



Math Skills Laboratory

MATH ACTIVITIES

Activity 1: Using SI Prefixes

Activity 2: Solving Thermal-rate Problems

MATH SKILLS LAB OBJECTIVES

When you complete these activities, you should be able to do the following:

- 1. Express a numerical value and unit, such 3.4×10^{-3} meters, in prefix notation (3.4 millimeters).*
 - 2. Rearrange the equation for heat-flow rate, $Q_H = \frac{H}{t}$. Solve for heat energy (H) or elapsed time (t).*
 - 3. Rearrange the equation for heat-flow rate caused by a temperature difference across a substance, $Q_H = \frac{kA\Delta T}{\ell}$. Solve for thermal conductivity (k), area of the substance (A), temperature difference across the material (ΔT) or the material thickness (ℓ).*
 - 4. Substitute appropriate numerical values and units in rate equations. Solve the equations.*
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LEARNING PATH

- 1. Read the Math Skills Lab. Give particular attention to the Math Skills Lab Objectives.*
 - 2. Study examples given in Table 1.*
 - 3. Work the problems for Activities 1 and 2.*
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ACTIVITY 1

Using SI Prefixes

Table 1 gives **examples** of certain physical quantities expressed as numbers with units. These are listed in Column 1. In the next column, these numbers are restated in equal *power-of-ten* units. In the final column, these same numbers are written with correct prefixes.

TABLE 1. USE OF SI PREFIXES

Physical Quantity	Quantity Restated in Power-of-ten Notation	Quantity Expressed with Prefix Notation
12,000 newtons (N)	$12 \times 10^3 \text{ N}$	12 kN
0.000325 meters (m)	or $0.325 \times 10^{-3} \text{ m}$ $325 \times 10^{-6} \text{ m}$	0.325 mm 325 μm
1401 volts (V)	$1.401 \times 10^3 \text{ V}$	1.401 kV
34,200 watts (W)	$34.2 \times 10^3 \text{ W}$	34.2 kW
1.87×10^{-7} seconds (sec)	or $0.187 \times 10^{-6} \text{ sec}$ $187 \times 10^{-9} \text{ sec}$	0.187 μsec 187 nsec
3.28×10^7 joules (J)	$32.8 \times 10^6 \text{ J}$	32.8 MJ
9,500 grams	$9.5 \times 10^3 \text{ gm}$	9.5 kg

Let's take a look at the first entry in Table 1. You can see that 12,000 N can be written in different ways.

$$12,000 \text{ N} = 12 \times 10^3 \text{ N} = 12 \text{ kilonewtons (or 12 kN)}$$

The prefix "kilo" equals 10^3 . The other examples in Table 1 are done the same way. Note carefully that there's more than one choice for writing a number in *power-of-ten* notation. For example, 0.000325 m can be written **either** as $0.325 \times 10^{-3} \text{ m}$ or $325 \times 10^{-6} \text{ m}$. The first choice leads to 0.325 millimeter, the second to 325 micrometers.

Note to the Student: If you have difficulty changing a number to power-of-ten notation or prefix notation, as in Table 1, you may wish to read **Preparatory Math Skills Activities 9, 10, 11, and 12**. These activities will show you how to write decimal numbers as power-of-ten numbers and **vice-versa**. You'll also learn about scientific notation and names/symbols used to indicate power-of-ten prefixes. After you have studied these activities, you should understand what's going on in Table 1.

PRACTICE EXERCISES FOR ACTIVITY 1

Complete the following exercises by expressing the physical quantity (number and unit) given in power-of-ten units and prefix units. Follow the examples in Table 1.

Physical Quantity		Power-of-Ten Units	Prefix Units
18.6 × 10 ⁷ joules		_____ × 10 ³ J	_____
	or	_____ × 10 ⁶ J	_____
6050 hertz		_____ × 10 ³ Hz	_____
1000 volts		_____ × 10 ³ V	_____
1.91 × 10 ⁻⁷ seconds		_____ × 10 ⁻⁶ sec	_____
	or	_____ × 10 ⁻⁹ sec	_____
3200 grams		_____ × 10 ³ gm	_____

ACTIVITY 2

Solving Thermal-rate Problems

EQUIPMENT

For this activity, you'll need a hand calculator.

This activity will give you practice in combining the skills learned in rearranging equations to isolate an unknown. This activity also will help you solve for an unknown quantity by substituting appropriate numerical values and units in thermal rate equations. Before you begin to solve problems, review the following equations and what the symbols mean.

The equation for heat-flow rate is stated as follows:

$$\text{Heat-flow Rate} = \frac{\text{Amount of Heat Transferred}}{\text{Elapsed Time}} \quad \text{Equation 1}$$

To simplify Equation 1, use the following symbols:

$$Q_H = \frac{H}{t} \quad \text{Equation 2}$$

where: Q_H = heat-flow rate (Btu/hr, kcal/sec, or cal/sec)
H = amount of heat energy transferred (Btu or cal)
t = elapsed time (hour, min, sec)

The equation for amount of heat transferred is as follows:

$$\text{Amount of Heat Transferred} = \text{Mass} \times \text{Specific Heat} \times \text{Temperature Difference} \quad \text{Equation 3}$$

To simplify Equation 3, use the following symbols:

$$H = mc\Delta T \quad \text{Equation 4}$$

where: H = amount of heat energy added or transferred to a body to cause a temperature rise (Btu, kcal, or cal)
m = mass of the body that undergoes a temperature rise (kg, gm or lb)
c = specific heat $\frac{\text{kcal}}{\text{kg}\cdot\text{C}^\circ}$ or $\frac{\text{Btu}}{\text{lb}\cdot\text{F}^\circ}$
 ΔT = temperature change of the body (C° or F°)

The heat-flow rate through a substance of uniform thickness with a temperature difference across opposite faces is given by the following equation:

$$Q_H = \frac{kA \Delta T}{\ell} \quad \text{Equation 5}$$

where: Q_H = heat-flow rate (Btu/hr, kcal/sec, cal/sec) through the material

k = thermal conductivity constant $\left[\frac{\text{Btu} \cdot \text{in.}}{\text{hr} \cdot \text{ft}^2 \cdot \text{F}^\circ} \text{ or } \frac{\text{cal} \cdot \text{cm}}{\text{sec} \cdot \text{cm}^2 \cdot \text{C}^\circ} \right]$

A = area of material (ft^2 , in^2 , m^2 , cm^2)

ΔT = temperature difference (F° , C°)

ℓ = uniform thickness of material (in., cm)

PRACTICE EXERCISES FOR ACTIVITY 2

Use one of the preceding equations to solve the thermal rate problems in the exercises that follow.

Problem 1: Given: A plywood-drying oven produces 250,000 Btu of heat during a 30-minute drying cycle.

Find: The heat-flow rate (Q_H) for the oven in Btu/hr.

Solution: (**Hint:** Use the equation, $Q_H = \frac{H}{t}$. Change $t = 30 \text{ min}$ to $t = 0.5 \text{ hr}$ before substituting into the equation.)

Problem 2: Given: The refrigeration unit on a meat-delivery truck is rated at 3 ton/hr (that is, 36,000 Btu/hr).

Find: The amount of heat the refrigeration unit will remove if it operates for 3.5 hours during an 8-hr on/off cycle.

Solution: (**Hint:** Use the equation, $Q_H = \frac{H}{t}$. Rearrange to isolate H . Then solve for H , knowing t and Q_H .)

Problem 3: Given: A sterilizer heating element used in a hospital is rated at 850 cal/min. It requires 1.8×10^5 calories of heat to sterilize instruments.

Find: The amount of time the heating element must operate to meet the sterilization standard.

Solution: (**Hint:** Use the equation, $Q_H = \frac{H}{t}$. Rearrange to isolate t . Then solve for t , knowing Q_H and H .)

Problem 4: Given: The refrigerated truck in Problem 2 is insulated with 3 inches of corkboard. Insulation made of corkboard has a thermal conductivity of $k = 0.30 \frac{\text{Btu} \cdot \text{in.}}{\text{hr} \cdot \text{ft}^2 \cdot \text{F}^\circ}$. The surface area on **one** side of the truck is 72 ft^2 . The outside temperature is 80°F , while the refrigerator temperature inside is 30°F .

Find: The heat-flow rate into the truck through one side. (Disregard the aluminum truck siding that usually covers the corkboard.)

Solution: (**Hint:** Use the equation, $Q_H = \frac{kA \Delta T}{\ell}$. Substitute values for k , A , ΔT and ℓ . Handle the units carefully.)

Student Challenge

Problem 5: Given: Conditions stated in Problems 2 and 4.
Find: The time, in minutes, that the 36,000-Btu/hr refrigeration unit in Problem 2 should operate **each hour** to remove the heat that comes in through the 72-ft² section of wall on the truck each hour (from Problem 4).

Solution: (**Hint:** Use the answers to Problem 2 and Problem 4 to help you solve this problem. You can do it!)

Problem 6: Given: Conditions stated in Problem 4, where thermal conductivity of corkboard is $k = 0.30 \frac{\text{Btu} \cdot \text{in.}}{\text{hr} \cdot \text{ft}^2 \cdot \text{F}^\circ}$, and the corkboard is 3 inches thick. The **temperature difference** between the inside and outside of the truck refrigerator is 50 F°.

Find: The total surface area (A) of the refrigerator truck in Problem 4 if the heat-flow rate into the truck is 2320 Btu/hr.

Solution: (**Hint:** Use the equation, $Q_H = \frac{kA\Delta T}{\ell}$ and rearrange it to isolate A. Then substitute values for Q_H , ℓ , k and ΔT .)

Problem 7: Given: A piece of brass, with specific heat, $c = 0.091 \text{ cal/gm} \cdot \text{C}^\circ$, is cooled from 80°C to 40°C. The heat-flow rate out of the material is 15.16 cal/sec for 20 minutes. (Assume the heat-flow rate is constant.)

Find: a. The heat given up by the brass.
b. The mass of the piece of brass.

Solution: (**Hint:** In Part a use the equation, $Q_H = \frac{H}{t}$. Rearrange to solve for H. Then substitute in known values of Q_H and t . In Part b, rearrange the equation, $H = mc\Delta T$, to solve for m . Then substitute known values of H [from Part a], c and ΔT .)

Problem 8: Given: While helping build a new home, the heating and air-conditioning technician decided to install a solar-powered heating system that uses a heat-storage tank. Space available for the tank is limited to one cubic meter (1 m³). The tank will hold 1000 kg of water (which has a specific heat $c = 1.0 \text{ kcal/kg} \cdot \text{C}^\circ$) or 2400 kg of crushed stone (which has a specific heat $c = 0.192 \text{ kcal/kg} \cdot \text{C}^\circ$). The temperature of either substance is to be raised 40 C°.

Find: a. The amount of heat that can be stored in each substance with a 40-C° temperature rise.
b. Which substance the technician should use if all other conditions are equal.

Solution: (**Hint:** For Part a, use the heat-transfer equation, $H = mc\Delta T$, for each substance—water and crushed stone.)