Off the Grid Unit

Lesson 5: DC to AC to DC Efficiency

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DESCRIPTION: This is part of the Off the Grid Unit. This lesson will continue to deal with **efficiency** of USB charging devices, but this time we will be using an **inverter** in order to create **AC** voltage from a battery pack, and then use a standard **AC** charger (what you would plug into the wall) to charge a USB device. Students will continue to use USB voltage/current meters to take readings on the charger-side of the circuit. After constructing these circuit components, students will measure the efficiency at which this inverter changes DC power back into DC power (in a DC-to-AC-to-DC conversion), and will collect the data in their journals using the self-created tables in their science journals.

GRADE LEVEL(S): 7-8 or 9-12

SUBJECT AREA(S): Energy fundamentals, electrical circuits, **efficiency**

ACTIVITY LENGTH: 2-4 days or 2-4 hours

LEARNING GOAL(S):

1. Students will use **multimeters** to measure voltage and current in circuits.
2. Students will use collected data and be able to make power calculations from this data.
3. Students will also be able to calculate **efficiency** from their **power** calculations.
4. Students will be able to compare **efficiencies** in order to identify the circuit that is most efficient.
5. Students will be able to make circuits from a diagram and vice versa.
6. Students will know what an inverter is and what it does.

NEXT GENERATION SCIENCE STANDARDS:

- 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.

COMMON CORE STATE STANDARDS:

- 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.

Materials List

- AA battery holders – 10AA and in series for a 12 Volt battery pack(1 per group of 2-3)
- AA rechargeable batteries – 10 per group
- USB current/voltage meters
- **multimeters** (2 per group – one for voltage and one for current)
- ATC fuse holders (used for measuring current) 1 per group (see pics below)
- Cell phone or device that uses a USB plug for charging – students can bring in a USB charging cord for their phone, or instructor can supply any USB charging device. I used LED bike taillights that charge with a USB.
- Male and female DC power plugs with pigtails (1 each per group)
- 12V female cigarette lighter plugs (to plug inverter in) with pigtails (1 each per group)
- **Inverter** – a small cigarette lighter inverter designed to be used in vehicles – usually limited to 100W or so

Other Supplies

Student Journals

Vocabulary

- Inverter
- Power: P = VI
- Efficiency: e = P_{out}/P_{in}
- ATC fuse
- Multimeter
- DC Power Plug
- Schematic or Circuit Diagram
- AC

Lesson Details

Planning and Prep

This is meant to be the 5th lesson in the **Off the Grid Unit.** This lesson could stand alone, but unless you are comfortable with building simple circuits and using multimeters, it might be a good idea to review the previous lessons. Note: **Polarity is very important when running inverters; you may damage the inverter if you wire it in reverse**.

You will need to obtain a small **inverter** that plugs into a car cigarette lighter socket for this lab. All groups will also be using a 12 Volt battery pack, or some other 12 V DC source that can be wired up to have a female cigarette lighter socket to plug the inverter into. As in the other lessons for this unit, students will be using an ATC fuse holder to measure current from the battery pack into the inverter (see Off the Grid Lesson 3). Students will also measure battery pack voltage using a multimeter either on the terminals of the battery or picking up voltage from the positive ATC fuse connections and the negative DC power plug (see **Lesson 3 Cell Phone Charging Efficiency**). Depending on your inverter, the efficiency comes out on the low side, but maybe not as low as expected when you consider all the energy transformations taking place between the battery packs the phone or USB device that is charging.

I have done this with one circuit for the entire class as I have only one inverter. I have one group set up the circuit while the other students are preparing the data table in their journals. Once the circuit is operating students can try their own phone on it or one of the devices I provide. They take data on this and then go make their efficiency calculations. Students should be encouraged to consider and answer the questions at the end of the Lab – name each energy transformation as the electricity flows from batteries to phone.

Student Background

Students participating in this lesson should be familiar with the content from **Off the Grid Unit Lessons 1-4**

Educator Background

Educators leading this lesson should be familiar with the following:

- Basic electrical understanding of simple circuits and use of meters
- Purpose and function of DC to AC inverters

Lesson sequence

This lesson can be completed in one 2-hour class period or two shorter periods.

Students will draw (and set up) circuits that take a 12 V voltage source (the battery pack) wired to a female cigarette lighter receptacle. Note that I only had one inverter, so I had one group set up the circuit. *Make sure that the polarity is wired correctly from the batteries to the female cigarette plug (red-to-red, black-to-black).* The second half of the circuit will consist of a car inverter that will plug into the female receptacle, and a power cable to connect to the AC output from the inverter.

Students will need to measure data, so we use the ATC fuse holders to allow us to insert the multimeter into the circuit to measure current on the battery-side (12 V side) of the circuit (see Lesson 3). We will also use the USB voltage/current meters that we used in Lesson 3 to measure the “Cell Phone side of the circuit.” Note that there is one energy conversion that we are *not* reading, which is the output from the inverter itself. In other words, this circuit converts from 12 V DC to 120 V AC to 5 V DC, and we are measuring at the 12 V and the 5 V sides.

Students should create the following table, record data from circuits, and answer questions below.

Description of Device Tested	Cell Phone side of circuit					12 V side of circuit that inverter is plugged into		
	Voltage	Current	Power P_{out}	Efficiency (%) $(P_{in}/P_{out}) \times 10^2$		Voltage	Current	Power P_{in}

After you have calculated your efficiencies, compare your values with other groups and answer the following questions:

1. How does this method of charging your phone compare to other methods we have experimented with? Rank it according to efficiency.
2. Describe all the energy transformations that take place between the battery pack and the phone – explain what is happening to the voltage and current at each place where they might change.
3. Can you think of a situation where you would recommend this method of charging a phone or USB device? Come up with at least one scenario.
4. AC electricity is the most commonly used. Why do you think that is? Do some research to support your answer.