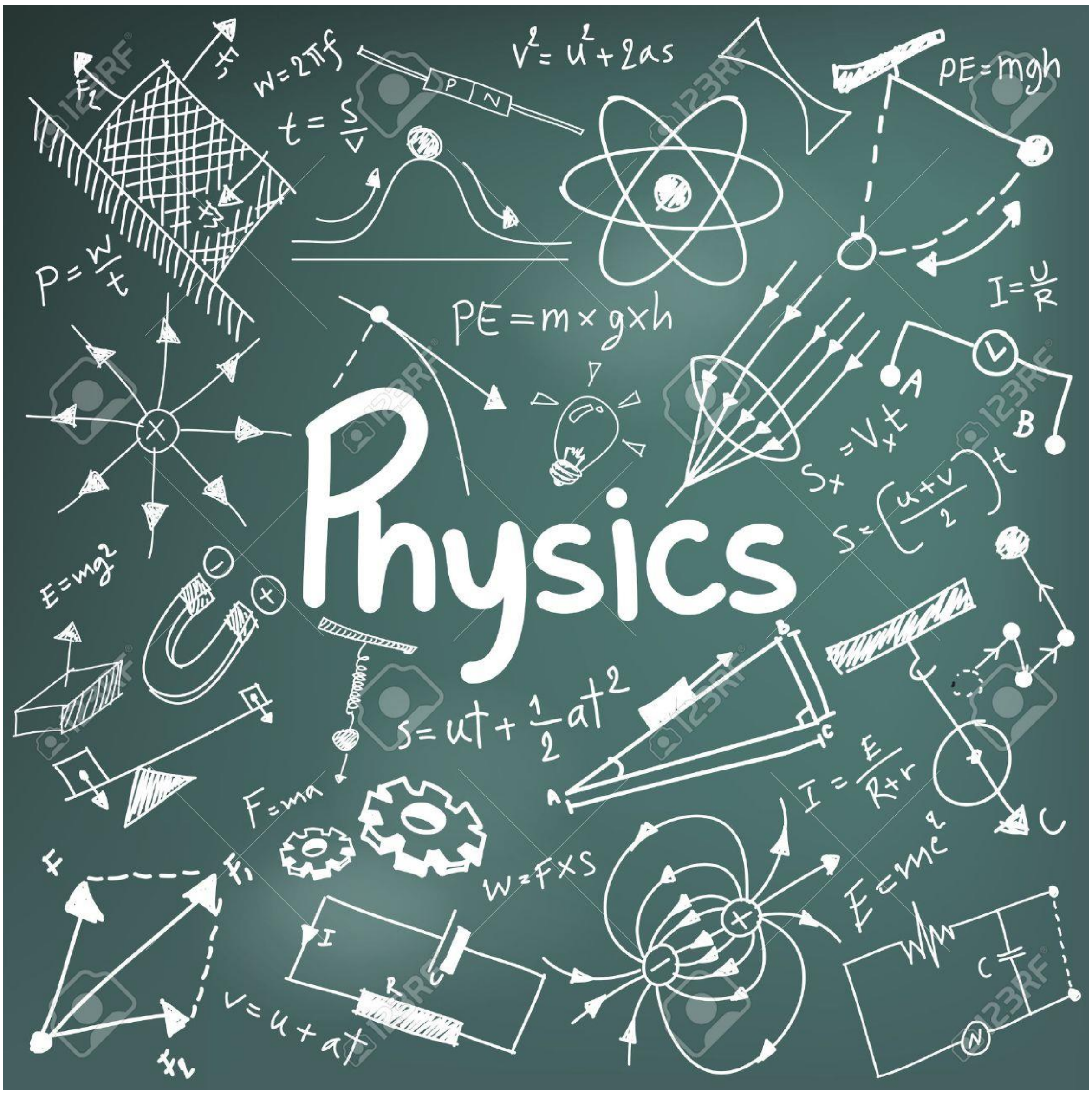
Grade 11 Physics

Outcomes, Concepts, and Problems



Mr. P. MacDonald

– Blank Page –

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			

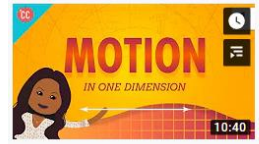
Overall Course Grade

- 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 = _______

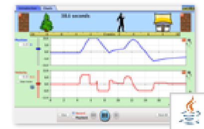
Example Percent Determinations

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 1: Kinematics in One Dimension

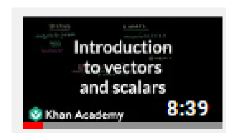

The Moving Man

Kinematics: The study of *how* objects move. That is, analyzing motion relating to an object's current motion. The analysis is often a mathematical approach to solving for quantities such as position, final or initial velocity or acceleration at an instant in time. Investigate this with the PhET simulation *The Moving Man.*

Motion: An object is said to be in motion when its position changes.

Frame of Reference: Something not moving with respect to an observer that can be used to detect motion; it is the "point-of-view" of the observer. For example, suppose someone on the ground is watching another person walking on a train. The person on the train has a velocity *relative* to the ground or *relative* to the train. Both frames of reference are correct but will yield different numerical results when analyzed.

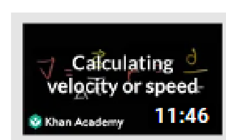
Coordinate System: The mathematical reference from which to measure quantities. It provides a reference for defining *direction* – up, down, left, right, north, west, east, south, etc. Solving problems in physics requires measurements to be positive or negative and it is the coordinate system that defines the positive direction.



Scalar: Measurements that are independent of direction and always positive in value. It is not that you choose not to communicate a direction, but rather, stating a direction *does not make sense*. For example, you would not tell someone their body temperature is 38 °C East. Other scalar quantities include time, mass, distance, and speed.

Vector: Measurements that have a magnitude *and* a direction (magnitude is the numerical value of the measurement). All vectors must be used relative to the positive direction as determined in the coordinate system. Vector quantities can be positive or negative, depending on the coordinate system and are communicated in writing by being bold font or with an arrow above them. For example, the variable for force could be written as ***F*** or $\vec{F}$. Visually, in diagrams, vectors quantities are represented by arrows. The length represents magnitude and the way it points is the direction. Other examples of vectors include position, displacement, velocity, and acceleration.

Distance: The length of the route between two points. Measurements of distance can never decrease. That is, you cannot take away the fact an object moved a certain distance. The odometer of a car, for example, measures a car's total distance traveled and it is illegal to tamper with it.



Position: An object's distance and direction from a reference point (within a coordinate system) at an instant in time. The change in position is called *displacement*.

Average Speed: An object's *total distance* traveled per time interval.

Instantaneous Speed: The speed of an object at an instant in time. Determining this usually requires data to be analyzed. One example is the speedometer of a car.

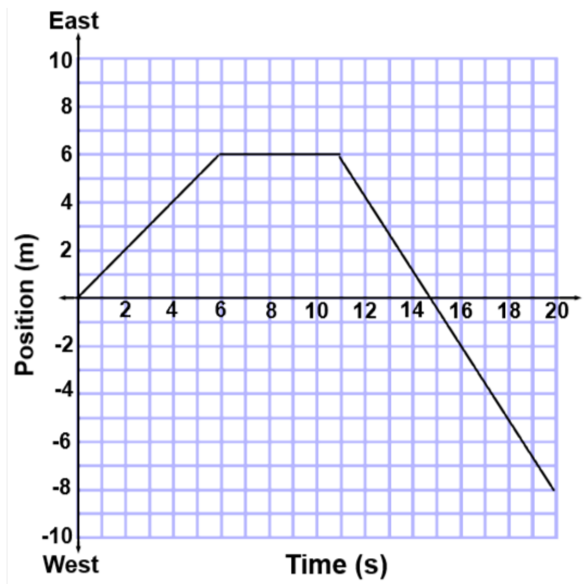
Average Velocity: An object's *change in position* per time interval. Changes in direction average out so the path taken does not matter. It is possible to have a value of zero.

Instantaneous Velocity: The velocity of an object at an instant in time (usually requiring data analysis). It is the object's instantaneous speed *and* direction.

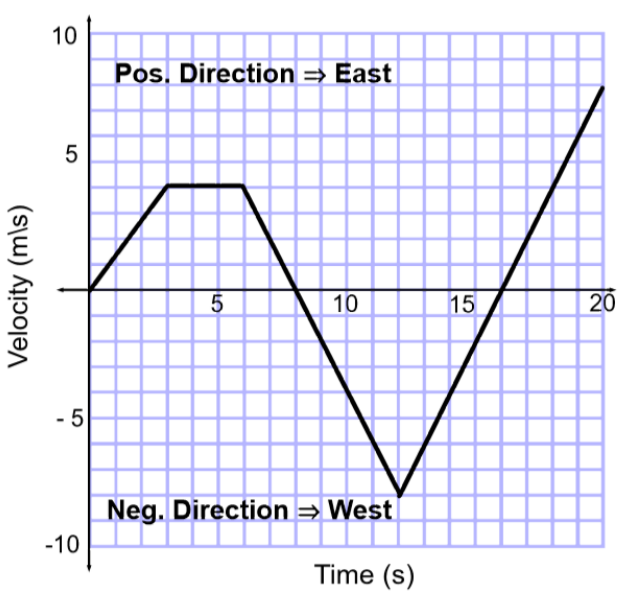
Acceleration: The change in an object's velocity per unit time. That means if an object's speed changes then it undergoes an acceleration. It also means that if only the object's direction changes then it accelerates! When an object changes direction it has an instantaneous velocity of zero, but its acceleration is not zero.

Analyzing Position–Time Graphs

- **Position**: Read from the position axis for the given time. It is how far and in what direction from a starting point.
- **Distance**: Add up all the motion using positive numbers. Follow the graph counting squares up and down until you get to the desired time. It is the total length an object traveled.
- **Direction Change**: When the velocity goes from positive to negative or vice versa.
- **Average Speed**: Distance (see above) divided by the time given in the question.
- **Instantaneous Speed**: Positive value of the slope of the line at the time given (find two points on the line and calculate rise/run).
- **Average Velocity**: Position (see above) divided by the time given in the question.
- **Instantaneous Velocity**: Slope of the line at the time given (find two points on the line and calculate rise/run). Can be positive or negative.



Analyzing Velocity–Time Graphs

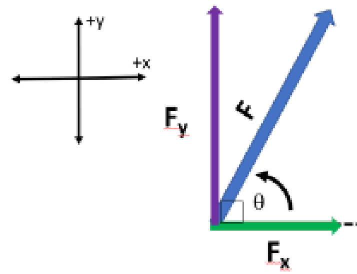


- **Velocity**: Read it from the velocity axis for the given time. It communicates the direction of travel, not the position.
- **Instantaneous Acceleration**: The slope of the line at the time given (find two points on the line and calculate rise/run). Can be positive or negative and the sign is the direction of the acceleration, not the object.
- **Distance**: For a certain time-interval, the distance is the area contained between the graph and the time axis (always use positive numbers when calculating).
- **Position**: For a certain time-interval, it is the area contained on the top minus the area contained on the bottom.
- **Direction Change**: When the velocity goes from positive to negative or vice versa.
- **Average Speed**: Total distance divided by the time.
- **Average Velocity**: Final position divided by the time.

Check out the PhET simulation again, but now make use of the graphical functions. Create a position-time and velocity-time graph to review the above concepts.


The Moving Man

Outcome 2: Kinematics in Two Dimensions



Perpendicular Components: When a vector makes an angle with one of the axes of a coordinate system, that vector is acting partly in each direction. A physics problem must be solved by analyzing one dimension at a time because perpendicular vectors are *independent* of each other. Take the diagram to the right. The force, ***F***, makes an anlge to the coordinate system so part of the force acts in the x-direction, $\boldsymbol{F_x}$, and the other in the y-direction, $\boldsymbol{F_y}$.

- Mathematically, they are calculated using right triangle trigonometry: $\boldsymbol{F_x} = \boldsymbol{F}\cos\theta$, and $\boldsymbol{F_y} = \boldsymbol{F}\sin\theta$. The sign of the component matches the direction of the coordinate system.
- If you know the perpendicular components, the vector can be calculated with the Pythagorean Theorem and the angle from the horizontal using $\tan^{-1} F_y/F_x$ (use only positive component values to calculate the angle).

Kinematics in 2D: These types of problems will read like previous problems, but the vectors could be angled to the coordinate system. To solve, calculate the perpendicular components for all vectors (watch for negative directions) and apply the physics relationship(s) in each dimension separately. If you are calculating a vector, the final answer's magnitude is determined with the Pythagorean Theorem and use the inverse tangent of the components to find the direction, or the angle.

Relative Velocity: When multiple vectors of the same type (like velocity) act on an object, the *resultant vector* (or resulting velocity) is determined through *vector addition*. Essentially, each vector is broken down into perpendicular components, and components of the same dimension are added together (taking direction into consideration). The resultant is calculated using Pythagorean Theorem and the direction with inverse tangent of the resultant's components. Some problems will give you the resultant and you need to calculate a missing vector. The process is the same, add up the vectors and one of the components will be unknown.

Vector Addition

Outcome 3: Dynamics in One and Two Dimensions

Dynamics: The study of *why* objects move. When all the forces acting on an object add to be greater than zero, then there is a *net force*. This will cause the object to accelerate, after which we apply kinematic concepts for an analysis.

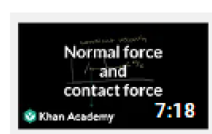
Force: ***F***, a vector quantity that is a push or a pull on and object. The unit of force is the Newton, N (pounds, or lb, in the United States). Many different forces can act on an object at the same time. The unit of a Newton breaks down into component units: $N = kg \cdot m/s^2$ (investigate forces using the PhET simulation to the right).

Forces and Motion: Basics

Types of Forces: Forces are grouped in to two categories – contact and noncontact forces. Contact forces require direct physical contact between objects (such as friction, applied and tension forces). Noncontact forces exert their forces on objects over a distance and create *fields* (such as gravity, magnetic and electric forces).

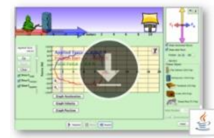
Applied Force: $\boldsymbol{F_a}$, this is usually a force created by a person or machine acting on an object.

Normal Force: $\boldsymbol{F_N}$, a force that acts perpendicular to a surface. For example, the stool you sit on provides a normal force upwards, equal to the magnitude of gravity's pull on you, your weight. The concept of normal force is prominent in our investigations and understanding of the force of friction.



Force of Friction: $\boldsymbol{F_f}$, this *electromagnetic* force acts between surface atoms of two objects in direct contact. These bonds must be broken to move the objects. The greater the normal force the more the objects are pushed together, so the stronger the bonds. The force of friction always acts opposite the direction of motion of the object or, if it is not moving, the direction of the net force acting on it. There are two types of frictional forces: static and kinetic.

Forces in 1 Dimension



Static Friction: A frictional force that must be overcome to get an object moving. Think of pushing a massive object, it does not move unless you apply a large force. That is because the force of friction is very strong due to a high normal force.

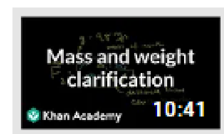
Kinetic Friction: A frictional force that must be overcome to keep an object moving. Kinetic friction is lower than static friction for any two surfaces. The electromagnetic bonds have less time to strengthen as they continually form and break due to the object's motion.

Coefficient of Friction: μ. Think of this as the "*electromagnetic stickiness*" between any two surfaces. It is unique for any two objects, and for our course, it is independent of surface area or location. All that matters are the two objects. Each type of friction has its own coefficient value. The symbol is the Greek letter mu, μ.

Forces and Motion

Force of Gravity: $\boldsymbol{F_g}$, Aa attractive force that acts over a distance between masses because of their warping of spacetime. For situations on Earth, it is the pull on objects towards the center of the Earth. It is often calculated by $\overrightarrow{F_g} = m\vec{g}$, where $\vec{g} = 9.81\, m/s^2$, the average acceleration due to gravity for the Earth. Another term for force of gravity is an object's *weight*.

Net Force: $\boldsymbol{F_{net}}$, is the vector sum of all the forces acting on an object. Vector sum means that only forces acting in the same *dimension* can be added together. For example, forces acting left, or right are not added with forces acting up or down – they are separate calculations. Objects accelerate in the direction of the net force.



Equilibrium: An object in equilibrium means that the net force acting on it is *zero*. This can happen if the object is at rest (a velocity of zero) or is moving with a constant velocity (an acceleration of zero).

Equilibrant: The vector, that when added, will result in the object achieving equilibrium.

Classical Mechanics: Developed in the late 1600s by Sir Isaac Newton. This system of physics treats matter and energy as separate entities, but it can predict the motion and interactions of objects. Such objects need to be much larger than an atom and traveling much slower than the speed of light.

Quantum Mechanics: Developed in the early 1900s, spearheaded by Albert Einstein, it treats matter and energy as one and the same through the famous equation $E = mc^2$. This system of physics can model the motion and energy of subatomic particles and objects traveling near the speed of light, $c \approx 300\,000\,000$ m/s as well as all classical physical systems.

Newton's 1st Law: An object at rest or in uniform motion will remain at rest or in uniform motion unless acted on by an external force. An external force brings an object out of equilibrium. For example, when traveling in a car and it takes a sharp turn you get squished into the door or another passenger. What is happening is that you are trying to continue uniform motion, but the car gets in your way.

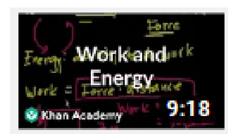
Newton's 2nd Law: The net (average) force acting on an object is equal to the product of the object's mass and (average) acceleration, ***F*** = *m**a***. This force has the same direction as the acceleration. This mathematically relates concepts of dynamics and kinematics.

Newton's 3rd Law: For every action there is an opposite and equal reaction. Forces act in pairs, called action-reaction pairs. Thus, if you punch a wall the wall "punches" back with the same force, possibly breaking your hand. Walking on the floor is possible because the floor pushes you forward (if you were to push the floor, the floor would move).

Inertial Frame of Reference: One in which Newton's Laws of motion are valid and can be applied. Every force can be explained. This frame of reference must be in equilibrium.

Non-Inertial Frame of Reference: One in which Newton's Laws of motion are not valid and cannot be applied. The frame of reference is not in equilibrium. In such a frame of reference, some aspects of an object's motion cannot be explained without the use of *fictitious forces*. For example, if a car is the frame of reference and it suddenly slows down, the passengers lunge forward. Relative to the car there was no push or pull to create such motion.

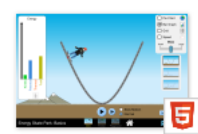
Outcome 4: Conservation of Mechanical Energy



Work: In physics, work is done on an object when a force causes a displacement of the object. Work is a measure of energy and uses the unit called Joules, J. For reference, about 1 J of work is lifting an apple to the top of your head. The mathematical relationship is *W* = ***Fd***. Only a force parallel to the direction of motion does work on an object. Work is a scalar quantity, but it can be positive or negative. The sign of work is not determined by a coordinate system. If the force and displacement are in the same direction, that is positive work, otherwise, work is negative.

Conservative Force: Does work on an object in such a way that the amount of work done is independent of the path taken. For example, lifting an object 1 meter off the ground will be the same if you lift it straight up or use a ramp (in the absence of friction). A system of only conservative forces will have energy changes that are reversible.

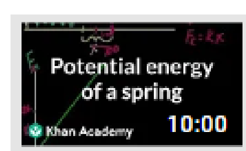
Nonconservative Force: The work done on an object is path dependent. Friction is such a force and removes energy from the system as heat. Such physics systems may not be reversible. In the natural world, most systems involve nonconservative forces. For example, when you bounce a ball it will not return to its original height because energy is lost from the collision with the floor in the form of deformations, heat, and sound.


Energy Skate Park: Basics

Kinetic Energy: E_K, is the energy associated with motion. Represented by $E_K = \frac{1}{2}mv^2$, where *m* is the object's mass in *kg* and *v* is the instantaneous speed in *m/s*. Kinetic energy is measured in Joules, *J*.

Potential Energy: Stored energy, the object has the *potential* to move. Such energy is associated with an object because of the position, shape, or condition of the object (e.g. pressing down on a spring or pulling a bow string stores energy because of a change of shape of the object).

Gravitational Potential Energy: E_g, is energy is stored in a gravitational field above a reference, or zero level of a gravitational source. (i.e. the surface of the Earth, but it can be set for each system). Mathematically, $E_g = mgh$, where *g* is the acceleration due to gravity and *h* is the height above a zero level (use only positive values).



Elastic Potential Energy: E_e, the energy stored that depends on the distance an object has been compressed or stretched. Elastic materials can restore its shape by applying a *restoring force*. That ability is summarized numerically by a what is called a spring constant, *k*. Highly flexible materials have a low k-value, whereas stiff materials have high k-values. Mathematically, the stored energy is $E_e = \frac{1}{2}kx^2$ where *x* is the compression or stretch length in meters. If a restoring force calculation is required, *Hooke's Law* is applied to the object: $F_s = -kx$. The expression is negative because the restoring force always acts opposite to the compression or stretch direction (this assumes stretch direction is positive). If maximum acceleration is at position *x*, then max velocity is at *x*/2. At maximum acceleration *v* = 0 m/s, and at max velocity, *a* = 0 m/s^2.

Work-Energy Theorem: Work must be done on an object to change its position. This theorem states that the work done on an object equals its energy gained or lost. Each form of energy applies its own version of the work-energy theorem: $W = \Delta E_K$, $W = \Delta E_g$, or $W = \Delta E_e$ and remember that $W = \boldsymbol{Fd}$, should force or displacement be part of the analysis. The symbol Δ (capital Greek letter delta) means "change in" so it will be an object's "final" – "initial" energy of that type.

Law of Conservation of Energy: Energy can neither be created nor destroyed, but it can be transformed from one form to another or transferred from one object to another. The total energy of an isolated system, including all forms of energy, always remains constant. Common examples include dropping an object – initially the object has a speed of zero but gravitational potential energy. Once released the gravitational potential energy decreases but its speed increases – gravitational potential energy is transformed into kinetic energy. In the absence of air resistance, the total energy remains constant. Use the PhET simulation on the right to explore energy transformations.


Energy Skate Park: Basics

- If all the forces in the system are conservative, then mathematically $\Delta E_T = 0$ where E_T is the total of all types of energies and is a constant. That means the change in total energy is zero.
- If nonconservative forces are exist then, mathematically $\Delta E_T = W_{nc}$, where W_{nc} is the work done by the nonconservative forces (for example, friction acting over a distance) and will evaluate to a negative value since that energy is removed from the system.

Outcome 1.1 & 1.2: Demonstrate an understanding that kinematic quantities are scalars or vectors and the importance that distinction plays when solving problems.

1. Describe why frame of reference is important and give two examples of how a choice of frame of reference can give two different results for the same object in motion.

2. Define motion.

3. List four measurements that are scalars and four that are vectors.

4. Would a speeding ticket be given for average or instantaneous speed?

5. Define instantaneous and average velocity.

6. Suppose you drive between two cities called A and B {weird, I know} with an average velocity of **v** and it takes time **t**.

   a. Now suppose you drive the same road between A and B but at twice the average velocity. Relative to the first trip how long did it take to drive?
   b. You must drive one more time between A and B but this time it takes four times as long. Relative to the first trip what was your average velocity?

7. Identify each of the following as a vector or scalar: speed, force, acceleration, distance, time, velocity, weight, temperature, and mass.

8. In words, what is the definition of acceleration? How do the units reflect this definition?

9. A car goes from 30 km/h [E] to 50 km/h [E]. What is the direction of the acceleration?

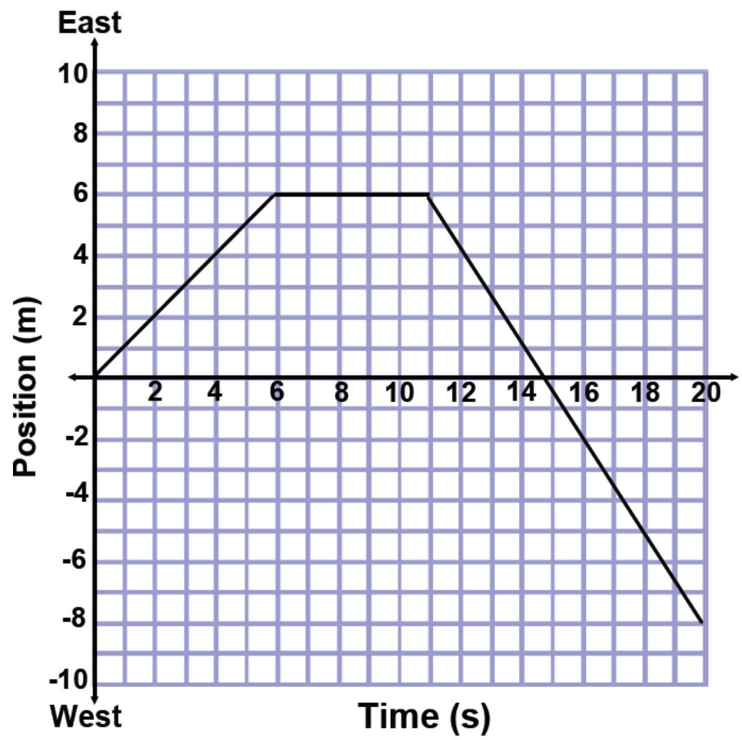
10. A truck goes from 90 km/h [E] to 45 km/h [E]. What is the direction of the acceleration?

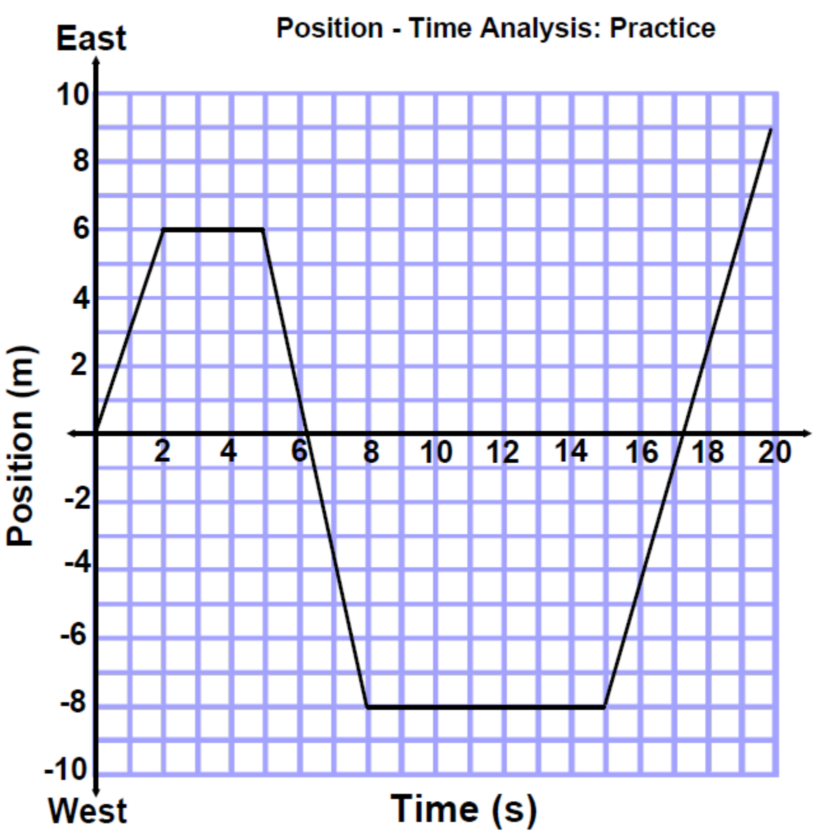
11. Give two examples where an object has a non-zero acceleration but an instantaneous velocity of zero.

12. Describe a situation where an object can have a constant speed and experience a non-zero acceleration.

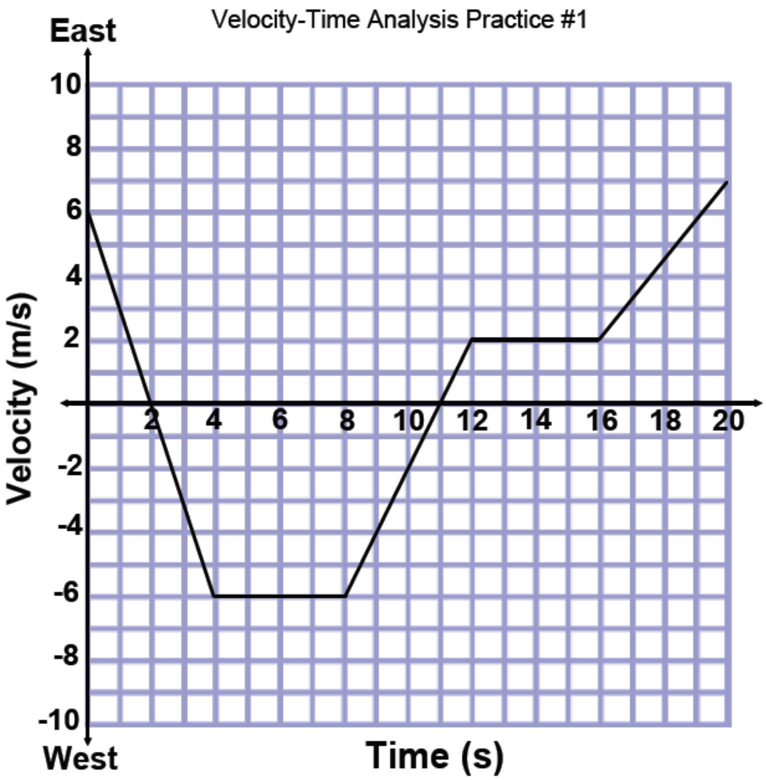
Outcome 1.3: Graphically analyze 1D relationships among position, velocity, acceleration, and time.

1. What was the object's position at the 4, 10 and 18 second marks? {relative to east: 4 m, 6 m, and -5 m}
2. Calculate the distance traveled during the first 14 seconds. {d = 11m}
3. Calculate the average speed during the first 14 seconds. {v_{sp} = 0.79 m/s}
4. Calculate the average velocity during the first 14 seconds. {$\mathbf{v_{avg}}$ = 0.071 m/s}
5. Calculate the instantaneous velocity at the 16-second mark. {**v** = –1.6 m/s}
6. Calculate the object's total distance traveled and final position. {d_{tot} = 20 m, $\mathbf{d_f}$ = –8 m}
7. Calculate the object's average speed and velocity for the full 20 seconds. {v_{sp} = 1.0 m/s, $\mathbf{v_{avg}}$ = 0.40 m/s}





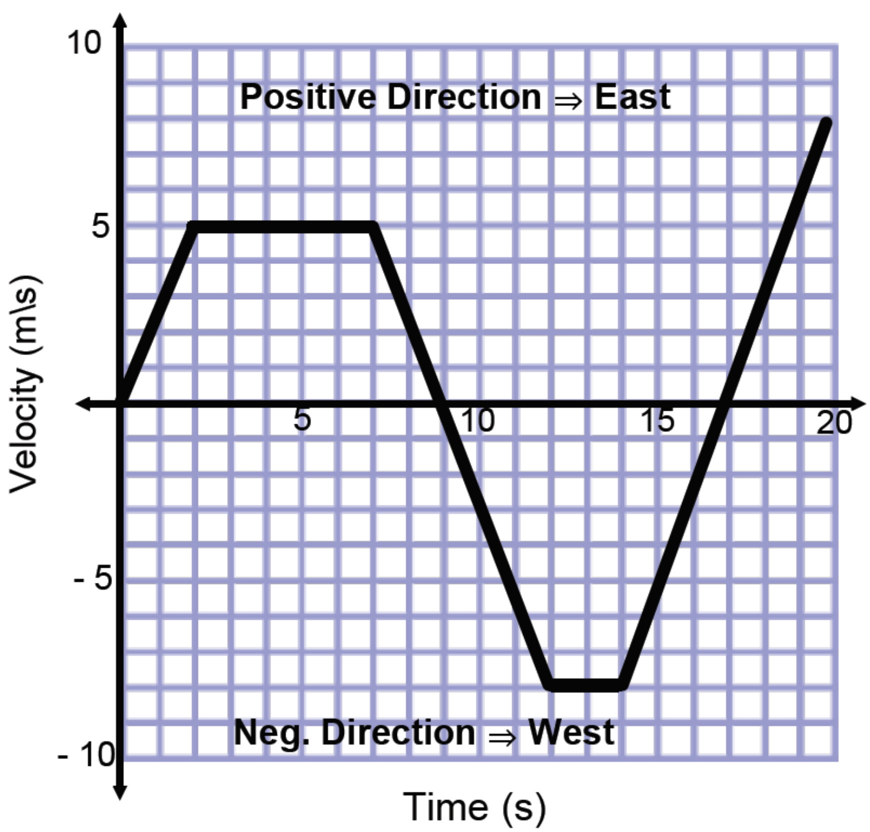
1. Calculate the instantaneous velocity at 1 and 6 seconds. {3 m/s, –5 m/s}
2. Calculate the distance covered during the first 8 seconds. {20 m}
3. At what times did the object return to the starting position? {around 6.2 and 17.2 seconds}
4. During what time interval{s} was the object traveling west? {5 – 8 seconds}
5. During what time interval{s} was the object's position west? {approx. 6 – 17 seconds}
6. How long was the object not moving? {10 seconds}
7. During what time interval{s} was the object east of the starting position, but traveling west? {5 – 6 s}
8. Calculate the average speed and velocity for the full 20 seconds. {v_{sp} = 1.85 m/s, $\mathbf{v_{avg}}$ = 0.45 m/s}
9. How long did it take the object to travel 11 m? {6 s}
10. At what time{s} was the object a distance of 3 m from the starting position? {1 s, 5.5 s, 6.8 s, 16.5 s, and 18 s}



1. What was the object's instantaneously velocity at 1, 6, and 18 seconds? {3 m/s, -6 m/s, 4.5 m/s}
2. For how many seconds was the object not accelerating? {8 seconds}
3. At what time{s} did the object change direction? {2 and 11 seconds}
4. Calculate the object's acceleration during the first 2 and last 4 seconds. {$-3\ m/s^2$, $1.25\ m/s^2$}
5. Calculate the distance and displacement at the 4 second mark. {*d* = 12 m, ***d*** = 0 m}
6. Calculate the average speed and average velocity at the 4 s mark. {v_{sp} = 3.0 m/s, v_{avg} = 0 m/s}

Calculate the total distance and displacement for the full 20 seconds. {*d* = 72 m, ***d*** = -6 m}

7. During what time interval{s} was the object traveling east but the acceleration was west? {0-2s}
8. During what time interval{s} was the object traveling west but the acceleration was east? {8-11s}
9. Calculate the average speed and average velocity for the 20 s. {v_{sp} = 3.6 m/s, v_{avg} = -0.3 m/s}



1. Calculate the acceleration from 0 to 2 seconds. {***a*** = $2.5\ m/s^2$}
2. Calculate the acceleration between 7 and 12 seconds {***a*** = $-2.6\ m/s^2$}
3. At what times{s} did the object change direction? {9 & 17 s}
4. For how many seconds was the object not accelerating? {13s}
5. From the start, how many seconds did it take the object to travel 20 m? {5s}
6. Calculate the distance traveled east during the full twenty seconds. {*d* = 47 m}
7. Calculate the distance traveled west during the full twenty seconds. {*d* = 40 m}
8. Calculate the average speed and velocity during the full 20 s. {v_{sp} = 4.35 m/s; v_{avg} = 0.35 m/s}

Outcome 1.4: Mathematically analyze the relationship among position, velocity, acceleration, and time.

1. Sam is driving along the highway towards Saint John. He travels 150 km in 3.00 h. What is his average speed for his trip? {50 km/h}
2. A vehicle travels 2345 m [W] in 315 s toward the evening sun. What is its average velocity? {7.4 m/s [W]}
3. What distance will a car, traveling 65 km/h, cover in 3.0 hrs? {195 km}
4. How long will it take to go 150 km [E] traveling at 50 km/hr [E]? {3.0 h}
5. What is the displacement of the Earth after one orbit about the Sun? What is the average velocity of the Earth after one orbit in m/s? {0 m; 0 m/s}
6. *Calculate the average speed of the Earth about the Sun in m/s. {29 885 m/s}
7. Calculate the time it will take to travel 200 000 m [N] traveling 10 m/s [N]. {20 000 s}
8. A soccer ball is kicked 25 m [E], then 15 m [E], 8 m [W], and finally 12 m [E]. All this takes place in 45 seconds. Calculate the average speed and velocity of the ball. {v_{sp} = 1.3 m/s; $\mathbf{v_{avg}}$ = +0.98 m/s [E]}
9. *A car drives 12 m/s [S] for 5.0 seconds, then 18 m/s [N] for 9.0 seconds, and finally 15 m/s [S] for 11 seconds. Calculate the average speed and average velocity. {v_{sp} = 15 m/s; $\mathbf{v_{avg}}$ = -2.5 m/s or 2.5 m/s [S]}
10. A car accelerates at a rate of 3.0 m/s^2. If the original velocity is 8.0 m /s, how many seconds, will it take the car to reach a final velocity of 25.0 m/s? {5.7 s}
11. The final velocity of a car is 30m/s. The car is accelerating at a rate of 2.5m/s^2 over an 8-second period. What was the initial velocity of the car? {10 m/s}
12. If a car, with an initial velocity of 10 m/s, accelerates at a rate of 50 m/s^2 for 3 seconds, Calculate its final velocity. {160 m/s}
13. Calculate the time it takes for a car, undergoing an acceleration of 5.6 m/s^2 [W], to change its velocity from 32 m/s [E] to 12 m/s [W]. {7.9 s}
14. A baseball is thrown with an initially velocity of 46 m/s [E]. After leaving the bat, it is going 35 m/s [W]. Calculate the acceleration of the ball if it was in contact with the bat for 0.34 seconds. {-240 m/s^2 or 240 m/s [W]}
15. A car accelerates from 15 m/s [E] to 25 m/s [W] in 26 seconds.
    a. Calculate the acceleration of the car. { $\vec{a}$ = –1.54 m/s^2}
    b. Calculate the position of the car at the end of the above acceleration. {$\vec{d_f}$ = –130 m}

16. A person is standing atop a cliff that is 250 m high cliff overlooking the water below. She drops a phone to the water below.
    a. Calculate the time it takes for the phone to hit the water below. {t = 7.1 s}
    b. Calculate the velocity as it enters the water. {$\vec{v}_f$ = –70.0 m/s}
    c. Calculate the velocity of the phone 75 m above the water. {$\vec{v}_f$ = –58.6 m/s}
    d. Calculate the height of the phone when its velocity is –35 m/s. {$\vec{d}_f$ = 188 m}

17. Standing on the ground a person throws a rock (take initial position to be zero meters). It leaves his hand with an upward velocity of 21 m/s.
    a. Calculate the length of time the rock will be traveling upwards. {t = 2.1 s}
    b. Calculate the rock's maximum height. {$\vec{d}_f$ = 22.5 m}
    c. Calculate the velocity of the rock when it is 15 m above the ground. {$\vec{v}_f = \pm$12.1 m/s}

18. A plane changes its velocity from 215 m/s [S] to 300 m/s [N]. The acceleration was 5.72 m/s^2 [N].
    a. Calculate the time it took the plane to change its velocity. {t = 90.0 s}
    b. Calculate the position of the plane after that time. {$\vec{d}_f$ = 3830 m [N]}
    c. *Calculate the distance the plane traveled in that time. Hint: find the distance the plane traveled in both the South and Northern directions. {d = 11 900 m}

19. A ball is bounced such that it leaves the ground with an upward velocity of 25 m/s.
    a. Calculate the total time the ball is in the air. {t_{air} = 5.1 s}
    b. Calculate the velocity of the ball when it is 20 m above the ground. {$\vec{v}_f$ = ± 15 m/s}
    c. Calculate the time for the ball to be 16 m above the ground. {t = 0.75 s and 4.3 s}

20. *Derive the formula: $v_f^2 = v_o^2 + 2a(d_f - d_o)$

Outcome 2.1 Measuring vectors and calculating the resultant position for 2D vectors using a scale diagram.

1. Use a protractor and ruler to measure all the following vectors. Measure all angles relative to the east-west line. The scale is 1 cm = 25 m.

a = ____________________________________

b = ____________________________________

c = ____________________________________

d = ____________________________________

e = ____________________________________

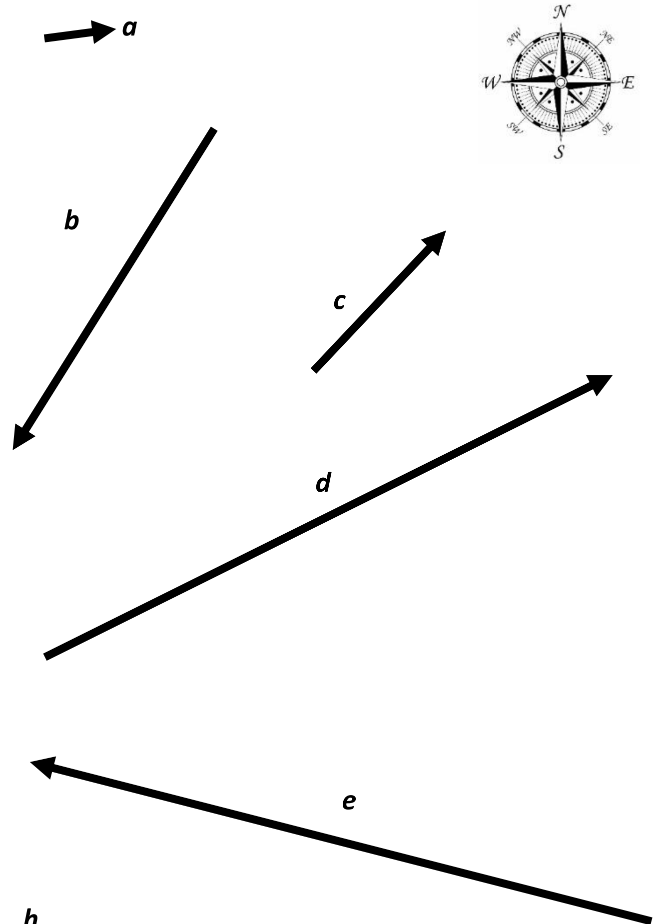
f = ____________________________________

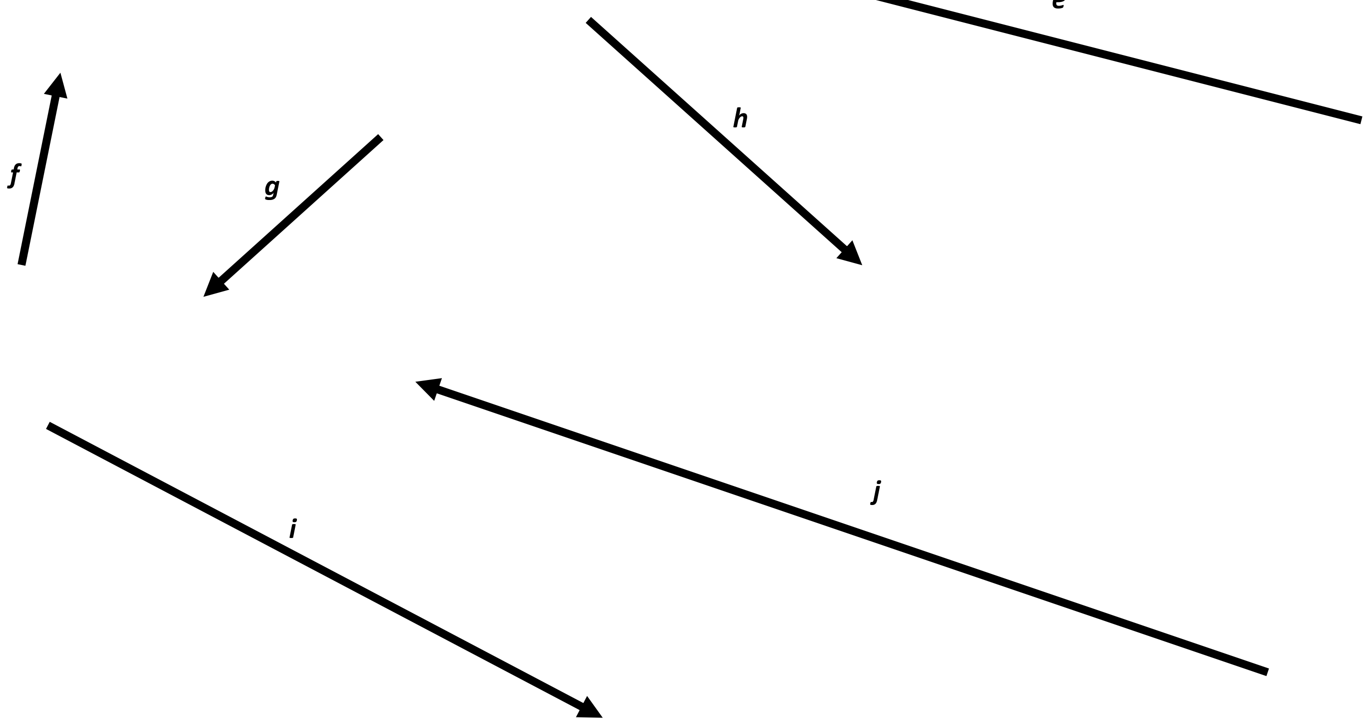
g = ____________________________________

h = ____________________________________

i = ____________________________________

j = ____________________________________





For questions 2 – 11: Using the scale given, draw the vectors and measure the resultant.

2. Scale: 1 cm = 10 m. ***a*** = 30 m [W], ***b*** = 45 m [N], ***c*** = 75 m [E] {***R*** = 64 m [E45N]}
3. Scale: 1 cm = 150 km. ***a*** = 630 km [S], ***b*** = 400 km [E], ***c*** = 275 km [S], ***d*** = 1050 km [W] {***R*** = 1114 km [W54S]}
4. Scale: 1 cm = 75 m. ***a*** = 620 m [E], ***b*** = 525 m [N], ***c*** = 900 m [W], ***d*** = 300 m [S] {***R*** = 359 m [W34N]}
5. Scale: 1 cm = 42 m. ***a*** = 228 m [E20S], ***b*** = 402 m [E70S], ***c*** = 519 m [W40N] {***R*** = 130 m [W70S]}
6. Scale: 1 cm = 10 m/s. ***a*** = 45 m/s [W60N], ***b*** = 70 m/s [W80S], ***c*** = 100 m/s [E45N] {***R*** = 54 m/s [E49N]}
7. 1 cm = 25 km. ***a*** = 208 km [E36S], ***b*** = 175 km [W72S], ***c*** = 133 km [W45N] {***R*** = 196 km [E84S]}
8. 1 cm = 65 m. ***a*** = 325 m [W60N], ***b*** = 429 m [E10N], ***c*** = 575 m [E33S] {***R*** = 743 m [E3S]}
9. 1 cm = 150 m. ***a*** = 982 m [E43S], ***b*** = 456 m [W15N], ***c*** = 621 m [E55N] {***R*** = 634 m [E4S]}
10. 1 cm = 38 km/h. ***a*** = 148 km/h [W23S], ***b*** = 275 km/h [E51S], ***c*** = 197 km/h [W65N] {***R*** = 104 km/h [W63S]}
11. 1 cm = 10 m/s^2. ***a*** = 75 m/s^2 [E], ***b*** = 32 m/s^2 [W29S], ***c*** = 105 m/s^2 [W75N] {***R*** = 88 m/s^2 [E77N]}

Trigonometric Review

Find the value of each trigonometric ratio to the nearest ten-thousandth.

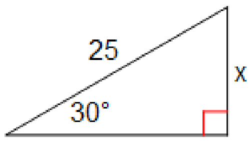
1) cos 45°
2) tan 51°
3) cos 37°
4) tan 16°
5) tan 35°
6) tan 54°

Find each angle measure to the nearest degree.

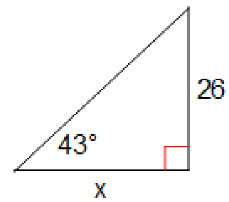
7) cos X = 0.6428
8) tan V = 1.8040
9) cos X = 0.8988
10) cos Z = 0.9455
11) cos W = 0.8290
12) cos V = 0.7431

Find the missing side. Round to the nearest tenth.

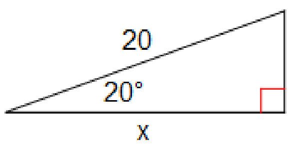
13)



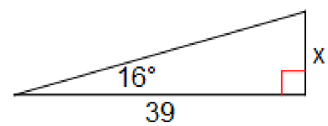
14)



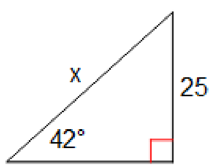
15)



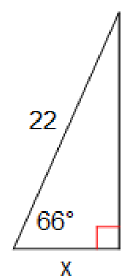
16)



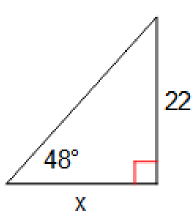
17)



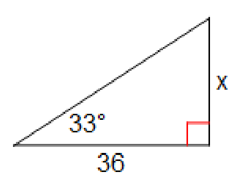
18)



19)



20)



Answers to Trigonometric Review

1) 0.7071	2) 1.2349	3) 0.7986	4) 0.2867
5) 0.7002	6) 1.3764	7) 50°	8) 61°
9) 26°	10) 19°	11) 34°	12) 42°
13) 12.5	14) 27.9	15) 18.8	16) 11.2
17) 37.4	18) 8.9	19) 19.8	20) 23.4

Outcome 2.2: Calculate the perpendicular components of each vector:

1. d_f = 652 m 20° up from positive x-axis. {d_{fx} = 613 m, d_{fy} = 223 m}
2. a = 7.8 m/s^2 80° down from negative x-axis. {a_x = -1.4 m/s^2, a_y = -7.7 m/s^2}
3. d_f = 7824 km 32° up from negative x-axis. {d_{fx} = -6635 km, d_{fy} = 4146 km}
4. v_o = 490 m/s [E25°N] {v_{oE} = 444 m/s, V_{oN} = 207 m/s}
5. d_o = 1200 m [E65°S] {d_{oE} = 507 m, d_{oN} = -1088 m}
6. a = 35 m/s^2 [W28°S] {a_E = -31 m/s^2, a_N = -16 m/s^2}
7. A ball is kicked from the ground with a velocity of 15.8 m/s at an angle of 30 degrees up from the horizontal. Calculate the initial vertical and horizontal velocity of the ball. {v_y = 7.9 m/s, v_x = 13.7 m/s}
8. A plane changes position by flying 623 km [W25N]. Calculate the East and North components of the change in position. {d_E = -565 km, d_N = 264 km}
9. From a location above the ground, a person tosses a coin to a person below. The coin has a velocity of 5.8 m/s at an angle of 56 degrees down from the positive horizontal axis. Calculate the components of this velocity. {v_x = 3.2 m/s, v_y = -4.8 m/s}

Outcome 2.3: Calculate the vector given the following perpendicular components:

1. a_x = 300 m/s^2, a_y = 195 m/s^2 {358 N, 33° up from the positive x-axis}
2. d_x = 437 km, d_y = -655 km {787 km, 56° down from positive x-axis}
3. v_E = -35 m/s, v_N = 50 m/s {61 m/s [W55°N]}
4. In calculating the acceleration on a car, the horizontal component is $\boldsymbol{a_E}$ = –5.1 m/s^2 and vertical $\boldsymbol{a_N}$ = 7.4 m/s^2. Calculate the acceleration of the car. {**a** = 9.0 m/s^2 [W55N]}
5. The horizontal component of a force is Fx = 46 N, the vertical component is Fy = – 21 N. Calculate the force vector. {**F**= 51 N 25° down from the positive x-axis}
6. A water current moves a sailboat 3.4 m/s [W]. The wind blows 2.6 m/s [N]. Calculate the velocity of the sailboat. {**v**=4.3 m/s [W37N]}

Outcome 2.4: Mathematically analyze kinematic problems in two dimensions.

1. Calculate the acceleration of an object that goes from 15.0 m/s [S] to 15 m/s [W] in 2.0 seconds. {***a*** = 10.6 m/s^2 [W45°N]}
2. A car is initially moving 7.5 m/s [N]. After 3.0 seconds the final velocity is 10.0 m/s [E40°N]. Calculate the acceleration. {***a*** = 2.57 m/s^2 [E8.1°S]}

3. A boat is sailing 6.5 m/s [E20°S]. A gust of wind provides an acceleration equal to 2.1 m/s^2 [E60°N] for 18 seconds.
    a. Calculate the velocity after the 18 seconds. {$\boldsymbol{v_f}$ = 39.4 m/s [E51°N]}
    b. Calculate the final position at that time. {***d*** = 378 m [E42°N]}

4. A glider is flying 9.2 m/s [E25°N]. A gust of wind changes the glider's trajectory to 11 m/s [E14°S] in 7.9 seconds.
    a. What was the acceleration of the glider? {***a*** = 0.88 m/s^2 [E70°S]}
    b. Calculate the final position of the glider at that time. {***d*** = 75 m [E3.7°N]}

5. *An object is moving 35 m/s [E40°N] and undergoes an acceleration of 3.7 m/s^2 [W10°N]. How much time is required for the final position to be 609 m [W72°N]? {*t* = 20 s}

Outcome 2.5: Vector addition and solving for missing vectors.

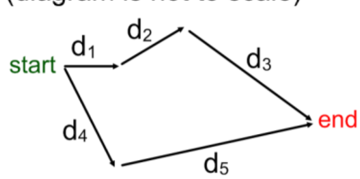
1. A car drives 55 km [W30S], 78 km [W65N] then 100 km [E]. Calculate the final position of the car. {47 km [E66°N]}

2. You are 37 km [W20°N] from Miramichi and must move to a position 15 km due West of the city. Calculate the displacement required. {***d*** = 24 km [E33°S]}

3. A coast guard boat is 75 km [E67°N] from port. A distress call comes in from a fishing vessel located 93km [E26°S] from port. Calculate the position of the fishing vessel from the coast guard boat? {***d*** = 122 km [E64°S]}

4. Given the information below, solve for the missing vector: {answer d_3 = 32 m [E23°S]}

(diagram is not to scale)



d_1 = 7.5 m [E]
d_2 = 12 m [E25N]
d_3 = ?
d_4 = 24 m [E55S]
d_5 = 36 m [E20N]

5. A boat's heading is directly across a river at 5.0 km/h [N]. The river is flowing east at 3.0 km/h.
    a. What is the velocity of the boat relative to someone standing on the dock where the boat departed? {***v*** = 5.8 km/h [E53°N]}
    b. How far down stream does it land if the trip takes 0.5 h? {$\boldsymbol{d_E}$ = 1.5 km}
    c. How wide is the river? {$\boldsymbol{d_N}$ = 2.5 km}

6. A river has a current of 6.0 m/s [E]. What speed must a boat be able to travel, relative to the water, to go straight across the river when it is aimed 75° upstream? {***v*** = 23.2 m/s}

7. It is 500 m straight east to get across a river. The river has a current of 3.7 m/s due south. You have a boat that can travel 10 m/s. Calculate the angle to aim the boat to get directly across the river? {E22°N}

Outcome 3.1: Explain, describe, and analyze the forces of friction and gravity in one dimension.

1. Define an object's weight and mass.

2. How is the distance between objects considered in the equation for the force of gravity?

3. Explain the force of gravity, both its classical {Isaac Newton} and special relativity {Einstein} definitions. What observations supported Einstein's definition of gravity?

4. Suppose the weight of a person has a magnitude of 652.58 N on Earth's equator.
    a. Calculate the mass of the person. {m = 66.723 kg}
    b. Calculate the magnitude of that person's weight at the North Pole. {F_g = 656.03 N}
    c. Calculate the magnitude of that person's weight on the International Space Station. {F_g = 605.81}

5. A lunar rover has a mass of 209 kg. Calculate the magnitude of its weight on Earth and on the Moon. {F_{gE} = 2050 N, F_{gM} = 343 N}

6. On Earth, the magnitude of an object's weight is 451 N. Calculate the magnitude of the object's weight on the planet Mars. {F_{gMars} = 171 N}

7. On Earth, the magnitude of an object's weight is 725 N. On a different planet, the same object has a weight magnitude of 1062 N. Calculate the acceleration due to gravity on the other planet. {g_{planet} = 14.4 m/s^2}

8. What causes friction?

9. What type of force is stronger, static, or kinetic friction and why?

10. What are the three conditions necessary to be able to apply the formula for calculating the force of friction?

11. Explain the coefficient of friction.

12. In what direction does kinetic friction always act?

13. What is the definition of a normal force?

14. A 33 kg mass, on Earth, rests on the floor. Calculate the normal force. {F_N = 324 N}

15. A 33 kg mass, on Mars, rests on the floor. Calculate the normal force. {F_N = 123 N}

16. A 21 kg mass, on Earth, rests on the floor. A person pushes down on the object with a force of 75 N. Calculate the normal force. {F_N = 281 N}

17. A 41 kg mass, on Earth, rests on the floor. A person pulls up on the object with 150 N of force. Calculate the normal force. {F_N = 252 N}

18. A 75 kg mass, on the Moon, rests on the floor. A person pulls up on the object with 61 N of force. Calculate the normal force. {F_N = 62 N}

19. A box is pushed along a table on Earth. The same box and table are used on the Moon. How do the forces and coefficients of friction compare for the object on Earth and the Moon?

20. The coefficient of kinetic friction between a book and a table is 0.21. The normal force provided by the table is 15 N. Calculate the force of kinetic friction. {F_{fk} = 3.2 N}

21. The force of static friction between a crate and the floor is 345 N. The normal force provided from the floor is 750 N. Calculate the coefficient of static friction. {μ_s = 0.46}

22. Calculate the normal force provided by a table if the force of kinetic friction is 65 N and the coefficient of kinetic friction is 0.18. {F_N = 361 N}

23. A 37 kg object is at rest on the floor. The coefficient of static friction is 0.35. Calculate the force of static friction that must be overcome to get the object moving. {F_{fs} = 127 N}

24. A 52 kg crate is moved across the floor. 78 N of kinetic friction act upon the crate. Calculate the coefficient of kinetic friction. {μ_k = 0.15}

25. A bag is dragged along the floor. The force of kinetic friction is 46 N, and the coefficient of kinetic friction is 0.23. Calculate the mass of the bag. {m = 20 kg}

26. An old, heavy TV sits on a table. The force of static friction is 91 N, and the coefficient of static friction is 0.39. Calculate the mass of the TV. {m = 24 kg}

27. A person is trying to lift a 24 kg box off the ground by applying a 75 N upward force. Calculate the normal force on the box. {F_N = 160 N [up]}

28. Calculate the normal force acting on a 34 kg rock located on the surface of Mars. {F_N = 126 N [up]}

29. A large box is pushed along the floor. The force of kinetic friction is 59 N and μ_k is 0.35. Calculate:
    a. The normal force acting on the box {F_N = 167 N}
    b. The mass of the box. {m = 17 kg}

30. A 75 kg object rests on the floor with μ_s = 0.67. Calculate the magnitude of the force of static friction if a person *pushes down* on the box with a force of 210 N. {F_f = 634 N}

31. A 75 kg object rests on the floor with μ_s = 0.67. Calculate the magnitude of the force of static friction if a person *pulls up* on the box with a force of 210 N. {F_f = 352 N}

32. A person pulls a 72 kg supply box across the surface of Mars. If μ_k = 0.41 calculate the magnitude of the force of friction. {F_f = 110 N}

33. An object is pressed up against a wall. In what direction do the normal and friction forces act?

34. Calculate the coefficient of static friction if a 12 kg box is held against the wall with a force of 325 N {μ_s = 0.36}

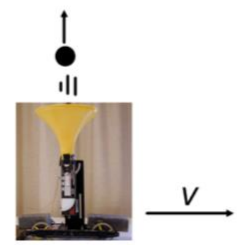
35. A 6.2 kg book is pressed against the wall. The coefficient of static friction between the book and wall is 0.16. Calculate the applied force necessary to keep the book from slipping down. {380 N}

36. A 14.7 kg box is pressed up against the wall using an applied force of 600 N. For the box not to fall, calculate the minimum coefficient of static friction necessary between the wall and the box. {0.24}

Outcome 3.2: Describe and apply Newton's 3 Laws of motion within inertial and non-inertial frames of reference in one dimension.

1. Define and compare classical and quantum mechanics.

2. Why are Newton's Laws of motion applicable on the Earth even though the Earth is technically a non-inertial frame of reference?
3. Give two examples of objects that cannot be analyzed with Newtonian mechanics.



4. Explain if the ball in the image to the right likely to land in the funnel if the cart is maintaining a constant velocity? What about if the cart has a constant acceleration?

5. Describe how the floor pushes you forward and that you do not push the floor.

6. Describe how Newton's 3rd Law applies to rocket launches.

7. Define net force.

8. Calculate the net force if these act on an object at the same time: F_1 = 42 N [E], F_2 = 70 N [W]. {F_{net} = 28 N [W]}

9. A box is pushed along the floor with an applied force of 93 N [E]. If 58 N of friction act on the box, calculate the net force. {F_{net} = 35 N [E]}

10. Calculate the necessary applied force to overcome 125 N of friction and have a net force of 182 N [E]. {F_a = 307 N [E]}

11. Describe how Newton's 2nd Law applies to rockets.

12. A towrope is used to pull a 1750 kg car across a flat surface, giving it an acceleration of 1.35 m/s^2. Calculate the net force acting on the car. {$\boldsymbol{F_{net}}$ = 2360 N}

13. A 5.2 kg bowling ball is accelerated from rest to a velocity of 12 m/s as the bowler covers 5.0 m of approach before releasing the ball. Calculate the net force on the ball during this time. { $\boldsymbol{F_{net}}$ = 75 N}

14. A high jumper falling at a 4.0 m/s lands on foam pit and comes to rest compressing the pit 0.40 m. If the pit can exert a net force of 1200 N on the high jumper breaking the fall, calculate the jumper's mass. {m = 60 kg}

15. In bench pressing 100 kg, a weightlifter applies an upward force of 1040 N. How large is the upward acceleration of the weights during the lift? {a = 0.59 m/s^2}

16. An elevator that weighs 3000 N is accelerated upward at 1.5 m/s^2. What applied force does the cable apply to give this acceleration? {F_a = 3460 N}

17. A car has a mass of 710 Kg. It starts from rest and travels 40 m in 3.0 s. Calculate the net force acting on the car assuming a uniform acceleration. {F_a = 6300 N}

18. A force is applied to a 50 kg object and results in a constant acceleration of 3.6 m/s^2 on a flat floor. The coefficient of kinetic friction is 0.15.
    a. Calculate the magnitude of the force of friction. {$|F_f|$ = 73.6 N}
    b. Calculate the net force. {F_{net} = 180 N}
    c. Calculate the applied force. {F_a = 253 N}

19. The net force on a box is 125 N and results in an acceleration of 10.5 m/s^2 along the ground. However, to keep that box moving an applied force of 175 N is required.
    a. Calculate the mass of the box. {12 kg}
    b. Calculate the normal force on the box. {117 N}
    c. Calculate the force of friction acting on the box. {–50 N}
    d. Calculate the coefficient of kinetic friction between the box and the ground. {0.43}

20. A 13 kg mass starts from 3.1 m/s and is accelerated to 18.6 m/s in 4.5 seconds from an unknown applied force. The coefficient of kinetic friction is 0.24.
    a. Calculate the acceleration of the mass. {3.4 m/s^2}
    b. Calculate the net force on the mass. {45 N}
    c. Calculate the magnitude of the force of kinetic friction on the mass. {31 N}
    d. Calculate the applied force. {76 N}

Outcome 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.

A. Net Force

1. Three forces act simultaneously on an object. One force is 10.0 N [N], the second is 15 N [W], and the third is 15.0 N [E60N]. Calculate the net force. {F_{net} = 24.2 N [W72°N]}

2. Two forces are acting on an object: F_1 = 345 N [E71°S] and F_2 = 415 N [W19°S]. Calculate a third force to create a net force of 378 N [E30°N]. {F_3 = 889 N [E47°N]}

B. Pulling or Pushing Objects at an Angle

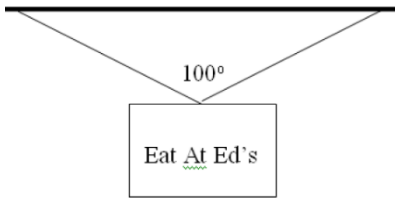
3. A student pushes a 25 kg lawn mower with a force of 150 N. The handle makes an angle of 35° to the horizontal.
    a. Calculate the vertical and horizontal components of the applied force. {F_{ay} = -86 N, F_{ax} = 123 N}
    b. Calculate the normal force. {F_N = 330 N}
    c. Calculate the net force if 85 N of friction exists. {F_{netx} = 38 N}
    d. Calculate the acceleration of the lawn mower. {a_x = 1.5 m/s^2}

4. Calculate the acceleration of a 15 kg toboggan that is pulled with an applied force of 45 N at an angle of 40° to the horizontal. The opposing force of friction is 28 N. {a_x = 0.43 m/s^2}

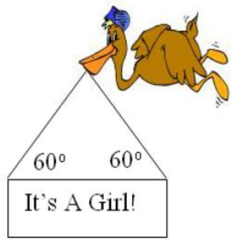
5. A 45 kg box is pulled with a force of 205 N by a rope held at an angle of 47° to the horizontal. The horizontal acceleration of the box is 0.20 m/s^2. Calculate the coefficient of kinetic friction. {μ_k = 0.45}

C. Tension and Hanging Objects

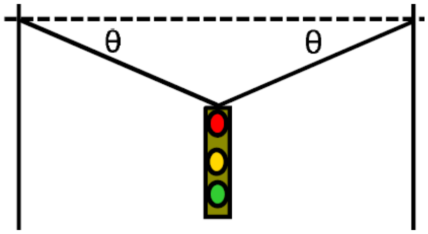
6. The sign has a mass of 5.0 kg. Calculate the tension in the cables. {F_T = 38 N}



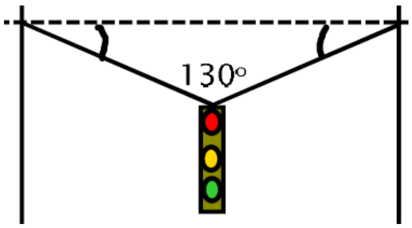
7. Calculate the force of tension in the cables if the sign has a mass of 10 kg. {F_T = 57 N}



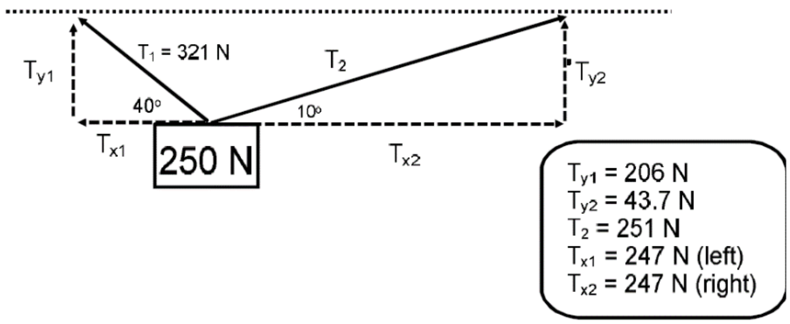
8. The cable being used to support a traffic light will break if the tension reaches 2100 N. Calculate the smallest angle possible if the traffic light has a mass of 110 kg. {θ = 15°}



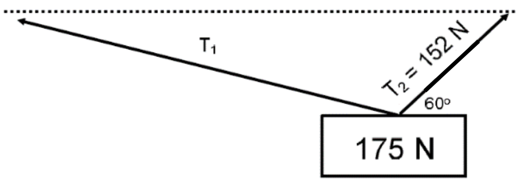
9. The cable being used to support a traffic light will break if the tension reaches 1750 N. Calculate the largest mass that can be hung on the wire. {m = 151 kg}



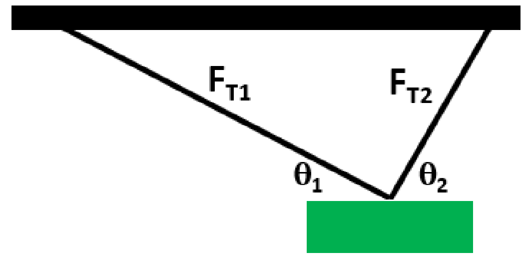
10. Calculate all the unknown variables labeled in the following sketch {the answers are in the block to the bottom right of the image}.



11. Calculate T_1 given the following information in the image on the right. {T_1 = 87 N}



12. *Calculate the force of tension in each wire given $\theta_1 = 32^o$, $\theta_2 = 48^o$ and the mass of the sign is 125 kg. {F_{T1} = 836 N, F_{T2} = 1054 N}



Outcome: 4.1 Define and apply the concept of work incorporating the following: kinetic, gravitational potential, elastic potential energy, and energy loss due to friction.

1. A piano is moved 12.7 m across a room. Calculate the force exerted if the work done is 2750 J. {***F*** = 217 N}

2. A person holds a briefcase at a constant height above the floor by exerting an upwards force of 30.0 N This person walks 20.0 m down the hall to her office. Calculate the work done on the briefcase, by the upwards force, during the walk. {*W* = 0 J}

3. Calculate the work done by friction and the applied force on a box. The applied force is 212 N moving the box across a 9.5 m long floor. The force of friction between the box and the floor is 87 N. {W_f = -826 J, W_{Fa} = 2014 J}

4. Starting from rest a car drives straight east from an applied force. It accelerates to a desired velocity, maintains that velocity, and then accelerates to a stop.
   a. In what direction is the applied force during the initial acceleration? Is the work done on the car, by this force positive or negative?
   b. In what direction is the applied force during the constant velocity? Is the work done on the car, by this force positive or negative?
   c. In what direction is the applied breaking force during the final acceleration? Is the work done on the car, by this force positive or negative?

5. To drive a car in a circle, the force of friction acts towards the center, at 90° to the velocity. Suppose a car drives at a constant speed in a circular path, explain why the work done by friction on the car is zero.

6. A 75 kg boulder rolled off a cliff and fell to the ground. If the force of gravity did 60 000 J of work on the boulder, how far did it fall? {*d* = 81.5m}

7. A person pushes a box down a hall by exerting 300 N of force. If the work done by the person is 1900 J, calculate the length of the hallway. {*d* = 6.33 m}

8. A 25 kg rock is rolled up a hill to a height of 12 m above its previous location. Calculate the work done by gravity. {W = -2943 J}

9. A spring is used to stop a sliding object by applying an average force of 40 N. If the stopping distance was 0.73 m, calculate the work done by the spring. {W = -29.2 J}

10. A bowling ball moving at 0.95 m/s has 4.5 J of kinetic energy. Calculate the mass of the bowling ball. {*m* = 10 kg}

11. A 56 kg skier reaches the bottom of a ski hill with a velocity of 7.25 m/s. Calculate her kinetic energy. {E_k = 1472 J}

12. A slingshot has an elastic cord. The cord has a spring constant of 1100 N/m.
    a. Using Hooke's Law, calculate the stretch length of the cord if a force of 455 N is applied. {x = 0.41 m}
    b. Calculate the elastic potential energy in the cord. {E_e = 92 J}

13. An object is hung from a vertical spring, extending it by 0.24 m. If the spring constant is 35 N/m, calculate the potential energy in the spring. {E_e = 1.0 J}

14. A force of 18 N compresses a spring by 0.15 m. By how much does the spring's potential energy change? {ΔE_e = 1.4 J}

15. A 4.45 kg picture is hung on the wall. Not happy with its position, the owner moves the picture to a location 2.5 m higher. Calculate how much gravitational potential energy the picture has gained. {ΔE_g = 109 J}

16. A roller-coaster train lifts its passengers up vertically through a height of 39.4 m from its starting position. Calculate the change in gravitational potential energy if the entire mass is 3900 kg. {$\Delta E_g = 1.51 \times 10^6$ J}

Outcome 4.2: Qualitatively and quantitatively analyze the conservation of mechanical energy with conservative and non-conservative forces.

1. The length of a rollercoaster track is 1425 m. The cart starts from rest and comes to a stop at ground level. Calculate the average force of friction if all the cart's energy was lost to thermal energy. The initial height of the roller coaster and mass are 25.9 m and 341 kg, respectively. {$\boldsymbol{F_f}$ = 61 N}

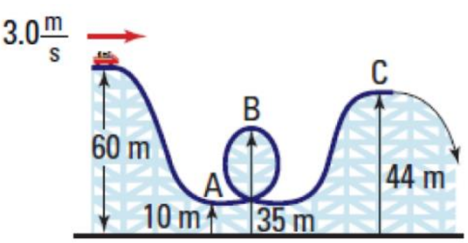
2. A 1.2 kg cart is moving along a table at 3.6 m/s when it collides with a spring bumper. Answer the following if it has a spring constant of 200 N/m, assuming no frictional forces.
    a. Calculate the maximum compression of the spring. {x = 0.29 m}
    b. Calculate the speed of the cart the instant the spring has been compressed 0.11 m. {v_f = 3.3 m/s}

3. A clown car has a total mass of 150 kg and is moving at 6.0 m/s when it hits a large spring. The cart is brought to a stop in 2.0 m. Calculate the spring constant. {k = 1350 N/m}

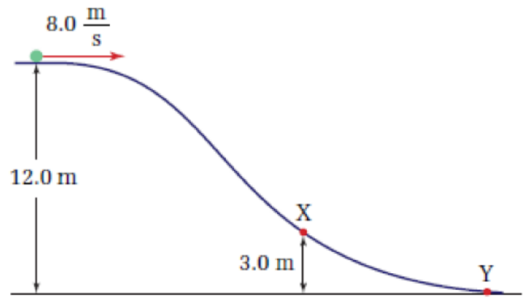
4. An archery bow has a spring constant of 485 N/m. If the bow is stretched 0.45 m and the arrow has a mass of 0.031 kg, calculate the speed of the arrow as it leaves the bow. {v_f = 56.3 m/s}

5. A 70.0 kg stunt person falls 8.25 m to a suspended net. Calculate the spring constant of the net if it stretches 1.40 m to stop the person's fall. {k = 6762 N/m}

6. A 250 kg roller coaster cart loaded with people has an initial velocity of 3.0 m/s. Calculate the velocity of the cart at A, B, and C. Assume the roller coaster is frictionless. {v_A = 31 m/s; v_B = 22.3 m/s; v_C = 18 m/s}

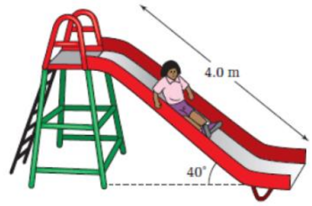


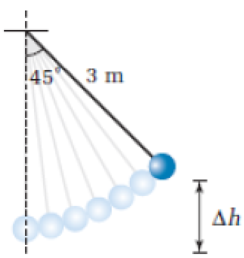
7. A sled at the top of a snowy hill is moving forward at 8.0 m/s. The total mass of the sled and rider is 70.0 kg. Calculate the speed of the sled at point X, which is 3.0 m above the base of the hill, if the snow does 1220 J of work on the sled on the way to point X. {v_f = 14.3 m/s}



8. The tallest point of a roller-coaster is 94.5 m.
   a. Calculate the speed of a cart at ground level. {v_f = 43.1 m/s}
   b. The actual ground level speed is 41.1 m/s, calculate the percentage of total mechanical energy lost to thermal energy due to friction. {E_{loss} = 9.1%}

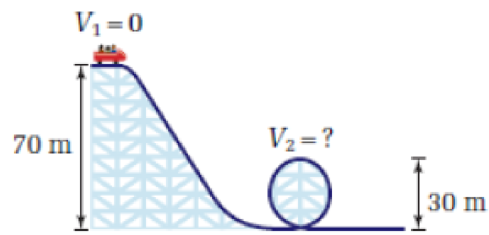
9. A 15 kg child, at rest, slides down a 4.0 m long slide that makes a 40° angle with the ground. The child's speed at the bottom is 3.2 m/s. Calculate the force of friction exerted on the child from the slide. {$\boldsymbol{F_f}$ = 75 N [up the slide]}





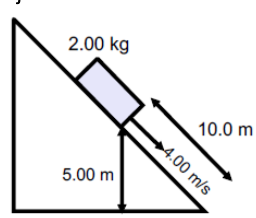
10. A 2.5 kg mass is attached to a 3.0 m long string and raised at an angle of 45° relative to the rest position. Calculate the velocity of the mass when it returns to the rest position once released. {v_f = 4.2 m/s}

11. A roller coaster is constructed with a circular vertical loop. Assuming no friction calculate the speed at the top of the loop. {v_f = 28 m/s}



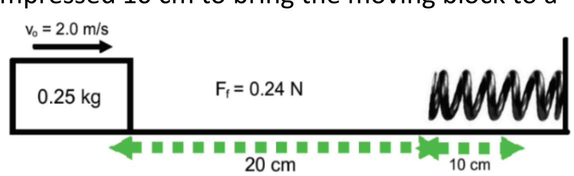
12. A 45 kg cyclist travelling 7.6 m/s on a 7.0 kg bike brakes suddenly and slides to a stop in 3.2 m.
    a. Calculate the work done by friction to stop the cyclist. {W_{nc} = -1502 J}
    b. Calculate the coefficient of friction between the skidding tires and the ground. {μ_s = 0.92}

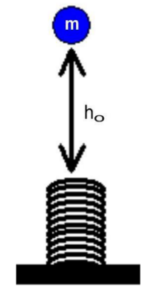
13. Calculate the velocity at the bottom of the ramp if the force of friction acting on the mass is 3.3 N {refer to the image to the right for more details}. {v_f = 9.0 m/s}



14. A 2.75 kg object is dropped 1.85 m on to a platform which is supported by a strong spring. The platform compresses 0.75 m to bring the object to a stop. Calculate the k-value of the spring. {k = 249 N/m}

15. Given the information in the diagram below and that the spring is compressed 10 cm to bring the moving block to a stop, calculate (remember to use distances in meters):
    a. The spring constant, k. {k = 85.6 N/m}
    b. The speed of the mass as it leaves the spring. {v_f = 1.8 m/s}

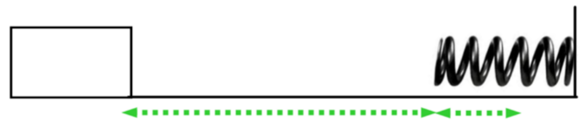




16. A 5.0 kg mass is dropped from 2.0 m on to a large spring. The k-value of the spring is 1406 N/m. Calculate how much the spring compresses to bring the mass to a stop. {x = 0.41 m}

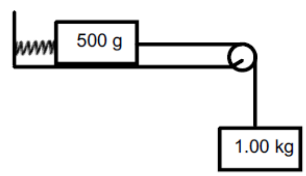
17. An 8.9 kg mass is dropped from a height of 7.6 meters above a large spring in neutral position. The spring constant is 175 N/m. Calculate the compression distance of the spring when the object has a speed of 5.3 m/s. {x = 3.0 m}

18. A 5.7 kg block is located 3.1 m from a large spring. At that point, the block is moving at 6.5 m/s. The force of kinetic friction between the block and the floor is 8.5 N. The spring constant is 80 N/m. Calculate the compression length of the spring to stop the block from moving. {x = 1.4 m}



19. A 5.7 kg block is located 7.4 m from a large spring. At that point, the block is moving at 12 m/s. The force of kinetic friction between the block and the floor is 25 N. The spring constant is 40 N/m. Calculate the compression length of the spring to stop the block from moving. {x = 2.8 m}

20. *In the diagram, the force of friction between the 500 g mass {or 0.5 kg} and the table is 4.8 N. The spring constant is 50 N/m. The system starts at rest with the spring at its natural length. Calculate the maximum speed the 1.0 kg mass will reach. {v_{max} = 0.58 m/s}



Outcome 5.1: Waves

1. What property of a mechanical wave is the same for a material no matter how the wave was created?

2. As a wave travels from one material into a different material, what property of the wave will not change?

3. Why are longitudinal waves also called pressure waves?

4. Sketch a diagram of a transverse wave and label a crest, trough, rest position, amplitude, and wavelength.

5. Define a standing wave and provide an example of such a wave in 1, 2 and 3 dimensions.

6. Define nodes and antinodes.

7. Define constructive and destructive interference.

8. How does the strength between medium particles and the mass of those particles affect the speed of waves through that medium?

9. What is friction as it pertains to waves and what effect does it have on waves?

10. What do waves transfer?

11. For a particular medium, if the wave frequency increases, how do the period and wavelength change?

12. A car tire completes 475 rotations in 12.5 seconds. Calculate the frequency and period of the spinning tire. {f = 0.026 Hz, T = 38 Hz}

13. A wave is created with a frequency of 300 Hz. It has a speed of 1200 m/s.
    a. Calculate the period of the wave. {T = 0.003 s}
    b. Calculate the wavelength of the wave. {λ = 4 m}

14. The period of a water wave is 2.5 seconds.
    a. Calculate the frequency of the waves. {f = 0.4 Hz}
    b. Calculate the length of time for 150 waves to pass by you. {60 s}

15. A wave takes 6.7 seconds to travel down a 12 m long string. The waves have a period of 1.5 seconds. Calculate the wavelength of the waves in the spring. {λ = 2.7 m}

16. Radio waves travel at 3.00 x 10^8 m/s. Calculate the wavelength of radio waves emitted by a radio station operating at 103.1 MHz. {λ = 2.9 m}

17. Two fishing boats are in the water. At a time when one boat is on a crest the other is in a trough and there are three crests between them. The boats are 125 m apart, and the wave period was measured to be 1.75 seconds. Calculate the speed of the waves. {v = 20 m/s}

Outcome 5.4: Refraction

1. Calculate the speed of light in flint glass. (v = 1.82 x 10^8 m/s)

2. Calculate the speed of light in ruby. (v = 1.95 x 10^8 m/s)

3. Calculate the index of refraction for a material in which light travels 2.75 x 10^8 m/s. (n = 1.09)

4. Calculate the index of refraction for a material in which light travels 1.21 x 10^8 m/s. (n = 2.48)

5. How many times faster does light travel in glycerin than in zircon? (1.31 times faster)

6. By how much does the speed of light decrease in diamond when light enters diamond from water? (1.01 x 10^8 m/s)

7. Calculate the wavelength of yellow light in ethyl alcohol if f = 7.05 x 10^{14} Hz. (λ = 3.12 x 10^{-7} m or 312 nm)

8. In air, yellow light has a wavelength of 589 nm. Calculate this light's wavelength in sodium chloride. (λ = 382 nm)

9. Calculate the wavelength of yellow light in diamond, if its wavelength in a perfect vacuum is 589 nm. (λ = 243 nm)

10. Calculate the distance light travels in 2.0 s in a perfect vacuum and water. (d_{vac} = 6.00 x 10^8 m; d_w = 4.50 x 10^8 m)

11. Light travels from air into flint glass with an angle of incidence of 25°. Calculate the angle of refractions. (θ_2 = 15°)

12. Light is traveling from an unknown medium into diamond. The angle of incidence is 42° and the angle of refraction is 28°. Calculate the index of refraction of the unknown medium. ($n_?$ = 1.7)

13. Light travels from Plexiglas into ruby. Calculate the angle of incidence if the angle of refraction is measured to be 16.8°. (θ_1 = 17.1°)

14. Light travels from water into an unknown material. The angle of incidence is 72° and the angle of refraction is 51°. Calculate the speed of light in the unknown material. (v = 1.84 x 10^8 m/s)

15. The speed of light in a certain material is 9.68 x 10^7 m/s. If light enters that material from crown glass with an angle of incidence of 33.5°, calculate the angle of refraction. (θ_2 = 15.7°)

16. Light is traveling from air into glycerin, calculate the largest possible angle of refraction. (θ_{max} = 43°)

17. Light is traveling from water into crown glass, calculate the largest possible angle of refraction. (θ_{max} = 61°)

18. Calculate the critical angle for flint glass into air. (θ_c = 37°)

19. Calculate the critical angle for diamond into water. (θ_c = 33°)

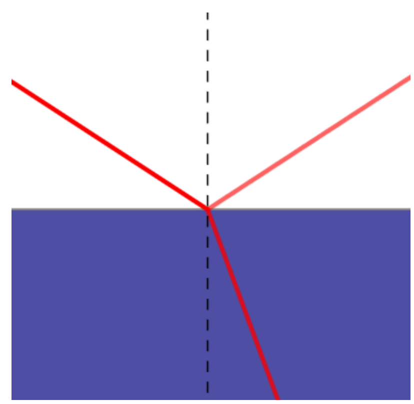
20. Calculate the critical angle for calcium chloride into glycerin. (θ_c = 73°)

21. Calculate the speed of light in a material that is measured to have an angle of refraction of 38°. The angle of incidence, in water, was 46°. (v = 1.93 x 10^8 m/s)

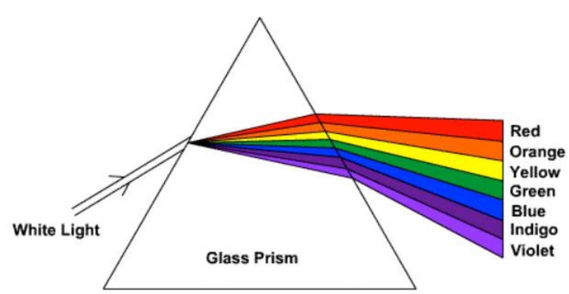
22. Calculate the angle of refraction for light traveling from carbon disulfide into ice if the angle of incidence is 75°.

23. *Light travels through a 10 cm wide block of flint glass from air. It enters with an angle of incidence of 30°. Calculate the lateral displacement of the emerging light ray. (d = 2.25 cm)

24. In the diagram to the right, label each of the following if the top part is the first medium:
    a. Refracted ray
    b. Angle of incidence
    c. Reflected ray
    d. Normal
    e. Incident ray
    f. Boundary
    g. Angle of refraction
    h. Angle of reflection



25. An angle of refraction in a medium is measured to be greater than the angle of incidence. Knowing that, compare the indexes of refraction and the speed of light between the two media.



26. Why does an object in a liquid, like a spoon in water, look bent or distorted?

27. Do all the colors of light travel the same speed in glass? If not, which color has the highest/lowest index of refraction?

28. How does refraction impact a sunrise and sunset?

29. Explain, in general, why light doesn’t leave a fiber optic cable until it reaches the end of the cable.

30. Why is the Moon red during a lunar eclipse? Why does it not appear to take another color?

31. Explain what the critical angle is and when it can occur.

32. What causes lateral displacement of light traveling through a rectangular piece of glass?

33. How did the human eye evolve to make use of refraction? How are corrective lenses implemented?

34. Why does a rear-view mirror show a dimmer image of what is behind a car when the mirror is tilted down?

35. How does a mirage of a puddle appear to be on the ground a large distance in front of you when walking or driving?