Chapter 1 Foundations

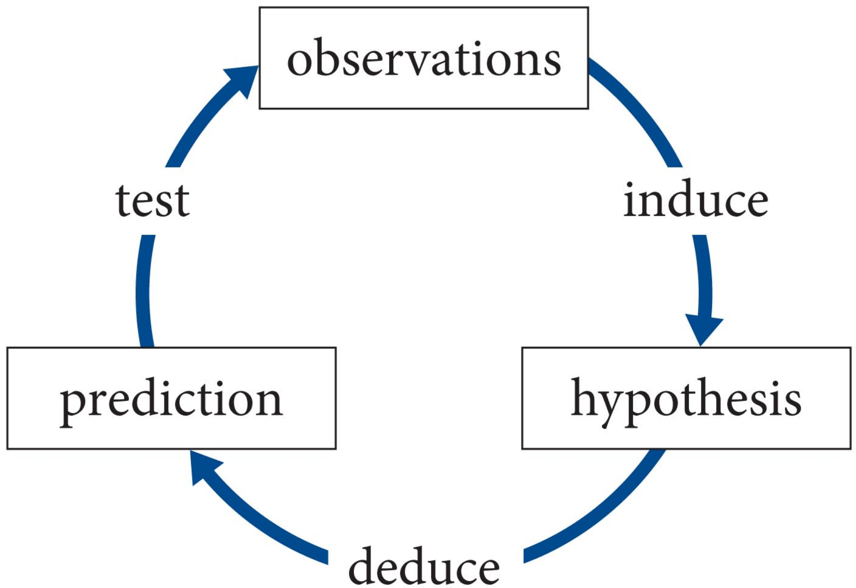
Concepts

Section 1.1: The scientific method

- Physics is about discovering the unifying patterns that underlie all physical phenomena
  - Ranging from the scale of subatomic particles to the DNA molecules and cells, and to the scale of stars and galaxies.
- The goal is to find the most fundamental laws that govern the universe and to formulate these laws in the most simple and precise way possible.
  - Some things are simpler than others

Section 1.1: The scientific method

- **The Scientific Method** is an iterative process by which scientists endeavor to construct these laws of nature.



- If the prediction is inaccurate you modify the hypothesis
- If the predictions prove to be accurate test after test it is elevated to the status of a **law** or a **theory**.

Exercise 1.1 Hypothesis or not

Which of the following statements are hypotheses?

(a) Heavier objects fall to Earth faster than lighter ones.

(b) The planet Mars is inhabited by invisible beings that are able to elude any type of observation.

(c) Distant planets harbor forms of life.

(d) Handling toads causes warts.

Exercise 1.1 Hypothesis or not (cont.)

SOLUTION (*a*), (*c*), and (*d*).

A hypothesis must be experimentally verifiable.

a) I can verify this statement by dropping a heavy object and a lighter one at the same instant and observing which one hits the ground first.

b) This statement asserts that the beings on Mars cannot be observed, which precludes any experimental verification and means this statement is not a valid hypothesis.

Exercise 1.1 Hypothesis or not (cont.)

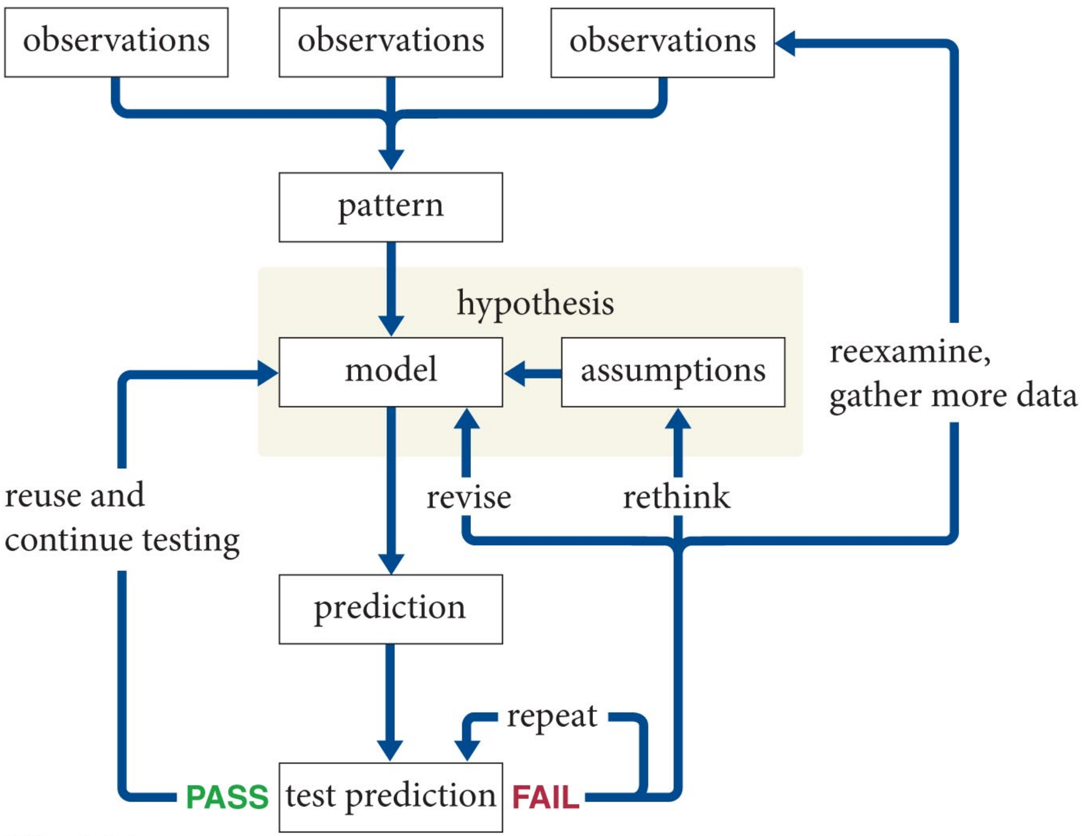
SOLUTION

c) Although we humans currently have no means of exploring or closely observing distant planets, the statement is in principle testable.

d) Even though we know this statement is false, it *is* verifiable and therefore is a hypothesis.

Section 1.1: The scientific method

- forming a hypothesis almost always involves developing a **model**
- a **model** is a simplified conceptual representation of some phenomenon.



Exercise 1.2 Dead music player

A battery-operated music player fails to play when it is turned on.

- Develop a hypothesis explaining why it fails to play.
- Make a prediction that permits you to test your hypothesis.
- Describe two possible outcomes of the test and what you conclude from the outcomes.

Exercise 1.2 Dead music player (cont.)

SOLUTION (one example):

Hypothesis: The batteries are dead.

Prediction: If I replace the batteries with new ones, the player should work.

Possible outcomes: (1) The player works once the new batteries are installed, which means the hypothesis is supported; (2) the player doesn't work after the new batteries are installed, which means the hypothesis is not supported and must be either modified or discarded.

Checkpoint 1.2

1.2 In the music player example, each outcome had a hidden assumption.

Hypothesis: The batteries are dead.

(1) The player works once the new batteries are installed, which means the hypothesis is supported;

(2) The player doesn't work after the new batteries are installed, which means the hypothesis is not supported and must be either modified or discarded.

Checkpoint 1.2

“supported” isn’t the same as “proven correct”

That the player works with new batteries doesn’t mean the old ones were dead.

- perhaps the old ones were in backwards?
- perhaps changing the batteries fixed a loose contact?

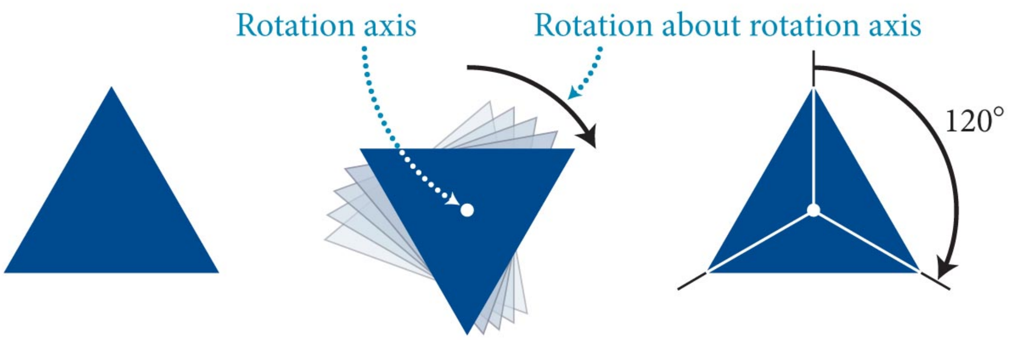
That the player doesn’t work with new batteries doesn’t mean the player is broken

- batteries could be in backwards both times
- new batteries might be dead too

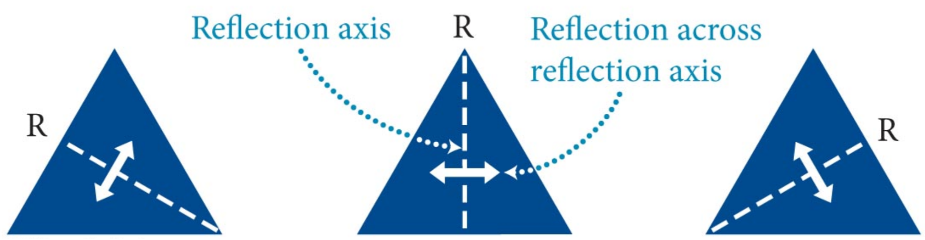
Section 1.2: Symmetry

- A vital requirement of any law is called **symmetry**.
- An object exhibits **symmetry** when certain operations performed on it does not change its appearance.

(*a*) Rotational symmetry: Rotating an equilateral triangle by 120° doesn't change how it looks



(*b*) Reflection symmetry: Across each reflection axis (labeled R), two sides of the triangle are mirror images of each other



Section 1.2: Symmetry

- Symmetry applies not only to shape but to phenomena.
- If we can alter an experiment in a way that leaves the results of it unchanged, then the phenomena tested is said to possess a certain symmetry.
- Any physical law that we develop to describe the phenomena must also possess this symmetry:
  - As an example, if rotating the apparatus by 90^{o} yields the same experimental results, then the phenomenon possesses *rotational symmetry*, and the mathematical expressions of the laws describe it should possess this symmetry.

Exercise 1.3 Change is no change

Does the snowflake have rotational symmetry?

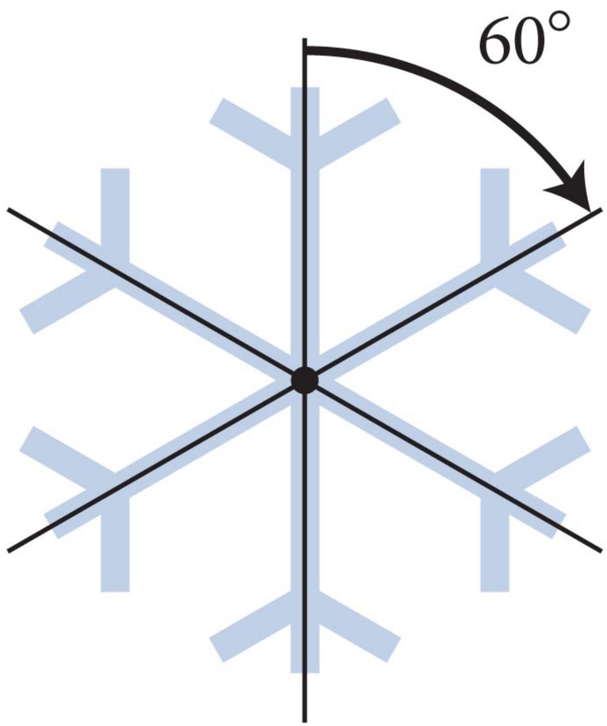
If so, what rotations leave its appearance unchanged?

Does it have mirror symmetry?

If so, along what axes?

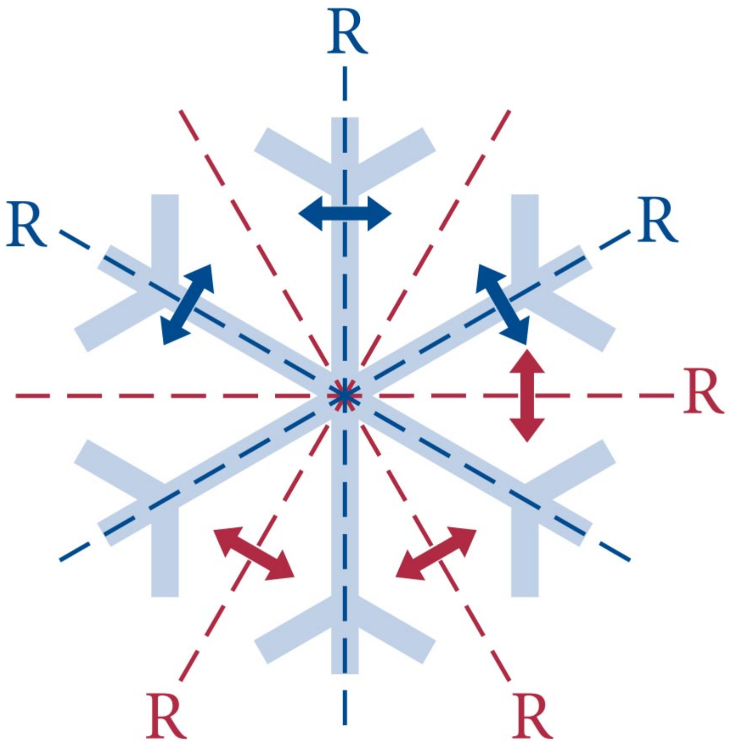
Exercise 1.3 Change is no change (cont.)

SOLUTION I can rotate the snowflake by 60º or a multiple of 60º in the plane without changing its appearance. It thus has (sixfold) rotational symmetry.



Exercise 1.3 Change is no change (cont.)

SOLUTION you can fold the flake in half along any of the three blue axes or any of the three red axes. The flake therefore has (six-fold) reflection symmetry



Section 1.3: Matter and the universe

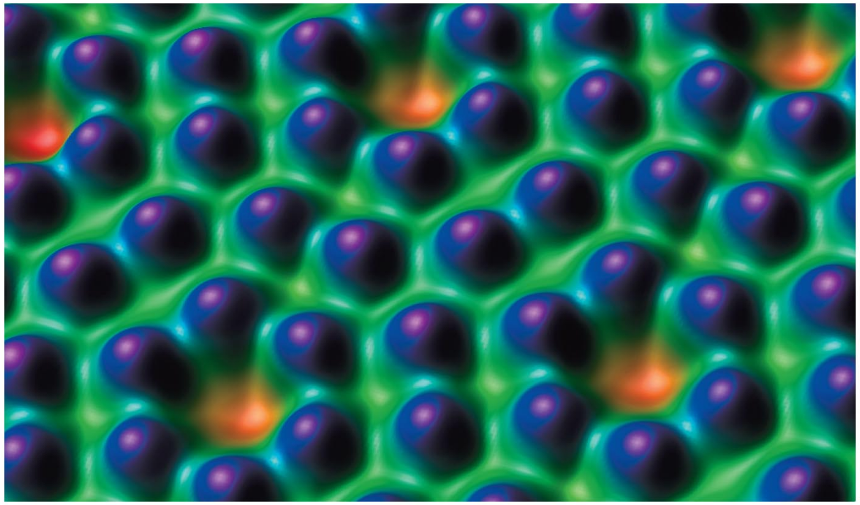
- The goal of physics: describe all that happens in the universe.
- The use of **physical quantities** is pivotal in developing concepts that describe natural phenomena.
- The fundamental physical quantity by which we map the universe is **length**:
  - The SI unit of length to be a **meter** and is abbreviated m.
  - The current definition of the meter is precisely defined through the (constant) speed of light

Section 1.3: Matter and the universe

- Because of the vast range of size scales in the universe, we often round off any values to the nearest power of ten.
- The nearest power of ten is called an **order of magnitude**.
- Any number between 0.3–3, call it 1
- Any number >3 but <30, call it 10
  - Example: 3 minutes = 180 seconds. In scientific notation this is 1.8×10^2 s. Since $1.8 < 3$, the order of magnitude value is 10^2 s.
  - Basically: "about 100" rather than "about 10 or 1000"
  - Example: Earth's circumference = 40,000,000 m $= 4 \times 10^7$ m. Order of magnitude value $= 10^8$ m.

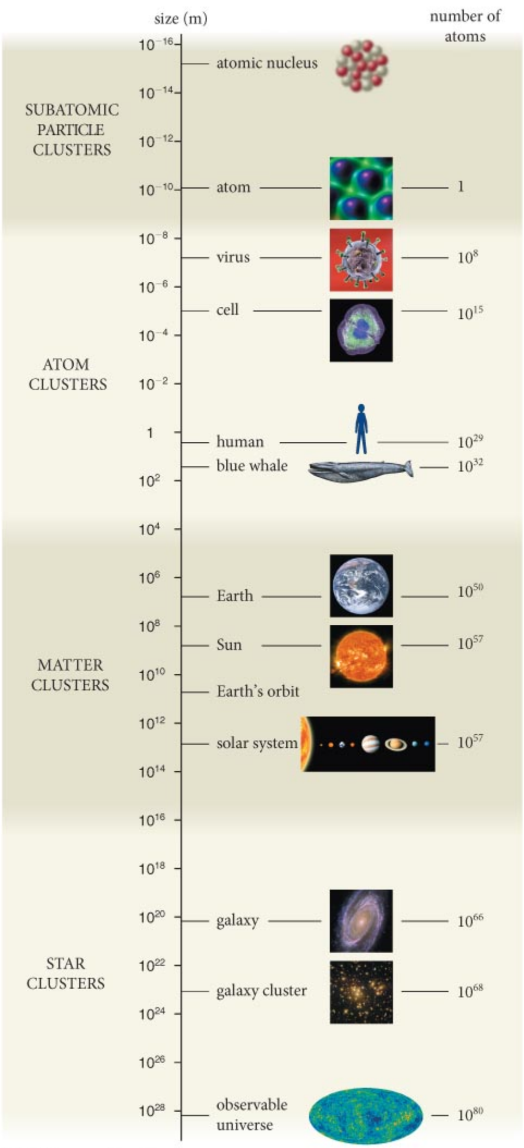
Section 1.3: Matter and the universe

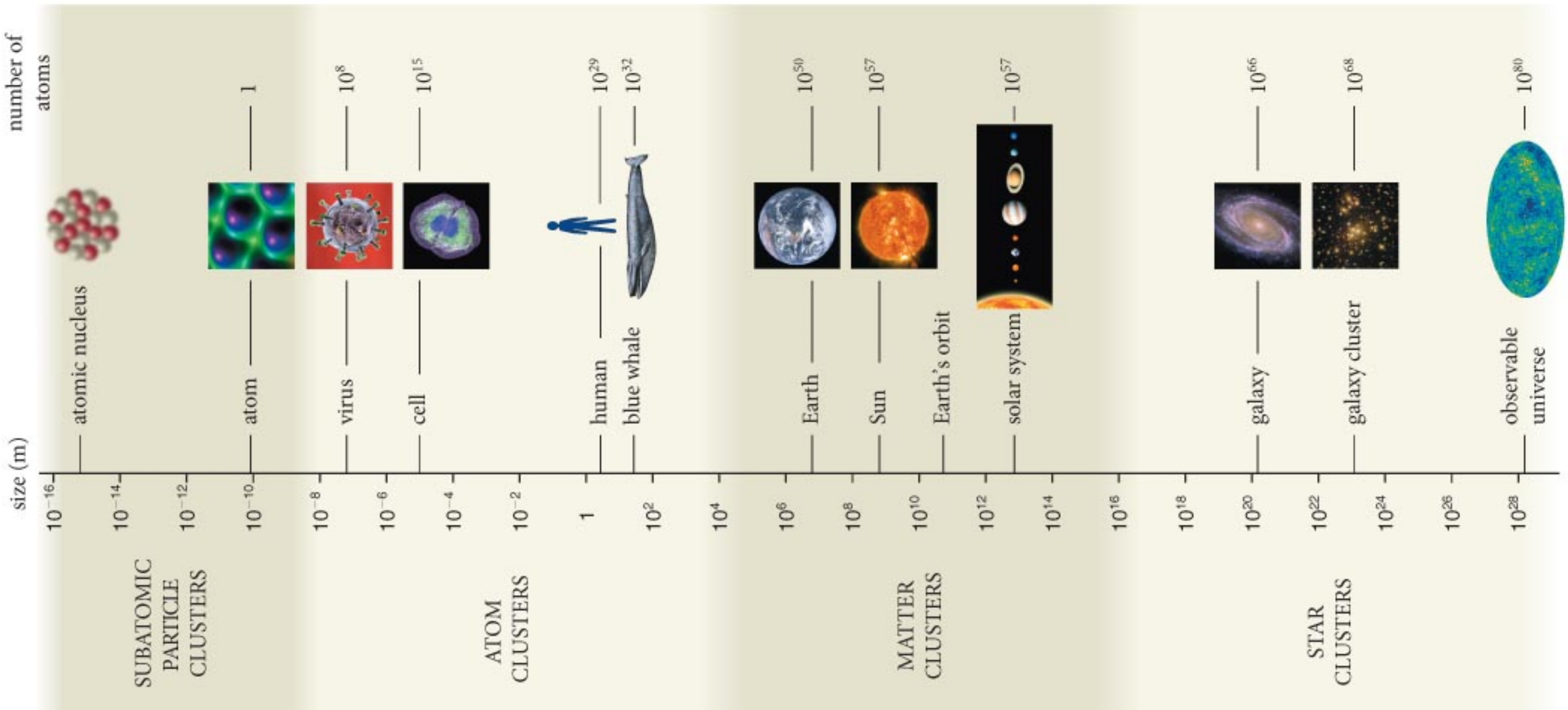
- All ordinary matter in the universe is made up of basic building blocks called atoms
  - Nearly all the matter in an atom is contained in a dense central nucleus, which consists of **protons** and **neutrons**.
  - A tenuous cloud of **electrons** surrounds this nucleus.
- Atoms have a diameter of about 10^{-10} m.
- The nucleus has a diameter of about 10^{-15} m.



- The figure shows the relative size of some representative objects in the universe.

- can you neglect things above/below a certain order away?




number of atoms
size (m)
atomic nucleus
atom
virus
cell
human
blue whale
Earth
Sun
Earth's orbit
solar system
galaxy
galaxy cluster
observable universe
1
10^{8}
10^{15}
10^{29}
10^{32}
10^{50}
10^{57}
10^{57}
10^{66}
10^{68}
10^{80}
10^{-16}
10^{-14}
10^{-12}
10^{-10}
10^{-8}
10^{-6}
10^{-4}
10^{-2}
1
10^{2}
10^{4}
10^{6}
10^{8}
10^{10}
10^{12}
10^{14}
10^{16}
10^{18}
10^{20}
10^{22}
10^{24}
10^{26}
10^{28}
SUBATOMIC PARTICLE CLUSTERS
ATOM CLUSTERS
MATTER CLUSTERS
STAR CLUSTERS

Exercise 1.4 Tiny universe

If all the matter in the observable universe were squeezed together as tightly as the matter in the nucleus of an atom, what order of magnitude would the diameter of the universe be?

Exercise 1.4 Tiny universe (cont.)

SOLUTION

From the chart: about 10^{80} atoms in the universe.

Arrange these atoms in a cube that has 10^{27} atoms per side

$$(10^{27} \times 10^{27} \times 10^{27} = 10^{81} \text{ atoms})$$

The diameter of a nucleus is about 10^{-15} m.

The length of a side of this cube would be

$$(10^{27} \text{ atoms})(10^{-15} \text{ m per atom}) = 10^{12} \text{ m}$$

A bit larger than the diameter of Earth's orbit around the Sun.

Alternate method

A single nucleus occupies a cubic volume of about

$$(10^{-15}\ \text{m})^3 = 10^{-45}\ \text{m}^3$$

If all 10^{80} atoms in the universe were squeezed together just as tightly, it would occupy a volume of about

$$10^{80} \times 10^{-45}\ \text{m}^3 = 10^{35}\ \text{m}^3$$

The side of a cube of this volume is 4.6×10^{11} m, which is the same order of magnitude as my first answer.

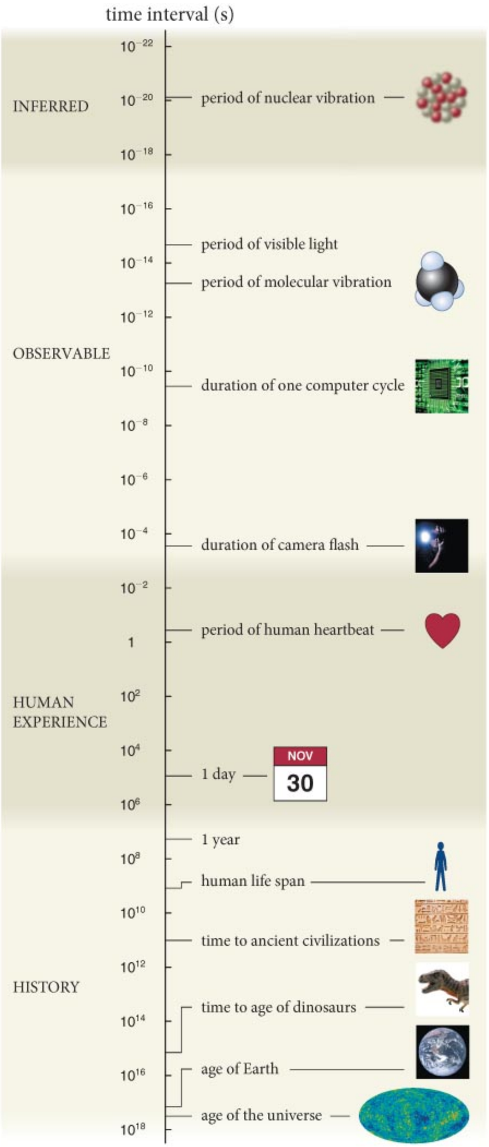
Section 1.4: Time and change

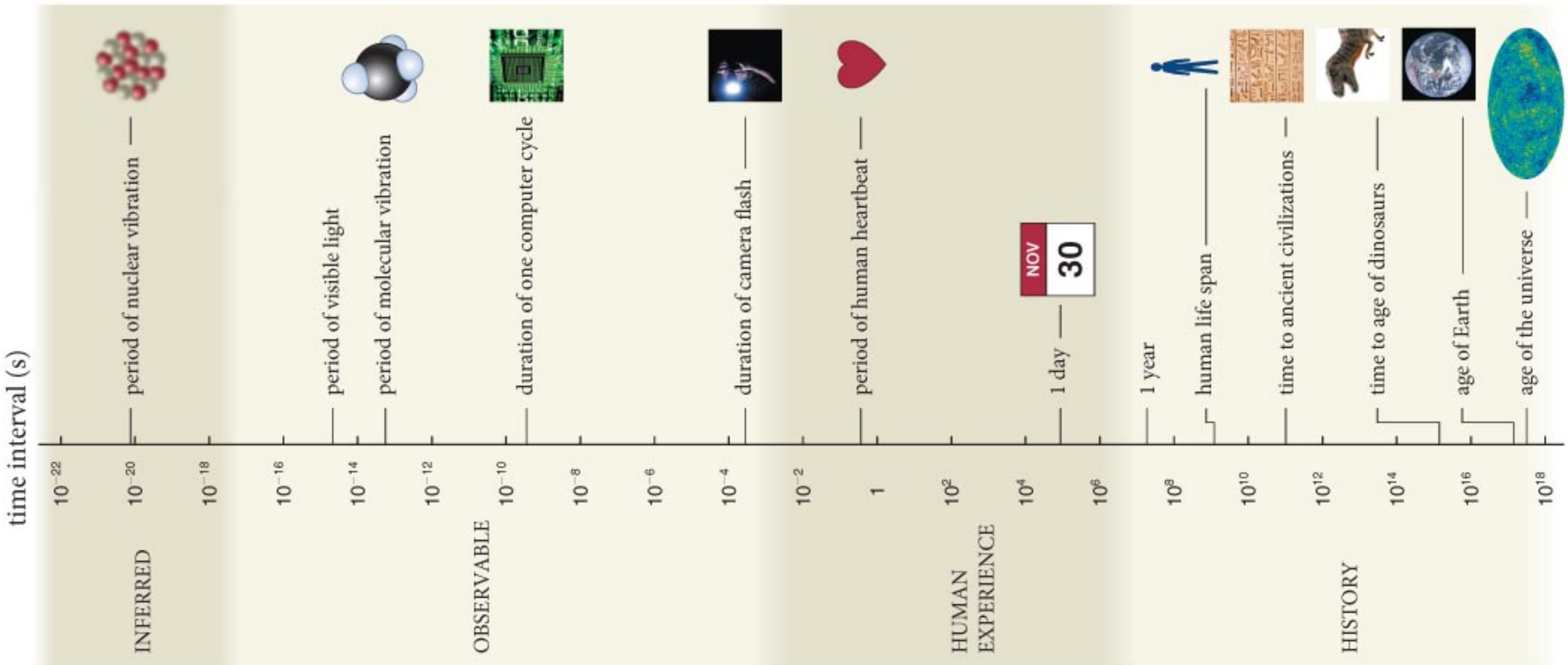
- Whereas we can freely choose the direction in all three dimensions of space, time flows in a single direction.
- This "arrow of time" only points to the future, and allows us to establish a causal relationship between events, which leads to the **principle of causality**:

  Whenever an event A causes event B, all observers see event A happen first.

Section 1.4: Time and change

- The standard unit of time is the **second** (abbreviated s).
- The second is defined as the duration of 9,192,631,770 periods of certain radiation emitted by cesium atoms.
- Essentially, based on the constant speed of light





time interval (s)
INFERRED
OBSERVABLE
HUMAN EXPERIENCE
HISTORY
10^{-22}
10^{-20}
10^{-18}
10^{-16}
10^{-14}
10^{-12}
10^{-10}
10^{-8}
10^{-6}
10^{-4}
10^{-2}
1
10^{2}
10^{4}
10^{6}
10^{8}
10^{10}
10^{12}
10^{14}
10^{16}
10^{18}
period of nuclear vibration
period of visible light
period of molecular vibration
duration of one computer cycle
duration of camera flash
period of human heartbeat
1 day
NOV
30
1 year
human life span
time to ancient civilizations
time to age of dinosaurs
age of Earth
age of the universe

Checkpoint 1.8

1.8 A single chemical reaction takes about 10^{-13} s. What order of magnitude is the number of sequential chemical reactions that could take place during a physics class?

Checkpoint 1.8

1.8 A single chemical reaction takes about 10^{-13} s. What order of magnitude is the number of sequential chemical reactions that could take place during a physics class?

Physics class is about 10^2 min or 6×10^3 s, of order 10^4.

In 1 s, one can fit 10^{13} reactions

In 10^4 s, one can fit $10^4 \times 10^{13} = 10^{17}$ reactions

Section 1.5: Representations

Section Goals

You will learn to

- Develop **representations** to visualize physical phenomena in the universe and the scientific models that explain them.
- Recognize that representations can possess a range of information from abstract to concrete.
- Classify representations into graphical and mathematical ones.

Section 1.5: Representations

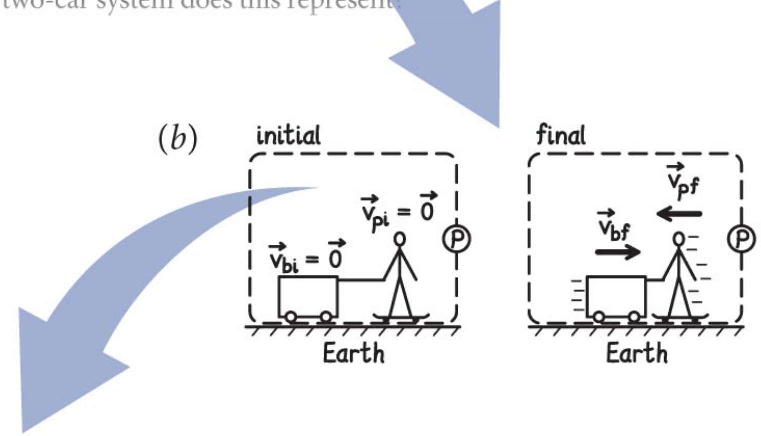
- An essential first step in solving a problem: make a **visual representation** of the available information
- Helps develop a qualitative understanding of the problem, and organize the information

Section 1.5: Representations

- Visual representations are an integral part of getting a grip on physics problems and developing models
- Catalog what you know, what you want to find
- Sketch the situation noting these

(*a*)

Two collisions are carried out to crash-test a 1000-kg car: (*a*) While moving at 15 mph, the car strikes an identical car initially at rest. (*b*) While moving at 15 mph, the car strikes an identical car moving toward it and also traveling at 15 mph. For each collision, what is the amount of kinetic energy that can be converted to another form in the collision, and what fraction of the total initial (*a*) kinetic energy of the two-car system does this represent?



(*c*)

$$\Delta v_x = v_{x,\mathrm{f}} - v_{x,\mathrm{i}} = \int_{t_\mathrm{i}}^{t_\mathrm{f}} a_x\,dt = a_x \int_{t_\mathrm{i}}^{t_\mathrm{f}} dt = a_x(t_\mathrm{f} - t_\mathrm{i}).$$

$$\Delta v_x = \lim_{\Delta t \to 0} \sum_{n=\mathrm{i}}^{\mathrm{f}} a_x(t_n)\,\Delta t \equiv \int_{t_\mathrm{i}}^{t_\mathrm{f}} a_x(t)\,dt$$

ABSTRACT ⟷ CONCRETE

Exercise 1.5 Stretching a spring

- One end of a spring is attached to a horizontal rod so that the spring hangs vertically.
- A ruler is hung vertically alongside the spring.
- The stretching properties of the spring are to be measured by attaching eight identical beads to the spring's free end.
- With no beads attached, the free end of the spring is at a ruler reading of 23.4 mm.
- With one bead attached, the end of the spring drops to 25.2 mm.

Exercise 1.5 Stretching a spring (cont.)

A total of six beads are added, giving the following readings:

bead number	ruler reading (mm)
2	26.5
3	29.1
4	30.8
5	34.3
6	38.2

Exercise 1.5 Stretching a spring (cont.)

Going forward?

(a) Make a pictorial representation of this setup.

(b) Tabulate the data *[mostly done]*

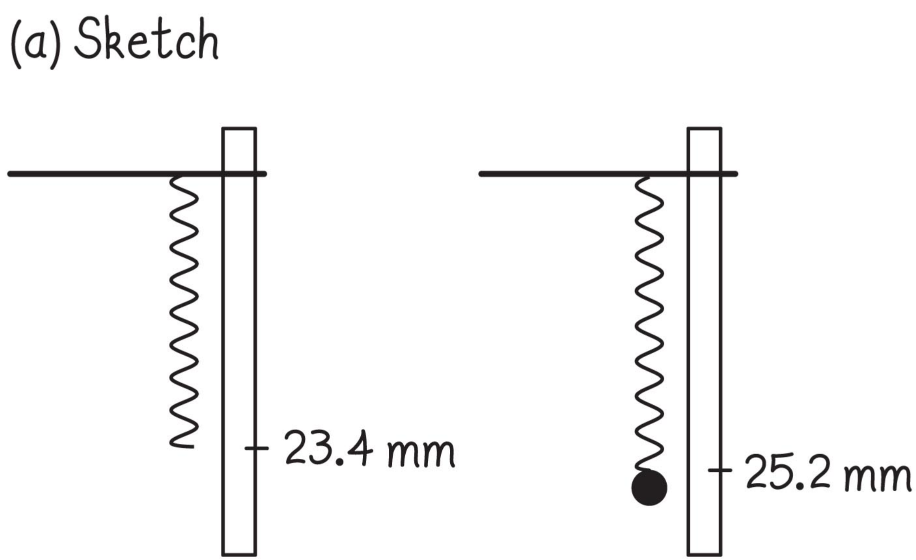
(c) Plot the data on a graph, showing the ruler readings on the vertical axis and the numbers of beads on the horizontal axis.

(d) Describe what can be inferred from the data.

Exercise 1.5 Stretching a spring (cont.)

SOLUTION (*a*) sketch

- Key items needed: spring, rod, ruler, and typical bead
- Indicate how the ruler readings are obtained.
- Don’t need to show all beads, one example is enough.
- Represented the general procedure of adding beads one (or two) at a time and how each addition changes the position of the spring end.



Exercise 1.5 Stretching a spring (cont.)

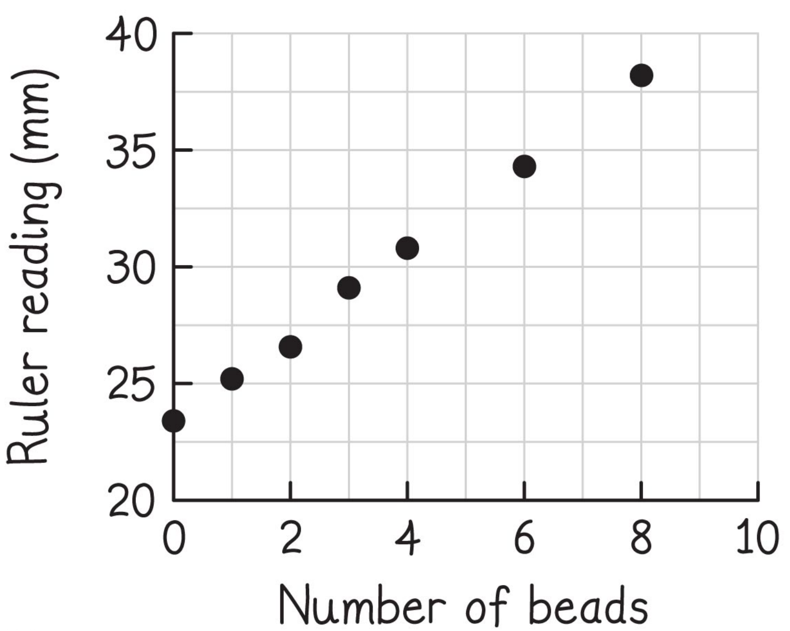
SOLUTION (*b*) complete table (*c*) make a plot (label axes!)

(*d*) Ruler readings vs. the numbers of suspended beads is linear. Each additional bead stretches the spring by about the same amount.

(b) Table

Number of beads	Ruler reading (mm)
0	23.4
1	25.2
2	26.5
3	29.1
4	30.8
6	34.3
8	38.2

(c) Graph



Chapter 1: Self-Quiz #1

Two children in a playground swing on two swings of unequal length. The child on the shorter swing is considerably heavier than the child on the longer swing. You observe that the longer swing swings more slowly.

Formulate a hypothesis that could explain your observation.

How could you test your hypothesis?

Chapter 1: Self-Quiz #1

Answer

Two plausible hypotheses to start with

(1) Longer swings swing more slowly than shorter swings.

Make swings the same length and have them swing again.

(2) Heavier children swing faster than lighter ones.

Ask them to trade places

(Turns out the first one is better.)

Quantitative Tools

Section 1.6: Physical quantities and units

Section Goals

You will learn to

- Name and understand the seven **base units** of the SI system of units.
- Use **power of 10 notation and metric prefixes** to represent large and small numbers and calculations involving them.
- Define the **density** of matter and its relationship to the mole and Avogadro's number.
- Perform **unit conversions** by use of a ratio of units.

Section 1.6: Physical quantities and units

- Table 1.1 gives the symbols of some of the physical quantities we use throughout this course.

Table 1.1 Physical quantities and their symbols

Physical quantity	Symbol
length	ℓ
time	t
mass	m
speed	v
volume	V
energy	E
temperature	T

Section 1.6: Physical quantities and units

- The system of units in science is called *Système Internationale* or **SI units**.
- The SI system consists of seven base units (shown below) from which all other units can be derived.

Table 1.2 The seven SI base units

Name of unit	Abbreviation	Physical quantity
meter	m	length
kilogram	kg	mass
second	s	time
ampere	A	electric current
kelvin	K	thermodynamic temperature
mole	mol	amount of substance
candela	cd	luminous intensity

Section 1.6: Physical quantities and units

- Very often we deal with quantities that are much less or much greater than the standards of 1 m, 1 s, etc.
- We use prefixes to denote various powers of 10, which make it easier to talk about such quantities, as seen below.

Table 1.3 SI prefixes

10^n	Prefix	Abbreviation	10^n	Prefix	Abbreviation
10^0	—	—			
10^3	kilo-	k	10^{-3}	milli-	m
10^6	mega-	M	10^{-6}	micro-	μ
10^9	giga-	G	10^{-9}	nano-	n
10^{12}	tera-	T	10^{-12}	pico-	p
10^{15}	peta-	P	10^{-15}	femto-	f
10^{18}	exa-	E	10^{-18}	atto-	a
10^{21}	zetta-	Z	10^{-21}	zepto-	z
10^{24}	yotta-	Y	10^{-24}	yocto-	y

Section 1.6: Physical quantities and units

- The **mole** (abbreviated mol) is the SI base unit that measures the quantity of a given substance.
- The mole is defined as the number of atoms in 12 x 10^{-3} kg of the most common form of carbon, carbon-12.
  - This number is called the Avogadro number N_A, and the currently accepted experimental value of N_A is

$$N_A = 6.0221413 \times 10^{23}$$

Table 1.3 SI prefixes

10^n	Prefix	Abbreviation	10^n	Prefix	Abbreviation
10^0	—	—			
10^3	kilo-	k	10^{-3}	milli-	m
10^6	mega-	M	10^{-6}	micro-	μ
10^9	giga-	G	10^{-9}	nano-	n
10^{12}	tera-	T	10^{-12}	pico-	p
10^{15}	peta-	P	10^{-15}	femto-	f
10^{18}	exa-	E	10^{-18}	atto-	a
10^{21}	zetta-	Z	10^{-21}	zepto-	z
10^{24}	yotta-	Y	10^{-24}	yocto-	y

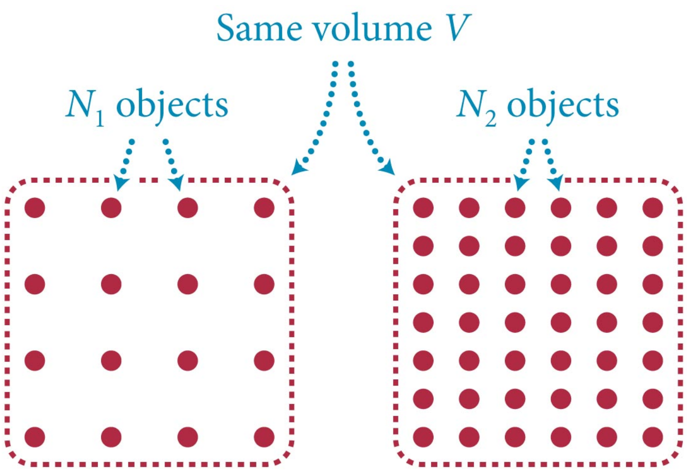
Section 1.6: Physical quantities and units

- An important concept used in physics is density:
  - Density measures how much of some substance there is in a given volume.
- The number of objects per unit volume is called **number density (*n*)**. If there are N objects in volume V, then

$$n \equiv \frac{N}{V}$$

- Mass density ρ is the amount of mass m per unit volume:

$$\rho \equiv \frac{m}{V}$$



The greater the number N of objects in a given space V, the higher the number density $n = N/V$. In this case $N_2 > N_1$, so $n_2 > n_1$.

Section 1.6: Physical quantities and units

- It is important to be able to convert back and forth between SI units and other units.
- The simplest way to convert from one unit to another is to write the conversion factor as a ratio equal to one. For example we can write

$$\frac{1\ \text{in.}}{25.4\ \text{mm}} = 1 \quad \text{or} \quad \frac{25.4\ \text{mm}}{1\ \text{in.}} = 1$$

- Because multiplying by 1 does not change a value, these ratios are easily used for unit conversions.
- As an example, if we want to convert 4.5 into millimeters:

$$4.5\ \text{in} = (4.5\ \cancel{\text{in}}.)\left(\frac{25.4\ \text{mm}}{1\ \cancel{\text{in}}.}\right) = 4.5 \times 25.4\ \text{mm} = 1.1 \times 10^{2}\ \text{mm}$$

Exercise 1.7 Unit conversions

Convert each quantity to a quantity expressed either in meters or in meters raised to some power:

(a) 4.5 in.

(b) 3.2 acres

(c) 32 mi

(d) 3.0 pints

Exercise 1.7 Unit conversions (cont.)

SOLUTION See Appendix C for conversion factors.

Or Google.

$$(a) \qquad (4.5\text{ in.})\left(\frac{2.54\times 10^{-2}\text{ m}}{1\text{ in.}}\right)=1.1\times 10^{-1}\text{ m}$$

$$(b) \quad (3.2\text{ acres})\left(\frac{4.047\times 10^{3}\text{ m}^2}{1\text{ acre}}\right)=1.3\times 10^{4}\text{ m}^2$$

Exercise 1.7 Unit conversions (cont.)

SOLUTION

$$(c) \qquad (32\text{ mi})\left(\frac{1.609\times10^{3}\,\text{m}}{1\text{ mi.}}\right)=5.1\times10^{4}\,\text{m}$$

$$(d) \qquad (3.0\text{ pints})\left(\frac{4.732\times10^{-4}\,\text{m}^{3}}{1\text{ pint}}\right)=1.4\times10^{-3}\,\text{m}^{3}$$

Section 1.7: Significant digits

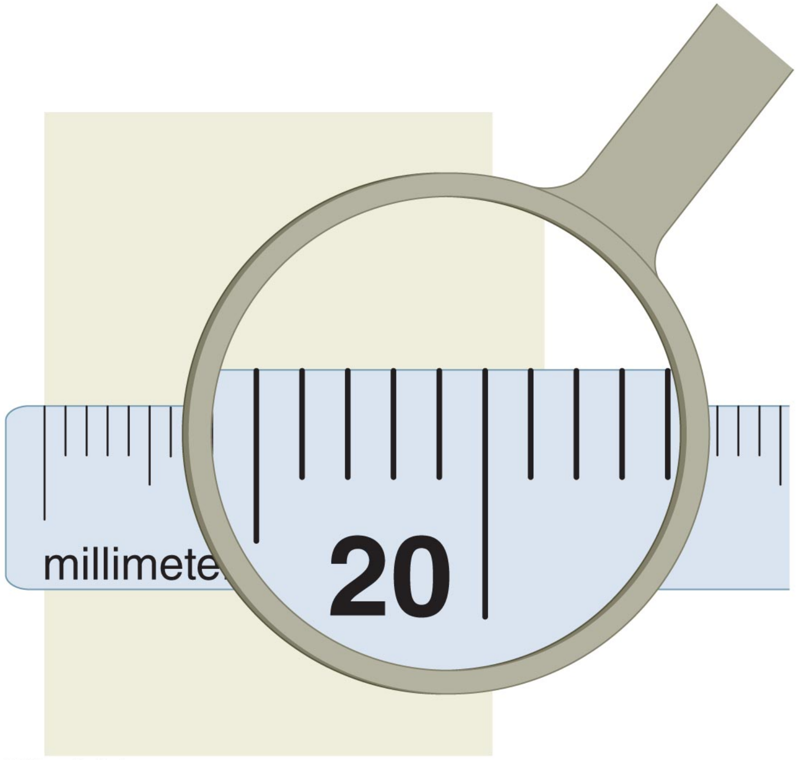
Section Goals

You will learn to

- Identify **significant digits** as the number of digits in a number that are known reliably.
- Enumerate the **number** of significant digits in a measurement.
- Apply the rules of significant digits in **calculations** involving measured quantities.

Section 1.7: Significant digits

- Know how to precisely state what you know about a situation.
- For example, suppose you measure the width of a paper (see figure) and it falls between 21 mm and 22 mm, but closer to 21 mm.
  - We might guess that it is 21.3 mm, but cannot be sure of the last digit.
  - By recording 21 mm, we are indicating that the actual value lies between 20.5 mm and 21.5 mm.
  - The value 21 mm is said to have two **significant digits.**
- **Number of digits implies accuracy**



Section 1.7: Significant digits

- By expressing a value with the proper number of significant digits, we can convey the precision to which that value is known.
- If a number does not contain zeros, all digits are significant:
  - 21 has two significant digits, 21.3 has 3 significant digits.
- Zeros that come between nonzero digits are significant:
  - 0.602 has 3 significant digits.
- Leading zeros are never significant:
  - 0.037 has two significant digits.

Section 1.7: Significant digits

- Trailing zeros to the right of a decimal point are significant:
  - 25.10 has 4 significant digits.
- Trailing zeros that do not contain a decimal point are ambiguous.
  - 7900 can have two to four significant digits.
- More obvious with scientific notation:
  - 7.900×10^3 has four significant digits.
  - 7.9×10^1 has one significant digit.
- For simplicity, consider all trailing zeros to be significant.

Section 1.7
Clicker Question 5

The number 0.03720 has ____ digits, ____ decimal places, and ____ significant digits?

1. 6, 5, 4
2. 5, 5, 3
3. 6, 5, 3
4. None of the above

Section 1.7
Clicker Question 5

The number 0.03720 has _____ digits, _____ decimal places, and _____ significant digits?

✔ 1. 6, 5, 4
2. 5, 5, 3
3. 6, 5, 3
4. None of the above

Section 1.7: Significant digits

- The rules for working with significant digits:
  - When multiplying or dividing quantities, result has same significant digits as least accurate input
  - When adding or subtracting quantities, the number of decimal places in the result is the same as the input that has the fewest decimal places.

- Don't overthink it.
  - Least accurate thing wins in a calculation
- Don't report every digit your calculator gives you

Section 1.8: Solving problems

Section Goals

You will learn to

- Develop a **systematic** four-step procedure to solve problems.
- Apply this procedure to some problems of interest to physicists.

Procedure: Solving problems

- No single fixed approach
- Helps to break problems into steps
- Follow a systematic approach
- Book uses a four-step procedure

Procedure: Solving problems (cont.)

1. **Getting started.**

   Given: carefully analyze information given.

   Find: what are you supposed to find/do?

   Sketch: organize with a sketch (or table of data)

   Concepts: determine concepts which apply

   note assumptions

Procedure: Solving problems (cont.)

2. **Devise plan.**

   What do you need to do to solve the problem?

   Which relationships/equations do you need?

   In what order do you need to use them?

   Do you have enough equations vs. unknowns?

Procedure: Solving problems (cont.)

3. **Execute plan.** Execute your plan, and then check your work for the following five important points:

   Vectors/scalars used correctly?

   Every question asked in problem statement answered?

   No unknown quantities in answers?

   Units correct?

   Significant digits justified?

Procedure: Solving problems (cont.)

4. **Evaluate result.** There are several ways to check whether an answer is reasonable.
   - Expectation based on your sketch & information given (e.g., has to be more than X or less than Y)
   - If your answer is an algebraic expression, check special (limiting) cases for which you already know the answer. (e.g., no friction)

Procedure: Solving problems (cont.)

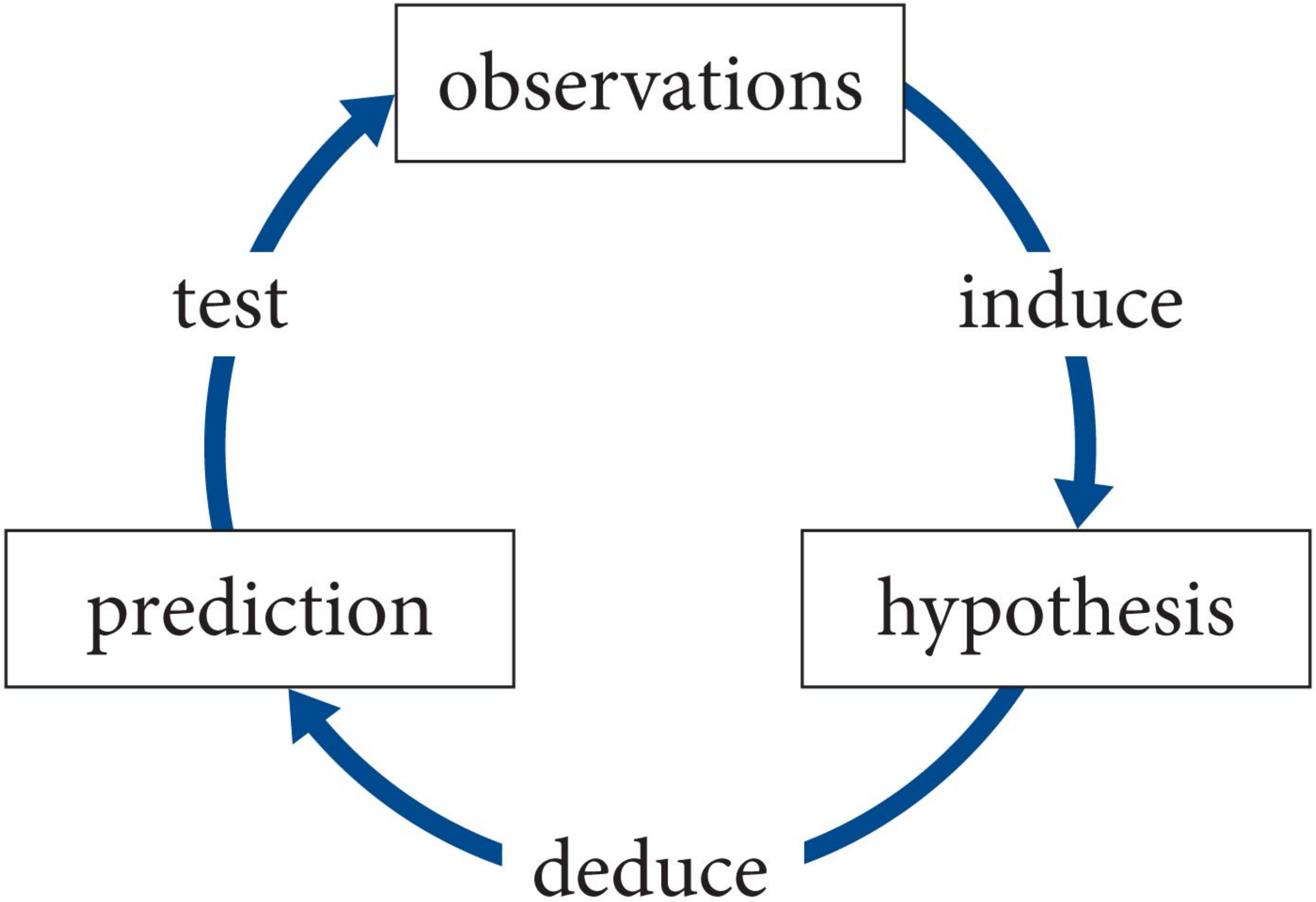
4. **Evaluate result.** Sometimes there may be an alternative approach to solving the problem
   - If so, see if it gives the same result. If it doesn't, check math & assumptions
   - If none of these checks can be applied to your problem, check the algebraic signs and order of magnitude.
   - Always check that the units work out correctly.

Concepts: The scientific method

- The **scientific method** is an iterative process for going from observations to a hypothesis to an experimentally validated theory.
- If the predictions made by a hypothesis prove accurate after repeated experimental tests, the hypothesis is called a **theory** or a **law,** but it always remains subject to additional experimental testing.

Chapter 1: Summary

Quantitative Tools: The scientific method



Concepts: Symmetry

- An object exhibits **symmetry** when certain operations can be performed on it without changing its appearance.
- Important examples are
    - *translational symmetry* (movement from one location to another)
    - *rotational symmetry* (rotation about a fixed axis
    - *reflection symmetry* (reflection in a mirror)
- The concept of symmetry applies both to objects and to physical laws.

Concepts: Some basic physical quantities and their units

- **Length** is a distance or extent in space. The SI (International System) base unit of length is the **meter** (m).
- **Time** is a property that allows us to determine the sequence in which related events occur. The SI base unit of time is the **second** (s).
- The **principle of causality** says that whenever event A causes an event B, all observers see event A happen before event B.
- **Density** is a measure of how much of some substance there is in a given volume.

Quantitative Tools: Some basic physical quantities and their units

- If there are N objects in a volume V, then the *number density* n of these objects is

$$n \equiv \frac{N}{V}$$

- If an object of mass m occupies a volume V, then the *mass density* ρ of this object is

$$\rho \equiv \frac{m}{V}$$

Quantitative Tools: Some basic physical quantities and their units

- To convert one unit to an equivalent unit, multiply the quantity whose unit you want to convert by one or more appropriate *conversion factors*. Each conversion factor must equal one, and any combination of conversion factors used must cancel the original unit and replace it with the desired unit. For example, converting 2.0 hours to seconds, we have

$$2.0\,\cancel{\text{h}} \times \frac{60\,\cancel{\text{min}}}{1\,\cancel{\text{h}}} \times \frac{60\text{ s}}{1\,\cancel{\text{min}}} = 7.2 \times 10^{3}\text{ s}$$

Chapter 1: Summary

Concepts: Representations

- Physicists use many types of representations in making models and solving problems:
  - Rough sketches and detailed diagrams are generally useful, and often crucial, to this process.
  - Graphs are useful for visualizing relationships between physical quantities.
  - Mathematical expressions represent models and problems concisely and permit the use of mathematical techniques.

Quantitative Tools: Representations

- As you construct a model, begin with a simple visual representation (example: represent a cow with a dot) and add details as needed to represent additional features that prove important.

Concepts: Significant digits

- The **significant digits** in a number are the digits that are reliably known.

Chapter 1: Summary

Quantitative Tools: Significant digits

- If a number contains no zeros, then all the digits shown are significant:
  - 345 has three significant digits;
  - 6783 has four significant digits.
- For numbers that contain zeros:
  - Zeros between two nonzero digits are significant: 4.03 has three significant digits.
  - Trailing digits to the right of the decimal point are significant: 4.9000 has five significant digits.
  - Leading zeros before the first nonzero digit are not significant: 0.000 175 has three significant digits.

Chapter 1: Summary

Quantitative Tools: Significant digits

- The number of significant digits in a product or quotient is the same as the number of significant digits in the input quantity that has the *fewest significant digits:*
  - 0.10 x 3.215 = 0.32
- The number of decimal places in a sum or difference is the same as the number of decimal places in the input quantity that has the *fewest decimal places:*
  - 3.1 + 0.32 = 3.4

Chapter 1: Summary

Concepts: Solving problems

Strategy for solving problems:

1. **Getting started.** Analyze and organize the information and determine what is being asked of you. A sketch or table is often helpful. Decide which physics concepts apply.
2. **Devise plan.** Determine the physical relationships and equations necessary to solve the problem. Then outline the steps you think will lead to the solution.

Concepts: Solving problems (cont.)

Strategy for solving problems:

3. **Execute plan.** Carry out the calculations, and then check your work using the following points:
   - Vectors/scalars used correctly?
   - Every question answered?
   - No unknown quantities in answers?
   - Units correct?
   - Significant digits justified?
4. **Evaluate result.** Determine whether or not the answer is reasonable.

Chapter 1: Summary

Concepts: Developing a feel

- To develop a feel for the approximate size of a calculated quantity, make an **order-of magnitude** estimate, which means a calculation rounded to the nearest power of ten.

Chapter 1: Summary

Quantitative Tools: Solving problems and developing a feel

- **Determining order of magnitude:**
  - Example 1:
  - 4200 is 4.200×10^3.
  - Round the coefficient 4.200 to 10 (because it is greater than 3), so that 4.200×10^3 becomes $10 \times 10^3 = 1 \times 10^4$.
  - The order of magnitude is 10^4.

Quantitative Tools: Solving problems and developing a feel

- **Determining order of magnitude:**
  - Example 2:
  - 0.027 is 2.7×10^{-2}.
  - Round the coefficient 2.7 to 1 (because it is less than 3), so that 2.7×10^{-2} becomes 1×10^{-2}.
  - The order of magnitude is 10^{-2}.

Chapter 1: Summary

Quantitative Tools: Solving problems and developing a feel

- **Strategy to compute order-of-magnitude estimates:**
  - Simplify the problem.
  - Break it into smaller parts that are easier to estimate.
  - Build your estimate from quantities that you know or can easily obtain.