Understanding Motion

Session Time: Two, 50-minute sessions

DESIRED RESULTS

ESSENTIAL UNDERSTANDINGS

The principles of aerodynamics allow an aircraft to fly, yet those same principles limit its ultimate performance and capabilities. (EU2)

Safe and efficient aviation operations require that pilots use math, science, and technology. (EU4)

A deep understanding of how an aircraft operates, which enables a pilot to fly an aircraft to its maximum capabilities in both normal and abnormal situations. (EU5)

ESSENTIAL QUESTIONS

1. Does a pilot need to understand Newton's laws of motion?

LEARNING GOALS

Students Will Know

- The meaning of Newton's laws of motion
- How Newton's laws of motion apply to aviation

Students Will Be Able To

- *State* and *explain* Newton's first three laws of motion. (DOK-L3)
- *Identify* and *formulate* examples of how Newton's first three laws of motion occur in aviation. (DOK-L1; DOK-L3)

ASSESSMENT EVIDENCE

Warm-up
As a precursor to Newton's First Law, ask students how NASA's Voyager I has continued to travel through space for more than 40 years without an engine.

Formative Assessment
Students will write at least three everyday examples for each of Newton's First and Second Laws of Motion.

Summative Assessment
Students will write several paragraphs that state and explain Newton's first three laws of motion in their own words. For each law of motion, students will give an example of how it occurs in aviation.

LESSON PREPARATION

MATERIALS/RESOURCES

- [Understanding Motion Presentation]
- [Understanding Motion Teaching Aid]

Egg Inertia Demonstration (per class)

- One hardboiled egg
- One raw egg

Pop Can Hero Activity

- Empty aluminum pop cans with pull tabs intact (one per team)
- Carpenter nails
- String or fishing line (about 20 inches per team)
- Water tub (one or two per class)
- Small nails
- Towels

LESSON SUMMARY

Lesson 1: Understanding Motion
Lesson 2: Four Forces
Lesson 3: Vectors of Flight

In this lesson, students will learn about Newton's first three laws of motion. To begin, students will be introduced to NASA's Voyager I and will be asked how the spacecraft has continued to travel through space for more than 40 years without an engine. This is a precursor to Newton's First Law.

A discussion about force will lead students through a discussion on the first law. The class will read Newton's version of the first law from "Principia Mathematica" and rephrase it in their own words. Inertia will be demonstrated using a hardboiled and a raw egg. After the law has been discussed, a video will summarize it. A class discussion will explain Newton's Second Law of Motion to students.

At the end of the first session, a formative assessment will ask students to devise real world examples of the first two laws.

The second session opens with a Pop Can Hero demonstration of Newton's Third Law. Following a video, the third law is applied to aerodynamics and the creation of lift. This will be followed by a class discussion gathering real world examples of the third law.

The lesson is concluded with the summative assessment asking students to state and explain Newton's three laws and apply them to aviation.

BACKGROUND

Sir Isaac Newton summed up motion in three laws:

Newton's First Law: "An object at rest stays at rest and an object in motion stays in motion unless acted on by an outside force."

- Impact on aviation: The first law describes an aircraft in balanced flight where acceleration is zero (if an object is at rest and stays at rest, or an object is in motion and it stays in motion, it has zero acceleration). As students will learn, there are four major forces acting on an aircraft; lift, weight, thrust, and drag. For an aircraft flying at a constant altitude and at a constant airspeed, lift and weight balance one another and so does thrust and drag. In this scenario, there is no net force on the airplane (or acceleration) and it travels at a constant velocity in a straight line. If the pilot increases the engine power, thrust and drag are no longer in balance and the aircraft will accelerate and increase in velocity.

Newton's Second Law: "When an object is acted upon by a force, its resulting acceleration is inversely proportional to the body's mass and directly proportional to the force acted upon the object."

- Impact on Aviation: One of the effects of the second law is that large aircraft require large engines. It also means that light aircraft are more affected by turbulence than heavier ones.

Newton's Third Law: "For every action, there is an equal and opposite reaction."

- Impact on aviation: It helps to explain the generation of lift for a rocket. Hot exhaust gases are produced inside the rocket which are accelerated as they pass through the engine's nozzle. The accelerated hot gases produce a thrust that propels the rocket in the opposite direction.

DIFFERENTIATION

To support student comprehension in the **ENGAGE** section, encourage students to ask questions about Voyager I and make connections to background knowledge before participating in the Warm-Up prompt. This will provide scaffolded support, help develop metacognition, and deepen their understanding of the topic.

To support student comprehension in the **EXPLORE** section, allow students to physically experience the definition of contact and non-contact force using materials found in the classroom. This strategy provides students with support in any sensory integration needs they may have, but also allows them to focus on the acquisition of new information.

LEARNING PLAN

ENGAGE

Teacher Material: Understanding Motion Presentation

Slides 1-3: Introduce the topic and learning objectives of the lesson.

Slide 4: Conduct the **Warm-Up.**

Warm-Up

As a precursor to Newton's First Law, introduce NASA's Voyager I to students. Ask them how Voyager I has continued to travel through space for more than 40 years without an engine.

Possible answer:

A spacecraft far from any source of gravity would need no thrust to keep it moving at a constant speed in a given direction. Once set in motion, it will keep moving forever without propulsion, since there is no friction in space to slow it down. But it does need an additional force—thrust—to change its speed or direction or both. It relies on Newton's law of inertia to stay in motion. It keeps moving because of Newton's First Law of Motion. Since there is no friction in space, it will keep moving until it encounters a force, such as gravity from a star, that affects its motion.

[DOK-L3; *explain*; DOK-L2; *predict*]

EXPLORE

Teacher Material: Understanding Motion Presentation

Slide 5: In this lesson, students will be learning about Newton's three laws of motion. Explain to students that Sir Isaac Newton's three laws of motion form the basic principles of modern physics. He was a physicist and a mathematician from the 17th century.

Slides 6-7: Before introducing the three laws, ensure that students know what a force is. Explain that a force is a push, pull or twist on an object resulting from the object's interaction with another object. Forces are an interaction between TWO objects. It is not possible to have a force on an object and not have another object involved. Forces are vectors and they have both magnitude and direction.

Forces occur in two forms: contact and non-contact. A contact force is when an object physically interacts with another object (e.g. a direct push or pull). A non-contact force is not a physical interaction, but rather by an "invisible" force like gravity or magnetism.

EXPLAIN

Teacher Material: Understanding Motion Presentation

Slide 8: Have students read Newton's explanation of the first law of motion from "Principia Mathematica", published in 1687.

As a class, ask them to restate the law in modern language. One of the most common ways to state it is: An object at rest stays at rest and an object in motion stays in motion unless acted on by an outside force.

Ask the class if they know of another name for Newton's First Law of Motion. It is also known as the Law of Inertia.

Slide 9: Remind students that the Voyager continues to travel through space without propulsion because it has inertia and there is no friction in space to slow it down. It will stay in motion until a force is acted upon it.

At the end of this slide, show students the video which reinforces Newton's law of mass and inertia using animated drawings.

- Newton's First Law of Motion: Mass and Inertia (Length 6:21)
  http://video.link/w/JFQd

Slide 10: As a demonstration of inertia, spin both a hardboiled egg and a raw egg. Stop each with your finger, then quickly let go. The hardboiled egg remains still, while the raw egg starts spinning again. Ask students why this is the case?

Explain to the students that one egg is raw, the other hardboiled. The soft yolk in the unboiled egg continued to rotate in the shell. It had inertia so it started spinning again after being initially stopped.

Slide 11: Introduce students to Newton's Second Law of Motion. Explain to students that when an object is acted upon by a force, its resulting acceleration is inversely proportional to the body's mass and directly proportional to the force acted upon the object.

Slide 12: The more mass an object has, the more force you must apply to make it accelerate—to change its speed or direction or both.

So, the more you want an aircraft to accelerate, the more force you must apply. To reach a certain speed you can apply a small force for a long time or a large force for a short time.

As another example, ask students to think of a Boeing 747. How is the magnitude of the 747's acceleration different when it is carrying a full load of cargo compared to the exact same airplane when it is flying empty?

Slide 13: Explain the mathematical formula behind Newton's second law. Acceleration is equal to the force applied divided by its mass. This law is commonly expressed as the force (F) acting on an object is equal to the mass (m) of an object times its acceleration (a).

Slide 14: Show students a video that summarizes Newton's Second Law of Motion.

- Newton's Second Law of Motion: F = ma (Length 4:05) http://video.link/w/goQd

Slide 15: Conduct the **Formative Assessment.**

Formative Assessment

To conclude the first session of this lesson, ask students to individually write down at least three everyday examples for each of Newton's First and Second Laws of Motion. Ask students to share their answers with the class. [DOK-L3; *formulate*]

Possible answers for the first law:

- *Car suddenly stops and you strain against the seat belt*
- *When riding a horse, the horse suddenly stops and you fly over its head*
- *The magician pulls the tablecloth out from under a table full of dishes*
- *Car turns left and you appear to slide to the right*

Possible answers for the second law:

- *Hitting a baseball, the harder the hit, the faster the ball goes*
- *Accelerating or decelerating a car*
- *The positioning of football players - massive players on the line with lighter (faster to accelerate) players in the backfield*
- *A loaded airplane versus an unloaded airplane*
- *Throw a wiffle ball and a baseball with the same acceleration, the baseball will go farther because of the greater mass*

EXTEND

Teacher Materials: Understanding Motion Presentation, Understanding Motion Teaching Aid

Slide 16: Perform the Pop Can Hero demonstration at the beginning of the second session. The objective of this activity is to demonstrate Newton's Third Law of Motion using thrust produced by falling water. This activity simulates the operation of the classic Hero's engine invented by Hero of Alexandria more than 2,000 years ago. It is a simple bladeless radial steam turbine which spins when the central water container is heated. Torque is produced by steam jets exiting the turbine, much like a tip jet or rocket engine. The engine was an early demonstration of the action-reaction principle (third law of motion) eventually stated by Sir Isaac Newton.

In this activity, holes are punched in the side of a soft drink can. The holes are angled pinwheel fashion. A string, tied to the pull tab, supports the can and permits it to rotate. The can is immersed in water and pulled out. Gravity draws the water through the angled holes, and streams shoot out in either a clockwise or counterclockwise direction. The streams produce an action force that is accompanied by a reaction force. The can spins in the opposite direction.

Teaching Tips

For time savings, the Pop Can Hero activity can be presented as a teacher demonstration to the whole class instead of as a small team activity.

Slide 17: Introduce Newton's Third Law, which states that for every action there is an equal and opposite reaction.

Every force applied to an object is opposed by an equal force in the opposite direction. In the case of a space shuttle or rocket launch, the space shuttle creates a downward force and the reaction force pushes the shuttle or rocket upward.

This principle applies when in the case of air and a propeller or air and the wing of an airplane.

A video summarizes Newton's Third Law of Motion.

- Newton's Third Law of Motion: Action and Reaction (Length 4:54)
  http://video.link/w/hoQd

Slide 18: Newton's third law helps explain the generation of lift for a rocket. Hot exhaust gases are produced inside the rocket which are accelerated as they pass through the engine's nozzle. The accelerated hot gases produce a thrust that propels the rocket in the opposite direction.

Slide 19: Similar to the previous session's formative assessment, ask students to give everyday examples of Newton's Third Law.

Questions

Everyday examples of Newton's Third Law include:

A jet engine

Gun recoil

Dropping a ball on the floor and having it bounce back

EVALUATE

Teacher Material: Understanding Motion Presentation

Slide 20: Conduct the **Summative Assessment.**

Summative Assessment

Working individually, ask students to write several paragraphs that state and explain Newton's first three laws of motion in their own words. For each law of motion, ask them to give an example of how it occurs in aviation. They should describe the appropriate interaction between the objects, how the force or principle is applied, and the result of the interaction. They may use drawings to illustrate their explanations.

[DOK-L4; *apply concepts*; DOK-L2; *interpret*; DOK-L1; *illustrate*]

Summative Assessment Scoring Rubric

Follows assignment instructions
Written explanation includes:

- A clear and accurate statement of each of Newton's Three Laws of Motion
- A relevant aviation related example
- Clear and accurate explanation of how the appropriate law of motion is demonstrated in their example
- Organized explanation
- Correct spelling and grammar

Contributions show in-depth thinking including analysis or synthesis of lesson objectives

Points	Performance Levels
9-10	Consistently demonstrates criteria
7-8	Usually demonstrates criteria
5-6	Sometimes demonstrates criteria
0-4	Rarely to never demonstrates criteria

GOING FURTHER

- "Why an Airplane Flies-Part 2: Newton's Laws of Motion" (Length 3:03)
  http://video.link/w/MyPd

STANDARDS ALIGNMENT

NGSS STANDARDS

Three-dimensional Learning

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.

- Science and Engineering Practices
  - Analyzing and Interpreting Data
  - Obtaining, Evaluating, and Communicating Information
- Disciplinary Core Ideas
  - PS2.A: Forces and Motion
  - PS2.B: Types of Interactions
- Crosscutting Concepts
  - Cause and Effect

COMMON CORE STATE STANDARDS

- **RST.11-12.7** - Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.
- **WHST.11-12.9** - Draw evidence from informational texts to support analysis, reflection, and research.
- **MP.2 -** Reason abstractly and quantitatively.

REFERENCES

https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/phak/media/pilot_handbook.pdf https://www.grc.nasa.gov/www/k-12/airplane/newton.html
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