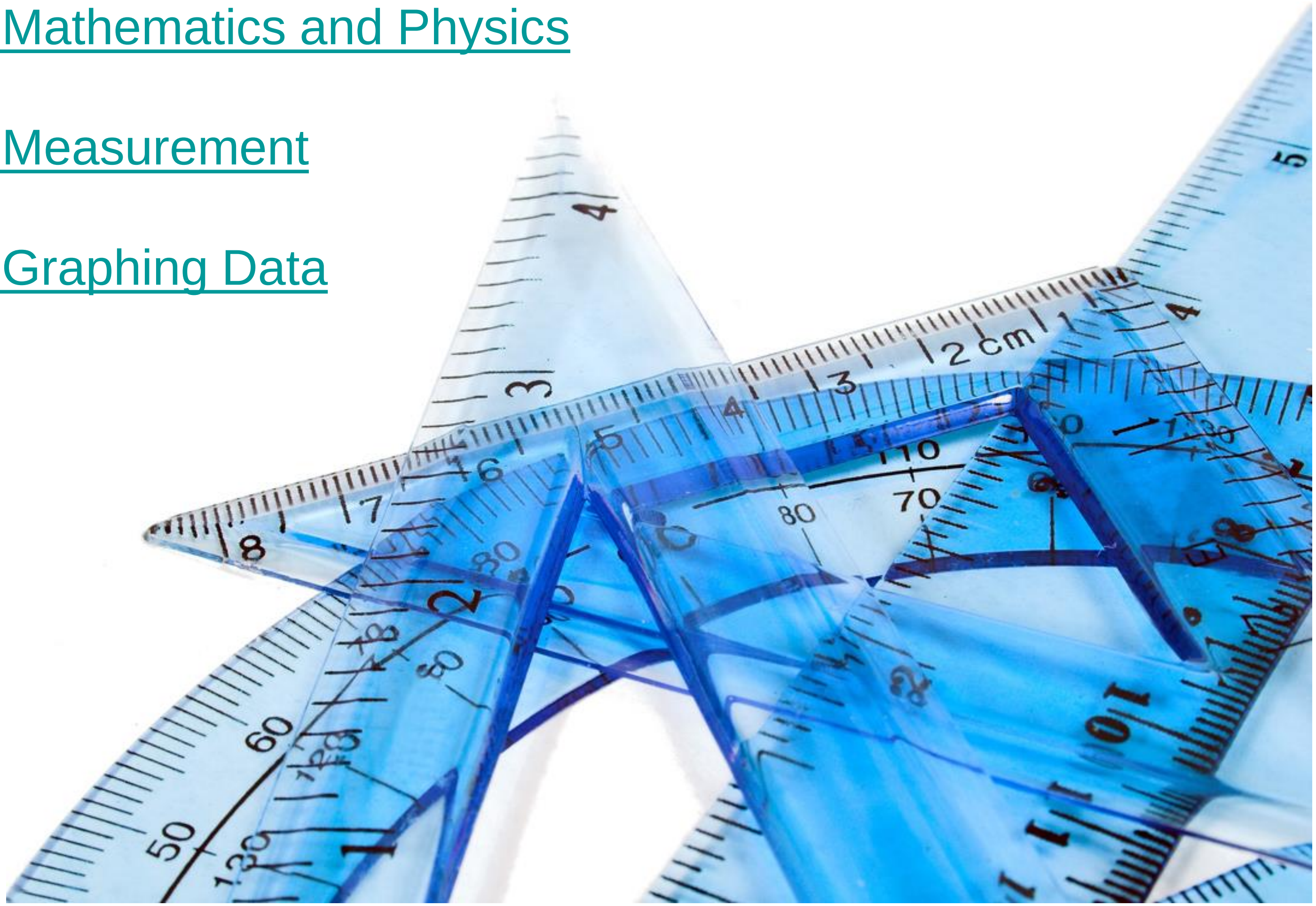
Physics

Chapter 1: Physics Toolbox



- Use mathematical tools to measure and predict.
- Apply accuracy and precision when measuring.
- Display and evaluate data graphically.

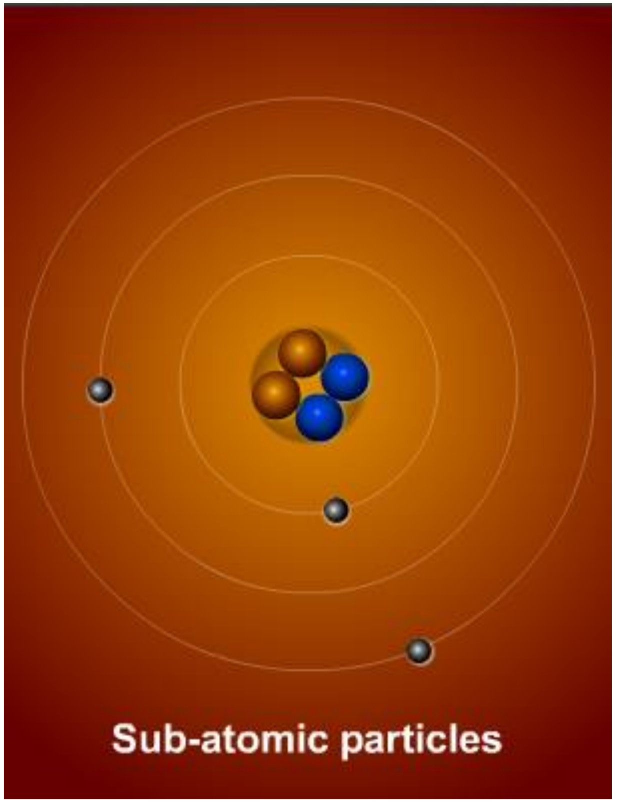
In this section you will:

- **Demonstrate** scientific methods.
- **Use** the metric system.
- **Evaluate** answers using dimensional analysis.
- **Perform** arithmetic operations using scientific notation.

What is Physics?

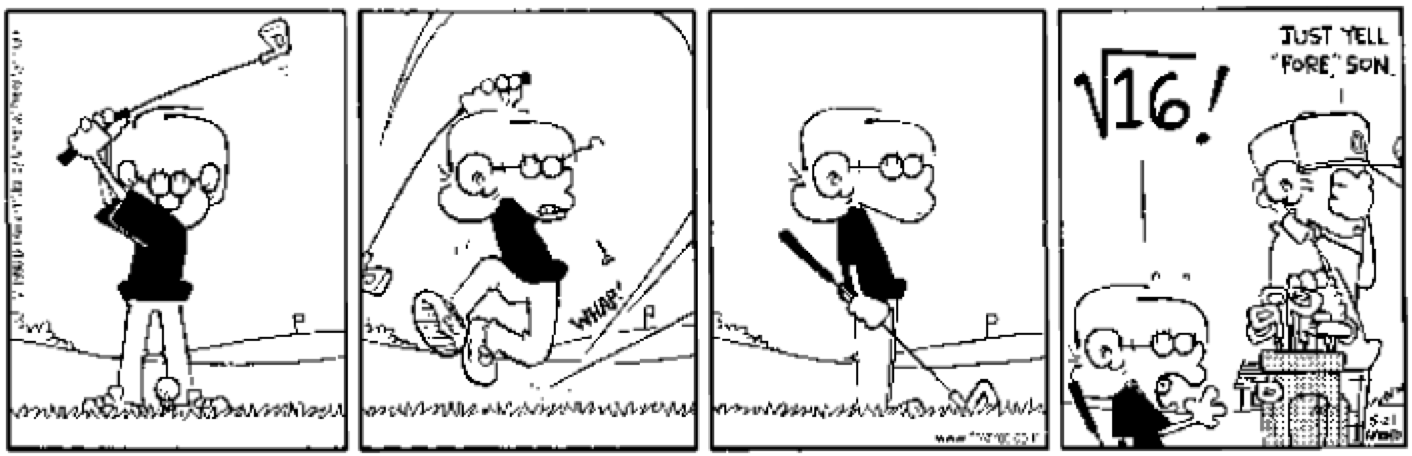
- **Physics** is a branch of science that involves the study of the physical world: energy, matter, and how they are related.

- Learning physics will help you to understand the physical world.



Mathematics in Physics

- Physics uses mathematics as a powerful language.
- In physics, equations are important tools for modeling observations and for making predictions.



Section

1.1

Electric Current

The potential difference, or voltage, across a circuit equals the current multiplied by the resistance in the circuit. That is, V (volts) = I (amperes) × R (ohms). What is the resistance of a lightbulb that has a 0.75 amperes current when plugged into a 120-volt outlet?

Electric Current

View Question

Step 1: Analyze the Problem

Electric Current

View Question

Identify the known and unknown variables.

Known:

I = 0.75 amperes

V = 120 volts

Unknown:

Electric Current

View Question

Step 2: Solve for the Unknown

Electric Current

View Question

Rewrite the equation so that the unknown value is alone on the left.

$$V = IR$$

Electric Current

? View Question

Reflexive property of equality.

$$IR = V$$

Divide both sides by I.

Section
1.1

Electric Current

View Question

Substitute 120 volts for *V*, 0.75 amperes for *I*.

$$R = \frac{120 \text{ volts}}{0.75 \text{ amperes}}$$

$$= 160 \text{ ohms}$$

Resistance will be measured in ohms.

View Question

Step 3: Evaluate the Answer

Electric Current

View Question

- Are the units correct?

  1 volt = 1 ampere-ohm, so the answer in volts/ampere is in ohms, as expected.

- Does the answer make sense?

  120 is divided by a number a little less than 1, so the answer should be a little more than 120.

Electric Current

View Question

The steps covered were:

- **Step 1:** Analyze the Problem
  - Rewrite the equation.
  - Substitute values.
- **Step 2:** Solve for the Unknown
  - Rewrite the equation so the unknown is alone on the left.
- **Step 3:** Evaluate the Answer

SI Units

- The example problem uses different units of measurement to communicate the variables and the result. It is helpful to use units that everyone understands.
- Scientific institutions have been created to define and regulate measures.
- The worldwide scientific community and most countries currently use an adaptation of the metric system to state measurements.

SI Units

- The Système International d'Unités, or SI, uses seven base quantities, which are shown in the table below.

SI Base Units		
Base Quantity	**Base Unit**	**Symbol**
Length	meter	m
Mass	kilogram	kg
Time	second	s
Temperature	kelvin	K
Amount of a substance	mole	mol
Electric current	ampere	A
Luminous intensity	candela	cd

SI Units

- The base quantities were originally defined in terms of direct measurements. Other units, called derived units, are created by combining the base units in various ways.

- The SI system is regulated by the International Bureau of Weights and Measures in Sèvres, France.

- This bureau and the National Institute of Science and Technology (NIST) in Gaithersburg, Maryland, keep the standards of length, time, and mass against which our metersticks, clocks, and balances are calibrated.

SI Units

- Measuring standards for kilogram and meter are shown below.

SI Units

- You probably learned in math class that it is much easier to convert meters to kilometers than feet to miles.
- The ease of switching between units is another feature of the metric system.
- To convert between SI units, multiply or divide by the appropriate power of 10.

SI Units

- Prefixes are used to change SI units by powers of 10, as shown in the table below.

Prefixes Used with SI Units				
Prefix	**Symbol**	**Multiplier**	**Scientific Notation**	**Example**
femto-	f	0.000000000000001	10^{-15}	femtosecond (fs)
pico-	p	0.000000000001	10^{-12}	picometer (pm)
nano-	n	0.000000001	10^{-9}	nanometer (nm)
micro-	μ	0.000001	10^{-6}	microgram (μg)
milli-	m	0.001	10^{-3}	milliamps (mA)
centi-	c	0.01	10^{-2}	centimeter (cm)
deci-	d	0.1	10^{-1}	deciliter (dL)
kilo-	k	1000	10^{3}	kilometer (km)
mega-	M	1,000,000	10^{6}	megagram (Mg)
giga-	G	1,000,000,000	10^{9}	gigameter (Gm)
tera-	T	1,000,000,000,000	10^{12}	terahertz (THz)

Dimensional Analysis

- You often will need to use different versions of a formula, or use a string of formulas, to solve a physics problem.
- To check that you have set up a problem correctly, write the equation or set of equations you plan to use with the appropriate units.

Dimensional Analysis

- Before performing calculations, check that the answer will be in the expected units.

- For example, if you are finding a speed and you see that your answer will be measured in s/m or m/s^2, you know you have made an error in setting up the problem.

- This method of treating the units as algebraic quantities, which can be cancelled, is called **dimensional analysis**.

Dimensional Analysis

- Dimensional analysis also is used in choosing conversion factors.

- A conversion factor is a multiplier equal to 1. For example, because 1 kg = 1000 g, you can construct the following conversion factors:

$$1 = \frac{1\text{ kg}}{1000\text{ g}} \qquad 1 = \frac{1000\text{ g}}{1\text{ kg}}$$

Dimensional Analysis

- Choose a conversion factor that will make the units cancel, leaving the answer in the correct units.

- For example, to convert 1.34 kg of iron ore to grams, do as shown below:

$$1.34\ \text{k}\cancel{\text{g}}\left(\frac{1000\ \text{g}}{1\ \text{k}\cancel{\text{g}}}\right) = 1340\ \text{g}$$

Significant Digits

- A meterstick is used to measure a pen and the measurement is recorded as 14.3 cm.
- This measurement has three valid digits: two you are sure of, and one you estimated.
- The valid digits in a measurement are called **significant digits**.
- However, the last digit given for any measurement is the uncertain digit.

Significant Digits

- All nonzero digits in a measurement are significant, but not all zeros are significant.
- Consider a measurement such as 0.0860 m. Here the first two zeros serve only to locate the decimal point and are not significant.
- The last zero, however, is the estimated digit and is significant.

Significant Digits

- When you perform any arithmetic operation, it is important to remember that the result never can be more precise than the least-precise measurement.
- To add or subtract measurements, first perform the operation, then round off the result to correspond to the least-precise value involved.
- To multiply or divide measurements, perform the calculation and then round to the same number of significant digits as the least-precise measurement.
- Note that significant digits are considered only when calculating with measurements.

Scientific Methods

- Making observations, doing experiments, and creating models or theories to try to explain your results or predict new answers form the essence of a **scientific method**.

- All scientists, including physicists, obtain data, make predictions, and create compelling explanations that quantitatively describe many different phenomena.

- Written, oral, and mathematical communication skills are vital to every scientist.

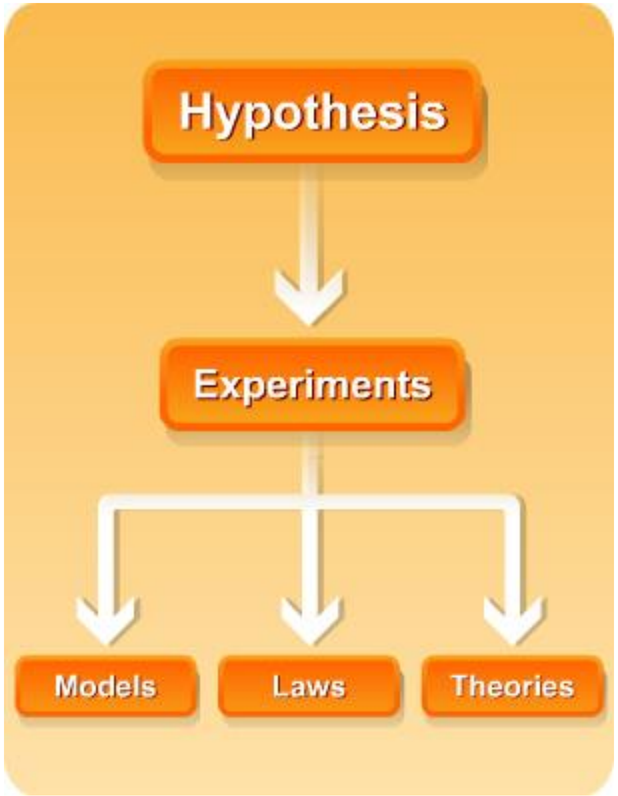
Scientific Methods

- The experiments and results must be reproducible; that is, other scientists must be able to recreate the experiment and obtain similar data.

- A scientist often works with an idea that can be worded as a **hypothesis**, which is an educated guess about how variables are related.

Scientific Methods

- A hypothesis can be tested by conducting experiments, taking measurements, and identifying what variables are important and how they are related. Based on the test results, scientists establish models, laws, and theories.



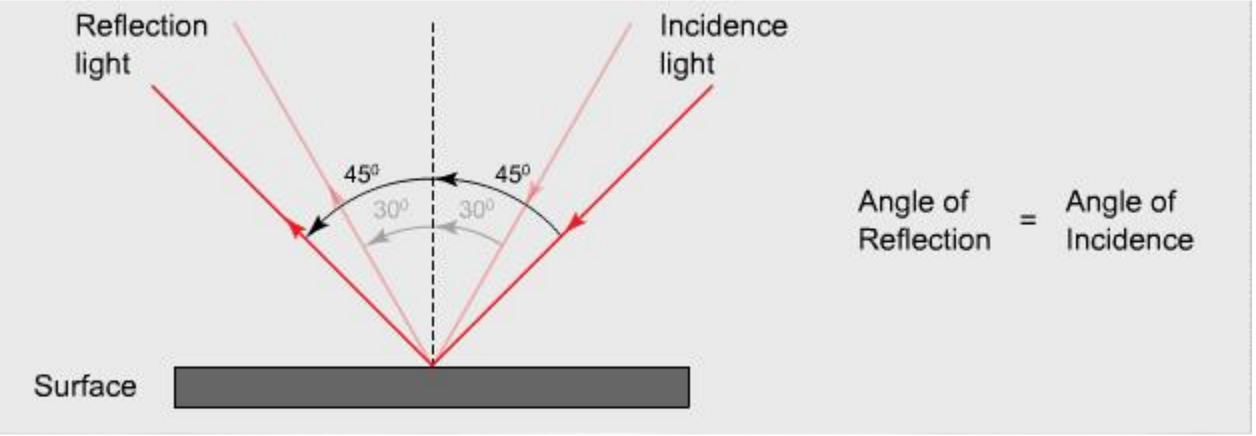
View Movie

Models, Laws, and Theories

- An idea, equation, structure, or system can model the phenomenon you are trying to explain.
- Scientific models are based on experimentation.
- If new data do not fit a model, both new data and model are re-examined.
- If a very well-established model is questioned, physicists might first look at the new data: Can anyone reproduce the results? Were there other variables at work?
- If the new data are born out by subsequent experiments, the theories have to change to reflect the new findings.

Models, Laws, and Theories

- In the nineteenth century, it was believed that linear markings on Mars showed channels.
- As telescopes improved, scientists realized that there were no such markings.
- In recent times, again with better instruments, scientists have found features that suggest Mars once had running and standing water on its surface.
- Each new discovery has raised new questions and areas for exploration.


Reflection
light
Incidence
light
45⁰
45⁰
30⁰
30⁰
Angle of
Reflection
=
Angle of
Incidence
Surface

View Movie

Models, Laws, and Theories

- A **scientific theory** is an explanation based on many observations supported by experimental results.
- A theory is the best available explanation of why things work as they do.
- Theories may serve as explanations for laws.
- Laws and theories may be revised or discarded over time.
- Theories are changed and modified as new experiments provide insight and new observations are made.

Question 1

The potential energy, *PE*, of a body of mass, *m*, raised to a height, *h*, is expressed mathematically as *PE* = *mgh*, where *g* is the gravitational constant. If *m* is measured in kg, *g* in m/s^2, *h* in m, and *PE* in joules, then what is 1 joule described in base unit?

A. 1 kg·m/s

B. 1 kg·m/s^2

C. 1 kg·m^2/s

D. 1 kg·m^2/s^2

Section

1.1

Answer 1

Answer: D

Reason: $PE = mgh$

$$\therefore 1\text{J} = 1\text{kg} \times \frac{\text{m}}{\text{s}^2} \times \text{m}$$

$$\therefore 1\text{J} = 1\text{kg} \cdot \left(\frac{\text{m}}{\text{s}}\right)^2$$

Question 2

A car is moving at a speed of 90 km/h. What is the speed of the car in m/s? (Hint: Use Dimensional Analysis)

A. 2.5×10^{1} m/s

B. 1.5×10^{3} m/s

C. 2.5 m/s

D. 1.5×10^{2} m/s

Section
1.1

Answer 2

Answer: A

Reason: $\left(\frac{90\text{ km}}{1\text{ h}}\right)\left(\frac{1000\text{ m}}{1\text{ km}}\right)\left(\frac{1\text{ h}}{60\text{ min}}\right)\left(\frac{1\text{ min}}{60\text{ s}}\right)=25\text{ m/s}$

Question 3

Which of the following representations is correct when you solve 0.030 kg + 3333 g using scientific notation?

A. 3.4×10^3 g

B. 3.36×10^3 g

C. 3×10^3 g

D. 3363 g

Answer 3

Answer: A

Reason: 0.030 kg can be written as 3.0×10^1 g which has 2 significant digits, the number 3 and the zero after 3.

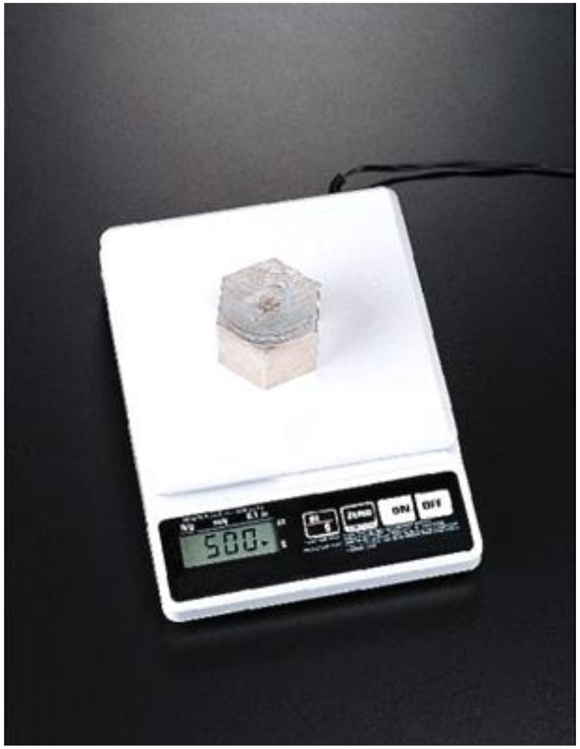
In number 3333 all the four 3's are significant hence it has 4 significant digits. So our answer should contain 2 significant digits.

In this section you will:

- **Distinguish** between accuracy and precision.
- **Determine** the precision of measured quantities.

What is a Measurement?

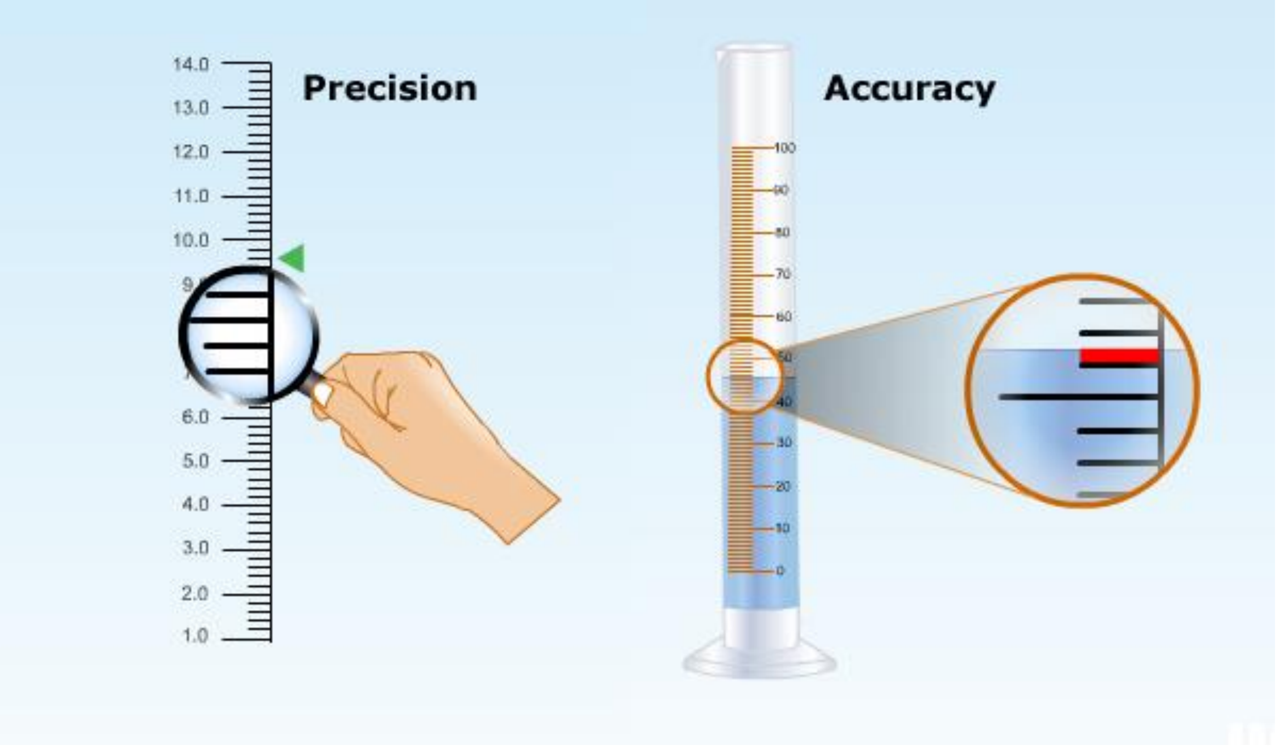
- A **measurement** is a comparison between an unknown quantity and a standard.
- Measurements quantify observations.
- Careful measurements enable you to derive the relation between any two quantities.



Comparing Results

- When a measurement is made, the results often are reported with an uncertainty.
- Therefore, before fully accepting a new data, other scientists examine the experiment, looking for possible sources of errors, and try to reproduce the results.
- A new measurement that is within the margin of uncertainty confirms the old measurement.

Precision Versus Accuracy



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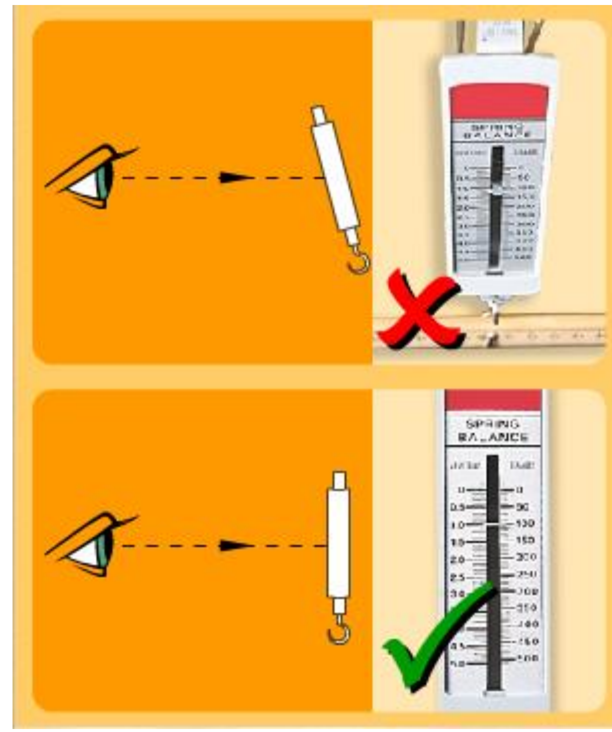
Techniques of Good Measurement

- To assure precision and accuracy, instruments used to make measurements need to be used correctly.
- This is important because one common source of error comes from the angle at which an instrument is read.
- To understand this fact better, observe the animation on the right carefully.



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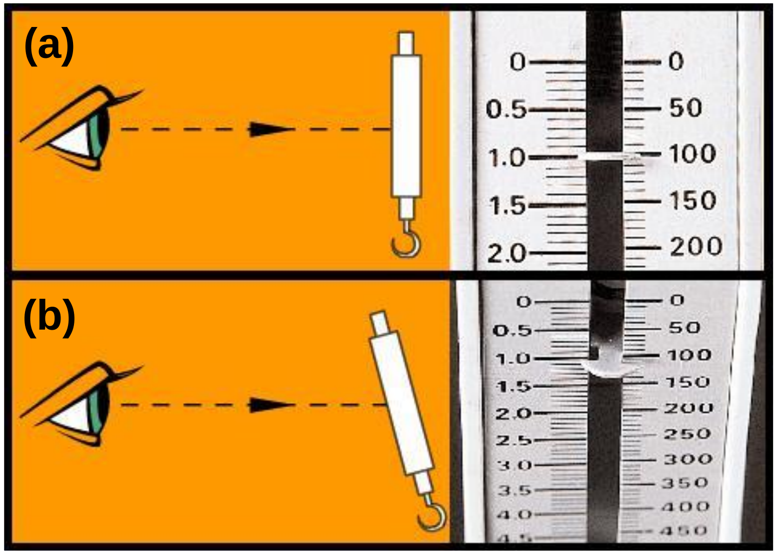
Techniques of Good Measurement

- Scales should be read with one's eye directly above the measure.
- If the scale is read from an angle, as shown in figure (b), you will get a different, and less accurate, value.
- The difference in the readings is caused by parallax, which is the apparent shift in the position of an object when it is viewed from different angles.



Question 1

Ronald, Kevin, and Paul perform an experiment to determine the value of acceleration due to gravity on the Earth (980 cm/s^2). The following results were obtained: Ronald - 961 ± 12 cm/s^2, Kevin - 953 ± 8 cm/s^2, and Paul - 942 ± 4 cm/s^2.
Justify who gets the most accurate and precise value.

A. Kevin got the most precise and accurate value.

B. Ronald's value is the most accurate, while Kevin's value is the most precise.

C. Ronald's value is the most accurate, while Paul's value is the most precise.

D. Paul's value is the most accurate, while Ronald's value is the most precise.

Answer 1

Answer: C

Reason: Ronald's answer is closest to 980 cm/s^2 and hence his result is the most accurate. Paul's measurement is the most precise within 4 cm/s^2.

Question 2

What is the precision of an instrument?

A. The smallest division of an instrument.

B. The least count of an instrument.

C. One-half of the least count of an instrument.

D. One-half of the smallest division of an instrument.

Answer 2

Answer: D

Reason: Precision depends on the instrument and the technique used to make the measurement. Generally, the device with the finest division on its scale produces the most precise measurement. The precision of a measurement is one-half of the smallest division of the instrument.

Question 3

A 100-cm long rope was measured with three different scales. The answer obtained with the three scales were:

1st scale - 99 ± 0.5 cm, 2nd scale - 98 ± 0.25 cm, and 3rd scale - 99 ± 1 cm. Which scale has the best precision?

A. 1st scale

B. 2nd scale

C. 3rd scale

D. Both scale 1 and 3

Answer 3

Answer: B

Reason: Precision depends on the instrument. The measurement of the 2^{nd} scale is the most precise within 0.25 cm.

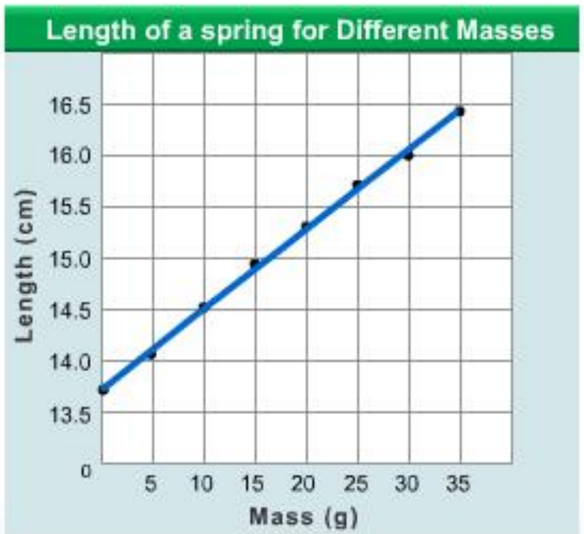
In this section you will:

- **Graph** the relationship between independent and dependent variables.
- **Interpret** graphs.
- **Recognize** common relationships in graphs.

Identifying Variables

- A variable is any factor that might affect the behavior of an experimental setup.
- It is the key ingredient when it comes to plotting data on a graph.
- The **independent variable** is the factor that is changed or manipulated during the experiment.
- The **dependent variable** is the factor that depends on the independent variable.

Graphing Data



Length of a spring for Different Masses

Mass Attached to Spring (g)	Length of Spring (cm)
0	13.7
5	14.1
10	14.5
15	14.9
20	15.3
25	15.7
30	16.0
35	16.4

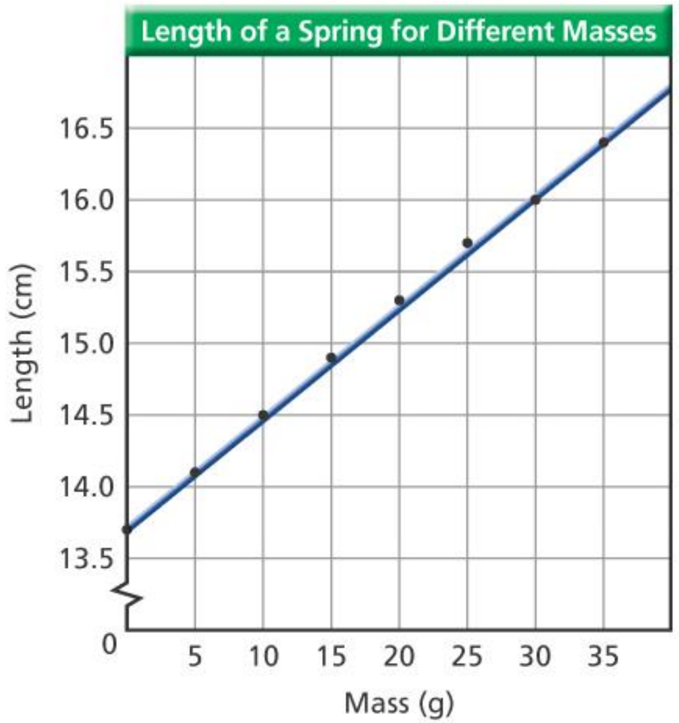
Click image to view the movie.

Linear Relationships

- Scatter plots of data may take many different shapes, suggesting different relationships.

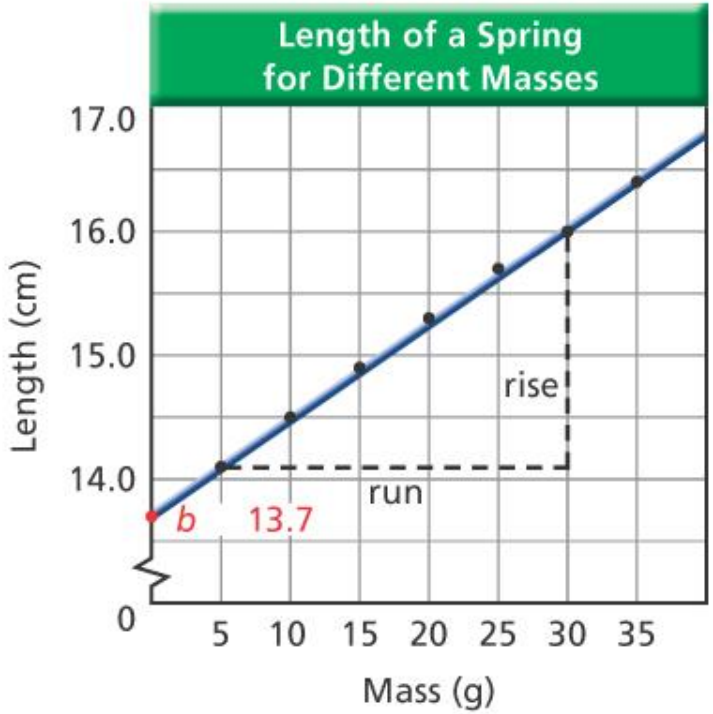
Linear Relationships

- When the line of best fit is a straight line, as in the figure, the dependent variable varies linearly with the independent variable. This relationship between the two variables is called a **linear relationship**.
- The relationship can be written as an equation.



Linear Relationships

- The slope is the ratio of the vertical change to the horizontal change. To find the slope, select two points, A and B, far apart on the line. The vertical change, or rise, Δ*y*, is the difference between the vertical values of A and B. The horizontal change, or run, Δ*x*, is the difference between the horizontal values of A and B.



$$\text{Slope} = m = \frac{rise}{run} = \frac{\Delta y}{\Delta x}$$

Linear Relationships

- As presented in the previous slide, the slope of a line is equal to the rise divided by the run, which also can be expressed as the change in *y* divided by the change in *x*.
- If *y* gets smaller as *x* gets larger, then $\Delta y/\Delta x$ is negative, and the line slopes downward.
- The *y*-intercept, *b*, is the point at which the line crosses the *y*-axis, and it is the *y*-value when the value of *x* is zero.

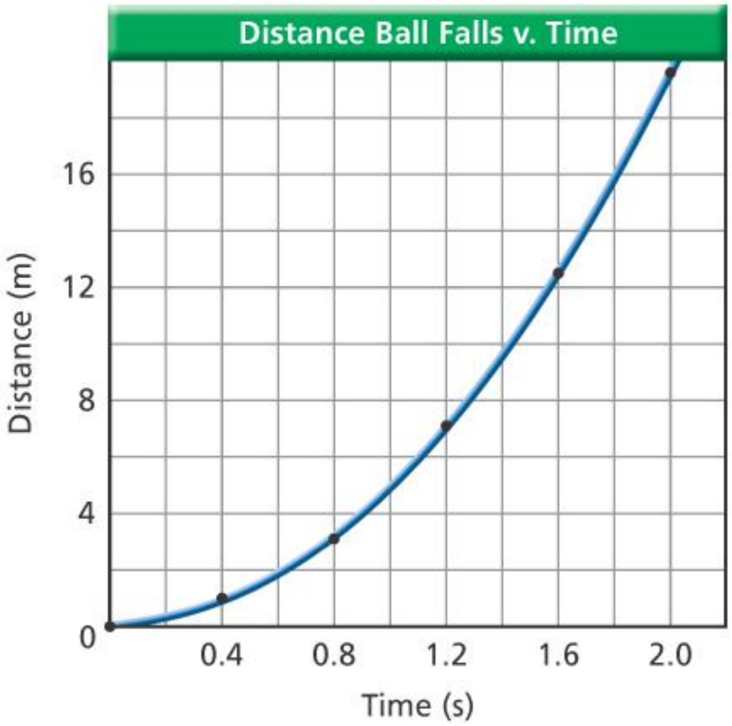
Nonlinear Relationships

- When the graph is not a straight line, it means that the relationship between the dependent variable and the independent variable is not linear.
- There are many types of nonlinear relationships in science. Two of the most common are the quadratic and inverse relationships.

Nonlinear Relationships

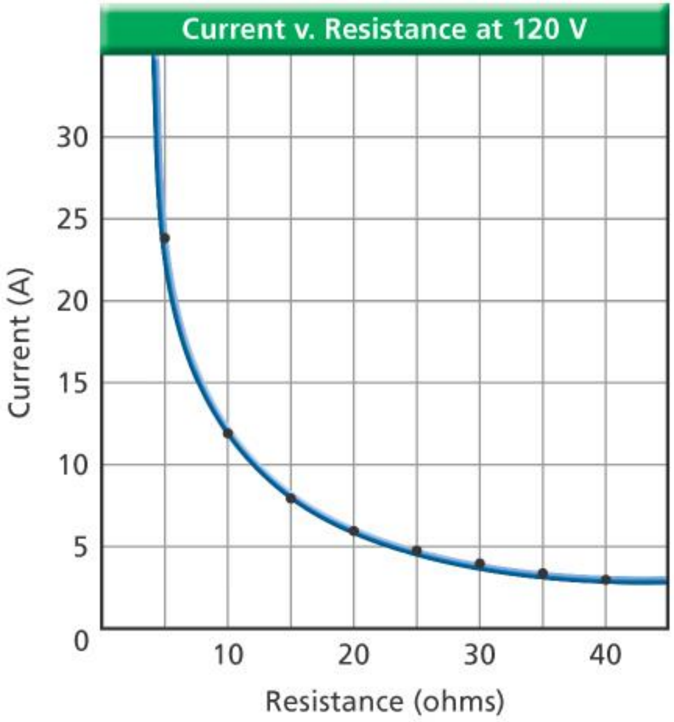
- The graph shown in the figure is a quadratic relationship.
- A **quadratic relationship** exists when one variable depends on the square of another.
- A quadratic relationship can be represented by the following equation:

$$y = ax^2 + bx + c$$



Nonlinear Relationships

- The graph in the figure shows how the current in an electric circuit varies as the resistance is increased. This is an example of an inverse relationship.
- In an **inverse relationship**, a hyperbola results when one variable depends on the inverse of the other.
- An inverse relationship can be represented by the following equation:



Nonlinear Relationships

- There are various mathematical models available apart from the three relationships you have learned. Examples include: sinusoids—used to model cyclical phenomena; exponential growth and decay—used to study radioactivity
- Combinations of different mathematical models represent even more complex phenomena.

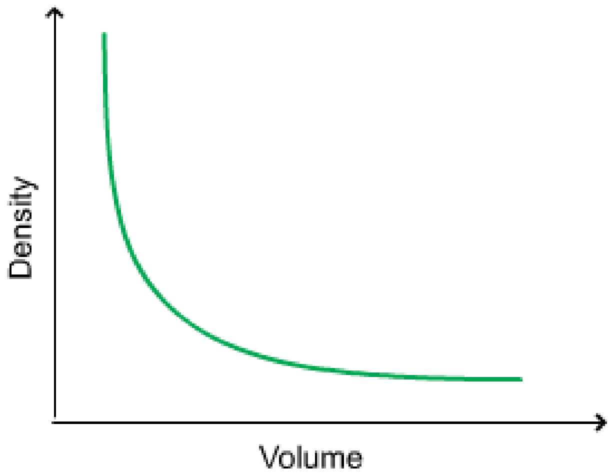
Predicting Values

- Relations, either learned as formulas or developed from graphs, can be used to predict values you have not measured directly.

- Physicists use models to accurately predict how systems will behave: what circumstances might lead to a solar flare, how changes to a circuit will change the performance of a device, or how electromagnetic fields will affect a medical instrument.

Question 1

Which type of relationship is shown following graph?



A. Linear

B. Inverse

C. Parabolic

D. Quadratic

Answer 1

Answer: B

Reason: In an inverse relationship a hyperbola results when one variable depends on the inverse of the other.

Question 2

What is line of best fit?

A. The line joining the first and last data points in a graph.

B. The line joining the two center-most data points in a graph.

C. The line drawn close to all data points as possible.

D. The line joining the maximum data points in a graph.

Answer 2

Answer: C

Reason: The line drawn closer to all data points as possible, is called a line of best fit. The line of best fit is a better model for predictions than any one or two points that help to determine the line.

Question 3

Which relationship can be written as $y = mx$?

A. Linear relationship

B. Quadratic relationship

C. Parabolic relationship

D. Inverse relationship

Answer 3

Answer: A

Reason: Linear relationship is written as $y = mx + b$, where b is the y intercept. If y-intercept is zero, the above equation can be rewritten as $y = mx$.

End of Chapter