02 Force and Translational Dynamics Copied on: 08/08/24

Content Area: **Science**
Course(s): **AP Physics 1**
Time Period: **Semester 1**
Length: **22 Periods**
Status: **Published**

Standards

	Patterns
SCI.HS.PS2.B	Types of Interactions
SCI.HS-PS2-1	Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.
SCI.HS.PS2.A	Forces and Motion
	Cause and Effect
SCI.HS-PS2-4	Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.
	Scale, Proportion, and Quantity
	Using Mathematics and Computational Thinking
SCI.HS-ESS1-4	Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.
SCI.HS.ESS1.B	Earth and the Solar System
	Analyzing and Interpreting Data

Enduring Understandings

The internal structure of a system determines many properties of the system.

A gravitational field is caused by an object with mass.

At the macroscopic level, forces can be categorized as either long-range (action-ata-distance) forces or contact forces.

Objects and systems have properties of inertial mass and gravitational mass that are experimentally verified to be the same and that satisfy conservation principles

All forces share certain common characteristics when considered by observers in inertial reference frames.

Classically, the acceleration of an object interacting with other objects can be predicted by using a = F/m

The acceleration of the center of mass of a system is related to the net force exerted on the system, where a = F/m

A field associates a value of some physical quantity with every point in space. Field models are useful for describing interactions that occur at a distance (long-range forces), as well as a variety of other physical phenomena.

Certain types of forces are considered fundamental.

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Essential Questions

1. Why do we feel pulled toward Earth but not toward a pencil?
2. Why is it more difficult to stop a fully loaded dump truck than a small passenger car?
3. Why is it difficult to walk on ice?

4. Why will a delivery truck filled wit bird sitting on its floor be the same weight as a truck with the same birds flying around inside?

Knowledge and Skills

2.1 Systems and Center of Mass

Knowledge

- System properties are determined by the interactions between objects within the system.
- If the properties or interactions of the constituent objects within a system are not important in modeling the behavior of the macroscopic system, the system can itself be treated as a single object.
- Systems may allow interactions between constituent parts of the system and the environment, which may result in the transfer of energy or mass.
- Individual objects within a chosen system may behave differently from each other as well as from the system as a whole.
- The internal structure of a system affects the analysis of that system.
- As variables external to a system are changed, the system's substructure may change.
- For systems with symmetrical mass distributions, the center of mass is located on lines of symmetry.

- The location of a system's center of mass along a given axis can be calculated using the equation xcm=sum(mx)/sum(m)

- A system can be modeled as a singular object that is located at the system's center of mass.

Skills

- Create quantitative graphs with appropriate scales and units, including plotting data.
- Calculate or estimate an unknown quantity with units from known quantities, by selecting and following a logical computational pathway.
- Compare physical quantities between two or more scenarios or at different times and locations in a single scenario
- Apply an appropriate law, definition, theoretical relationship, or model to make a claim.

2.2 Forces and Free-Body Diagrams

Knowledge

- Forces are vector quantities that describe the interactions between objects or systems.
    - A force exerted on an object or system is always due to the interaction of that object with another object or system.
    - An object or system cannot exert a net force on itself.
- Contact forces describe the interaction of an object or system touching another object or system and are macroscopic effects of interatomic electric forces.
- Free-body diagrams are useful tools for visualizing forces being exerted on a single object or system and for determining the equations that represent a physical situation.

- The free-body diagram of an object or system shows each of the forces exerted on the object by the environment.

- Forces exerted on an object or system are represented as vectors originating from the representation of the center of mass, such as a dot. A system is treated as though all of its mass is located at the center of mass.
- A coordinate system with one axis parallel to the direction of acceleration of the object or system simplifies the translation from free body diagram to algebraic representation. For example, in a free-body diagram of an object on an inclined plane, it is useful to set one axis parallel to the surface of the incline.

Skills

- Create diagrams, tables, charts, or schematics to represent physical situations.
- Calculate or estimate an unknown quantity with units from known quantities, by selecting and following a logical computational pathway.
- Justify or support a claim using evidence from experimental data, physical representations, or physical principles or laws.
- Compare physical quantities between two or more scenarios or at different times and locations in a single scenario

2.3 Newton's Third Law

Knowledge

- Newton’s third law describes the interaction of two objects in terms of the paired forces that each exerts on the other.
- Interactions between objects within a system (internal forces) do not influence the motion of a system’s center of mass.
- Tension is the macroscopic net result of forces that segments of a string, cable, chain, or similar system exert on each other in response to an external force.
    - An ideal string has negligible mass and does not stretch when under tension.
    - The tension in an ideal string is the same at all points within the string.
    - In a string with non negligible mass, tension may not be the same at all points within the string.
    - An ideal pulley is a pulley that has negligible mass and rotates about an axle through its center of mass with negligible friction.

Skills

- Create diagrams, tables, charts, or schematics to represent physical situations.
- Predict new values or factors of change of physical quantities using functional dependence between variables.
- Applyanappropriatelaw,definition,theoreticalrelationship,ormodeltomakeaclaim.
- Justify or support a claim using evidence from experimental data, physical representations, or physical principles or laws.

2.4 Newton's First Law

Knowledge

- The net force on a system is the vector sum of all forces exerted on the system.

- Translational equilibrium is a configuration of forces such that the net force exerted on a system is zero.
- Newton's first law states that if the net force exerted on a system is zero, the velocity of that system will remain constant.
- Forces may be balanced in one dimension but unbalanced in another. The system's velocity will change only in the direction of the unbalanced force.
- An inertial reference frame is one from which an observer would verify Newton's first law of motion.

Skills

- Create qualitative sketches of graphs that represent features of a model or the behavior of a physical system.
- Derive a symbolic expression from known quantities by selecting and following a logical mathematical pathway.
- Justify or support a claim using evidence from experimental data, physical representations, or physical principles or laws.
- Apply an appropriate law, definition, theoretical relationship, or model to make a claim.

2.5 Newton's Second Law

Knowledge

- Unbalanced forces are a configuration of forces such that the net force exerted on a system is not equal to zero.
- Newton's second law of motion states that the acceleration of a system's center of mass has a magnitude proportional to the magnitude of the net force exerted on the system and is in the same direction as that net force
- The velocity of a system's center of mass will only change if a nonzero net external force is exerted on that system.

Skills

- Create diagrams, tables, charts, or schematics to represent physical situations.
- Derive a symbolic expression from known quantities by selecting and following a logical mathematical pathway.
- Predict new values or factors of change of physical quantities using functional dependence between variables.
- Apply an appropriate law, definition, theoretical relationship, or model to make a claim.

2.6 Gravitational Force

Knowledge

- Newton's law of universal gravitation describes the gravitational force between two objects or systems as directly proportional to each of their masses and inversely proportional to the square of the distance between the systems' centers of mass.
    - The gravitational force is attractive.
    - The gravitational force is always exerted along the line connecting the centers of mass of the two interacting systems.

- The gravitational force on a system can be

  considered to be exerted on the system's center of mass.

- A field models the effects of a noncontact force exerted on an object at various positions in space.
  - The magnitude of the gravitational field created by a system of mass M at a point in space is equal to the ratio of the gravitational force exerted by the system on a test object of mass m to the mass of the test object.
  - If the gravitational force is the only force exerted on an object, the observed acceleration of the object (in m/s2) is numerically equal to the magnitude of the gravitational field strength (in N/Kg) at that location.
- The gravitational force exerted by an astronomical body on a relatively small nearby object is called weight.
- If the gravitational force between two systems' centers of mass has a negligible change as the relative position of the two systems changes, the gravitational force can be considered constant at all points between the initial and final positions of the systems.
- Near the surface of Earth, the strength of the gravitational field is g = 10 N/kg
- The magnitude of the apparent weight of a system is the magnitude of the normal force exerted on the system
- If the system is accelerating, the apparent weight of the system is not equal to the magnitude of the gravitational force exerted on the system.
- A system appears weightless when there are no forces exerted on the system or when the force of gravity is the only force exerted on the system.
- The equivalence principle states that an observer in a non inertial reference frame is unable to distinguish between an object's apparent weight and the gravitational force exerted on the object by a gravitational field.
- Objects have inertial mass, or inertia, a property that determines how much an object's motion resists changes when interacting with another object.
- Gravitational mass is related to the force of attraction between two systems with mass.
- Inertial mass and gravitational mass have been experimentally verified to be equivalent.

Skills

- Create diagrams, tables, charts, or schematics to represent physical situations.
- Derive a symbolic expression from known quantities by selecting and following a logical mathematical pathway.
- Predict new values or factors of change of physical quantities using functional dependence between variables.
- Justify or support a claim using evidence from experimental data, physical representations, or physical principles or laws.

2.7 Kinetic and Static Friction

Knowledge

- Kinetic friction occurs when two surfaces in contact move relative to each other.

    - The kinetic friction force is exerted in a direction opposite to the motion of each surface relative to the other surface.
    - The force of friction between two surfaces does not depend on the size of the surface area of contact.
- The magnitude of the kinetic friction force exerted on an object is the product of the normal force the surface exerts on the object and the coefficient of kinetic friction.
    - The coefficient of kinetic friction depends on the material properties of the surfaces that are in contact.
    - Normal force is the perpendicular component of the force exerted on an object by the surface with which it is in contact; it is directed away from the surface.
- Static friction may occur between the contacting surfaces of two objects that are not moving relative to each other.
- Static friction adopts the value and direction required to prevent an object from slipping or sliding on a surface.
    - Slipping and sliding refer to situations in which two surfaces are moving relative to each other.
    - There exists a maximum value for which static friction will prevent an object from slipping on a given surface.
- The coefficient of static friction is typically greater than the coefficient of kinetic friction for a given pair of surfaces.

Skills

- Create qualitative sketches of graphs that represent features of a model or the behavior of a physical system.
- Calculate or estimate an unknown quantity with units from known quantities, by selecting and following a logical computational pathway.
- Compare physical quantities between two or more scenarios or at different times and locations in a single scenario.
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2.8 Spring Force

Knowledge

- An ideal spring has negligible mass and exerts a force that is proportional to the change in its length as measured from its relaxed length.
- The magnitude of the force exerted by an ideal spring on an object is given by Hooke's law
- The force exerted on an object by a spring is always directed toward the equilibrium position of the object–spring system.

Skills

- Create quantitative graphs with appropriate scales and units, including plotting data.
- Derive a symbolic expression from known quantities by selecting and following a logical mathematical pathway.
- Comparephysicalquantitiesbetweentwoormorescenariosoratdifferenttimesand locations in a single scenario.

- Createexperimentalproceduresthatareappropriateforagivenscientificquestion.
- Applyanappropriatelaw,definition,theoreticalrelationship,ormodeltomakeaclaim.

2.9 Circular Motion

Knowledge

- Centripetal acceleration is the component of an object's acceleration directed toward the center of the object's circular path.
    - The magnitude of centripetal acceleration for an object moving in a circular path is the ratio of the object's tangential speed squared to the radius of the circular path
    - Centripetal acceleration is directed toward the center of an object's circular path.
- Centripetal acceleration can result from a single force, more than one force, or components of forces exerted on an object in circular motion
    - At the top of a vertical, circular loop, an object requires a minimum speed to maintain circular motion. At this point, and with this minimum speed, the gravitational force is the only force that causes the centripetal acceleration
    - Components of the static friction force and the normal force can contribute to the net force producing centripetal acceleration of an object traveling in a circle on a banked surface.
    - A component of tension contributes to the net force producing centripetal acceleration experienced by a conical pendulum.
- Tangential acceleration is the rate at which an object's speed changes and is directed tangent to the object's circular path.
- The net acceleration of an object moving in a circle is the vector sum of the centripetal acceleration and tangential acceleration.
- The revolution of an object traveling in a circular path at a constant speed (uniform circular motion) can be described using period and frequency.
    - The time to complete one full circular path, one full rotation, or a full cycle of oscillatory motion is defined as period, T.
    - The rate at which an object is completing revolutions is defined as frequency, f.
    - For an object traveling at a constant speed in a circular path, the period is given by the derived equation T=(2*pi*r)/v
- For a satellite in circular orbit around a central body, the satellite's centripetal acceleration is caused only by gravitational attraction. The period and radius of the circular orbit are related to the mass of the central body.

Skills

- Create quantitative graphs with appropriate scales and units, including plotting data.
- Derive a symbolic expression from known quantities by selecting and following a logical mathematical pathway.
- Predict new values or factors of change of physical quantities using functional dependence between variables.
- Createexperimentalproceduresthatareappropriateforagivenscientificquestion.
- Justify or support a claim using evidence from experimental data, physical representations, or physical principles or laws.

Transfer Goals

Patterns: Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.

Cause and Effect: Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.

Scale, Proportion, and Quantity: In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change.

Systems and System Models: A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.

Energy and Matter: Tracking energy and matter flows, into, out of, and within systems helps one understand their system's behavior.

Structure and Function: The way an object is shaped or structured determines many of its properties and functions.

Stability and Change: For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.

Assessments

https://docs.google.com/document/d/1wR7bQF-8AQoRrt0g4C3hKja0yjwDjC9_BiAmONWbTcI/edit?usp=sharing

Modifications

https://docs.google.com/document/d/1ODqaPP69YkcFiyG72fIT8XsUIe3K1VSG7nxuc4CpCec/edit?usp=sharing