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.

\[ W = F \cdot D \]

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.

\[ E_{\text{pot}} = M \cdot g \cdot h \quad E_{\text{kin}} = \frac{1}{2} M \cdot v^2 \]

Machines make tasks easier by reducing the force we must apply (\( F_{\text{in}} \)), 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:

\[ \text{Power} = \frac{\text{Work}}{\text{time elapsed}} \]

\[ P = \frac{W}{t} \]

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

\[ \text{Power} = \frac{\text{Energy transferred}}{\text{time elapsed}} \]

\[ P = \frac{E}{t} \]

Power is measured in units of joules/second.

One joule/second = 1 watt

Power is measured in units of ft-lbs/sec, also called horsepower (hsp).

One horsepower = 746 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.

\[
P = \frac{E}{t} \quad \text{or} \quad E = Pt
\]

\[
P = \text{power (in watts)} \quad E = \text{energy (in joules)} \quad t = \text{time (in seconds)}
\]

(Example)

How many kilowatt hours of energy are used when a 100 watt light bulb burns for 6.5 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?

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

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?

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

Example 3: Find the kWh used.

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

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

An 18 watt CF bulb costs $12 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:

\[
18 \text{ watts} \times \frac{1 \text{ kilowatt}}{1,000 \text{ watts}} \times 10,000 \text{ hrs} \times \frac{0.085}{\text{kilowatt hour}} = 15.30
\]

2. Purchase price of CF bulb = $12.00

3. Total cost = $15.30 + $12.00 = $27.30
Minimizing Electricity Costs, Continued

Incandescent Bulb

1. Operating cost of incandescent bulb:

\[
75 \text{ watts} \times \frac{1 \text{ kilowatt}}{1,000 \text{ watts}} \times 10,000 \text{ hrs} \times \frac{0.085}{\text{ kilowatt hour}} = 65.75
\]

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:

\[
\text{Cost of Incandescent} = \frac{70.75}{27.30} = 2.6
\]

Using an incandescent bulb for 10,000 hours costs 2.6 times more than using a CF bulb.
**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.

\[ P = \frac{W}{t} \quad \text{or} \quad P = \frac{E}{t} \]

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.
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 if operated for the same length of time: microwave oven, washing machine, refrigerator, or toaster, or range?

R.3 What is a kilowatt hour? How is the amount of your monthly electric bill determined?

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?