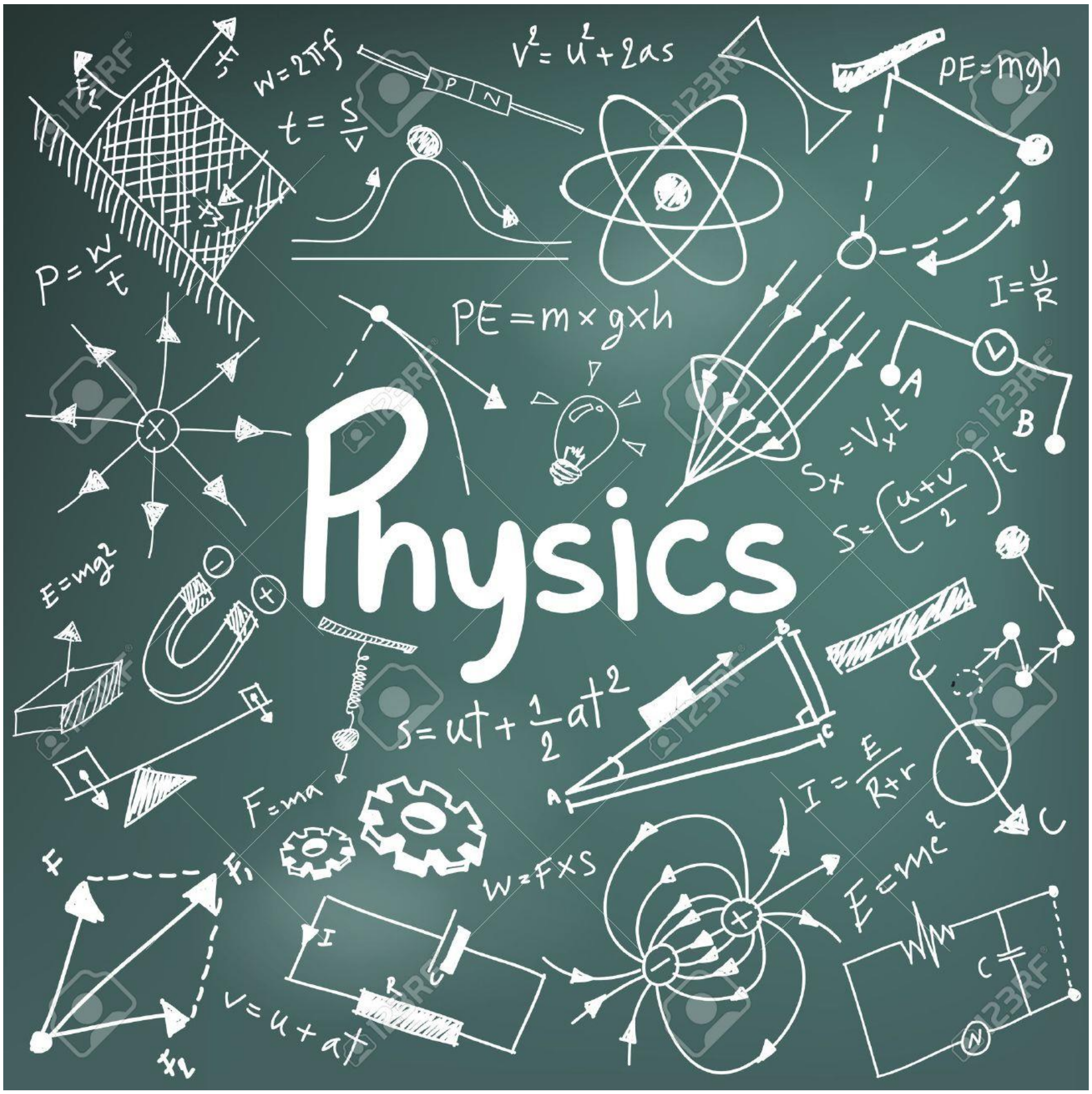
Grade 12 Physics

Outcomes, Concepts, and Problems



Mr. P. MacDonald

The reference digital text ***Openstax: Physics High School*** will be used throughout the course (grade 12 will also require the *College Physics* digital text for outcome 6.3). Readings can be found within the outcome description and the page reference is for the PDF file, not a printed version. Within the first few days of school, go through ***Chapter 1*** to add to your understanding of what physics is all about. Physics 11 has five units and Physics 12 has four units. Each unit breaks down into *Outcomes*. Each outcome is assessed and will be used to determine your grade for your Physics course.

1 **Kinematic Motion in One Dimension:** Kinematics is the study of *how* objects move.

- 1.1 Define and identify scalars and vectors. Classify each of the quantities listed in outcome 1.2 as a scalar or vector. ***Chapter 2, Pg. 67 – 80***
- 1.2 Recognize and define position, displacement, distance, velocity, speed, acceleration, force, and their units. ***Course Concept Guide***
- 1.3 Graphically analyze one-dimensional relationships among position, velocity, acceleration, and time. ***Chapter 2, Pg. 81 – 96***
- 1.4 Mathematically analyze the relationship among position, velocity, acceleration, and time in 1D. ***Chapter 3. Pg. 107 – 127***

2 **Kinematic Motion in Two Dimensions:** Much of physics relies on being able to solve problems in 1, 2 or 3 dimensions. In high school, we study 1 and 2 dimensional problems. Outcomes 2.1 – 2.3 are about the mathematics behind analyzing 2D problems. Outcomes 2.4 and 2.5 apply the 2D analysis to kinematic concepts from Unit 1. ***Chapter 5.1 & 5.2, Pg. 157-175***

- 2.1 Measuring vectors and the resultant position for 2D vectors using a scale diagram.
- 2.2 Calculating perpendicular components of vectors.
- 2.3 Calculating vectors (magnitude and direction) given the components.
- 2.4 Mathematically analyze the relationship among displacement (position), velocity, acceleration, and time in 2D.
- 2.5 Vector addition and solving for missing vectors.

3 **Dynamics**: The study of *why* objects move. This unit describes the types of forces and Newton's Laws of motion. ***Chapter 4, Pg. 129 – 156***

- 3.1 Explain, describe, and analyze the forces of gravity and friction. Including the types and causes of friction, the coefficient of friction, and determining normal force given the situation in one dimension.
- 3.2 Describe and apply Newton's 3 Laws of motion within inertial and non-inertial frames of reference in one dimension.
- 3.3 Qualitatively and quantitatively analyze the various types of forces including friction, normal, gravitational, applied, tension, and the concept of net force in two dimensions.

4 **Conservation of Mechanical Energy**: Understanding changes that take place in a system is often aided by considering energy exchanges. Students will learn the concept of work, relative to physics, identify forms of energy and that energy for a system is a constant. ***Chapter 9, Pg. 293-313***

- 4.1 Define and apply the concept of work incorporating the following: kinetic, gravitational potential, and elastic potential energy.
- 4.2 Qualitatively and quantitatively analyze the conservation of mechanical energy with conservative and non-conservative forces.

5 **Electromagnetic Radiation**: The following outcomes relates foundational information of the types of EM radiation (radio waves, light, x-rays, etc.). ***Chapters 13 - 17***

- 5.1 Waves
- 5.2 Doppler Shift*
- 5.3 Electromagnetic Spectrum*
- 5.4 Refraction
- 5.5 Lenses*
- 5.6 Diffraction*

6 **Kinematics & Dynamics in 2D**: The study of why objects move in two-dimensional space. This unit applies the concept of perpendicular components to solve problems. Problems, or systems, involve:

6.1 In depth quantitative analysis of a projectile motion. ***Chapter 5.3, Pg. 176-185***

6.2 Applying Newton's Laws of motion for objects on an incline plane. ***Chapter 5.4, Pg. 185-192***

6.3 Learn and apply the concept of net torque to solve static equilibrium problems. ***OpenStax College Physics: Chapter 9, Pg. 329-354***

6.4 Collisions and explosions in one and two dimensions. ***Chapter 8, Pg. 267-287***

7 **Circular Motion & Universal Gravitation**: This explores how and why an object travels in a circular path (be it a ball on a string, an amusement park ride, or the Moon about the Earth, for example). Universal gravitation is a deeper analysis of the force of gravity between two masses and is further analyzed with Kepler's Laws of planetary motion.

7.1 Qualitatively and quantitatively analyze circular motion using vectors and Newton's laws. ***Chapter 6, Pg. 211-236***

7.2 Quantitatively apply Newton's law of gravitation and Kepler's third law of planetary motion to solve problems. Identify and explain Kepler's three laws of planetary motion. **Chapter 7, Pg. 243-260**

8 **Electric Circuits, Fields & Electromagnetic Forces**: Forces can affect objects over a distance and through space without physical contact. The analysis of that affect requires the physics concept of fields. When a current is made to pass through a wire, it creates a magnetic field, and vice-verse. Coulomb's Law allows for the mathematical analysis of the interaction of charged objects.

8.1 Qualitatively and quantitatively analyze electric charge and electric fields, including Coulomb's Law. ***Chapter 18, Pg. 563-606***

8.2 Quantitatively analyze electric circuits. Concepts include Ohm's Law, series and parallel circuits, and electrical power. ***Chapter 19, Pg. 617-653***

8.3 Qualitatively analyze magnetism including magnetic poles, fields, and moving charges. ***Chapter 20, Pg. 663-669***

Physics Investigations

- Physics investigations may take place throughout the course. Such investigations will link directly to learning a particular outcome. Often, questions relating to any investigations will appear on assessments.

Classifying Mistakes

For any type of assessment, determine the type of mistake and the learning opportunity, that is, how to prevent the mistake from happening again. The purpose is to give us information on any learning barriers you are experiencing, and work towards removing them. Use the guide, below, to determine the type of mistake(s) and the learning opportunity.

Type	Type Definition and Examples of Learning Opportunities
Minor	An abnormal mistake, hard to catch, not made often, and not part of the problem solving. • Forgetting to divide by a number that is written down • A number or sign is not carried down to the next math step • Calculator buttons miss-hit • No units in final answers
Background	Usually in the form of mathematical mistakes. • Equation solving • Order of operations • Algebra rules (like and unlike terms)
Conceptual	These mistakes link to gaps in understanding the concepts of physics. • Vector signs • Incorrect formula • Incorrect setup or analysis • Concepts and definitions not fully understood

Strong Work Ethic and Skills for Success

- On task during class
    - This is the only time I can help you learn. Use it.
- Proper use of technology
    - Turn off your notifications, like completely. This is the main reason student work suffers.
- Time/task management
- Problem solving skills
    - Not just math, but the approach to any problem.
- Reflection
    - No big write up necessary. “Did I work to my best today?”
- Take initiative with your learning.
    - You have the course materials for the entire semester. Use them.
- Personal workspace (outside of class)
- Goal setting
- Ask questions during class lessons.
    - Seek your own answers before asking the teacher during work time.
- Ask for feedback
- Use of course resources
    - It is all there. Everything. Go forth, learn.
- Embrace mistakes and learn from them

The Eight Science and Engineering Practices (NGSS)

Learning Target	Description
SEP1: Asking Questions and Defining Problems	A practice of science is to ask and refine questions that lead to descriptions and explanations of how the natural and designed world(s) works and which can be empirically tested. Engineering questions clarify problems to determine criteria for successful solutions and identify constraints to solve problems about the designed world. Both scientists and engineers also ask questions to clarify ideas.
SEP2: Developing and Using Models	A practice of both science and engineering is to use and construct models as helpful tools for representing ideas and explanations. These tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations. Modeling tools are used to develop questions, predictions, and explanations; analyze and identify flaws in systems; and communicate ideas. Models are used to build and revise scientific explanations and proposed engineered systems. Measurements and observations are used to revise models and designs.
SEP3: Planning and Carrying Out Investigations	Scientists and engineers plan and carry out investigations in the field or laboratory, working collaboratively as well as individually. Their investigations are systematic and require clarifying what counts as data and identifying variables or parameters. Engineering investigations identify the effectiveness, efficiency, and durability of designs under different conditions.
SEP4: Analyzing and Interpreting Data	Scientific investigations produce data that must be analyzed in order to derive meaning. Because data patterns and trends are not always obvious, scientists use a range of tools—including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Scientists identify sources of error in the investigations and calculate the degree of certainty in the results. Modern technology makes the collection of large data sets much easier, providing secondary sources for analysis. Engineering investigations include analysis of data collected in the tests of designs. This allows comparison of different solutions and determines how well each meets specific design criteria—that is, which design best solves the problem within given constraints. Like scientists, engineers require a range of tools to identify patterns within data and interpret the results. Advances in science make analysis of proposed solutions more efficient and effective.
SEP5: Using Mathematics and Computational Thinking	In both science and engineering, mathematics and computation are fundamental tools for representing physical variables and their relationships. They are used for a range of tasks such as constructing simulations; solving equations exactly or approximately; and recognizing, expressing, and applying quantitative relationships. Mathematical and computational approaches enable scientists and engineers to predict the behavior of systems and test the validity of such predictions.
SEP6: Constructing Explanations and Designing Solutions	The end-products of science are explanations, and the end-products of engineering are solutions. The goal of science is the construction of theories that provide explanatory accounts of the world. A theory becomes accepted when it has multiple lines of empirical evidence and greater explanatory power of phenomena than previous theories. The goal of engineering design is to find a systematic solution to problems that is based on scientific knowledge and models of the material world. Each proposed solution results from a process of balancing competing criteria of desired functions, technical feasibility, cost, safety, aesthetics, and compliance with legal requirements. The optimal choice depends on how well the proposed solutions meet criteria and constraints.
SEP7: Engaging in Argument from Evidence	Argumentation is the process by which evidence-based conclusions and solutions are reached. In science and engineering, reasoning and argument based on evidence are essential to identifying the best explanation for a natural phenomenon or the best solution to a design problem. Scientists and engineers use argumentation to listen to, compare, and evaluate competing ideas and methods based on merits. Scientists and engineers engage in argumentation when investigating a phenomenon, testing a design solution, resolving questions about measurements, building data models, and using evidence to evaluate claims.
SEP8: Obtaining, Evaluating, and Communicating Information	Scientists and engineers must be able to communicate clearly and persuasively the ideas and methods they generate. Critiquing and communicating ideas individually and in groups is a critical professional activity. Communicating information and ideas can be done in multiple ways: using tables, diagrams, graphs, models, and equations as well as orally, in writing, and through extended discussions. Scientists and engineers employ multiple sources to obtain information that is used to evaluate the merit and validity of claims, methods, and designs.

Assessment and Evaluation

Outcomes will be graded from 1 to 6. That grade will be based on evidence from multiple sources including all or some of the following: observations, conversations, formative, and summative assessments.

Expert: Demonstration of a deep/thorough understanding of the concept	**6**	• Chose an appropriate strategy. • Successfully applied the necessary background skills and proper concepts to complete solutions. • Solutions contained no minor mistakes, or a summative contains at most two. • Clearly and concisely explained how to solve the problem using appropriate vocabulary, diagrams, and a coordinate system. "Did I show my work?" • Evaluated the reasonableness of my answer. "Does this make sense for the situation?" • Concept understood to a high degree to teach it to someone else. • **Concept can be applied to new problems.**
	5	• Chose an appropriate strategy. • Solution(s) contained an error(s) related to a background skill. • The concept can be explained using appropriate vocabulary. • **The concept can be applied successfully in known problems.**
Apprentice: Good/Satisfactory understanding of the concept	**4**	• Chose an appropriate strategy. • A solution contained a concept error. A summative contained at most two such errors. • Minor mistakes and background skill errors are common. • Explanations of a problem contained *mostly* appropriate terminology. • Mistakes were identified and corrected after referring to a key. • **More practice is needed solving this type of problem**.
	3	• Chose an appropriate strategy. • Solution(s) contained a combination of concept errors, errors related to background skills and minor mistakes. • A lack of necessary background skills to solve problems. • Notes, examples, or help was needed to solve problems. • Explanations did not contain proper terminology. • **Help from an expert is required solving this type of problem**.
Novice: Minimal-to-no understanding of the concept	**2**	• Incorrect strategy(ies) chosen for a problem(s). • Step-by-step instructions are required to solve problems. • Tasks could not be performed to an acceptable standard. • **Consistent extra help from an expert is required**.
	1	• Basics of what was needed to solve the problem was not known. • Solution left blank; first step not known. • **Teaching by an expert is required**.

Learning Category	**Classification Level**	**Only shortly before report cards will a percentage mark be determined**		
Expert	6	95 – 100		
	5	86	90	94
Apprentice	4	73	80	85
	3	60	66	72
Novice	2	50	56	59
	1	0	25	49

Students will log their grades in their Physics Book. The overall grade is guided with the calculation of the *median* and *mean* of all grades.

*Reassessing outcomes is encouraged, and times will be made available during the semester.
*No traditional final exam. Reassessment is possible.

Course Outcome Tracking

Physics 112 Unit/Outcome	Description	Grade	Physics 122 Unit/Outcome	Description	Grade
1.1 & 1.2	Define and identify scalars and vectors. Classify each of quantity listed in outcome 1.2 as a scalar or vector. Recognize and define position, displacement, distance, velocity, speed, acceleration, force, and their units.		**6.1**	In depth quantitative analysis of a projectile motion.	
1.3	Graphically analyze one-dimensional relationships among position, velocity, acceleration, and time.		**6.2**	Applying Newton's Laws of motion for objects on an incline plane.	
1.4	Mathematically analyze the relationship among position, velocity, acceleration, and time in 1D.		**6.3**	Learn and apply the concept of net torque to solve static equilibrium problems.	
2.1	Measuring vectors and the resultant position for 2D vectors using a scale diagram.		**6.4**	Collisions and explosions in one and two dimensions.	
2.2	Calculating perpendicular components of vectors.		**7.1**	Qualitatively and quantitatively analyze circular motion using vectors and Newton's laws.	
2.3	Calculating vectors (magnitude and direction) given the components.		**7.2**	Quantitatively apply Newton's law of gravitation and Kepler's third law of planetary motion to solve problems. Identify and explain Kepler's three laws of planetary motion.	
2.4	Mathematically analyze the relationship among displacement (position), velocity, acceleration, and time in 2D.		**8.1**	Qualitatively and quantitatively analyze electric charge and electric fields, including Coulomb's Law.	
2.5	Vector addition and solving for missing vectors.		**8.2**	Quantitatively analyze electric circuits. Concepts include Ohm's Law, series and parallel circuits, and electrical power.	
3.1	Explain, describe, and analyze the forces of gravity and friction. Including the types and causes of friction, the coefficient of friction, and determining normal force given the situation in one dimension.		**8.3**	Qualitatively analyze magnetism including magnetic poles, fields, and moving charges.	
3.2	Describe and apply Newton's 3 Laws of motion within inertial and non-inertial frames of reference in one dimension.		**9.1**	Climate Literacy and Science. Separate resources will be issued. (In Development)	
3.3	Qualitatively and quantitatively analyze the various types of forces including friction, normal, gravitational, applied, tension, and the concept of net force in two dimensions.				
4.1	Define and apply the concept of work incorporating the following: kinetic, gravitational potential, and elastic potential energy.				
4.2	Qualitatively and quantitatively analyze the conservation of mechanical energy with conservative and non-conservative forces.				
5.1 – 5.6	The following outcomes relate foundational information of the types of EM radiation (radio waves, light, x-rays, etc.).	N/A			

Overall Course Grade

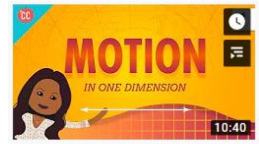
- Calculate your *median* by arranging your grades from lowest to highest. The grade in the middle is *likely* your overall grade. If there is no exact middle number, average the two middle numbers.
- Calculate your mean by adding all the grades up and divide by how many there are.
- Use a pencil, if you are writing your grades here because grades will fluctuate over the semester.

Median = _______ Mean = _______

Example Percent Determinations

Median	Mean	Percent	Reason
4	3.8 – 4.2	80 %	Median and mean match or are close
	4.3 or higher	85 %	Mean is much higher than median
4	3.7 or lower	73 %	Mean is much lower than median

Crash Course Physics & Kahn Learning Academy: These are a series of YouTube videos produced by certified scientists and educators. They are suggested viewing material to complement many of the concepts introduced in Physics. The digital version of this document contains a link to the videos, otherwise a search of YouTube will find the video or related videos.



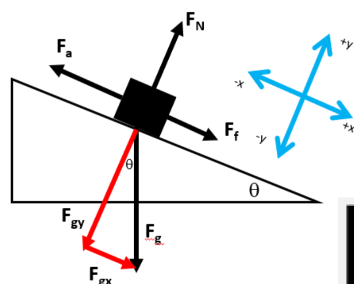
Outcome 6: Extension of Kinematics & Dynamics in 2D

Projectile Motion: The only force acting on a launched object is gravity (we assume no air resistance).

- When launched at an angle, the projectile's velocity will have a horizontal, x, and vertical, y, component. Solving these problems requires the application of kinematic equations in each dimension separately.
- Since gravity only affects the vertical direction, there are no forces, hence no acceleration, in the horizontal direction.
- Horozintal and vertical motion occur within the same time interval, *t*, so time is the link between the motion in each dimension.
- **Range**: The horizontal position where the projectile lands, d_{fx}. The maximum range occurs for angles of 45°, and if landing at the same vertical position as it was launched, complementary angles (angles that add to 90°) have the same range.
- At maximum height the projectile is changing directions so the instantaneous velocity is zero.

Projectile Motion

Forces on an Incline: If the object is on an incline or ramp the coordinate system is rotated the same degree as the angle the ramp is to the ground, then it is the force of gravity that is broken into components. The trigonometry yields the following based on the plane of the ramp being the x-axis:

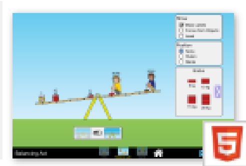


$F_{gx} = F_g sin\theta$
$F_{gy} = F_g cos\theta$

Connected Masses on a Ramp: Break the appropriate forces into components and then apply Newton's 2nd Law but now we include the sum of all the masses that accelerate. Picture the problem stretched out in one dimension to determine the direction of forces. Forces of tension are equal and opposite and cancel out when adding all forces. To find the force of tension, apply Newton's 2nd Law to one of the masses.

Ramp: Forces and Motion

Torque: Think of this as rotational power. When an object is made to rotate around a pivot point by a force acting on a lever arm (think prying something loose or a playground see-saw), that rotation is a result of a torque being applied. It is also the turning or twisting effectiveness of a force. The sign of a torque depends on which way a force would rotate an object. clockwise rotation is negative torque and counterclockwise is positive torque.



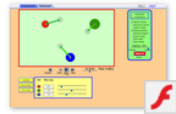
Balancing Act

Net Toque: The sum of all the torques acting on an object, incorporating all the rotational directions.

Static Equilibrium: If a system is said to be in static equilibrium, then the net force and net torque are zero. Often, solving such problems requires the use of net torque first because there are too many unknown force variables. By making the pivot point at the location of an unknown force, the net torque analysis eliminates that unknown force from the mathematical equation, allowing for another force to be calculated.

Center of Mass: If able to rotate freely, an object rotates about its center of mass. Objects (like a beam) can be analyzed as if all its mass is contained at one point.

Linear Momentum: An object's tendency to continue on-course, that is, to continue to move in the same direction. Momentum is directly proportional to the object's speed and mass, so the greater the mass and speed, the higher the momentum. The direction of an object's momentum is the same as its velocity, so objects traveling in different directions will have opposite signs.



Collision Lab

Elastic Collision: One in which objects separate after colliding. Kinetic energy is conserved.

Inelastic Collision: One in which objects stick together after colliding. Kinetic energy is not conserved. Collision can be perfectly elastic, inelastic, or anything in-between.

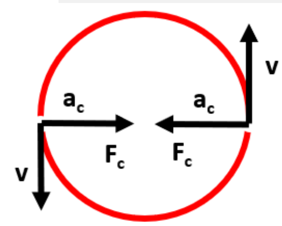
Conservation of Momentum: When two, or more, objects interact (collide) the total momenta before and after the collision is conserved. That means momentum cannot be lost or gained. Momentum is conserved in all dimensions and velocities must be broken up into perpendicular components to allow for the mathematical analysis if each dimension. If an object explodes, the momentum of all the individual pieces must add to zero, assuming the object was at rest before in exploded.

Outcome 7: Circular Motion & Universal Gravitation

Uniform Circular Motion: Motion in a circular path at a constant speed, centered at one point. Note that it is not constant velocity because in a circle the direction continually changes. Because the direction continually changes, objects in circular motion are accelerating. The velocity as also called tangential velocity because it is always pointing at a tangent to the circular path.

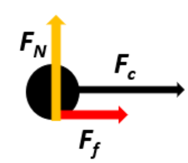
Radial Direction: When considering circular motion, any vector that is on a line that passes through the center of the circle. Vectors do not need to point towards the circle to be considered radial, just have to line up with the center.

Centripetal Acceleration: The acceleration of an object moving in a circle. It always points towards the center of the circle (with is the direction of the change in velocity) and is perpendicular to the object's velocity.

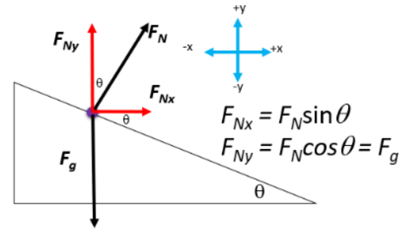


Centripetal Force: Any net force causing circular motion. It is directed towards the center of the circle. For an object to travel a circular path at a specific velocity, a certain amount of centripetal force is required. For example, the force of gravity provides the centripetal force for the Moon to travel about the Earth. Or swing a ball on a rope too fast and the rope could break because it was not designed to provide a centripetal force high enough. Travel around a corner too fast in a car and friction between the road and tires might not be high enough to maintain the circular motion and the car could leave the road.

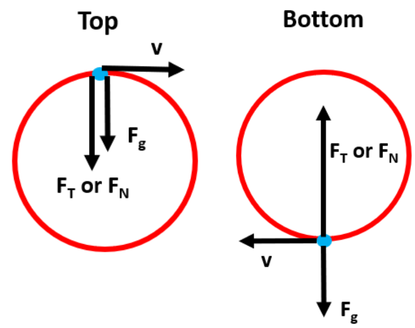
Unbanked Turn: When an object makes a circular turn on horizontal, level ground. The centripetal force for the turn comes from the force of static friction between the object and the ground. If it is a car, for example, it is the force of static friction between the tires and the road.



Banked Turn: When an object travels around a turn and that turn makes an angle with the horizontal, it is possible for the object to navigate the turn without relying on friction. Because it is banked, part of the normal force is directed towards the center of the circle, and this force provides the centripetal force necessary to safely make the turn. When friction is taken into consideration, it is possible to safely make the turn at a higher maximum speed. In that case, there is a component of friction that points towards the center of the circle and one that points down to the Earth (the magnitude of the force of friction points down the banked turn). This is why many highway exit ramps, and race track corners, are banked.



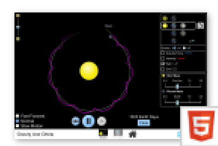
Vertical Circular Motion: This is considered when the object moves in a circle such that the force of gravity acts in the radial direction (so the object changes height above the Earth). The mathematics is similar, the difference being taking into account the force of gravity. The focus of interest will be the motion at the top and bottom of the circle. At the top, the object must have a minimum velocity to maintain the circular motion. At the bottom, the object would have a maximum velocity without breaking the string/rope (string tension is a maximum) or causing a person to suffer an injury (higher force on the body).



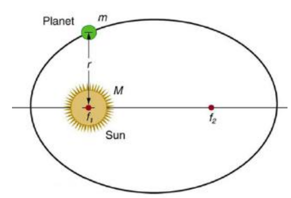
Universal Gravitation: Newton's work showed that the force of gravity is an attractive force proportional to the product of the two interacting masses and inversly proportional to the square of the distance between their centers. For this unit, assume all orbits are circular (the are actually ellipses) and the mass of the object in orbit is much, much lower compared to the mass of the other object (if the masses are comparable, then the object will orbit each other).

- **Orbital Velocity**: The tangential speed of the object about another object. It is perpendicular to the force of gravity.
- **Period**: The time to complete one full orbit.
- **Orbital Radius**: The distance between the centers of mass of each object.
- **Altitude**: The distance above the surface of the object in orbit.

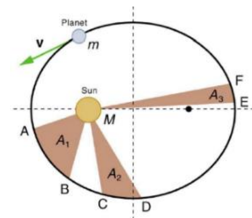
Gravity Force Lab: Basics


Gravity And Orbits

Kepler's 1st Law: The orbit of each planet about the Sun is an ellipse with the Sun at one focus. The Earth, for example, is closest to the Sun in January and farthest away in June. The difference of those distances for the Earth are small compared to the average distance between the Earth and Sun. Some objects, like comets, have very elliptical orbits so their surface temperatures vary greatly.



Kepler's 2nd Law: Each planet moves to that an imaginary line drawn from the Sun to the planet sweeps out equal areas in equal times.



Kepler's 3rd Law: For any system where objects orbit about another object that has a much greater mass, i.e., like the Moon or any satellites orbiting the Earth, the ratio of the squares of the periods for any two satellites is equal to the ratio of the cubes of their average distances from the central body. This comes out of applying the concepts and mathematics of circular motion and Newton's equations for the force of gravity.

Outcome 8: Electromagnetic Forces & Fields

Electromagnetic Force: One of the four fundamental forces of nature. It consists of the static electricity, moving electricity, and magnetism. All atomic and molecular interactions (like friction, chemical reactions, physical properties like boiling points) are manifestations of the electromagnetic force.

Electric Charges: Protons are positively charged particles and electrons are negatively charged. Objects can become charged by gaining or losing electrons. Protons are fixed within the nucleus of atoms and the atoms, nor protons, are free to move in materials.


Balloons and Static Electricity

Law of Charges: There are two types of charges, positive and negative. Opposite charges attract, like charges repel, and both positively and negatively charged objects attract neutral objects by *polarizing* the charges in neutral objects.

Fundamental Charge, q: q = 1.60 x 10^{-19} C, measured in the SI unit of the coulomb, C. This is the charge of one electron and one proton. Any charged object is an integral multiple of the fundamental charge. Usually, this charge is thought of as an excess or deficit of electrons.

Quarks: While electrons do not have a substructure, high energy particle collision experiments have revealed that protons and neutrons are made of even smaller particles called quarks. There have been six types of quarks discovered, two of which, **Up** and **Down** quarks, make up protons and neutrons. Unexpectically, quarks have been shown to have a partial electrical charge. Up quarks have a charge of $+\frac{2}{3}q$, and down quarks a charge of $-\frac{1}{3}q$.

- Proton = 2 Up + 1 Down = $+\frac{2}{3}q + \frac{2}{3}q - \frac{1}{3}q = +1q$
- Neutron = 1 UP + 2 Down = $+\frac{2}{3}q - \frac{1}{3}q - \frac{1}{3}q = 0q$

Law of Conservation of Charge: In any process, the total charge is constant. That means charge cannot be destroyed or created when objects interact.

Antimatter: A particle that has the same properties as a "normal" particle except it has an opposite charge. When a particle and its antimatter counterpart collide, they annihilate one another releasing a burst of energy. The anti-electron, called the positron, behaves like an electron but has a positive charge. The anti-proton is the counterpart to the proton and is made of 2 up antiquarks and 1 down antiquark. Interestingly, one of physics' biggest questions is, "*where is all the antimatter in the universe?*" as particles and anti-particles are created at the same time.

Electrical Conductor: A material that allows for the movement of valence electrons. Electrons collide with atoms or molecules in common conductors, resulting in some energy loss. The amount of energy loss varies by material. Metals and salt water are common examples.

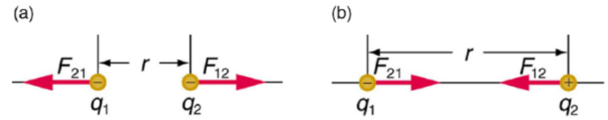
Superconductor: These allow for the movement of charge without any loss of electrical energy.

Electrical Insulator: A material that inhibits the movement of valence electrons. Some common examples are plastic, glass, rubber, and pure water.

Induction: This is a method of creating an electric charge on an object without direct contact. Devices that can charge batteries without contact were developed using this foundational concept (such devices also use *magnetic* induction).


Balloons and Static Electricity

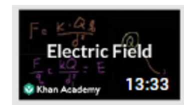
Electric Polarization: When a neutral object is made to have two regions of charge, one positive and one negative. This is usually the result of a charged object being placed near the neutral object. This is the reason charged object attract neutral objects.



Coulomb's Law: A mathematical foundation for calculating the force of electric attraction or repulsion. Named after Charles Coulomb who spearheaded much of the research of static electricity. The electric force is a vector, and each charged object applies a force on all other charges. Newton's 3rd Law still holds, and a reference charge experiences a force equal and opposite to the force it provides on another charge. (video is electrostatics).

Field: A field is a way of visualizing and tracking a force that acts over a distance (non-contact forces like gravity, electric and magnetic forces). Fields are represented by lines and the more lines per unit area the greater the force acting on a reference, or test, object.

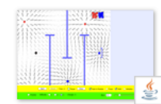
Electric Field: The region around a charged object, Q, that affects the motion of a positive test charge. Mathematically, its strength is the ratio of the Coulomb force to the positive test charge.



Electric Field Lines: Used to visually represent the electric field strength on a positive test charge from a charge, Q. The greater the field strength the more lines per unit area and arrows are used to indicate the direction of the electric force. Since the test charge is always positive, arrows always point toward negative Q-charges and away from positive Q-charges. The five electric field line properties (rules) are summarized below:


Charges and Fields

1. Field lines must begin on positive charges and terminate on negative charges, or at infinity in the hypothetical case of isolated charges.
2. The number of field lines leaving a positive charge or entering a negative charge is proportional to the magnitude of the charge.
3. The strength of the field is proportional to the closeness of the field lines, i.e. it is proportional to the number of lines per unit area perpendicular to the lines.
4. The direction of the electric field is a tangent to the field line at any point in space.
5. Field lines can never cross. The field is unique at any point, so a test charge does not have a "choice" on how to move.

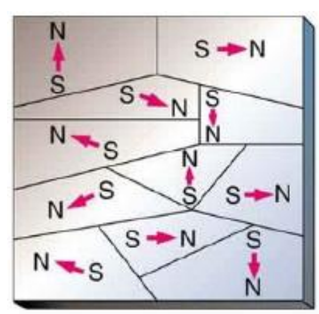

Electric Field Hockey

Electric Current: The rate at which a charge moves, measured in amperes (A, which is C/s).

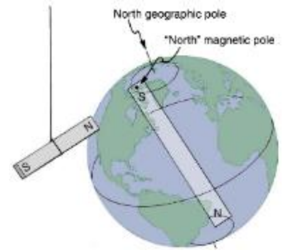
Conventional Current: The direction that a positive charge would flow. In wires, made of metal, positive charges do not move, and it is the negative electrons that flow. Lightning is another example of a discharge of electrons. However, positive ions can move in fluids and biological systems, so it is not only electrons that can create a current.

Magnetism: The result of moving charged particles. Within a solid magnet, this is the result of electron motions within the atom. When electrons are forced through a conducting wire, that motion creates a magnetic field. A magnet is created in a material when its magnetic domains all line up.

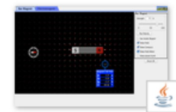
Magnetic Domains: Small regions within a materal where there has been a polarization of charge. The existance of these regions do not make a material a magnet, but if all of these regions allign, or are made to allign, then a magnet is created. The poles of a magnet line up with the poles of the magnetic domains and are named north and south poles.



Electromagnetic Force: The name given to all the forces that result from the motion of charged particles.



Magnetic Poles: The opposite ends of a magnet (or magnetic domains) and always occur in pairs. Slicing a magnet into smaller and smaller pieces creates smaller magnets with a north and south pole. Like poles repel and opposite poles attract. The Earth's core produces a large magnetic field with poles near the geographical north and south poles. Note that the geographical north pole and the magnetic south pole. The poles are defined based on what direction the north end of a compass points.

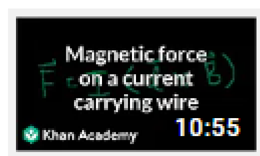


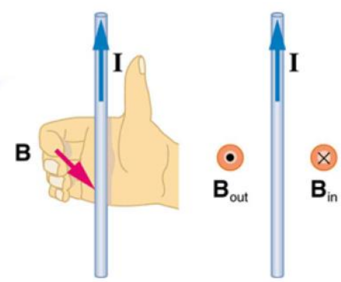
Magnets and Electromagnets

Electromagnet: Created by wrapping an electrically conductive wire around a metal (ferromagnetic) material. A current through the wire will produce a magnetic field and temporarily magnetize the metallic core. Within the core, there is an internal alignment of electron spins. The current creates a magnetic dipole.

Magnetic Field Lines: A visual representation of the magnetic field strength, the *B-field*. The direction of the field lines is defined to be the direction in which the north end of a compass needle points. The magnetic field strength is represented by the variable ***B*** and is measure in units of Tesla, *T*, or Gauss, *G*. The four rules for magnetic fields are:

1. The direction of the magnetic field is tangent to the field line at any point in space. A small compass will point in the direction of the field line (so to the south pole).
2. The strength of the field is proportional to the closeness of the line. It is exactly proportional to the number of lines per unit area perpendicular to the lines (called the areal density).
3. Magnetic field lines can never cross, meaning the field is unique at any point in space.
4. Magnetic field lines are continuous, forming closed loops without a beginning or end. The go from north pole to the south pole. (note this is different from electric field lines that begin at a positive charge and end at a negative charge)

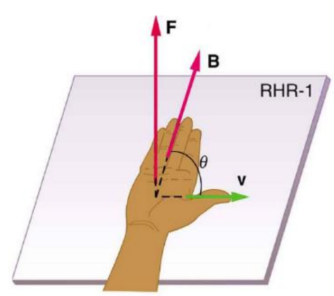




Right Hand Rule 2 (RHR-2): The direction of the magnetic field generated by a current is perpendicular to the direction of the current. The RHR-2 is a way to help remember and visualize the magnetic field (it is called RHR-2 because there is another right-hand-rule for a charge moving through a magnetic field). Picture the wire being held in your right-hand fingers with your thumb pointing in the direction of the current. Your fingers curl in the direction of the magnetic field, ***B***. Note the symbols used to represent the direction of the magnetic field for a current in a wire.

Lorentz Force: This is the name of the force applied on a moving charge from a magnetic field. The force is directly proportional to the charge on the moving object, its velocity and the magnetic field strength. The Lorentz force is perpendicular to the magnetic field and the force on a negative charge is in the exact opposite direction to that on a positive charge.

Right Hand Rule 1 (RHR-1): To determine the direction of the magnetic force on a positive moving charge, you point your thumb of the right hand in the direction of ***v***, the fingers in the direction of ***B***, and a perpendicular to the palm points in the direction of ***F***. There are no magnetic forces on a static (stationary) charge, only moving ones. Electric fields do not affect magnetic fields unless the charge is moving.



$F = qvB \sin\theta$

$\mathbf{F} \perp$ plane of $\mathbf{v}$ and $\mathbf{B}$

Outcome 6.1: Qualitative and quantitative analysis of a projectile on earth.

1. Neglecting air friction, how does increasing the mass of a projectile affect its maximum height and range if no other initial conditions are changed?

2. Mars has an acceleration due to gravity that is about 1/3rd that of Earth. How would the trajectory on Mars compare to that on Earth for the same initial velocity and neglecting air resistance? Support your answer with an explanation.

3. An archer shoots an arrow at 159 m/s at an angle of 10^{o} up from the horizontal. The arrow hits a target located at the same height it was fired.
    a. Calculate the time it takes the arrow to land. {5.6 s}
    b. Calculate the maximum height reached by the arrow. {39 m}
    c. Calculate the range to the target. {877 m}

4. An airplane is traveling parallel to the ground at 55 m/s and an altitude of 925 m. The pilot is to drop a supply crate, from rest, into a target area.
    a. At what horizontal distance before the target drop zone, should the pilot release the crate? {756 m}
    b. Calculate the velocity with which the crate strikes the target. {146 m/s 68^{o} down from the horizontal}

5. A ball is kicked from the ground with a velocity of 16.0 m/s, 35^{o} up from the horizontal.
    a. Calculate the time to reach maximum height. {t = 0.935 s}
    b. Calculate the maximum height. {d_{fy} = 4.3 m}
    c. Calculate the time to land back on the ground. {t = 1.87 s}
    d. Calculate the range. {d_{fx} = 24.5 m}
    e. Calculate the velocity 1.2 seconds after the kick. {v_f = 13.3 m/s, 11^{o} down from the horizontal}

6. A marble rolls of a 1.8 m high table and lands 3.2 m from the base of the table. Calculate the velocity with which the marble left the table. {v_x = 5.3 m/s}

7. A ball is thrown from a height of 2.1 m. 2.5 seconds later, the ball is caught at a height of 0.75 m, 15 m from where it was thrown.
    a. Calculate the initial velocity of the ball. {v_o = 13.2 m/s, 63^{o} up from the horizontal}
    b. Calculate the maximum height of the ball. {d_{fy} = 9.1 m}
8. A ball is thrown to a location (d_{fx}, d_{fy}) = (42 m, 3.5 m) from position (0, 0). The launch angle was 55^{o} up from the horizontal.
    a. Calculate the time to reach that position. {t = 3.4 s}
    b. Calculate the launch velocity. {v_o = 21.5 m/s}

9. A person is atop a 75 m cliff and throws a rock 20^{o} *down* from the horizontal. The rock is to land on the ground, 45 m from the base of the wall.
    a. Calculate the launch velocity necessary. {v_o = 13.8 m/s}
    b. Calculate the time to reach the final location. {t = 3.46 s}

10. A projectile fired at an angle strikes a target 8.42 seconds later. The range was 1260 m and the projectile landed at the same height it was launched. Calculate the launch velocity of the projectile. {155 m/s 15^{o} up from horizontal}

11. A ball is thrown from the top on a building towards the wall of a second building 15.2 m away. The initial velocity 6.5 m/s at an angle of 20° down from the horizontal. How far below its original position did the ball hit the other building? {d_f = 35.9 m below launch height}

12. A hockey puck is hit at a 45° angle and lands 35 m away. Calculate the launch velocity of the puck. {v_o = 19 m/s}

13. A baseball is hit and just clears the fence that is 3.5 m high and 110 m from the position where the ball was hit. Calculate the initial speed of the ball if the launch angle was 52° above the horizontal. {33 m/s}

14. Calculate the angle to hit a golf ball so that it will land in the hole 156 m away. The ball is hit with an initial velocity of 42 m/s and the hole is the same height as the golf ball. {θ = 30° or 60°}

15. A cannon on a battleship is located at the bow {front} of the ship and facing straight ahead in the direction the ship is moving. The cannon is positioned 8.5 m above the water, angled 30° up from the horizontal and fires at 75 m/s. Relative to the water the ship is moving 12 m/s towards a stationary target. Calculate the range of the cannon. {606 m}

16. Calculate the angle(s) to kick at ball with 22 m/s of speed, such that it lands 35 m away. {θ = 23° or 67°}

17. Calculate the angle(s) to shoot a cannonball with 120 m/s, such that it lands 1250 m away. {θ = 29° or 61°}

18. A cannon is located on a cliff 51 m above the ground and launches a cannonball at 82 m/s. Calculate the angle(s) necessary to hit a target on the ground located 700 m from the base of the cliff. {θ = 33° or 53°}

19. An arrow is to hit a target located at (d_{fx}, d_{fy}) = (72 m, 23 m) from initial position (0, 0). The launch speed is 65 m/s. Calculate the launch angle(s). {θ = 23° or 85°}

20. You need to launch a T-shirt to a fan located 4.8 m above you and a horizontal distance from you of 12 m. Your shirt cannon fires at 15 m/s. Calculate the angle up from the horizontal to shoot the T-shirt towards the lucky fan. {θ = 40° or 71°}

21. *Suppose you are trying to throw a ball at the exact spot your friend will be while she is running. You both start at the same position, and she runs at a constant 4.1 m/s in a straight line for 3.0 seconds before you throw the ball at 25° up from the horizontal. The ball is caught at the same height it was thrown. Calculate the speed at which you need to throw the ball. {v_o = 15 m/s}

22. *Assume $d_{oy} = d_{fy}$, if you double the launch speed of a projectile, by what factor will that effect the travel time?

23. *Assume $d_{oy} = d_{fy}$, if you double the launch angle of a projectile {keeping $0 \le \theta \le 45°$}, by what factor will that effect the travel time?

24. *Show mathematically that the trajectory (height as a function of horizontal position) of a projectile is parabolic.

25. *Show mathematically that two complementary angles will result in an equal range for the case $d_{oy} = d_{fy}$.

26. *Derive a formula for the necessary launch angle if the target coordinates are (x, y) relative to the launch position and initial velocity *v*.

Outcome 6.2: Applying Newton's laws of motion for objects on an incline plane.

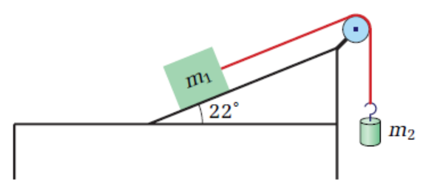
1. A 33 kg block is sliding down a 35° incline. The coefficient of kinetic friction is 0.13.
   a. Calculate the applied force up the ramp necessary so the block accelerates with a magnitude of 0.75 m/s^2 down the ramp. {$|F_a| = 126\text{ N}$}
   b. Recalculate to determine the applied force required to accelerate the block up the ramp at 0.75 m/s^2. {$|F_a| = 245\text{ N}$}

2. A 25 kg box is placed on a 33° incline. The coefficient of kinetic friction is 0.38. Calculate the acceleration of the box. {$|a| = 2.2\,\frac{m}{s^2}$}

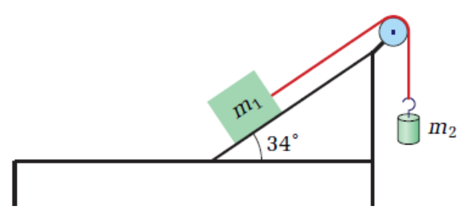
3. An inclined ramp is to be used to slide an object down at a constant velocity. The coefficient of kinetic friction is 0.38. Calculate the angle required for this to happen. {θ = 21°}

4. A counterweight is used to slide an object up an inclined plane that makes a 42° angle with the horizontal. The mass on the ramp is 40 kg. The coefficient of kinetic friction on the plane is 0.33.
   a. For the acceleration of the object to be 0.72 m/s^2 up the ramp, what must be the mass of the counterweight? {M_2 = 43 kg}
   b. Calculate the tension in the string. {$|F_T| = 388\text{ N}$}
5. A counterweight is used to help slide a 70 kg object *down* an inclined plane of 38°. The counterweight has a mass of 25 kg. The coefficient of kinetic friction on the plane is 0.21.
   a. Calculate the acceleration of the masses. {$|a| = 0.66\,\frac{m}{s^2}$}
   b. Calculate the tension in the string. {$|F_T| = 262\text{ N}$}

6. The block in the diagram has a mass of 14.5 kg and the freely hanging object has a mass of 8.5 kg. The coefficient of kinetic friction between the block and the ramp is 0.18 and the object will move up the ramp.
   a. Calculate the acceleration of the masses. {$|a| = 0.26\,\frac{m}{s^2}$}
   b. Calculate the tension in the string. {$|F_T| = 81\text{ N}$}

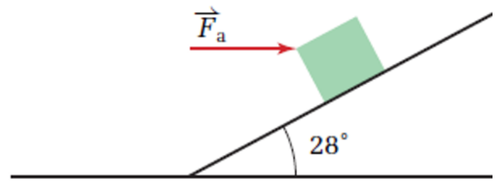


7. The block in the diagram has a mass of 7.25 kg and the hanging object has a mass of 5.95 kg. μ_s = 0.47 and μ_k = 0.12.
   a. What force, directed up the ramp, would you have to apply to the block to make the objects start to move? {$|F_a| = 9.1\text{ N}$}
   b. Calculate the acceleration of the masses assuming the same applied force up the ramp. {$|a| = 1.6\,\frac{m}{s^2}$}
   c. Calculate the tension in the string while the masses are accelerating. {$|F_T| = 49\text{ N}$}

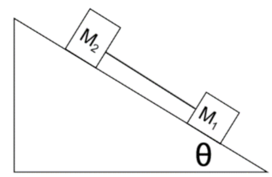


8. A 61 kg container sits on a ramp.
   a. If the coefficient of static friction is 0.68, at what angle of the ramp would the container just start to slide? {θ= 34°}
   b. If the coefficient of kinetic friction is 0.18, what would be the acceleration of the container at that angle? {$|a| = 4.0$ m/s^2}

9. A new worker in a warehouse is pushing an 85 kg crate up a ramp. $\mu_s = 0.75$. Instead of pushing directly up the ramp, the worker is pushing parallel to the ground.
   a. Calculate the applied force necessary to overcome static friction. $\{|F_a| = 1778\ \text{N}\}$
   b. An experienced worker tells the new worker to push directly up, parallel to the ramp. With this revelation, calculate the applied force necessary to overcome static friction. $\{|F_a| = 944\ \text{N}\}$



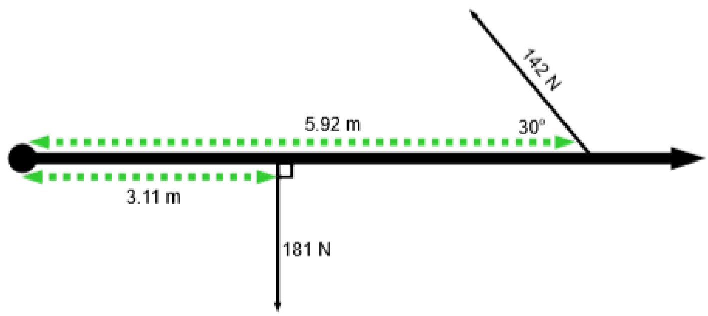
10. The masses in the diagram are connected by a massless string {compared to the mass of the objects}. $M_1 = 19$ kg, $M_2 = 13$ kg, $\theta = 24°$, $\mu_{k1} = 0.15$, and $\mu_{k2} = 0.22$.
    a. Calculate the acceleration of the masses. $\{|a| = 2.4\ \frac{m}{s^2}\}$
    b. Calculate the tension in the string. $|F_T| = 4.7\ \text{N}\}$



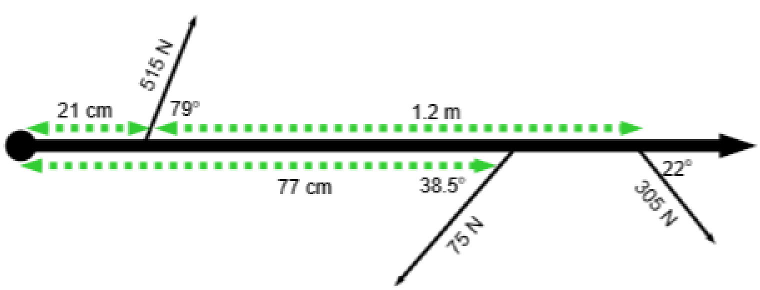
Outcome 6.3: Learn and apply the concept of net torque to solve static equilibrium problems.

A. Net Torque

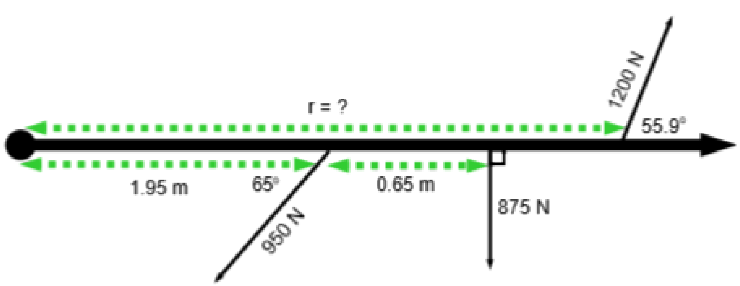
1. Calculate the net torque. $\{\tau_{net} = -143\ \text{Nm}\}$



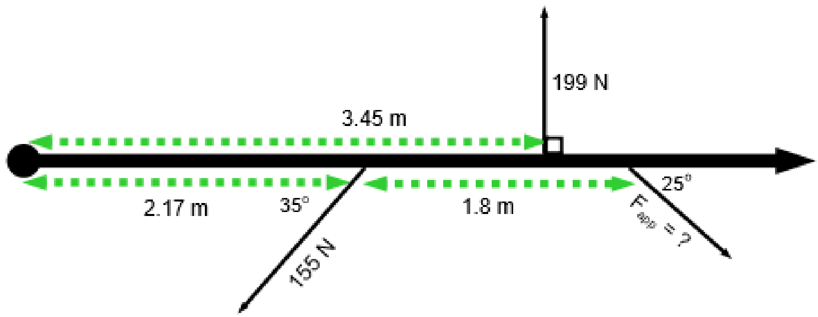
2. Calculate the net torque. $\{\tau_{net} = -91\ \text{Nm}\}$



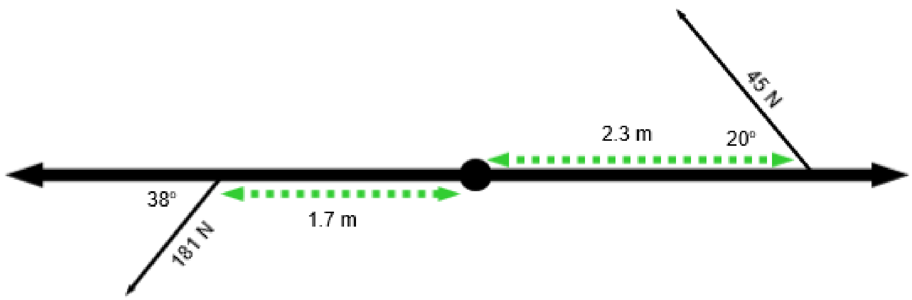
3. The net torque is zero, calculate the missing quantity. {r = 3.98 m}



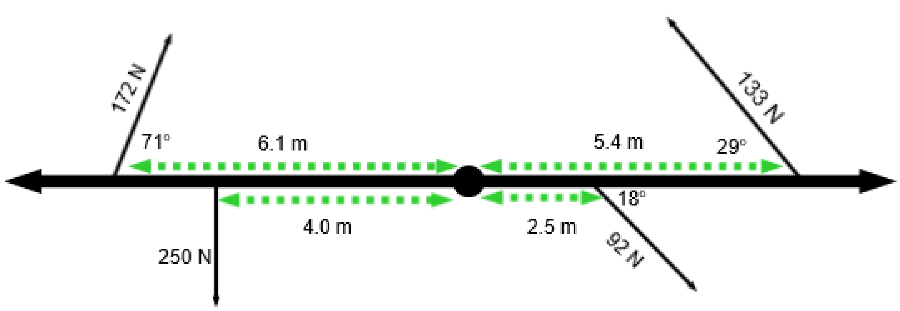
4. The net torque is zero, calculate the missing quantity. {F_{app} = 294 N}



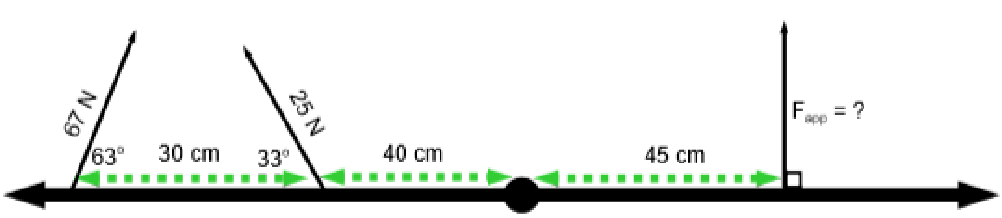
5. Calculate the net torque. {τ_{net} = 224 Nm}



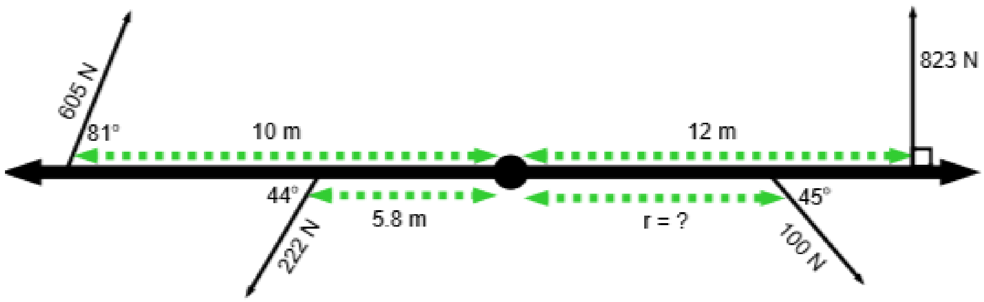
6. Calculate the net torque. {τ_{net} = 285 Nm}



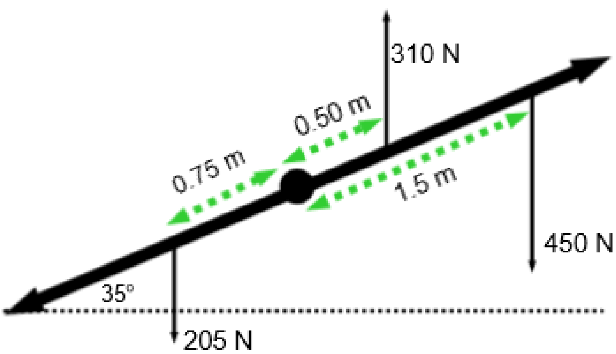
7. The net torque is zero, calculate the missing quantity. {F_{app} = 105 N}



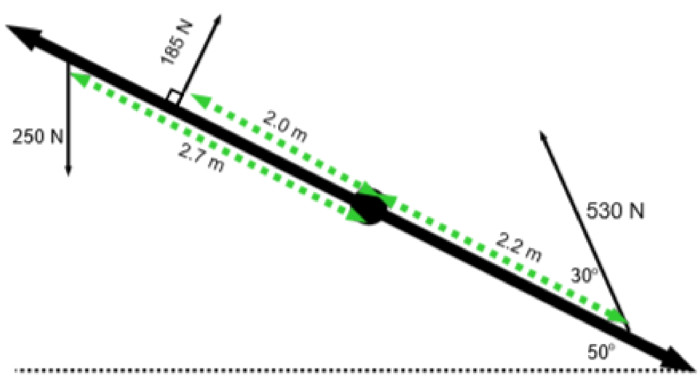
8. The net torque is zero, calculate the missing quantity; image not to scale. {r = 67.8 m}



9. Calculate the net torque if all the forces are perpendicular to the horizontal dashed line. {τ_{net} = –300 Nm}

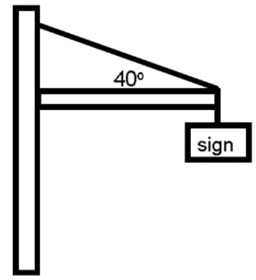


10. Calculate the net torque. The left-most force is perpendicular to the horizontal. {τ_{net} = 647 Nm}

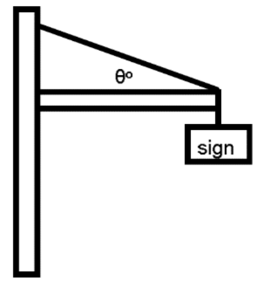


B. Static Equilibrium

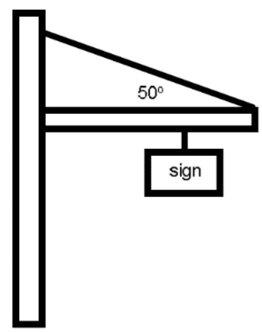
1. The beam has a mass of 170 kg and is 6.0 m long. The sign has a mass of 75 kg and is located at the end of the beam.
   a. Calculate the tension in the wire. {F_T = 2442 N}
   b. Calculate the force acting on the hinge, where the beam meets the pole. {F = 2048 N, 24° up from the horizontal}



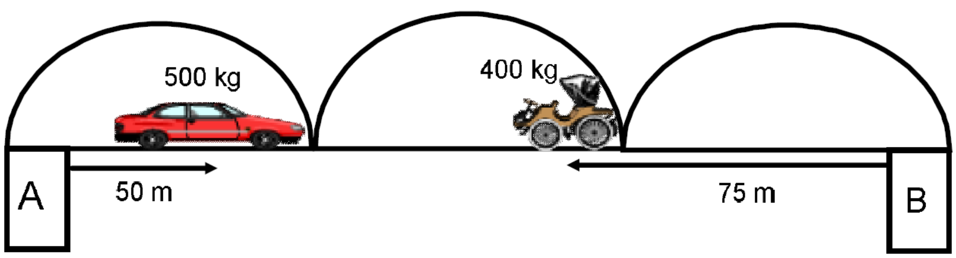
2. The cable in the diagram to the right will break if the tension reaches 1500 N. The beam is 15 m long and has a weight of 1050 N. The sign has a weight of 500 N.
   a. Calculate the smallest angle that can be made with the horizontal. {θ = 43°}
   b. Calculate the force acting on the hinge using the angle found above. {F = 1217 N, 26° up from the horizontal}



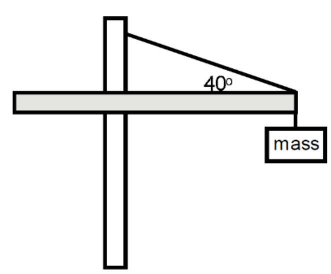
3. The cable will break under a stress of 2300 N. The beam is 150 kg and 8.0 m long. The object is located 5.5 m from the left end of the beam.
   a. Calculate the maximum mass that can be supported by the cable. {m = 152 kg}
   b. Calculate the force acting on the hinge. {F = 1904 N, 39° up from the horizontal}

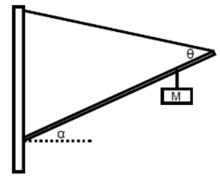


4. The bridge in the diagram below spans 225 m and has a mass of 8500 kg. Calculate the force each column supports. {F_A = 46942 N; F_B = 45272 N}

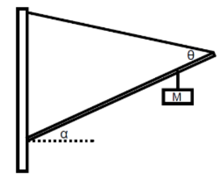


5. The boom of a crane {the beam} has a mass of 625 kg. The hinge is located 10 m from the left end and 15 m from the right end. The mass at the right end is 300 kg.
   a. Calculate the tension in the cable. {F_T = 6168 N}
   b. Calculate the force on the hinge. {F_h = 6960 N; 47° up from horizontal}
   c. If this beam did not extend to the left the tension would have been 7440 N. Explain why the tension is lower by having part of the boom on the opposite side of the pivot point.

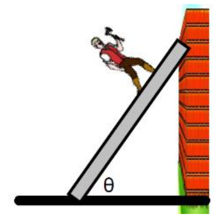




6. The cable in the diagram will break if the tension reaches 1800 N. The beam is 15 m long and has a mass of 60 kg and makes an angle of α = 30° with the horizontal. The cable makes an angle of 60° with the beam and the hanging mass is located 10 m from the hinge.
   a. Calculate the maximum mass that can be attached. {m = 230 kg}
   b. Calculate the force on the hinge for that mass. {F = 2493 N, 51° counterclockwise from the horizontal or 21° counterclockwise from the beam}



7. The cable in the diagram will break if the tension reaches 1074 N. The beam is 12 m long, has a mass of 72 kg and makes an angle of α = 40° with the horizontal. The hanging mass is located 8.5 m from the hinge and has a mass of 144 kg.
   a. Calculate the minimum angle that can be used to attach the cable to the beam. {θ = 75°}
   b. Calculate the force on the hinge for that angle. {F = 1742 N, 60° up from the horizontal or 20° up from the beam}



8. Calculate the coefficient of static friction necessary for the ladder not to slip along the ground. The ladder has a mass of 32 kg, the person has a mass of 44 kg, the ladder is 7.0 m long, the man is 5.5 m from the base of the ladder. The ladder makes an angle of 55° with the ground. There is no friction between the ladder and the wall. {μ_s = 0.47}

9. A 4.0 m long 25 kg ladder is leaning up against a wall and makes a 60° angle with the ground. A 75 kg person is 3.0 m up the ladder. The coefficient of static friction between the ladder and the wall is 0.72. For the ladder not to move, calculate the coefficient of static friction between the ladder and the ground. {μ_s = 0.35}

10. *A 10 m long 20 kg ladder rests against the side of a building. A 64 kg person needs to be 7.5 m up the ladder. The coefficient of static friction between the ground and the ladder is 0.46 and between the building and the ladder it is 0.58. Calculate the smallest angle that will support the person without slipping. {θ = 53°} *Hint*: Analyze the net force in *x* and *y* to determine the frictional forces, then apply static torque.

Outcome 6.4: Collisions and Explosions in 1D and 2D.

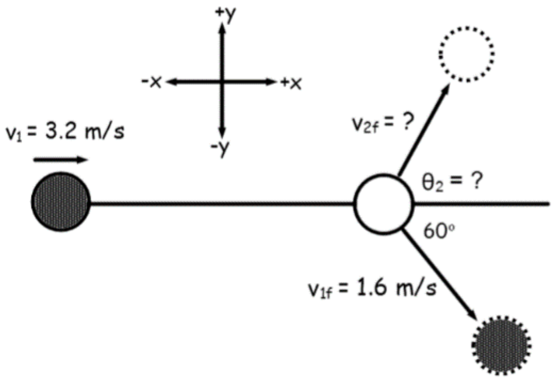
A. 1-Dimension

1. Two cars are heading directly towards each other. The mass of car A is 375 kg and a velocity of +1.8 m/s. The mass of car B is 422 kg with a velocity of –1.4 m/s. When they collide, they fuse together and continue to move in a straight line. Calculate their velocity immediately after they collide. {***v*** = +0.11 m/s}

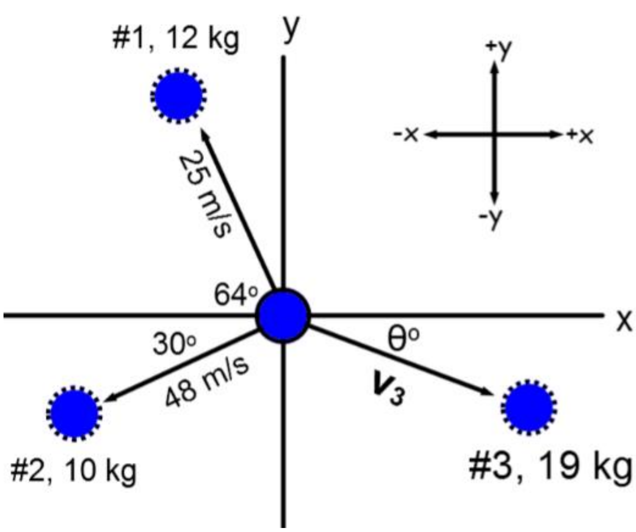
2. A 1385 kg cannon containing a 58.5 kg cannon ball is at rest. The cannon fires the ball with a velocity of 49.8 m/s, calculate the initial velocity of the cannon the instant after it fires the cannon ball. {***v*** = –2.7 m/s}

B. 2-Dimensions

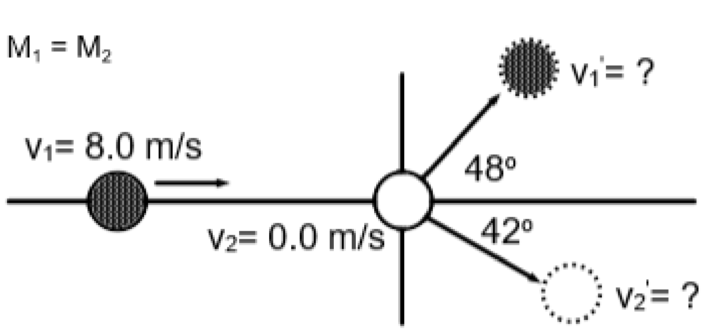
3. A pool ball traveling to the right strikes another, stationary ball. Each ball has the same mass. Use the information given in the diagram to calculate the velocity of pool ball #2. {$\boldsymbol{v_{f2}}$ = 2.77 m/s at 30° up from +x-axis}



4. An object explodes into three pieces. Given the information in the diagram below, calculate the velocity of the third piece. Note: the diagram may not be accurate in depicting the direction {quadrant} of the third piece. {$\boldsymbol{v_3}$ = 28.8 m/s at 3.1° down from +x-axis}

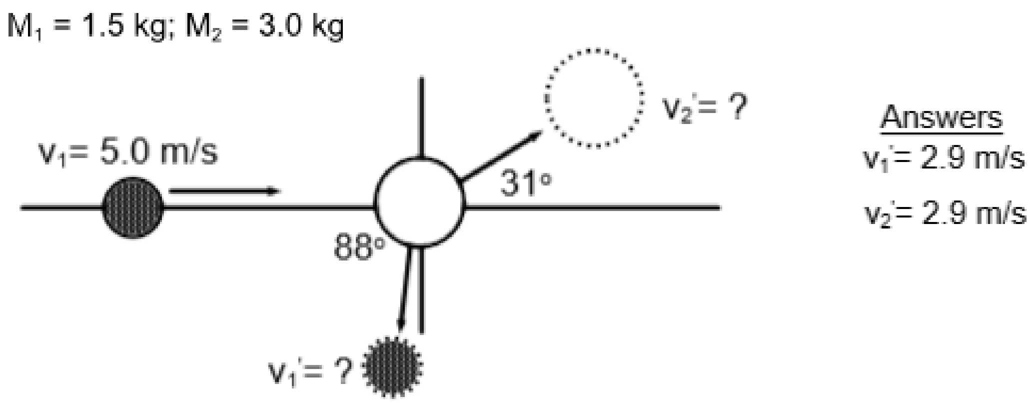


5. Calculate the velocity of each object after the collision.

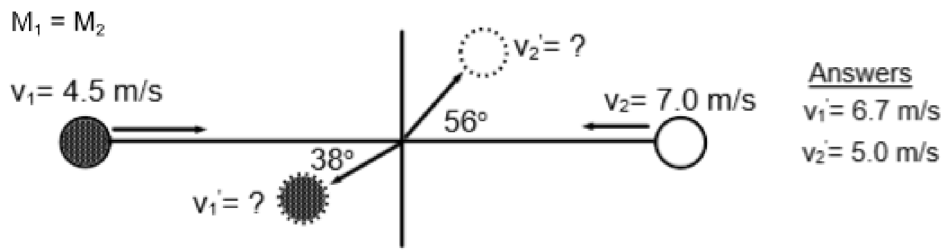


Answers
v_1'= 5.3 m/s
v_2'= 6.0 m/s

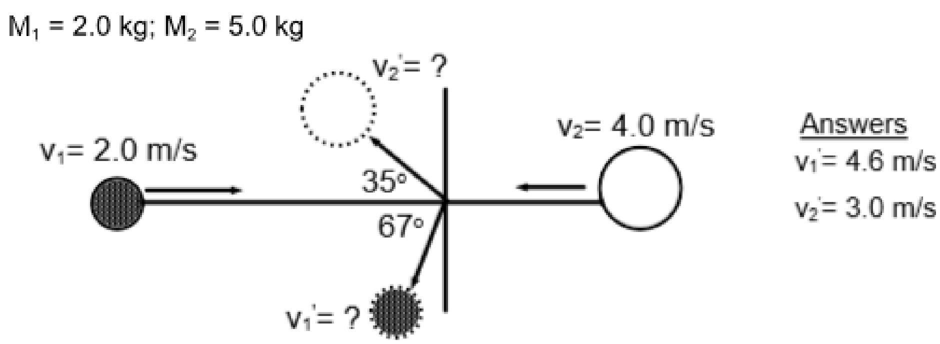
6. Calculate the velocity of each object after the collision.



7. Calculate the velocity of each object after the collision.



8. Calculate the velocity of each object after the collision.



Outcome 7.1: Qualitatively and quantitatively analyze circular motion using vectors and Newton's laws.

A. Horizontal, Uniform Circular Motion

1. A plane flying at a constant speed in a circular path of radius 5500 m completes one revolution every 485 seconds. Calculate the centripetal acceleration of the plane. {$a_c = 0.922\ m/s^2$}

2. A 1.2 kg stone attached to a 2.0 m long string is whirled in a horizontal circle. At what speed must the stone move for its centripetal acceleration to equal 9.81 m/s^2. {v = 4.4 m/s}

3. A mass of 0.50 kg is tied to one end of a rope and is swung in a circle of radius 1.0 m. The speed is 4.0 m/s. Calculate centripetal force. {$F_c = 8.0$ N}

4. A communications satellite has a period of 5600 s and an orbital radius of 6.8 x 10^6 m. If the mass is 2000 kg, calculate the centripetal force keeping the satellite in orbit. {F_c = 17 000 N}

5. A 1.5 kg ball on a string is swung in a horizontal circle. The string will break under a tension of 350 N. Calculate the maximum velocity of the ball if the string is,
   a. 0.5 m long {v = 10.8 m/s}
   b. 1.5 m long {v = 18.7 m/s}

6. A 50.0 kg satellite that is 7.00 x 10^6 m from the center of the Earth is orbiting at a speed of 1000 m/s. Calculate:
   a. The time it takes to orbit the Earth once. {T = 44 000 s}
   b. The centripetal acceleration of the satellite. {a_c = 0.143 m/s^2}
   c. The centripetal force keeping the satellite in orbit. {F_c = 7.14 N}

7. A boy holds a 0.25 kg toy 6.00 m from the center of a merry-go-round by means of a string. The toy has a tangential velocity of 3.0 m/s.
   a. How long does it take the merry-go-round to make one revolution? {T = 12.6 s}
   b. Calculate the tension in the string. {F_T = 0.375 N}

8. The Moon has a mass of 7.4 x 10^{22} kg. It is 4.0 x 10^8 m from the center of the Earth and orbits the Earth every 2.4 x 10^6 seconds. Calculate:
   a. The velocity of the Moon. {v = 1050 m/s}
   b. The force needed to keep the Moon in orbit. {F_c = 2.03 x 10^{20} N}

9. A 1200 kg is traveling through a 90^o corner with a radius of 15.9 m. It takes the car 2.50 seconds to make the turn. Calculate:
   a. The velocity of the car. {v = 10.0 m/s}
   b. The centripetal acceleration of the car. {a_c = 6.28 m/s^2}
   c. The centripetal force acting on the car. {F_c = 7500 N}
   d. The maximum speed the car could make the corner at if the maximum force available between the tires and the pavement is 5000 N due to ice. {v = 8.14 m/s}

10. A 25 kg object is moving along a circular path at a constant speed of 4.0 m/s completes one trip around the circle in 5.0 seconds. The coefficient of static friction is 0.75.
    a. Calculate the radius of the circle. {r = 3.2 m}
    b. Calculate the acceleration of the object. {a_c = 5.0 m/s^2}
    c. Calculate the centripetal force and the force of static friction. {F_c = 125 N; F_f = 184 N}
    d. Calculate the farthest position the object can be placed and keep the circular motion {r = 4.7 m}

11. A 1750 kg truck is traveling through a 90^o corner with a radius 24.8 m. It takes the truck 3.17 seconds to make the turn driving at its maximum safe velocity. Calculate the coefficient of static friction between the tires and the road. {μ_s=0.62}

12. An amusement park ride consists of a large cylinder that rotates around a vertical axis. People stand on a ledge inside. When the rotational speed is high enough, the ledge drops away and people "stick" to the wall. If the period of rotation is 2.5 seconds and the radius is 3.5 m, calculate the minimum coefficient of friction required to keep the riders from sliding. {$\mu_s = 0.44$}

13. A circular platform is designed to spin horizontally {around a vertical axis} with a period of 1.6 seconds. How far from the center should a mass be placed to not fly off if the coefficient of static friction is 0.57? {r = 0.36 m}

14. A mass is to be placed 1.75 m from the center of a spinning platform. The coefficient of static friction is 0.41. Calculate the maximum frequency of the spinning platform such that the mass would not move. {f = 0.24 Hz}

15. A car rounds a 92 m radius corner without losing traction at a speed of 26 m/s. Calculate the coefficient of static friction between the tires and the road? {$\mu_s = 0.75$}

16. The maximum speed a car can have to safely take a turn is 30 m/s. On a cold morning ice has reduced the coefficient of static friction by a factor of three. Calculate the new maximum speed for the car to safely navigate the same turn under icy conditions. {v = 17 m/s}

17. A 3.50 mass with a kinetic energy of 43.75 J goes through a 90° corner with a radius of 1.25 m. If the centripetal force acting on the mass in the corner is 70.0 N, calculate the velocity of the mass as it leaves the corner. {5.00 m/s}

18. *An object starts at rest and is subjected to a force over 7.00 m. After the object is free of that force, a 224 N force can turn the object through a 90° corner with a radius of 0.25 m. Calculate the initial force. {$F_o = 4.0$ N}

19. *A model train car is coasting (no driving force) on a circular track. Initially the centripetal force necessary to keep the car going around the track is 5.0 N. If after the car has gone halfway around the circle the necessary centripetal force has been reduced to 1.86 N. Calculate the force of friction acting on the car. {$F_f = 0.50$ N}

B. Banked Curves

20. Without relying on friction, calculate the maximum speed a car can travel around a 120 m curve and banked at 18°. {v = 20 m/s}

21. Without relying on friction, calculate the angle necessary to bank a curve of 150 m such that cars can safely navigate it traveling 25 m/s. {$\theta = 23^{o}$}

22. A turn is to be banked at 25° for vehicles to navigate, without relying on friction, at 30 m/s. Calculate the required radius of the turn. {r = 197 m}

23. A 1575 kg airplane makes a 1325 m radius turn at 125 m/s.
    a. Calculate the bank-angle the airplane makes with the horizontal. {$\theta = 50^{o}$}
    b. Calculate the centripetal force acting on the airplane. {$F_c = 18\ 573$ N}
    c. Calculate the lift {the upward force perpendicular to the wings} on the airplane. {$F_{lift} = 24\ 245$ N}

24. For comfort, a passenger airplane keeps a low bank-angle of 12°. A 737 plane is traveling 225 m/s and needs to adjust course.
    a. Calculate the turning radius required. {r = 24 278 m}
    b. Calculate the centripetal force necessary for a 60 500 kg 737 plane to make that turn. {Fc = 126 156 N}
    c. Calculate the centripetal force experienced by a 75 kg passenger. {F_c = 156 N}
    d. Calculate the lift acting on the wings. {F_{lift} = 606 777 N}

25. A 125 m turn is to be constructed on Earth and on Mars. The maximum velocity for each turn is 15 m/s.
    a. Calculate, for each planet, the angles the turn needs to be banked at for vehicles to navigate the turn without relying on friction. {θ_{Earth} = 10°, θ_{Mars} = 26°}
    b. Why is a larger angle required for a banked turn on a planet with a lower acceleration due to gravity?

26. A 75 m turn is banked at 20°. The coefficient of static friction between the tires and road is 0.55. Calculate the maximum velocity to safely navigate the turn. {v = 29 m/s}

27. Vehicles will be taking a banked turn at 28 m/s. The bank will be made at an angle of 15° with the ground. With a coefficient of static of 0.65, calculate the required radius of the turn. {r = 72 m}

28. Calculate the minimum coefficient of static friction necessary for a truck to safely navigate an 87 m radius turn that is banked at 18° while driving 32 m/s. {μ = 0.63}

29. A race car track needs to build banked turns. The cars will have a maximum speed of 56 m/s and a coefficient of static friction of 0.74 between the tires and the ground. The radius of curvature for the turns is 120 m. Calculate the bank-angle necessary for the cars to safely navigate the corners. {θ = 33°}

C. Vertical Circular Motion

30. A rope has a length of 1.2 m. At the end of the rope is a 10.5 kg mass.
    a. Calculate the minimum velocity to swing the mass in a complete vertical circle. {v = 3.4 m/s}
    b. If the rope breaks under a tension of 750 N, calculate the maximum velocity. {v = 8.6 m/s}

31. The fastest a 350 kg motorcycle can travel is 35 m/s. Calculate the radius of the largest vertical circle that the motorcycle can safely travel around. {r = 125 m}

32. A rope will break under a tension of 1250 N. The desired speed of a 7.25 kg mass at the bottom of a vertical circle is 16 m/s. A piece of rope 1.2 m long is used. With support from calculations, will the rope break before the mass reaches 16 m/s?

33. When a person is traveling in a vertical circle, they experience an *apparent weight*. Mathematically, this is the normal force acting on an object. Calculate the apparent weight of a 58 kg person at the top and bottom of a vertical loop. The circular speed is a constant 14 m/s and the loop has a radius of 12 m. {F_{Ntop} = 378 N; F_{Nbot} = 1516 N}

Outcome 7.2: Quantitatively apply Newton's law of gravitation and Kepler's 3rd law of planetary motion.

1. Consider the Earth, Moon, and Sun system.
    a. Calculate the gravitational force between the Earth and the Sun. {Fg = 3.58×10^{22}}
    b. Calculate the gravitational force between the Earth and the Moon. {Fg = 1.99×10^{20}}
    c. Which object is responsible for the tides on Earth, the Sun, or the Moon? {Moon}
    d. A tidal force is a measure of the change in force with distance. Calculate the magnitude of the tidal force between the Sun – Earth and the Moon – Earth systems {find a formula for d**Fg**/d**r** first; if you didn't learn this yet in math then have another student show you their formula}. {$Tide_{Earth\text{-}Sun} = 4.70 \times 10^{11}$ N/m; $Tide_{Earth\text{-}Moon} = 1.03 \times 10^{12}$ N/m}

2. How far apart would you have to place two 7.0 kg bowling balls so that the force of gravity between them would be 1.25×10^{-4} N? Would it be possible to place them that close together? {r = 0.0051 m}

3. Calculate the gravitational force between the electron and the proton in a hydrogen atom if they are 5.30×10^{-11} meters apart. {Fg = 3.61×10^{-47} N}

4. On Venus, a person with a mass of 68 kg would weigh 572 N. Calculate the mass of Venus if its radius is 6.31×10^{6} meters. {M = 5.0×10^{24} kg}

5. In an experiment, an 8.0 kg lead sphere is brought close to a 1.5 kg mass. The gravitational force between them is 1.28×10^{-8} N. Calculate the separation of the masses. {r = 0.25 m}

6. The radius of Uranus is 4.3 times the radius of Earth. The mass of Uranus is 14.7 times the Earth's Mass. How does the gravitational attractive force on Uranus' surface compare to that on Earth's? {F_{Uranus} = 0.8FEarth}

7. Along a line connecting Earth and the Moon, at what distance from Earth's center would an object have to be located so that the gravitational attractive force of Earth on the object was equal in magnitude and opposite in direction from the gravitational attractive force of the Moon on the object? {3.46×10^{8} m or 0.9xEarth-Moon Dist}

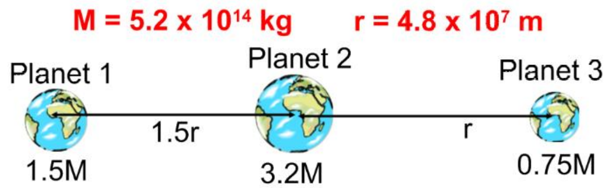
8. Suppose you launch a projectile at an angle at the Earth's surface. Then you launch the same projectile, at the same angle, on a planet that is 12 times the mass of the Earth and 2.8 times Earth's radius. How many times higher and farther {or lower and shorter} would it travel on the new planet. {0.65xHeight and range}

9. Calculate how far above the Earth's surface you must be to experience an acceleration due to gravity of 0.5g? {altitude = 2.64×10^{6} m}

10. Two planets are separated by 2.5×10^{8} m. One planet is 8 times as massive as the other. Calculate where an object would have to be positioned to experience a force of gravity from the larger planet that is twice the smaller. {1.67×10^{8} m from 8M planet's center}

11. Calculate:
    a. The acceleration of the Moon from the Earth {$a_m = 2.7 \times 10^{-3}$ m/s^2}.
    b. The acceleration of the Earth from the Moon. {$a_E = 3.3 \times 10^{-5}$ m/s^2}

12. Calculate the net force on each planet in the images below. The answers are to the right of the image.



- F_{net1} = 18109 N to the right
- F_{net2} = 2087 N to the right
- F_{net3} = 20200 N to the left

13. Jupiter's moon Io orbits Jupiter once every 1.769 days. Its average orbital radius is 4.216×10^8 m. Calculate Jupiter's mass. {$M = 1.9 \times 10^{27}$ kg}

14. Some weather satellites orbit the Earth every 90.0 minutes. Calculate the altitude of such a satellite. {alt = 275000m}

15. Calculate the speed of the Moon in its orbit about the Earth. {v = 1019 m/s}

16. Calculate the speed of the Earth around the Sun. {v = 29750 m/s}

17. A satellite orbits the Moon 60 km above its surface.
    a. Calculate the satellite's orbital period. {T = 6848 s, or 114 minutes}
    b. Calculate the satellite's orbital velocity. {v = 1651 m/s}

18. A star at the edge of the Andromeda galaxy appears to be orbiting the center of that galaxy at 200 km/s. The star is 7.45×10^{17} meters from the galaxies center. Calculate the mass of the Andromeda galaxy. {6.24×10^{41} kg}

19. The polar-orbiting environmental satellites orbit at a low altitude. The satellites orbit 14.1 times a day.
    a. Calculate the satellite's altitude. {alt = 860 000 m}
    b. Calculate the satellite's orbital speed. {v = 7423 m/s}

20. The altitude of the International Space Station is 226 km.
    a. Calculate the ISS' orbital speed. {v = 7770 m/s}
    b. Calculate the ISS' period in minutes. {T = 5340 s, or 89 minutes}

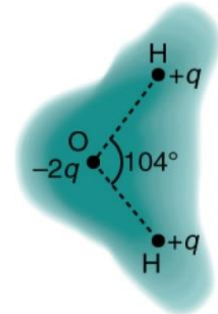
21. A geosynchronous satellite orbits above the same location of the Earth's Equator. Calculate the orbital speed and altitude of such a satellite. {$r = 1.86 \times 10^9$ m, 6.5 x Earth-Moon Distance}

Outcome 8.1: Qualitatively and quantitatively analyze electric charge and electric fields, including Coulomb's law.

1. There are very large numbers of charged particles in most objects. Why, then, don't most objects exhibit static electricity?

2. If you have charged an electroscope by contact with a positively charged object, describe how you could use it to determine the charge of other objects. Specifically, what would the leaves of the electroscope do if other charged objects were brought near the knob?

3. Describe how a positively charged object can be used to give another object a negative charge. What is the name of this process?



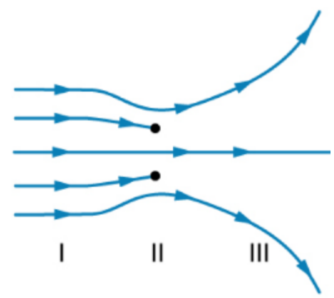
4. The image shows the charge distribution of a water molecule, which is a polar molecule because it has an inherent separation of charge. With that in mind, explain what effect humidity has on removing excess charge from objects.

5. In terms of Coulomb's Law, why is a polar molecule attracted by both positive and negative charges?

6. Water, a polar molecule, has a higher melting point {0°C} than carbon dioxide {–57°C}, a non-polar molecule. Use the concept of electric forces to explain why this is.

7. Why must the test charge, *q*, in the definition of the electric field be vanishingly small?

8. Are the direction and magnitude of the Coulomb force unique at a given point in space? What about the electric field?



9. An electric field extending over three regions is shown in the diagram.
   a. Are there any isolated charges? If so, in what region and what are their signs?
   b. Where is the field the strongest?
   c. Where is it weakest?
   d. Where is the field the most uniform?

10. How many electrons are needed to form a charge of -2.00 nC? {1.25×10^{10} e^-}

11. How many electrons must be removed from a neutral object to leave a net charge of 0.500 µC? {3.13×10^{12} e^-}

12. To start a car engine, the car battery moves 3.75×10^{21} electrons through the starter motor. How many coulombs of charge were moved? {q = 600 C}

13. Suppose an object has 1.00×10^{16} protons and a net charge of +192 µC.
    a. How many fewer electrons are there than protons? {1.2×10^{15} fewer e^-}
    b. If you paired them up, what fraction of the protons would have no electrons? {$\#e^-/\#\ p^+ = 0.12$}

14. Calculate the repulsive force between two –30.0 nC charges that are 0.08 m apart? {**F** = 1.26×10^{-3} N}

15. Two point charges exert a 5.00 N force on each other. What will the force become if the distance between them is increased by a factor of three? {**F** = 0.556 N}

16. Two point charges are brought closer together, increasing the force between them by a factor of 25. By what factor was their separation decreased? {**r** decreased by a factor of 5}

17. How far apart must two point charges of 75.0 nC {typical of static electricity} be to have a force of 1.00 N between them? {r = 5.06×10^{-5} m}

18. A test charge of +2.0 μC is placed halfway between a charge of +6.0 μC and another of +4.0 μC separated by 0.10 m.
    a. Calculate the magnitude of the net force on the test charge. {$\mathbf{F}_{net}$ = 14 N}
    b. What is the direction of this force {away from or toward the +6 μC charge}? {away from the +6.0 μC charge}

19. Suppose two equal, but opposite, charges of q = 1.0 C are separated by 1000 m {1.0 km}.
    a. Calculate the electrostatic force of attraction between them. {**F** = 8990 N}
    b. If the objects could accelerate towards each other, would it be constant or change?
    c. Is 1.0 C a significant amount of charge?

20. Two point charges totaling +8.00 μC exert a repulsive force of 0.150 N on one another when separated by 0.500 m.
    a. Calculate the charge on each. {q_1 = 7.44 μC, q_2 = 0.560 μC}
    b. Calculate the charge on each if the force was attractive and still totaled +8.0 μC. {q_1 = 8.49 μC, q_2 = –0.49 μC}

21. Point charges of 5.00 μC and –3.00 μC are placed 0.250 m apart.
    a. Where can a third charge be placed so that the net force on it is zero? {not possible, explain why}
    b. Recalculate if both charges are positive. {**r** = 0.141 m from 5.00 μC charge}

22. Calculate the magnitude and direction of an electric field that exerts a 2.00 x 10^{-5} N upward force on a –1.75 μC charge. {E = 11.4 N/C [down]}

23. What is the magnitude and direction of the force exerted on a 3.50 μC charge by a 250 N/C electric field that points due east? {**F** = 8.75 x 10^{-4} N [E]}

24. Calculate the magnitude of the electric field 2.00 m from a point charge of 5.00 μC. {1.12 x 10^{4} N/C}

25. Calculate the initial {from rest} acceleration of a proton in a 5.00 x 10^{6} N/C electric field {such as one created by a Van de Graaf} {**a** = 4.78 x 10^{14} m/s^2}

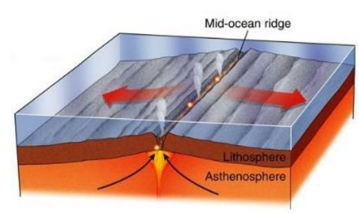
26. Separately, sketch the electric field lines near a point charge +q and a point charge of –3.00q.

Outcome 8.1: Quantitatively analyze electric circuits. Concepts include Ohm's Law, series and parallel circuits and electrical power.

1. In Development 😊

Outcome 8.2: Qualitatively analyze magnetism; including magnetic poles, fields, and moving charges.

1. Volcanic and other such activity at the mid-Atlantic ridge extrudes material to fill the gap between separating tectonic plates associated with continental drift. The magnetization of rocks is found to reverse in a coordinated manner with distance from the ridge. What does this imply about the Earth's magnetic field and how could the knowledge of the spreading rate be used to give a historical record?



2. List the ways in which magnetic field lines and electric field lines are similar and how they differ.

3. Noting that the magnetic field lines of a bar magnet resemble the electric field lines of a pair of equal and opposite charges, do you expect the magnetic field to rapidly decrease in strength with distance from the magnet?

4. Is the Earth's magnetic field parallel to the ground at all locations? If not, where is it parallel to the surface? Is its strength the same at all locations? In not, where is it the greatest?

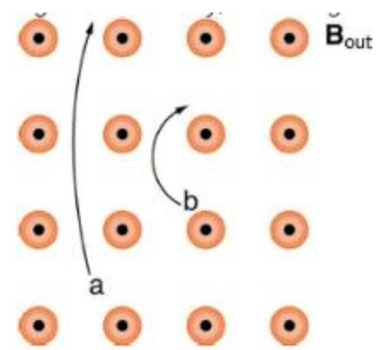
5. If a charged particle moves in a straight line through some region of space, can you say that the magnetic field in the region is necessarily zero?

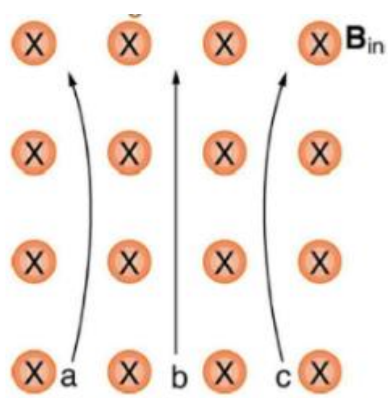
6. How can the motion of a charged particle be used to distinguish between a magnetic and an electric field?

7. Describe how the Earth's magnetic field can shield us from high-energy, cell damaging, charged particles from space.

8. What direction would a proton be deflected if it approached perpendicular to the equator? What about an electron?

9. Refer to the image on the right to answer the following:
    a. Which of the particles has the greatest velocity, assuming they have identical charges and masses?
    b. Which of the particles has the greatest mass, assuming all have identical charges and velocities?





10. What are the signs of the charges on the particles in the image to the left?