Off the Grid: *Energy Transformation and Efficiency*
Measuring Electrical Efficiency

Unit Overview

AUTHOR: Brett McFarland

DESCRIPTION OF UNIT: The focus of this unit is to be able to collect data on and then calculate the electrical efficiencies of photovoltaic modules as well as Buck and Boost USB charging circuits. Students will need to measure Current and Voltage using multimeters and USB current and voltage meters and then calculate Power In and Power Out and use these to calculate efficiency of the device.

GRADE LEVELS: 7 – 12

SUBJECT AREAS: Energy Fundamentals, Efficiency, Energy Transformations, Conservation of Energy, Electrical Fundamentals, DC-DC voltage conversions, Multimeter use, Power and Energy Calculations, Physics

ACTIVITY LENGTH: This can vary wildly depending on how much background students have – with circuits, multimeters, energy concepts, and math skills – and if circuits are being built up for the first time. Students who are familiar with circuits and using multimeters should be able to complete this unit in 3-4 weeks. It may take 1-2 weeks to get comfortable with using meters, and understanding electrical circuits. Individual activities can be completed in 2-3 hours.

LEARNING GOALS:

1. Students will be able to measure current and voltage with multimeters.
2. Students will be able to make a simple circuit diagram from an actual circuit and vice versa.
3. Students will keep a journal to take class notes and keep data for labs. It will be a resource to be used during labs and assessments.
4. Students will know the difference between parallel and series (battery and solar module) circuits as well as the expected voltage and current from either.
5. Students will be able to calculate power and efficiency from current and voltage data gathered from a working circuit.

NEXT GENERATION SCIENCE STANDARDS:
HS.Energy

- HS-PS3-3. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.
- HS-PS3-1. Create a computational model to calculate the change in the energy of one

component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.

Engineering Design

- HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

Elementary School Science

- 4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.

COMMON CORE STATE STANDARDS:
Common Core Math Standards for High School

- N-Q 1. Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.
- N-Q 2. Define appropriate quantities for the purpose of descriptive modeling.
- N-Q 3. Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.
- A-SSE 1.a. Interpret parts of an expression, such as terms, factors, and coefficients.
- F-IF 4. Interpret functions that arise in applications in terms of the context. For a function that models a relationship between two quantities, interpret key features of graphs and tables in terms of the quantities, and sketch graphs showing key features given a verbal description of the relationship. *Key features include: intercepts; intervals where the function is increasing, decreasing, positive, or negative; relative maximums and minimums; symmetries; end behavior; and periodicity.*
- A-CED 4. Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. *For example, rearrange Ohm' s law V = IR to highlight resistance R.*

Materials List (per group of 2-4 – see screenshots to help identify some materials)

- Soldering Iron (Optional but recommended to have first students doing this activity to solder and heat shrink needed circuits and then used these for future groups only soldering to create a special circuit or repair existing one.)
- Heat Shrink Tubing 3/16" (can be used to temporarily hold twisted wires together or with solder for a permanent circuit)
- Lead Free Solder – harder to work with but no lead
- Wire Cutter Stripper – 1 per group
- Male and Female DC Power Plugs 5 each per group

AFUNTA new 10pack 10 inch(30cm) 2.1 x 5.5mm DC Power Pigtail Female + 2.1 x 5.5mm DC Power Pigtail MALE
by AFUNTA

$8.99 ~~$20.18~~ Prime
Get it by **Wednesday, Oct 14**

10
FREE Shipping on orders over $35
Product Features
Center positive 2.1mm *DC plug* Includes *female* pigtail connector
Electronics: See all 10,910 items

- Small jumper wires with alligator clips (6 per group)
- Multimeters - 2 per group (one is set up for current, the other for Voltage)
- 3-6 different cigarette lighter phone chargers
- Cigarette Lighter Female sockets (Teacher Tip: The female socket is useful but not necessary. It does, however, identify the positive and negative terminals on the cigaretty lighter phone chargers)

Roll over image to zoom in

uxcell® Car Charger Power Cigarette Lighter Female Socket Black w 26cm Cable
by uxcell
43 customer reviews

Price: $4.50 & **FREE Shipping**

In Stock.
Estimated Delivery Date: March 17 - 22 when you choose Expedited at checkout.
Ships from and sold by iOkeler.

- UXCELL (U excel !) is the sole authorized Seller of uxcell products
- Product Name : Car Cigarette Lighter Socket;Material(External) : Plastic, Metal;Color : Black, Red;Body Dimension : 64 x 29mm/ 2.5" x 1.1"(L*D)
- Cable Length : 26cm / 10.2"
- Weight : 45g
- Package Content : 1 x Car Cigarette Lighter Socket

› See more product details

- USB current/voltage meter

DROK® Dual USB 2.0 Digital Multimeter Ampere Voltage Capacity Power Meter 7 Modes Monitor for Fast Charging Data Sync DC 3.2-10V 0-3A Volt Amp Charger Detector Mobile Solar Panel Alignment Tester
by DROK
328 customer reviews | 14 answered questions

Price: ~~$25.88~~
Sale: $9.99 & **FREE Shipping** on orders over $35. Details
You Save: $15.89 (61%)

In Stock.
Sold by DROK and Fulfilled by Amazon. Gift-wrap available.

Want it Wednesday, Oct. 14? Order within **2 hrs 5 mins** and choose **Two-Day Shipping** at checkout. Details

Size: **LED Display**

- 2 Buck Converters: one is adjustable the other is a 12V-24V to 5V converter

DROK® 3A/15W Power Converter DC 8-22V 12V to 5V USB Connector Adapter Car Charger For iPhone/HTC/Nokia (New)

DROK® Mini DC-DC Voltage Buck Converter Volt Regulator 5V-30V to 0.8-29V Step-down Transformer Inverter Power Supply Module 5A Constant Adjustable (New)

- Cell phone or other device to charge (student's own phone is best) USB to phone charging cord (have students should bring in personal cables)
- NiMH AA cells – each group will need 10

- AA series battery holders – one each for 10 AA, 4AA, 3 AA, 6-8 AA
- ATC fuse holder and 2-3 Amp ATC fuse – can use the holder to make current measurement easier by removing fuse and sticking multimeter probes into either side of the fuse holder so current will run through meter
- Vernier Pyranometer & LabQuest 2 (optional – one per class)
- USB-charged bike light (optional – for demo or activity)

Vocabulary:

- Voltage
- Current
- Resistance
- Power
- Energy
- Energy Transformation
- Efficiency
- Series
- Parallel
- Fuse
- DC and AC
- MintyBoost®
- Amps
- Volts
- Amphrs (Amp-hours)
- Boost
- Buck
- Energy Transformation
- Watts
- ATC fuse
- Schematic
- Circuit Diagram
- Solder
- Heat Shrink Tubing
- BioLite

Lesson Details

Lesson Sequence: Off the Grid Unit

Lesson Code	Lesson Number	Lesson Description	Lesson/Activity Length
OTG-1	Lesson 1	Introduce meters and use with *Solar Power Lab Activity*	3-5 hrs
OTG-2	Lesson 2	Research terms and concepts, Journal and discuss. *Think-Pair-Share* and *Written Assessment, Hands-on*	2-3 hour
OTG-3	Lesson 3	*Cell Phone Charger Efficiency Lab*	2-3 hr
OTG-4	Lesson 4	Exploring Buck and Boost Converters	2-3 hr
OTG-5	Lesson 5	AC to DC efficiency 110AC to 5VDC	1 hr
OTG-6	Lesson 6	Biolite and Efficiency – The Thermoelectric Effect and Charging from Stick Burning!	1-2 hrs
OTG-7	Lesson 7	Designing an Off Grid Charging System	3-5 hrs

Planning and Prep

- You will need to order many of the components for this unit: Amazon is one good source for the **Buck** and **Boost** converters and the USB current meters.
- This Unit will begin with some explanations about the various terms followed by *Student Research and Journaling* about the terms. I recommend Wikipedia, and students should try to put information into their own words. Writing should be done by hand, legible and make sense for someone with no prior knowledge. Terms are listed in the Vocabulary section.
- Next, students should set up and do Lesson 1. Journals should be used to draw a schematic for the solar panel circuits. Students will gain experience by using meters, taking data and performing Energy and Power calculations. Students should then compare results and review use of meters as a group.
- The Think-Pair-Share activity should take place next. Students will work in randomly selected pairs and discuss the concepts and units and attempt to answer questions one at a time off the *Think-Pair-Share* sheet included. Students should be jotting down their responses in their journals, and each question should take around 5 minutes for the pairs to discuss, and then share with the group as noted in the sheet.
- After this activity students can be assessed with the *Written Assessment #1* and the *Hands-on Assessment #2*. The first hour of the *Lesson 3* will entail everyone doing a trial run, to get up to speed using the tools. I think groups of two are ideal, but depending on equipment availability, this activity will work with groups of 3-4.
- Formative assessments will be important to make sure students are properly using the tools, and recording data correctly. During labs or activities, the instructor can wander the room and check on this.
- The included Think-Pair-Share activities, and written assessment on terms and units creates opportunity for the instructor to assess understanding of the terms. Lesson 3 will give students a chance to get used to using the meters and gear as well as taking useful data. Data will be taken simultaneously for Input and Output and students need to make sure the readings are somewhat stable and not jumping dramatically.
- Students should discuss how the charge level of a phone affects efficiency and how phones should be “on” so even if fully charged they will still be running off of the charger. This unit requires a lot of graphing; I recommend doing most of the graphing by hand on paper. Then, time permitting, students may enter data into Excel for more accurate graphing.
- One goal of this unit is to use data to compare efficiencies of charging methods. The final activity/lab is a group-based experiment, where the class will use the **Biolite** camp stove to charge a phone. Coming up with the Energy Input of burning sticks is no trivial matter, and two methods are discussed for this – the “easy way” (using manufacturers specs) and the hard way (taking data on heating water and then performing calculations). The hard way is a great intro into specific heat and could lead to all kinds of interesting discussions, but will take more time.

Student Background

Students participating in this lesson should be familiar with the following:

- Some prior knowledge of **circuits**, **circuit diagrams**, knowing how to measure **current** and **voltage** with a **multimeter**, and some basic manipulation of variables in a formula would be helpful, though most of this should be reviewed to some extent, depending on the students.

Educator Background

Educators leading this lesson should be familiar with the following:

- All of the vocab terms, using **multimeters**, **soldering**, and managing chaos.
- I have included small screenshots of items that will not be easy to find except online.
- Refer to the document “Important Units and Formulas” to ensure that you are familiar with all of the concepts listed.

Extensions

- Students try their own car phone charger to compare with other chargers. Compare the **MintyBoost®** with 4 AA batteries to see if it affects efficiency.
- Do a cost/benefit ratio for different phone chargers. Use data to see if one phone charger will charge faster than the others. Find the highest power phone charger. Compare power to efficiency for the various chargers.
  Compare different fuels for the **Biolite** by measuring how fast a given amount of water boils.