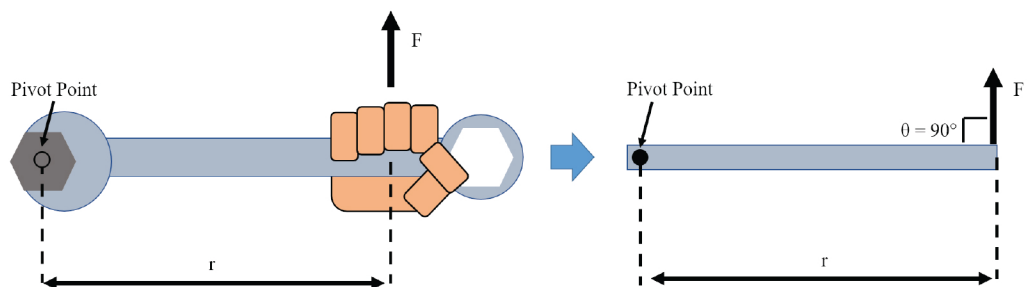
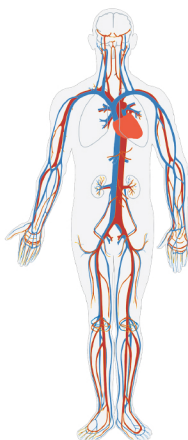
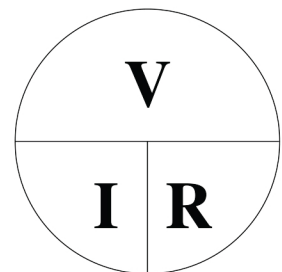
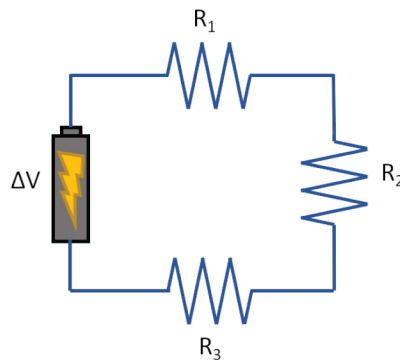
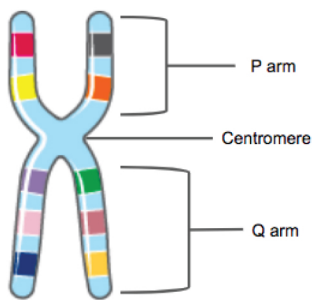
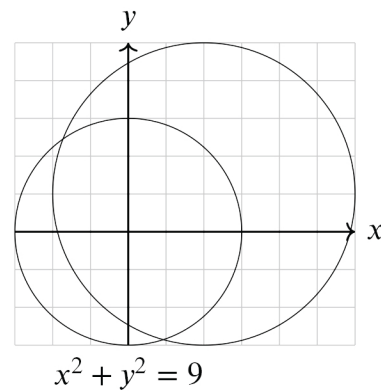
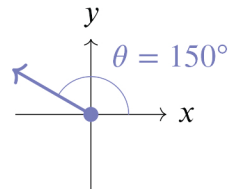
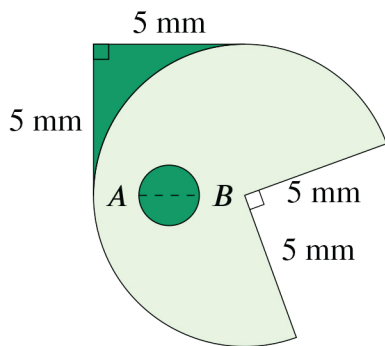
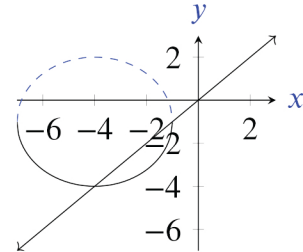
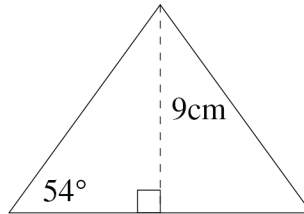


Math & Science

Introductory - Advanced Aptitude Development

$$m = \frac{\Delta y}{\Delta x} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{\text{rise}}{\text{run}}$$



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Math & Science

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Preface

There are many talented athletes in the sports world; the one thing they all have in common is strength and conditioning training. It does not matter how talented an athlete is; their performance is improved with that training. Similarly, math and science are like strength and conditioning training for industry workers; it does not matter how talented we are; we are improved by employing that training.

Fortune 500 companies prefer CEOs with engineering degrees because engineers specialize in problem solving. The core curriculum for engineering majors is math and science based. A healthy aptitude in math and science, among other things, conditions the mind to formulate actions that will yield desired outcomes when challenges arise. The more math and science we are exposed to, the better we can make good decisions in response to challenges. Academic problem solving practice translates into real world problem solving capabilities.

The hope is that this book will be another tool on our tool belt that we can use to get the job done right. Just like how athletes must undergo continual training to perform at the highest levels, we must also continue to train our minds to excel in our performance. Let the journey begin!

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Contents

| | | |
|----------|--|-----------|
| 1 | Decimals and Fractions | 1 |
| | Decimal Fundamentals | 2 |
| | What is a decimal? | 2 |
| | Decimal addition | 2 |
| | Decimal subtraction | 3 |
| | Decimal multiplication | 4 |
| | Decimal division | 5 |
| | Fraction Fundamentals | 6 |
| | What is a fraction? | 6 |
| | Reducing fractions | 7 |
| | Proper and Improper Fraction Multiplication | 8 |
| | Proper and Improper Fraction Division | 9 |
| | Fraction Addition | 9 |
| | Fraction Subtraction | 11 |
| | Mixed Number Multiplication and Division | 11 |
| | Mixed Number Addition and Subtraction | 12 |
| | Ordering Fractions and Decimals | 13 |
| | Converting Fractions into Decimals | 13 |
| | Converting Decimals into Fractions | 13 |
| | Finding a Common Denominator For Multiple Fractions | 14 |
| | Sorting Lists of Fractions and Decimals | 15 |
| | Word problems with fractions and decimals | 16 |
| | Finding Key Information and Ignoring Extraneous Data | 16 |
| | Translating English into Mathematics | 17 |
| | Dealing with Multiple Steps | 19 |
| | Chapter 1 Test | 22 |
| 2 | Ratios, Proportions and Percents | 27 |
| | Ratio and Proportion Fundamentals | 28 |
| | Ratio and Proportion Basics | 28 |
| | Variation | 29 |
| | Solving Simple Ratio and Proportion Word Problems | 29 |
| | Percent Fundamentals | 31 |
| | Converting Percents into Decimals and Fractions | 31 |
| | Percent Word Problems | 32 |
| | Percent Change Increase and Decrease | 33 |

| | |
|--|-----------|
| Simple Interest | 34 |
| Chapter 2 Test | 36 |
| 3 Dimensional Analysis | 39 |
| Base Measurements | 40 |
| Dimensional Analysis | 43 |
| Numerator unit changes | 43 |
| Denominator unit changes | 44 |
| Both Numerator and Denominator unit changes | 45 |
| Dimensional Analysis Word Problems | 46 |
| Multi-dimensional analysis | 47 |
| Area | 47 |
| Volume | 49 |
| Multi-dimensional analysis Word Problems | 50 |
| Temperature Conversion | 51 |
| Units as products and ratios of units | 52 |
| Using formulas to solve problems | 54 |
| Dealing with unfamiliar or obscure units | 56 |
| Chapter 3 Test | 58 |
| 4 Algebra Basics | 61 |
| Algebra Basics | 62 |
| Exponents and Square Roots | 62 |
| Order of operations | 63 |
| Algebraic Expressions | 64 |
| Properties of Operations | 66 |
| Simplifying Expressions | 67 |
| Evaluating Expressions | 69 |
| One-variable linear equations | 70 |
| One-variable linear absolute value equations | 71 |
| One-variable linear equality word problems | 73 |
| Number Lines | 74 |
| Graph and solve one-variable linear inequalities | 75 |
| One-variable linear absolute value inequalities | 76 |
| One-variable linear inequality word problems | 78 |
| Chapter 4 Test | 80 |
| 5 Two-Variable Linear Algebra | 85 |
| The Cartesian (x,y) Plane | 86 |
| Slope | 86 |
| Point-Slope Form | 88 |
| Slope-Intercept Form | 90 |
| Standard Form | 93 |
| Two-variable linear inequalities | 94 |
| Piecewise functions | 96 |
| Solving Systems by Substitution | 99 |

| | |
|--|------------|
| Solving Systems by Elimination | 100 |
| Linear System Word Problems | 100 |
| Graphs of Linear Systems and Inequalities | 102 |
| Linear and Inequality System Word Problems | 104 |
| Chapter 5 Test | 106 |
| 6 Exponents and Logarithms | 111 |
| Exponent Properties | 112 |
| Radical Properties | 113 |
| Rationalizing denominators | 114 |
| Finding Inverse Functions | 115 |
| Properties of Logarithms | 117 |
| Solving Exponential Equations | 118 |
| Solving Logarithmic Equations | 120 |
| Applying Inverse Functions | 121 |
| Graphs of Exponential Equations | 122 |
| Graphs of Logarithmic Functions | 124 |
| Exponential Word Problems | 125 |
| Logarithmic Word Problems | 127 |
| Chapter 6 Test | 129 |
| 7 Quadratics and Higher Degree Polynomials | 133 |
| Special Polynomial Multiplication Patterns | 134 |
| Factoring Quadratics | 135 |
| Completing the Square | 139 |
| Basic Complex Number Operations | 141 |
| Solving Quadratics | 142 |
| Quadratic Word Problems | 144 |
| Solving Radicals | 146 |
| Radical Word Problems | 148 |
| Graphing Quadratics | 151 |
| Graphing Radicals | 153 |
| Factoring and Solving Polynomial Equations | 155 |
| Graphing Polynomial Equations | 157 |
| Chapter 7 Test | 161 |
| 8 Polygons and Related Geometry | 163 |
| Line and angle terminology | 164 |
| Angle Hunting with Parallel Lines | 165 |
| Triangle Classifications, Theorems, and Postulates | 167 |
| Solving for unknowns around triangles | 169 |
| Quadrilateral classifications and theorems | 170 |
| Solving for unknowns around quadrilaterals | 172 |
| Triangle and Quadrilateral Areas | 174 |
| Area Word Problems | 176 |
| Prism and Pyramid Volumes | 178 |

| | |
|---|------------|
| Volume Word Problems | 180 |
| Working with scale and similarity | 183 |
| Similar figure and trigonometry word problems | 187 |
| Working with regular polygons and regular bases | 189 |
| Prism and Pyramid Surface Areas | 190 |
| Surface Area Word Problems | 192 |
| Chapter 8 Test | 194 |
| 9 Circles and Related Geometry | 199 |
| Radians and DMS | 200 |
| Arcs and Circumferences | 201 |
| Discs and Sectors | 202 |
| Circle Word Problems | 203 |
| Circle Trigonometry | 204 |
| Rotational Rates | 206 |
| Rotational Rate To Distance Traveled | 206 |
| Cartesian Circles | 208 |
| Spheres, Cylinders, and Right Cones | 210 |
| Geometric Probability | 211 |
| Geometric Probability Word Problems | 213 |
| Chapter 9 Test | 216 |
| 10 Statistics and Probability | 221 |
| One-Variable Data | 222 |
| Central Tendency | 222 |
| Spread | 224 |
| Outliers | 226 |
| Categorical vs. Continuous Data | 231 |
| Single Variable Data Displays | 231 |
| Shape | 238 |
| Correlating two variables | 242 |
| Scatterplots | 242 |
| Kinds of correlation | 243 |
| Regression lines | 245 |
| Non-linear regression | 246 |
| Probability | 247 |
| Counting | 247 |
| Independence, dependence, and functional independence | 250 |
| Confidence Interval | 252 |
| Survey and Experiment Design | 253 |
| Good and Bad Randomness | 253 |
| Valid vs. Invalid Sampling Types | 253 |
| Kinds of Potential Bias | 255 |
| Experiments | 257 |
| Placebos and Blinds | 257 |
| Chapter 10 Test | 259 |

| | |
|---|------------|
| 11 Science Fundamentals | 263 |
| Science Fundamentals | 264 |
| Scientific Terminology | 264 |
| Science Comprehension | 265 |
| Scientific Method | 266 |
| Scientific Method Application | 268 |
| Presentation of Scientific Data | 271 |
| Practice | 273 |
| Chapter 11 Test | 274 |
| 12 Life Science | 279 |
| Life Fundamentals | 280 |
| Essential Functions of Life | 280 |
| Cell Organization | 281 |
| Parts Of A Cell | 282 |
| Molecular Basis For Heredity | 282 |
| Human Body Systems | 285 |
| Skeletal System | 286 |
| The Nervous System | 286 |
| The Circulatory System | 288 |
| The Respiratory System | 289 |
| Reproductive System | 290 |
| The Endocrine System | 290 |
| The Digestive System | 291 |
| The Urinary System (Excretory System) | 292 |
| The Lymphatic / Immune System | 292 |
| Homeostasis | 293 |
| Maintaining the Human Body: Nutrition and Homeostasis | 293 |
| Micronutrients | 293 |
| Macronutrients | 294 |
| Disease Transmission and Prevention | 294 |
| Ecosystem | 295 |
| Energy pyramid | 296 |
| Types of Energy Within An Ecosystem | 297 |
| Flow of Matter In An Ecosystem | 297 |
| Carrying Capacity of an Ecosystem | 298 |
| Relationships Between Organisms In An Ecosystem | 299 |
| Perfect Balance? Disruption of an Ecosystem? | 299 |
| Chapter 12 Test | 300 |
| 13 General Physics | 305 |
| Kinematics | 306 |
| 1D Motion | 306 |
| 2D Motion | 308 |
| Kinematics | 310 |
| Force | 311 |

| | |
|--|------------|
| Newton's Law | 311 |
| Types of Forces | 312 |
| Application of Newton's Laws | 312 |
| Force | 314 |
| Angular Motion | 315 |
| Uniform Circular Motion | 318 |
| Angular Motion | 319 |
| Torque | 320 |
| Rigid Bodies | 322 |
| Torque | 327 |
| Momentum | 327 |
| Momentum | 333 |
| Energy | 333 |
| Work | 334 |
| Types of Energy | 335 |
| Power | 340 |
| Energy | 342 |
| Thermodynamics | 343 |
| Temperature | 343 |
| Volume and Density | 343 |
| States of Matter | 344 |
| Ideal Gas Law | 345 |
| Work on an Ideal Gas | 348 |
| Heat | 350 |
| Heat Engines | 352 |
| Thermodynamics | 355 |
| Electrostatics | 356 |
| Coulomb's Law | 356 |
| Waves | 357 |
| Electromagnetic Radiation | 358 |
| Electrostatics | 360 |
| Circuits | 361 |
| Current | 361 |
| Resistance | 361 |
| Electric Potential | 362 |
| Power | 362 |
| Circuits | 364 |
| Practice Exercise Answers | 387 |
| Chapter Test Answers | 405 |
| Index | 423 |

Proper and Improper Fraction Division

Dividing by a proper or improper fraction is similar to the multiplication process. However, there is an additional step that must be performed when solving division problems. Dividing by a number is the same as multiplying by that number's reciprocal. In the case of proper and improper fractions, generating a reciprocal is achieved by switching the numerator and denominator. Then multiply as is done with the multiplication of proper and improper fractions.

Examples

$$1.) \frac{2}{3} \div \frac{4}{9} = \frac{2}{3} \cdot \frac{9}{4} = \frac{3}{2} = 1\frac{1}{2}$$

$$2.) \frac{2}{\frac{4}{7}} = 2 \div \frac{4}{7} = 2 \cdot \frac{7}{4} = \frac{7}{2} = 3\frac{1}{2}$$

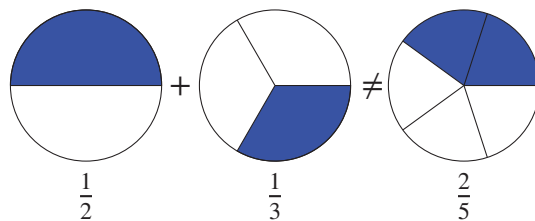
1.2.4 Practice

$$1) \frac{5}{6} \div \frac{3}{4} = \quad 2) \frac{\frac{2}{9}}{\frac{8}{15}} = \quad 3) \frac{12}{49} \div \frac{21}{25} = \quad 4) \frac{3}{7} \div \frac{28}{9} = \quad 5) \frac{4}{7} \div \frac{9}{11} = \quad 6) \frac{2}{36} \div \frac{23}{45} =$$

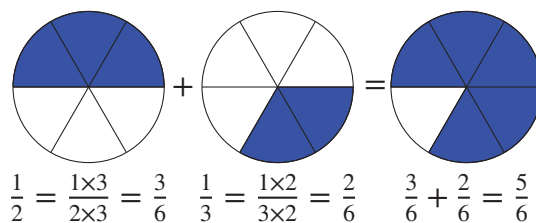
$$7) \frac{8}{9} \div \frac{33}{14} = \quad 8) \frac{7}{8} \div \frac{9}{16} = \quad 9) \frac{\frac{6}{27}}{\frac{16}{30}} = \quad 10) \frac{12}{25} \div \frac{14}{15} =$$

Fraction Addition

Fractions can combine to form new fractions or whole integers. However, fraction addition does not work the same way as integer addition. To illustrate this point examine the figure below.



To add fractions, the number of divisible parts (the denominators) have to match for each fraction. So in the previous example, each half could be cut into thirds to make six parts, and each third could be cut into halves to make six parts in the second fraction.



Ratio and Proportion Fundamentals

Ratio and Proportion Basics

It is often useful to compare two different values. Like determining which city has a better crime rate and by how much? How many teachers are there for every student in the class? What is the comparison between the company's debt to its equity? Which job has better pay per hour?

A ratio is a way to compare two numbers. Ratios are sometimes written as fractions, and other times they are separated with a ":" or "to." If there is one teacher for every eight students, the teacher to student ratio is either $\frac{1}{8}$, 1:8, or 1 to 8. Likewise, if there are 20 scholarships available and 35 students qualified, the scholarship to students ratio is $\frac{20}{35}$, 20:35 or 20 to 35. Ratios should be reduced to their simplest form, in this case, $\frac{4}{7}$, 4:7, or 4 to 7.

Example

Super flyweight boxer Juan Fernandez Pablo has fought 28 times in his career; he won 21 times with no draws. What is his career win to loss ratio?

$$\frac{\text{wins}}{\text{losses}} = \frac{21}{7} \div \frac{7}{7} = \frac{3}{1} \quad \text{His career win/loss ratio is 3:1.}$$

Two equivalent ratios are called proportional. Proportions are typically expressed as two equivalent fractions separated by an equal sign. Geometry provides visualization for ratios and proportions.

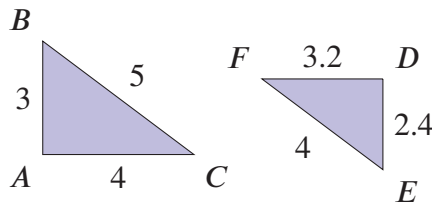
Examples

- 1) The ratio of a to b is 5 to 7.

$$\frac{a}{b} = \frac{5}{7}$$

- 2) The proportions of the lengths of corresponding sides in similar triangles are all equal.

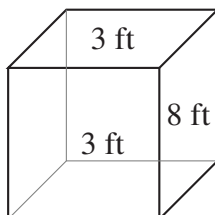
$$\triangle ABC \sim \triangle DEF \rightarrow \frac{AB}{DE} = \frac{AC}{DF} = \frac{BC}{EF}$$



$$\text{e.g. } \frac{AB}{DE} = \frac{AC}{DF} = \frac{BC}{EF} = 1.25$$

Volume

Volume adds yet another dimension that can be analyzed. In the closet example, there was a length of 3 feet and a width of 3 feet. When the additional dimension of height is added, we can determine how much space is available to be occupied. If the height of the closet is 8 feet, using the formula ($V = lwh$) we can calculate that the volume of the closet is 72 ft^3 .



Again, multi-dimensional analysis can be utilized when there is a need to convert from one unit to another desired unit. Continuing with the closet example, the volume of the closet is 72 ft^3 ; there is a need to know how many cubic yards of material can be stored in the closet. This is accomplished by following the same process as multi-dimensional analysis for area, except the equivalent numerator and denominator are cubed. When units are cubed, converting those units requires multiplying by a cube. The multi-dimensional analysis of 72 ft^3 in terms of yd^3 works out as follows:

$$72 \text{ ft}^3 \left(\frac{1 \text{ yd}}{3 \text{ ft}} \right)^3 = 72 \text{ ft}^3 \left(\frac{1 \text{ yd}^3}{27 \text{ ft}^3} \right) = 2.7 \text{ yd}^3$$

Example

John is struggling with redoing his math homework. He was asked to convert 1 cubic inch into cubic feet. He made the mistake of thinking one foot is equivalent to 6 inches when a foot is 12 inches. What was John's original answer, and what should have been his answer?

What John thought was:

$$\left(\frac{\text{foot}}{6 \text{ inches}} \right)^3 = \left(\frac{\text{foot}^3}{216 \text{ inches}^3} \right)$$

so he gave the answer of 216 cubic inches per cubic foot.

The real answer is based on the fact that one foot is equivalent to 12 inches, which by a similar process yields one cubic foot is equivalent to 1,728 cubic inches.

3.4.2 Practice

- 1) Write 1 m^3 per freezer in terms of L per freezer. ($1 \text{ L} = 1,000 \text{ cm}^3$)
- 2) Write 4 containers per ft^3 in terms of containers per yd^3 .
- 3) Write one bacterium every $2 \text{ } \mu\text{m}^3$ in terms of bacteria per cm^3 .
- 4) 45 in^3 in terms of cm^3 is?

| English to Algebra Translation | |
|----------------------------------|----------------|
| a number increased by 7 | $x + 7$ |
| a number reduced by 6 | $x - 6$ |
| 3 times a number | $3x$ |
| a number divided by 5 | $\frac{x}{5}$ |
| one third of a number | $\frac{1}{3}x$ |
| 4 times a number increased by 3 | $4x + 3$ |
| one number minus another number | $x - y$ |
| the square of a number times two | $2x^2$ |

Example

- 1) A car manufacturer is going to produce x number of cars. They need to order tires for the cars that will be produced. According to inventory, 17004 tires are already in their warehouse. Write an algebraic expression to determine the number of tires that need to be ordered.

$$4x - 17,004$$

4.3 Practice

Translate the following to an algebraic expression:

- 1) decreasing a number by 5
- 2) the product of six times a number increased by 8
- 3) 15 more than a number plus 3 times another number
- 4) the quotient of 12 and a number minus 3
- 5) the difference of -6 multiplied by a number and another number squared increased by 11

Translate the following to English:

- 6) $n + 18$
- 7) $6x$
- 8) $\frac{x}{5} - 8$
- 9) $13x - 7 + y^2 - 4$
- 10) $\frac{1}{8}x - 4$

Point-Slope Form

There are many situations in which it is useful to describe the mathematical equation for a line. A line's equation describes how steep the line is, where it starts, and how two variables interact.

A linear function has a very straight graph, such that the two variables change together at a consistent rate across the whole graph. Linear functions are the most straightforward functions to draw, describe, graph, and understand.

The point-slope form of a graph is the most useful for solving for slope or finding a certain point. It is beneficial for any problem that involves a graph and solving for a value.

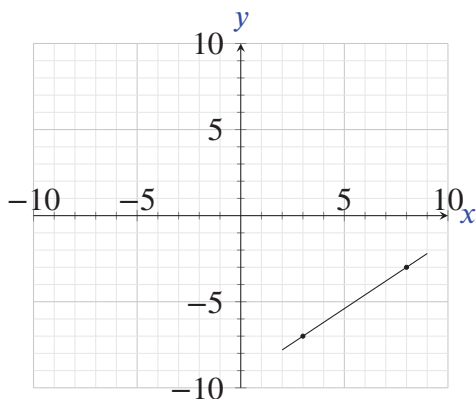
Because the slope of a line never changes, knowing the slope of a line and one point on the line is enough to write an equation for that line using the slope formula. Remove the subscripts for the second point, so they become just y and x .

$$\frac{y - y_1}{x - x_1} = m \rightarrow y - y_1 = m(x - x_1)$$

This formula is handy, which is why it is a rare visitor to multiple choice exams and answer keys: it presents an infinite number of solutions for any given line. Often one will be implicitly or directly asked to solve for y and simplify. However, point-slope form is often the fastest way to generate the equation when only one point is known or when the line has a restricted domain (because the real world is full of line segments that do not necessarily cross any axis lines) for a line. Sometimes the graphing point-slope form is faster relative to other forms of lines because it can target the most convenient point for graphing while the other forms are too rigid. **Note: Be careful with signs. The formula has two sign changes.**





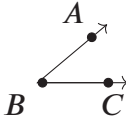


Examples

- 1) Find an equation for the line segment in the graph.



First, find convenient points to work with. The two points identified from the graph are (3, -7) and (8, -3).

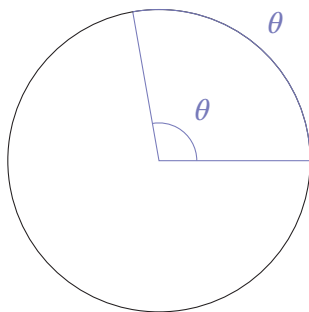
Line and angle terminology

| Term | Definition | Diagram | Notation or Sentence |
|--------------|---|---|--|
| Point | A zero dimensional object used for location. |  | A |
| Line | A one dimensional object of infinite length. |  | \overleftrightarrow{AB} |
| Line segment | A finite portion of a line. |  | \overline{AB} |
| Ray | Half of a line. |  | \overrightarrow{AB} |
| Angle | Two rays coming out from the same point. |  | $\angle B$ or $\angle ABC$ or $\angle CBA$ |
| Degree | The angle or arc measure corresponding to $\frac{1}{360}$ of a circle. |  | 1° |
| Minute | The angle or arc measure corresponding to $\frac{1}{60}$ of a degree. | <div>Invisible at this scale.</div> | $0^\circ 1'$ |
| Second | The angle or arc measure corresponding to $\frac{1}{60}$ of a minute. | <div>Invisible at this scale.</div> | $0^\circ 0' 1''$ |
| Radian | The angle or arc measure corresponding to one radius length along a circle. |  | 1 rad. Radian measures often contain π and then may go with other units. |

Radians and DMS

Humans measure items all the time. Height is measured year after year as a child grows. Weight is used to measure flour, water, salt, and yeast in a loaf of bread. Speed is measured in a car to determine how fast we are going. Angles are measured to determine a direction or location. As with all measurements, there is a standard way to measure angles.

Either radians or degrees can be used to determine the size of an angle or the size of an arc length, which is a portion of a circle. When these units are used to measure arcs, the arc measurement equals the matching central angle measure.



Converting between radians and degrees requires knowing that there are 2π radians in a circle, and 360° in a circle. The conversion will be using either $\frac{\pi}{180^\circ}$ or $\frac{180^\circ}{\pi}$, memorizing the reduced fractions is not as important as remembering the underlying concept.

Examples

- 1) Convert $\sqrt{2}$ radians to an angle rounded to the nearest second using a calculator.

$$\sqrt{2} \left(\frac{180^\circ}{\pi} \right) \approx 81.02846845^\circ$$

Multiply the decimal portion by 60 to get the minutes.

$$0.02846845^\circ \approx 1.708107248'$$

Multiply the decimal portion of this to get the seconds.

$$0.708107248' = 42.4864349''$$

Rounding as directed, the final answer is $81^\circ 1' 42''$.

- 2) Convert $100^\circ 45' 20''$ into radians.

$$\left(100 + \frac{45}{60} + \frac{20}{3600} \right) \left(\frac{\pi}{180^\circ} \right) = \frac{4534\pi}{8100} = \frac{2267\pi}{4050}$$

9.1 Practice

(Answers to practice begins on page 400)

- 1) Convert $40^\circ 40' 40''$ into radians.
- 2) Using a calculator, convert 1 radian to an angle rounded to the nearest second.

Spread

The term spread refers to how closely packed or loosely packed a data set happens to be. The quartiles are the specific benchmarks within a sorted data set that give a quick way of summarizing the shape of a data set.

- Q_0 is the minimum point in the data set.
- Q_1 is the median of the data subset that goes from the minimum to the median of the original set and is called the first quartile.
- Q_2 is the median of the original set.
- Q_3 is the median of the data subset that goes from the median to the maximum of the original data set and is called the third quartile.
- Q_4 is the maximum of the original data set.

To visualize this, imagine having a number line ranging from 0 to 8 so $Q_0 = 0$, $Q_1 = 2$, $Q_2 = 4$, $Q_3 = 6$, $Q_4 = 8$. The idea is that between any Q_n and Q_{n+1} is 25% of the original data set.

The interquartile range, known as *IQR* for short in many places, is simply $Q_3 - Q_1$. It is a way to measure the spread of the middle 50% of the data.

Standard deviation is an incredibly useful number in statistics. The standard deviation describes how the data points in a data set vary from the mean value, or how far each data point *deviates* from the *standard* (or mean).

If all the data points are close to the mean, the standard deviation is small. If all the data points are far from the mean, the standard deviation is large. Standard deviation is a critical concept because a study with a large standard deviation is not considered scientifically valid. After all, the numbers vary too much to show a clear pattern or draw a strong conclusion. While important, standard deviation has a tedious calculation:

$$s_x = \sqrt{\frac{\sum_{i=1}^{i=n} (x_i - \bar{x})^2}{n - 1}}$$

Here, s_x stands for standard deviation, x_i stands for an individual data point, \bar{x} stands for the mean of the data, and n stands for the number of data points in the sample or population.

To find the standard deviation, find the square of the difference between each data point and the mean, then add all of those values together. Divide by the number of values in the sample minus 1 and finally take the square root. For a large data set, this takes an extremely long time.

For example, consider a sample:

$$x \in \{2, 3, 3, 4\}$$

Science Fundamentals

Scientific Terminology

Professionals in the world of science use terms that can seem intimidating to those who are not familiar with scientific terminology. Having a solid knowledge of key scientific terms can aid in the understanding of scientific information. Below is a list of common scientific terms that you may encounter:

Figure 6: Scientific Terms

| Term | Definition |
|--------------------|---|
| Cause | Events that provide the generative force of something. |
| Conclusion | A position or opinion reached after considering and analyzing evidence. |
| Context | The set of facts or circumstances that surround a problem or situation. |
| Control group | Group that is randomly chosen not to receive the experimental treatment. |
| Control variable | A variable that does not change during an experiment. |
| Dependent variable | Variable that responds to the independent variable. Dependent variable is what is being measured in the experiment. |
| Double-blind | Neither the researcher nor the subject knows if the subject is receiving the treatment or a placebo. |
| Effect | A result that is caused by a previous phenomenon. |
| Evaluate | Estimate the nature, quality, ability or significance of a problem, idea, or situation. |
| Experimental group | Subjects randomly chosen to receive the experimental treatment. |
| Fact | Information about events that have occurred that is supported by evidence. |
| Hypothesis | A prediction that serves as the starting point for an investigation. |
| Independence | One factor does not have influence on another. |
| Infer | Conclude by reasoning. |
| Inference | Drawing a conclusion on the basis of circumstantial evidence. |
| Opinion | A belief or judgement. |
| Placebo | Artificial treatment that should have no real effect. |
| Scientific Law | Descriptions of natural phenomena that describe an observation. |
| Scientific Theory | An explanation of an idea based on observations, explanations, and reasoning. |

Source: "Scientific Method Vocabulary Terms."

Ecosystem

There are many processes that organisms undergo in order to sustain life. All of these processes occur at the cellular level in either plants, animals, or other microorganisms. Plants are producers that use sunlight and water to convert carbon dioxide to carbohydrates (sugar) through a process known as photosynthesis. Photosynthesis is a vital process to maintain balance in an ecosystem because plants are able to take waste gases like carbon dioxide and facilitate the production of oxygen, which is utilized by almost all living organisms.

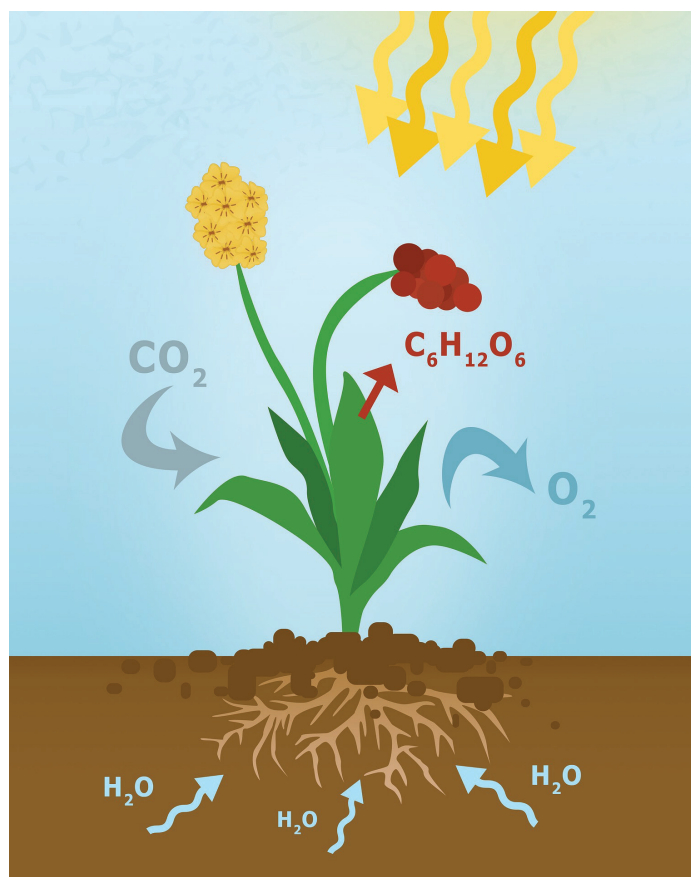


Figure 30. Photosynthesis process

Another cellular process that is important to the sustainability of life is fermentation. Fermentation is an anaerobic (without oxygen) metabolic process in which microorganisms like bacteria and yeast convert sugar to gases, alcohol, or acids. Muscle cells of the human body can also go through the fermentation process producing lactic acid. This build up of lactic acid occurs when muscles are exposed to high intensity exercises and are deprived of oxygen. A person can feel this through muscle soreness or cramps.

- (d) $2000 \text{ rev}/\text{min}^2$
3. A satellite orbiting the planet does due to centripetal acceleration. What force causes the centripetal force to keep The satellite in planetary orbit?
- (a) Kinetic Friction
 (b) Normal
 (c) Gravitational
 (d) Elastic

Torque

Torque τ is the amount of force required to cause a rotation and is commonly referred to the turning force. Consider a wrench unscrewing a bolt as depicted in figure 44. The wrench acts as a lever arm or rigid rod where the pivot point is centered around the bolt. The force is applied perpendicular to the lever arm. If the force is applied parallel to the lever area, i.e., pushing into the wrench length-wise, the bolt will not turn. Where you place your hand on the wrench will affect the amount of torque you apply to unscrew the bolt.

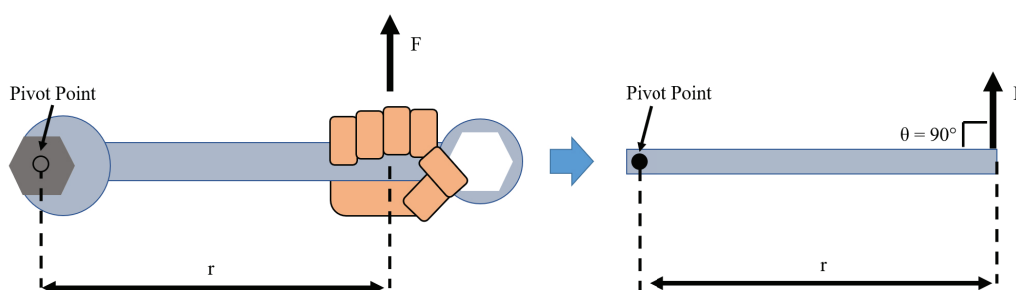


Figure 44. wrench

Formally torque is written with the Greek letter τ and mathematically written as the product of the distance from the pivot point (r), the force applied (F) to create the torque, and the (\sin) of the angle between the lever arm and the direction of the force, θ .

$$\tau = rF \sin \theta \quad (16)$$

From equation 16 we can deduce that the units for torque is a meter Newton, mN . **Note:** $\sin \theta$ is unit less.

Index

A

absolute value, 71
absolute zero, 343
Acquired immunity, 292
acquired mutations, 283
adrenal glands, 290
Analysis, 266
Angle, 164
angular motion, 316
antibodies, 292
Anus, 292
apothem, 189
Approximately normal, 241
arc, 201

B

balanced, 238
bell curve, 227
bias, 254
bimodal, 223
bisector, 208
Boltzman constant, 346
Brain, 286

C

calorie, 351
carbohydrates, 294
cardiac muscle, 285
Carrying capacity, 298
centroid, 168
centromere, 283
Chemical energy, 297
chord, 208
chromosome, 283
circle, 202, 208
circuits, 361
circulatory system, 288
circumcenter, 168
circumference, 201
claims, 267
cluster sample, 254
commensalism, 299
common denominator, 10

common factors, 7
Conclusions, 266
conduction, 350
cones, 210
confidence interval, 252
confidence model, 252
Convection, 351
convex polygon, 189
coronavirus, 294
correlation, 244
cos, 184
Coterminal angles, 205
Coulomb's Law, 356
Culture biases, 255
current, 361
cutoff, 229
Cylinders, 210
cytokinesis, 280

D

decimal, 2
decomposers, 297
Degree, 164
denominator, 6
Deoxyribonucleic acid, 282
dependence, 250
dependent variable, 234
diaphragm, 289
diatomic gas, 350
digestive system, 291
dioxide exchange, 289
Direct variation, 29
disc, 202
displacement, 306
divisor, 5
double blind, 257

E

ecosystem, 296
elastic collision, 328
electrical energy, 297
electrostatic, 356
endocrine system, 290

endothermic processes, 351
enthalpy, 351
Esophagus, 292
evaporation, 350
evidence, 267
exothermic process, 352
Experiment, 266

F

fermentation, 295
force, 29, 311
Fractions, 6

G

gametes, 280, 290
genotype, 283
geographic bias, 255

H

heat, 350
heat engine, 352
hemoglobin, 288
Herbivores, 297
histones, 283
homeostasis, 293
Hormones, 290
hypotenuse, 184
Hypothesis, 266

I

immune systems, 292
Improper fractions, 6
incenter, 168
independence, 250
independent, 234, 250
indexing number, 222
inelastic collision, 327
inertia, 324
integers, 2
integumentary system, 285
Interest, 34
interquartile range, 224
involuntary, 285
isobaric, 348

isochoric, 348

Isosceles trapezoids, 177

isothermal, 349

J

jointly proportional, 30

K

kidneys, 292

kinematics, 306

kinetic, 312

L

Large Intestine, 292

LCD, 14

ligaments, 286

line of regression, 243

Line segment, 164

Linear Pair, 165

lungs, 289

lymphatic, 292

M

macromolecules, 282

macronutrients, 293

Mass, 29

mean, 222

median, 222

meiosis, 280

melting point, 345

metastasizing, 283

micronutrients, 293

microorganisms, 294

Minute, 164

mitosis, 280

mixed number, 6

mode, 222

modes, 238

momentum, 327

monatomic atom, 350

monatomic gases, 350

Mouth, 291

Multicellular, 281

multimodal, 223

muscular system, 285

mutualism, 299

N

Nerves, 286

nervous system, 286

Newton's laws, 311

Number lines, 74

numerator, 6

O

Observation, 266

organelle, 282

orthocenter, 168

outlier, 226

overline, 5

P

Pancreas, 291

Parallel, 165

parallelograms, 175

parasitism, 299

pathogens, 292, 294

percent, 31

Percent change, 33

Perpendicular, 165

perpendicular bisector, 208

phase change, 344

Phase equilibrium, 345

photosynthesis, 295, 297

Pituitary gland, 290

placeholder, 2

plasma, 289

Point, 164

positive displacement, 306

potential energy, 333

power, 340

predictions, 245

prisms, 190

probability, 247

procedure, 270

Producers, 297

Proper fractions, 6

proportional, 28

Punnett square, 284

pyramid, 178

Q

quadrilaterals, 170

quartile, 224

R

Radian, 164

radians, 200

Radiation, 351

randomness, 253

ratio, 28

reciprocal, 9

rectangles, 175

Rectum, 292

red blood cells, 289

remainder, 7

reproductive system, 290

resistance, 361, 362

Respiration, 296

respiratory system, 289

rhombuses, 175

Ribosomes, 282

right prism, 190

right skew, 240

rotational rate, 206

rotations per minute, 206

S

sample, 225

scatterplot, 242

scientific method, 267

Second, 164

sector, 202

semiperimeter, 174

Similar, 183

simple interest, 34

sin, 184

skeletal system, 286

skewed, 238

Small Intestine, 292

specific heat, 351

spectrum, 358

Spinal Cord, 286

spread, 224

square, 214

squares, 175

Standard deviation, 224

statistical validity, 254

stem and leaf plot, 236

Stomach, 292

supercritical, 345

surface area, 192
systematic sample, 254

T

T-cell, 292
tan, 184
Temperature, 349
Thermal energy, 297
thermal energy, 344
thermal equilibrium, 350
thermodynamics, 348
Thymus, 291
Thyroid gland, 291
torque, 320

Transversal, 165
triangles, 167
trigonometry, 184
trimodal, 223
trophic, 297
tumors, 283

U

unimodal, 223
urethra, 292
urinary system, 292

V

V Angles, 165

Vaccines, 294
vector, 204
Veins, 289
velocity, 307
virus, 280
voluntarism bias, 255
voluntary, 285

W

White blood cells, 289
whole numbers, 2
Work, 334