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ABSTRACT

This Teacher Education and Mathematics (TEAM) content module focuses on metric measurement. Topics addressed include decimal structure and prefixes, precision in measurement, reference measures, United States customary and metric systems, volume, area, and conversion. The module consists of: (1) an instructor's text; (2) an instructor's guide and solutions to student exercises; (3) student materials and exercises; and (4) student summary and review. The instructor's text provides specific directions for guiding lessons and commentary on mathematics content and mathematics attitudes. This is accomplished by a "facing pages" format whereby the right-hand page provides step-by-step teaching directives while the left-hand page provides teaching insights, other options of instruction, and psychological or attitudinal strategies, when appropriate. The guide and solutions to exercises gives the instructor approaches to the exercises and solutions to problems. Student materials and exercises provide such items as diagrams, charts, and centimeter-squared paper to be used by students. Exercises include problems that apply the concepts and problem-solving strategies developed in the module; they may be used as part of the instructional activities, as content for small-group activities, as homework assignments, or as review materials. The student summary and review summarizes the content of the module, focusing on formulas, terminology, key concepts, problem-solving strategies, and examples of techniques used. (JN)

Metric Measurement

A Course to Reduce Math Anxiety and Sex-Role Stereotyping in Elementary Education

TEAM

TEACHER EDUCATION AND MATHEMATICS

Queens College of the City University of New York
Women's Educational Equity Act Program/U.S. Department of Education

TEAM

TEACHER EDUCATION AND MATHEMATICS

A Course to Reduce Math Anxiety and Sex-Role Stereotyping in Elementary Education

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INTRODUCTION

The Metric Measurement module consists of an Instructor's Text, Instructor's Guide and Solutions to Student Exercises, Student Materials Exercises, and Student Summary and Review.

The Instructor's Text provides the instructor with (1) specific directions for guiding lessons and (2) commentary on the math content and on math attitudes. This is accomplished by a special "facing pages" format. The right-hand page provides the instructor with the presentation modes of problems and teaching directives, while the left-hand page, "Commentary and Notes," provides teaching insights, other options of instruction, and, often, psychological strategies. Space for the instructor to add her or his own notes about a particular point in the lesson or about teaching experiences with the class (for future reference and use) is also provided on the left-hand page. In other words, the directions on the right-hand page clearly point out to the instructor what steps to take in presenting the lesson, while the commentary/notes page on the left supplements the instruction with explanations, additional instructional options, attitudinal interventions, and organizational alternatives to the teaching presentation. The Instructor's Text includes a set of content objectives, specified to indicate the scope and structure of the module, and student evaluation materials that contain several questions for each objective so that the instructor can select items for quizzes.

The Instructor's Guide and Solutions to Student Exercises gives the instructor approaches to the exercise materials and solutions for the problems.

Student Materials and Exercises provides such things as diagrams, charts, and centimeter-squared paper to be used by the students. Instructors should plan to make transparencies of appropriate materials for use on overhead projectors during class time. The exercises include problems that apply the concepts and problem-solving strategies developed in the module. These problems can be used as part of the instructional activities, as content for small-group activities, as homework assignments, or as review materials.

Student Summary and Review summarizes the content of the module (formulas, terminology, key concepts, problem-solving strategies, and examples of techniques used). These notes are to be given to students after they have participated in the learning activities of the module.

Finally, the instructor's attention is drawn to the following list of materials (page x) needed to present the lessons as outlined in the Instructor's Text.

LIST OF MATERIALS NEEDED

The following materials will be needed to present the lessons in Metric Measurement:

- Metric measuring tapes
- Metric scale for measuring body weight (mass)
- Chart for measuring height
- Celsius oral thermometer
- Meter stick
- Cubic decimeter box
- Centimeter cubes (a handful)
- Cubic meter demonstration model
- Square meter
- Mass pieces: kilogram and others
- One-gram packets of artificial sweetener
- Centimeter-squared paper (see Student Materials and Exercises, pages III-3 and III-4, for reproducible samples)
- Cardboard decimeter strips (about one centimeter wide--not calibrated)
- Lined index cards (or narrowly ruled paper)
- One roll of adding machine or cash register tape
- Small coffee can
- New pencil (not sharpened)
- Small objects for students to measure (paper clip, coat button, thumbtack, aspirin tablet, etc.)
- Station signs (optional), labeled as follows: STATION 1, STATION 2, STATION 3, WEIGH-IN, TEMPERATURE STATION, and HEIGHT
- Large tables

METRIC MEASUREMENT

I

INSTRUCTOR'S TEXT

OBJECTIVES

The objectives of the Metric Measurement module are:

1. Select appropriate metric units to measure length, area, volume (capacity), mass (weight), and temperature.

2. Estimate, using metric units.

3. Make comparisons between commonly used metric units and parts of the body or familiar objects in the environment.

4. Convert and compute within the metric system.

5. Demonstrate knowledge of concepts of measurement.

6. Use accepted standards for recording metric measurements.

7. Demonstrate knowledge of the structure of the metric system--e.g., the decimeter, cubic decimeter (liter), and kilogram relationship that defines the linear, volume (capacity), and mass systems.

These objectives are provided here to indicate the scope and structure of the module to you. A copy of these objectives should be distributed to students with the Student Summary and Review so that students can use them to organize their study and preparation for a quiz.

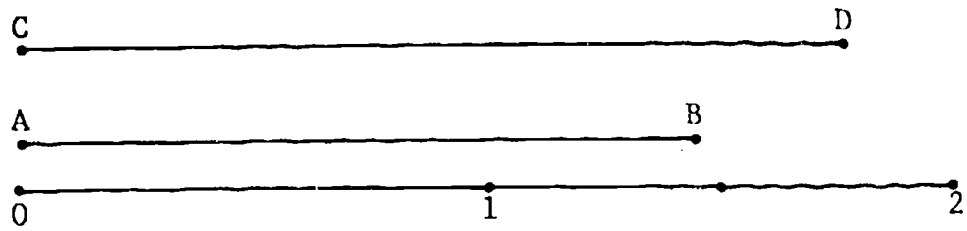
Sample items for the objectives are included at the end of this section of the module.

COMMENTARY AND NOTES

Some students may become anxious at the idea of a quiz. Explain that papers will not be collected nor will they be graded. This explanation will help students view the quiz as a way of assessing themselves and of seeing directly how much they have learned, without the onus of testing.

Allow about 45 minutes for students to work on the activities. Then engage the group in a discussion of what they have learned.

Item 1 on facing page: Emphasize that it is the midpoint that is used to decide upon the length. Thus segment $\overline{AB}$ has the length 1 decimeter, while segment $\overline{CD}$ is 2 decimeters long.



Item 2 on facing page: It may be useful to help students see the pattern that verifies that 11 points are needed to divide a segment into 10 equal parts.

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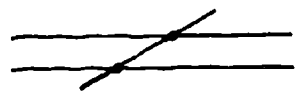
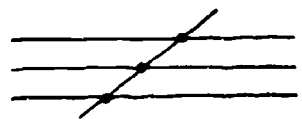
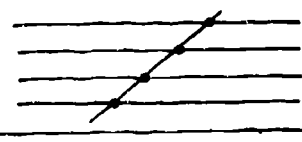
	2	1
	3	2
	4	3

Item 3 on facing page: Provide ruled index cards or narrowly ruled paper for students to use.

OBJECTIVES

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2. Estimate, using metric units.

3. Make comparisons between commonly used metric units and parts of the body or familiar objects in the environment.

4. Convert and compute within the metric system.

5. Demonstrate knowledge of concepts of measurement.

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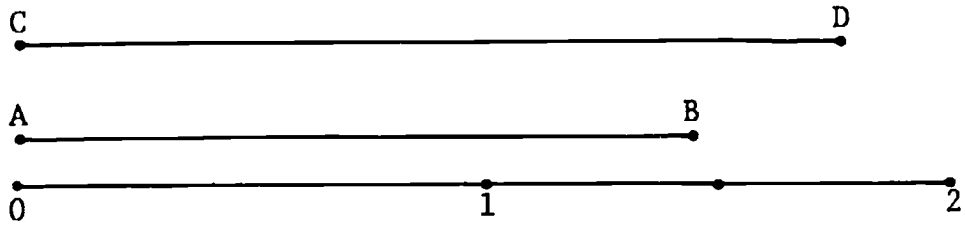

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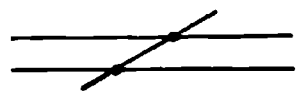
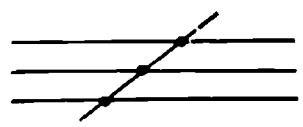
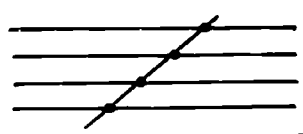
	2	1
	3	2
	4	3

Item 3 on facing page: Provide ruled index cards or narrowly ruled paper for students to use.

BEGINNING THE PROGRAM

Begin by distributing copies of the "Metric Quiz" (see Student Materials and Exercises, page III-7). Ask students to answer those questions with which they are comfortable. Tell students that they will be able to complete the quiz during the course of the metric measurement session as they clarify their understanding of the metric system, and let them know that the quiz will be discussed at the end of the session.

Next, distribute the worksheets "Linear Measurement Activities" and "Metric Me" (see Student Materials and Exercises, pages III-9 to III-11). Ask students to work in pairs. Some should be taking their own measurements while others are working on the linear measurement activities. Advise students that the linear measurement activities should be done in the sequence specified on the worksheet.

Be sure to move among the students, asking and answering questions as they work. Following are examples of the ideas that typically need clarification.

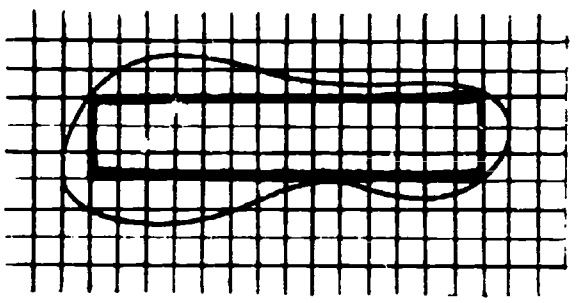
1. Using an uncalibrated measuring device (such as a decimeter strip) produces a whole number as the measure of the length. As an example, the height of the coffee can is about 1 dm. This is its height correct to the nearest decimeter. Even if a calibrated tool were used, in order to measure to the nearest decimeter one would ignore all subdivisions and use eye judgment to judge the nearest decimeter.

2. To subdivide the decimeter length into 10 equal parts, one needs 11 lines. The "Linear Measurement Activities" worksheet contains a guide. (Students will probably need help with this.)

3. Tell students to use the centimeter-squared paper (more can be reproduced by the instructor from page III-3 or III-4 of Student Materials and Exercises, if needed) to trace their feet. The number of whole squares should be counted, and the number of squares used by the partial squares can be estimated. This procedure can be facilitated by pointing out the arrays of squares that can be counted more rapidly by multiplying.

   Example:

   3 x 14 = 42



Area may be a topic that is not clearly understood. Tell students that more time will be devoted to discussing area a little later on. Right now students should be encouraged to proceed through the activities so that they can obtain the "flavor" of the different kinds of measurement tasks.

Remind students to estimate before measuring. Have them consider a pace to be the distance from the heel of one foot to the heel of the other, as one usually walks. It is a good idea to take several steps, measure the entire distance, and then compute the average.

After allowing time for students to work out some of the measurements, help them summarize what they have learned from their work. All measurement is approximate. Eye judgment and precision of measuring tools are only two of the factors that make it possible to obtain different answers for the measure of the same object. Encourage the use of the words about or approximately when referring to a measure.

If there is interest, point out that although the meter is now defined in terms of a light-wave spectrum of the gas Krypton 86, it has had two other definitions in the past. (Some students might enjoy investigating this history.) At one time the meter was defined as one ten-millionth of the great circle arc from the Equator to the North Pole. At another time it was standardized as the length of a metal bar kept by the French government. In any event, point out to students that the important thing is that there exists a standard length called the meter and that the metric system is built around it.

It would be helpful to prepare a transparency of the "Place Value Chart" and project it while the discussion takes place. Note that the place value chart has been set up to show the decimal structure of the numeration, monetary, and measurement systems.

This material uses the National Bureau of Standards notation for large numbers. The comma is no longer used to separate groups of three digits. Instead, a space is used. Thus, 3,487, 521 is written 3 487 521. In the case of four-digit numbers, neither a space nor a comma is used. Thus, 9438 is the correct form for a four-digit number.

Some students may measure the length and width of the foot and multiply these two measures to obtain the area of the footprint. Have them count the actual number of squares to see the fallacy of this approach.

Decimal Structure and Prefixes

Indicate to students that in the metric system, the meter (m) is the basic unit of length. Refer to the linear measurement activities to show that the metric system is a decimal system.

Demonstrate the subdivisions of the meter, using a meter stick. Define the prefixes for the subdivisions and multiples and give the symbols, calling attention to correct usage. Refer to the "Place Value Chart" (see Student Materials and Exercises, page III-5) during the discussion.

Present the subdivisions as follows:

deci	10 dm	=	1 m
centi	10 cm	=	1 dm; 100 cm = 1 m
milli	10 mm	=	1 cm; 100 mm = 1 dm; 1000 mm = 1 m

Present the multiples as follows:

deka	1 dam	=	10 m
hecto	1 hm	=	100 m
kilo	1 km	=	1000 m

Be sure to tell the students that these prefixes have the same meaning and are used in the same way with the liter, the basic unit of volume (capacity), and with the gram, the basic unit of mass (weight).

Make the following points:

1. Officially, the metric system is known as SI (for Systeme international d'unités), whereas the measurement system we use now is known as U.S. Customary.

2. Periods are not used with the metric symbols (mm, not mm.).

3. The letters of the symbols are always lowercase, except for liter (L) and Celsius (C).

COMMENTARY AND NOTES

Methods of converting from one unit of measure to another are discussed in another section of this module.

The zero (0) to the left of the decimal point is the conventional standard for indicating that the whole number part has not been omitted.

4. No plurals are used. Thus 10 cm, not 10 cms, is correct.

5. Mixed measures are never used. Thus 1 m, 6 dm, 2 cm should be expressed as 162 cm or 16.2 dm or 1.62 m.

6. The units used most frequently are the meter, the centimeter, the kilometer, the liter, the milliliter, the gram, and the kilogram.

Precision in Measurement

A measure such as 1.623 m indicates that the smallest unit of measure used is the millimeter, since the places have the following values:

meter	decimeter	centimeter	millimeter
1.6	2	3	

Thus 1.6 m, 1.60 m, and 1.600 m each convey different meanings about the precision of the measure. The last measure, 1.600 m, is the most precise. It is correct to the nearest millimeter, since there is a zero in the thousandths place. The measure 1.60 m shows that the centimeter is the smallest unit used, whereas the measure 1.6 m shows that the decimeter is the smallest unit used. When a measure such as 1.623 m is expressed in terms of dm, cm, or mm, the results appear as follows:

16.23 dm

162.3 cm

1623 mm

No matter which unit is used to express the result, the digit 3 represents the number of millimeters in the measure. Thus:

0.003 m = 3 mm

0.03 dm = 3 mm

0.3 cm = 3 mm

State the general principle concerning precision in measurement:

The smaller the unit used, the more precise is the measure.

Reference Measures

As you proceed with a discussion of the activities of this module, point out the importance of being able to refer to body measurements and the

There are other references that students may appreciate. For example, the diameter of the wire used in paper clips is about 1 millimeter. Other references are described in "All You Will Need to Know About Metric" (National Bureau of Standards Chart), page III-6 in Student Materials and Exercises.

Students who are accustomed to the U.S. Customary system typically want to convert to the more familiar U.S. Customary measures. Conversion should be avoided. Point out that reference measures should be used instead, to assist with estimating and appreciating metric measures.

measurements of familiar objects in the environment. Point out that the doorknob on a standard door is about a meter's distance from the floor.

Indicate that if a person is 162 cm tall, other lengths close to 162 cm can be estimated and appreciated in terms of that height. The width of the fingernail of the index finger is about 1 cm. How much snow is 3 cm of snow? Refer to the fingernail for help.

Ask: "Who was better able to choose a reasonable weight for a young woman after weighing himself or herself?"

Note that room temperature is about 20°C, while body temperature is about 37°C.

U.S. Customary and Metric Systems

Converting from one system to the other should be avoided. However, during the period of transition, students will find it helpful to make gross comparisons, such as:

- A meter is a little bit longer than a yard.
- A liter is a bit more than a quart.
- A kilogram is somewhat more than two pounds.

Help students clarify which metric units are the appropriate ones to use for specific tasks. During the discussion refer to "All You Will Need to Know About Metric" (see Student Materials and Exercises, page III-6). The following questions can be used to stimulate discussion:

1. Which metric unit would you use instead of the mile in U.S. Customary? (Kilometer)

2. Which metric unit would you use in place of the pound? (Kilogram)

3. What unit is used to measure one's height in the metric system? (Centimeter)

Be sure to point out to students that a measure expressed in metric units is not necessarily even close in numerical size to a measure expressed in U.S. Customary (for example, 37 degrees Celsius, but 98.6 degrees Fahrenheit).

COMMENTARY AND NOTES

Most students will recall the volume formula ($V = lwh$), but few students will understand its meaning. Take the time to show how the cubes form an array--an arrangement of objects in rows and columns--on the first floor, yielding the lw product, and then how h "floors" of blocks yield h(lw), or a total of lwh blocks.

Students may need clarification of the meaning of the symbols m^3, dm^3, cm^3. For instance, dm^3 is read "decimeter cubed" or "cubic decimeter." The digit 3 is used in a manner different from how the usual exponent is treated. No power or multiplication is intended. The symbol dm^3 is used in its entirety to denote the unit of measure used to measure volume.

You may wish to ask students to check packaged foods in a supermarket and report on the metric measures used for various items.

It is helpful to have a demonstration model of a cubic meter set up so that it and the cubic centimeter can be juxtaposed.

Ask students whether they have ever felt intimidated by very large numbers. Ask whether or not large numbers have had meaning for them.

The term mass may be unfamiliar to students and thus may produce some discomfort. It should be pointed out that one's mass remains unchanged - in the room, on top of a mountain, etc.--even though one's weight does vary according to the pull of gravity. Thus, the correct term is mass; we weigh an object to obtain its mass. (Do not, however, insist upon the correct usage by students. But do use the term correctly yourself, whenever possible, so that students can learn by example.)

The water must have the temperature 4°C. However, this additional information is not important to the structure of the metric system. It can be given or withheld at the instructor's discretion.

The packet of artificial sweetener is another example of a reference measure.

Volume

The Liter

Demonstrate a cubic decimeter as an open box, one decimeter long on each edge. Indicate that the capacity (volume) of the box is one liter. Show cylindrical containers of various shapes that also hold a liter.

Next, begin to cover the "first floor" of the cubic decimeter with centimeter cubes. Elicit from the students the understanding that 10 x 10, or 100, centimeter cubes fit on the first floor, and that there are 10 floors, hence 1000 cm^3, or 1 dm^3.

The prefix milli justifies the statement:

$$1000 \text{ mL} = 1 \text{ L}$$

Since 1 L = 1 dm^3, elicit from the students the conclusion that

$$1000 \text{ cm}^3 = 1000 \text{ mL, or } 1 \text{ cm}^3 = 1 \text{ mL}$$

Point out that it is not always the case that liquids are measured in milliliters while solids are measured in cubic centimeters. Both are used to measure volume.

Use a similar line of reasoning to relate cm^3 to m^3. Elicit from the students the understanding that 100 cm^3 fit along one edge, 100 x 100 on the floor, and 100 x 100 x 100, or 1 000 000 cm^3, on 100 floors. This is a good model of 1 million, a number that often seems out of one's grasp and difficult to visualize. Remind students that they now have a reference for the number 1 million.

The Gram

Although the National Bureau of Standards uses the kilogram as the basic unit of mass (weight), it is simpler for learners to think about the gram in the same manner as they think about the meter and the liter. When the prefixes are added, the students can transfer the meaning from their previous understandings of linear measurement.

Hold up a cubic centimeter block and say, "If this were an open box and I filled it with water, the water would weigh 1 gram. The mass of the water would be 1 gram."

Hold up a packet of artificial sweetener that weighs a gram. Pass around the packet or a centimeter cube so that students can get the feel of a gram. If possible, pass around a kilogram mass piece as well.

Actually, the National Bureau of Standards uses the kilogram as the basic unit of mass. However, clearly it is simpler to use the prefixes with gram in the same manner as they are used with meter and liter. Therefore, in these materials gram is used to refer to the basic unit of mass.

Again, point out to students that an array is an arrangement of objects in rows and columns.

Elicit from students a comprehension of the relationship between a gram and a kilogram. Ask questions designed to develop the meaning of the terms decigram, centigram, milligram, dekagram, hectogram, and kilogram. Make the point that the gram and the kilogram are the units most often used.

Summarize the metric system by pointing out the systematic way in which the linear, volume, and mass systems are related.

- The meter is used as the basic unit of length.
- A subdivision of the meter, the decimeter, is used to construct a cube whose capacity is called a liter. The liter is the basic unit of capacity (volume).
- The mass of 1 cm of water is called a gram. The gram is the basic unit of mass.

Area

Remind students that in the "Metric Me" activity they were asked to find the area of their footprints. Draw a picture of a footprint on the chalkboard.

Ask: "How did you go about calculating the area of your footprint?" Elicit from the students the procedure of counting the number of square centimeters.

Say, "Some of you used a shortcut for counting squares. You multiplied two numbers. When can you do this?"

At this point, it is important that students clarify the meaning of the $A = bh$ (or $A = lw$) formula for computing the area of a rectangle. Draw a 3 x 4 array of squares, similar to the accompanying diagram, to show that there are $3 \cdot 4$, or 12, squares in all. Thus, $A = bh$ is a formula for counting the number of squares in an array of squares.

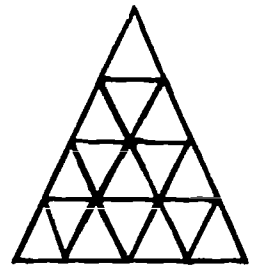
COMMENTARY AND NOTES

You may wish to indicate that it is only after children have had experience with nonstandard units that they begin to appreciate the need for standard units that everyone can agree upon.

Square centimeters (symbolized cm^2), square decimeters (dm^2), and square meters (m^2) are among the standard units of area used in the metric system.

Students sometimes misunderstand a symbol such as m^2, assuming that it represents the square of a number (3^2 or the like). Make it clear that the symbol m^2, in its entirety, stands for square meter--a square that is one meter long on each side.

It is customary to use square units to measure area. This is probably because squares "fit together" to cover surfaces better than other shapes do. However, you may wish to call attention to the accompanying figure, a triangle that is covered with smaller triangles. We can compute the area of the larger triangle as 16 triangular units.



It is appropriate to review the method of computing the perimeter of a figure.

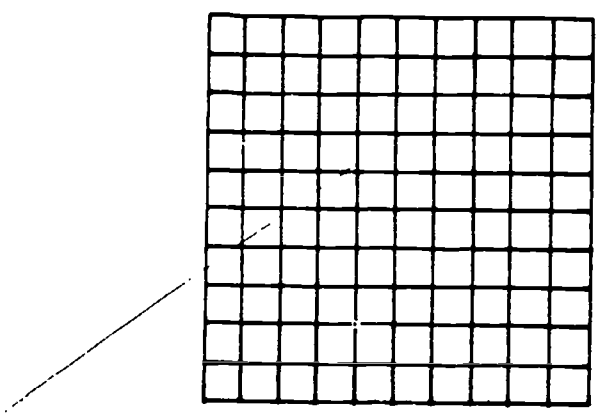
Point out that the square centimeter is a standard unit of measure that is used for measuring area. Theoretically, any shape can be used, provided that it completely covers the surface to be measured.

Develop the relationship among mm^2, cm^2, dm^2, and m^2 by using 10 x 10 arrays of squares. It is a good idea to actually demonstrate each of the square units so that students can gain an appreciation of their comparative sizes. The accompanying diagram can be used to show that:

10 dm = 1 m, and 1 m^2 = 10·10, or 100 dm^2

10 cm = 1 dm, and 1 dm^2 = 10·10, or 100 cm^2

10 mm = 1 cm, and 1 cm^2 = 10·10, or 100 mm^2



Make the point that while the linear unit is divided into 10 equal parts, the area of the square unit is divided into 100 equal parts.

Make the necessary numerical substitutions to show that:

$$1\ m^2 = 1\ 000\ 000\ mm^2$$

Suggest that students retain this as another reference for the number 1 million. Ask them to picture the number of square millimeters in 1 square meter.

Give students the experience of computing the areas of the figures on the worksheet "Area Activity Sheet" (see Student Materials and Exercises, page III-12). By placing a sheet of centimeter-squared paper beneath the worksheet, students can calculate the area of each figure. In discussing the results of the activity, elicit from students the following observations:

- Figures may have equal areas and different shapes.
- Figures may have equal areas and different perimeters.

Refer to a picture of a 10-by-10 array of squares, such as the one in the preceding section on area, whenever students need a reinforcement of these area relationships.

Conversion

Begin the discussion of conversions within the metric system with a linear measure such as 162 cm, perhaps the height of one of the students. Say, "Knowing that 10 cm = 1 dm, how can we express this measure in terms of decimeters?"

Help students understand that:

- It is necessary to answer the question "How many sets of 10 are in 162?"
- The question is answered by means of division of 162 by 10.
- Division by 10 is accomplished by moving the decimal point one place to the left. Thus, 162 ÷ 10 = 16.2, and 162 cm = 16.2 dm.

Ask: "Is it reasonable to expect the number of decimeters to be smaller than the number of centimeters?"

At this point it will be helpful to elicit from students the realization that measuring a given length with a small unit produces a larger number than the one obtained by measuring the same length with a larger unit of measure. Thus, in converting from centimeters to decimeters, a number smaller than the given one (162) is expected. Hence division is the chosen operation.

Have students turn to the worksheet "Metric Conversions" (see Student Materials and Exercises, page III-13), which is to be completed in conjunction with the following presentation.

Begin by providing practice with conversions of linear measures within the metric system. In each case, ask students to follow these steps:

1. First, decide whether they are to convert from a smaller unit to a larger one (or from a larger unit to a smaller one).
2. Second, indicate the relationship between the two units involved.
3. Third, decide whether to multiply or divide by 10, by 100, by 1000, etc. This decision should be made based on the decision made in the first step, above, and on whether the answer must be a number larger or smaller than the given number.

After providing ample practice with linear conversions, move to conversions involving area and volume. Verify or review the basic area relationships developed in the preceding section. Then show how area conversions are made, using the same three-step method as described above for linear conversions.

COMMENTARY AND NOTES

It may be helpful for students to see, once again, the relationship between cm^3 and dm^3. Use the open decimeter cube and the centimeter cubes to demonstrate.

Every so often, stop to ask such questions as: How large is that? Is that very heavy? These are the kinds of questions that can best be answered by using one's own reference measures.

The Student Summary and Review, Part IV, will help students reinforce their understanding of the structure of the metric system and of the key units of measure.

As an example, to convert 3.2 m^2 to square centimeters, we reason:

1. We are converting from a larger to a smaller unit.
2. Since 100 cm = 1 m, 10 000 cm^2 = 1 m^2 (100·100 = 10 000).
3. We must multiply in order to obtain a greater number of square centimeters than the given number of square meters.

Thus, 10 000·3.2 = 32 000, and 3.2 m^2 = 32 000 cm^2.

Use a similar approach for volume conversions. Review or verify that:

10 dm = 1 m, and also 1000 dm^3 = 1 m^3

100 cm = 1 m, and 1 000 000 cm^3 = 1 m^3

To convert 932 dm^3 to m^3, divide by 1000 (from a smaller to a larger unit; from a larger to a smaller number of units). Thus:

932 dm^3 = 0.932 m^3

After each conversion is made, be sure to ask students to decide whether the answer is reasonable and expected.

STUDENT EVALUATION

An approach to evaluation is provided in the section on student evaluation in the Instructor's Handbook, along with ideas for creating a classroom climate that encourages and supports students' achievement. Suggestions are offered for helping students to prepare for quizzes, for providing feedback on performance, and for reassessing when necessary.

The Metric Measurement objectives below are accompanied by sample items. Select items according to the content objectives you have covered in the module.

Objective 1. Select appropriate metric units to measure length, area, volume (capacity), mass, and temperature.

a. Given the metric measurement units centimeter, meter, kilometer, square centimeter, milliliter, liter, gram, and kilogram, indicate which unit is appropriate for measuring each of the following:

(1) Your height
(2) A sip of milk
(3) The distance from New York to Boston
(4) Your waist
(5) Your mass (weight)
(6) The contents of a small bottle of soda
(7) The surface of a small shelf
(8) The distance from Queens to Manhattan

b. To measure the length of your thumb, it would be most appropriate to use:

(1) The meter
(2) The liter
(3) The kilometer
(4) The centimeter

c. In the metric system, liquids are purchased by:

(1) The gram
(2) The centimeter
(3) The milliliter
(4) The Celsius

d. What unit would you use to measure the mass of:

(1) A nickel
(2) A man
(3) A car
(4) A packet of artificial sweetener

e. To measure the area of your hand, you would use:

(1) Centimeters
(2) Square centimeters
(3) Cubic centimeters
(4) Milliliters

f. The distance from New York to Chicago is measured in:

(1) Liters
(2) Meters
(3) Kilometers

Objective 2. Estimate, using metric units.

a. If the thermometer in your house reads 20°C in the winter, will you feel comfortable?

b. Estimate the width of a light-switch plate in centimeters.

c. Estimate the temperature of cold water from a faucet, using degrees Celsius.

d. An aspirin tablet might have a mass of 324 _____.

e. Name an object that has a mass of more than 1 kilogram.

f. The head of a nail might have an area of 30 _____.

g. Draw a line segment that is about a decimeter in length.

Objective 3. Make comparisons between commonly used metric units and parts of the body or familiar objects in the environment.

a. Name a part of the human body that can be used as a reference for the measure 1 centimeter.

b. Name several objects that are about a meter long.

c. Name several objects that weigh about a kilogram.

d. The thickness of a dime is approximately:

(1) 1 cm
(2) 1 mm
(3) 1 m

e. One millimeter is approximately the thickness of:

(1) A pencil
(2) A dollar bill
(3) A dime

f. A liter has approximately the same volume as:

(1) A half-pint drinking glass
(2) A gallon jug
(3) A quart bottle

g. It is likely that the area of the surface of a book would be expressed in:

(1) Square milliliters
(2) Square centimeters
(3) Square meters

Objective 4. Convert and compute <u>within</u> the metric system. Convert each measure to the unit indicated:

a. _____ L = 967 mL

b. 32 dm^2 = _____ cm^2

c. 3.04 m = _____ cm

d. 2 m^3 = _____ cm^3

e. 3241 g = _____ kg

f. 483 mL = _____ L

g. 2431 g = _____ kg

h. 3.4 m = _____ cm

i. 3 m^3 = _____ cm^3

j. 2.5 dm^2 = _____ cm^2

k. 4.3 m = _____ cm

l. 1342 g = _____ kg

m. 5.2 dm^2 = _____ cm^2

n. 8 m^2 = _____ cm^3

o. 968 mL = _____ L

Objective 5. Demonstrate knowledge of concepts of measurement.

a. A length is recorded as 8.4 cm, correct to the nearest tenth of a centimeter. The actual length is:

(1) From 8.05 cm to 8.55 cm, not including 8.55 cm
(2) From 8.3 cm to 8.5 cm, not including 8.5 cm
(3) From 8.35 cm to 8.45 cm, not including 8.45 cm
(4) From 7.9 cm to 8.9 cm, not including 8.9 cm

b. Which measurement shows accuracy to the nearest centimeter?

(1) 1.6 m
(2) 1.61 m
(3) 16 dm

c. Which represents the most precise measurement?

(1) 0.94 L
(2) 9.4 dL
(3) 947 mL

Objective 6. Use accepted standards for recording metric measurements.

a. Of the following measures used in the metric system, the only one that uses a capitalized symbol is:

(1) The meter
(2) The liter
(3) The gram

b. The modernized version of the metric system is known as:

(1) IS
(2) ISU
(3) SI

c. A manufacturer of vinegar labels its bottles "946ML." Rewrite "946 ML." in correct metric form.

d. Of the following equal metric measurements, which one is given in incorrect form?

(1) 1.63 m
(2) 16.3 dm
(3) 1 m, 6 dm, 3 cm

Objective 7. Demonstrate knowledge of the structure of the metric system--e.g., the decimeter, cubic decimeter (liter), and kilogram relationship that defines the linear, volume (capacity), and mass systems.

a. If a glass contains 25 mL of water, how many grams does the water weigh?

b. The metric system is based on multiples of:

(1) 10
(2) 12
(3) 16

c. In the measure 1.653 m, the 5 represents the number of:

(1) Meters
(2) Decimeters
(3) Centimeters
(4) Millimeters

d. A unit of volume that is the same as one cubic decimeter is the:

(1) Meter
(2) Liter
(3) Gram

e. One milliliter is the same as:

(1) 1 g
(2) 1 cm^2
(3) 1 cm^3

METRIC MEASUREMENT

II

INSTRUCTOR'S GUIDE AND SOLUTIONS TO STUDENT EXERCISES

This section of Metric Measurement contains solutions for exercises presented in Student Materials and Exercises. The solutions are accompanied by some explanations and suggestions.

The student exercises include problems that apply the concepts and problem-solving strategies developed in this module. The exercises can be used as part of instructional activities, as in-class activities for individuals or small groups, as assignments, or as review materials.

METRIC QUIZ*

Select the answer which best completes each statement.

1. The height of a man playing center on a typical men's basketball team is approximately:

   a. 6 m

   b. 240 m

   c. 2 m

   d. 78 cm

2. My car was low on oil, so I told the gas station attendant to add:

   a. 2 mL

   b. 1 L

   c. 10 mL

   d. 20 L

3. The diameter of a coffee cup is about:

   a. 1 cm

   b. 8 cm

   c. 20 cm

   d. 50 cm

4. In order to bake a cake in a moderate oven, one should set the oven temperature at about:

   a. 100°C

   b. 180°C

   c. 220°C

   d. 350°C

---

*Adapted from "Don't Just Think Metric--Live Metric," by Richard J. Shumway and Larry Sachs. From Arithmetic Teacher, February 1975.

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   a. 2 mL
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   d. 20 L

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   a. 100°C
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---

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5. A good weight (mass) for a college-age girl of average height would be about:

   a. 130 g
   b. 40 g
   c. 150 kg
   d. 55 kg

6. The length of a car is approximately:

   a. 5 m
   b. 15 mm
   c. 26 m
   d. 3 cm

7. A large gulp of soda would be about:

   a. 10 L
   b. 200 mL
   c. 40 L
   d. 20 mL

8, A good temperature at which to set your home thermostat for comfortable living would be:

   a. 90°C
   b. 32°C
   c. 70°C
   d. 20°C

LINEAR MEASUREMENT ACTIVITIES

(Answers will vary. Some possibilities are listed below.)

Please engage in the following activities in the order given.

Proceed to Station 1.

STATION 1:

Each cardboard strip is 1 decimeter long. After estimating the length of each object, use the decimeter strip to measure. Record your results.

Object	Estimate	Measurement
Width of this sheet of paper		2 dm
Length of the table		13 dm
Length of the pencil		2 dm
Diameter of the coffee can		1 dm
Height of the box		3 dm

Would it be appropriate to measure the length of this room in decimeters? Why or why not?

Proceed to Station 2.

STATION 2:

Use adding machine or cash register tape to make a length of 10 decimeters. We call this new length 1 meter.

Name 5 objects in the room that can be measured by using the meter as the unit of length.

Estimate each length in meters. Then measure to check. Use the 1-meter measuring tape you have just made.

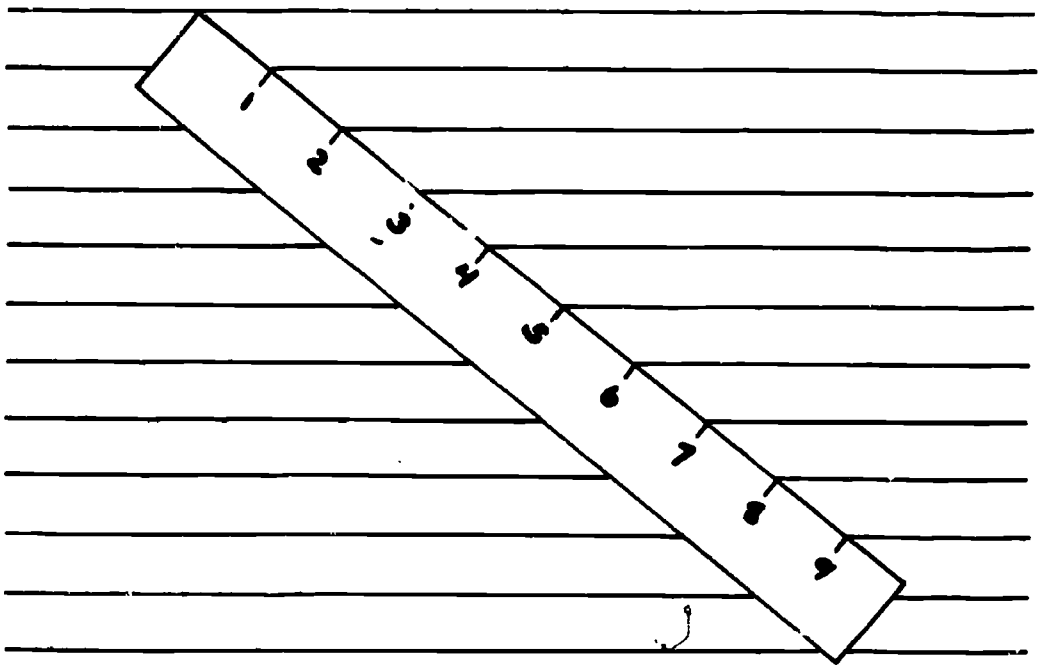
Object	Estimate	Measurement
Height of the chalkboard		1 m
Height of the doorknob from the floor		1 m
Width of the classroom		3 m

Would it be appropriate to measure the width of your fingernail in meters? In decimeters? Why or why not?

Proceed to Station 3.

STATION 3:

A unit of length can be subdivided into any number of equal parts. Here is a way to subdivide your decimeter strip into 10 equal parts. Use lined index cards or narrowly ruled paper to subdivide your decimeter strip into 10 centimeters.



Name 5 objects in the room for which the centimeter is the appropriate unit of measure. Estimate each length. Measure. Record your results.

Object	Estimate	Measurement
Length of a paper clip		3 cm
Diameter of a coat button		2 cm

List some distances (or lengths) for which a unit of measure smaller than the centimeter would be appropriate. (Length of a frame of small photo film)

List some distances (or lengths) for which a unit of measure larger than the meter would be appropriate. (Distance from New York to Los Angeles)

METRIC ME

(Answers will vary. Possible results are listed below.)

Work with a partner. You will find measuring equipment at stations around the room. In each case use the appropriate metric unit of measure.

1. My height	155-185 cm
2. My waist	55 cm
3. My weight (mass)	50 kg
4. My chest measurement	92 cm
5. The distance around my fist	25 cm
6. The distance around my head at the top of my eyebrows	56 cm
7. The distance from my elbow to my longest fingertip (cubit)	40 cm
8. The area of my footprint	150 cm^2
9. My body temperature	37°C
10. The length of my pace	1 m

11. Am I a square? or

What kind of rectangle am I--horizontal or vertical?

$$\frac{\text{Reach (arms outstretched)}}{\text{Height}} = \frac{65 \text{ cm}}{158 \text{ cm}}$$

If $\frac{\text{reach}}{\text{height}}$ has a value close to 1, the answer is square.

If $\frac{\text{reach}}{\text{height}} < 1$, the answer is vertical rectangle.

If $\frac{\text{reach}}{\text{height}} > 1$, the answer is horizontal rectangle.

Area Activity Sheet

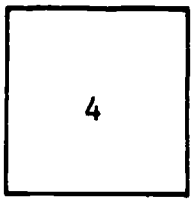


Figure A

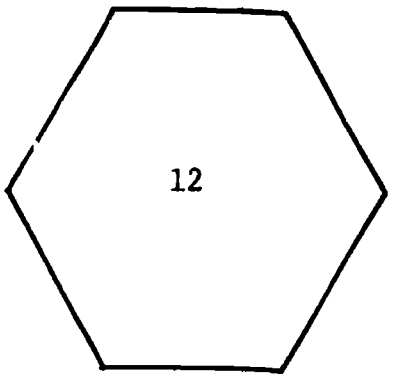


Figure B

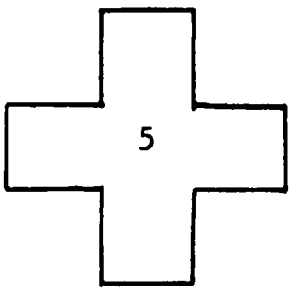


Figure C

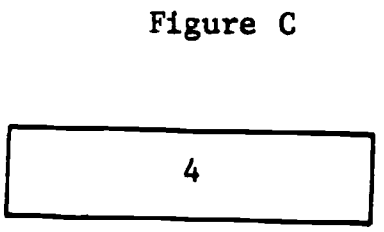


Figure D

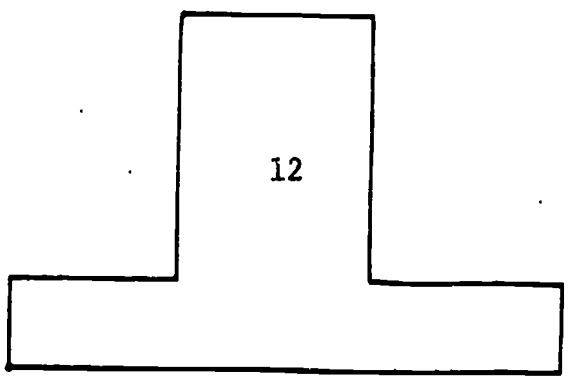


Figure E

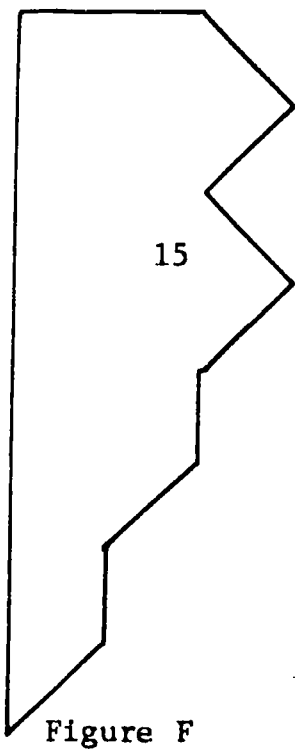


Figure F

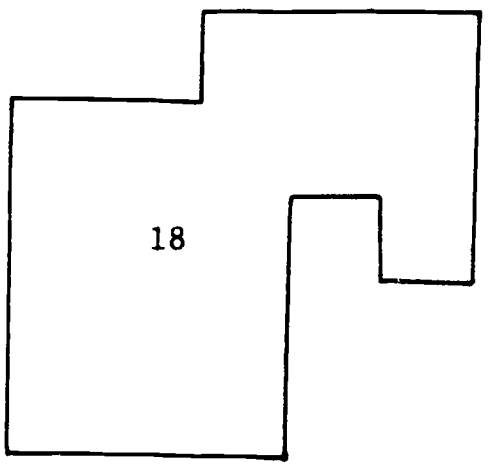


Figure G

METRIC CONVERSIONS

1. Complete each statement:

   a. 867 cm = [8.67] m

   b. 632 m = [63 200] cm

   c. 367 mm = [0.367] m

   d. 26 428 m = [26.428] km

   e. 0.349 dm = [3.49] cm

   f. [0.0035] m = 0.035 dm

   g. [0.436] m = 43.6 cm

   h. 37.4 km = [37 400] m

2. Complete each statement:

   a. [500] dm^2 = 5 m^2

   b. 32 cm^2 = [0.32] dm^2

   c. 3 dm^2 = [0.03] m^2

   d. 4 m^2 = [4 000 000] mm^2

3. Complete each statement:

   a. 947 cm^3 = [0.947] dm^3

   b. 947 mL = [0.947] L

   c. 6.496 kL = [6496] L

   d. 947 L = [0.947] kL

4. Complete each statement:

a.	1	m	=	1000	mm
b.	1	m^2	=	1 000 000	mm^2
c.	1	m^3	=	1 000 000 000	mm^3
d.	63	g	=	63 000	mg
e.	7.3	kg	=	7300	g
f.	0.632	kg	=	632	g
g.	75	g	=	75 000	mg
h.	3200	g	=	3.2	kg

METRIC MEASUREMENT

III

STUDENT MATERIALS AND EXERCISES

STUDENT MATERIALS

Centimeter-Squared Paper

PLACE VALUE CHART

	Thousands	Hundreds	Tens	Ones	Tenths	Hundredths	Thousandths
Numeration	1000	100	10	1	0.1	0.01	0.001
Metric Prefixes	kilo (k)	hecto (h)	deka (da)		deci (d)	centi (c)	milli (m)
Metric Length	kilometer (km)			meter (m)	decimeter (dm)	centimeter (cm)	millimeter (mm)
Metric Mass	kilogram (kg)			gram (g)			milligram (mg)
Metric Capacity (Volume)				liter (L)			milliliter (mL)
Money	$1000.00	$100.00	$10.00	$1.00	$.10 (dime)	$.01 (cent)	$.001 (mill)

Other terms: micromillionth; megamillion times; metric ton (tonne)--a thousand kilograms

All You Will Need to Know About Metric

(For Your Everyday Life)

10

Metric is based on Decimal system

The metric system is simple to learn. For use in your everyday life you will need to know only ten units. You will also need t get used to a few new temperatures. Of course, there are other units which most persons will not need to learn. There are even some metric units with which you are already familiar: those for time and electricity are the same as you use now.

BASIC UNITS

METER: a little longer than a yard (about 1.1 yards)
LITER: a little larger than a quart (about 1.06 quarts)
GRAM: a little more than the weight of a paper clip

(comparative sizes are shown)

1 METER

1 YARD

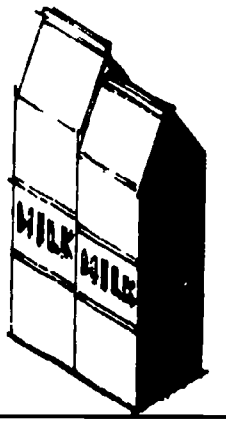
25 DEGREES FAHRENHEIT

COMMON PREFIXES
(to be used with basic units)

milli: one-thousandth (0.001)
centi: one-hundredth (0.01)
kilo: one-thousand times (1000)

For example:
1000 millimeters = 1 meter
100 centimeters = 1 meter
1000 meters = 1 kilometer

1 LITER



1 QUART

OTHER COMMONLY USED UNITS

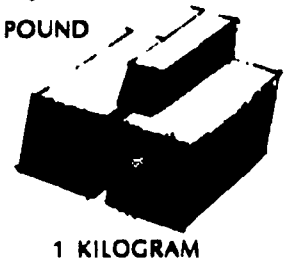
millimeter:	0.001 meter	diameter of paper clip wire
centimeter:	0.01 meter	a little more than the width of a paper clip (about 0.4 inch)
kilometer:	1000 meters	somewhat further than ½ mile (about 0.6 mile)
kilogram:	1000 grams	a little more than 2 pounds (about 2.2 pounds)
milliliter:	0.001 liter	five of them make a teaspoon

1 POUND

OTHER USEFUL UNITS

hectare: about 2½ acres
metric ton: about one ton

25 DEGREES CELSIUS

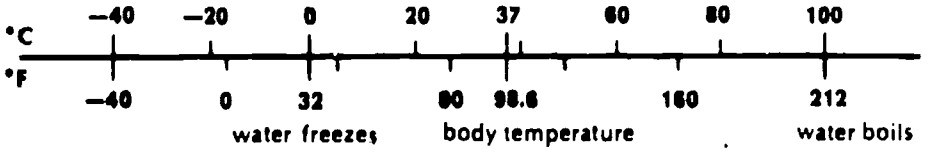


1 KILOGRAM

WEATHER UNITS:

FOR TEMPERATURE
degrees Celsius

FOR PRESSURE
kilopascals are used
100 kilopascals = 29.5 inches of Hg (14.5 psi)



For more information, write to: Metric Information Office, National Bureau of Standards
Washington, D.C. 20234

STUDENT EXERCISES

METRIC QUIZ*

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   c. 2 m

   d. 78 cm

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   b. 1 L

   c. 10 mL

   d. 20 L

3. The diameter of a coffee cup is about:

   a. 1 cm

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   c. 20 cm

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4. In order to bake a cake in a moderate oven, one should set the oven temperature at about:

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   c. 220°C

   d. 350°C

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6. The length of a car is approximately:

   a. 5 m
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   c. 26 m
   d. 3 cm

7. A large gulp of soda would be about:

   a. 10 L
   b. 200 mL
   c. 40 L
   d. 20 mL

8. A good temperature at which to set your home thermostat for comfortable living would be:

   a. 90°C
   b. 32°C
   c. 70°C
   d. 20°C

LINEAR MEASUREMENT ACTIVITIES

Please engage in the following activities in the order given.

Proceed to Station 1.

STATION 1:

Each cardboard strip is 1 decimeter long. After estimating the length of each object, use the decimeter strip to measure. Record your results.

Object	Estimate	Measurement
Width of this sheet of paper		
Length of the table		
Length of the pencil		
Diameter of the coffee can		
Height of the box		

Would it be appropriate to measure the length of this room in decimeters? Why or why not?

Proceed to Station 2.

STATION 2:

Use adding machine or cash register tape to make a length of 10 decimeters. We call this new length 1 meter.

Name 5 objects in the room that can be measured by using the meter as the unit of length.

Estimate each length in meters. Then measure to check. Use the 1-meter measuring tape you have just made.

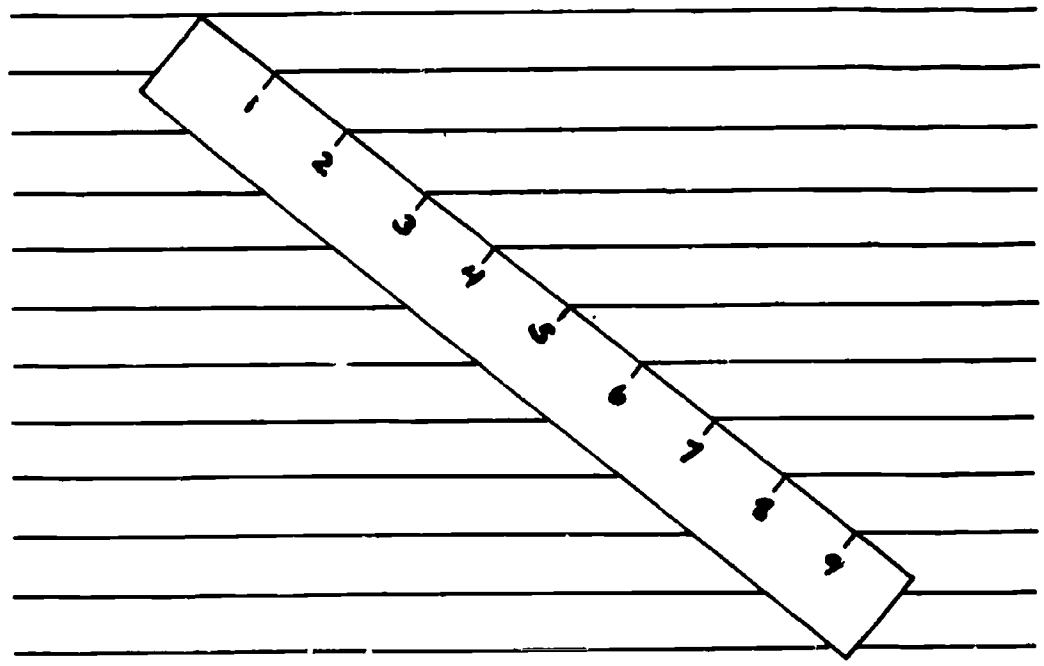
Object	Estimate	Measurement

Would it be appropriate to measure the width of your fingernail in meters? In decimeters? Why or why not?

Proceed to Station 3.

STATION 3:

A unit of length can be subdivided into any number of equal parts. Here is a way to subdivide your decimeter strip into 10 equal parts. Use lined index cards or narrowly ruled paper to subdivide your decimeter strip into 10 centimeters.



Name 5 objects in the room for which the centimeter is the appropriate unit of measure. Estimate each length. Measure. Record your results.

Object	Estimate	Measurement

List some distances (or lengths) for which a unit of measure smaller than the centimeter would be appropriate.

List some distances (or lengths) for which a unit of measure larger than the meter would be appropriate.

METRIC ME

Work with a partner. You will find measuring equipment at stations around the room. In each case use the appropriate metric unit of measure.

1. My height _____

2. My waist _____

3. My weight (mass) _____

4. My chest measurement _____

5. The distance around my fist _____

6. The distance around my head at the top of my eyebrows _____

7. The distance from my elbow to my longest fingertip (cubit) _____

8. The area of my footprint _____

9. My body temperature _____

10. The length of my pace _____

11. Am I a square?
    or
    What kind of rectangle am I--horizontal or vertical?
    Formula:

$$\frac{\text{Reach (arms outstretched)}}{\text{Height}} = \frac{\quad}{\quad} = \quad$$

Area Activity Sheet

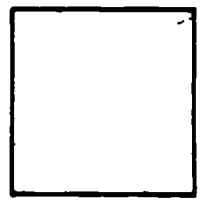


Figure A

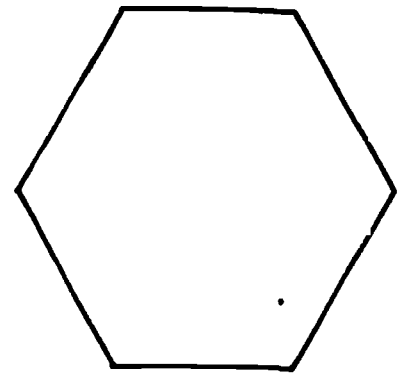


Figure B

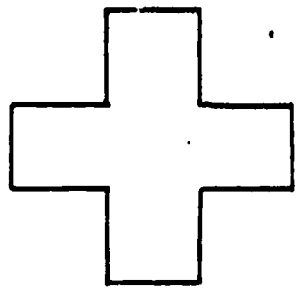


Figure C

Figure D

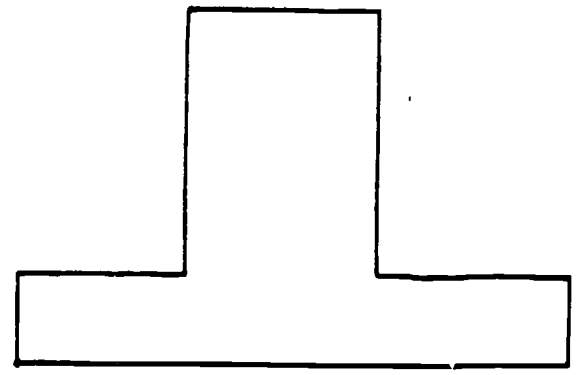


Figure E

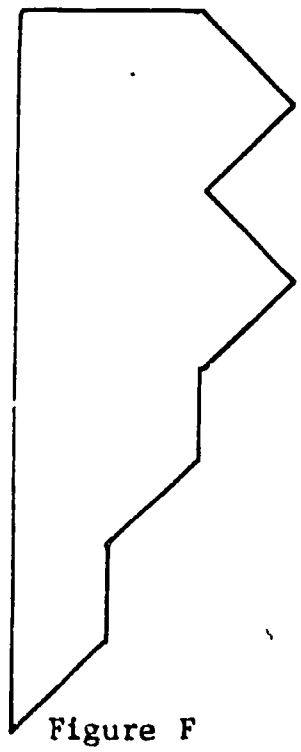


Figure F

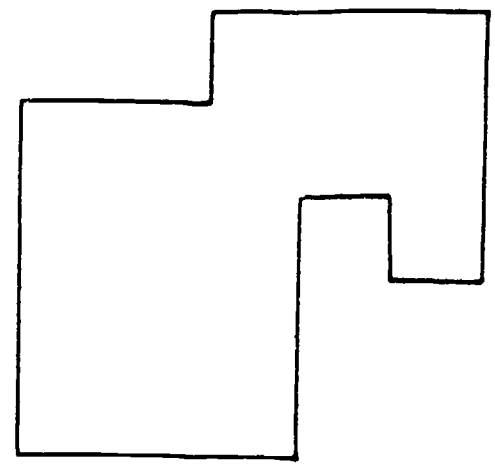


Figure G

METRIC CONVERSIONS

1. Complete each statement:

   a. 867 cm = _____ m

   b. 632 m = _____ cm

   c. 367 mm = _____ m

   d. 26 428 m = _____ km

   e. 0.349 dm = _____ cm

   f. _____ m = 0.035 dm

   g. _____ m = 43.6 cm

   h. 37.4 km = _____ m

2. Complete each statement:

   a. _____ dm^2 = 5 m^2

   b. 32 cm^2 = _____ dm^2

   c. 3 dm^2 = _____ m^2

   d. 4 m^2 = _____ mm^2

3. Complete each statement:

   a. 947 cm^3 = _____ dm^3

   b. 947 mL = _____ L

   c. 6.496 kL = _____ L

   d. 947 L = _____ kL

4. Complete each statement:

a. 1 m = _____ mm

b. 1 m^2 = _____ mm^2

c. 1 m^3 = _____ mm^3

d. 63 g = _____ mg

e. 7.3 kg = _____ g

f. ____ kg = 632 g

g. 75 g = _____ mg

h. ____ g = 3.2 kg

TEAM

METRIC MEASUREMENT

IV

STUDENT SUMMARY AND REVIEW

To the Student: This summary and review includes the key ideas discussed and presented throughout the Metric Measurement module. You will probably find it useful to compare your notes from class sessions with this entire section.

METRIC TIPS

1. The measurement system we now use is called U.S. Customary.

2. The metric system is officially known as SI (Système international d'unités).

3. The metric system uses symbols rather than abbreviations. Thus, no periods are used (cm, kg, and mL are examples).

4. No plurals are used. Thus 6 dm, not 6 dms, is correct.

5. Note that the only symbols that are capitalized are those for liter (L) and Celsius (C).

6. Mixed measures are not used in SI. One's height would be given as 162 cm or 16.2 dm or 1.62 m, and not as 1 m, 6 dm, 2 cm. The latter is implied by the former.

7. The units most frequently used are the meter, the centimeter, the kilometer, the liter, the milliliter, the gram, and the kilogram.

8. Because all measurement is approximate, always use the terms about or approximately when referring to a measure.

I. LINEAR MEASUREMENT

A. Meter:* symbolized m (no period)

1. Estimate and then measure five common objects to the nearest meter.

2. Name three objects that are about one meter long.

B. Decimeter:* symbolized dm

1. The prefix deci means one-tenth of. Verify that a decimeter is one-tenth of a meter.

2. Estimate and verify the linear measurement of five common objects to the nearest decimeter.

3. Name three things that are about one decimeter long.

4. Express each of the following measures in terms of the meter:

a. 7 meters, 4 decimeters _____ m

b. 58 decimeters _____ m

c. 5 m and 8 dm _____ m

d. 19 dm _____ m

e. 46 decimeters _____ m

C. Centimeter:* symbolized cm

1. Consult a meter stick to verify that there are 10 centimeters in a decimeter. How many centimeters are in a meter? What is the meaning of the prefix centi?

2. Identify some part of your hand that is about a centimeter long.

3. Estimate and measure other small objects to the nearest centimeter.

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*The spelling metre is also acceptable. Both spellings are used.

4. Express each of the following in terms of the indicated unit.

a. 6 cm = _____dm 6 cm = _____m

b. 32 cm = _____dm 32 cm = _____m

c. 185 cm = _____dm 185 cm = _____m

d. 0.76 m = _____dm 0.76 m = _____cm

e. 0.8 dm = _____ m 0.8 dm = _____cm

D. Millimeter:* symbolized mm

1. Estimate and measure objects to the nearest millimeter. Each centimeter contains 10 millimeters. Why is it true that 1 mm = 0.001 m?

2. Estimate and measure objects to the nearest millimeter.

The smaller the unit used, the more precise the measurement. For example:

- 3 m is measured to the nearest meter.
- 3.0 is measured to the nearest decimeter (tenth of a meter).
- 3.02 m is measured to the nearest centimeter (hundredth of a meter).
- 3.023 m is measured to the nearest millimeter (thousandth of a meter).

Thus, 3.023 is the most precise.

3. Express each measure in terms of the indicated unit.

a. 9 mm = _____cm

9 mm = _____dm

9 mm = _____ m

b. 16 mm = _____cm

16 mm = _____dm

16 mm = _____ m

*The spelling metre is also acceptable.

c. 0.009 m = _____dm

0.009 m = _____cm

0.009 m = _____mm

d. 0.204 m = _____dm

0.204 m = _____cm

0.204 m = _____mm

e. 0.3 m = _____dm

0.3 m = _____cm

0.3 m = _____mm

f. 3.5 dm = _____mm

3.5 dm = _____cm

3.5 dm = _____ m

E. Kilometer:* symbolized km

The prefix kilo means one thousand times. Thus:

1 km = 1000 m

F. Other less commonly used multiples of the meter are:

dekameter: 1 dam = 10 m

hectometer: 1 hm = 100 m

II. AREA

A. Verify that there are:

1. One hundred square centimeters in a square decimeter ($100\ cm^2 = 1\ dm^2$)

2. One hundred square decimeters in a square meter ($100\ dm^2 = 1\ m^2$)

*The spelling metre is also acceptable.

B. Complete the following:

_____ cm^2 = 1 m^2

C. Name a unit of area more precise than a square centimeter.

III. VOLUME

A. Examine a cubic decimeter (dm^3).

How many cubic centimeters (cm^3) fit on the "first floor" of the decimeter cube?

B. Complete the following:

1. _____ cm^3 = 1 dm^3

2. _____ dm^3 = 1 m^3

3. _____ cm^3 = 1 m^3

C. Which unit--cm^3, dm^3, or m^3--should be used to measure the volume (capacity) of each of the following?

1. A matchbox

2. An ice cream carton

3. This room

4. A box of facial tissues

D. The basic unit of volume is the liter* (symbolized L). The liter is defined as a cubic decimeter. Thus, 1 L = 1 dm^3.

1. Show that a small coffee can holds about a liter.

2. Show that a liter is somewhat more than a quart.

3. How does a milliliter (mL) compare in volume (capacity) with a cubic centimeter (cm^3)?

4. Estimate, then measure, the volume of various bottles and containers.

---

*The spelling litre is also acceptable.

5. Express each of the following in terms of the indicated measure:

   a. 6 cm^3 = _____ dm^3

   b. 0.076 L = _____ mL

   c. 238 mL = _____ L

   d. 0.27 m^3 = _____ cm^3

   e. _____ mL = 0.01 L

IV. MASS (WEIGHT)

A. Mass is the amount of material in an object. Many people use weight and mass as synonyms. We weigh a book and find that its mass is about 1 kilogram. Identify a few objects you can associate with the mass of a gram and with the mass of a kilogram.

B. Complete the following:

   1. 300 g = _____ kg

   2. _____ g = 6.20 kg

   3. 0.08 kg = _____ g

V. TEMPERATURE

A. Temperature is symbolized °C (degrees Celsius).

B. Use a thermometer to measure your own body temperature.

C. What is the temperature of cool drinking water?

D. Use a thermometer to observe the temperature change under warm tap water.