OLD 03 Circular Motion and Gravitation

Content Area: **Science**
Course(s):
Time Period: **Semester 1**
Length: **4 weeks**
Status: **Published**

Standards

SCI.HS.PS2.A	Forces and Motion
SCI.HS.PS2.B	Types of Interactions
SCI.HS.ESS1.B	Earth and the Solar System
SCI.HS-ESS1-4	Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.
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-PS2-4	Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.
	Cause and Effect
	Scale, Proportion, and Quantity
	Analyzing and Interpreting Data
	Using Mathematics and Computational Thinking
	Patterns

Enduring Understandings

Vector Fields

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.

Fundamental Forces

Certain types of forces are considered fundamental.

Gravitational and Electric Forces

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

Gravitational Field/Acceleration Due to Gravity on Different Planets

A gravitational field is caused by an object with mass.

Inertial vs. Gravitational Mass

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

Centripetal Acceleration and Centripetal Force

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

Free-Body Diagrams for Objects in Uniform Circular Motion

Classically, the acceleration of an object interacting with other objects can be predicted by using

Applications of Circular Motion and Gravitation

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

Essential Questions

1. How does changing the mass of an object affect the gravitational force? § Why is a refrigerator hard to push in space?

2. Why do we feel pulled toward Earth but not toward a pencil? § How can the acceleration due to gravity be modified?

3. How can Newton's laws of motion be used to predict the behavior of objects? 4. How can we use forces to predict the behavior of objects and keep us safe?

5. How is the acceleration of the center of mass of a system related to the net force exerted on the system?

6. Why is it more difficult to stop a fully loaded dump truck than a small passenger car?

Knowledge and Skills

Knowledge

Vector Fields

A vector field gives, as a function of position (and perhaps time), the value of a physical quantity that is described by a vector.

a. Vector fields are represented by field vectors indicating direction and magnitude.

b. When more than one source object with mass or electric charge is present, the field value can be determined by vector addition.

c. Conversely, a known vector field can be used to make inferences about the number, relative size, and locations of sources.

Fundamental Forces

Gravitational forces are exerted at all scales and dominate at the largest distances and mass scales.

Gravitational and Electric Forces

Gravitational force describes the interaction of one object with mass with another object with mass.

a. The gravitational force is always attractive.

b. The magnitude of force between two spherically symmetric objects of mass m1 and m2 is F = Fm1m2/r^2 , where r is the center-to-center distance between the objects.

c. In a narrow range of heights above Earth's surface, the local gravitational field, g, is approximately constant.

Gravitational Field/Acceleration Due to Gravity on Different Planets

A gravitational field g at the location of an object with mass m causes a gravitational force of magnitude mg to be exerted on the object in the direction of the field.

a. On Earth, this gravitational force is called weight.

b. The gravitational field at a point in space is measured by dividing the gravitational force exerted by the field on a test object at that point by the mass of the test object and has the same direction as the force.

c. If the gravitational force is the only force exerted on the object, the observed freefall acceleration of the object (in meters per second squared) is numerically equal to the magnitude of the gravitational field (in Newtons/kilogram) at that location.

The gravitational field caused by a spherically symmetric object with mass is radial and, outside the object, varies as the inverse square of the radial distance from the center of that object.

a. The gravitational field cause by a spherically symmetric object is a vector whose magnitude outside the object is equal to Gm/r^2.

b. Only spherically symmetric objects will be considered as sources of the gravitational field.

Inertial vs. Gravitational Mass

Gravitational mass is the property of an object or a system that determines the strength of the gravitational interaction with other objects, systems, or gravitational fields.

a. The gravitational mass of an object determines the amount of force exerted on the object by a gravitational field.

b. Near Earth's surface, all objects fall (in a vacuum) with the same acceleration, regardless of their inertial mass

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

Centripetal Acceleration and Centripetal Force

The acceleration is equal to the rate of change of velocity with time, and velocity is equal to the rate of change of position with time.

a. The acceleration of the center of mass of a system is directly proportional to the net force exerted on it by all objects interacting with the system and inversely proportional to the mass of the system.

b. Force and acceleration are both vectors, with acceleration in the same direction as the net force.

c. The acceleration of the center of mass of a system is equal to the rate of change of the center of mass velocity with time, and the center of mass velocity is equal to the rate of change of position of the center of mass with time.

d. The variables x, v, and a all refer to the center-of-mass quantities.

Free-Body Diagrams for Objects in Uniform Circular Motion

If an object of interest interacts with several other objects, the net force is the vector sum of the individual forces. Projectile motion and circular motion are both included in AP Physics 1.

Free-body diagrams are useful tools for visualizing forces being exerted on a single object and writing the equations that represent a physical situation.

a. An object can be drawn as if it were extracted from its environment and the interactions with the environment were identified.

b. A force exerted on an object can be represented as an arrow whose length represents the magnitude of the force and whose direction shows the direction of the force.

c. A coordinate system with one axis parallel to the direction of the acceleration simplifies the translation from the free-body diagram to the algebraic representation.

d. Free-body or force diagrams may be depicted in one of two ways—one in which the forces exerted on an object are represented as arrows pointing outward from a dot, and the other in which the forces are specifically drawn at the point on the object at which each force is exerted.

Applications of Circular Motion and Gravitation

An observer in a reference frame can describe the motion of an object using such quantities as position, displacement, distance, velocity, speed, and acceleration.

a. Displacement, velocity, and acceleration are all vector quantities.

b. Displacement is change in position. Velocity is the rate of change of position with time. Acceleration is the rate of change of velocity with time. Changes in each property are expressed by subtracting initial values from final values

c. A choice of reference frame determines the direction and the magnitude of each of these quantities.

d. There are three fundamental interactions or forces in nature: the gravitational force, the electroweak force, and the strong force. The fundamental forces determine both the structure of objects and the motion of objects.

e. In inertial reference frames, forces are detected by their influence on the motion (specifically the velocity) of an object. So force, like velocity, is a vector quantity. A force vector has magnitude and direction. When multiple forces are exerted on an object, the vector sum of these forces, referred to as the net force, causes a change in the motion of the object. The acceleration of the object is proportional to the net force.

f. The kinematic equations only apply to constant acceleration situations. Circular motion and projectile motion are both included. Circular motion is further covered in Unit 3.

g. For rotational motion, there are analogous quantities such as angular position, angular velocity, and angular acceleration.

h. This also includes situations where there is both a radial and tangential acceleration for an object moving in a circular path.

Forces are described by vectors.

a. Forces are detected by their influence on the motion of an object.

b. Forces have magnitude and direction

A force exerted on an object is always due to the interaction of that object with another object.

a. An object cannot exert a force on itself.

b. Even though an object is at rest, there may be forces exerted on that object by other objects.

c. The acceleration of an object, but not necessarily its velocity, is always in the direction of the net force exerted on the object by other objects.

If one object exerts a force on a second object, the second object always exerts a force of equal magnitude on the first object in the opposite direction.

Skills

1. Articulate situations when the gravitational force is the dominant force.

2. Use Newton's law of gravitation to calculate the gravitational force that two objects exert on each other and use that force in contexts other than orbital motion.

2. Use Newton's law of gravitation to calculate the gravitational force between two objects and use that force in contexts involving orbital motion (for circular orbital motion only in Physics 1).

3. Apply F =mg to calculate the gravitational force on an object with mass m in a gravitational field of strength g in the context of the effects of a net force on objects and systems

4. Apply g = Gm/r^2 to calculate the gravitational field due to an object with mass m, where the field is a vector directed toward the center of the object of mass m

5. Approximate a numerical value of the gravitational field (g) near the surface of an object from its radius and mass relative to those of Earth or other reference objects

6. Design a plan for collecting data to measure gravitational mass and to measure inertial mass and to distinguish between the two experiments.

7. Evaluate, using given data, whether all the forces on a system or whether all the parts of a system have been identified.

8. Design a plan to collect and analyze data for motion (static, constant, or accelerating) from force measurements, and carry out an analysis to determine the relationship between the net force and the vector sum of the individual forces.

9. Re-express a free-body diagram representation into a mathematical representation, and solve the mathematical representation for the acceleration of the object.

10. Create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively.

11. Express the motion of an object using narrative, mathematical, and graphical representations.

12. Design an experimental investigation of the motion of an object.

13. Analyze experimental data describing the motion of an object and express the results of the analysis using narrative, mathematical, and graphical representations.

14. Represent forces in diagrams or mathematically, using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation

15. Analyze a scenario and make claims (develop arguments, justify assertions) about the forces exerted on an object by other objects for different types of forces or components of forces.

16. Describe a force as an interaction between two objects and identify both objects for any force. [

17. Construct explanations of physical situations involving the interaction of bodies using Newton's third law and the representation of actionreaction pairs of forces.

18. Use Newton's third law to make claims and predictions about the action-reaction pairs of forces when two objects interact.

19. Analyze situations involving interactions among several objects by using free-body diagrams that include the application of Newton's third law to identify forces.

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_BiAmONWbTcl/edit?usp=sharing

Modifications

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