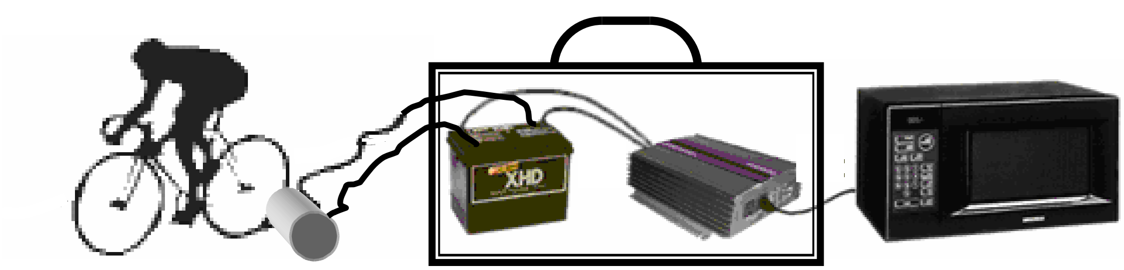
Human Energy Generation and Electrical Signal Measurement

Contemporary Technical Problem and Benefit to Society:
Energy generation, and its efficient usage, is becoming a pervasive problem in today's society as fuel prices continue to increase. Providing low cost energy to remote areas, depressed regions, and third world countries would have a tremendous impact on their lifestyle. Also, many devices such as communications equipment have low power requirements, while many high power devices only require this power for short periods of time. In both examples, low cost, low power generators can provide enough stored energy to power devices and improve the quality of life for a substantial fraction of the world's population. Of particular importance to improved lifestyle is the pumping of water, purification of water, generation of light, and heating of food. Less significant, but also important are power tools, transportation, and communication. A clear understanding of these issues is important for the development of responsible engineers and citizens.

This project has several purposes:
1. Demonstrate the generation of power by a human source.
2. Demonstrate in a real way how much power is needed to operate many of the devices in a student's own life.
3. Demonstrate the storage of energy in an electrical energy storage device such as a battery.
4. Determine the efficiency of the conversion of DC-energy into more usable AC-energy.
5. Introduce students to the measurement of a variety of electrical signals, and to specifically provide a real example of calculus fundamentals using energy and power.

Apparatus Overview:
A bicycle attached to a properly sized DC generator will be available for student teams to use at their convenience. The DC generator will be attached to a portable battery pack with an on-board power inverter. The power inverter will be able to provide power for any devices the students choose.

Procedure Overview:
Using the gear ratios available on a standard multi-speed bicycle, the students will choose their optimal torque and speed to maximize their power generation. Attached to the DC side of the battery will be a voltmeter and an ammeter. While generating power, students will record the voltage and current at roughly 15 second intervals. Later they will enter these into a spreadsheet, where they will calculate instantaneous power and total energy generated. When they get tired of generating power, the student teams will take the portable energy storage devices with them and use them with various devices. Using a special low cost commercially available meter, the AC current, voltage, power, and total energy used can be determined. Students can then compare the energy out of the battery pack with the energy into the battery pack to determine the efficiency of the DC-AC inversion. Students will also be asked how much energy they could expect to produce in an average 8-hour day, and to determine what household devices they could use and for how long.



Human Energy Generation

Apparatus:
This experiment requires a bicycle, a permanent magnet motor capable of generating several hundred watts, a deep cycle battery for energy storage, a power inverter, an AC Kill-a-watt energy-power meter, a DC voltmeter, a DC ammeter, and wires capable of at least 50A DC. The students will provide the various AC loads.

Generator:
The components of the apparatus can be collected separately and assembled by the instructors. Alternatively, the specific components can be purchased directly from Windstream Power as detailed below. These are specifically designed to work together, and require little effort to construct.

Portable Power Pack

Bike Power Generator

Metering
Although the Windstream Portable Power Pack has some metering on both the DC and AC sides, it is more instructive to include the following meters in the experiment.

On the DC side, it is important to measure both the DC voltage and DC current out of the generator (into the battery). These values will be used to determine the power going into the battery pack. An accurate high current clamp-on ammeter is perfect for this, as the wires going from the generator to the battery do not need to be cut to insert the ammeter.

On the AC side, there is a wonderful device called the “Kill-a-watt EZ.” It plugs directly into an AC outlet, with the appliance plugging directly into the Kill-a-watt. The Kill-a-watt can then display AC volts, AC amps, AC watts, AC frequency, AC apparent power, cumulative kilowatt-hours, and cost of usage for the plugged-in appliance.

High Current Clamp-on DC Ammeter

Multimeter for DC voltage

“Kill-a-watt EZ” AC meter

can display

- cumulative kilowatt-hours
- volts, amps, watts, Hz, VA
- cost of usage per day, week, or year

Cost:

Component	Cost	Source
Bike generator	$595	Windstream Power
Portable Power Pack	$475	Windstream Power
Bicycle	$ 50	Any Yard Sale
DC Voltmeter	$100	Any Electronics Vendor
DC High Current Ammeter (Clamp on)	$250	PowerStream
Kill-a-watt AC meter	$ 50	Powermeterstore

A nice apparatus can be put together for less than $1500. It is suggested that two generators, and three to four portable power packs should be purchased so as to process more students, if funds are available. The portable power packs only weigh 20 lbs so they are easy carried. It is also suggested that a “Kill-a-watt” meter should be purchased for every team so that they can individually determine power usage in their dorm rooms.

Teams:
This lab is ideally suited to teams of three to five students. Each team must sign up for times on the bike generators. Time slots of 30-60 minutes are best. The students can take turns riding the bike. While doing the generation, one student will be on the bike, one or two students can be reading the meters, and one or two students can be recording data. For *using* the stored energy, the number of students is less important.

Duration:
It is anticipated that this lab can be completed in 1-3 weeks depending on how the instructor wishes to use it.

Procedure:

Teams will schedule times on the bicycle generator.

At the bicycle generator station, the team and the lab instructor will verify all the power and meter connections. The generator should be connected to the portable power pack, with the addition of the clamp-on DC ammeter, and a DC voltmeter.

The ideal team size is four students, however three or five students can suffice. One student should be on the bicycle, one student should be reading the two meters, one student should be monitoring the time, and one student should be recording the data. Any time period can be used for the sampling interval, but fifteen seconds works well.

With one student pedaling, every fifteen seconds, the student-time-monitor will tell the student-meter-reader to read the meters aloud, with the student-recorder entering the DC voltage and DC current into a spreadsheet. This will continue as long as someone in the team is pedaling. It is important for each team member to have a turn on the bike so that the teams can see that each member has a different optimal power level.

Upon completion of their time on the bicycle generator, the students will do the following calculations using the recorded data in the spreadsheet.

Determine the (roughly) instantaneous power, by multiplying the measured DC voltages times the corresponding measured DC currents, that is $P = V\,I$.

Determine the total stored energy by summing up the energy stored during each fifteen second interval (a practical discussion of integration can be included by the instructor if appropriate). This cumulative sum is easily done using the spreadsheet, or using $E = (15\text{sec})*(V_1I_1+ V_2I_2+ V_3I_3+ V_4I_4+ V_5I_5+ V_6I_6+\ldots)$ joules. The factor of 15 seconds is the sampling interval. The students should convert the stored energy from joules to kilowatt-hours.

Assuming a generator efficiency of 80%, the team should determine how much energy was wasted, or converted to heat, by the generator during the charging process. Students should consider how much of their energy was converted to heat.

Determine the total stored charge by summing up the current measurements from each 15 second interval. This cumulative sum is easily done using the spreadsheet, or using $Q = (15\text{sec})*(I_1+I_2+I_3+I_4+I_5+I_6+\ldots)$ coulombs. The factor of 15 seconds is the sampling interval. It is appropriate to convert the stored charge in coulombs to AHrs, by dividing it by 3600 seconds per hour. This is important because the battery pack is a 20 AHr pack, and overcharging should be avoided to prolong the life of the pack.

Plots of DC voltage, DC current, power, and cumulative energy should be included in the final write-up of the lab.

After charging the portable power pack in their scheduled time slot, the team will check-out a portable power pack. They will be responsible for returning it in working order and in a timely fashion so other teams can use it. They will also be given a "Kill-a-watt" meter to use. The team will take the portable power pack to their room (or wherever) and use it to provide AC power to some appliance or device. They will plug the "Kill-a-watt" meter into the portable power pack, and plug the appliance or device into the "Kill-a-watt" meter. They will use the "Kill-a-watt" meter to determine the total energy out of the portable power pack. By comparing this value of energy out of the portable power pack with the measured energy into the portable power pack, a value for the energy conversion efficiency of the portable power pack can be determined for their specific AC current level.

When the portable power pack is discharged, the students should return it to the lab as soon as possible. The student teams should keep the "Kill-a-watt" meter as long as possible, and find the power consumption of several appliances and devices, which should be included in the lab report. It is also interesting for them to determine the power consumption of devices that are plugged-in, but not turned on and their required power levels.

Using their list of power consumption for household devices, and the energy conversion efficiencies, the student team will be asked to make a table of how long each team member would be required to pedal the bike to power those devices for a normal time-period of usage.

<u>Reporting:</u>

A laboratory report is required at the end. The report should be written using some standard word processor. It should include all equations, plots of all signals using the spreadsheet, all required values from the procedure, and a list of power usage of household devices along with pedaling times. The students are asked to make suggestions on improving the generation, storage, and usage of energy in this country. The students are also asked to determine how their bicycle generator could transform an impoverished village in a third world country.