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Lab #1: Kinematics

Background: Isaac Newton compared movements with displacement, velocity, acceleration, and force. Isaac Newton described movement as kinematics. The British physicist provided multiple equations now in high school and college classrooms. Today, we describe acceleration from gravity by a linear equation.

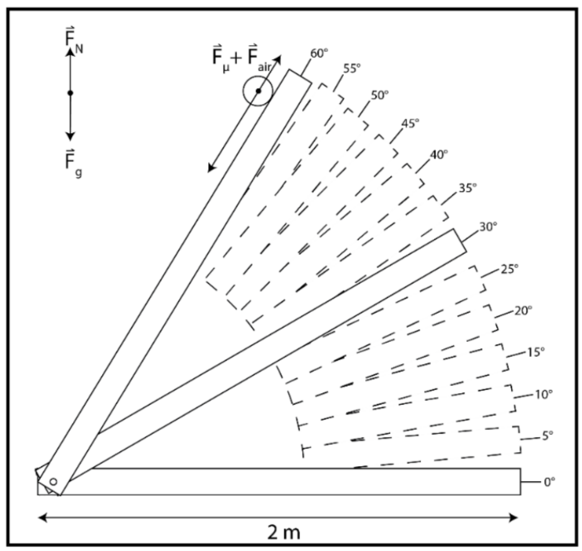
Goal: The acceleration from gravity derived from an average, and actual vs expected error.

Null Hypothesis: Equations from Newton never predict an exact solution about displacement.

Alternative Hypothesis: Equations from Newton predict an exact solution about displacement.

Learning Outcomes:

1. Problems evaluating frame of reference, displacement, velocity, and acceleration.
2. A relationship described between friction, air resistance, and other forces.
3. Experimental data tabulated from multiple measurements with one variable.
4. A line graphed of force as a function of angle.
5. Percent errors validating acceleration from gravity.



Equation #1: Velocity:

$$\vec{v}_{avg} = \frac{\Delta\vec{d}}{\Delta\vec{t}} = \frac{d_f - d_0}{t_f - t_0}$$

Equation #2: Acceleration:

$$\vec{a}_{avg} = \frac{\Delta\vec{v}}{\Delta\vec{t}} = \frac{v_f - v_0}{t_f - t_0}$$

Equation #3: Newton's First Law:

$$\vec{F}_g = m\vec{a}_g$$

Equation #4: Air Resistance:

$$\vec{F}_{air} = \frac{1}{2}\rho AC\vec{v}$$

Equation #5: Kinetic Friction:

$$\vec{F}_\mu = \mu m a_g$$

Equation #6: Force as a function of angle:

$$\vec{F} = ma = \vec{F}_g - \vec{F}_{air} - \vec{F}_\mu = m\vec{a}_g - \frac{1}{2}\rho AC\vec{v} - \mu m a_g = (1-\mu)m\vec{a}_g - \frac{1}{2}\rho AC\vec{v} = \text{"}mx + b\text{"}$$

Equation #7: Standard Deviation:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N}|x_i - \bar{x}|^2}{N}}$$

Equation #8: Percent Error:

$$Percent\ error\ (\%) = \frac{|Measurable\ value - Actual\ value|}{|Actual\ value|} * 100\%$$

Evaluation:

Note: Please practice answers on paper before submission.

1. What are displacement, velocity, and acceleration?
2. What is a graph from experimental data about velocity?
3. What is a graph from experimental data about acceleration?
4. Why is percent error important?
5. Newton was or was not correct about the equations?

Lab #2: Motion Graphing

Background: Free body diagrams apply to diagrams about movement by Newton's laws. Engineers sketch the system before the experiment via determination of total force. Gravity is a force in sketches, along the x-, y-, and z-axis, in addition to, friction, tension, or normal forces. Although, angles are difficult to new students, especially with cosine and sine. Today, students draw a free body diagram about a cart on a ramp.

Goal: The acceleration from gravity with derived error of the actual vs. expected physics.

Null Hypothesis: The velocity of the cart is not dependent on time throughout the experiment.

Alternative Hypothesis: The velocity of the cart is dependent on time throughout the experiment.

Learning Outcomes:

1. Problems involving frame of reference, displacement, velocity, and acceleration.
2. Experimental data tabulating a record with one changing variable.
3. A line of the tabulated data as a function of angle, then standard deviation.
4. Percent error to historically recorded values and constants

Equation #1: Velocity:

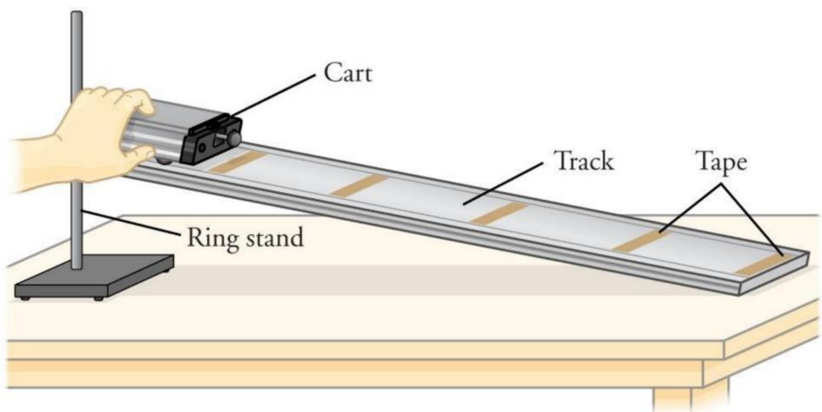
$$\vec{v}_{avg} = \frac{\Delta \vec{d}}{\Delta t} = \frac{d_f - d_0}{t_f - t_0}$$

Equation #2: Acceleration:

$$\vec{a}_{avg} = \frac{\Delta \vec{v}}{\Delta t} = \frac{v_f - v_0}{t_f - t_0}$$

Equation #3: Newton's First Law:

$$\vec{F}_g = m\vec{a}_g$$



Equation #7: Standard Deviation:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N} |a_i - \bar{a}|^2}{N}}$$

Equation #8: Percent Error:

$$Percent\ Error\ (\%) = \frac{|Measured\ value - Actual\ value|}{|Actual\ value|} * 100\%$$

Tabular Data:

Measurement [Full Distance]	Time (sec)
1	
2	
3	
4	
5	
6	

7	
8	
9	
10	
Measurement [Half Distance]	**Time (sec)**
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

<u>Evaluation:</u>

Note: Please practice answers on paper before submission.

1. What are differences between displacement, velocity, and acceleration?
2. What is the free body diagram above? A label of gravity, and normal are requisite.
3. Why is half distance and full distance in the experiment?
4. What is the acceleration?
5. What is the force from movement?

Lab #3: Repetitive Motion

Background: Automotive and robotic assembly is repetitive. Since the first vehicle by Henry Ford to Charlie Chaplin's initial films, motion is a childhood favorite. Prior in time, mechanical dolls repetitively wrote articles by Pierre Jaquet-Droz. Also, vintage watches from Swiss-manufacturing repetitively determined time. Today, in home devices generate simple motions, including printers and dishwashers. For class, we generate basic repetitive motion.

Goal: Discrete m

ovements measured by a series of photogates and a graph about a transient object.

Null Hypothesis: The independent and dependent variables in then graph below have no relationship.

Alternative Hypothesis: The independent and dependent variables in the graph have a relationship.

Learning Outcomes:

1. A car on a rail repeating movements back and forth along the rail.
2. A graph about measured position vs. time of repetitive motions done by hand.
3. Velocity from moving the rail car in both positive and negative directions.
4. The plot of acceleration from calculating velocity.

Equation #1: Position:

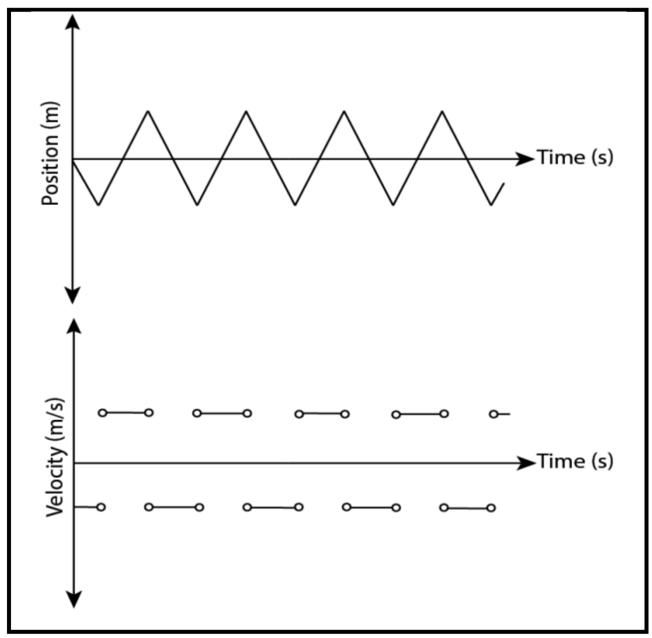
$$\Delta \boldsymbol{x} = \boldsymbol{x_2} - \boldsymbol{x_1}$$

Equation #2: Velocity:

$$\vec{\boldsymbol{v}} = \left(\frac{\boldsymbol{x_2} - \boldsymbol{x_1}}{\boldsymbol{t_2} - \boldsymbol{t_1}}\right)$$

Equation #3: Acceleration

$$\vec{\boldsymbol{a}} = \left(\frac{\vec{\boldsymbol{v}}_2 - \vec{\boldsymbol{v}}_1}{\boldsymbol{t_2} - \boldsymbol{t_1}}\right)$$



Tabular Data: Photogate 1-2 (cm): _______ Photogate 2-3 (cm): _____ Photogate 3-4 (cm): ______

	Photogate																			
	#1	**#2**	**#3**	**#2**	**#1**	**#2**	**#3**	**#2**	**#1**	**#2**	**#3**	**#2**	**#1**	**#2**	**#3**	**#2**	**#1**	**#2**	**#3**	**#2**
Time (ms)																				

Evaluation:

Note: Please practice answers on paper before submission.

1. What are the independent and dependent variables in the experiment?
2. A description about certainty in the experiment between time and position.
3. What is velocity?
4. Acceleration relates to velocity and position, why?
5. A graph of time vs. position, time vs. velocity, and time vs. acceleration.

Lab #4: Acceleration

Background: The construction, design, and purpose of machines is mechanical engineering. The field touches on virtually every motion, along with safety by failure, functionality, aesthetics, and durability. The failure process entails investigative preservation, visual inspection, electrical testing, reliability per use, and failure mechanism. For today's lab, students inhibit an approach of upward motion through mathematical calculation.

Goal: A prediction about mass and angle from trials stalling an upward motion.

Null Hypothesis: The independent and dependent variables in the graph below have no relationship.

Alternative Hypothesis: The independent and dependent variables in the graph below have a relationship.

Learning Outcomes:

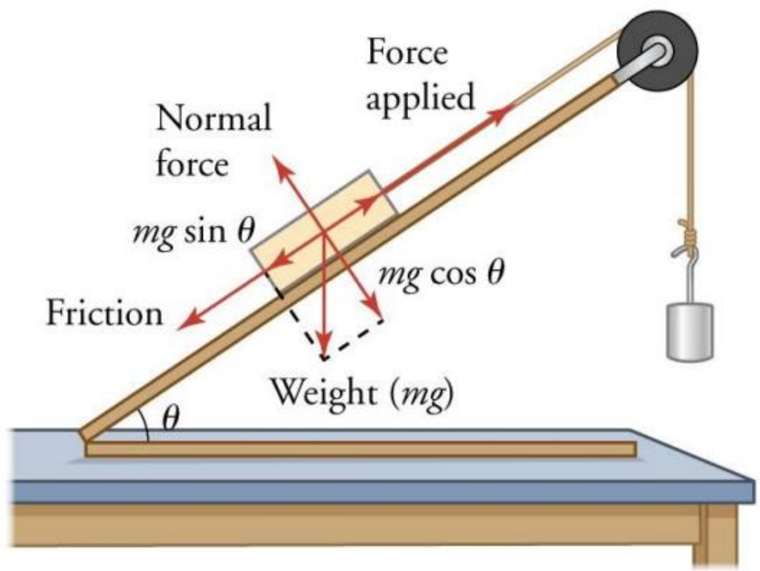
1. An incline angle before measuring linear motion on a ramp.
2. Communicate with others, what is the maximum limit of motion.
3. For three attempts, the maximum mass to an exact stall.

Equation #1: Angles:

$$\cos\boldsymbol{\theta} = \frac{adjacent}{hypotenuse}$$

$$\sin\boldsymbol{\theta} = \frac{opposite}{hypotenuse}$$

$$\tan\boldsymbol{\theta} = \frac{opposite}{adjacent}$$



Equation #2: Newton's 2nd Law:

$$\vec{\boldsymbol{F}} = \boldsymbol{m}\vec{\boldsymbol{a}} = \boldsymbol{m}\left(\frac{\vec{\boldsymbol{v}}_2 - \vec{\boldsymbol{v}}_1}{\boldsymbol{t}_2 - \boldsymbol{t}_1}\right)$$

Tabular Data: Ramp Length (cm): ________ Angle (°): _________ Mass of Cart (g): __________

Experiment	Mass (g)	Length of Travel (m)	Time of Travel (s)
Trial #1			
Trial #2			
Trial #3			

Evaluation:

Note: Please practice answers on paper before submission.

1. What are the independent and dependent variables in the experiment?
2. A description about certainty in the experiment between mass and length of travel.
3. What is velocity in the experiment above?
4. Why are trigonometric equations important to an incline or ramp?
5. Were the trials accurate predictors to stall?

Lab #5: Newton's Third Law of Motion

Background: Newton's third law relates equal forces of opposite direction. For the third law, balloons pronounce an upward rocket thrust. The equal and opposite corollary in a balloon is inertia. A balloon of ideal pressure and dimension simulates conditions of Newton's third law with little drag and friction. For this morning's lab, students produce different pressure systems to substantiate Newton's law.

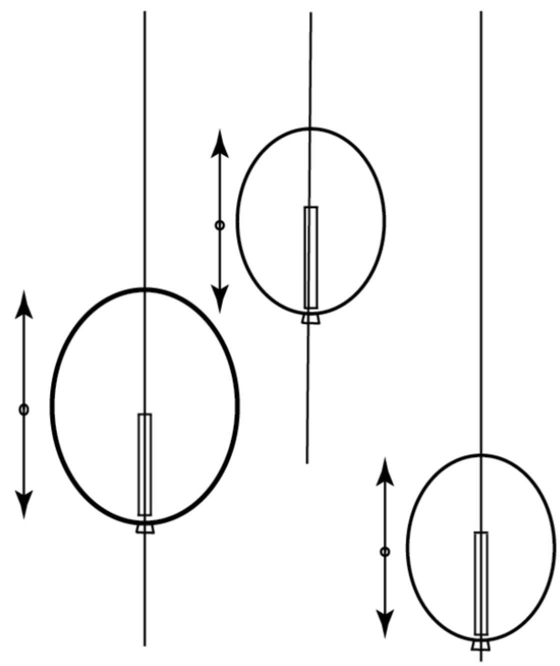
Goal: Prior to lab, the pressure and distance of a balloon modelled on a string from mathematics.

Null Hypothesis: The independent and dependent variables in the graph below have no relationship.

Alternative Hypothesis: The independent and dependent variables in the graph below have a relationship.

Learning Outcomes:

1. A balloon-straw system predicts internal pressure
2. The Ideal Gas Law for intermediate prediction of internal balloon pressure
3. Average distance traveled by a balloon in an experiment
4. Compare and contrast predicted vs. actual pressure in a written argument



Equation #1 – Pressure: $P = \frac{Force}{Area}$

Equation #2 – Ideal Gas Law: $PV = nRT$

Equation #3 - Force: $F = ma = m\frac{\Delta v}{\Delta t}$

Equation #4 - Average: $\overline{x} = \frac{\sum_{i=1}^{n} x_i}{n}$

Tabular Setup: Total Mass (g): ______________________

Experiment	Radius (m)	Predicted Pressure (atm)	Distance (m)	Travel Time (s)	Actual Pressure (atm)
Trial #1					
Trial #2					
Trial #3					
Trial #4					
Trial #5					
Predicted Average (atm):			**Actual Average (atm)**		
Standard Error (atm):			**Standard Error (atm):**		

Evaluation:

Note: Please practice answers on paper before submission.

1. What are the independent and dependent variables in the experiment?
2. The Ideal Gas Law had what purpose?
3. Five total trials were in the experiment. How many trials are necessary in a 95% confidence level? How does confidence level prove a hypothesis?
4. What were clues about the actual pressure?
5. Standard errors are not in the equations. Where is the standard error equation? Please, a citation.

Lab #6: Forces 1-D

Background: Gravity is a fundamental force of the natural universe. The effect upon mass is determinable to the accuracy and precision of the clock measurement. By a vertical ring stand, students delve into free fall, plotting data, calculating accuracy, along with determining precision of their methods.

Goal: Statistically determine the gravitational acceleration constant and experimental error.

Null Hypothesis: Position and time variables have no relationship in the experiment.

Alternative Hypothesis: Position and time variables have a relationship in the experiment.

Learning Outcomes:

1. At Earth's Sea level, gravitational acceleration, a constant using photogates.
2. A simple displacement, velocity, acceleration, and force plot from the data.
3. The accuracy and precision of measured constants with many experimental trials.

Equation #1: y-component:

$$y = y_0 - v_x t - \frac{1}{2} g t^2$$

Equation #2: Standard Deviation:

$$\sqrt{\frac{\sum_{i=1}^{N}(x_i - \overline{x}_i)^2}{N}}$$

Equation #3: Percent Error:

$$Percent\ Error = \frac{|Measured - Actual|}{Actual} * 100\%$$

Tabular Data: **Height (cm):** ___________ **Mass (g):** ___________

Measurement	Time (s)	Velocity (m/s)	Acceleration (m/s^2)	Force (N)
Photogate #1				
Photogate #2				
Photogate #3				
Photogate #4				
Photogate #5				

Evaluation:

Note: Please practice answers on paper before submission.

1. What are the independent and dependent variables in the experiment?
2. What was purpose of Equation #1?
3. Five total trials were in the experiment. What was the average time, velocity, acceleration, and force? A calculation individually or total average is applicable?
4. What was percent error?
5. Three plots prepared with position (m) vs. time (s), velocity (m) vs. time (s), and acceleration (m) vs. time(s).

Lab #7: Projectile Motion

Background: Documentation of projectiles existed from before the 12th century. The arcs of high-tensile bow and arrow represent a historic point in African and Eurasian history. Projectile motion led researchers to space, and beyond. For lab, students predict location and distance.

Goal: An equation about arcs from time, position, and velocity by using Newton's laws.

Null Hypothesis: The position and time variables have no dependent relationship.

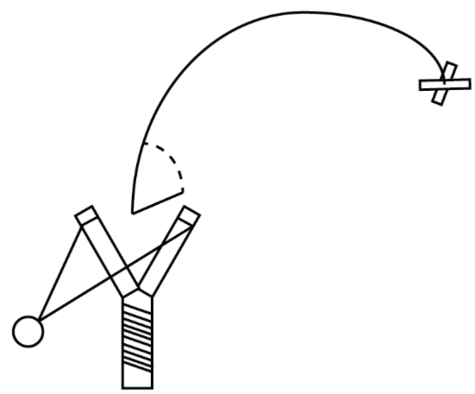
Alternative Hypothesis: The position and time variables have a dependent relationship.

Learning Outcomes:

1. Two equations having separable and dependent time components.
2. A position predicted by an angle via a model from Newton.
3. The actual distance compared to a target already on the floor before experiment.

Equation #1 - Position:

$$x = vt + x_0$$



Equation #2 - Velocity:

$$v = at + v_0$$

Equation #3 - Acceleration:

$$a_g = 9.8\, m/s^2$$

Derivation:

Tabular Data: Angle (°): ______________ Force (N): _______________________

Experiment	Predicted x-Position (m)	Predicted y-Position (m)	Actual x-Position (m)	Actual y-Position (m)
Trial #1				
Trial #2				
Trial #3				
Trial #4				
Trial #5				
Average				

Evaluation:

Note: Please practice answers on paper before submission.

1. What are the independent and dependent variables in the experiment?
2. What was the purpose of Equation #1, #2, and #3?
3. A paragraph written about the derivation, experiment, and trials.
4. Which variable, x or y is dependent on gravity?
5. How close was the target to prediction?

Lab #8: Forces 2-D

Background: Forces have separable components. Within the Cartesian coordinate system, individuals practice the F_x, F_y, and F_z forces on a free body diagram. An example is an incline with 2-dimensional forces in both x-and-y directions from gravitational acceleration up the slope. Today, we apply Newton's 2nd Law to determine the free body diagram and individual components.

Goal: An object traveling by gravity up an incline, across a pulley, and down a ledge.

Null Hypothesis: The force in the x-direction never depends on the force in the y-direction.

Alternative Hypothesis: The force in the x-direction depends on force in the y-direction.

Learning Outcomes:

1. A free body diagram of a mass balanced on an incline by a block.
2. The forces to movement (F_x, F_y) after mass releases.
3. Newton's 2nd Law demonstrating where forces equate.

Equation #1: Angles:

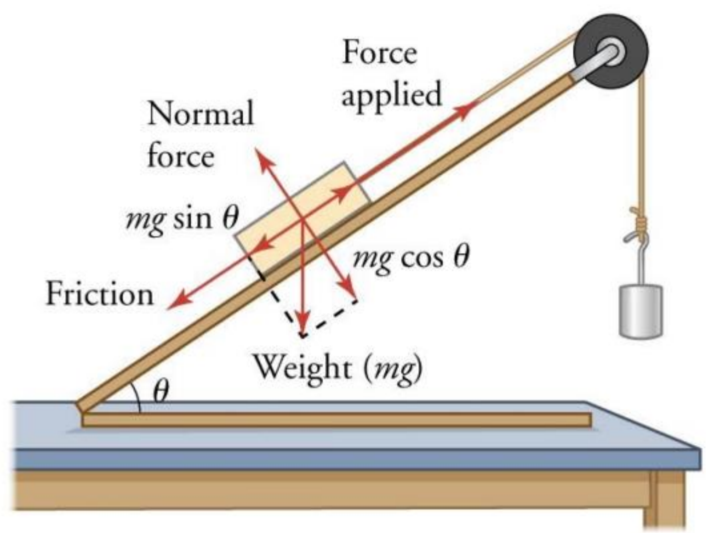
$$\cos\boldsymbol{\theta} = \frac{adjacent}{hypotenuse}$$

$$\sin\boldsymbol{\theta} = \frac{opposite}{hypotenuse}$$

$$\tan\boldsymbol{\theta} = \frac{opposite}{adjacent}$$

Equation #2: Newton's 2nd Law:

$$\vec{\boldsymbol{F}} = \boldsymbol{m}\vec{\boldsymbol{a}} = \boldsymbol{m}\left(\frac{\vec{v}_2-\vec{v}_1}{t_2-t_1}\right)$$



Tabular Data: Length (cm): ____ Angle (°): _____Mass of Cart (g): ___ Mass of Weight (g): ____

Measurement	Time (s)	Velocity (m/s)	Acceleration (m/s²)	$\vec{F}$ (N)	$\vec{F}_x$ (N)	$\vec{F}_y$ (N)
Photogate #1						
Photogate #2						
Photogate #3						
Photogate #4						
Photogate #5						

Evaluation:

Note: Please practice answers on paper before submission.

1. What are the independent and dependent variables in the experiment?
2. What was purpose of Equation #1?
3. What is the free body diagram from the incline?
4. A plot about graphs showing time vs. x-position and time vs. y-position?
5. What is the free body diagram where forces equate?

Lab #9: Pulleys and Tension

Background: A pulley system is historical. The framework transfers force in a circular motion and distributes tension across further connections. The first pulley operation was in 1500 BCE by Mesopotamians for resources. Archimedes used pulleys and Leonardo Da Vinci. For exposure to multi-pulley systems, students measure the force of gravity across three types of vertical hoists.

Goal: Newton's second law applied to force across multiple pulleys.

Null Hypothesis: Displacement is not dependent by mass with a number of pulleys.

Alternative Hypothesis: Displacement is not dependent by mass with a number of pulleys.

Learning Outcomes:

1. A pulley system using single, double, and triple wheels.
2. The distance during free fall by applying a body diagram with tensions.
3. The error extracted from measurements in a one-, two-, three-, or tuple-wheel systems.

Displacement of Pulley System:

Single Pulley System	
Mass A (g)	
Mass B (g)	
Predicted Displacement (m)	
Actual Displacement (m)	
Error (m)	

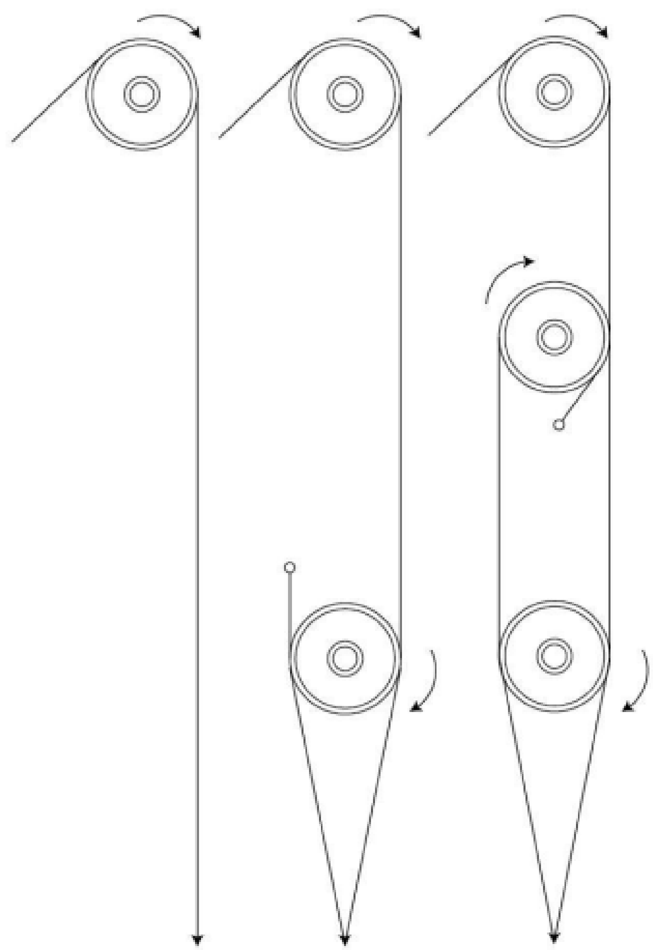
Calculations:

Double Pulley System	
Mass A (g)	
Mass B (g)	
Predicted Displacement (m)	
Actual Displacement (m)	
Error (m)	

Calculations:

Triple Pulley System	
Mass A (g)	
Mass B (g)	
Predicted Displacement (m)	
Actual Displacement (m)	
Error (m)	

Calculations:



Evaluation:

Note: Please practice answers on paper before submission.

1. What are the independent and dependent variables in the experiment?
2. What happens from additional pulleys?
3. What is the free body diagram about each system?
4. Why is a triple pulley system helpful with lift?
5. What is the error in each system?

Lab #10: Periodic Motion – 1D

Background: An occurrence at regular intervals is periodic. When about a circle, the direct motion is recurrent and cyclic. In a single dimension, amplitude distinguishes (co)sinusoidal model by extreme position. While, frequency describes periodic behavior. The solution to the model is unique and about natural motion. A circular ring represents a wave when perpendicular. For lab, students rotate a ring for periodic motion.

Goal: A continuous movement about unit circle by oscillating a wire loop.

Null Hypothesis: The motion around a unit circle never represents a wavey motion.

Alternative Hypothesis: The motion around a unit circle represents a wavey motion.

Learning Outcomes:

1. Unit circle exposure by experimental periodic rotation around a circular object.
2. Angular rotation directly depends on wavey motion along a line in different dimensions.
3. A model about error from rotational motion with a metal ring in two-dimensional space.

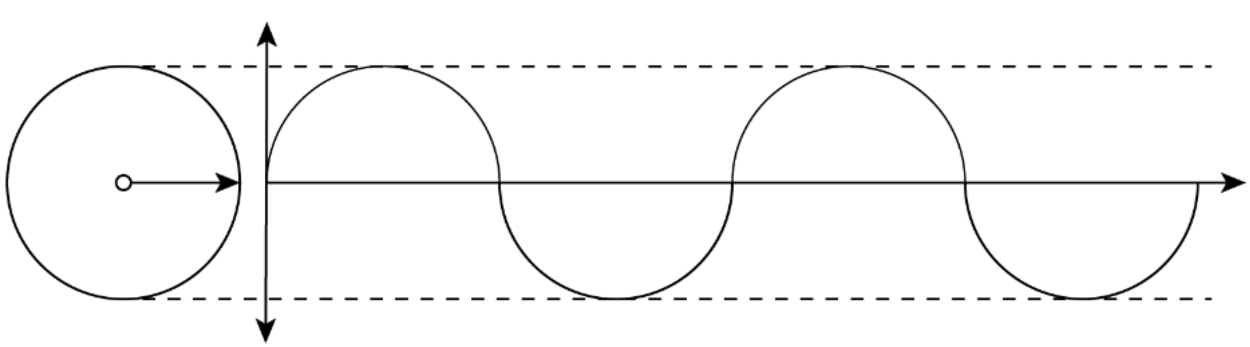
Equation #1 & #2 - Periodic Motion in x-, and y-directions

$$x(t) = A\cos(\omega t + \varphi) \qquad\qquad y(t) = A\sin(\omega t + \varphi)$$

Tabular Data: Rotation time (sec): ___________________

Rotation time	**Unit Circle**				**Periodic Wave**			
_____________sec	Member Values			Average	Member Values			Average
Amplitude (cm)								
Frequency (1/s)								
Period (s)								
Phase (rad)								

Model Position (cm): ___________ Model Position (cm): _____________



Evaluation:

Note: Please practice answers on paper before submission.

1. The metal ring did what?
2. What is amplitude?
3. What is frequency?
4. Why was motion repetitive and periodic?
5. What is phase?
6. What was the error from rotation?

Lab #11: Simple Harmonic Motion

Background: Simple harmonic motion on a pendulum describes oscillatory motions. The sinusoidal behavior from position matches a sine (or cosine) function near equilibrium. With a weight and pivot point, students determine a model of frequency, displacement, and periodic motion.

Goal: A simple harmonic oscillator calculation from parameters in a pendulum near minimum.

Null Hypothesis: The angular frequency from a pendulum is never dependent on time.

Alternative Hypothesis: The angular frequency from a pendulum is dependent on time.

Learning Outcomes:

1. A trigonometric model to harmonic motions from a pendulum.
2. Boundary conditions exposed through a sinusoidal function.
3. The frequency, position, and period of a sizeable multimeter pendulum.

Equation #1: Period:

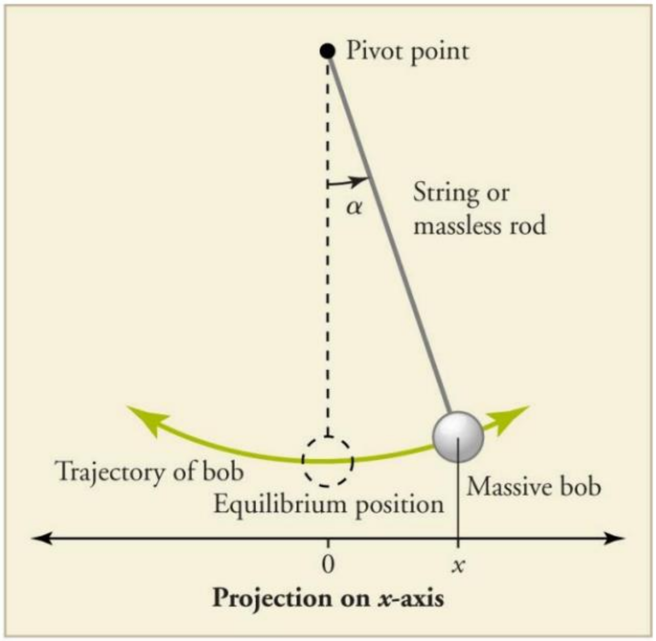
$$Period\ (s) = T = 2\pi\sqrt{\frac{L}{g}}$$

Equation #2: Angle:

$$\alpha\ (t) = \omega t + \phi$$

Equation #2: Displacement:

$$x = A\sin(\omega t + \phi)$$



Tabular Data: Length of String (cm): __________ Mass of Weight (g): _________

Trials	Time (s)	Displacement (m)	Angle (°)	Period (s)	ω (rad/s)
Trial #1					
Trial #2					
Trial #3					
Trial #4					

Evaluation:

Note: Please practice answers on paper before submission.

1. What was the average period from the pendulum?
2. What is the mathematics from period to angular frequency?
3. A heavier mass has similar or different outcomes?
4. What was the angular frequency?
5. What is a boundary condition?

Lab #12: Momentum

Background: Conservation of momentum symbolizes total object mass at a velocity. The momentum vector is the displacement by an object times mass per duration of travel. In a system without friction, drag, or other forces, momentum conserves during collision. Today's experiment transfers momentum before and after the collision. From photogates, the average and precise measuring about a perfectly elastic collision.

Goal: Quantitatively measure conservation and the total momentum of contact.

Null Hypothesis: Momentum of a car has no relationship before and after collision.

Alternative Hypothesis: Momentum of a car has a relationship before and after collision.

Learning Outcomes:

1. Collisions between frictionless physics cars at different marked lengths.
2. Quantitatively measure velocity with a series of photogates.
3. Experimental practice measuring the mass of objects.
4. A hypothesis before experiment about predicting the collision parameters.
5. Momentum to kinetic energy for further calculating conservation of energy.

Equation #1: Momentum:

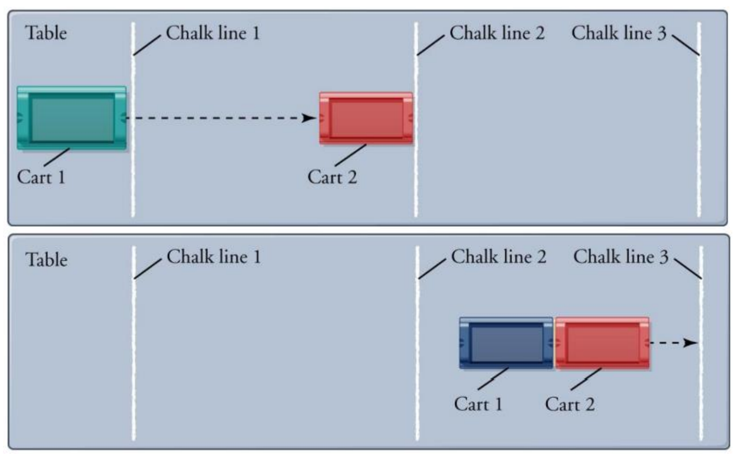
$$p = mv$$

Equation #2: Total Momentum:

$$\left(\sum_{i=1}^{n} m_i v_i\right)_{initial} = \left(\sum_{i=1}^{n} m_i v_i\right)_{final}$$

Equation #3: Kinetic Energy:

$$K.E. = \frac{1}{2}mv^2$$



Tabular Data: Mass Car #1 (g): ___________________ Mass Car #2 (g):___________________

Trial	Initial		Final	
	Velocity #1 (cm/s)	Velocity #2 (cm/s)	Velocity #1 (cm/s)	Velocity #2 (cm/s)
1				
2				
3				
4				
5				
6				
7				
8				
9				

Evaluation:

Note: Please practice answers on paper before submission.

1. What was the average velocity of car #1 before collision?
2. What was the average velocity of car #2 after collision?
3. A paragraph about the momentum transfer.
4. What was the kinetic energy of car #1 before collision?
5. What was the kinetic energy of car #2 after collision?

Lab #13: Potential Energy Storage

Background: Across sciences, potential energy is the difference to ground. Count Rumford's studied thermodynamics, and also formulae about local heat and energy. Primary discoveries by Count Rumford (Benjamin Thompson) were plants correlation to rays from the sun, intensity in wax candles, conduction, convection, hot weights, and instrumentation thereof. Later scientists, Davy, Lavoisier, Mayer, Joule, Kelvin, and Carnot characterized their discoveries of thermo- and electrodynamics. Soon after, potential energy solidified. In the afternoon, students determine potential energies linear relationship.

Goal: A relationship between height and potential energy through a ramp with spherical mass.

Null Hypothesis: Potential energy has no correlation to height on a slope.

Alternative Hypothesis: Potential energy has a correlation to height on a slope.

Learning Outcomes:

1. Conservation of energy through potential and kinetic energy transfer.
2. A graph incorporating height vs. potential energy or gravity, mass, and height.
3. In words, how to increase experimental accuracy and precision.

Equation #1: Momentum:

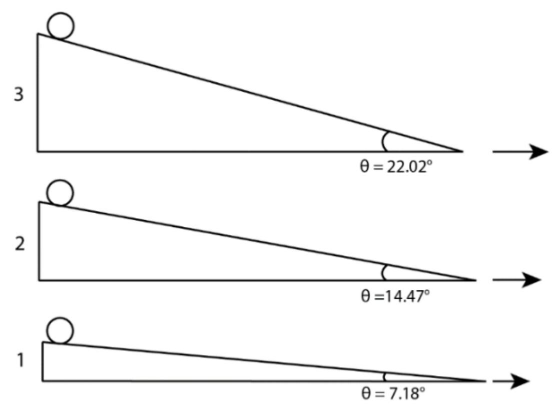
$$K.E. = \frac{1}{2}mv^2$$

Equation #2: Total Momentum:

$$a_g = 9.8\,m/s^2$$

Equation #3: Kinetic Energy:

$$\Delta E = KE + PE \ \cong 0$$



Tabular Data: Mass Car #1 (g): ___________________ Mass Car #2 (g):_______________

Experiment	Ramp #1		Ramp #2		Ramp #3	
	Distance (m)	Time (sec)	Distance (m)	Time (sec)	Distance (m)	Time (sec)
Mass #1						
Mass #1						
Mass #1						
Kinetic Energy (J)						
Potential Energy (J)						

Evaluation:

Note: Please practice answers on paper before submission.

1. What was the average kinetic energy in each trial?
2. What was the average potential energy in each trial?
3. How close were potential and kinetic energy?
4. What height effected potential energy?
5. A plot about Height (m) vs Potential Energy (J).

Lab #14: Mechanical Waves

Background: A mathematical representation of waves is foundational. Every day students hear terms about ‘the speed of sound’, ‘light’, ‘p-wave’, ‘s-wave’, and ‘earthquake!’ Traditional calculations found in the medium of travel, but also less complexity. An incident wave reflects into an observable interference. For today’s lab, thoughts explore incident phase, frequency, amplitude, and kinetic energy.

Goal: The kinetic energy of a transverse or longitudinal wave produced on a spring.

Null Hypothesis: The kinetic energy never depends on the wave function from the spring.

Alternative Hypothesis: Kinetic energy depends on the wave function from the spring.

Learning Outcomes:

1. Observable waves on spring by oscillating frequency and/or phase of movement.
2. Quantitatively determine the amplitude of a wave with a standard ruler.
3. A multitude of wavelengths across varying frequencies.
4. A functional relationship of simple waves using laboratory information.
5. Separately, kinetic energy calculating a model to the experimental waves.

Equation #1: Wave Equation:

$$y(t) = A\sin(\omega t + \varphi)$$

Equation #2: Velocity of Wave:

$$v = \lambda f$$

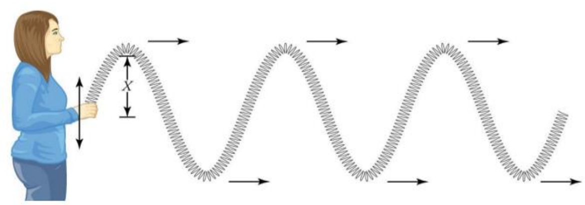
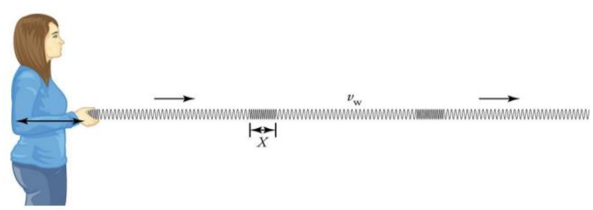


Figure 11.2: A **transverse** wave, showing the amplitude *X* and direction of motion.

Equation #3: Kinetic Energy:

$$K.E. = \frac{1}{2}mv^2$$



Tabular Data:

Experiment	Phase	Frequency (1/s)	Amplitude (cm)	Wavelength (cm)	Function of Wave y(t)	Velocity (cm/s)	Kinetic Energy (J)
Trial #1							
Trial #2							
Trial #3							
Trial #4							
Trial #5							

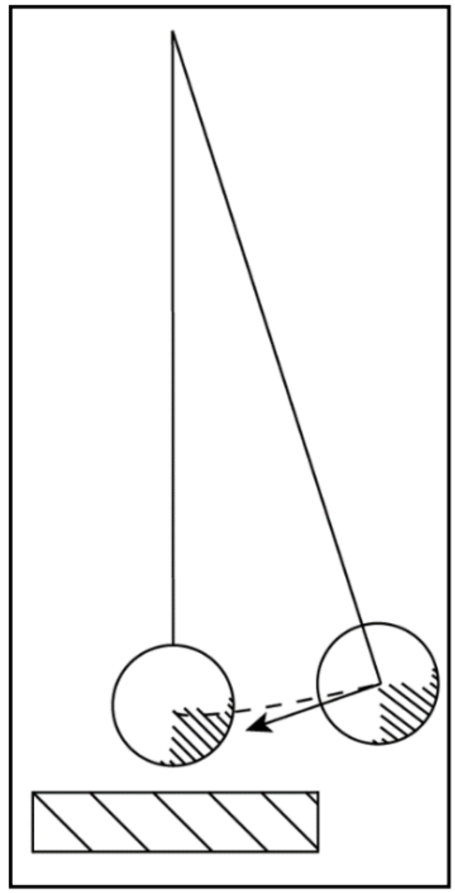
Evaluation:

Note: Please practice answers on paper before submission.

1. What is phase?
2. Why is frequency essential to Equation #1?
3. Amplitude contributes to Equation #1? How?
4. What was the wavelength from each trial?
5. Kinetic Energy was similar or dissimilar between each trial?

Lab #15: Pendulum Momentum

Background: In China, Ganzhou, Jiangxi Province is a large pendulum. At 12.8-meters, Harmony Tower commissioned a pendulum in a clock by clockmakers - Smith of Derby. Prior to 2010's design, another pendulum existed for experimentation. With a length of 4,250 feet, two lengths of No. 24 steel piano wire, Professor Fred W. McNair of College of Mines, Michigan utilized Tamarack Mines with weighted bobs Down a shaft labelled No. 5 suspended an experiment about gravitational separation. Science Magazine published results of gravitational separation on Friday, June 20th, 1902. For examination, students' measure momentum from a pendulum.



Goal: Standardize momentum for a single pendulum then collide two pendulums

Null Hypothesis: Angular momentum never depends on time.

Alternative Hypothesis: Angular momentum depends on time.

Learning Outcomes:

1. A standard calibration for (later) measure of angular momentum.
2. Two pendulums as a momentum transfer experiment and observation of inelastic collision.
3. Momentum for single and double pendulum movements.

Equation #1: Angular Velocity:

$$\omega = \frac{v}{r}$$

Equation #2: Angular Momentum:

$$\vec{L} = \mathrm{I}\omega$$

Tabular Data: Mass #1 (kg): _________ Mass #2 (kg): ____________

Pendulum Calibration					
Experiment	**Radians (rad)**	**Time (sec)**	**Angular Velocity (rad/s)**	**Moment of Inertia (kg/m^2)**	**Angular Momentum (kg/m^{2}s)**
Trial #1					
Trial #2					
Trial #3					
Average					

Second Pendulum Collision					
Experiment	**Radians (rad)**	**Time (sec)**	**Angular Velocity (rad/s)**	**Moment of Inertia (kg/m^2)**	**Angular Momentum (kg/m^2s)**
Trial #1					
Trial #2					
Trial #3					
Average					

Evaluation:

Note: Please practice answers on paper before submission.

1. What are radians?
2. Calibration had what purpose? Why was a second pendulum important?
3. What is momentum?
4. What is the mathematical relationship between moment of inertia and angular momentum?
5. Two pendulums generated error? What was the average error?

Lab #16: Electrostatics

Background: Electrostatic forces relate to Coulomb's Law. An electron's charge act across distance by both direction and magnitude. The force is proportional through an inverse square law and during laboratory experiment. Two balloons charge by electrostatic electricity and exemplify Coulomb's Law. A coefficient describes the experiment (Equation #1) as a universal constant. Student's examine charges, a proportional constant, and a reciprocal square in Coulomb's law.

Goal: An experiment testing laws and equations, specifically Coulomb's.

Null Hypothesis: The distance from midline (center) is not proportional to Coulomb's constant.

Alternative Hypothesis: Distance from midline (center) is proportional to Coulomb's constant.

Learning Outcomes:

1. An apparatus using balloons and tangential forces.
2. Experimental values accurately quantifying Coulomb's constant
3. A precise determination by using uncertainty.

Equation #1: Coulomb's constant:

$$k_e = 8.998\ x\ 10^9\ \ N \cdot m^2/C^2$$

Equation #2: Electron charge:

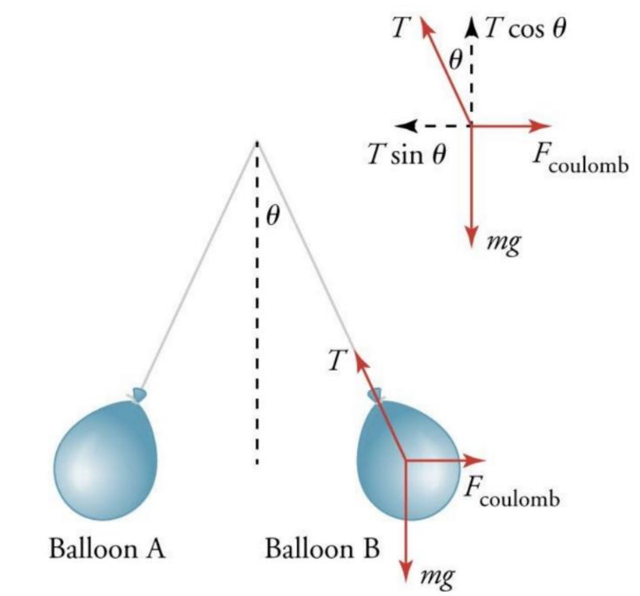
$$q = 1.602\ x\ 10^{-19}\ \ C$$

Equation #3: Coulomb's Law:

$$\vec{F} = k_e \frac{q_1 q_2}{r^2}$$

Equation #4: Force of Coulomb:

$$\vec{F} = m\vec{g} \tan\theta$$



Tabular Data: Mass Balloon A (g): __________ Mass Balloon B (g): ___________

Experiment	Distance from Center (cm)	Measured Coulomb Constant ($N*m^2/C^2$)
Trial #1		
Trial #2		
Trial #3		
Trial #4		
Trial #5		
Trial #6		
Trial #7		
Trial #8		
Trial #9		

Average Coulomb Constant ($N*m^2/C^2$): ______________________________________

Uncertainty of Measurement (%): ____

Evaluation:

Note: Please practice answers on paper before submission.

1. What is a tangent function?
2. What is a relationship between Equations #1 and #2?
3. Any human errors arise from the experiment?
4. What were experimental values about Coulomb's constant?
5. How justifiable is error from actual Coulomb's constant?

Lab #17: Ohm's Law

Background: Ohm's Law describes a direct relationship between voltage, current, and resistance. Voltage (V) is potential difference from an energy source in an electric circuit. While current (C) is the flow of electrons in a conductive wire. Current flow is directly proportional to voltage by a coefficient, resistance (R). The linear relationship in the experiment was evidence to conductance. Students, today prepare a standard curve from a voltmeter across a circuit.

Goal: A standard curve (linear relationship) graphed between voltage and current.

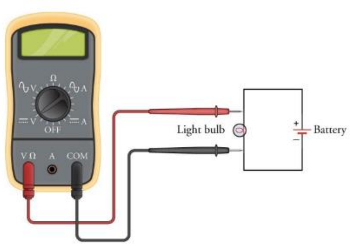
Null Hypothesis: Voltage is independent to current in electrical circuits.

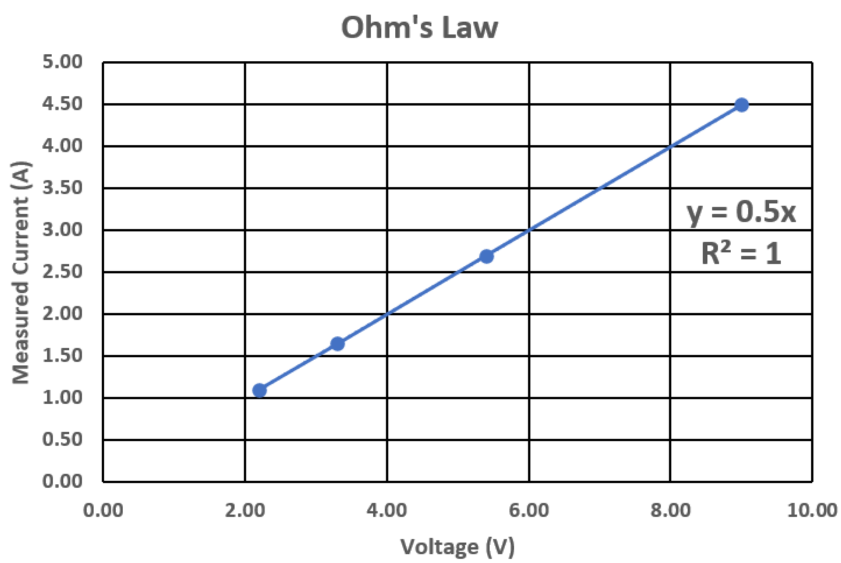
Alternative Hypothesis: Voltage is dependent to current in electrical circuits.

Learning Outcomes:

1. An electric circuit's current by using a voltmeter (ammeter).
2. A light bulb contains resistance across positive and negative terminals.
3. A linear curve collected at specific voltages onto a plot and graph.

Equation #1: Ohm's Law: $V = IR$





Tabular Data: Instrument Model: ______________________

Experiment	Voltage (V)	Current (A)
Circuit #1		
Circuit #2		
Circuit #3		
Circuit #4		
Circuit #5		

Evaluation:

Note: Please practice answers on paper before submission.

1. A 5-7 sentence paragraph about voltage, current, and resistance.
2. What changed between each experiment?
3. Voltage and current have units, any specific reason?
4. Voltage (V) versus Current (I) plot.
5. What was the light bulb’s resistance?

Lab #18: Resistor Circuits

Background: Circuits are conductive paths to positive and negative charges. Series circuits contain resistance across a single path, while parallel circuits resistance across multiple paths. Despite nearly infinite combinations, the simplest circuit involve wires, resistors, and batteries. A voltmeter or ammeter measure circuit voltage and amperage, respectively. A demonstration about Kirchhoff's law is the plan in the lab below.

Goal: Students examining series and parallel circuits through ammeter values.

Null Hypothesis: Current is not directly proportional to resistance in series and parallel circuits.

Alternative Hypothesis: Current is directly proportional to resistance in series and parallel circuits.

Learning Outcomes:

1. Ammeter or voltmeter usage for circuit information.
2. Multiple circuits engineered as series and parallel circuits in a rigid test.
3. Kirchhoff's law from collected electrical values as proof to the law.

Equation #1: Kirchhoff's Law for Currents:

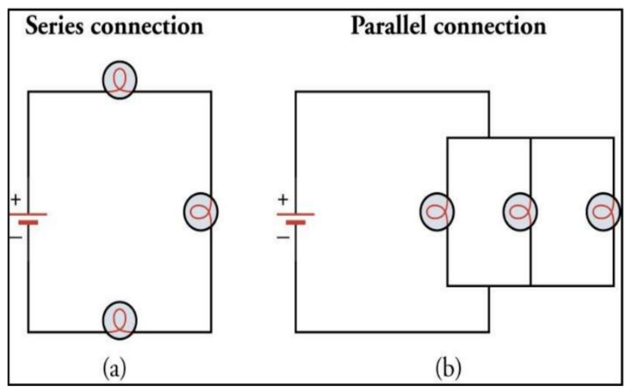
$$\sum_{i=1}^{n} I_i = I_1 + I_2 + I_3 + \cdots + I_n = 0$$

Equation #2: Kirchhoff's Law for Voltage:

$$\sum_{i=1}^{n} V_i = V_1 + V_2 + V_3 + \cdots + V_n = 0$$

Equation #3: Kirchhoff's Law for Resistance:

$$\sum_{i=1}^{n} \frac{1}{R_i} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots + \frac{1}{R_n} = 0$$



Experimental Data:

Series Circuit:
Parallel Circuit:

Evaluation:

Note: Please practice answers on paper before submission.

1. What are series and parallel circuits?
2. Gustav Kirchhoff made laws for series and parallel circuits. Why?
3. How many circuits are necessary as proof to Kirchhoff's law?
4. What changed between each experiment?
5. What is error from the experiment above?

Lab #19: Torque

Background: Torque is an extension from kinematics. A tangential force upon a perpendicular axis is directly proportional to force-distance i.e., torque. A force applies across a length in a circular motion, as torque. The alternative perspective is angular momentum (L) and the relation to moment of inertia (I). By acceleration from gravity, the demonstration involves incremental mass onto a wrench and bolt.

Goal: Torque for a fastened bolt or nut and angular momentum from the same system.

Null Hypothesis: Torque is not dependent on mass in a linear equation.

Alternative Hypothesis: Torque is dependent on mass in a linear equation.

Learning Outcomes:

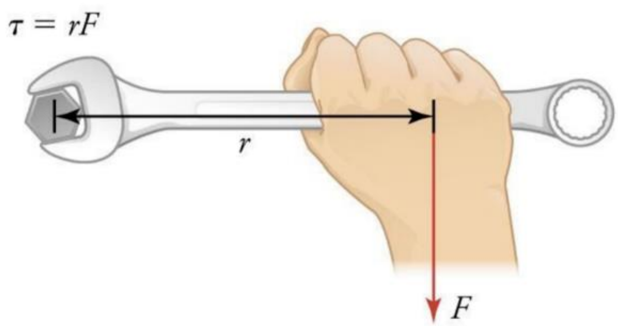
1. An apparatus to quantitatively measure the torque of a bolt.
2. Accurate torque from an arithmetic mean (or average) and multiple samples.
3. Precise torque in the system by multiple experiments using standard deviation.

Equation #1: Torque:

$$\tau = rF$$

Equation #2: Angular Momentum

$$L = I \times \omega$$



Tabular Data:

Tool	Length (cm)	Trial	Total Mass (g)	Force (N)	Torque (N*m)	Average Torque (N*m)
Wrench #1		1				
		2				
		3				
Wrench #2		4				
		5				
		6				
Wrench #3		7				
		8				
		9				

Sum Average Torque (N*m): ___________________

Standard Deviation (N*m): ±_________________

Evaluation:

Note: Please practice answers on paper before submission.

1. What is torque?
2. What is angular momentum?
3. What was the average torque?
4. How precise was the experiment about torque?
5. A paragraph (5-7 sentences) about torques relationship to a hand and wrench.

Lab #20: Angular Momentum

Background: Gyroscope applications model a stationary center of mass. In laboratory settings, gyroscopes rotate about a point with a rigid and symmetrical frame. The generated torque of gyroscope stabilizes or destabilizes the origin i.e., structural center of mass. A formula governs gyroscopes under Cartesian and spherical dimensions. Our experiment has two linear functions; center of mass and a rotation axis in a plane.

Goal: A gyroscopic torque and angular momentum from rotation, angle, and gravity.

Null Hypothesis: Angular momentum has no direct correlation to angular velocity.

Alternative Hypothesis: Angular momentum has a direct correlation to angular velocity.

Learning Outcomes:

1. An object precesses about a rotational point - the 'origin.'
2. Torque from a gyroscope with the radius of rotation, mass, and gravitational force.
3. Angular momentum around a disc from a verifiable experimental setup.

Equation #1: Torque:

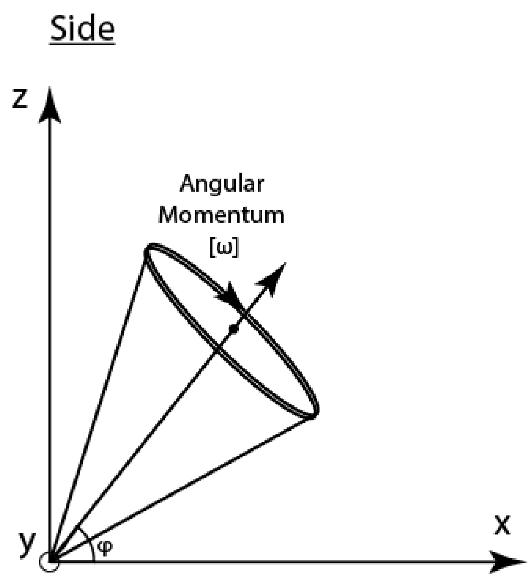
$$\tau = rF$$

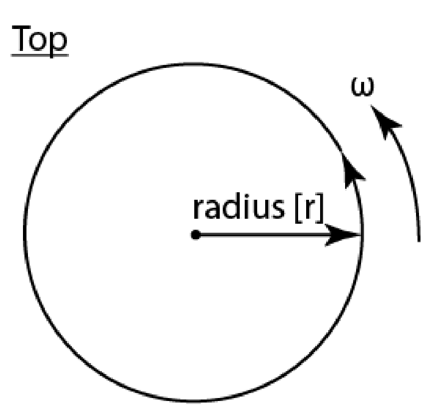
Equation #2: Angular Momentum

$$\vec{L} = I\vec{\omega} = \vec{r} \times \vec{p} = m\,(\vec{r} \times \vec{v})$$

Equation #3: Moment of Inertia (Disc)

$$I_z = I_x + I_y = \frac{1}{2}MR^2$$





Experimental Data:

Mass of Counterweight (g):_________________

Length of Rope (m):_______________________

Angular Velocity (rad/s):____________________

Radius of Gyroscope (m): __________________

Angle of Gyroscope (°):_____________________

Torque of Gyroscope (kg m^2):________________

Evaluation:

Note: Please practice answers on paper before submission.

1. What is torque?
2. What is angular velocity?
3. What is a gyroscope?
4. What proves the alternative hypothesis?
5. What data disproves the null hypothesis?

Lab #21: Conservation of Angular Momentum

Background: A system has conserved angular momentum under zero external torque. For a disc orthogonal to gravity, the law of conservation of angular momentum predicts accurate and precise data. To model angular motion, forces balance across a disc at a radial distance. In a proper model, students rotate a flywheel with specific properties, then solve for total angular momentum.

Goal: Masses on a rotational disc quantify the law of conservation of angular momentum.

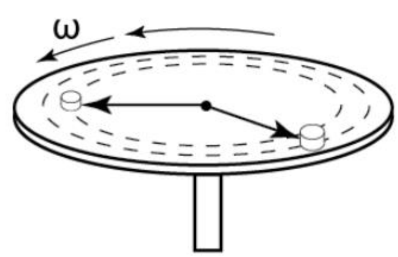
Null Hypothesis: Angular momentum never conserves on a rotational disc.

Alternative Hypothesis: Angular momentum conserves on a rotational disc.

Learning Outcomes:

1. Average trials determining the accuracy of angular conservation.
2. Qualitatively and quantitatively evaluate the standard error of experimental setup

Side



Equation #1: Torque:

$$\tau = rF$$

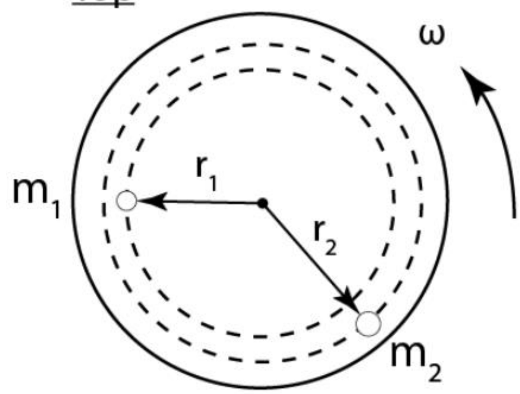
Equation #2: Angular Momentum

$$\vec{L} = I\vec{\omega} = \vec{r} \times \vec{p} = m\,(\vec{r} \times \vec{v})$$

Equation #3: Moment of Inertia

$$I_z = I_x + I_y = \frac{1}{2}MR^2$$

Top



Tabular Data:

Experiment	Trial	Mass (kg)		Radius (m)		Predicted		Actual		
		A	B	A	B	Angular Momentum A (kg rad/s)	Angular Momentum B (kg rad/s)	Angular Velocity (rad/s)	Angular Momentum A (kg m²/s)	Angular Momentum B (kg m²/s)
1	1a									
	1b									
	1c									
								Average		
								Standard Error		

Experiment	Trial	Mass (kg)		Radius (m)		Predicted		Actual		
		A	B	A	B	Angular Momentum A (kg rad/s)	Angular Momentum B (kg rad/s)	Angular Velocity (rad/s)	Angular Momentum A (kg m^2/s)	Angular Momentum B (kg m^2/s)
2	2a									
	2b									
	2c									
								Average		
								Standard Error		

Experiment	Trial	Mass (kg)		Radius (m)		Predicted		Actual		
		A	B	A	B	Angular Momentum A (kg rad/s)	Angular Momentum B (kg rad/s)	Angular Velocity (rad/s)	Angular Momentum A (kg m^2/s)	Angular Momentum B (kg m^2/s)
3	3a									
	3b									
	3c									
								Average		
								Standard Error		

Model	Experiment	Model
Conservation of Momentum Prediction	1	
	2	
	3	
Conservation of Momentum Actual	1	
	2	
	3	
Standard Error of Conservation of Momentum		

Evaluation:

Note: Please practice answers on paper before submission.

1. What is moment of inertia?
2. How conservative was angular momentum?
3. What was the standard error?
4. Why ever use a null or alternative hypothesis?
5. What equation modeled conservation of angular momentum from above?

Glossary:

ABOUT (preposition) – dealt; specific to; central; in apposition to
ABOVE (adverb) – on top; greater coordinate; more; important
ACCELERATION (noun) – a measure rating velocity differences
ACCURATE (noun) – exact; average; agreeable or correct value
ACROSS (adverb) – from both sides; the other side; opposite
ACT (verb) –exercise; perform; operate; praxis practicing
ACTUAL (adjective) – factual; true; exact amount; real quantity
ADD (verb) – mathematical magic combining separate numbers
ADJACENT (adjective) –nearby; neighbors; beside; next to
AESTHETIC (noun, adjective) – artistic movement; beauty
AFRICA (noun) – continent; etymology sources foreign phonetics outside the English language; a continent before English
AFTER (preposition) – beyond; consecutively; typically, later
AFTERNOON (noun) – after 12 o'clock and before 6 o'clock sharp
AIR (noun) – gas mixture in the atmosphere around Earth
ALONG (preposition) – beside; We walked 'next to' romantic castle walls: the curtain, earthwork, shield, and battlement.
ALREADY (adverb) – earlier passage; prior; previously
ALSO (adverb) – Furthermore; too
ALTERNATIVE (adjective) – another; beside; not exact duplicate
ALTHOUGH (conjunction) – rather; in spite; as though
AMMETER (noun) – instrument measures current in Coulombs per second; Coulombs moving past instrument point per second
AMPERAGE (noun) – strength in amperes within electrical circuit
AMPLITUDE (noun) – greatest, maximum, or largest in range
AN (determiner) – alternative to "a" for consonant or silent vowel
AND (conjunction) – abstract list in communication and language
ANGLE (noun) – degree; radian; ratio between sides; triangle
ANOTHER (determiner) – additionally; and; an other
ANSWER (noun, verb) – evaluation; solution; reply; react
ANY (determiner, pronoun) – certainly not chosen in group
APPARATUS (noun) – tool; equipment; gadget; not instrument
APPLICABLE (adjective) – relatable; collateral; reasonable
APPLICATION (noun) – particle; document; log; paper for records
APPLY (verb) – use or push; spread forward; request; put
APPROACH (noun, verb) – action; deal; converse; communicate
ARC (noun, verb) – shape; story; movement around circular shape
ARE (verb) – present tense word expressing state, space, or time
ARGUE (verb) – conflict; debate; oppose by clear judgement
ARISE (verb) – start; become; came into visibility; notice
ARITHMETIC (noun) – maths with simple operations; real numbers added, subtracted, multiplied, or divided
AROUND (adverb) – location nearby and surrounding something
ARROW (noun) – long dart; stick with feathers and point
ARTICLE (noun) – formal document in journals; legal agreement
AS (adverb, preposition, conjunction) – like; similar to; because
ASSEMBLE (verb) – group; gather; combine; bring; organize
AT (preposition) – in the direction; exactly; about; show
ATTEMPT (noun, verb) – initial act; effort; trial; try
AUTOMOTIVE (adjective) – combustion engine; road vehicle
AVERAGE (noun) – representation; total per number; typical
AXIS (noun) – real or imaginary line; coordinate system
BACK (adverb) – backward; previously; not forward; earlier
BACKGROUND (noun, adjective) – scenery behind; lower sound; history in an individual life; profession; role; not nearer; far away
BALANCE (noun, verb) – apparatus measuring mass; distribute
BALLOON (noun, verb) – rubber or cloth bag; expand; increase
BASIC (adjective) – simple; not complex; common
BATTERY (noun) – storage converting chemical to electrical energy with both a cathode and anode for the circuit
BEFORE (preposition, adverb, conjunction) – earlier; at a time
BEHAVIOR (noun) – regular or irregular acts by living creatures
BELOW (adverb, preposition) – not above; beneath; lower than
BETWEEN (preposition, adverb) – halfway; within; space along
BEYOND (adverb) – farther than; greater than; outside
BLOCK (noun, verb) – hard cube; square group; stop, prevent
BOB (noun, verb) – quick object; move gently; up and down
BODY (noun) –main portion; large part; whole group
BOLT (noun, verb) – metal fastener; metallic lock; clamp
BOTH (determiner, pronoun) – two things; together
BOUNDARY (noun) – real or imaginary line; edge; limit; border
BOW (noun, verb) – mid-range weapon; musical stick
BRITISH (adjective) – reference to: Great Britain; an island next to Republic of Ireland; sovereign state with 2000+ years history; England, Scotland, and Whales; English people or language
BULB (noun) – glass lit by electric arc, filament, gas, or junction
BUT (conjunction) – rather; also; except; in addition
BY (preposition) – with; proximity; near or next to something
CALCULATE (verb) –prove; judge; number; deduce; deliberate
CALIBRATE (verb) – mark in units; align; set; check
CANDLE (noun) – wax cylinder for lighting space or room
CAR (noun) – automotive vehicle; mobile; train; automobile
CART (noun, verb) – wagon; small vehicle; push; pull; transport
CARTESIAN (noun, adjective) – René Descartes; linear coordinates
CENTER (noun, verb) – middle; central; align to point; balance
CENTURY (noun) – 100 years; Middle English, cent (1/100th)
CERTAIN (adjective) – without doubt; truly; factual; likely
CHANGE (verb) – alter; make; take; improve; remove; adapt
CHARACTER (noun) – particular personality; stereotype; quality
CHARGE (noun) – Coulomb (C) unit; One ampere per second
CHILDHOOD (noun) – time when humans live before adult
CHINA (noun) – nation landmarked by Pacific Ocean, Amur River, Gobi Desert, Tien Shan mountains, and Himalayas
CIRCLE (noun) – round shape with constant diameter and no vertex; ring; disc; onion or orange sectioned into planes
CIRCUIT (noun, verb) – system fully closed; wire looped; travel
CITE (verb) – reference; mention; official speaking or writing
CLASS (noun, verb) – humans learning together in a room; abstract standard, degree, or ideal; physical attribute, taxon, relation, family, method, or variable; segment; divide
CLASSROOM (noun) – room with students and teacher; school
CLOCK (noun, verb) – instrument measuring time; time
CLOSE (verb) – shut; not open; "Convenience and meat pie stores are often accessible. Commerce never closes"
COEFFICIENT (noun) – multiple; factor; constant term multiplying
COLLECT (verb) – gather; bring; receive; ask; accumulate
COLLEGE (noun) – school after secondary education; university
COLLIDE (verb) – hit; crash; jar; moment; violent shock
COMBINE (verb) – group together; join into whole; organize
COMMISSION (verb) – formal discovery; administrate
COMMUNICATE (verb) – speaking, writing, or passing thought
COMPARE (verb) – examine differences between multiple things
COMPLEX (adjective) – not simple; difficult; multiple parts
COMPONENT (noun) – piece in machine or equipment; essential
CONDITION (noun, verb) – state; arrangement; clause; supposition
CONDUCTION (noun) – heat or electricity transport in medium
CONDUCTIVE (adjective) – substance passing heat or electricity
CONFIDENCE (noun) – personal ability, emotion, skill; dogmatic
CONNECT (verb) – link; join; combine; mutual relationship
CONSERVE (verb) – less waste, damage, or change; sustain
CONSTANT (noun, adjective) – value with no variance; value fixed to a number; regular; unambiguous definition; continuous
CONSTRUCT (noun, verb) – idea or theory; prepare; build; prove
CONTACT (noun, verb) – friend; person met; touch; connect
CONTAIN (verb) – include; kept; retain; no spreading
CONTINUOUS (adjective) – without interruption; nonstop

CONTRAST (noun, verb) – clear distinction; discrepancy; mark
CONTRIBUTE (verb) – kind effort; generously provide; achieve
CONVECTION (noun) – heat or electricity flowing in medium
COORDINATE (noun, verb) – exact point; arrange; align
COROLLARY (noun) – theorem with proof; hypothesis from results
CORRECT (verb, adjective) – agree; accept; normal; actual; right
CORRELATE (verb) – affiliate; relate; justify; connect
COSINE (noun) – function related to angle in a right triangle; cosθ
COULOMB (noun) – unit about charge (C); 6.24×10^{18} electrons per coulomb; Charles-Agustin de Coulomb (R.I.P. 1806), father Henry Coulomb also with unit, electrical inductance (H - Henry)
COUNT (verb) – total; sum; recite; combine; consider; discuss
COUNTERWEIGHT (noun) – weight balancing another weight
CURRENT (noun, adjective) – coulombs per second; present time
CURVE (noun, verb) – continuous line; not straight object; form
CYCLE (verb) – repeat; iterate; perform; movement
DATA (noun) – numbers collected into a form; table; information
DAY (noun) – full rotation on Earth; morning to night; 24 hours
DELVE (verb) – scour; comb; investigate; examine; search
DEMONSTRATE (verb) – present; prove; attest; public expressing
DEPEND (verb) - rely; secondary cause; influence; base
DERBY (noun) – tournament; competition; championship
DERIVE (verb) – began; develop; originate source; obtain; get
DESCRIBE (verb) – communicate; say; write; report; recognize
DESIGN (verb) – prepare with style; decorate; make; draw
DESPITE (preposition) – notice; prevent; without interaction
DESTABILIZE (verb) – not stable; not settle; upsetting
DETERMINE (verb) – evaluate; discover; direct; influence
DEVIATE (verb) – depart; anomalous behavior; vary
DEVICE (noun) – apparatus; invention; tool; gadget; appliance
DIAGRAM (noun) – schematic; graphic; plan; operation
DIFFERENT (adjective) – not similar; diverse; disparate
DIFFICULT (adjective) – skill or effort; not easy; hard
DIMENSION (noun) – measurement; caliber; factor; scale
DIRECT (verb, adjective) – point; project; straight; associate
DISC (noun) – flat object shaped into a circle; dinner plate, frisbee
DISCOVERY (noun) – action or process founding information
DISCRETE (adjective) – separable; divisible; alone; seclusive
DISHWASHER (noun) – appliance for washing cutlery and flatware
DISPLACE (verb) – force; take; expel; persecute; move
DISPROVE (verb) – authenticate; attest; challenge; banter
DISSIMILAR (adjective) – not exactly same; not identical; atypical
DISTANCE (noun, verb) – space; length; scale; avoid
DISTINGUISH (verb) – notice; recognize; scribe; politically identify
DISTRIBUTE (verb) – give; provide; transport; sell; spread; supply
DOCUMENT (noun, verb) – manuscript; note; archive; record
DO (verb) – independent act; perform; exercise; operate
DOLL (noun) – toy; puppet; effigy; dummy; mannequin; figure
DOUBLE (noun, verb, adjective) – substitute; similar; twice
DOWN (noun, verb, adverb, adjective) – feathers; lower; to; dole
DRAG (verb) – pull; force; carry; move; transport; progress
DRAW (verb) – sketch; act; make; express; classify; create; define
DURABLE (adjective) – strong; without damage; persistent
DURATION (noun) – time length; total period; span; length
DURING (preposition) – over; through; amidst; by; circa; around
EACH (pronoun, adverb) – individual; apiece; all; consider; per
EFFECT (noun, verb) – consequence; aftermath; cause; condition
ELASTIC (noun, adjective) – rubber; resistance to stress; plasticity
ELECTRIC (adjective) – power from electricity; intense; 19^{th} century invention during World's Fair; 20^{th} century household commodities; 21^{st} century utilities and central services
ELECTRODYNAMICS (noun) – experiments about particles moving and properties during movement, such as mass, charge, and spin
ELECTRON (noun) – atomic particle with negative charge and one-half spin; fermion; elementary particle; Joke, "You positive? Not."
ELECTROSTATIC (adjective) – electricity from stationary objects
ENERGY (noun) – potential; power; resource for work
ENGINEER (noun, verb) – role building; arrange; design
ENTAIL (verb) – involve; has; require; result
EQUAL (verb, adjective) – match; equivalent; same amount
EQUATION (noun) – function; statement; both independent and dependent relationships; representation; interpolate; extrapolate
EQUILIBRIUM (noun) – chemical balance; accordance; harmony
ERROR (noun) – distant; variation; accuracy; precision; mistake
ESPECIAL (adjective) – more than; notable; unequivocal
ESSENTIAL (adjective) – important; crucial; key; principle
EURASIA (noun, adjective) – Europe plus Asia - Eurasia
EVALUATE (verb) – consider; judge; calculate; conclude; gauge
EVER (adverb) – constantly; continuously; eternally; again
EVERY (adjective, determiner) – all members, things, or ideas; all
EVIDENCE (noun) – historical, physical, or abstract fact deduction; witness or generalization; induction; corollary
EXACT (adjective) – correct; definite; accurate; rational
EXAMINE (verb) – observe; dissect; carefully interpret
EXAMPLE (noun) – representation; specimen; piece from group
EXEMPLIFY (verb) – summate; demonstrate; base; benchmark
EXIST (verb) – live; reside; feature; actual or real being.
EXPECT (verb) – predict; believe early; hope; stipulate
EXPERIMENT (noun, verb) – scientific discovery from tests
EXPLORE (verb) – search; discover; become familiar; venture
EXPOSE (verb) – bring into observation; uncover; present
EXTEND (verb) – move toward bigger or longer; increase
EXTERNAL (adjective) – outside; beyond; exterior; outer
EXTRACT (noun, verb) – essence; remove; separate; divide
EXTREME (adjective) – maximum; dangerous; greater than regular
FAILURE (noun) – not successful; with no standard; no agreement
FASTEN (verb) – mantle; join by fixture; hardware affixing
FAVORITE (adjective) – indefinite; without regret; in satisfaction; in fickle manner; by no fear; emotional; enjoyable; sensual
FEET (noun) – unit about length; standard length; 12 inches; 5,280 to one mile; Customary unit measuring length in United States of America from fall of British empire in 1765 to 1783
FIELD (noun, verb) – agriculture; grassland for animals; location by husbandman e.g. farmer; turf; natural grass; mathematical region described by scalars, vectors, or tensors; indirectly deal; divide
FILM (noun, verb) – pictures moving; cinema; record; animate
FINAL (noun, adjective) – terminal; last; end; furthest; eventual
FIND (verb) - discover; build; base; bring into existence;
FIRST (noun, adjective, adverb) – original; immediate; debut
FIVE (noun) – total fingers on hand or edges around pentagon
FLOOR (noun) – ground; surface for walking; lowest level
FLOW (verb) –continuously moving; liquids or gases moving;
FLYWHEEL (noun) – heavy wheel rotating on machinery
FOR (preposition) – because; purpose of; as; in agreement with
FORCE (noun, verb) – inertia; momentum changing; move
FORD (noun) – Henry Ford friend to Thomas Edison; Influential vehicle in history because efficient motors; Ford company producing airplanes, boats, and cars from Detroit, Michigan
FORMULA (noun) – standard relationship; acceptable expression
FORTH (adverb) – from a point; forward; out; away; into visibility
FOUNDATION (noun) – organization or state; idea or fact
FRAME (noun, verb) – border; structure; outline; enclosure
FRAMEWORK (noun) – structure supported by system; structure with ideas, rules, or beliefs for future advancement
FREE (verb, adjective, adverb) – not kept; no limit; without cost
FREQUENCY (noun) – count about how often; per second; Hertz
FRICTION (noun) – force during static and dynamic interface
FRIDAY (noun) – day in a week; special day in many religions, cultures, languages, nations, and divinities from celestial bodies
FROM (preposition) – relationship between cause and effect, initial to final state, or points, such as distance; designate origin

FUNCTION (noun) – natural purpose; mathematical expression passing the vertical line test; official event with ceremony
FUNDAMENTAL (adjective) – elementary; essential; important to
FURTHER (adverb) – great distance in space, time, level, or degree
GAS (noun, verb) – chemical phase; not liquid or solid; fill; empty
GENERATE (verb) – cause; produce; bring into existence; make
GOAL (noun) – aspiration; intention; purpose; aim; objective
GOVERN (verb) – steer; authorize; kubernan; gubernare
GRAPH (noun, verb) – picture about info; plan; chart; map; plot
GRAVITY (noun) – physical force from mass; Gravity describes mechanics in tides, seasons, orbit, and growth in vegetation
GROUND (noun) – floor; surface below feet; reason or argument
GYROSCOPE (noun) – wheel inert to gravity; sensor rotating or vibrating for gravitational measurements by standard proportion
HAND (noun, verb) – appendage of four fingers and thumb; move
HAPPEN (verb, adverb) – occur; do; probably; perhaps; oddly
HARMONIC (adjective) – fundamental; frequent; sinusoid in math
HAVE (verb) – occur; act; own; verb related to an event or action
HEAR (verb) – sense about sound in ear; receive; listen; know
HEAT (noun, verb) – energy transferred between substances; first law in thermodynamics; a quality in-home about warmth; warm
HEAVY (adjective) – high weight; a lot; strong; catastrophic
HEIGHT (noun) – distance from ground; length; vertical dimension
HELP (verb) – assist; care; improve; facilitate; guide; attend
HIGH (adjective) – far from ground; above; aloft; scary distance
HISTORY (noun) – past events or actions; important topics
HOIST (verb) – lift; elevate; pick upward; raise by equipment for
HOT (adjective) – high temperature above normal condition; spicy
HOW (adverb) – what steps; way; critical steps toward outcome
HUMAN (noun) – ape; surgent animal with vaulted skull; creature adorning stone in complex symbolic world; successful, adept, and resourceful with tools, but unpredictable nature in society; weird
HYPOTHESIS (noun) – best guess; explanation; abstract idea
IDEAL (noun, adjective) – principle; perfect outcome; immaculate
IMPORTANT (adjective) – principle; critical; influential
IN (preposition) – within; inside; into; part to; interior; segment
INCIDENT (noun, adjective) – unhappy event; episode; next to
INCLINE (noun, verb) – hill; bank; angle; slope; slant; pitch
INCLUDE (verb) – by smaller parts; antonym to exclude; embody
INCORPORATE (verb) – include; acquire; set organized
INCREASE (verb) – become large; grow; rise up; big raising
INCREMENT (noun, verb) – single step; smallest placement; ramp
INDEPENDENT (noun, adjective) – it alone; not reliant; individual
INDIVIDUAL (adjective) – separate; by itself; isolated; single thing
INELASTIC (adjective) – not rubber; not plastic; In physics, a situation when kinetic energy decreases after collision by friction
INERTIA (noun) – momentum; motion; movement after rest
INFORMATION (noun) – tid bits about a situation, person, or event; not always truthful, but typically news or knowledge
INHIBIT (verb) – stop; halt; avoid; prevent an action; limit
HOME (noun) – residence; In foreign language, ham, heem, or heim. Many synonyms describe a home, such as the apartment, condo, townhouse, mobile, flat, farmhouse, log cabin, chalet, tent, bungalow, pad, dormitory, lodge, crib, penthouse, chamber, suite, tenement, studio, duplex, condominium, castle, and keep
INITIAL (noun, adjective) – acronym to pronoun. from the start
INSPECT (verb) – observe; look; check; investigate particulars
INSTRUMENT (noun) – object prospecting character and insight
INTENSE (adjective) – strong; potent; major; vigorous; incredible
INTERFERE (verb) – interact; involve; connect; propagate; spread
INTERMEDIATE (adjective) – between; middle; interim; middle
INTERNAL (adjective) – inside; innate; inner; central; privates
INTERVAL (noun) – short time; period; numbers between two endpoints; educators write intervals as closed $[x_1, x_2]$ or open (x_1, x_2). Hominids prefer greater (<) or less (>) than. Also, educators write intervals by sets (⊂) and subsets (⊆).
INTO (preposition) – inside; aspect; enjoyable; inward
INVERSE (noun, adjective) – opposite; reverse; contrary; an expression about a function for corresponding between
INVESTIGATE (verb) – carefully inspect; examine well
INVOLVE (verb) – participate; influence; mate; join
IS (verb) – move; separate; indicate; cast an idea
JOULE (noun) – unit; 1 Joule = 1 Newton-meter; potential; work; heat; energy in a system; James Prescott Joule founded a measure
JUSTIFY (verb) – argue with reasonable doubts; reason; bet
KELVIN (noun) - unit counting from absolute zero temperature (K)
KINEMATICS (noun) – topic in general physics about motion
KINETIC (adjective) – about inertia, collisions, rate, and motion
LAB (noun) – environment were scientists test ideas for fun or fact
LABEL (noun, verb) – information; cultural communication; tag
LARGE (adjective) – big; more than average or typical; hefty
LATER (adverb) – after; in future time; at the end; toward the end
LAW (noun) – rules; action or fact about belief; standard opinion; process or argument in city, county, state, or nation; persuasion
LEAD (noun, verb) – a controller, absent minded; cause, especially by bad events or influence; the first in a funny competition
LEARN (verb) – increase ability; gain knowledge; practice
LEDGE (noun) – flat surface for furniture; a cliffside; abrupt incline
LENGTH (noun) – measurement in one-dimension; distance
LESS (adverb) – small amount or degree; short; not as much
LEVEL (noun, verb) – French invention balancing by gravity, air and water; tool; instrument; horizontally or vertically balance
LIFT (verb) – raise; bring upward; hoist; move up; increase
LIGHT (noun, verb) – sun; lamp; illumination; luminosity; lit
LIMIT (noun, verb) – greatest amount; extremum; boundary; Instructors define limits by an argument 'near values'; allow
LINE (noun, verb) – long or thin mark; Geometry characterized lines as straight, curve, parallel, perpendicular, or intersect; align
LINEAR (adjective) – along a slope or incline; stepwise; straight
LITTLE (adjective) – low; tiny; less than average, important, and essential, but greater than diminutive; emphasis about size
LOCAL (adjective) – region; province; area; short distance; division
LOCATION (noun) – site; exact coordinate; special place
LONGITUDE (noun) – geographic lines describing earth; vertical
LOOP (noun, verb) – circular object, but thin; turn; coil; curve.
MACHINE (noun, verb) – equipment; appliance; tool; grind; turn
MAGAZINE (noun) – booklet; publication; articles + photographs
MAGNITUDE (noun) – scale; urgency; math – distance from zero
MAKE (verb) – action with produce; cause; create; issue; model
MANY (pronoun, adjective) – multiple things; large number; a lot
MARK (noun, verb) – symbol as a clue; judge; correct.
MASS (noun, adjective) – unit; kilograms, pounds; tons; large
MATCH (noun, verb) – competition; agreement; equal; accord
MATHEMATICS (noun) –quantitative and symbolic reasoning
MAXIMUM (adjective) – extreme; upper limit; great amount
MEAN (noun, verb) – representation; expectation; estimation; In statistics, an estimator without bias to true values
MEASURE (noun, verb) – a value; standard; assess by increment
MECHANICAL (adjective) – kinetic; automatic; operational
MEDIUM (noun, adjective) – conveyance; middle; passage
MEMBER (noun) – fellow; mate; compeer; associate
MESOPOTAMIA (noun) – region in middle east from Mediterranean Sea to Iraq with stone, metal, water, and wood
METAL (noun) – chemical elements described by Periodic Table of Elements up to semi-metals line; substance conducting heat and electricity; hard, ductile, shiny, or malleable, and solid substance
METHOD (noun) – way for performing action; particular avenue
mg (noun) – milligram; unit about mass; 1/1000 grams
MICHIGAN (noun) – state in U.S.A from 1837; 10.14 million pop.
MIDLINE (noun) – line dividing left and right or upper and lower
MINE (noun, verb) – a hole for coal, metal, or salt in ground; dig
MINIMUM (noun) – lowest output, smallest value in range

MODEL (noun, verb) – representation; duplicate; example; copy
MOMENT (physics) – how many units over a specific distance
MOMENTUM (noun) – inertia; mass multiplied by velocity
MOTION (noun) – movement; action; formal agreement
MOVE (verb) – displace; direct; force; change; carry; scoot
MULTIMETER (noun) – originally an instrument from United Kingdom of Great Britain and Ireland measuring volts or amps
MULTIPLE (adjective) – more than one; many; divisible number
MULTITUDE (noun) – people; large body; crowd
NATURAL (adjective) – nature; not artificial; effortless; authentic
NEAR (verb, adjective, adverb) – close; not far; almost; proximate
NECESSARY (adjective) – key; important; essential; particular
NEGATIVE (adjective) – numbers less than zero; absence
NEVER (adverb) – not any; no more; no way; absolutely not
NEW (adjective) – novel; latest; current; never in the past
NEWTON (noun) – unit for force; Isaac Newton derived ideas about inertia, gravity, color, and light with annotation
NO (noun, adverb) – for nobody; not I; surely never; hardly
NORMAL (adjective) – regular; ordinary; average; usually
NOT (adverb) – suspect; doubt; denial and about an action
NOTE (noun, verb) – formal post; piece; document; notice
NOW (adverb) – currently; not in past or future; ergo
NULL (adjective) – empty; in mathematics, empty; without
NUMBER (noun, verb) – sign or symbol about amount; count
NUT (noun) – the metal lock, jam, cap, or slot by internal thread
OBJECT (noun, verb) – thing; item; intention; purpose; act
OBSERVE (verb) – carefully examine; mark; describe; custom
OCCUR (verb) – happen; pass; event; met; found; exist
OF (preposition) – indicates an origin, expression, possession, position or location nearby; of translates to von in German
ON (preposition) – above; along; upon; higher; on the top
ONE (pronoun, noun) – individual; first natural number
ONTO (preposition) – on now; action about future tense
OPERATE (verb) – effect; work; cause; set; drive; use; go
OPPOSITE (adjective) – not alike; no resemblance; not equal
OR (conjunction) – connection between two or more ideas
ORIGIN (noun) – initial action, event, or idea e.g. birthplace
ORTHOGONAL (adjective) – perpendicular; right angle; square
OSCILLATE (verb) – wave; rock; move; repeat; fluctuate; vibrate
OTHER (pronoun) – another; in the group; not it, but next to it
OUR (pronoun) – relationship to multiple people; themselves
OUTCOME (noun, verb) – conclusion; consequent; result
PAPER (noun) – material from wood in sheets for communication
PARAGRAPH (noun) – sentences grouped into single statement
PARALLEL (adjective) – same sloped lines or edges; not skew
PARAMETER (noun) – variables measured by an instrument
PATH (noun) – pathway; corridor; trail; hall; passage; walkway
PENDULUM (noun) – device oscillating lower in height by gravity
PER (preposition) – rate expressed by division in ratio or fraction
PERCENT (adverb) – ratio into 100 or one per every 100 (%)
PERFECT (adjective) – superb; best; done; fine; top; fair
PERIOD (noun, adjective) – length in time; row; historical time
PERPENDICULAR (adjective) – angle at 90° to horizontal surface
PERSPECTIVE (noun) – interpretation; perception; physical angle
PHASE (noun, verb) – In chemistry, solid, liquid, gas, or plasma; Physics describes phase by horizontal shift in sinusoids; introduce
PHOTOGATE (noun) – light switch sensing movement by laser
PHYSICIST (noun) – job with great knowledge in physical universe
PHYSICS (noun) – in special terminology, thoughts about motion
PIANO (noun) – instrument; Twinkle, Twinkle Little Star: G-G-D-D-E-E-D-C-C-B-B-A-A-G-D-D-C-C-B-B-A-D-D-C-C-B-B-A-G-G-D-D-E-E-D-C-C-B-B-A-A-G
PIVOT (noun, verb) – central point for balancing; turn or twist
PLAN (noun, verb) – decision about future events; steps; stage
PLANE (noun) – 20st century aeroplane first flown in North Carolina by the Wright Brothers in 1903; vehicle for flying
PLANT (noun, verb) – vegetation; garden; dug into the ground
PLEASE (verb) – request; ask; beckon; solicit; demand; wish
PLOT (noun, verb) – arc; diagram; image; chart; show; illustrate
POINT (noun, verb) – explanation about ideas or facts; coordinate
POSITION (noun, verb) – location in spaces, times, or roles; move
POSITIVE (adjective) – natural numbers; positive integers; hopeful
POTENTIAL (noun, adjective) – ability; successful skills or talent
PRACTICE (noun, verb) – action toward ability; produce ability
PRECESSION (noun) – rotation around a point or vertical axis
PRECISE (adjective) – precision; variation; dispersion; exactness
PREDICT (verb) – future acts with an outcome; future result
PREPARE (verb) – brace; shelter; stock; made; equip; plan
PRESERVE (verb) – store without fatigue
PRESSURE (noun) – unit described by force per area; pounds per square inch; pascals; atmospheres; millimeters of mercury; torr
PRIMARY (adjective) – essential; important; top; fundamental
PRINT (noun) – transpose; copy; produce by ink on paper; publish
PRIOR (adjective) – before; in the past; long ago; earlier; beside
PROBLEM (noun) – question; a challenge; difficult situation
PROCESS (noun, verb) – method; series; order; steps; perform
PRODUCE (noun, verb) – end result; effect; generate; create
PROFESSOR (noun) – role teaching in university or college
PROJECTILE (noun) – object accurately flung or shot into air
PRONOUNCE (verb) – specific saying in articulate accent
PROOF (noun, verb) – evidence; show truths; declare facts
PROPER (adjective) – right; good; official; just, fair; formal
PROPERTY (noun) – natural relation; physical measure; chemist define properties into intensive and extensive quantities; intensive properties are a ratio between two extensive properties
PROPORTION (noun) – comparable amount; whole relation
PROVE (verb) – particular evidence; exact truth; true argue
PROVIDE (verb) – assist; give to; offer; supply; prepare
PROVINCE (noun) – populous city; busy area; active region
PUBLISH (verb) – produce documents; prepare public paper
PULLEY (noun) – mechanical equipment for moving objects by wheel and line; a mechanism for lift by rope and pivot
PURPOSE (noun, verb) – goal or aim; an idea; construct; fashion
QUALITY (noun) – observation; attribute; nature; property
QUANTITY (noun) – amount; total; size; bulk; analysis
RADIAN (noun) – angle; degree; gradian; steradian; arc; subtend
RADIAL (adjective) – outward motion from midpoint; radiative
RADIUS (noun) – half a diameter; circumference per 2-π
RAIL (noun) – infrastructure beside traffic direction; metal bar
RAMP (noun, verb) – incline; slope; road; angle; path; route
RAY (noun) – light; beam; column; source; sunlight; sunbeam
REASON (noun, verb) – argument; explanation; compare
RECIPROCAL (adjective) – help each other for advantage; inverse;
RECORD (noun, verb) – account; table; list; store; write; note
RECURRENT (adjective) – many times; regular; episodic
REFERENCE (noun, verb) – quote; mention; cite; report; refer
REFLECT (verb) – not transmit, absorb, or refract; bounce; send
REGULAR (noun, adjective) – often; usual; ordinary; commonly
RELATE (verb) – associate; agree; describe; reasonably connect
RELATIONSHIP (noun) – kinship; relation; correspondence
RELEASE (verb) – free; move; allow; leave; drop; distribute
RELIABLE (adjective) - trustworthy; clear; dependable; countable
REPEAT (verb) – circle; oscillate; revolve; spin; rotate; happen
REPRESENT (verb) – write, speak, or listen in place for (an)other(s)
REQUISITE (adjective) – important beforehand; necessary
RESEARCH (noun, verb) – specific genre; discover; study; pervade
RESIST (verb) – fight; refuse; deny; act against an attacker
RESISTOR (noun) – passive component in electrical circuits measured by Ohms (Ω) for accurate current from source
RESOURCE (noun, verb) – valuable object for either physical or abstract reason; organization or department specially aiding

RESPECT (noun, verb) – abstract qualities, features, details, events, or actions for admiring; accept; think; accustom
RESULT (noun, verb) – outcome; effect; response; calculate
RIGID (adjective) – not plastic; strong, stiff, or hard; solid
RING (noun, verb) – metal looped in a circle; a bell sounding
ROBOT (noun) – digital machine performing job; mechanical computer forced into eternal labor for servitude and drudgery
ROCKET (noun, verb) – explosive cylinder burning fuel; quick rise
ROPE (noun) – thread twisted into cord; tie; lasso; bind; bound
ROTATE (verb) – turning around point or center line; move
RULER (noun) – tool measuring length; length with increment
SAFE (adjective) – not harmful; not injurious; not dangerous
SAME (adjective) – similar; alike; equivalent; identical; next to
SAMPLE (noun, verb) – small substance for test; test; example
SCHOOL (noun, verb) – facility for teaching; assembly; educate
SCIENCE (noun) – careful examination testing nature; measurements focused in systematic analysis and honest inquiry
SCIENTIST (noun) – science career in hospital, college, or agency
SEA (noun) – saltwater; pelagic water; larger waterbody than lake
SECOND (noun, verb, adjective, adverb) – after the first instance
SENTENCE (noun) – expressions combined into a statement
SEPARATE (verb, adjective) – divide; bifurcate; not together
SERIES (noun) – items ordered by a comparable relationship
SETTING (noun) – background; environment; place and time
SETUP (noun, adjective) – arrangement; association to assembly
SHAFT (noun) – long rod or pole on tool, in wheel, or weapon
SHOW (noun, verb) – theatre; program; display; demonstrate
SIMILAR (adjective) – same; comparable; mostly alike; not distinct
SIMPLE (adjective) – easy; not complex; not difficult; plain
SIMULATE (verb) – computationally present; mock; create; model
SINCE (adverb) – from a past occurrence; in time; at a later time
SINE (noun) – ratio between opposite and hypotenuse; sinusoid
SINGLE (verb, adjective) – choose; individual; solo; alone; only
SINUSOID (noun) – sine wave; oscillatory function; periodic wave
SKETCH (noun, verb) – simple example; draw; describe; illustrate
SLOPE (noun, verb) – mountainside; incline; ramp; angle; slant;
SOLID (noun) – chemical phase with definite volume and shape
SOLUTION (noun) – aqueous mixture with solutes and solvents
SOLVE (verb) – detail; explain; prepare; find; define; character
SOON (adverb) – due time; before the finally; ahead; shortly
SOURCE (noun, verb) – origin; from the cause; supply; get
SPACE (noun, verb) – volume; empty area; make a region; arrange
SPECIFIC (adjective) – one; particular; obvious; infallible
SPEED (noun, verb) – absolute velocity; movement; rate; go
SPHERE (noun) – shape like ball, sun, pebble, bubble, or marble
SPRING (noun, verb) – metal coiled into helix; season; stretch
SQUARE (noun, verb, adjective) – shape with four similar edges and four right angles; quadrilateral; multiply by itself; 90° angle
STABLE (adjective) – firm; regular; successful; expectable
STALL (noun, verb) – space kept; engine stall; sudden stop
STAND (verb) – vertically align; make upright; base; pose
STANDARD (noun, adjective) – basic criteria; not special; usual
STATIONARY (noun, adjective) – office supply; not movable
STATISTICS (noun) – heuristic about proving hypothesis; subject
STEEL (noun) – iron composed with minor carbon (2.2% w/w)
STORAGE (noun) – place holding personal collections; store;
STRING (noun, adjective) – twine; thread; bind; harness; tie
STRUCTURE (noun, verb) – arrangement; organization; plan; set
STUDENT (noun) – person learning in classroom; pupil
STUDY (verb) – practice; educate; learn; apply; interpret; parse
SUBMISSION (noun) – documents given for responsibility
SUBSTANTIATE (verb) – prove; dispel; attest; fight; support
SUM (noun, verb) – calculation; add; total; found; decide
SUN (noun) – warm star in sky casting rays onto shoulders
SUSPEND (verb) – inhibit; stop; prevent; end; limit; judge
SYMBOL (noun) – sign, shape, or object, such as a national flag
SYMMETRICAL (adjective) – reflection about an axis
SYSTEM (noun) – a set; a collection; interaction between pieces
TABULATE (verb) – format into a table; arrange; show
TAMARACK (noun) – larch; wooded tree; tamarack mine
TANGENT (noun) – straight line perpendicular to normal; slope with zero-intercept; trigonometric function; $\tan(\theta)$=opp/adj
TARGET (noun, verb) – rings patterned for projectile; focus
TENSION (noun) – force on a string; stiff and tight string;
TERMINAL (adjective) – point toward; from central; final
TERM (noun, verb) – values fixed; division in time; name
TEST (noun, verb) – exam; discover; qualify; work; produce
THE (determiner) – definite article; particular; clear; in context
THEIR (pronoun) – third-person possessive pronoun about them
THEN (adverb, adjective) – preposition to a clause; next; after
THEREOF (adverb) – aforementioned; respectfully; hereof; allude
THERMODYNAMICS (noun) – actions studying heat or work
THIRD (noun, adjective, adverb) – not first and not second; 3rd
THIS (pronoun) – a person, place, or thing; specifically
THOUGHT (noun) – an idea; abstract action or event
THREE (noun) – number; after two and before four; sum of one and two; prime; ostriches are herbivores with three stomachs
THROUGH (adverb) – from one end; from beginning to end
THROUGHOUT (adverb) – every piece; the whole time
THRUST (noun, verb) – story arc; main point; push rapidly
TIME (noun, verb) –minute; hour; day; year; measure duration
TO (preposition) – an expression for agreeing, needing, or wanting
TODAY (noun, adverb) – current day; this day; right now
TOOL (noun) – equipment with specific purpose; device for repair
TORQUE (noun, verb) – force times distance; angular force
TOTAL (noun, adjective) – entire; everything; largest; all
TOUCH (verb) – bring together; bring next to; lightly place
TOWER (noun, verb) – spire; steeple; keep; donjon; raise above
TRADITION (noun) – ceremony; heritage; principle or belief
TRANSFER (verb) – move; transport; place; arrange; displace
TRANSIENT (adjective) – temporary; ephemeral; momentary
TRANSVERSE (adjective) – perpendicular; incident; normal
TRAVEL (noun, verb) – journey; tour; explore; traverse; visit
TRIAL (noun, verb) – at/to courtroom; test; assay; burden; judge
TRIGONOMETRY (adjective) – math distinguished by triangles
TRIPLE (verb, adjective) –multiply by three; three times; more than double, but less than quadruple; to three similar pieces
TWO (noun) – one < two < three; an even prime number; number amounting to human eyes, ears, nostrils, legs, arms, and lungs
TWO-DIMENSIONAL (adjective) – a space; x-and-y; dimensions for shapes including the triangle, circle, square, or rhombus
TYPE (noun, verb) – particular category; a division; attribute
UNCERTAIN (adjective) – without knowledge; not clear; unsure
UNDER (preposition) – less than; below; not agreeable; lower
UNIQUE (adjective) – special; only; uncommon; rare; unusual
UNIT (noun) – exact quantity; standard measure; single item
UNIVERSAL (adjective) – everywhere; everyone; without absence
UNIVERSE (noun) – all physical matter, earth included
UP (adverb) – higher; ascent; near; greater; improve; end
UPON (preposition) – on; above; onto; atop; there; at; over
UPWARD (adverb) –toward; uplift; vertical; upturn; erect
USE (noun, verb) – purpose; apply; prepare; add; impose
UTILIZE (verb) – use; make; purpose; effect; turn; got; give
VALIDATE (verb) – authorize; accept; approve; ratify; sign
VALUE (verb) – inspect; compare; rate; judge; estimate
VARIABLE (noun, adjective) – symbol; letter; not constant; no set
VARY (verb) – change; not according; disturb; alter; make
VECTOR (noun) – expression with size and direction; carrier
VEHICLE (noun) – transportation; car, bus, or truck
VELOCITY (noun) – distance per second; movement; rate
VERIFY (adjective) – provable; without false claim; unlikely
VERSUS (preposition) – against; vs.; comparably; and second

VERTICAL (adjective) – higher; not horizontal; column
VIA (preposition) – through; a way to; by; from
VINTAGE (noun; adjective) – particular; original; official
VIRTUAL (adjective) – almost; particular; not real; not done
VISUAL (noun, adjective) – picture; image; descript
VOLT (noun) – unit in electricity; unit (V) for potential per charge
VOLTMETER (noun) – tool measuring volts by two terminals
WAS (verb) – been; verb related to past action, event, or state
WATCH (noun, verb) – clock; monitor; check; look; leer; peer
WAVE (noun, verb) – oscillation; sinusoid; flag; jostle; sway
WAVELENGTH (noun) – length unit about one full-period in wave
WAX (noun) – hydrophobic organic compound with low melting point; bees prepare wax from glands; candles burn wax
WE (pronoun) – nominative pronoun in 1st-person about plural
WEIGHT (noun, verb) – mass on earth; scale; test; balance
WERE (verb) – simple word about the past tense 'be'
WHAT (pronoun) – people, place, thing, action, event, state that
WHEEL (noun, verb) – a circle for moving objects on axel; direct
WHEN (adverb) – at which time; to what extent; until; a fact that
WHERE (adverb) – in what place; Dutch waar and German wo
WHICH (determiner) – in the selection; what; before a clause
WHILE (noun, conjunction) – the length; together; during; at least
WHY (adverb) – for what; reasonably; duly; phonetically /waI/
WIRE (noun, verb) – metal braided or stranded; fasten; connect
WITH (preposition) – together; along; additionally; in unison
WITHIN (adverb) – inside; coincident; timely; possibly
WITHOUT (adverb) – absent action; expression denying with
WORD (noun, verb) – expression; collection; particular saying
WRENCH (verb) – metal tool with head, profile, and handle; pull
WRITE (verb) – communicate; transfer thought or ideas
X-DIRECTION (noun) – number line; particular axes; x-coordinate
X-POSITION (noun) – first value in coordinate pair; on x-axis
Y-COMPONENT (noun) – projection in vector about size on y-axis
Y-DIRECTION (noun) – position on y-axis in cartesian space; y-axis
Y-POSITION (noun) – second value in coordinate pair; y-location
Z-AXIS (noun) – axis in Cartesian space perpendicular to x and y