Electrical Household Appliances – Lesson 6
Appliance Physics, Tasks, Power, and Energy

Summer 2004 **Cal Poly Pomona**

Objectives: (i) Investigate the physical principles involved in the operation of common electrical household appliances. (ii) Identify the tasks done by each appliance. (iii) Determine the power ratings of each appliance. (iv) Estimate the energy each appliance uses monthly and the total energy use for all appliances. (v) Compare the latter estimate with actual electrical energy use, as shown on a utility bill.

Background: The electric power required by an electric appliance can be estimated as (the appliance's electric CURRENT) × (the VOLTAGE across its terminals). For example if the current through a household light bulb is 0.5 amperes and the voltage across its filament is the common 120 volts, then its power is (0.5 amperes) × (120 volts) = 60 ampere volts = 60 watts. Note: 1 amp × 1 volt is defined to be 1 watt.

As we saw earlier, power represents the RATE at which electric energy is being fed to an appliance. Note that the power is properly zero if the voltage across the appliance is zero – which is true when it is switched OFF. Fortunately, most electric appliances have labels that give their power ratings, and it is not necessary to know the electric currents flowing through them to calculate their power requirements. Furthermore, the VOLTAGE supplied to most household appliances is 120 volts, so Power = (120 volts) × (CURRENT in amps). From this equation, it is clear that higher power appliances require more amps.

The electric energy, in kilowatt hours (kWh), used by an appliance over a time interval is

$$\text{Energy (kWh)} = \frac{\text{POWER (watts)} \times \text{TIME (hr)}}{1000\ (\text{watt} \cdot \text{hr/kWh})}.$$

<u>Example</u>: The electric energy used by a 100 watt light bulb operating for 24 hours is (100 watts) × (24 hours) / (1000 watt hours/kWh) = 2.4 kWh. The typical cost of 1 kWh of electric energy from Southern California Edison is approximately $.13. Thus 2.4 kWh of electric energy costs (2.4 kWh) × (0.13 $/kWh) = $0.31.

Many electric appliances operate using one or more of the following three parts:

A. electric motor (e.g., a fan),

B. electric current flowing through a conductor that gets hot (e.g., a toaster),

C. an electromagnet (e.g., a solenoid valve that quickly opens and closes, controlling water flow in a washing machine).

A good, educational exercise is to try to identify which one or combination of these three parts apply to common appliances.

Activity 1 – Appliance Physics

a. Discuss with your partner which of the above three parts, A, B, C, apply to: a light bulb, vacuum cleaner, refrigerator, electric toothbrush, radio, computer, portable electric heater, dishwasher, and door chime. Write your conclusions in paragraph or table format.

b. Make a table with 5 columns, as illustrated below. In column 1 show each appliance name. The headers of columns 2, 3, and 4 are, respectively, "electric motor," "heated electric conductor," and "electromagnet." Column 5 has the header "other." List as many electric appliances in your home as you can (a partial list is shown on page 4), writing YES or NO, as appropriate in each of columns 2-4 and writing descriptive words in column 5 if the appliance has other interesting parts.

Appliance Name	Has Electric Motor	Has a Heated Electric Conductor	Has Electromagnet	Other Interesting Parts

Activity 2 – Energy Tasks

Typically, an appliance is designed to do a primary task, and it is helpful to understand and use the following five task categories:

heating (H)
cooling (C)
lighting (L)
mechanical work (W)
information-processing & transfer (IPT)

For example, a toaster does heating, a refrigerator does cooling, a light bulb does lighting, an electrical tooth brush does mechanical work (namely, it exerts a force through some distance), and a cell phone does information processing and transfer. Some appliances do more than one task. For example, most of the energy fed to a light bulb becomes heat rather than light. This heat delivery is a helpful secondary task in winter, but an annoying problem that can require increased air conditioning in summer.

a. Make a table with 6 columns, as illustrated on the next page. In column 1 show each appliance name. Column 2 – primary task, column 3 – appliance's power rating, column 4 – estimated hours used monthly, column 5 – calculated monthly energy use in kilowatt hours (kWh), and column 6 – calculated monthly cost. You may use the attached table of typical appliance powers to estimate the power required by each appliance.

Appliance Name	Primary Task	Power (watts)	Monthly Hours ON	Monthly Energy (kWh)	Monthly Cost (@ $.13/kWh)

b. Obtain a recent electric bill from your home. Compare your estimated energy use in kWh with the number of kWh actually billed by the utility company, and calculate the net cost of 1 kWh of electric energy.

c. Using your bill, calculate the kWh per person, per day. Share your result with the rest of the class.

Summary Questions

a. Develop a microscopic model to explain why a conductor heats up when electric current flows through it. Sketch and describe it.

b. Given that electric currents generate magnetic fields, why don't your keys get attracted to the power cords on electric appliances?

c. Which energy tasks have the highest power requirements? How can you minimize the cost of operating these appliances?

d. If "too many" appliances are ON simultaneously, why might a fuse blow or a circuit breaker trip? Hint: Appliances are connected in parallel. Recall what happens to the maximum current in a parallel circuit as more and more devices are added.

e. Why do some appliances have 3-pronged plugs? Hint: The third prong is connected to the appliance's chassis (metal frame) and plays a role only if, due to some failure, the chassis becomes electrically charged, possibly endangering its user.

f. There are several ways to use less electric energy: (i) increase an appliance's efficiency (perhaps by buying a newer model), (ii) partially or fully curtail usage of some appliances, (iii) substitute another fuel for some tasks. List some ways you might do each of these in your home.

Typical Appliance Power Ratings
(which *might* differ from *your* appliances)

Appliance Name	Power (watts)
Air Conditioner (room)	1350
Central	5000
Automatic Blanket	200
Ceiling Fan	75
Clock	4
Clothes Dryer	4500
Coffee Maker	850
Computer	360
Dishwasher	1300
Evaporative "swamp" cooler	100
Freezer, frost-free	440
Food Mixer or Blender	110
Furnace blower fan motor	400
Garbage disposal	400
Heater, portable	1500
Hair Dryer	1250
Iron (hand)	1100
Lighting-Kitchen	250
Lighting-Bedrooms	450

Appliance Name	Power (watts)
Lighting-Outdoor	150
Lighting-Living Room	500
Lighting-Office	150
Lighting-Other	400
Microwave	1450
Pool filter motor	1500
Radio-Stereo	110
Range (stove top)	2000
Range (oven)	5000
Refrigerator, standard	265
Refrigerator, frost-free	500
Television	250
Toaster	1100
VCR	25
Vacuum cleaner	700
Washing machine	600
Water heater (electric)	3200
Waterbed heater	300
Whole-house exhaust fan	110