4. <u>Significant Figures</u> (W p24-29)

1. Measurement always includes some **uncertainty**. = Observed values always include some uncertainty. (This is the basic standpoint in science.)

20 30 [Q1] What are the values, A and B shown? A = A В B = [Q2] What is the length of the clip? ? cm 7 0 1 2 3 4 5 6 8 9 10 Centimeters [Q3] What is the length of the clip? ? cm 2 3 0 1 4 5 6 7 8 9 10 Centimeters

[Rule-1] In a measurement, we must read the digits that are determined by marks of a device and additionally estimate one more digit. The digits are all significant figures.

2. The number of significant figures 桁数

[Q2] How many significant figures are there in the following numbers?:

 [Example] 123
 --- It has three significant figures

 (a)
 0.000054 --

 (b)
 3.001×10^5 --

 (c)
 2.70 --

 (d)
 2700 --

 (e)
 0.002700 --

[Rule-2] a) All non-zero numbers are significant

b) Zeros between non-zero numbers are significant
c) Leading zeros before a number are not significant.
d) Trailing zeros after a number are uncertain whether they are significant or not unless there's a decimal point.

Compare: 250 250. 250.0 250.00

3. [Rule-3] Scientific notation specifies the number of significant figures

 $\begin{array}{cccc} [Q3\mathchar`-1] & 0.0316 & \rightarrow \\ & 31.60 & \rightarrow \\ & 316.0 & \rightarrow \\ & 3160 & \rightarrow \\ & 2900 & \rightarrow \\ & 2900.0 & \rightarrow \end{array}$

[Q3-2] Write the numbers at the right using scientific notation.

[Q3-3] Find the product of the mass of Earth and the mass of a hydrogen atom.

[Q3-4] Divide the mass of hydrogen atom by the mass of Earth.

4. [Rule-4] <u>Multiplication and Division</u> --- The quantity with <u>the fewest significant figures</u> in input determines the number of significant figures in the answer.

Example: $\frac{123.45 \times 0.0555}{22.20} = 0.30862500 \rightarrow 0.309$ (Rounding)

5. Rounding (or Rounding-off)

[Q5-1] Round the followings to three significant digits:

- 1) $23.47 \rightarrow$ 2) $23.429 \rightarrow$ 3) $23.449 \rightarrow$
- 4) $23.445 \rightarrow$
- 4) 25.451
- 5) 23.45 \rightarrow 6) 23.55 \rightarrow
- 7) 23.450 →
 8) 23.4501 →

[Rule-5] Rounding

- a) Round down if the digit flowing the last significant figure is a 0,1,2,3 or 4.
- b) Round up if the digit flowing the last significant figure is a6,7,8 or 9.
- c) Round <u>up</u> if the digit following the last significant figure is a 5 followed by a nonzero digit. 54.8511 → 54.9 54.8501 → 54.9
- d) Round <u>down</u> if the last significant figure is an <u>even</u> number and the next digit is a 5, with no other nonzero digits.
 54.85 → 54.8 54.85000 → 54.8
- e) Round <u>up</u> if the last significant figure is an <u>odd</u> number and the next digit is a 5, with no other nonzero digits. $54.75 \rightarrow 54.8$ $54.75000 \rightarrow 54.8$

[Q5-2] Find the number of significant figures of the following quantities:

- a) 5 h 23 min
- b) 1 h 23 min
- c) 1 h 23 min 11 s
- d) 3 h 23 min 11 s
- e) 5'5"

[5-3] Find the solutions:

- a) 5.0 m x 5.0 m =
- b) 5 m x 5 m =
- c) 5 students x 5 biscuits/student =

6. [Rule-6] <u>Addition and Subtraction</u> --- The result is limited by the number with the largest uncertain decimal position in input.

Example: $123.4500 \qquad [Q6-1] \qquad 17.3 \qquad 0.039 \qquad 5.361 \\
12.20 \qquad + 0.48 \qquad + 2.66 \qquad - 2.5 \\
+ 0.0063 \\
135.6563 \rightarrow 135.66 \\
6 \qquad 6 \qquad - 135.66 \qquad - 13$

[Q6-2] A parking lot is 144m long and 47.66 m wide. What are the area and the perimeter of the lot?



7. **Rounding Errors** (Round-off Errors) – How to avoid them? [Q7-1] A cow walks 3 km in 4 hours.

(a) What is the average speed of the cow?

(b) How far does it walk for 12 hours?

 $[\mathrm{Q7}\text{-}2]$ Find the circumference of a circle with a radius of $4.10~\mathrm{cm}$

[Rule-7] **Keep at least one extra digit** throughout your calculations to avoid "rounding error"





A Supplement to Significant Figures - Use Your Common Sense!

[22]

100: t	hree p	ossibil	ities
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- (1 significant figures) $50 \le 100 < 150$ 1)
- (2 significant figures) $95 \le 100 < 105$ 2)
- 3) (3 significant figures) 99.5 $\leq 100 < 100.5$

Using our "common sense," 1, 2 and 3 significant figures should be rejected in this case. Using our common sense, the distance of the "100-m dash" must be 100.000 \pm 0.005. (No formal information has been found.)

[24] Two distances, "2 km," are used like integer. Not one significant figure.

22. Calculate In 2009, Usain Bolt of Jamaica set a world record of 9.58 s in the 100-m dash. What was his average speed? Give your answer in meters per second and kilometers per hour.

24. Think & Calculate A train travels in a straight line

at 20.0 m/s for 2 km, then at 30.0 m/s for another 2 km.

(a) Is the average speed of the train greater than, less

(b) Verify your answer to part (a) by calculating the

than, or equal to 25 m/s? Explain.

average speed.

[25] 2-km trip:	Integer-like expression	25. Verify Determine the average speed of the bicycle in Conceptual Example 2.4 for the entire 2-km trip. Verify that it is less than 20 km/h, as expected.
[26] t = 0t = 15t = 2 st = 11 s	Integer-like expression	 26. A rose-covered parade float is at x = 0 at time t = 0. The float moves in a straight line at 2.0 m/s for the next 5 s before coming to a stop. After a 5-s stop, the float moves again at 1.0 m/s in the same direction as before. (a) Sketch the position-time graph for the float from the time t = 0 until the time t = 15 s. (b) From your graph, determine the positions of the float at t = 2 s and t = 11 s.
[32] t =0	Integer-like expression	32. Interpret Graphs Referring to Problem 30 and Figure 2.11, what is the average velocity of the tennis

+	_	5	a
- L	_		

Figure 2.11, what is the average velocity of the tennis player between t = 0 and t = 5 s?

II. Speed and Velocity (中学の復習と丸めの応用)

1. Average Speed and Instantaneous Speed

Average Speed =
$$\frac{\text{distance}}{\text{elapsed time}}$$
 [m/s] [km/h] (1)

[Q1a] Shinkansen super express Nozomi#9 departs at 7:10 am at Tokyo and arrives at 12:29 at Hakata. The distance between Tokyo and Hakata is 1069.1 km. What is the average speed in km/h?



Fig 4

[Q1b] In the above question, what is the significant figure for the solution?

[Q2] In Q1, what is the average speed in m/s?

[Q3] You are driving at a constant **instantaneous speed** of 60 km/h. How far do you drive for 15 minutes?

 $[\rm Q4]$ A car on a highway travels from A position to B position travels in 2.0 h at an average speed of 80 km/h. After that the car travels from B position to C position in 1.5 h at an average speed of 60 km/h.

(a) What is the distance from A position to C position.

(b) What is the average speed between A position to ${\rm C}$ position.

