PHYS 225
Fundamentals of Physics: Mechanics

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Fall 2024

Lecture 2: Measurement

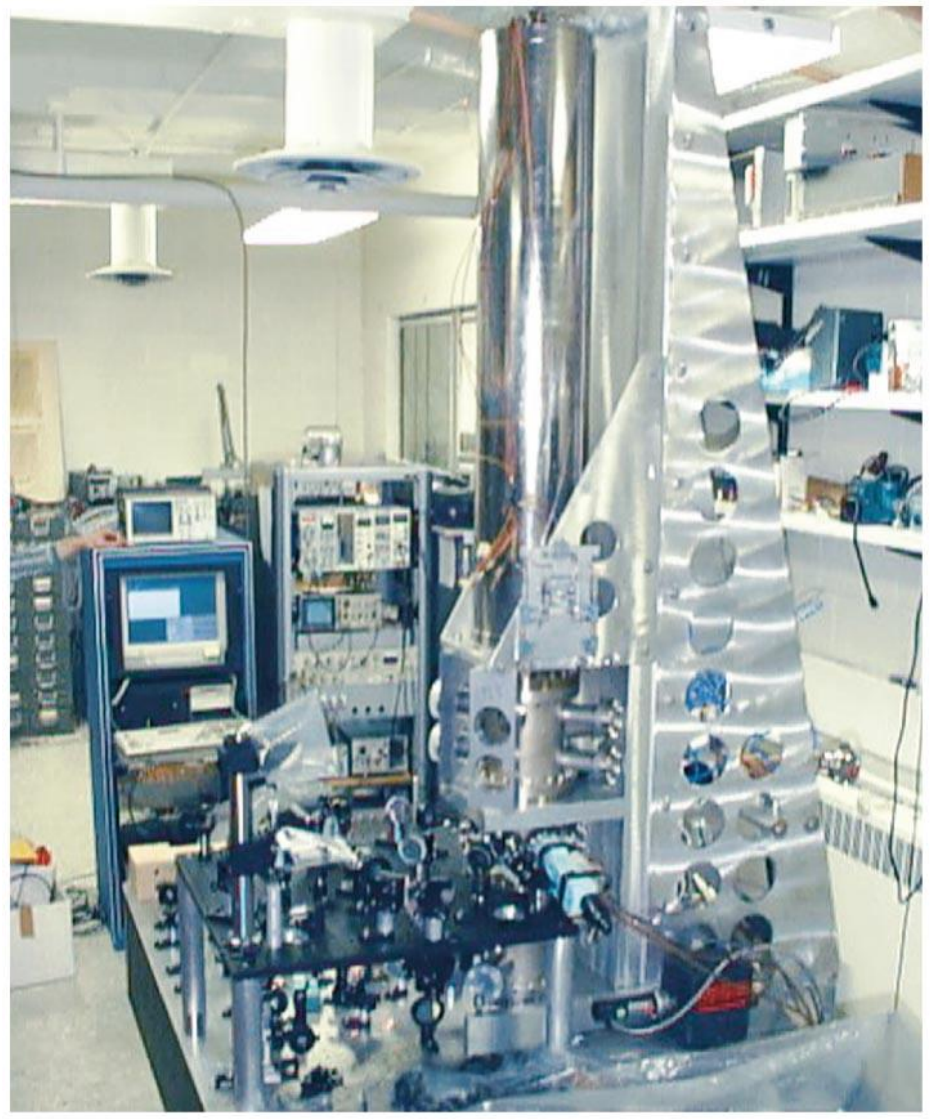
CALIFORNIA STATE UNIVERSITY
FULLERTON

Learning goals

- Base quantities
- Unit conversion
- Dimensional analysis

Time

- What is time?
  - Hard to define
  - Measure of the sequence of how long an event takes
  - A “4th dimension”
- SI unit:
  - Second (s)



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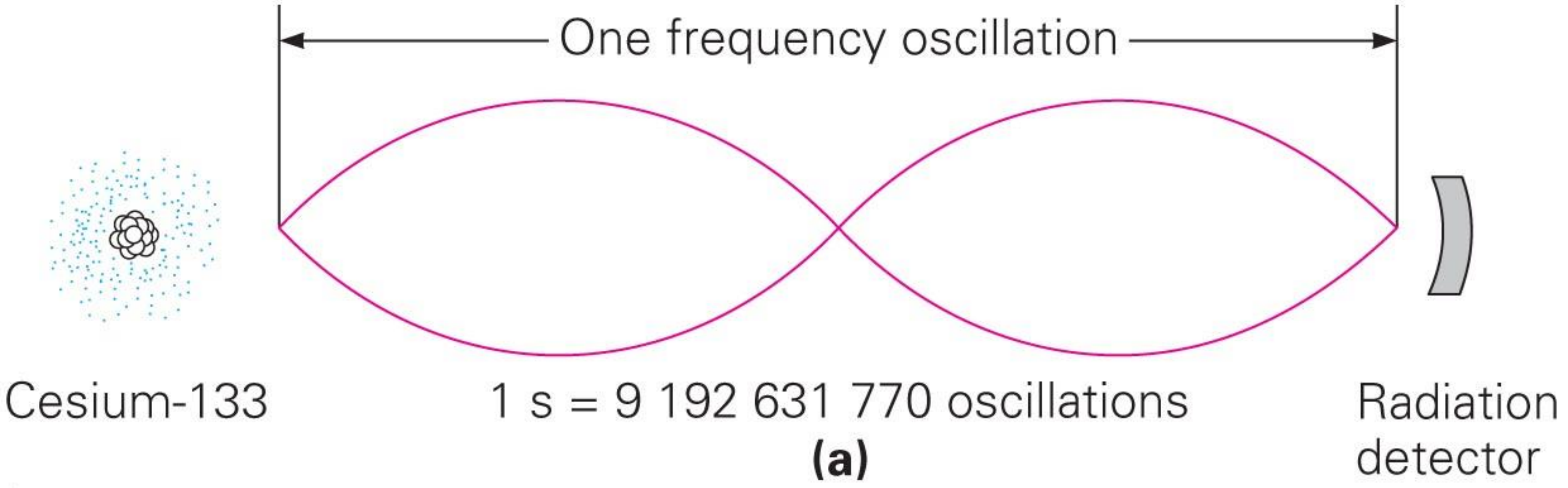


(a)

Time scales

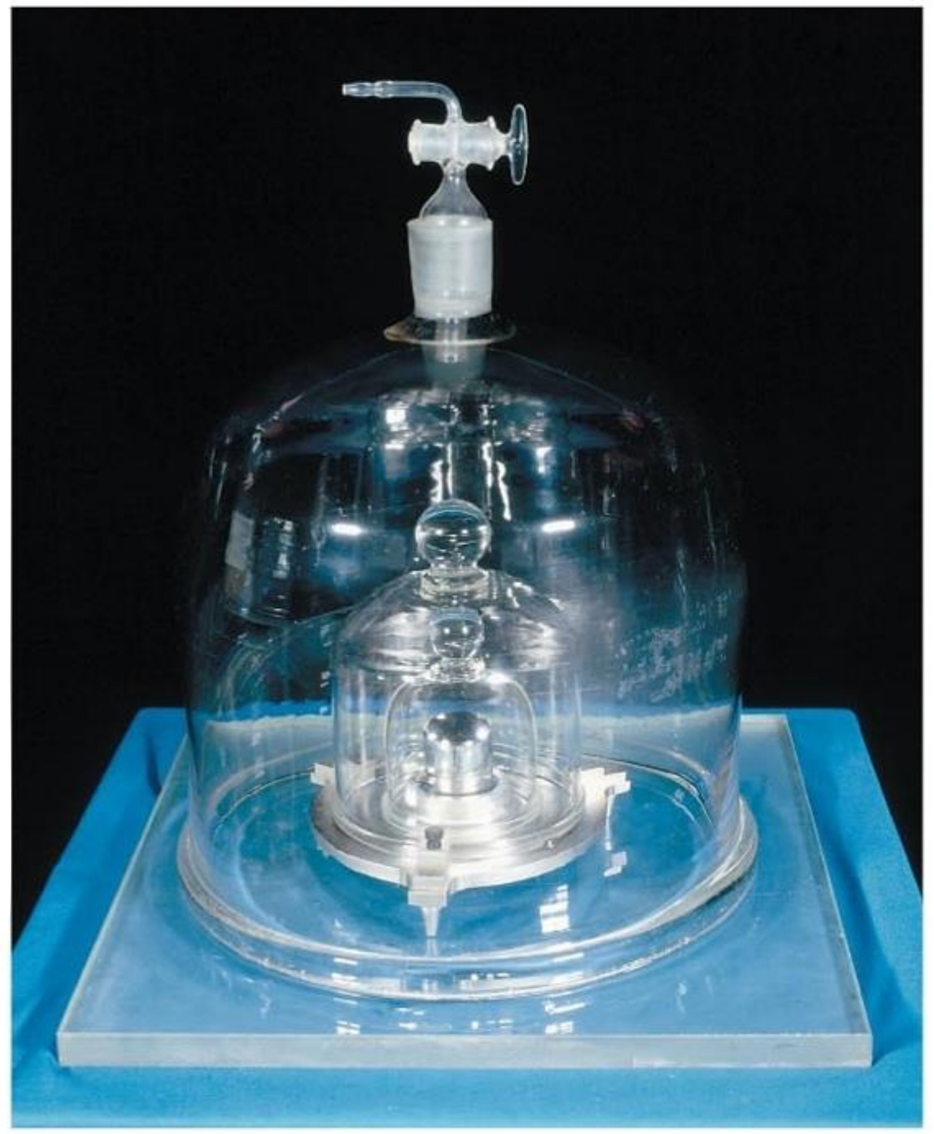
Time = $10^{?}$ s

Age of universe	18
Age of Earth	17
Time since appearance of humans on Earth	13
Average human life expectancy	9
Winter break at CSUF	6
This lecture	3
“This word”	0
Blink of an eye	-1
Best human reaction time	-2
1 cylce of a 1960s computer	-6
Light travels 1 foot	-9
1 cycle of modern supercomputer	-11
Shortest measured period of time	-17

1 hr = 3600 s

Mass

- What is mass?
  - Defined as the the resistance to accelerate.
  - Proportional to the “amount of stuff”
- SI unit:
  - Kilograms (kg)



(b)

Defined as the mass of a cylinder of platinum and iridium stored in France.

Mass scales

Mass = $10^{?}$ kg

Mass of observable universe	53
Our galaxy	42
Black hole at center of our galaxy	37
Sun	30
Earth	25
Mass of all living humans	11
Largest living tree	6
Adult human	2
Bottle of soda/pop/Coke	0
Fruit fly	-7
Average human cell	-12
HIV-1 virus	-18
Caffeine molecule	-25
Proton	-27
Electron	-31
Electron neutrino	-35

Mixed units

- You can have quantities measured in combinations of basic units

Quantity	Unit
mass	kg
time	s
length	m
area	m^2
volume	m^3
velocity (v)	m/s
acceleration	m/s^2

Base quantities

Mixed quantities

Energy : Joules ~ $kg \cdot m^2 s^{-2}$

Unit conversion

- **Unit conversion** is important in daily life and technology.
- Unit conversion **errors** can cost money and lives
  - On Sept. 23, 1999, NASA lost the $125 Million Mars Climate Orbiter spacecraft due to **wrong unit conversion**. (Watch video: https://youtu.be/urcQAKKAAl0)

Remember the Mars Climate Orbiter incident from 1999?

https://www.simscale.com/blog/nasa-mars-climate-orbiter-metric/

Chain-link rule for unit conversion

- **Example:** John is 73 inches. How tall is John in meters? Given:

$$1 \text{ in} = 2.54 \text{ cm} = 0.0254 \text{ m}$$

Step 1: Conversion factor:

$$1 = \frac{0.0254\,m}{1\,in}$$

Step 2:

$$73\,in = 73\,in \cdot \frac{0.0254\,m}{1\,in} \approx 1.85\,m$$

Chain-link rule for unit conversion

- The **chain-link rule** standardizes unit conversion
- In **chain-link rule**, we multiply a physical quantity by "1", where "1" is the **conversion factor** including units
- **For example:** Convert 73 in to meters
  - **Step 1**: Conversion factor , $1 = \dfrac{0.0254\ m}{1\ in}$
  - **Step 2**: Substitute **Step 2** to **Step 1**: $73.0 in = 73.0\ in \times 1 = 73.0\ \cancel{in} \times \dfrac{0.0254 m}{1 \cancel{in}}$

$$= 1.85 m$$

Don’t forget to write the units

- Always write the units in unit conversion:

$$73in = 73in \times \frac{0.0254m}{1in} = 1.85m$$

- Forgetting to include the units makes Tuffy cry

Clicker question 1

- 1 cm is 0.01 m. How is 1 cm^3 converted to m^3?

A 1 cm^3 = 0.01 m^3

B 1 cm^3 = 1×10^{-6} m^3

Unit conversion of comprehensive units

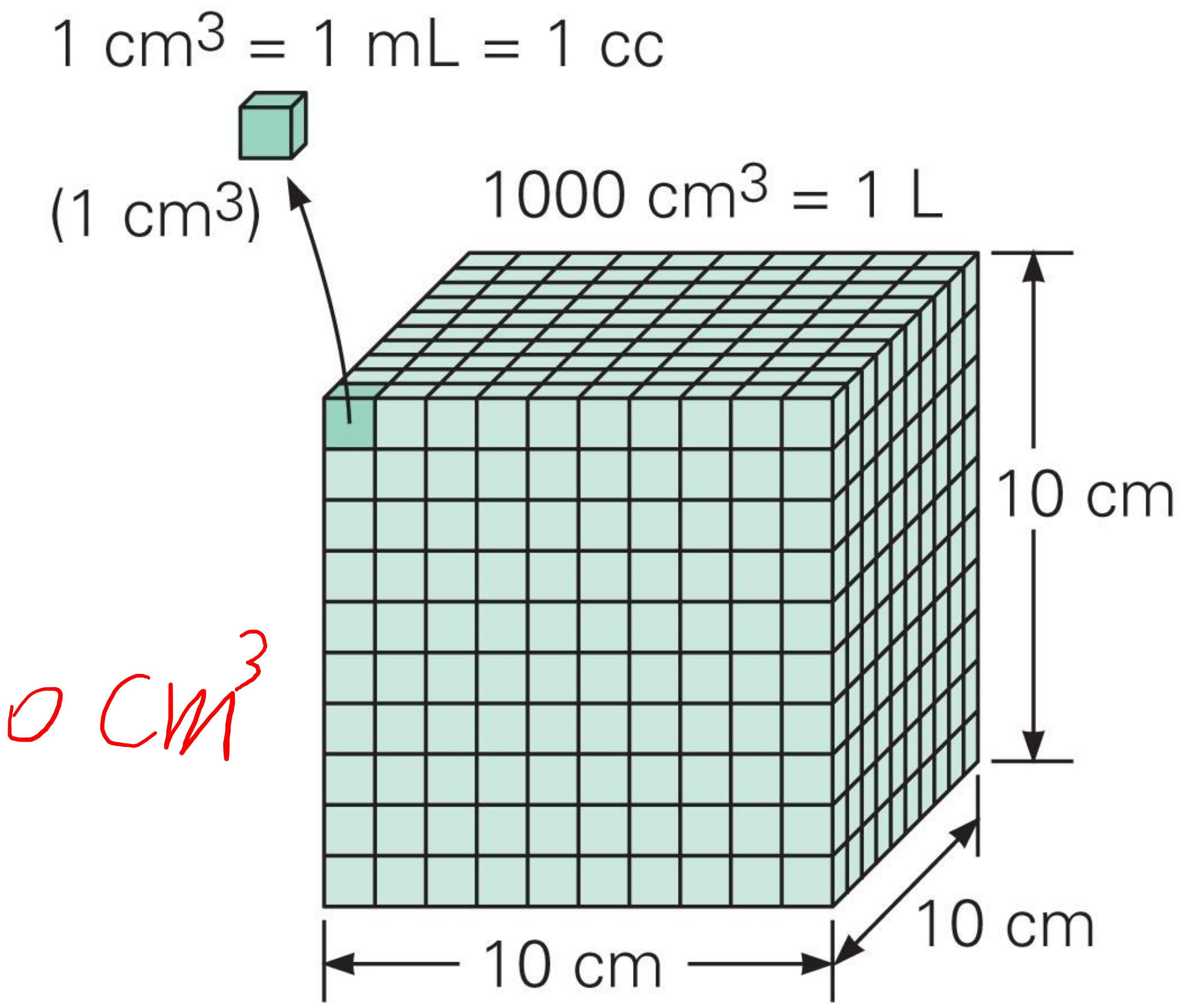
- If a unit is raised to a power, so is the conversion factor
  - Examples

1. Convert 1 dm^3 to cm^3

Step 1 : Conv. fac.

$$1^3 = \left(\frac{10\ cm}{1\ dm}\right)^3$$

Step 2 : $1\ dm^3 = 1\ dm^3 \cdot \left(\frac{10\ cm}{1\ dm}\right)^3 = 1000\ cm^3$



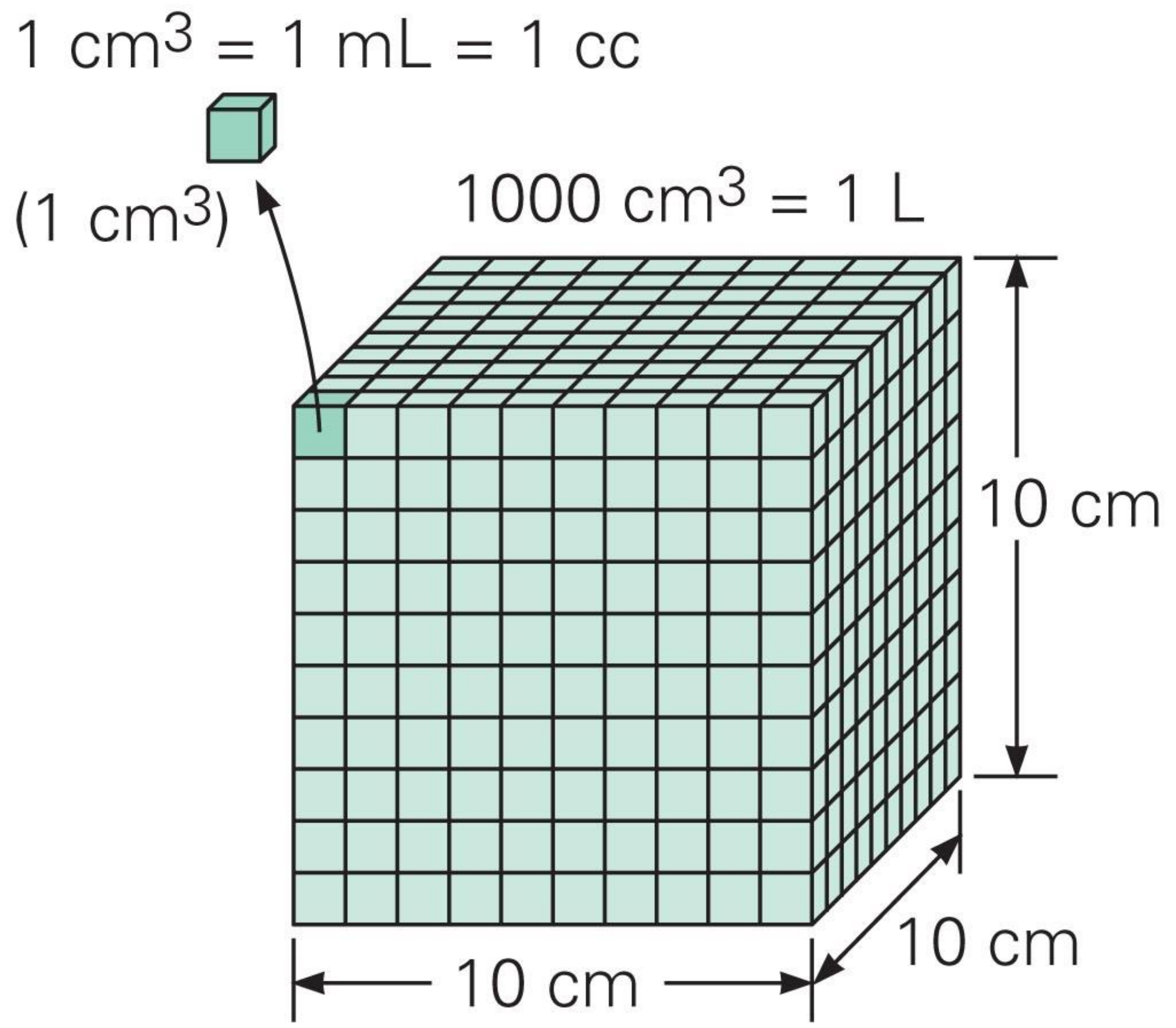
Unit conversion of comprehensive units

- If a unit is raised to a power, so is the conversion factor
  - Examples

1. Convert 1 dm^3 to cm^3

$$1\ \mathrm{dm}^3 = 1\ dm^3 * (1)^3$$

$$= 1 dm^3 * \left(\frac{10\ cm}{1\ dm}\right)^3 = 1000\ cm^3$$



Clicker question 1

- 1 cm is 0.01 m. How is 1 cm^3 converted to m^3?

A

1 cm^3 = 0.01 m^3

B

1 cm^3 = 1× 10^{-6} m^3

Step 1: $1^3 = \left(\frac{0.01\,m}{1\,cm}\right)^3$

Step 2: $1\,cm^3 = 1\,cm^3 \cdot \left(\frac{0.01\,m}{1\,cm}\right)^3$

$= 1 \times 10^{-6}\,m^3$

Example 1

- 1 mile = 1609 m. What is 55 mph (miles per hour) in m s^{-1}?

Step1: Conv. fac.

$$\frac{1\,\text{mile}}{1609\,\text{m}} = 1 \quad , \quad 1\,\text{hr} = 3600\,\text{s} \rightarrow \frac{1\,\text{hr}}{3600\,\text{s}} = 1$$

Step2: $\frac{55\,\text{mile}}{\text{hr}} \cdot 1 \cdot 1 = \frac{55\,\cancel{\text{mile}}}{\cancel{\text{hr}}} \cdot \frac{1609\,\text{m}}{1\,\cancel{\text{mile}}} \cdot \frac{1\,\cancel{\text{hr}}}{3600\,\text{s}}$

$$\approx 24.6\,\text{m}\,\text{s}^{-1}$$

Chain-link rule review

Step 1: Conv. fac.

$$1 = \frac{?}{?}$$

Step 2:

$$\text{Old} \times \underset{\text{Con. fac.}}{\underline{\quad\quad}} = \text{new}$$

Dimensional analysis

Unit must balance

- Both sides of an equation must have the same units
  - This limits the kinds of equations you can write
  - **Example**: Relating distance *d*, velocity *v*, and time *t*

m ms^{-1} s

Clicker question 2

- Which of the following equations correctly relates distance *d*, velocity *v*, and time *t* (i.e., which have the right units?)

A $v = dt$

B $v = d/t$

C $v = t/d$

D $v = 1/(dt)$

Quantity:	v	=	d	/	t
Unit:	m/s		m	/	s

Example 3

- Suppose $A = BC$, where A has the units L/M and C has the units L/T. What's the dimension of B?

Step 1: $A = BC \rightarrow B = \frac{A}{C}$

Step 2: $B = \frac{A}{C}$

A: $\frac{L}{M}$

C: $\frac{L}{T}$

$\frac{\frac{L}{M}}{\frac{L}{T}} = \frac{T}{M}$

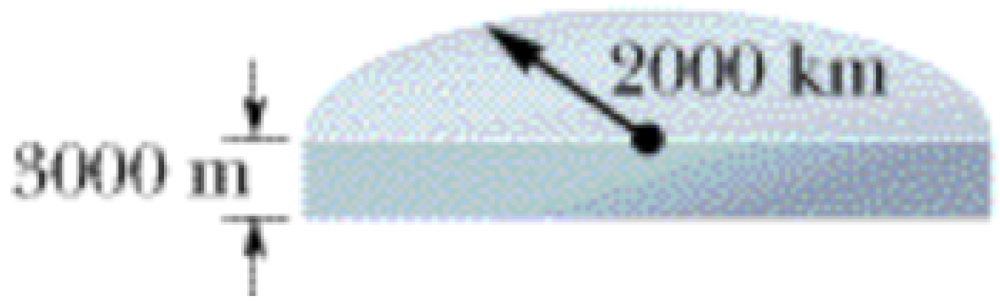
Example 4

Prefixes

Antarctica is roughly semicircular, with a radius of 2.00×10^3 km (see the figure). The average thickness of its ice cover is 3.00×10^3 m. How many cubic centimeters of ice does Antarctica contain? (Ignore the curvature of Earth.)

h

Goal: Volume (m^3)



Given: r, h

$A = \pi r^2$

Step 1: Volume = Area × h

$m^3 = m^2 \times m$

$$\text{Volume} = \frac{\pi r^2}{2} \times h \approx \frac{3.14\,(2.00 \times 10^6\ m)^2}{2} \times (3000\ m)$$

$$= 1.88 \times 10^{16}\ m^3$$

Step 2:

10^5 cm ~ conv. fac. $\frac{10^5\ cm}{1\ km} = 1$

$$1.88 \times 10^{16}\ m^3 = 1.88 \times 10^{16}\ m^3 \times \left(\frac{100\ cm}{1\ m}\right)^3 \approx \boxed{1.88 \times 10^{22}\ cm^3}$$

Wrap up concepts of Chapter 1

- Learning objectives
  - Measurements
  - Base quantities and units
  - Order of magnitude and prefixes
  - Significant figures
  - Unit conversion
  - Dimensional analysis

More examples

- In the end of Chapter 1: Measurement and units on Canvas:
  - eTextbook -> Chapter 01 Student Solutions Manual

SI: 4:00 ~ 5:15 pm, Tu, Th

Homework 1

- Due next Thursday
- Module 1.4: Homework assignment
- **Need more practice?**
  - Canvas -> eTextbook for Chapter 1 -> Chapter 01 Student Solutions Manual

Pre-lecture survey for Chapter 2 before the next class

- Module 2.1: Pre-lecture survey (Due before the next lecture)

Next lecture: Motion along a straight line