Period 9 Activity Sheet Solutions: Power

Activity 9.1: How Much Power Do Appliances Require?

a) **Light Bulbs:** Connect the small hand-cranked generator to the 4-bulb tray.

Compare how easily the crank turns when 0, 1, 2, 3, and 4 bulbs are lit. When is the crank easiest to turn and most difficult to turn?

The crank is easiest to turn when no bulbs are lit. As you increase the load by adding bulbs, more power is required to turn the crank.

b) **Appliances:** Use a wattmeter to measure the power requirements of the light bulb, the hair dryer on low and high settings, the toaster, and mixer. Record your measurements and compare them to the power requirements (the wattage) listed on the appliances.

Appliance	Power Measurement	Appliance Wattage
Light Bulb		
Hair dryer (high)		
Hair dryer (low)		(no wattage rating is given)
Toaster		
Mixer		

c) **Electric Drill:**

1) Measure the power requirement of the drill. ____________________
2) Measure again while squeezing the drill bit with the hand clamp. ______________
3) Explain any difference in power requirements.

When you squeeze the drill bit, you increase the load. The drill must do more work against the force of friction to turn the bit. More power is required to do more work.

Activity 9.2: How Much Power Do You Use for Daily Activities?

a) **The Stairs:** Using the classroom stairs, a timer, a meter stick, and the scale, find the power a member of your group requires to climb the stairs.

1) Measure the person's weight in newtons (1 lb = 4.45 newtons). ___________________
2) Measure the height of the stairs in meters (1 ft = 0.305 m). ____________________
3) Measure the time in seconds needed to climb the stairs. ___________________
4) Calculate the person's gain in potential energy from climbing the stairs.

$$E_{pot} = M\ g\ h$$

____

Activity 9.2, Continued: How Much Power Do You Use for Daily Activities?

5) How much work was done against the force of gravity to climb the stairs?________

Work = Force x Distance. Here, force = the person's weight in newtons.

6) How much power was required when doing this work?____________________________

Power = Work / time elapsed

7) Is the total power the person produced while climbing the stairs more, less, or equal to this amount? Explain your answer:

In any process, some energy is wasted. In addition to the energy you use to raise your body up the stairs, your body converts some of its stored chemical energy into thermal energy. Therefore, the total power produced is more.

8) Suppose a student weighing 160 pounds climbs a stairway with a vertical height of 4 feet in 2 seconds. How many horsepower are required? (Hint: 1 hp = 550 ft-lbs/s)

$$P = \frac{W}{t} = \frac{Mgh}{t} = \frac{160\text{ lbs} \times 4\text{ ft}}{2\text{ s}} = 320\text{ ft-lbs/s}$$

$$\frac{1\text{ hp}}{\cancel{550\text{ ft-lbs/s}}} \times \cancel{320\text{ ft-lbs/s}} = 0.6\text{ hp}$$

b) **The Bike:** Using the exercise bike connected to several 50 watt bulbs and a timer, find how much energy is required to light the bulbs.

1) How many bulbs were lit? __________ How many watts is this?

__# of bulbs x 50 watts/bulb__

2) How long were the bulbs lit? ___________________

3) How much energy did this require?

$$P = \frac{E}{t} \qquad \text{so, } E = P\,t$$

4) Was the total energy you expended pedalling the bike the same, more, or less than the energy needed to light the bulbs? Explain your answer.

More energy was required. Some of your energy was wasted by frictional forces in the bicycle and the generator.

Activity 9.3: How Much Does Electricity Cost?

a) **Measuring Electricity – Reading a Kilowatt-hour Meter**

1) Plug a hair dryer into the kilowatt-hour meter and describe what happens to the meter when the dryer is set on "low."

The disk rotates slowly, measuring the electricity provided to the hair dryer.

2) What happens when the dryer is changed to "high"?

The disk rotates more rapidly, indicating that more electricity is being used per unit of time.

3) How many kilowatt-hours does the dial on your kilowatt-hour meter read? _________

b) **Calculating the Cost of Electricity – Your Electric Bill**

1) Examine an electric bill. How many kilowatt-hours of electricity were used? ________
2) What was the total cost of the electricity used? ___________
3) Calculate the cost of electricity used per kilowatt-hour

$$\textbf{Total cost of electric bill} \times \frac{1}{\text{kWh of electricity}} = \frac{\text{cost}}{\text{kWh}}$$

c) **Conserving Electricity**

Your instructor will demonstrate a compact fluorescent and an incandescent bulb. Compare the brightness of the bulbs.

1) How many watts of power does each bulb use?

Compact fluorescent ________________ Incandescent ______________

2) If electricity costs $0.10 per kilowatt-hour, how much money per hour does the compact fluorescent bulb save compared to the incandescent bulb?

Suppose that the compact fluorescent used 20 watts and the incandescent used 60 watts. Find the difference between the cost to operate each bulb per hour.

Compact fluorescent: $$\frac{\$0.10}{\cancel{\text{kWh}}} \times \frac{20\ \cancel{\text{watts}}}{} \times \frac{1\ \cancel{\text{kW}}}{1{,}000\ \cancel{\text{watts}}} \times \frac{1\ \cancel{\text{hour}}}{} = \$0.002$$

Incandescent: $$\frac{\$0.10}{\cancel{\text{kWh}}} \times \frac{60\ \cancel{\text{watts}}}{} \times \frac{1\ \cancel{\text{kW}}}{1{,}000\ \cancel{\text{watts}}} \times \frac{1\ \cancel{\text{hour}}}{} = \$0.006$$

The amount saved per hour is $0.006 - $0.002 = $0.004 per hour. The incandescent bulb costs 3 times as much to operate as the compact fluorescent bulb.

3) Explain why the compact fluorescent requires less energy to produce the same amount of light.

Both bulbs convert electrical energy into radiant energy in the form of visible light and infrared radiation. The compact fluorescent bulb converts a larger fraction of the energy into visible light and wastes less energy heating the light bulb glass with infrared radiation.

d) **Payback Time**

Your instructor will demonstrate a model windmill electric generator used to light 4 bulbs.

1) How many watts of power does the windmill produce when a fan blows onto its blades? (Assume that each of the 4 bulbs requires 62 milliwatts of power.)

$$\textbf{62 milliwatts} = 62 \times 10^{-3}\ \text{watts}$$

$$\frac{62 \times 10^{-3}\ \text{watts}}{\cancel{\text{bulb}}} \times 4\ \cancel{\text{bulbs}} = 248 \times 10^{-3}\ \text{watts} = 0.25\ \text{watts}$$

2) If a real windmill could generate an average of 2,500 times this much power, how many kilowatt-hours of energy could a windmill in continuous operation generate each year?

If the model windmill can generate

$$0.25 \text{ \sout{watts}} \times \frac{1 \text{ kW}}{1{,}000 \text{ \sout{watts}}} \times \frac{24 \text{ \sout{hours}}}{\text{\sout{day}}} \times \frac{365 \text{ \sout{days}}}{\text{year}} = \frac{2.2 \text{ kWh}}{\text{year}}$$

then a real windmill could generate

$$2{,}500 \times \frac{2.2 \text{ KWh}}{\text{year}} = \frac{5{,}500 \text{ kWh}}{\text{year}}$$

3) Suppose that you have been given the choice of purchasing electricity for $0.12 per kilowatt-hour or generating your own electricity using a windmill. The windmill costs $3,000 to purchase and $200 per year for upkeep.

a) If you use 5,000 kWh of electricity per year, how much money could you save in 10 years by using the windmill as your only source of electric power?

Purchasing electricity for 10 years costs

$$\frac{\$0.12}{\text{\sout{kWh}}} \times \frac{5{,}000 \text{ \sout{kWh}}}{\text{\sout{year}}} \times 10 \text{ \sout{years}} = \$6{,}000$$

Generating your own electricity for 10 years costs

$$\$3{,}000 + \left(\frac{\$200}{\text{\sout{year}}} \times 10 \text{ \sout{years}}\right) = \$3{,}000 + \$2{,}000 = \$5{,}000$$

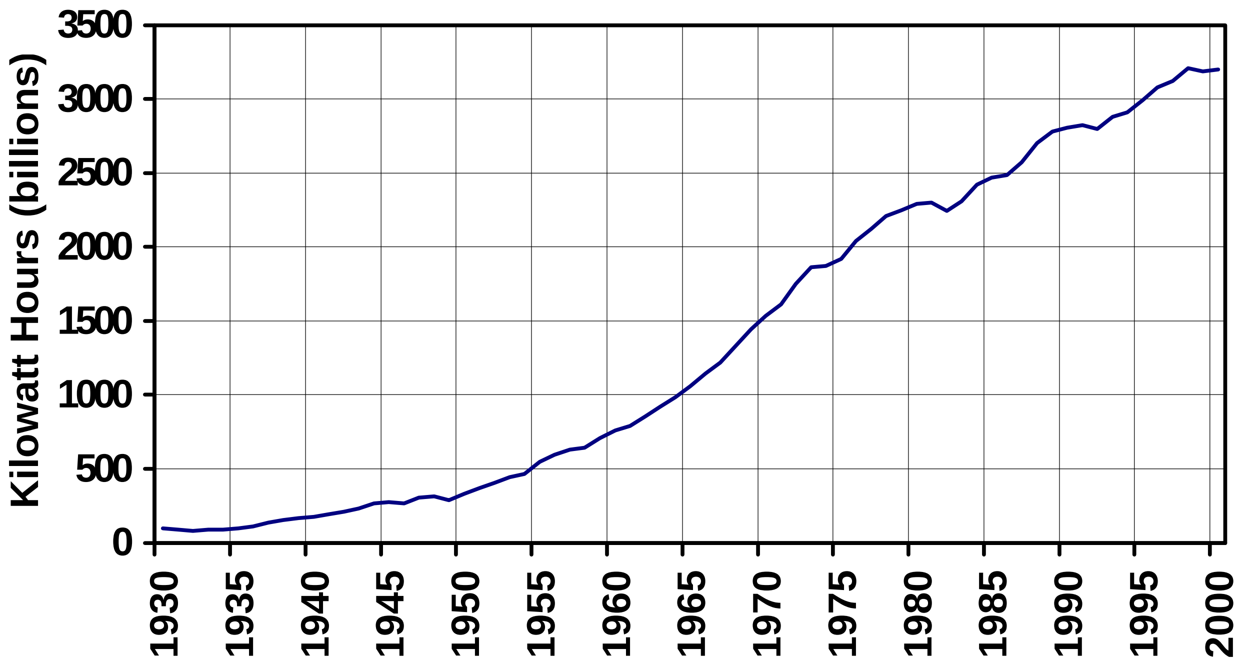
You save $6,000 - $5,000 = $1,000 after 10 years.

b) Is the payback time for the windmill more or less than 10 years? _**less**_

e) Group Discussion Question: You have just moved into an apartment and must decide which electric appliances to purchase. Your apartment is not air conditioned and you hear that the furnace is not very warm in winter. You are on a budget and can spend no more than $1,000 per year for electricity. Using the cost estimates in Table 9.2 in your textbook, decide which appliances you will use.

Activity 9.4: What Is the Difference between Linear and Exponential Growth?

Figure 1: Electricity Production in the U.S.



a) Identify the time periods during which the rate of increase in electricity production was approximately linear. **Between 1975 and 1995 the growth in electricity production was approximately linear.**

b) Explain how you determined that this growth was linear.

Between 1975 and 1985 production increased from approximately 2,000 billion kWh to 2,500 billion kWh, an increase of 500 billion kWh. Between 1985 and 1995, production again increased by approximately 500 billion kWh, from 2,500 billion kWh to 3,000 kWh. Production increased by a constant amount during these 10-year periods, so the growth was linear.

c) Identify the time periods during which the rate of increase in electricity production was approximately exponential. **Between 1955 and 1975 the growth in electricity production was approximately exponential.**

d) Explain how you determined that this growth was exponential.

Between 1955 and 1965, production doubled from approximately 500 billion kWh to 1,000 billion kWh. Between 1965 and 1975, production doubled from approximately 1,00 billion kWh to 2,000 billion kWh. Since production doubled during these periods, the growth was exponential.

e) What is the doubling time of the exponential growth periods? **_10 years_**