
PHY 101 Lecture #12: Electrical Energy in Daily Life

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<http://physics.syr.edu/courses/PHY101.01Fall/>

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Outline

1. High voltage power transmission
2. Electrical use in the home
3. Battery-operated devices
4. What are batteries?

The power transmission problem

A household may use 1200 W.

At 120 V, $I = 10\text{A}$.

All households in a city are in parallel across the wires from the generator.

Say a city has 10,000 households.

At 120 V, $I_{\text{city}} = 10^5\text{ A}$.

From Ohm's Law, city has $R = V/I = .0012\text{ ohms}$.

Can we supply power to the city without putting most of the power in the wires?

Power transmission problem II

Romer, Figure 9.34.

Generator, transmission lines, and city make simple series circuit.

If we want only 10% of power to heat the wires, need only 10% of voltage drop in wires.

Wires must have $R = 5 * 10^{-5}$ ohms.

If wires were 30 miles long, made of copper, they would need to have diameter of 4.5 m.

Solving the transmission problem with high voltage

Supply each household's 1200 W as 120 kV,
 $I = 10$ mA.

Whole city uses only 100 A.

City's resistance $R = V/I = 1200$ ohms.

Now 30 mile power transmission wires can
have resistance of 50 ohms.

If made of copper, can have diameter of 4.5 mm.

This is practical.

Solving the safety problem with step down transformers

120 kV would be a real safety hazard at home.

Solution: a step down transformer near every home, to reduce the voltage to 120 V.

Safe and efficient transmission of electric power depends on transformers.

This is why AC is chosen over DC.

Electricity use in daily life

Typical electric appliance uses ~ 100 W.

But hair dryer uses about 2 kW,
electric stove uses 12 kW.

Can check power rating on nameplate of
appliance.

Sometimes gives current, multiply it by 120 V to find
power rating in watts.

Cost of electricity

Electric utilities bill for electrical energy.

Electrical energy $E = P * t$.

Utility bills figured in units of kilowatt-hours.

Multiply power use in kW by duration of use in hours to find energy in kWh.

Niagara Mohawk charges \$ 0.10/kWh.

My household bill last month: \$85.

My household's overall energy budget

Last month's bill: 850 kWh.

There are 720 hours in 30 days.

My household uses 1.2 kW on average.

This is typical for an American household.

Battery-operated devices

Some things plug into the wall.

Others use much less electricity, stored in batteries.

Radios, Walkpersons

Cordless phones/cell phones/PDAs

Watches

Cars (for starting)

Laptop computers

Flashlights

Cordless microphones

Energy storage in batteries

Energy *capacity* of a battery rated in *ampere-hours*.

Actual energy stored is product of battery voltage times capacity in ampere-hours, yielding energy in watt-hours.

$$1 \text{ Wh} = 3.6 * 10^3 \text{ joules.}$$

Energy storage examples

Alkaline D cell (“Energizer”) stores 18 amp-hrs
@ 1.5 V = 27 watt-hours,
almost 100,000 joules.

Car battery (lead-acid) can store 100 amp-hrs
@ 12 V = 120 watt-hours.

Alkaline cells thrown out after 1 use.

“primary” batteries

Lead-acid batteries can be recharged.

Storage batteries

What are batteries?

Battery related to an *electrochemical cell*:

Two *electrodes* made of dissimilar metals, immersed in a conducting liquid *electrolyte*.

When you construct an electrochemical cell, find a voltage between two electrodes.

Voltage depends mainly on material of electrodes.

Voltage in the range of 1 to 4 volts.

Current can flow from positive to negative electrode, until chemical changes stop it.

Copper-zinc cell

Insert sheets of copper and zinc into beaker of dilute sulphuric acid (or even a lemon.)

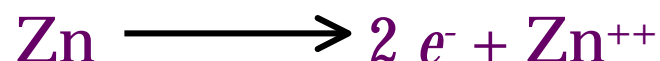
Voltage of about 1 volt appears between the two electrodes. (Copper is positive.)

Bubbles of hydrogen gas appear.

What is going on?

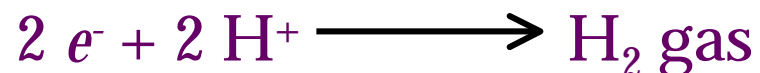
Chemical reactions in an electrochemical cell

At zinc electrode:



Electrons stay in electrode while Zn^{++} goes into electrolyte, making Zn electrode negative.

At copper electrode:



Copper gives up electrons to electrolyte, making copper electrode positive.

Chemical energy in an electrochemical cell

A cell is a store of *chemical energy* that can be converted into electrical energy.

As electrode chemical reactions proceed, chemical energy is converted into electrical potential energy.

Converted again to other forms as current flows in external circuit.

Chemical energy is exhausted when reaction can proceed no further

(e.g. when Zn electrode is dissolved.)