 volts*** across the ***4,000 ohm*** network. This is called the *loaded voltage*.



1g. What is the LOADED voltage on the network?

_____ **volts**

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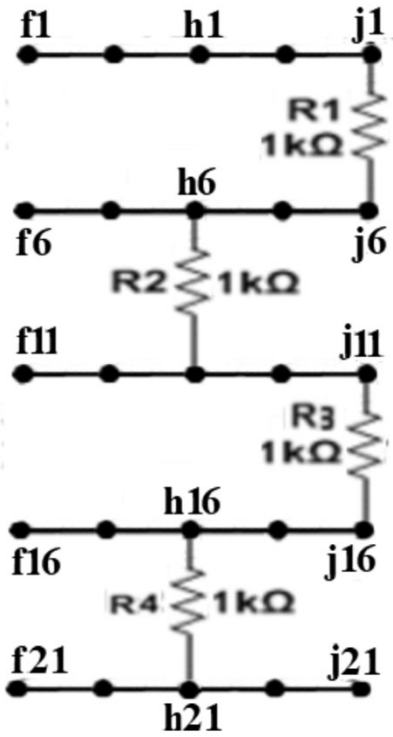
Lab Module 1 –1h

RESISTOR VOLTAGE DIVIDER PROOF

Referring to the Figure at the right, measure the voltage Drop across each resistor with the lead placed as noted:



1h1.) V_{R1}**: j1** to **j6**: _____ **volts**

1h2.) V_{R2}**: h6** to **h11**: _____ **volts**

1h3.) V_{R3}**: j11** to **j16**: _____ **volts**

1h4.) V_{R4}**: h16** to **h21**: _____ **volts**

NOTE: *The voltage drops should be nearly the same!*

1h5.) Does adding the four ***individual*** voltage drops **1h1** though **1h4** equal the same voltage you found in the four resistor load circuit of **1g** when measuring from **j1** to **h21**? **Yes __ or No __?**

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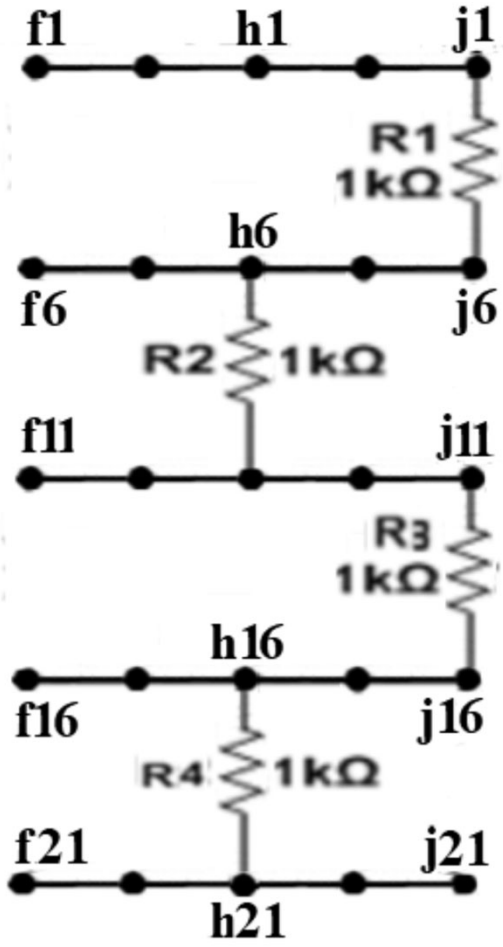
Lab Module 1 -1i, -1j and -1k

VOLTAGE DROPS ACROSS FOUR RESISTORS IN SERIES

Referring to the Figure at the right, measure the Power Module output voltage with the **RED** lead at **j1** for the circuit indicated connecting **BLACK** or **GROUND** as noted:



Reduce the resistor load by shorting out one or more resistors with a jumper wire as indicated:

1i.) A **"three series 1KΩ resistor - 3000Ω load"**

Jumper from f21 to f16: _____ volts

1j.) A **"two series 1KΩ resistor - 2000Ω load"**

Jumper from f21 to f11: _____ volts

1k.) A **"1KΩ resistor - 1000Ω load"**

Jumper from f21 to f6: _____ volts

NOTE: *The loaded values should all be less than volts of the unloaded value*

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Questions?

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Next Week: Session #03

DUE: Sensor Research Paper Proposal

DUE: Lab #01: Measuring Resistance and Voltage

Lecture: Displays and Light-emitting Diode (LED) Devices; signals, sensors, transducers and output devices; Microcontrollers; Installing the IDE and examples.

Readings: **Vilros** *(VILROS Ultimate Starter Kit Guide; vilros.pdf); Elegoo and Lavfin "manuals and tutorials"*

Hands-On: Lab #02:

Vilros Circuit 1: Blinking a LED; Vilros Circuit 2: Potentiometer

Requires Arduino UNO R3 Advanced Starter Kit or Equivalent

For Session 4:

DUE: Lab #02 Circuit 1Blinking a LED & Circuit 2: Potentiometer

Lecture: Coding and examples.

Readings: **Vilros** *(Basic Arduino Projects in VILROS Ultimate Starter Kit Guide; vilros.pdf)*

Hands-On: Lab #03:Circuit 3: RGB LED and Circuit 4: Multiple LEDs

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Any Questions?

Please send me an email
Include the slide number and question(s)

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End

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