

Preview of Period 9: Power

9.1 Measuring the Power of Appliances

How much power do appliances use?

9.2 Measuring Your Power

How much power do you use for daily activities?

9.3 Measuring the Cost of Electricity

How much does electricity cost?

9.4 Growth in Electricity Use

How has electricity use increased over the past century?

Review of Work and Energy

Work is done on an object against a force.

- ◆ An object is lifted against the force of gravity
- ◆ A box is pushed across the floor against the force of friction.

$$W = F D$$

Objects gain **energy** when work is done on them.

- ◆ A raised object gains gravitational potential energy.
- ◆ A box pushed across the floor gains kinetic energy of motion.

$$E_{pot} = M g h \quad E_{kin} = \frac{1}{2} M v^2$$

Machines make tasks easier by reducing the force we must apply (F_{in}), but they cannot reduce the amount of work needed.

What is Power?

Power is a rate describing the amount of work done per unit of time:

Power = Work/time elapsed

$$P = \frac{W}{t}$$

We can also think of power as the amount of energy transferred per unit time:

Power = Energy transferred/time elapsed

$$P = \frac{E}{t}$$

Power is measured in units of joules/second.

One joule/second = 1 watt

Power is also measured in ft-lbs/sec or horsepower (hsp).

One horsepower = 746 watts

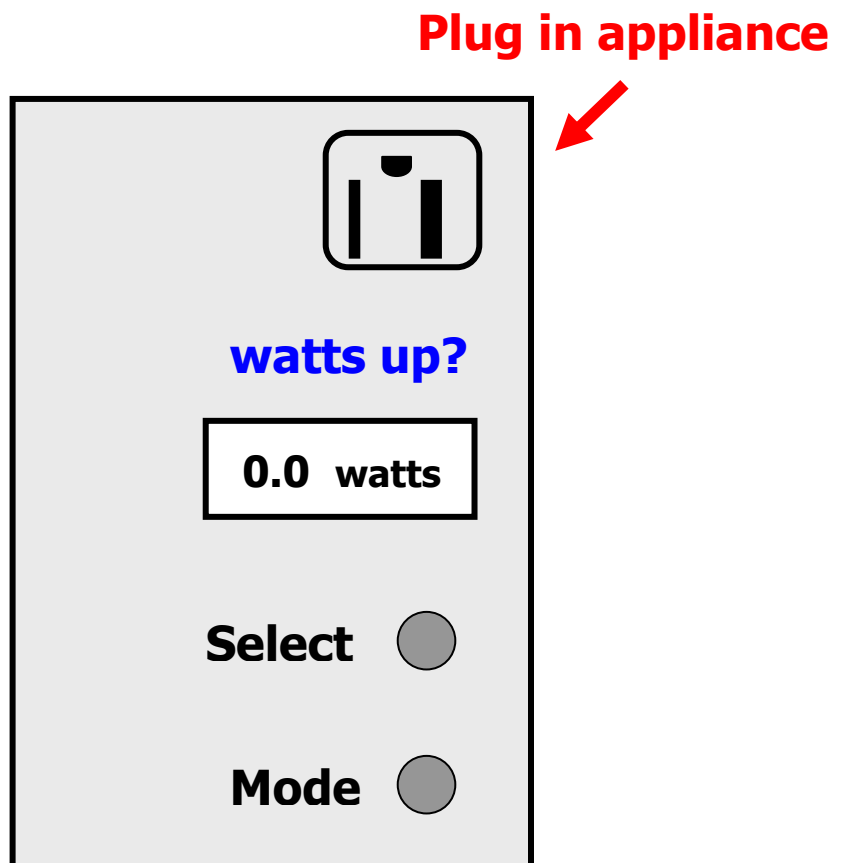
One ft-lb/sec = 0.0018 hsp = 1.36 watts

Act. 9.1- 9.2: Power Requirements

- Light the bulbs using power generated by your muscles. Which energy conversions take place as you crank the generator?
- Do the power requirements of the appliances match their wattages? Which has the largest power requirement?
- How does increasing the “load” on the drill affect its power requirement?
- Time yourself climbing the stairs. How much gravitational potential energy do you gain? Calculate the power required.
- How much energy is required to light the bulbs connected to the exercise bicycle?

Measuring Power with a Wattmeter

- 1) Plug the wattmeter into the power strip.
- 2) Plug the appliance into the outlet in the front of the wattmeter.
- 3) Turn the appliance on. The appliance wattage appears in the display screen.



Act. 9.3: The Cost of Electricity

Power companies charge for electricity in units of **kilowatt hours (kWh)**. One kilowatt hour is 1,000 watts of energy provided per hour.

- ◆ The energy used equals the power required by the appliance multiplied by the operating time.
- ◆ Find the energy used by an appliance by solving the power equation for energy, E .

$$P = \frac{E}{t} \quad \text{or} \quad E = P t$$

P = power (in watts)

E = energy (in joules)

t = time (in seconds)

(Example)

How many kilowatt hours of energy are used when a 100 watt light bulb burns for 6½ hours?

$$\cancel{100 \text{ watts}} \times \frac{1 \text{ kilowatt}}{\cancel{1,000 \text{ watts}}} \times 6.5 \text{ hours} = 0.65 \text{ kWh}$$

Calculations with Electricity Costs

Example 1: Find the total cost of electricity

If electricity costs 7.5 cents/kWh, what is the cost of 0.44 kWh of electricity?

$$0.44 \text{ kWh} \times \frac{\$0.075}{\text{kWh}} = \$0.033$$

Example 2: Find the cost per kilowatt hour

If 0.44 kWh of electricity costs 3.3 cents, what is the cost of electricity per kWh?

$$\$0.033 \times \frac{1}{0.44 \text{ kWh}} = \frac{\$0.075}{\text{kWh}}$$

Example 3: Find the kWh used.

If electricity costs 7.5 cents/kWh, how many kWh can you buy for 3.3 cents?

$$\$0.033 \times \frac{1 \text{ kWh}}{\$0.075} = 0.44 \text{ kWh}$$

Minimizing Electricity Costs

Payback time is the time it takes to recover the additional cost of purchasing an energy efficient, more expensive appliance from the savings in energy costs.

(Example 9.5)

A 25 watt CF bulb costs \$5 to purchase and lasts for 10,000 hours. A 75 watt incandescent bulb costs \$0.50 to purchase and lasts for about 750 hours. If electricity costs \$08.5/kWh, what is the cost of purchasing and operating each type of bulb for 10,000 hours?

Compact Fluorescent Bulb

1. Operating cost of CF bulb:

$$25 \text{ ~~watts~~} \times \frac{1 \text{ ~~kilowatt~~}}{1,000 \text{ ~~watts~~}} \times 10,000 \text{ ~~hrs~~} \times \frac{\$0.085}{\text{~~kilowatt hour~~}} = \$21.25$$

2. Purchase price of CF bulb = \$5.00

3. Total cost = \$21.25 + \$5.00 = \$26.25

Minimizing Electricity Costs, Continued

Incandescent Bulb

1. Operating cost of incandescent bulb:

$$75 \text{ watts} \times \frac{1 \text{ kilowatt}}{1,000 \text{ watts}} \times 10,000 \text{ hrs} \times \frac{\$0.085}{\text{kilowatt hour}} = \$63.75$$

2. Number of bulbs needed for 10,000 hrs:

$$10,000 \text{ ~~hours~~} \times \frac{1 \text{ bulb}}{750 \text{ ~~hours~~}} = 14 \text{ bulbs}$$

3. Purchase price of bulbs:

$$14 \text{ ~~bulbs~~} \times \frac{\$0.50}{\text{~~bulb~~}} = \$7.00$$

4. Total cost = \$63.75 + \$7.00 = \$70.75

Compare the cost of the two types of bulbs:

$$\frac{\text{Cost of Incandescent}}{\text{Cost of CF}} = \frac{\$70.75}{\$21.25} = 3.3$$

Using an incandescent bulb for 10,000 hours costs 3.3 times more than using a CF bulb.

Estimated Power Requirements of Appliances

Appliance	Average Wattage of Appliance	Annual Kilowatt-Hours	Annual Cost at \$0.10 per Kilowatt-Hour
FOOD PREPARATION			
Blender	720	15	\$1.50
Coffee Maker	900	100	\$10.00
Dish Washer	1200	360	\$36.00
Freezer (frostless, 15 cu ft)	440	1800	\$180.00
Frying Pan	1200	200	\$20.00
Mixer	130	13	\$1.30
Oven, microwave	1500	300	\$30.00
Oven, self cleaning	3000	1100	\$110.00
Range	8200	1200	\$120.00
Refrigerator (frostless, 12 cu ft)	320	1200	\$120.00
Toaster	1100	40	\$4.00
Waste Disposal	450	30	\$3.00
LAUNDRY			
Clothes Dryer	5000	1000	\$100.00
Iron (hand)	1000	140	\$14.00
Washing Machine	500	100	\$10.00
Water Heater	2500	4200	\$420.00
COMFORT			
Air Conditioner (room)	1600	1400	\$140.00
Electric Blanket	200	150	\$15.00
Dehumidifier	300	400	\$40.00
Fan (rollaway)	170	140	\$14.00
Heater (portable)	1300	180	\$18.00
Humidifier	180	160	\$16.00
Lamp, Incandescent	100	180	\$18.00
Lamp, Fluorescent	15	27	\$2.70
Waterbed Heater	400	720	\$72.00
HYGIENE			
Hair Dryer	1000	14	\$1.40
Shaver	14	2	\$0.20
Toothbrush	7	5	\$0.50
INFO/ENTERTAINMENT			
Television	70	56	\$5.60
Stereo	50	40	\$4.00
Personal Computer	100	225	\$22.50

Act. 9.4: Growth Rates

Linear Growth

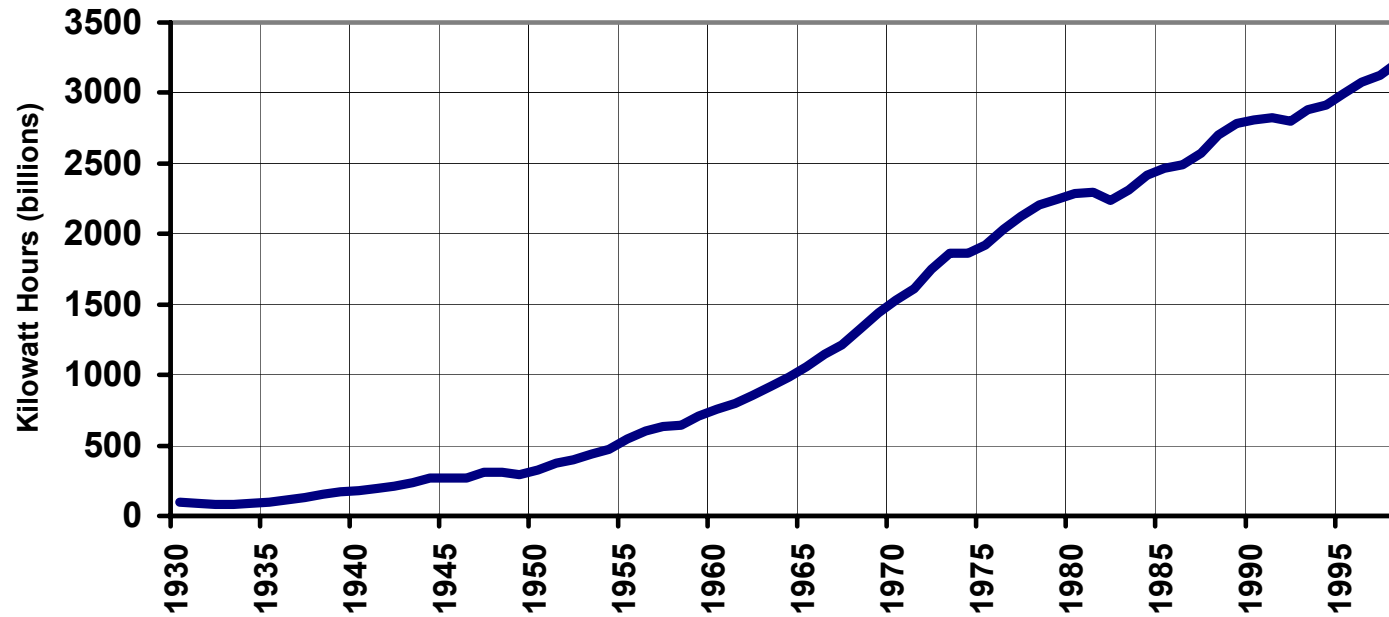
- ◆ Linear growth is **constant**. Its graph is a straight line.
- ◆ The **same amount** is added during each time period.
- ◆ The amount added is independent of the initial amount.
- ◆ The amount added is independent of the number of elapsed time periods.

Exponential Growth

- ◆ Exponential growth is **not constant**. Its graph is an upward curving line.
- ◆ The amount added changes with each time period.
- ◆ Exponential growth **doubles the amount** of the quantity during each time period.
- ◆ The amount added depends on the initial amount and on the number of time periods.
- ◆ The **doubling time** is the length of time required for the quantity to double.

Act. 9.4: Growth Rates

Electricity Production in the U.S.



Period 9 Summary

9.1:Power is the rate at which work is done or energy is transferred.

$$P = W/t \quad \text{or} \quad P = E/t$$

Power is measured in joules/second, or watts, in metric units and in ft-lbs/second or horsepower in English units.

9.2:Electrical energy provided to homes is measured and billed in kilowatt hours.

9.3:Payback time is the time it takes to recover the additional cost of purchasing an energy efficient, more expensive appliance from the savings in energy costs.

Period 9 Summary, Continued

9.4: Electricity production in the U.S. has grown rapidly - at times linearly and at other times exponentially.

- ◆ Linear growth adds a **constant amount** to the initial amount each time period.
- ◆ Linear growth rates are **independent of the initial amount and the number of time periods.**



Exponential growth **doubles** the amount each time period.

- ◆ Exponential growth rates are **dependent on the initial amount and on the number of time periods elapsed.**
- ◆ The time needed to double a quantity is called its **doubling time.**

Period 9 Review Questions

- R.1** What is power? Give a definition and equations.
- R.2** Which of the following appliances would be likely to use the most energy per second: microwave oven, washing machine, refrigerator, or toaster?
- R.3** What is a kilowatt-hour? What quantity does the electric company bill you for – power, energy, or some other quantity?
- R.4** How could it be profitable for a power company to encourage customers to use less electricity?
- R.5** How can you determine whether a graph is increasing linearly or exponentially?