

# 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**

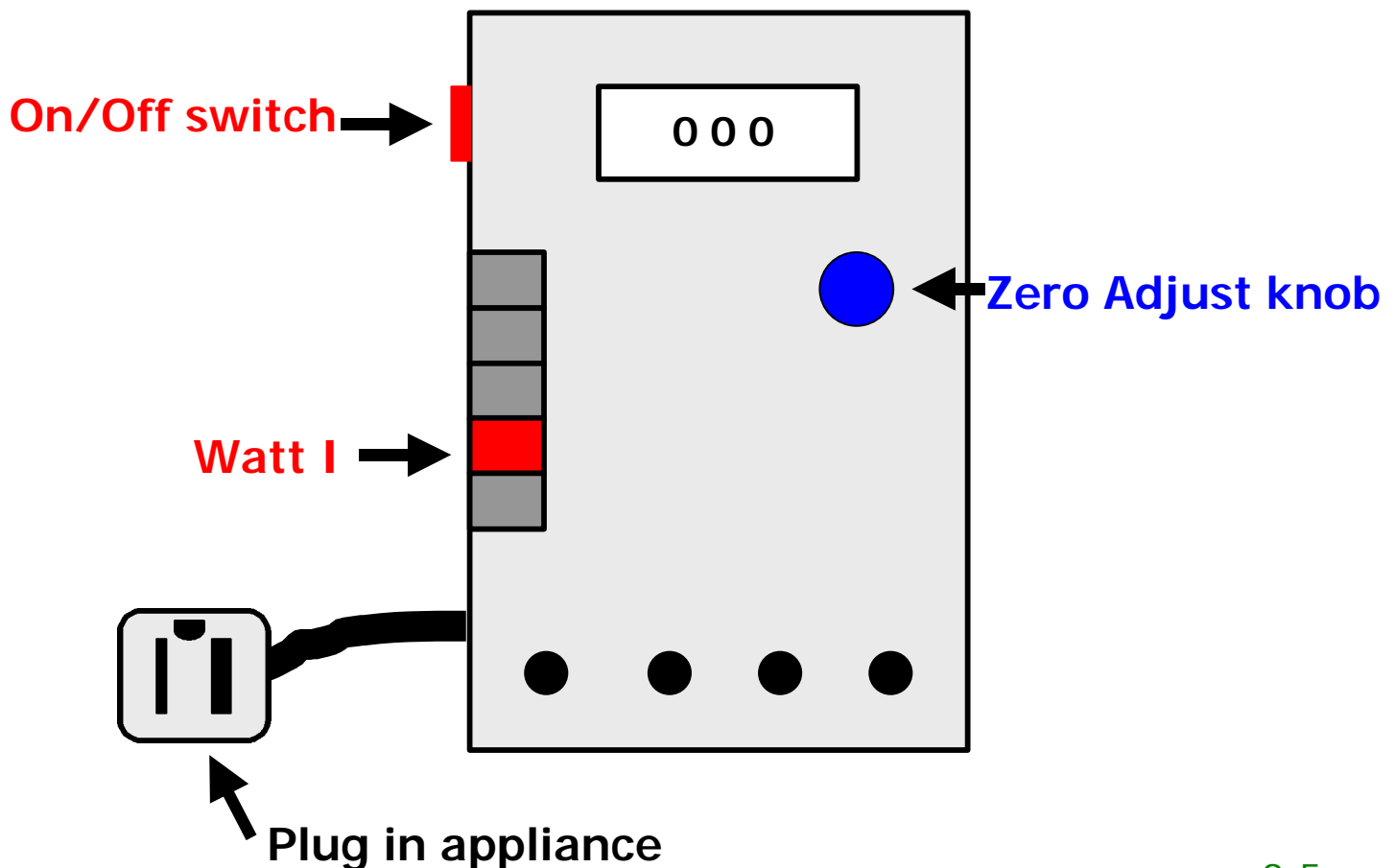
**One ft-lb/sec = 0.0018 hsp = 1.36 watts**

## 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 and turn it **on**.
- 2) Press the **"Watt I"** button.
- 3) Clear the meter by adjusting the **Zero Adjust knob** until the display reads 0 0 0.
- 4) Plug the appliance into the outlet in the cord attached to the wattmeter.
- 5) Read the power requirement.
- 6) **Turn the meter OFF when you finish!**



## 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?

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

## 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?

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

## 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 \$0.085/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
<b>FOOD PREPARATION</b>			
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
<b>LAUNDRY</b>			
Clothes Dryer	5000	1000	\$100.00
Iron (hand)	1000	140	\$14.00
Washing Machine	500	100	\$10.00
Water Heater	2500	4200	\$420.00
<b>COMFORT</b>			
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
<b>HYGIENE</b>			
Hair Dryer	1000	14	\$1.40
Shaver	14	2	\$0.20
Toothbrush	7	5	\$0.50
<b>INFO/ENTERTAINMENT</b>			
Television	70	56	\$5.60
Stereo	50	40	\$4.00
Personal Computer	100	225	\$22.50

## Act. 9.4: Growth Rates

### Linear Growth

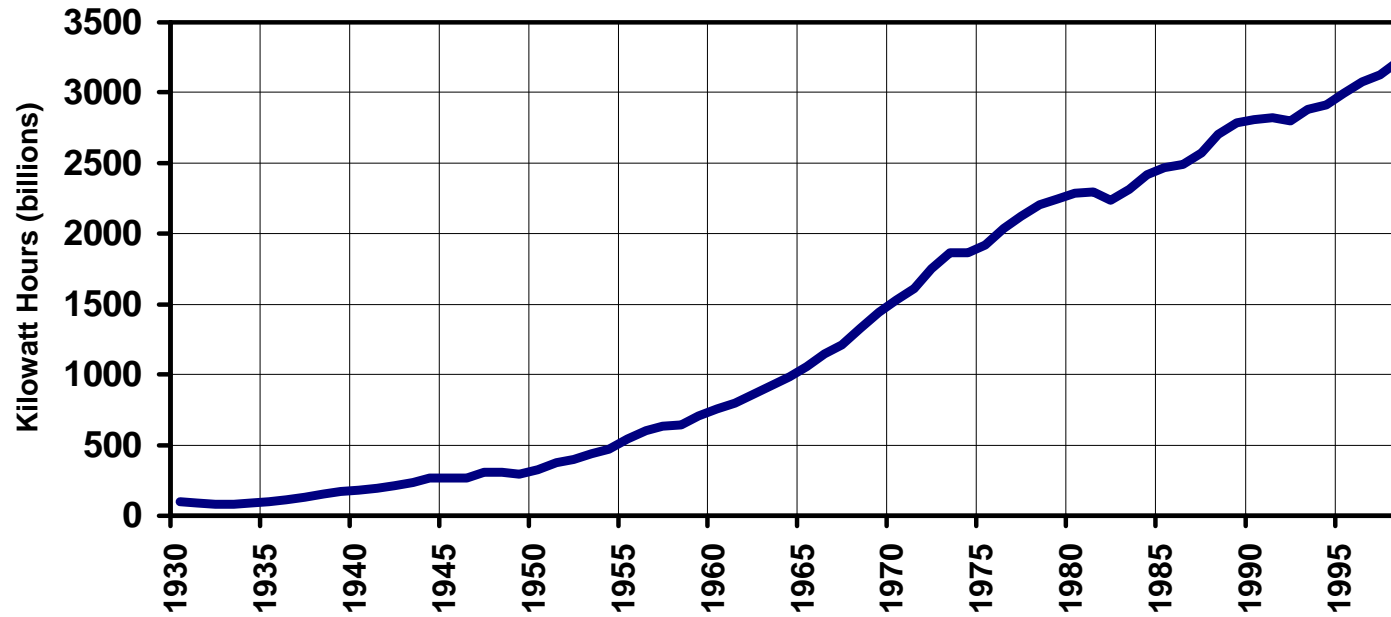
- ◆ Linear growth is **constant**. Its graph is a straight line.
- ◆ The **same amount** is added during each time period.
- ◆ The amount added is independent of the initial amount.
- ◆ The amount added is independent of the number of elapsed time periods.

### 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 power per year: microwave oven, washing machine, refrigerator, toaster, or range?
- 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?