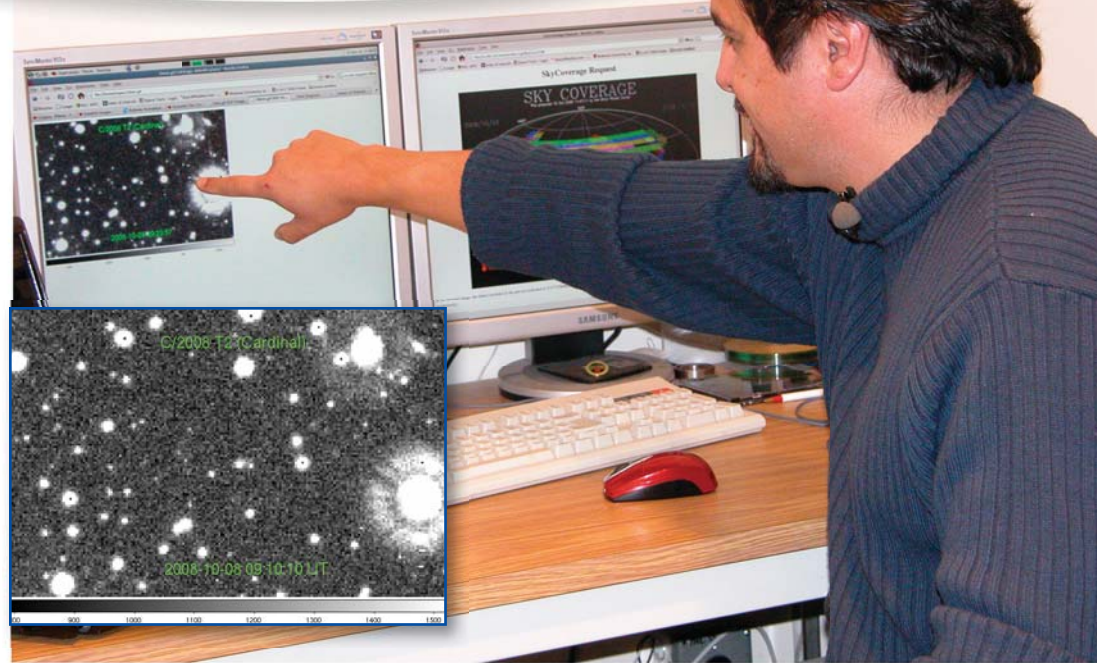# 1.1

SI Measurement

Focus on …

- justifying the units used for a measurement
- solving problems that involve linear measurement
- explaining the process used to estimate a linear measurement
- selecting appropriate referents

Rob Cardinal, who is of the Siksika First Nation is a researcher at the University of Calgary's Rothney Astrophysical Observatory. On October 1, 2008, he took some images that he thought were of an asteroid. It turned out to be an undiscovered comet and was named Comet Cardinal. Whether you are exploring the universe, hiking in the Rockies, or travelling in the Prairies you will be using linear measurement with SI units. SI stands for Système International d'Unités. What SI units can you name? What type of measurement is associated with each unit?

Materials

- three items that are non-standard measuring units (e.g., coin, paperclip)
- SI measuring tape
- grid paper

Investigate Dimensions of a Rectangle

What effect does the unit of measurement have on the length-to-width ratio of a rectangle?

1. Work with a partner. Draw a rectangle on half of a sheet of paper.

2. Choose three non-standard units to measure the dimensions of your rectangle. Estimate how many of each non-standard unit it takes to measure the length and width of your rectangle.

3. Measure the dimensions using each non-standard unit. Record all data in a chart or table. You may need to record measurements using fractions or decimals.

The length of this rectangle is $5\frac{1}{2}$ dimes.
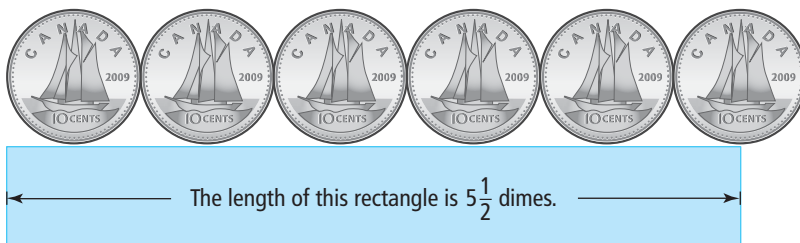
4. Estimate the length and width of your rectangle in millimetres and centimetres. Then, confirm your estimate by measuring using each of these standard units. Record your estimates and measurements.

5. For each unit of measurement, plot your measurements as (length, width) coordinate pairs on a grid.

6. Reflect and Respond

a) Describe any patterns you see in the graph.

b) Does the ratio of length to width for your rectangle vary when you change the units of measurement? Explain.

7. Discuss the advantages and disadvantages of using standard units for measuring distance.

Link the Ideas

Canada's official measurement system is **SI (Système International d'Unités)**. Some SI units for linear measurement are listed in the table.

Unit	Abbreviation	Multiplying Factor
kilometre	km	1000
hectometre	hm	100
decametre	dam	10
metre	m	1
decimetre	dm	0.1
centimetre	cm	0.01
millimetre	mm	0.001

Various measuring instruments allow accurate measurement of distances in standard units. You can also develop personal **referents** to use when estimating measurements.

SI (Système International d'Unités)

- a system of measurement in which all units are based on multiples of ten
- the metre is the basic unit of length

referent

- an item that an individual uses as a measurement unit for estimating
- for example, the height of a doorknob above the floor is about 1 m, or the thickness of a dime is about 1 mm

Measuring Instruments

SI rulers, metre sticks, and measuring tapes give measurements to the nearest millimetre, or 0.1 cm. A caliper can accurately measure to the nearest tenth of a millimetre, or 0.01 cm, depending on the scales.

Follow these steps to read a caliper.

1. Read the value on the fixed scale that is located exactly at or just to the left of the zero on the moving scale.

   For the caliper shown, the reading is 2.2.

2. Identify the next line on the moving scale that aligns with a line on the fixed scale. Read the value on the fixed scale.

   For this caliper, it is the line on the moving scale that represents 0.03.

3. The final reading is 2.23 cm. (2.2 + 0.03 = 2.23)
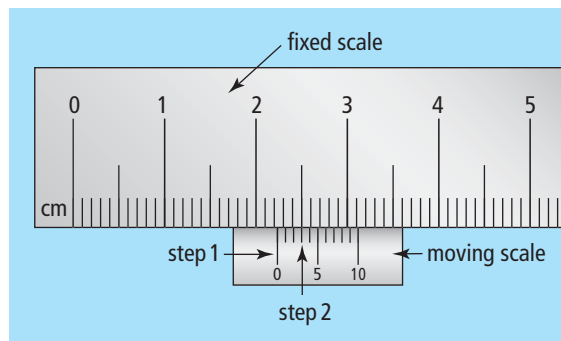
Referents

A non-standard measuring unit can be used as a personal referent. Referents help individuals estimate in standard units, such as SI units. For example, suppose you use the width of your fingernail to approximate 1 cm. Then, when you measure something that appears to be as wide as 4 of your fingernails, you can estimate that it is 4 cm wide.

Several referents are possible for each of the main linear SI units, the millimetre, centimetre, metre, and kilometre. Finding a referent for a kilometre is more difficult, because it is a large unit. You might choose a referent for a kilometre to be 12 or 13 city blocks.

Example 1   Estimate and Measure Using SI Units

Estimate each distance using an appropriate referent. Then, measure each distance.

a) the thickness of a CD case
b) the height of the seat of a chair
c) the width of this page

Solution

a) Use the width of one fingernail as a referent for 1 cm.

The thickness of a CD case is approximately as wide as half of one fingernail. Estimate the thickness of a CD case as 0.5 cm. Measure, using an SI ruler or caliper. The thickness of a CD case is 4.5 mm or 0.45 cm.

b) The height of the seat of a chair is approximately half of waist height. Use waist height as a referent for 1 m. Estimate the seat of the chair as 0.5 m high, or 50 cm. Measure, using a measuring tape. The height of the seat of a chair is 46 cm.

c) Use the width of one fingernail as a referent for 1 cm. Count the number of fingernails that fit across half of this page and double the number. An estimate of the width of this page is 22 cm. Measure the width using an SI ruler. The width of this page is 21.5 cm.

Your Turn

Estimate the height of the chalk or marker tray on a blackboard or whiteboard using an appropriate referent. Then, measure this height.

Example 2 Convert Between SI Units for Length

A newspaper reported the following measurements in different stories.

The distance from Earth to the moon is 38 440 300 000 cm.
A worm measures 0.0019 m.

a) For each measurement, state a more appropriate SI unit. Justify your choice.
b) Convert the given measurement to the more appropriate unit.

Solution

a) The distance from Earth to the moon is very large. It could be measured in kilometres rather than centimetres. The length of a worm is very small. It could be measured in millimetres rather than metres.

b) Convert 38 440 300 000 cm to kilometres.

Use *unit analysis* to calculate the number of centimetres in 1 km.
1 km = 1000 m and 1 m = 100 cm
So, 1 km = (1000)(100) cm
  1 km = 100 000 cm

$$38\,440\,300\,000\text{ cm}\left(\frac{1\text{ km}}{100\,000\text{ cm}}\right) = 384\,403\text{ km}$$

The measurement 38 440 300 000 cm can be converted to 384 403 km.

Convert 0.0019 m to millimetres.

Let x represent the number of millimetres.
Use proportional reasoning.
  1000 mm = 1 m
$$\frac{1000\text{ mm}}{1\text{ m}} = \frac{x\text{ mm}}{0.0019\text{ m}}$$
  $1000(0.0019) = x$
    $1.9 = x$

How do you decide which values to use for the numerator and denominator?

The measurement 0.0019 m can be converted to 1.9 mm.

Your Turn

Convert each measurement to a more appropriate SI unit. Justify your choice of unit.
a) A tube of toothpaste is 205 mm long.
b) The circumference of a highlighter measures 0.06 m.
c) You travel 590 000 m from Regina to Winnipeg.
d) The top of a door is 2110 mm high.

Example 3 Solve a Problem Involving Linear Measurement

Kyla buys an oversized wooden barrel. She cuts it in half to make a planter. She wants to place a metal band around the planter, 4 cm from the top, to hold the planter together.

a) If the radius 4 cm from the top of the planter is 0.6 m, what length of band will she need? Express your answer to the nearest centimetre.

b) If the bottom band of her planter is 1 m shorter than the top band, what is the radius of the planter at the bottom band? Express your answer to the nearest centimetre.

c) What is the difference between the radius of the planter at the top band and the radius at the bottom band?

d) Show how much the radius of any barrel increases if 1 m is added to the length of a band. State your answer as an exact value. Then, express your answer to the nearest centimetre.

Solution

a) The length of the band is equal to the circumference of the planter at 4 cm from the top.

$C = 2\pi r$
$C = 2\pi(0.6)$
$C = 3.7699\ldots$ **How do you convert 3.77 m to centimetres?**

The length of the band 4 cm from the top is 3.77 m or 377 cm.

b) The circumference of the planter at the bottom band is equal to the length of the bottom band. The length of the bottom band is 0.5 m shorter than the top band.

$3.77 - 1.0 = 2.77$

The length of the bottom band is 2.77 m.

Calculate the radius of the planter at the bottom band.

$C = 2\pi r$
$2.77 = 2\pi r$
$\dfrac{2.77}{2\pi} = r$
$0.4408\ldots = r$

The radius of the planter at the bottom band is 0.44 m or 44 cm.

c) Calculate the difference between the two radii.

$0.6 - 0.44 = 0.16$

The difference between the radius of the planter at the top band and the radius at the bottom band is 0.16 m or 16 cm.

d) The formula, $C = 2\pi r$, represents the circumference, C, for any barrel with radius, r. A barrel whose circumference increases by 1 m and radius increases by x metres can be represented by the following formula.

$C + 1 = 2\pi(r + x)$
$C + 1 = 2\pi r + 2\pi x$
$C + 1 = C + 2\pi x$ Substitute C for $2\pi r$.
$1 = 2\pi x$
$\dfrac{1}{2\pi} = x$

The radius of the barrel increases by the exact value $\dfrac{1}{2\pi}$.

$\dfrac{1}{2\pi} = 0.1591549431$

The radius of the barrel increases by approximately 0.16 m or 16 cm for every 1 m increase in circumference.

How does this answer relate to your answer to part c)?

Why do you think this increase will hold true for any size barrel?

Your Turn

Suppose the inner rim of a Red River cart wheel has a circumference of 7.1 m. Each spoke is 1 m long. What is the diameter of the centre circular hub of the wheel?

Key Ideas

- Each unit in the SI measurement system is a multiple of 10. All linear measurements are derived from the metre. The most common units are the kilometre (km), metre (m), centimetre (cm), and millimetre (mm).

- The kilometre is a large unit (1 km = 1000 m) and is suitable for measuring large distances.

- The millimetre is a small unit $\left(1 \text{ mm} = \frac{1}{1000} \text{ m}\right)$ and is suitable for measuring small distances.

- A referent is a personal measurement unit that you can use to estimate measurements in standard units, such as SI units.

  Estimate the length of an eyeglass case.

  Use a personal referent, such as "the width of your palm is 7.5 cm."

  The length of an eyeglass case measures 2 times as wide as your palm.
  $7.5(2) = 15$

  Estimate the length of the eyeglass case to be 15 cm.

Check Your Understanding

Practise

1. **a)** Estimate the perimeter of each figure in an appropriate SI unit.

   i)

   ii)

   b) Measure the perimeter of each figure. If all the angles in each figure are right angles, is it necessary to measure all sides of the figures? Explain.

2. a) On a plain piece of paper, draw a letter S whose curve length you estimate to be each distance.

    i) 25 mm   **ii)** 20 cm

  b) Explain how you could measure the distance of each curved letter you drew.

  c) Measure each S and compare your measurements with the required distances. If you are out by more than 5 mm for part i) or 2 cm for part ii), try drawing the letter again.

3. What reading is shown on each measuring instrument? Give each reading in both millimetres and centimetres.
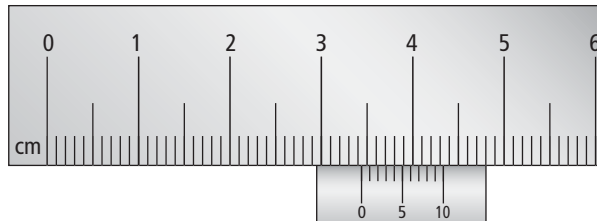
  a) SI ruler

  b) SI caliper
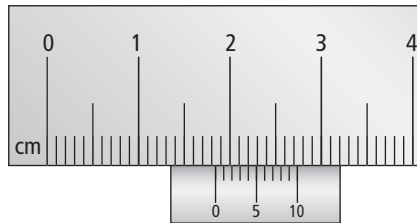
  c) SI caliper

4. The photograph shows a wind-tunnel test of the airflow over a model of NASA's heavy launch vehicle, called Ares V.

  a) Assume the photo and model show a reduction of approximately 1:1000. What is the actual length of Ares V?

 **b)** What is the diameter of one of the actual solid-rocket boosters?

5. Consider each measurement. State whether it is reported in the most appropriate unit. If it is not, explain why and convert to a more appropriate unit.

   a) The highest mountain in Canada, Mount Logan, has a height of 595 900 cm.

   b) The diameter of a water bottle is 0.064 m.

   c) The world's tallest bear was 4200 mm.

   d) A whooping crane's wingspan is 0.001 95 km.

Apply

6. A circular model railway track is made by connecting 12 pieces like the one shown.

32 cm
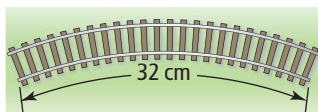
   a) When the 12 track pieces are assembled, what distance does a toy train travel along the inside of the track?

   b) Calculate the radius of the inside edge of the track, to the nearest millimetre.

   c) Estimate the radius of the outside edge of the track.

7. Give some examples of measuring instruments that are used to measure distance in the home, community, or workplace. Show or explain how one of these instruments works.

8. Jacques wants to build a trundle wheel. He wants the wheel to go around once for every metre the trundle wheel is pushed. What will be the radius of his trundle wheel?

9. A magazine editor needs to assess whether the photograph can be reduced proportionately to fill the rectangle below. Can it be? Explain, using measurements and ratios.
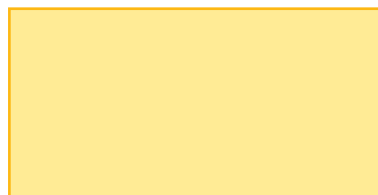
10. The photograph shows an inukshuk overlooking Rankin Inlet in Nunavut. Suppose the height of the inukshuk is 4.1 m. What is the height of the person standing in the photo, to the nearest tenth of a metre?
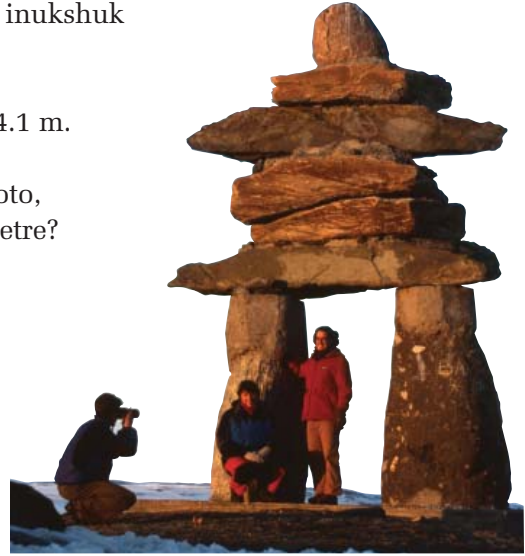
11. a) Measure the diameter of a Canadian dime and quarter.

b) Calculate the ratio of the diameter of a dime to the diameter of a quarter.

c) If this ratio applies for a quarter and a loonie, what would the diameter of the loonie be? Does the ratio apply? Justify your reasoning.

12. Use the map of part of the Northwest Territories to help answer the following questions.
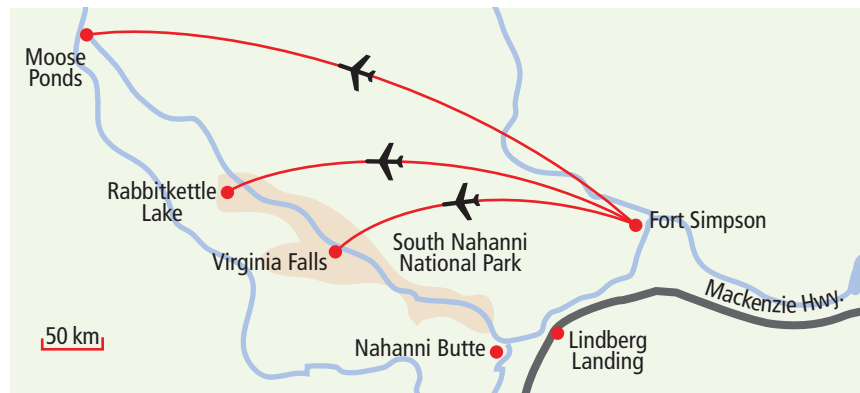
a) Express the scale of the map as a ratio in lowest terms.

b) Estimate the distance from Fort Simpson to Moose Ponds. Measure and compare the distance with your estimate.

c) Compare the distances from Virginia Falls and Rabbitkettle Lake to Fort Simpson. How much greater is the distance from Rabbitkettle Lake?

13. A geostationary satellite is in orbit 35 800 km above Earth's equator. The average radius of Earth at the equator is 6380 km.

a) Draw and label a diagram of Earth and the path of the satellite.

b) What distance does an observer on the equator travel in one day due to Earth's rotation? Express your answer to the nearest tenth of a kilometre

c) How far must the geostationary satellite travel in one day to appear stationary above Earth? Express your answer to the nearest tenth of a kilometre.

d) How much faster is the satellite travelling than the observer on Earth? Hint: Use the following formula.

Velocity (in kilometres per hour) $= \dfrac{\text{distance (in kilometres)}}{\text{time (in hours)}}$

14. (**Unit Project**) The music industry involves the production, distribution, and sale of music in a variety of forms. Since the 1960s, music distribution has evolved from vinyl records to cassette tapes, to CDs, and to MP3s. Each change emphasized that smaller is better.

a) For the actual-size cassette shown, use a suitable referent to estimate the dimensions of the cassette case. Explain why you used that referent.

b) Measure and calculate the perimeter of each different face of the cassette case, in millimetres. How many perimeters do you need to calculate?

c) Vinyl records are available in three sizes—45 rpm (revolutions per minute), 78 rpm, and $33\frac{1}{3}$ rpm or LP size. A 45 record has an actual diameter of 17.5 cm. Estimate the diameter of the LP in the photograph. Then, by measuring and determining a scale, calculate the actual diameter of the LP, in millimetres.

LP record

45 record

Extend

15. The scale of an aerial photograph can be approximated as the ratio of the camera's focal length to the airplane's altitude. For this aerial photograph taken near Fort McMurray, AB, the airplane's altitude is 305 m. The camera's focal length is 45 mm. What is the greatest distance across the crater shown in the photo?

16. Your lawn has the dimensions shown. You cut the grass using a mower that cuts with a width of 52 cm.

A   16.5 m

13.5 m
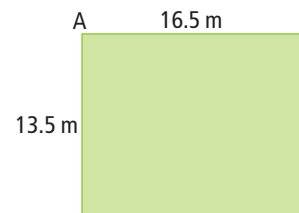
  a) To mow the entire lawn, what is the minimum distance you must walk? You start at A and return to A when finished.

  b) Does your route, for example, along the perimeter versus in rows, affect the distance you walk? Explain.

Create Connections

17. Imagine a band or ring placed tightly around Earth at the equator. You cut the band and lengthen it by 1 m. If you could block the new band so it is equally spaced above the equator, what distance would it be away from Earth? Assume Earth is circular at the equator and the radius of Earth is about 6400 km.

18. Work with a partner. Sometimes a sprained ankle needs to be wrapped with a compression bandage.

  a) Estimate the length of elastic bandage needed to wrap your ankle then foot repeatedly for four cycles.

  b) Wrap your ankle and foot using the figure eight wrapping technique with a strip of cloth. Measure the length required. Compare your estimate with the actual measurement.

  c) Darwin estimates the length of bandage by determining the approximate circumferences of his ankle and foot and multiplying the sum by four. He notices that his estimate is not close to his actual measurement of the bandage. Explain why.

19. Sandra lives in Salmon Arm, BC. She wants blue orchard mason bees to live in her backyard. She purchases a bee nesting box and intends to place it in one of her flower beds. The front of the box measures 15 cm by 15 cm on the inside. The outer diameter of each nesting tube is 8 mm.

a) Estimate the number of tubes that can fit inside the box.

b) Draw and label a diagram showing the dimensions of the nesting box.

c) Calculate the maximum number of tubes that can fit inside the box. Then, describe one way to check your work.

20. A factory makes frying pans. The inside surface of each pan is coated with a non-stick coating. You are hired to verify the formula that the factory uses to calculate the area of the inside surface.

The company formula is $S = \pi d\left(\dfrac{d}{4} + h\right)$, where S represents the inside surface area, in square centimetres; d represents the diameter of the pan across the top, in centimetres; and h represents the height up the side of the pan, in centimetres.

a) Measure a frying pan. Calculate the inside surface area using a technique of your choice. Give your answer in terms of π. Then, calculate the surface area using the company formula. Compare the values. Is the factory formula correct? Justify your response.

b) Li says that most frying pans will have an inside surface area slightly greater than the one calculated using the formula. Do you agree with Li? Explain why. Use an example and a diagram to support your explanation.

21. **MINI LAB** Work in a small group to establish a personal referent for a kilometre. Mark off a square that has sides of length 25 m. For each group member, measure the time it takes to walk around the square once.

Step 1 Estimate how long it might take to walk 1 km.

Step 2 Measure actual times by having each group member walk at a normal pace 10 times around the square. Why might your estimate not be close to the actual time?

Step 3 Walk along a street or road for your length of time from step 2. Measure the distance using an outdoor measuring device.

Step 4 List some places that are about 1 km from your school or home.

Materials
- SI measuring tape
- watch
- outdoor measuring device, such as an odometer, pedometer, trundle wheel, or measuring tape