Unit 4
Forces and Motion

Physical Science
Mrs. Valentine

4.1 Reference, Distance, and Displacement

- Objective:
  - I will understand relative motion and be able to select a good reference point. I will be able to distinguish between distance and displacement.
- Vocabulary:

Frame of Reference	Relative Motion	Distance	Displacement	Motion

4.1 Reference, Distance, and Displacement

- Motion
  - The state in which one object's distance from another is changing
  - To describe motion accurately and completely, a frame of reference is necessary.
  - Frame of Reference
    - A system of objects that are not moving with respect to one another.
    - Relative motion is movement in relation to a frame of reference.
      - Ex: train moving past a platform, car driving past a sign
      - Make sure to choose a meaningful reference
      - Reference should not be moving WITH the object being observed

4.1 Reference, Distance, and Displacement

- Distance vs. Displacement
  - Distance
    - The length of a path between two points.
    - When an object moves in a straight line, the distance is the length of the line connecting the object's starting and ending points.
    - Symbol & SI Units
      - Symbol: d
      - SI Units: meter
      - Common to use other units to match larger or smaller distances (kilometers for larger, centimeter for smaller, for instance).
    - Examples: 5 meters, 3 miles, 4 feet

4.1 Reference, Distance, and Displacement

– Displacement
  - The direction from the starting point and the length of a straight line from the starting point to the ending point.
  - Distance AND direction
  - More useful for giving directions and describing motion
  - Symbol & SI Units
    – Symbol: x
    – SI Units: meter
  - Examples : 5 meters west, 3 miles east, 4 feet to the left

4.2 Scalar and Vector Quantities

- Objective:
  – I will be able to recognize scalar and vector quantities. I will be able to perform simple vector addition. I will be able to graph position-time graphs, velocity-time graphs, and motion maps.

- Vocabulary:

Scalar Quantity	Linear Graph	Vector	Vector Addition	Resultant Vector

4.2 Scalar and Vector Quantities

- Scalar Quantity
  - A physical measurement that does not contain directional information.
  - Examples
    - Distance
    - Speed
    - Time

4.2 Scalar and Vector Quantities

- Vector Quantity
  - A quantity that has both magnitude and direction.
  - Often represented with arrows. The size of the arrow indicates the magnitude while the arrow head points in the direction of the vector.
  - Examples
    - Velocity
    - Acceleration
    - Force

4.2 Scalar and Vector Quantities

- Vector addition is the combining of vector magnitudes and directions.
  - Linear displacement
    - If two vectors on the same line are in the same direction, add the magnitudes
    - If the two vectors on the same line are in opposite directions, subtract the vectors. The resulting direction will be that of the larger vector.
  - Nonlinear displacement
    - Combine vectors in two or more different directions by graphing.
  - The resultant vector is the vector sum of two or more vectors.

4.2 Scalar and Vector Quantities

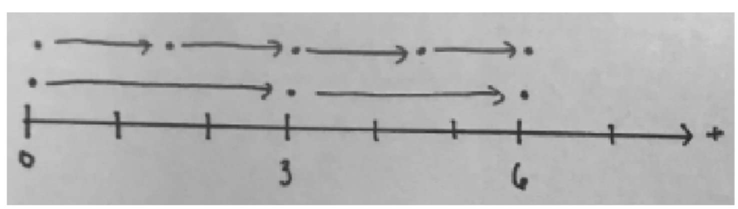
- Graphing Motion
  - Position vs. Time Graphs
    - A position vs. time graph is an excellent way to describe motion.
    - Time is on the x-axis and position is on the y-axis.
    - Linear graphs (formed from line segments).
    - Shows the direction by the sign of the slope (positive or negative).
    - The slope of a position vs. time graph is equal to velocity.

4.2 Scalar and Vector Quantities

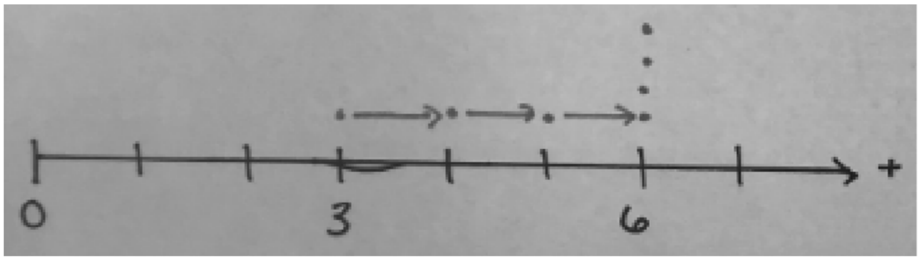
- Motion Maps
  - Uses arrows and a number line to represent motion.
    - Longer arrows = faster motion
    - Multiple dots at same time = object rested at that position

4.2 Scalar and Vector Quantities

- Examples
  - The red car was faster
    - Longer arrows
    - Dots spaced out
  - The blue car was slower
    - Shorter arrows
    - Dots closer

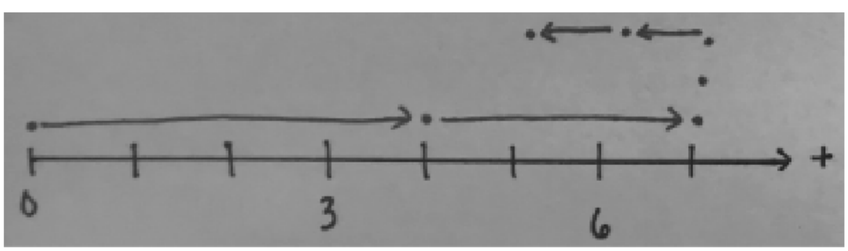


4.2 Scalar and Vector Quantities



- Object moved slowly, starting at 3 (not 0) and moved in the positive direction until position 6, where it stopped.

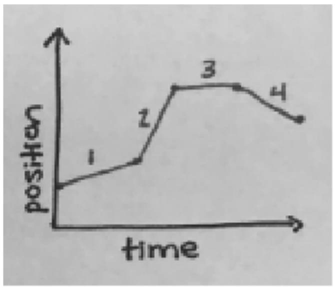
4.2 Scalar and Vector Quantities



- Object moved quickly until position 4, then slowed slightly to move to position 7. At position 7, the object paused before turning around and slowly moving back in the negative direction.

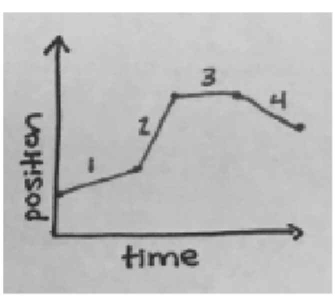
4.2 Scalar and Vector Quantities

– Given the position vs. time graph below, create a velocity vs. time graph and a motion map. Describe the motion.

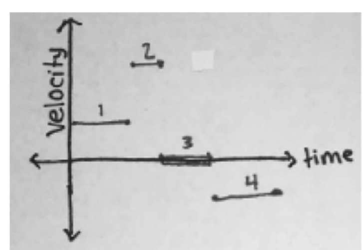


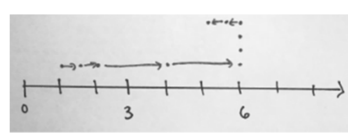
4.2 Scalar and Vector Quantities

– Given the position vs. time graph below, create a velocity vs. time graph and a motion map. Describe the motion.



Description:
(1) Did not start at 0. Started slow (lower slope).
(2) Faster (steeper slope).
Both (1) and (2) are positive (up).
(3) Did not move (slope = 0).
(4) moved slowly in the negative direction.





4.3 Speed, Velocity, and Acceleration

- Objective:
  - I will understand the difference between speed and velocity. I will be able to calculate velocity, acceleration, and momentum.

- Vocabulary:

Speed	Average Speed	Nonlinear Graph	Velocity	Acceleration
Constant Acceleration	Instantaneous Speed	Instantaneous Acceleration		

4.3 Speed, Velocity, and Acceleration

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4.4 Forces, Gravity, and Free-Fall

- Objective:
  - I will understand the difference between balanced and unbalanced force. I will be able to recognize several types of forces, especially gravity. I will be able to represent forces using system schema and force addition diagrams.
- Vocabulary:

Free Fall	Force	Net Force	Balanced Forces	Unbalanced Forces
Gravity	Terminal Velocity	Projectile Motion	Weight	
Strong Nuclear Force	Weak Nuclear Force	Gravitational Force	Centripetal Force	Normal Force

4.4 Forces, Gravity, and Free-Fall

- Force
  - A force is a push or a pull.
  - Can cause a resting object to move, or it can accelerate a moving object by changing the object's speed or direction.
  - Spring scales can be used to measure force.
  - SI Units: Newton (N)
    - One newton is the force that causes a 1-kilogram mass to accelerate at a rate of one meter per second each second.
    - $1N = 1kgm/s^2$
  - Force is a vector.

4.4 Forces, Gravity, and Free-Fall

- NOTE: forces cannot be added unless they are acting on the same object.
- Net force is the overall force acting on an object after all the forces are combined.
- Balanced Forces
  - When the forces on an object are balanced, the net force is zero and there is no change in the object's motion
  - Forces that combine to have a net force of 0 are called balanced forces.
  - These forces are equal and opposite, and are acting on the same object.
  - Ex: a tug-of-war stalemate.

4.4 Forces, Gravity, and Free-Fall

- Unbalanced Forces
  - An unbalanced force is a force that results when the net force acting on an object is not equal to zero.
  - When an unbalanced force acts on an object, the object accelerates.
  - If forces are acting in opposite directions but are not equal, they will produce an unbalanced force.

4.4 Forces, Gravity, and Free-Fall

- Gravity
  - A force that acts between any two masses.
  - An attractive force that pulls objects together.
  - Does not require objects to be in physical contact to affect them.
  - The strength of gravity between two objects depends upon the relative masses of the objects and the distance between them.
    - The closer two objects are, the stronger the gravitational force.
    - The more mass one object has relative to the other, the stronger gravitational force.

4.4 Forces, Gravity, and Free-Fall

- Earth's gravity
  - Holds you on the ground
  - Acts downward toward the center of Earth.
  - Acceleration due to gravity is $9.8 m/s^2$.
  - Free Fall
    - Gravity causes objects to accelerate downward while air resistance acts in the direction opposite to the motion and reduces acceleration.
    - Free Fall is the movement of an object toward Earth solely because of gravity.

4.4 Forces, Gravity, and Free-Fall

- Terminal Velocity
  - The constant velocity of a falling object when the force of air resistance equals the force of gravity.
  - Increasing the surface area perpendicular to gravity decreases terminal velocity (causes it to fall more slowly).
    - Example: drop a balled up piece of paper vs. a flat piece of paper with the same mass.

4.4 Forces, Gravity, and Free-Fall

- Projectile Motion
  - The motion of a falling object (projectile) after it has been given an initial forward velocity.
  - The combination of an initial forward velocity and the downward vertical force of gravity causes the ball to follow a curved path.
  - Two balls fall with the same acceleration and strike the ground at the same time, even if one is simply dropped and the other has been given an initial forward velocity.

4.4 Forces, Gravity, and Free-Fall

- Weight vs. Mass Review
  - Weight is a measure of the force of gravity on an object.
    - This changes as an object moves from celestial body to celestial body.
    - Measured in newtons.
    - Weight equals an object's mass times its acceleration due to gravity $W = mg$.
  - Mass is a measure of the amount of matter in an object.
    - This does not change regardless of the location of the object.
    - Measured in kilograms.

4.4 Forces, Gravity, and Free-Fall

- Types of Forces
  - Nuclear forces – two forces, the strong nuclear force and the weak nuclear force, act within the nucleus to hold it together.
    - Strong Nuclear Force
      - A powerful force of attraction that acts only on the neutrons and protons within the nucleus, holding them together
    - Weak Nuclear Force
      - An attractive force that acts only over a short range (about 10^{-18}m).

4.4 Forces, Gravity, and Free-Fall

- Centripetal Force
  - A center-direct force that continuously change the direction of an object to make it move in a circle.
  - The moon and man-made satellites around Earth experience this force.
- Gravitational Force (F_g)
  - Attractive force that acts between any two masses.
  - Acts over large distances.
  - Newton's law of universal gravitation states that every object in the universe attracts every other object.

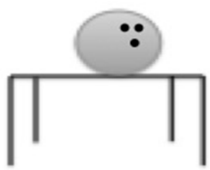
4.4 Forces, Gravity, and Free-Fall

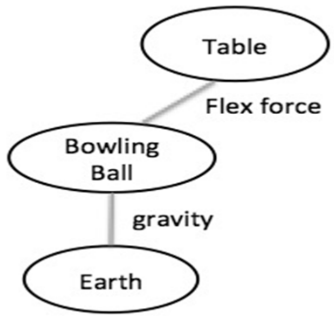
- Normal Force (F_N)
  - The force that is exerted upon an object that is in contact with another stable object.
  - Also known as flex force
- Tension Force (F_T)
  - The force that is transmitted through a string, rope, cable, or wire when it is pulled tight by forces acting from opposite ends.
- Elastic Force (F_e)
  - The force exerted by a compressed or stretched spring upon an object that is attached to it.

4.4 Forces, Gravity, and Free-Fall

- Force Diagrams and System Schema
  - A system schema is a bubble map of the objects enacting forces on each other and show the forces using lines between objects.
  - A force diagram is a diagram that shows the forces acting on an object using arrows to indicated magnitude and direction of the forces.
  - A force addition diagram shows how these forces compare and indicate any net force acting on an object.

4.4 Forces, Gravity, and Free-Fall





Cartoon **System Schema** **Force Diagram** **Force Addition Diagram**

4.4 Forces, Gravity, and Free-Fall

Cartoon **System Schema** **Force Diagram** **Force Addition Diagram**

4.5 Friction

- Objective:
  - I will understand how friction affects motion. I will be able to distinguish between the four types of friction.
- Vocabulary:

Friction	Static Friction	Sliding Friction	Rolling Friction	Fluid Friction
Fluid				

4.5 Friction

- Friction is a force that opposes the motion of objects that touch as they move past each other.
- Without friction, the world would be a very different place.
  - Surfaces would be slipperier than ice
  - Walking and using many common instruments, like forks or cars, would be impossible.
  - Acts at the surface where two objects are in contact. This includes all three major states of matter (solids, liquids, and gases).
- Types of Friction
  - There are four main types of friction: static friction, sliding friction, rolling friction, and fluid friction.

4.5 Friction

- Static Friction (F_{fs})
  - The friction force that acts on objects that are not moving.
  - Always acts in the direction opposite tot that of the applied force.
  - Examples:
    - Pushing a piece of paper to the whiteboard, and the paper does not fall.
    - When you push off with each step while walking, static friction between the ground and your shoe keeps your shoe from sliding.

4.5 Friction

- Sliding Friction (F_{fk})
  - A force that opposes the direction of motion of an object as it slides over a surface.
  - Less than static friction
    - Motion is still possible.
    - Less force is needed to keep an object moving than to start it moving.
  - Examples:
    - Rubbing your hands together has friction, which generates heat.
    - When you slide a book across a table, it quickly slides to a stop.

4.5 Friction

- Rolling Friction(F_{fk})
  - The friction force that acts on rolling objects.
  - About 100 to 1000 times less than the force of static or sliding friction for a given material.
  - Ball bearings in items like skate wheels and fidget spinners reduce the friction to make the items more efficient.
  - Examples:
    - A tire rolling along the road as a car drives forward.
    - The wheels of a roller-skate along the rink floor.

4.5 Friction

- Fluid Friction(F_{fk})
  - A force that opposes the motion of an object through a fluid
  - Weakest type of all friction forces.
  - A fluid is a substance that can change shape, including liquids and gases.
  - Common fluid friction force: air resistance
    - The fluid friction between objects and the air
    - At higher speeds, air resistance can become significant
    - Reduces acceleration.
  - Examples:
    - A boat sailing across a lake
    - Lubricated pistons firing in an engine

4.6 Newton's 3 Laws of Motion

- Objective:
  - I will understand and be able to apply Newton's three laws of motion. I will understand momentum and its roll in motion.
- Vocabulary:

Inertia	Newton's First Law of Motion	Law of Inertia	Newton's Second Law of Motion	Newton's Third Law of Motion
Action Force	Reaction Force	Momentum	Law of Conservation of Momentum	

4.6 Newton's 3 Laws of Motion

- Newton's First Law
  - Inertia is the tendency of an object to resist a change in its motion.
    - Mass is a measure of the inertia of an object and depends on the amount of matter the object contains.
  - According to Newton's First Law of motion, the state of motion of an object does not change as long as the net force acting on the object is zero.
    - Also called the Law of Inertia
    - Another way of wording Newton's first law is that an object in motion remains in motion, or an object at rest remains at rest, unless an unbalanced force acts on it.

4.6 Newton's 3 Laws of Motion

- Examples
  - When you are riding in a car, and the driver slams on the brakes, you lurch forward into your seatbelt.
  - It is more difficult to start moving a heavy object than it is to keep one going that is already in motion.

4.6 Newton's 3 Laws of Motion

- Newton's Second Law
  - The acceleration of an object is equal to the net force acting on it divided by the object's mass.
  - Another way of stating this is that force is equal to the product of an object's mass and its acceleration.
  - The acceleration of an object is always in the same direction as the net force.
  - Equations: $F = ma$ or $a = F/m$

4.6 Newton's 3 Laws of Motion

- Examples
  - A boy pushes forward a cart of groceries with a total mass of 40.0kg. What is the acceleration of the cart if the net force on the cart is 60.0N?
  - What is the upward acceleration of a helicopter with a mass of 5000kg if a force of 10 000N acts on it in an upward direction?
  - An automobile with a mass of 1200kg accelerates at a rate of $3.0 m/s^2$ in the forward direction. What is the net force acting on the automobile?
  - A 25-N force accelerates a boy in a wheelchair at $0.5 m/s^2$. What is the mass of the boy and the wheelchair?

4.6 Newton's 3 Laws of Motion

- Newton's Third Law
  - Whenever one objects exerts a force on a second object, the second object exerts an equal and opposite force on the first one.
  - These forces are called action and reaction forces.
    - These forces are equal in size and opposite in direction.
    - Action and reaction forces do not cancel because they are not acting on the same object. Only when equal and opposite forces are acting on the same object do they result in a net force of zero.

4.6 Newton's 3 Laws of Motion

- Examples
  - When a hammer strikes a nail, it bounces back up from the force the nail exerts on the hammer.
  - When you slap your hand against a desk, it hurts from the force the desk applies back on your hand.
  - If two people are on ice skates, and person A pushes person B, person A will move backward from the reaction force from person B.

4.6 Newton's 3 Laws of Motion

- Momentum
  - The product of an object's mass and its velocity.
  - An object with a large momentum is difficult to stop.
  - An object has a large momentum if the product of its mass and velocity is large.
  - A bowling ball moving at the same speed as a golf ball has significantly more momentum.
  - The momentum for any object at rest is zero.
  - Equation & SI Unit
    - Equation: $\rho = mv$
    - SI Unit: kgm/s

4.6 Newton's 3 Laws of Motion

- Law of Conservation of Momentum
  - When objects collide, momentum is conserved (i.e. has a constant value).
  - According to the law of conservation of momentum, if no net force acts on a system, then the total momentum of the system does not change.
  - In a closed system, the loss of momentum of one object equals the gain in momentum of another object – momentum is conserved.