

# Significant Digits and Measurement

What digits are significant when recording a measurement?

## Why?

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Scientists do a lot of measuring. When scientists use an instrument (such as a ruler, graduated cylinder, spectrophotometer or balance) to measure something, it is important to take full advantage of the instrument. However, they can't cheat and record a better measurement than the instrument is capable of. There is an understanding among scientists of the proper way to record valid measurements from any instrument. When you are the scientist, you must record data in this way. When you are reading other scientists' work, you must assume they recorded their data in this way.

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## Model 1 – Ruler A




Susan	3 cm
Maya	2 cm
Jonah	2.5 cm
Tony	3.00 cm
Emily	3¼ cm
Dionne	3.33 cm

1. What distances can you be certain of on the ruler in Model 1?
2. Six students used the ruler in Model 1 to measure the length of a metal strip. Their measurements are shown at the right. Were all of the students able to agree on a single value (1, 2, 3...) for any digit (ones place, tenths place, etc.) in the measurement? If yes, which value and digit did they agree on?
3. The ruler in Model 1 is not very useful, but a measurement can be estimated. Discuss in your group how each student might have divided up the ruler “by eye” in order to get the measurement that he or she recorded.

## Model 2 – Ruler B

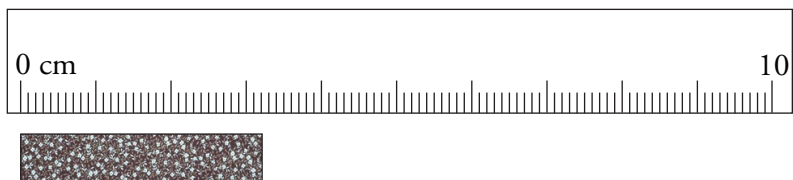


Susan	3.2 cm
Maya	3.1 cm
Jonah	3.3 cm
Tony	3 cm
Emily	3.25 cm
Dionne	3.20 cm

- The students obtained a better ruler, shown in Model 2. What distances can you be certain of on this ruler?
  - Were the students able to agree on a single value (1, 2, 3...) for any digit (ones place, tenths place, etc.) in their measurements using the ruler in Model 2? If yes, what value in what digit did they agree on?
  - What feature of the ruler in Model 2 made it possible for the students to agree on a value in that digit?
-  7. There will always be uncertainty in any measurement. This causes variation in measurements even if people are using the same instrument. Compare the variation in the measurements made by the six students using the rulers in Models 1 and 2. Which ruler resulted in greater variation? Explain why that ruler caused more variation.



## Model 3 – Ruler C



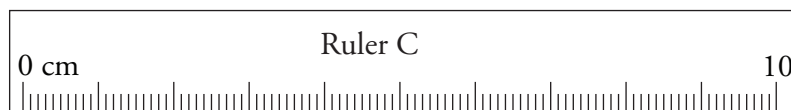
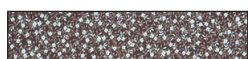
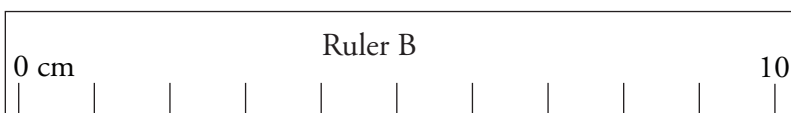
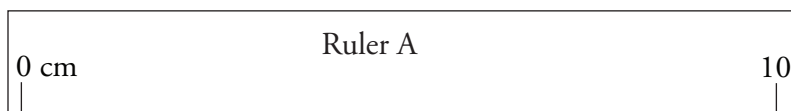
Susan	3.21
Maya	3.20 cm
Jonah	3.22 cm
Mark	3.2 cm
Emily	3.215 cm
Dionne	3.205 cm

- The students obtained an even better ruler, shown above in Model 3.
  - Were the students able to agree on a single value for any of the digits in their measurements using the new ruler? If yes, what value(s) did they agree on in which digits?
  - What feature of the ruler in Model 3 made it possible for the students to agree on the values in those digits?

## Read This!

When humans use measuring instruments, variation is expected. Everyone will estimate differently between marks on the instrument. On the other hand, digits that are certain (based on marks on the instrument) should not vary from person to person.

### Model 4 – Valid Measurements



Valid Measurements	Invalid Measurements
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3 cm	2.5 cm
2 cm	3.00 cm
	$3\frac{1}{4}$ cm
	3.33 cm

3.2 cm	3 cm
3.1 cm	3.25 cm
3.3 cm	3.20 cm

3.21 cm	3.2 cm
3.22 cm	3.215 cm
3.20 cm	3.205 cm



9. The measurements taken in Models 1–3 have been combined in Model 4. The measurements that follow the rules of measurement agreed upon by scientists are in the “Valid Measurements” column. Those that do not follow the rules are in the “Invalid Measurements” column. For each valid measurement shown in Model 4, draw a square around the certain digits (if any) and circle the digits that were estimated (if any).

10. Based on the examples in Model 4, circle the best phrase to complete each sentence below.

- In a valid measurement, you record (zero, one, two) estimated digit(s).
- In a valid measurement, the estimated digit is the (first digit, second to last digit, last digit) in the measurement.
- In a valid measurement, the estimated digit corresponds to (the largest marks, the smallest marks, one tenth of the smallest marks) on the instrument.



11. Using Ruler B from Model 4, Tony recorded a measurement of 3 cm. Explain why this was an invalid measurement.
12. Using Ruler B from Model 4, Dionne recorded a measurement of 3.20 cm, which was invalid. But when Maya made the same measurement using Ruler C, it was considered valid. Explain why the zero was acceptable when using Ruler C, but not when using Ruler B.
13. A student recorded the length of a test tube as 5.0 cm. Which ruler in Model 4 was the student using? Explain.
14. In Model 4, Ricky recorded his measurement 3.19 cm using Ruler C. His classmates thought he was wrong because his second digit was not “2.” However, Ricky’s recorded measurement is perfectly valid. Explain.

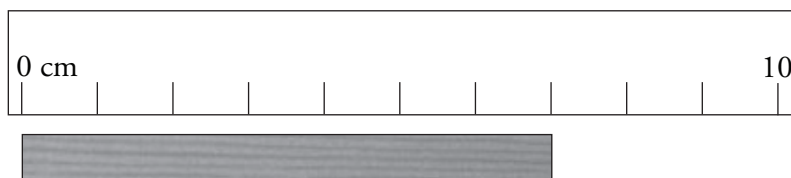
## Read This!

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When a measurement is recorded properly, all of the digits that are read directly (certain) and one estimated (uncertain) digit are called **significant digits**. The number of allowable significant digits is determined by the marks or gradations of the instrument. Sometimes a “0” is the estimated digit and must be recorded.

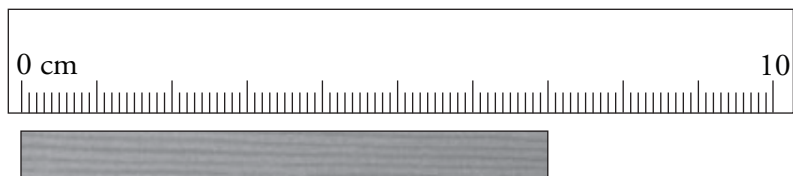
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15. Record the length of the wooden splint to the proper number of significant digits.



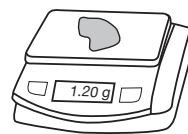


16. Record the length of the wooden splint to the proper number of significant digits.



## Extension Questions

17. When using an electronic device, such as an electronic balance, the measurement displayed on the screen is assumed to have one estimated digit included. In fact, you'll often see the estimated digit changing rapidly, because there is fluctuation in the estimate. Explain why it is important to record the zero in the measurement shown to the right.



18. Consider a 1000-mL graduated cylinder with marks every 100 mL.
- A student records the volume of liquid in the cylinder as 750 mL. Is this a correct measurement? Explain.
  - Are all of the digits in the described measurement of 750 mL significant? Explain.
19. A student properly records the length of a block as 120 cm. Draw the markings on the ruler that was used to measure the block.

