EE 1701/1703

Climate Crisis: Implementing Solutions

David Maiden Mueller
PhD Researcher
maide002@umn.edu

College of Science & Engineering
University of Minnesota

EE 1701 / 1703 Climate Crisis: Implementing Solutions

Introductory course for both EE majors and non-majors, providing an overview of:

- electrical generation
- energy storage
- electrical distribution
- electrical applications

The accompanying lab provides hands-on experience with the fundamentals of DC electricity, exploring solar and wind generation, battery storage, and applications of electrical energy through LEDs and motors.

https://mohan.umn.edu/ee1701

EE 1701 / 1703 Climate Crisis: Implementing Solutions

Course Content:

- Climate Change: Causes, Contributors, Consequences
- Electricity as a Solution to Combat Climate Change
- Energy from Conventional Fossil Fuel Sources
- Nuclear Power
- Hydroelectric Power
- Wind Power
- Solar Power
- Residential/Rooftop Solar and Community Solar Gardens
- Electric Power Distribution
- Energy Storage
- Electrifying Transportation
- Energy Conservation

Lab Content:

- Indoor Hydroponic Farming (with LEDs)
- Greenhouse Effect due to CO_2
- Simulating Electrical Fundamentals
- Internal Resistance of a Battery
- Photovoltaic Cells: iV Curve and MPP
- Photovoltaic Panels in Series and Parallel
- Economics of Rooftop Solar
- Economics of Community Solar Gardens
- Resistive and Electronic Dimming
- DC Motors
- Wind Turbines: iV Curve and MPP

U of MN College in Schools Program

Capturing students’ interest early is critical to increasing the number who consider electrical engineering when selecting their path after graduation.

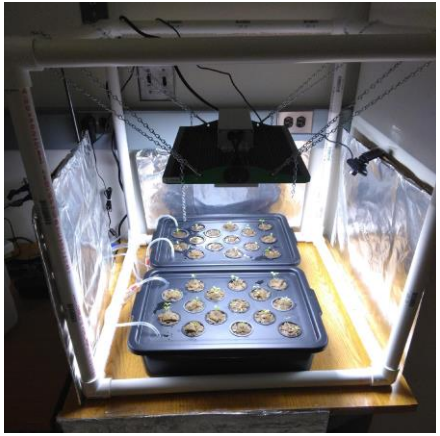
EE 1701 / 1703 are available to students at Minnesota high schools through the University of Minnesota’s college-in-schools (CIS) program.

Past and present participants include:

> Avalon School, Harding High School, Minnetonka High School, Richfield High School, Twin Cities Academy

Ensuring that a more diverse population of students (race, gender, economic background) are exposed to electrical engineering leads to a more diverse, and thus more equitable, electrical engineering workforce.

EE 1703 Indoor Hydroponic Farming



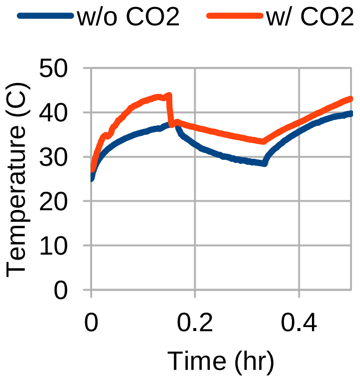
Summary

- Students grow lettuce indoors using deep-water hydroponics
- Electricity, water, and nutrient usage are tracked
- Recurring labor hours (monitoring and replenishment of nutrient solution, pruning, adjustment of the light) are tracked

Learning Objectives

- Demonstrate how plants can be grown indoors with LED lighting
- Investigate the cost components of growing produce and determine which one(s) are the primary drivers of the price

EE 1703 Greenhouse Effect due to CO_2



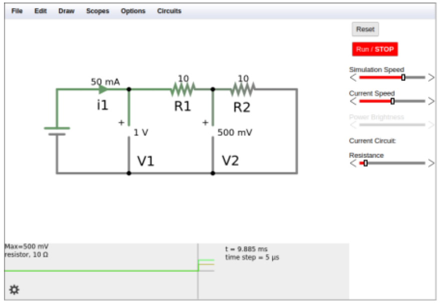
Summary

- Students measure temperature in a bowl sealed with saran wrap
- Incandescent lamps used to add heat to the system
- Reaction of vinegar with baking soda used to generate CO_2
- Students compare heating/cooling curves with and without CO_2

Learning Objectives

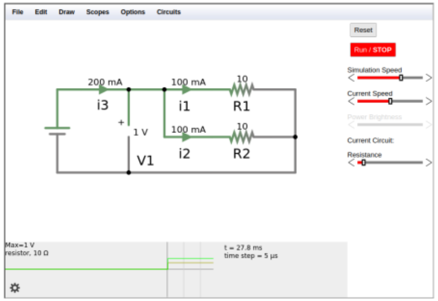
- Demonstrate how the presence of CO_2 acts as additional insulation, leading to higher temperatures in the bowl

EE 1703 Simulating Electrical Fundamentals



Summary

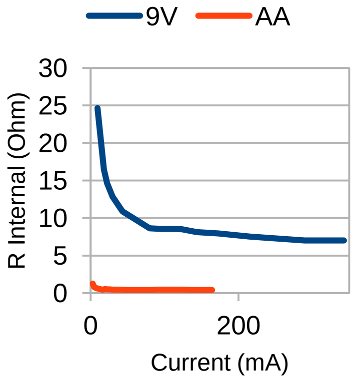
- Students use the Falstad circuit simulator to simulate ideal voltage sources, voltage and current sensors, and resistances in series and parallel
- https://www.falstad.com/circuit/



Learning Objectives

- Understand voltage, current, and resistance (Ohm's Law)
- Understand the behavior of resistances in series and parallel
- Be able to calculate equivalent resistances in series and parallel
- Learn to use a simple circuit simulator

EE 1703 Internal Resistance of a Battery



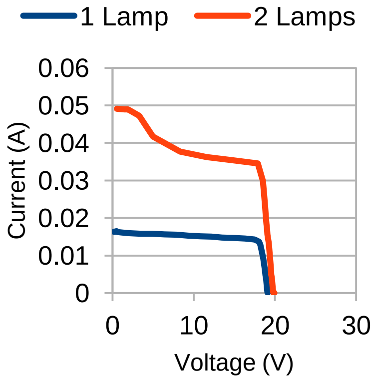
Summary

- Students load 9V and AA batteries across a range of resistance values using a decade resistance box
- Students use measurements of the terminal voltage and current to estimate the internal resistance of the battery

Learning Objectives

- Understand the concepts of electrical power and energy
- Learn how to use a multimeter for measuring voltage and current
- Understand how internal resistance leads to changes in the terminal voltage under load
- Understand how internal resistance decreases usable energy

EE 1703 Photovoltaic Cells: iV Curve and MPP



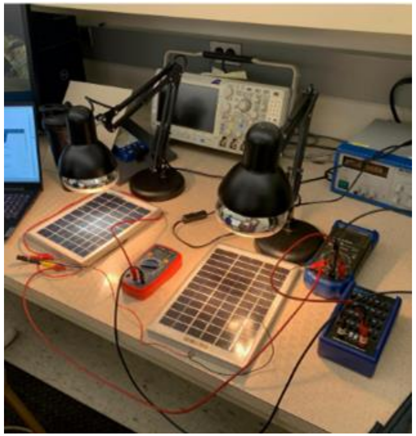
Summary

- Students map out the iV curve for a solar panel at 2 different light intensities (one and two lamps)
- Students plot the PV curve at both light intensities and locate the point where maximum power is generated

Learning Objectives

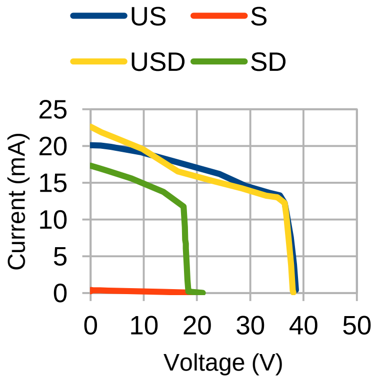
- Understand the basics of photovoltaic (PV) panels
- Understand the importance of the iV characteristic curve and how to find it experimentally
- Understand the importance of the maximum power point (MPP) and how to find it

EE 1703 Photovoltaic Cells in Series and Parallel



Summary

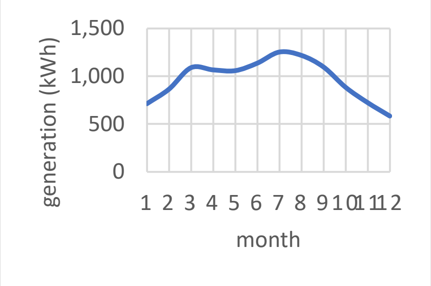
- Students map out the iV curve for a pair of solar panels connected in series, with and without shading, and with and without bypass diodes
- Experiment is repeated with the panels connected in parallel, with and without shading, and with and without a bypass diode

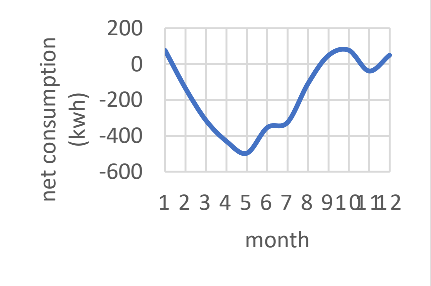


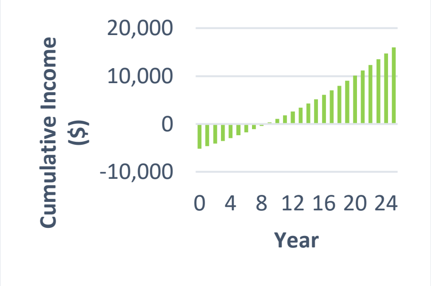
Learning Objectives

- Understand the effect on the combined iV curve of connecting photovoltaic panels in both series and parallel
- Understand the importance of bypass diodes when panels are connected in series

EE 1703 Economics of Rooftop Solar







Summary

- Students first size a solar array based on an assumed yearly load profile (provided) and mean hours of sun per day (from an online calculator)
- Students then compare the economics of paying for the system up-front vs paying for the system using a loan

Learning Objectives

- Understand the primary factors (technical and economic) when considering installation of rooftop solar power
- Understand up-front cost, payback interval, net economic benefit

Year	Electricity Rate	Yearly Electricity Cost for Non-Subscriber	Excel Credit	CSG Fee	Yearly Electricity Cost for Subscriber	Yearly Savings for Subscriber	Cumulative Savings
-	$/kW-h	$	$/kW-h	$/kW-h	$	$	%
1	$0.12	$1,080.76	$0.15	$0.13	$938.31	$142.45	$142.45
2	$0.12	$1,110.48	$0.15	$0.14	$938.31	$172.17	$314.62
3	$0.13	$1,141.02	$0.15	$0.14	$957.55	$183.46	$498.09
4	$0.13	$1,172.40	$0.16	$0.14	$977.18	$195.22	$693.30
5	$0.13	$1,204.64	$0.16	$0.15	$997.19	$207.45	$900.75
6	$0.14	$1,237.77	$0.17	$0.15	$1,017.59	$220.18	$1,120.93
7	$0.14	$1,271.80	$0.17	$0.15	$1,038.39	$233.41	$1,354.34
8	$0.15	$1,306.78	$0.18	$0.16	$1,059.60	$247.18	$1,601.52
9	$0.15	$1,342.71	$0.18	$0.16	$1,081.22	$261.49	$1,863.02
10	$0.15	$1,379.64	$0.19	$0.16	$1,103.26	$276.38	$2,139.39
11	$0.16	$1,417.58	$0.19	$0.17	$1,125.74	$291.84	$2,431.24
12	$0.16	$1,456.56	$0.20	$0.17	$1,148.65	$307.92	$2,739.15
13	$0.17	$1,496.62	$0.20	$0.17	$1,172.00	$324.62	$3,063.77
14	$0.17	$1,537.78	$0.21	$0.18	$1,195.81	$341.97	$3,405.73
15	$0.18	$1,580.06	$0.21	$0.18	$1,220.08	$359.98	$3,765.72
16	$0.18	$1,623.52	$0.22	$0.19	$1,244.82	$378.70	$4,144.42
17	$0.19	$1,668.16	$0.23	$0.19	$1,270.03	$398.13	$4,542.54
18	$0.19	$1,714.04	$0.23	$0.20	$1,295.74	$418.30	$4,960.85
19	$0.20	$1,761.17	$0.24	$0.20	$1,321.93	$439.24	$5,400.09
20	$0.20	$1,809.61	$0.24	$0.20	$1,348.63	$460.97	$5,861.06
21	$0.21	$1,859.37	$0.25	$0.21	$1,375.84	$483.53	$6,344.59
22	$0.21	$1,910.50	$0.26	$0.21	$1,403.58	$506.92	$6,851.51
23	$0.22	$1,963.04	$0.27	$0.22	$1,431.84	$531.20	$7,382.71
24	$0.22	$2,017.02	$0.27	$0.22	$1,460.64	$556.38	$7,939.09
25	$0.23	$2,072.49	$0.28	$0.23	$1,490.00	$582.50	$8,521.59

As mentioned in the worksheet, if the contract is terminated before it is over (before 25 years) the subscriber will need to pay for the next year as well. The following value takes this into account when calculating the total savings over time.
*The termination fee is 0 if the years of subscription is set to 25.

	Value	Unit
Savings (With Termination)*	$8,521.59	$

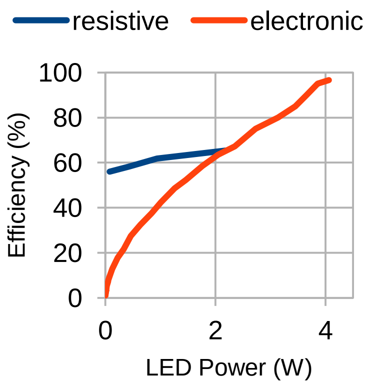
Summary

- An assumed yearly load profile and mean hours of sun per day are used as inputs
- Students use a spreadsheet to calculate the cumulative savings in electricity costs over a 25-year period based on different assumptions about the prices/credits and inflation of those prices/credits

Learning Objectives

- Learn about community solar gardens
- Use a spreadsheet to explore the financial benefits of subscribing to a community solar garden

EE 1703 Resistive and Electronic Dimming



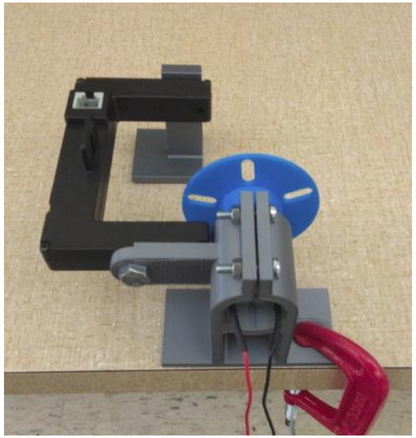
Summary

- Students use a DC power supply to map out the iV curve for an LED panel
- Students evaluate the efficiency of a resistive dimmer and an electronic dimmer used to power the LED panel

Learning Objectives

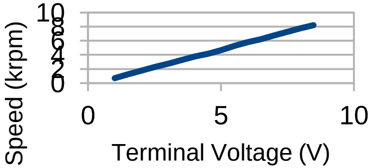
- Map out the iV curve for an LED panel
- Understand resistive dimming
- Understand electronic dimming using pulse-width modulation
- Understand that efficiency is a function of operating point and that the best option may depend on the operating point

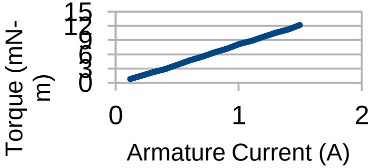
EE 1703 DC Motors



Summary

- Students use a photogate sensor to measure the no-load speed for a DC motor as a function of voltage
- Students use a lever arm and digital scale to measure the stall torque of a DC motor as a function of current

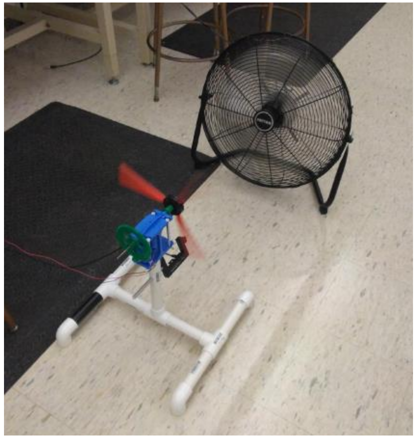


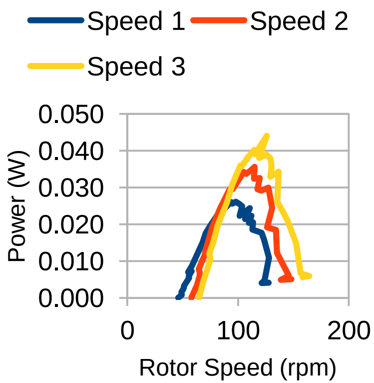


Learning Objectives

- Understand the voltage equation (steady-state) for DC motors
- Understand the torque equation for DC motors
- Experimentally determine the voltage and torque constants for a DC motor

EE 1703 Wind Turbines: iV Curve and MPP





Summary

- Students use a fan and turbine (with a DC motor as the generator) to simulate a wind-turbine generator system
- A decade resistance box is used to sweep the load for the generator to map out the iV curve
- Power vs rotor speed is captured at 3 different fan speeds

Learning Objectives

- Demonstrate that DC motors can also be used as generators
- Understand how the iV curve for a wind-turbine generator varies with both load and wind speed
- Understand how to find the maximum power point

Leveraging 3D Printing: