SIERRA COLLEGE	MECH 10 - Lab 09 Batteries	Mechatronics Real Skills Real Jobs

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Date: October 6, 2019
Professor Steven Gillette

Abstract
In this lab, I experimented with lemon juice and dry cell battery phenomenon by leveraging zinc and copper plates in lemon juice. I placed two of the batteries in series and in parallel and observed voltage and current present both open and with resistor loads. I additionally leveraged dry cell batteries and conducted similar experiments.

Learning Objectives

- Build a wet cell battery from dissimilar metals and electrolyte
- Connect batteries in voltage adding and current adding configuration
- Measure electrical values using a digital voltmeter
- Calculate battery current and power capacity under various loads

Notes:

1. Took all voltage measurements relative to ground (unless otherwise stated)
2. Recorded relevant measurements and calculation results in data tables
3. Recorded all measured values on the circuit schematics
4. Used all available precision in calculations, rounded off answers to 3 significant figures

Materials

Quantity	**Wet Cell**
2	copper plates
2	zinc plates
2	plastic cups
2	doubled sided stickers
2	paper clip leads, black, solid core wire
2	paper clip leads, red, solid core wire
1	alligator clip jumpers
1 each	resistors, 10K, 6.8K, 5.2K, 2.4K, 1K
	lemon juice or coffee
Quantity	**Dry Cell Voltage Adding**
2	1.5V dry-cell batteries in battery clip
3	alligator clip jumpers
1 each	Resistors – 5.2kΩ, 2.4kΩ, 1kΩ, 510Ω, 240Ω & 150Ω, 68Ω
Quantity	**Dry Cell Current Adding**
2	1.5V dry-cell batteries in battery clip
4	alligator clip jumpers
1 each	Resistors -820Ω, 510Ω, 240Ω, 150Ω, 100Ω & 47Ω, 10Ω (1/2 Watt)

Tools

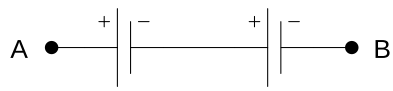
Quantity	**Description**
1	DMM

Procedure –Wet Cell Voltage Adding

1. Built two wet cells from copper and zinc plates and lemon juice electrolyte. Made sure the paperclips leads were not immersed in the electrolyte.
2. ***Measured & recorded*** the voltage from each cell. Recorded which pole is positive (copper or zinc).

Cell 1 = 0.992V Cell 2 = 0.962V The Copper pole appeared to be the positive pole.

3. Connected the cells in series (voltage adding). Two or more cells connected together are a battery.



VOLTAGE ADDING

4. ***Measured & recorded*** the battery open circuit voltage and compared to the theoretical maximum (1.28V x 2) using the % Error formula.

Test #	Resistance (Ohms)	Battery Voltage
1	open circuit	1.913

$$\% \, Error = \frac{1.913V - (0.992V + 0.962V)}{(0.992V + 0.962V)} \, x \, 100$$

$$\% \, Error = \frac{1.913V - 1.954V}{1.954V} \, x \, 100$$

$$\% \, Error = \frac{0.041V}{1.954V} \, x \, 100$$

$$\% \, Error = \frac{-0.041V}{1.954V} \, x \, 100$$

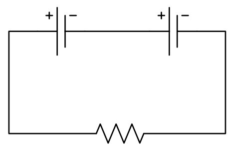
$$\% \, Error = -0.021 \, x \, 100$$

$$\% \, Error = 2.1\%$$

5. ***Measured and recorded*** the resistance of a nominal 10K resistor

Test #	Resistance (Ohms)
2	10.02E+03

6. Completed the battery circuit by adding approximately 10kΩ load resistance.



VOLTAGE ADDING

7. ***Measured and recorded*** the battery voltage.

Test #	Battery Voltage
2	0.714

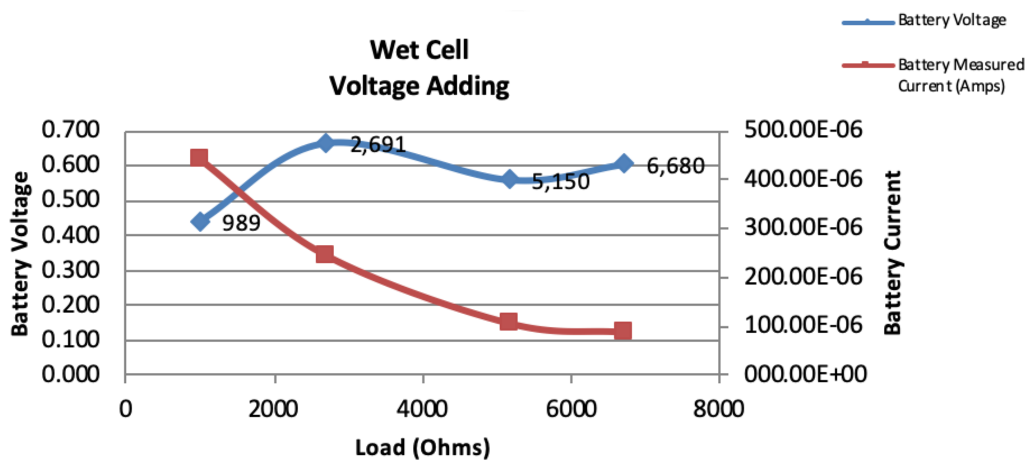
8. ***Calculated and recorded*** the battery current using Ohm's Law and the resistor measured value. Used measured resistance values for all current calculations.

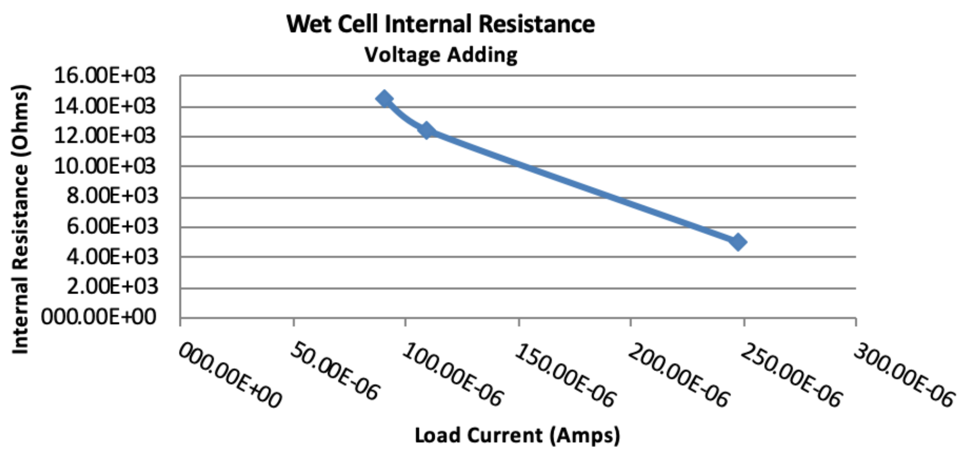
Test #	Battery Measured Current (Amps)
2	71.26E-06

9. ***Measured, calculated and recorded*** battery voltages and currents for load resistances of approximately 6.8KΩ, 5.2kΩ, 2.5kΩ, & 1kΩ.

Test #	Resistance (Ohms)	Battery Voltage	Battery Measured Current (Amps)
3	6.68E+03	0.604	90.42E-06
4	5.15E+03	0.560	108.74E-06
5	2.69E+03	0.666	247.49E-06
6	989.00E+00	0.440	444.89E-06

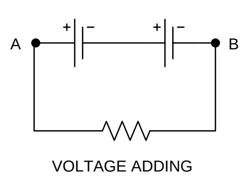
10. Created a line plot showing battery voltage and current versus load resistance.





Procedure –Dry Cell Voltage Adding

11. Connected two dry-cell batteries in voltage adding configuration.



12. ***Measured and recorded*** the open circuit battery voltage.

Test #	Resistance (Ohms)	Battery Voltage
1	open circuit	3.088

13. Completed the circuit by adding approximately 5kΩ of load resistance.

14. ***Measured and recorded*** the battery voltage.

Test #	Resistance (Ohms)	Battery Voltage
2	5.15E+03	3.035

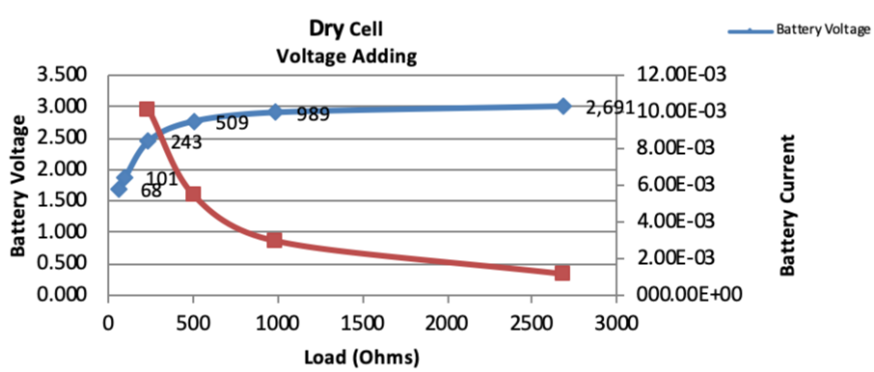
15. ***Calculated and recorded*** battery current using Ohm's Law and measured resistor values. Used measured resistance values for all current calculations.

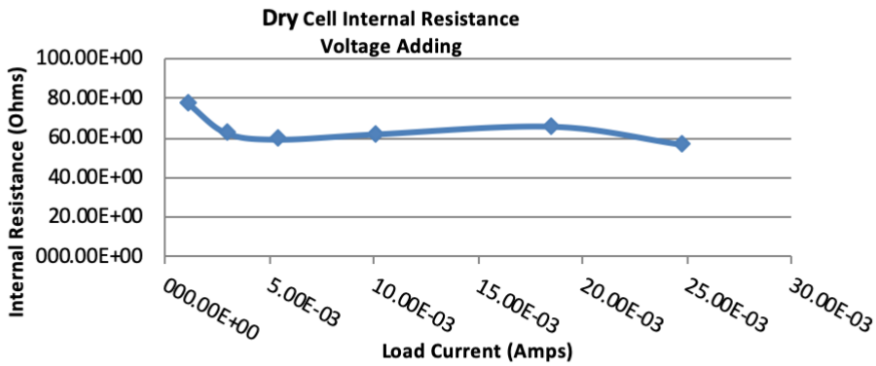
Test #	Battery Measured Current (Amps)
2	589.32E-06

16. ***Measured, calculated and recorded*** battery voltages and currents for load resistances of approximately 2.4kΩ, 1kΩ, 510Ω, 240Ω & 110Ω, 67Ω.

Test #	Resistance (Ohms)	Battery Voltage	Battery Measured Current (Amps)
3	2.69E+03	3.002	1.12E-03
4	989.00E+00	2.904	2.94E-03
5	509.00E+00	2.765	5.43E-03
6	243.00E+00	2.460	10.12E-03
7	101.00E+00	1.870	18.51E-03
8	68.00E+00	1.680	24.71E-03

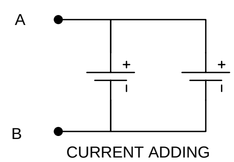
17. Created a line plot with two Y-axes showing voltage and current versus load resistance.





Procedure –Dry Cell Current Adding

18. Connected two dry-cell batteries in current adding configuration.



19. ***Measured and recorded*** the open circuit battery voltage.

Test #	Resistance (Ohms)	Battery Voltage
1	open circuit	1.555

20. Completed the circuit by adding approximately 820Ω of load resistance.
21. ***Measured and recorded*** the battery voltage.

Test #	Resistance (Ohms)	Battery Voltage
2	829.000E+00	1.551

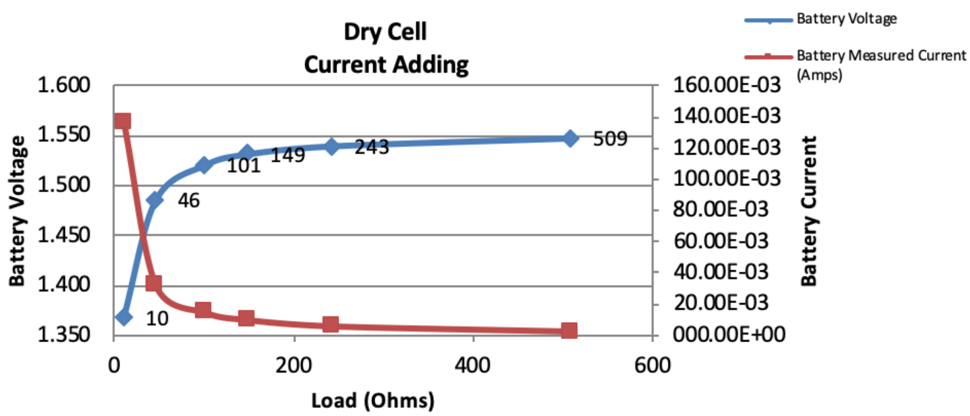
22. ***Calculated and recorded*** battery current using Ohm's Law and measured resistor values. Use measured resistance values for all current calculations.

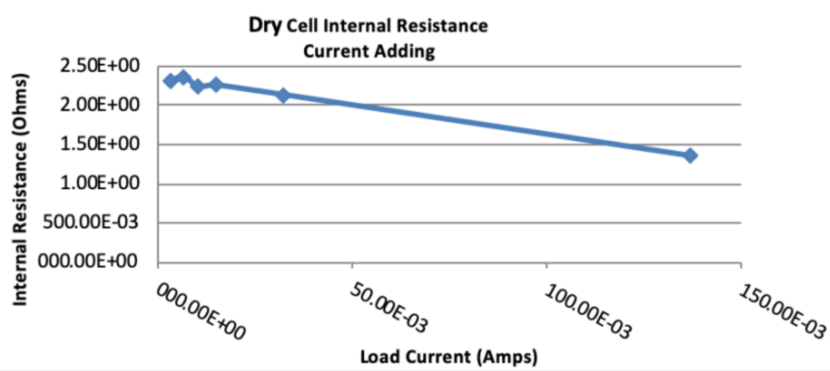
Test #	Battery Measured Current (Amps)
2	1.87E-03

23. ***Measured, calculated and recorded*** battery voltages and load currents for load resistances of approximately 510Ω, 270Ω, 150Ω, 100Ω & 47Ω, 10Ω (1/2 Watt)

Test #	Resistance (Ohms)	Battery Voltage	Battery Measured Current (Amps)
3	509.000E+00	1.548	3.04E-03
4	243.000E+00	1.540	6.34E-03
5	149.000E+00	1.532	10.28E-03
6	101.000E+00	1.521	15.06E-03
7	46.000E+00	1.486	32.30E-03
8	10.000E+00	1.368	136.80E-03

24. Created a line plot with two Y-axes showing voltage and current versus load resistance.





Formulas

% Error

$$\%Error = \frac{measured - \exp ected}{\exp ected} x100\%$$

Where;
%Error = % change between measured and expected values
measured = a value taken from direct measurement
expected = a value taken from component or process specifications

Cell Internal Resistance

$$R_{CI} = \frac{V_{NL} - V_{FL}}{I_{FL}}$$

Where;
R_{CI} = cell internal resistance (Ohms)
V_{NL} = no load voltage
V_{FL} = full load voltage
I_{FL} = full load current

Critical Thinking

1. **Wet Cell Voltage Adding**– using your line plots as reference, does increased circuit current cause an increase or decrease in battery voltage?

In the wet cell voltage adding circuit, an increased current was observed to cause a decrease in battery voltage.

2. **Dry Cell** – using your line plot as a reference, which battery configuration provides the "stiffest" (the most stable) voltage output at higher current levels; current adding or voltage adding?

The most stable voltage output at higher current was observed in the voltage adding circuit.

3. **Dry Cell** – Does cell internal resistance increase or decrease with load?

In the dry cell circuit, cell internal resistance was observed to decrease with an increase in load current.

Appendix A – Lab Notes

SIERRA COLLEGE	MECH 10 - Lab 09 Batteries	Mechatronics Real Skills Real Jobs
Name Cayce Graves		9/26/19

Learning Objectives

- Build a wet cell battery from dissimilar metals and electrolyte
- Connect batteries in voltage adding and current adding configuration
- Measure electrical values using a digital voltmeter
- Calculate battery current and power capacity under various loads

Notes:

1. Take all voltage measurements relative to ground (unless otherwise stated)
2. Record relevant measurements and calculation results in data tables
3. Record all measured values on the circuit schematics
4. Use all available precision in calculations, round off answers to 3 significant figures

Materials

Quantity	Wet Cell
2	copper plates
2	zinc plates
2	plastic cups
2	doubled sided stickers
2	paper clip leads, black, solid core wire
2	paper clip leads, red, solid core wire
1	alligator clip jumpers 5.1k 2.7k
1 each	resistors, ~~10K~~, ~~6.8K~~, ~~5.2K~~, ~~2.4K~~, ~~1K~~
	lemon juice or coffee
Quantity	**Dry Cell Voltage Adding**
2	1.5V dry-cell batteries in battery clip
3	alligator clip jumpers 2.7k
1 each	Resistors – ~~5.2kΩ~~, ~~2.4kΩ~~, ~~1kΩ~~, ~~510Ω~~, ~~240Ω~~ & 150Ω, 68Ω
Quantity	**Dry Cell Current Adding**
2	1.5V dry-cell batteries in battery clip
4	alligator clip jumpers
1 each	Resistors ~~820Ω~~, ~~510Ω~~, ~~240Ω~~, 150Ω, 100Ω & ~~47Ω~~, ~~10Ω~~ (1/2 Watt)

Tools

Quantity	Description
1	DMM

Procedure –Wet Cell Voltage Adding

1. Build two wet cells from copper and zinc plates and lemon juice electrolyte. Make sure the paperclips leads are not immersed in the electrolyte.
2. ***Measure & record*** the voltage from each cell. Record which pole is positive (copper or zinc).

C1 .992 ✓

C2 .962

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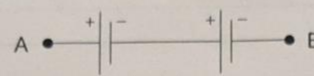
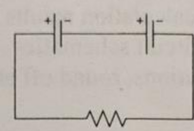
3. Connect the cells in series (voltage adding). Two or more cells connected together are a battery.



1.913V

VOLTAGE ADDING

4. ***Measure & record*** the battery open circuit voltage and compare to the theoretical maximum (1.28V x 2) using the % Error formula.
5. ***Measure and record*** the resistance of a nominal 10K resistor 10.02kΩ
6. Complete the battery circuit by adding approximately 10kΩ load resistance.

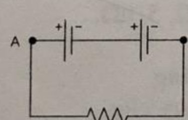


VOLTAGE ADDING

7. ***Measure and record*** the battery voltage. .714V
8. ***Calculate and record*** the battery current using Ohm's Law and the resistor measured value. Use measured resistance values for all current calculations. (see MECH 10 Lab Spreadsheet) 6.8 = .604V ✓ 5.2 = .560V ✓
9. ***Measure/calculate and record*** battery voltages and currents for load resistances of approximately 6.8KΩ, 5.2kΩ, 2.5kΩ, & 1kΩ. 2.7 = .666V ✓
10. Create a scatter plot showing battery voltage and current versus load resistance (see MECH 10 Lab Spreadsheet) 1k = .440V ✓

Procedure –Dry Cell Voltage Adding

11. Connect two dry-cell batteries in voltage adding configuration.



VOLTAGE ADDING

12. ***Measure and record*** the open circuit battery voltage. 3.088V ✓
13. Complete the circuit by adding approximately 5kΩ of load resistance. 3.035V
14. ***Measure and record*** the battery voltage.
15. ***Calculate and record*** battery current using Ohm's Law and measured resistor values. Use measured resistance values for all current calculations.
16. ***Measure/calculate and record*** battery voltages and currents for load resistances of approximately 2.4kΩ, 1kΩ, 510Ω, 240Ω & 110Ω, 67Ω. (see MECH 10 Lab Spreadsheet)
17. Create a scatter plot with two Y-axes showing voltage and current versus load resistance. (see MECH 10 Lab Spreadsheet)

2.7k = 3.002
1k = 2.904
510Ω = 2.765
240Ω = 2.460
110Ω = 1.870
68Ω = 1.680

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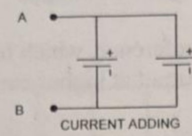
Procedure –Dry Cell Current Adding

18. Connect two dry-cell batteries in current adding configuration.



19. ***Measure and record*** the open circuit battery voltage. 1.555
20. Complete the circuit by adding approximately 820Ω of load resistance.
21. ***Measure and record*** the battery voltage. 1.551
22. ***Calculate and record*** battery current using Ohm's Law and measured resistor values. Use measured resistance values for all current calculations.
23. ***Measure/calculate and record*** battery voltages and load currents for load resistances of approximately 510Ω, 270Ω, 150Ω, 100Ω & 47Ω, 10Ω (1/2 Watt) (see MECH 10 Lab Spreadsheet)
24. Create a scatter plot with two Y-axes showing voltage and current versus load resistance. (see MECH 10 Lab Spreadsheet)

510 = 1.548
240 = 1.54
150 = 1.532
100 = 1.521
47 = 1.486
10Ω = 1.363

Formulas

% Error

$$\%Error = \frac{measured - expected}{expected} x100\%$$

Where;
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1. **Wet Cell Voltage Adding**– using your scatter plots as reference, does increased circuit current cause an increase or decrease in battery voltage?

2. **Dry Cell** – using your scatter plot as a reference, which battery configuration provides the "stiffest" (the most stable) voltage output at higher current levels; current adding or voltage adding?

3. **Dry Cell** – Does cell internal resistance increase or decrease with load? Current

Grading Criteria

		Points Possible	Points Earned
Documentation	Abstract, introduction, experiment, data results, conclusions, attachments, clarity, spelling, grammar	**10**	
Wet Cell	Voltage data points accurate and recorded in data table	**5**	
	Voltage and load resistance data shown on scatter plot	**5**	
Dry Cell Voltage Adding	Voltage and current data points accurate and recorded in data table & scatter plot	**10**	
Dry Cell Current Adding	Voltage and current data points accurate and recorded in data table & scatter plot	**10**	
Critical Thinking	Questions answered completely & accurately. State conclusions drawn and lessons learned from the lab	**10**	
On-time submittal	Lab report is submitted in accordance with the assignment due date as posted on Canvas	**5**	
	Total	**55**	

Lab Report Format

Abstract - a summary and high-level overview of the lab and its results
Introduction - State the objectives of the laboratory and list the equipment required
Experiment - Describe the procedure used to carry out the lab
Results Data - list data taken in table or graphical format where appropriate
Critical Thinking - State the conclusions drawn and lessons learned from the laboratory activities. Answer any questions found within the lab procedure.
Attachments – grading criteria, verification signatures, circuit diagrams, lab procedures & notes

Grading Criteria

		Points Possible	Points Earned
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	Voltage and load resistance data shown on scatter plot	**5**	
Dry Cell Voltage Adding	Voltage and current data points accurate and recorded in data table & scatter plot	**10**	
Dry Cell Current Adding	Voltage and current data points accurate and recorded in data table & scatter plot	**10**	
Critical Thinking	Questions answered completely & accurately. State conclusions drawn and lessons learned from the lab	**10**	
On-time submittal	Lab report is submitted in accordance with the assignment due date as posted on Canvas	**5**	
	Total	**55**	

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