# 02 Force and Translational Dynamics

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

## Standards

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|---|---|
| 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

### Systems

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

### The Gravitational Field

A gravitational field is caused by an object with mass.

### Contact Forces

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

### Newton's First Law

Objects and systems have properties of inertial mass and gravitational mass that are experimentally verified to

be the same and that satisfy conservation principles

**Newton's Third Law and Free-Body Diagrams**

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

**Newton's Second Law**

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

**Applications of Newton's Second Law**

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

## Essential Questions

1. How can the properties of internal and gravitational mass be experimentally verified to be the same?

2. How do you decide what to believe about scientific claims?

3. How does something we cannot see determine how an object behaves?

4. How do objects with mass respond when placed in a gravitational field?

5. Why is the acceleration due to gravity constant on Earth's surface?

6. Are different kinds of forces really different?

7. How can Newton's laws of motion be used to predict the behavior of objects?

8. Why does the same push change the motion of a shopping cart more than the motion of a car?

## Knowledge and Skills

## Knowledge

**Systems**

A system is an object or a collection of objects. Objects are treated as having no internal structure.

a. A collection of particles in which internal interactions change little or not at all, or in which changes in these interactions are irrelevant to the question addressed, can be treated as an object.

b. Some elementary particles are fundamental particles, (e.g., electrons). Protons and neutrons are composed of fundamental particles (i.e., quarks) and might be treated as either systems or objects, depending on the question being addressed.

c. The electric charges on neutrons and protons result from their quark compositions.

Systems have properties that are determined by the properties and interactions of their constituent atomic and molecular substructures. In AP Physics, when the properties of the constituent parts are not important in modeling the behavior of the macroscopic system, the system itself may be referred to as an object.

**The Gravitational 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.

**Contact Forces**

Contact forces result from the interaction of one object touching another object, and they arise from interatomic electric forces. These forces include tension, friction, normal, spring (Physics 1), and buoyant (Physics 2).

**Newton's First Law**

Inertial mass is the property of an object or system that determines how its motion changes when it interacts with other objects or systems.

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

**Newton's Third Law and Free-Body Diagrams**

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.

**Newton's Second Law**

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 Newton's Second Law**

The linear motion of a system can be described by the displacement, velocity, and acceleration of its center of mass. The variables x, v, and a all refer to the center-of-mass quantities.

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.

Forces that the systems exert on each other are due to interactions between objects in the systems. If the interacting objects are parts of the same system, there will be no change in the center-of-mass velocity of that system.

## Skills

1. Model verbally or visually the properties of a system based on its substructure and relate this to changes in the system properties over time as external variables are changed.

2. 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.

3. Make claims about various contact forces between objects based on the microscopic cause of these forces.

4. Explain contact forces (tension, friction, normal, buoyant, spring) as arising from interatomic electric forces and that they therefore have certain directions

5. Design an experiment for collecting data to determine the relationship between the net force exerted on an object, its inertial mass, and its acceleration.

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

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

8. 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.

9. Challenge a claim that an object can exert a force on itself

10 Describe a force as an interaction between two objects, and identify both objects for any force.

11. Construct explanations of physical situations involving the interaction of bodies using Newton's third law and the representation of action-reaction pairs of forces.

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

objects interact.

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

14. Predict the motion of an object subject to forces exerted by several objects using an application of Newton's second law in a variety of physical situations, with acceleration in one dimension.

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

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

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

18. Use representations of the center of mass of an isolated two-object system to analyze the motion of the system qualitatively and semi-quantitatively.

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

20. Apply Newton's second law to systems to calculate the change in the center-of-mass velocity when an external force is exerted on the system.

21. Use visual or mathematical representations of the forces between objects in a system to predict whether or not there will be a change in the center-of-mass velocity of that system.

## 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