Amp It Up! Engineering/Technology and Industry Lesson Extension

Teacher Name(s), School and District: Cindy Noftle, Danvers High School, Danvers, MA

Course Name: Algebra 2

Lesson/Unit Name: Aviation: Newton's Laws of Motion

Science or Education Topic(s): Newton's Laws of Motion, Lift force, Velocity, Weight, and Acceleration

Engineering Technology Industry Related Field/Activity: GE Aviation

- CCSS.Math.Practice.MP1 Make sense of problems and persevere in solving them.
- CCSS.Math.Practice.MP2 Reason abstractly and quantitatively.
- CCSS.Math.Practice.MP3 Construct viable arguments and critique the reasoning of others.
- CCSS.Math.Practice.MP4 Model with mathematics.
- CCSS.Math.Practice.MP5 Use appropriate tools strategically.
- CCSS.Math.Practice.MP6 Attend to precision.
- CCSS.Math.Practice.MP7 Look for and make use of structure.
- CCSS.Math.Practice.MP8 Look for and express regularity in repeated reasoning.

When Taught: June 2017

Abstract: In 200 words or less, please provide a summary of your objectives, implementation, and the results of your implementation.

The lesson will begin with a video clip of the Blue Angels air show. The Blue Angels squad flies aircraft powered by GE Aviation F414 engines. A class discussion will follow regarding the Blue Angels and the aerobatic maneuvers that they perform.

Next will be a brief synopsis of GE Aviation and the work that they do in regards to jet engines. There are four video clips that will provide details about GE Aviation, the engineering team, and the jet engines that they produce. As they watch the video clips, students will take notes on important facts presented in the videos. Students will be guided to include information regarding the mathematics and science principles that are involved in building jet engines. There is also a link to a History of GE Aviation article.

The Aviation Performance task will be distributed to each student. In groups students will read through, discuss the information provided, analyze each example and its solution, and find the solutions to the exercises.

Students will use algebra and the Newton's laws of motion to determine exact values for variables such as lift, acceleration, energy, and mass.

Objectives and assessment: Using the table below, identify at least 3-5 learning objectives (content and/or pedagogical) and describe how each will be assessed.

Objectives *By the end of this lesson/unit, the students will be able to:*	**Assessment** *How was the objective assessed? List the example of formative or summative assessment.*
Compute weight and lift force using Newton's first law of motion	Students will work in small groups to solve specific problems related to Newton's first law of motion.
Evaluate acceleration as a change in velocity over time	Students will work in small groups to solve specific problems related to Newton's laws of motion.
Compute force, mass, and acceleration using Newton's second law of motion	Students will work in small groups to solve specific problems related to Newton's laws of motion; Each student will be given a number in the group. To present the answer, a number will be called at random. Students with that number will explain the answer to the question.
Understand Newton's third law of motion - the concept of action and reaction	Have each student write down a question and its answer to ask the whole class; Students will take turns asking their questions and discussing the responses.

Engineering/Technology Link: Please check the appropriate box(es) in question 1. And provide a brief answer to question 2.:

1. How did you *introduce* engineering/ technology concepts or the company/industry focus in your course? Check the appropriate box(es) or choose Other.

   ☐ X Defined terms (science, engineering, technology)

   ☐ X Described the engineering design process

   ☐ X Engineering design challenge related to industry

   ☐ X Overview of the company

   ☐ X Challenge based on 'industry specific' area of focus (manufacturing process, quality control, measurement, development, teamwork etc.)

   ☐ Other: _____

2. After introducing the concepts, what did/will the students do to explore and apply the engineering/technology and industry specific concepts? (include information about the actual activity students did, discussions they had, or instructional strategies you used)
   Students will watch videos prior to working on the assigned exercises. The videos will explain the concepts. Then there will be a teacher-led discussion about the concepts. The Aviation Performance task contains 4 sections that highlight a specific example and then is followed by exercises that students will solve in their small groups. Each section will be attempted by the students and discussed as a class before moving on to the next section. This will ensure that students understand the concepts in the section before proceeding to the next section.

Level of Inquiry: Which of the following best describes the level of inquiry (adapted from Bell 2005) you used for this lesson/unit? Check the appropriate level.

- ☐ *X Structured inquiry*: Instructor provides question and procedure. Students determine the results based on given procedures.
- ☐ *Guided inquiry*: Instructor provides question. Students design procedure and determine the results.
- ☐ *Open inquiry*: Students investigate their own research question. Students design procedures and implement the procedure on their own.

Lesson Extension Plan:

Title/Topic: Use Newton's Laws of Motion to Solve Aviation Problems
Time (minutes): 90 to 150 minutes
Company Name and brief Description: GE Aviation is located in Lynn, Massachusetts. This organization primarily operates in the Aircraft Engines and Engine Parts business / industry within the Transportation Equipment sector. This organization has been operating for approximately 11 years. GE Aviation is estimated to generate $7.4 million in annual revenues, and employs approximately 24 people at this single location. The Lynn facility continues to assemble jet engines for the United States Department of Defense, subsidiary services and commercial operators. Engines assembled at this plant include the F404, F414, T700, and CFE738. The plant at Lynn also produces the -3 and -8 variants of the CF34 regional jet engine, the CT7 commercial turboprop power plant and commercial versions of the T700 turbo shaft that are also called the CT7. (source: Wikipedia)

Overview of the Lesson

The Aviation Performance task contains 4 sections that highlight a specific example and then is followed by exercises that students will solve in their small groups. Each section will be attempted by the students and discussed as a class before moving on to the next section. This will ensure that students understand the concepts in the section before proceeding to the next section.

Standard(s)/Unit Goal(s) to be addressed in this lesson:

Mathematics (Grades 9–12)

Algebra

Generalize patterns using explicitly defined and recursively defined variables
Interpret representations of functions of two variables
Approximate and interpret rates of change from graphical and numerical data
Understand pattern, relations, and functions
Represent and analyze mathematical situations and structure using algebraic symbols

Problem Solving

Solve problems that arise in mathematics and in other contexts
Apply and adapt a variety of appropriate strategies to solve problems

Understand Numbers

Understand and use ratios and proportions to represent quantitative relationships

Essential Question(s) addressed in this lesson:

What are the four forces that affect flight? How does the mass of an object affect the force needed to move it? (Answer: Lift, drag, weight, and thrust; if an object is three times as large as another object then it would need three times as much force to move it the same amount)

Objectives:

State the three Laws of Motion and solve real-world examples of these laws.

Link to Industry:

The Blue Angels fly six F/A-18 Hornet aircraft powered by General Electric's F414 engines.

What students should know and be able to do before starting this lesson:

Students should have a basic understanding of variables, equations and how to solve a multi-step equation.

Instructional Materials/Resources/Tools

Students will be provided with links to video clips, handouts, and an explanation of the objectives of the lesson as well as the expected outcome. Students will be expected to use their Chrome books and/or calculators.

Lesson Delivery

Lesson Opening

As a class, students will watch the Blue Angels Air Show video clip. A whole group discussion about the specific maneuvers that the Blue Angels execute will take place. The discussion will transition to GE Aviation and the projects

During the Lesson (activities/labs/challenges)

Students will separate into small groups to work together to go through the examples and their solutions. They will discuss the exercises and find the solutions to them. They may need to review more examples of Newton's three laws of motion.

Lesson Closing: Review the four forces that affect flight and discuss with students how thrust provides the forward force on the airplane. Ask students to explain in their own words the concept of action and reaction. Have students list the specific formulas that are used for each of the three laws of motion.
Assessment
Student Assessment: Student responses to true/false questions regarding lift, drag, weight, and thrust requiring thumbs up and down response. All responses will be tallied and discussed.
Delivery Assessment: Students liked watching the video clips and were highly interested in the Blue Angels. They were fascinated by the building of jet engines and recognized how much responsibility the engineers have to get the engine built perfectly. They found the mathematics used in the exercises to be basic and easy to do.
Extension: Students can research the role of engineers in designing aircraft. They can write a short paper describing the mathematics that engineers use in their daily work.

Additional resources and assessments: List the attachments here.
Attachments should include handouts, readings (with references), lab write-ups, rubrics, exams/quizzes, and/or other similar materials.

Blue Angels F/A-18 Jets Air Show San Francisco, CA
https://www.youtube.com/watch?v=W7Gm2Qj-n_U

GENX Engine Build Video:
https://www.youtube.com/watch?v=GKFdX4Z1QPs

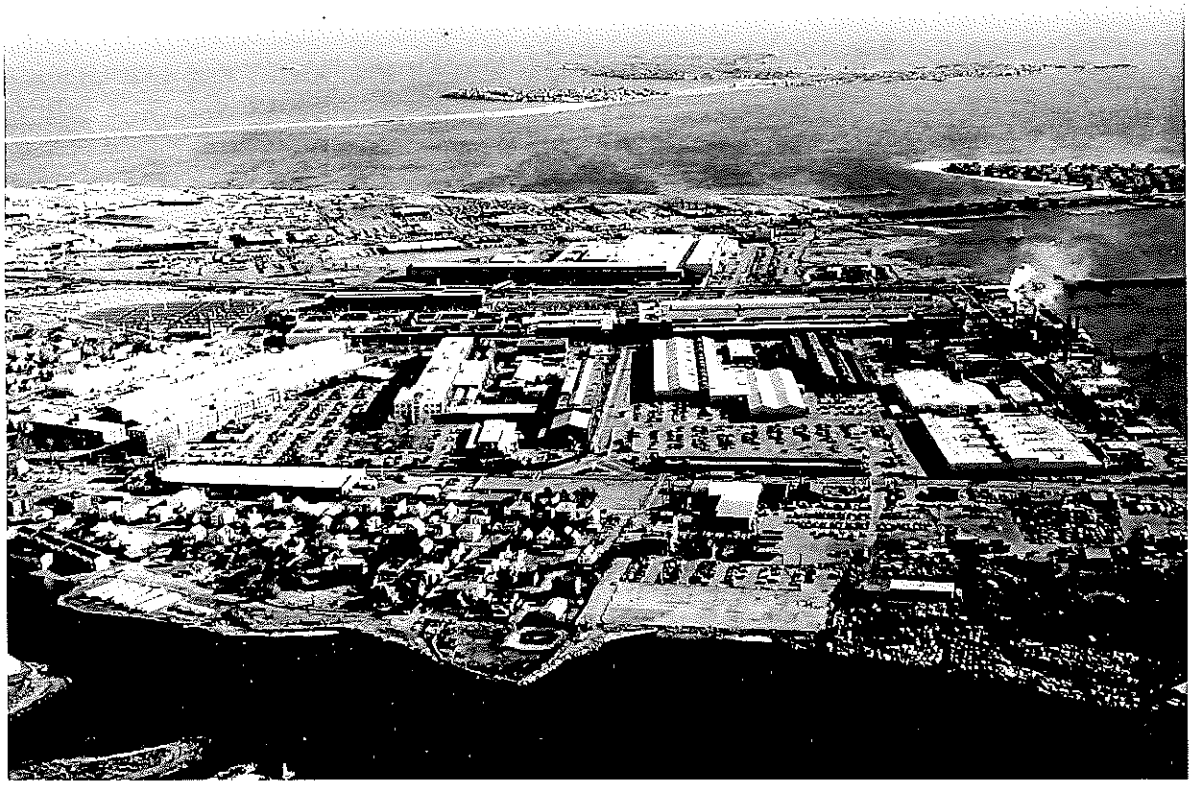
GE Aviation Jet Flight Engine Technology
https://www.youtube.com/watch?v=z9SnDrUhZxQ

GE Weather Proof Aircraft Engine Testing
https://www.youtube.com/watch?v=_PR0Ka_J2P4

Meet GE Aviation Engineering
https://www.youtube.com/watch?v=zJNMJsMd2XI

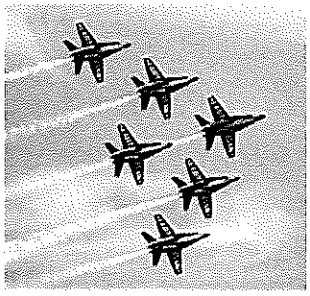
GE History
http://www.geaviation.com/company/aviation-history

GE Aviation, River Works Plant, Lynn, MA

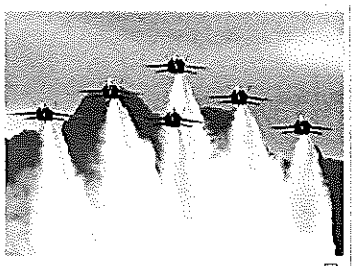


Name _____ Date_____

Blue Angels

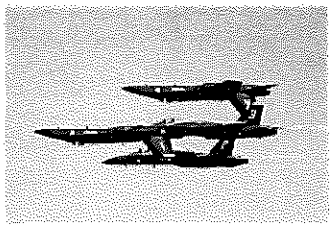


The Blue Angels is a flight aerobatic squad with pilots from the Navy and the Marines. The squadron was formed in 1946. The Blue Angels fly six F/A-18 Hornet aircraft powered by General Electric's F414 engines. They perform aerobatic maneuvers throughout the United States. The performance showcases loops, rolls, and transitions from one formation to another. In addition, some of the maneuvers include flying toward each other in what appears to be a collision course and mirror formations.

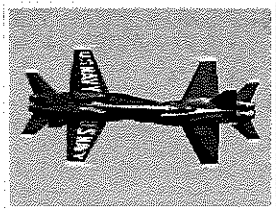


Blue Angels on Delta Formation.

Blue Angels aircraft perform the "Section High Alpha", the slowest maneuver of their show. During the maneuver the two jets slow down to 125 knots (232 km/h) as they pitch the nose of the F/A-18 up to 45 degrees.



Blue Angels in the double farvel formation.



The solos performing the "opposing knife-edge" pass. The far aircraft is actually slightly higher than the near aircraft to make them appear in-line to the audience.

When an aircraft is in flight, there are four forces acting on it. They are **lift**, **weight**, **thrust**, and **drag**. *Lift* is what pushes the airplane up, while *weight* is the gravitational force that pulls the airplane down. *Thrust* is what moves the airplane forward and creates air speed. *Drag* is a force that slows the airplane down. It is a force that acts on an object in the opposite direction that the object is moving. When the thrust is greater than the drag, the airplane moves forward. The thrust must balance the drag of the airplane when cruising. When the weight is greater than the lift, the airplane descends.

At GE Aviation the engineers use their understanding of scientific principles, such as Newton's laws of motion and mathematics to design, analyze and improve their F414 engines. Engineers use algebra to determine exact values for variables such as velocity, temperature, acceleration, energy and mass. As they design jet engines, they aim to minimize weight of the parts and materials. Some of the parts are constructed of a composite material in order keep the airplane as light a possible. When designing airplanes, the engineers apply Newton's third law of motion to determine how to power the aircraft. Using these real results enables engineers to design efficient, safe and successful aircraft.

Newton's Laws of Motion

1) Every object persists in its state of rest or uniform motion unless an unbalanced force acts it on. (Law of inertia)
2) Acceleration is produced when a force acts on a mass. For a constant mass, force equals mass times acceleration.
3) For every action, there is an equal and opposite reaction. The mass of object 1 times the acceleration of object 1 equals the mass of object 2 times the acceleration of object 2.

Name _____ **Date** _____

Aviation: Newton's Laws of Motion

Consider an airplane in flight. If the airplane is traveling at a constant altitude, the lift and weight cancel each other. If an airplane travels at a constant speed, thrust will equal drag. So there is no force on the airplane and it will more forward.

Example
Suppose an aircraft has a mass of 184,000 kg. What is the minimum force required to get the aircraft into the air?

Solution
The lift force must be greater than the weight of the aircraft in order for it to get into the air. To find the weight force you must use the following information.

Weight is measured in Newton's. $1\,\text{N} = 1\,\text{kg} \bullet \frac{m}{s^2}$

Mass is measured in kilograms (kg). Gravity on Earth is a constant: 9.8 m/s^2

Weight = Mass times Gravity
$W = mg$
$W = (184{,}000\ \text{kg})(9.8\ \text{m/s}^2)$
$W = 1{,}803{,}200\ \text{N}$

The lift force must exceed 1,803,200 N to get the aircraft to stay in the air.

Exercises

1. An aircraft has a mass of 179,000 kg. What is the minimum force required to get the aircraft into the air?

2. A jet is flying at a constant height of 11, 284 km with a constant speed of 1300 km/h. The jet weighs 110,000 kg. What is the force acting on the jet due to its weight?

3. Suppose an airplane has a thrust of 103, 250 N, what is the drag?

4. What happens when the drag of the plane is greater than the thrust generated by the engine?

Name _____ **Date** _____

Aviation: Newton's Laws of Motion

Matching

Match each definition with the appropriate vocabulary word.

1.____	The force that decreases when the spoilers are used.	A. Weight
2.____	The faster the air is pushed through the jet engine, the more forceful this is.	B. Newton's First Law
3.____	This, along with weight, acts as resistance to aircraft motion.	C. Vortices
		D. Streamlines
4.____	If thrust is greater than drag, this law describes the increase in velocity.	
		E. Newton's Second Law
5.____	When thrust and drag are in balance, this law explains why the aircraft has a constant velocity.	
6.____	Jets produce thrust through the application of this law of motion	F. Thrust
7.____	For an aircraft to fly, the lift must be greater than this force.	G. Lift
		H. Newton's Third Law
		I. Drag

Name _____ **Date** _____

Aviation: Newton's Laws of Motion

Newton's second law of motion can be seen in the motion of an airplane. If an airplane is not traveling at a constant velocity, then the plane is either accelerating or decelerating. Acceleration is the change in velocity with respect to time. For a constant mass, force equals mass times the change in velocity with respect to time.

$F = ma$ can be written as $F = \frac{m(v_1 - v_0)}{(t_1 - t_0)}$.

Example

Suppose an aircraft has a mass of 200,000 kg and is cruising at a 250 m/s at a constant altitude. If the afterburners apply an additional thrust of 50,000 N, what speed does the jet reach in 60 s?

Solution

You can use the formula: $F = \frac{m(v_1 - v_0)}{(t_1 - t_0)}$. First identify the variables. Then solve for the missing variable, speed.

Additional thrust F = 50,000 N
Mass m = 200, 000 kg
Initial velocity v_0 = 250 m/s
Final velocity v_1
Initial time t_0 = 0 s
Desired time t_1 = 60 s

$$F = \frac{m(v_1 - v_0)}{(t_1 - t_0)}$$

$$50{,}000 = \frac{200{,}000(v_1 - 250)}{(60 - 0)}$$

$$50{,}000 = \frac{200{,}000(v_1 - 250)}{60}$$

$$3{,}000{,}000 = 200{,}000(v_1 - 250)$$

$$15 = v_1 - 250$$

$$265 = v_1$$

The speed of the airplane at 60 seconds is 265 m/s.

Exercises

1. Suppose a 12,000 kg aircraft touched down at 90 m/s and it took 30 seconds to stop.
    a. What is the average acceleration of the aircraft? Explain your answer.

    b. What force is applied to this aircraft?

2. A jet is cruising at 240 mph and accelerates at an average of 0.3 m/s^2 for 450 s. What is the jet's final speed?

3. A 5500 kg helicopter accelerates upward at 4.0 m/s^2. What is the lift force exerted on the helicopter?

Name _____ **Date** _____

Aviation: Newton's Laws of Motion

Newton's third law of motion is critical to aircraft. There are action-reaction forces that are at work. To create lift, the wings push the air in a downward direction. The more air that is pushed downward, the greater the lift. The acceleration of an aircraft is another example of Newton's third law of motion. As the engine pushes out exhaust, the reaction force is a thrusting in the opposite direction.

Example
Suppose an aircraft has a mass of 194,000 kg collides with a seagull that has a mass of 1.8 kg.

a) Which one experiences the greater impact?

b) Which one experiences the greater acceleration in the opposite direction?

Solution

A collision between an aircraft and a seagull demonstrates Newton's third law of motion. For every action, there is an equal and opposite reaction. The mass of object 1 times the acceleration of object 1 equals the mass of object 2 times the acceleration of object 2.

The force of the seagull on the plane is equal to the force of the plane on the seagull. This means that the acceleration for the seagull will be extremely large, while the acceleration for the aircraft will be extremely small.

Exercises

For Exercises 1 and 2, fill in the blank with the appropriate word.

1. The jet engine's _____ is accelerating a mass of gas and sending it out the tailpipe.

2. The equal and opposite _____ is thrust.

3. According to Newton's third law, every force is accompanied by an equal and opposite *reaction* force. Explain why these forces do not cancel each other out.

Key

Name _____ Date _____

Aviation Worksheet Newton's Laws of Motion

Consider an airplane in flight. If the airplane is traveling at a constant altitude, the lift and weight cancel each other. If an airplane travels at a constant speed, thrust will equal drag. So there is no force on the airplane and it will more forward.

Example
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Solution
The lift force must be greater than the weight of the aircraft in order for it to get into the air. To find the weight force you must use the following information.

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$W = 1{,}803{,}200\text{ N}$

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1. An aircraft has a mass of 179,000 kg. What is the minimum force required to get the aircraft into the air?

   $W = mg$
   $= (179{,}000\text{ kg})(9.8\text{ m/s}^2)$
   $= 1{,}754{,}200\text{ N}$

2. A jet is flying at a constant height of 11, 284 km with a constant speed of 1300 km/h. The jet weighs 110,000 kg. What is the force acting on the jet due to its weight?

   $W = mg$
   $= (110{,}000\text{ kg})(9.8\text{ m/s}^2)$
   $= 1078000\text{ N}$

3. Suppose an airplane has a thrust of 103, 250 N, what is the drag?

   the thrust equals drag since plane traveling at constant speed.

4. What happens when the drag of the plane is greater than the thrust generated by the engine?

   the plane will slow down

Name Key Date _____

Aviation: Newton's Laws of Motion

Matching

Match each definition with the appropriate vocabulary word.

1. G The force that decreases when the spoilers are used.
2. F The faster the air is pushed through the jet engine, the more forceful this is.
3. I This, along with weight, acts as resistance to aircraft motion.
4. E If thrust is greater than drag, this law describes the increase in velocity.
5. B When thrust and drag are in balance, this law explains why the aircraft has a constant velocity.
6. H Jets produce thrust through the application of this law of motion
7. A For an aircraft to fly, the lift must be greater than this force.

A. Weight

B. Newton's First Law

C. Vortices

D. Streamlines

E. Newton's Second Law

F. Thrust

G. Lift

H. Newton's Third Law

I. Drag

key

Exercises

1. Suppose a 12,000 kg aircraft touched down at 90 m/s and it took 30 seconds to stop.
   a. What is the average acceleration of the aircraft? Explain your answer.

$$\text{average acceleration} = \frac{(v_1 - v_0)}{(t_1 - t_0)}$$
$$= \frac{0\ m/s - 90\ m/s}{30\ s - 0\ s}$$
$$= \frac{-90\ m/s}{30\ s}$$
$$= (-3\ m/s^2)$$

The negative acceleration means that the plane is slowing down.

   b. What force is applied to this aircraft?

$$F = ma$$
$$= (12{,}000\ kg)(-3\ m/s^2)$$
$$= -36{,}000\ kg \cdot m/s^2$$
$$= -36000\ \text{Newtons}$$

The negative force means that the force is going against the aircraft's motion.

2. A jet is cruising at 240 mph and accelerates at an average of 0.3 m/s^2 for 450 s. What is the jet's final speed?

$$\text{average acceleration} = \frac{(v_1 - v_0)}{(t_1 - t_0)}$$
$$.3\ m/s^2 = \frac{v_1 - 240\ m/s}{450\ s - 0\ s}$$
$$135\ m/s = v_1 - 240\ m/s$$
$$375\ m/s = v_1$$

3. A 5500 kg helicopter accelerates upward at 4.0 m/s^2. What is the lift force exerted on the helicopter?

The total acceleration is 4.0 m/s^2 that the helicopter is accelerating plus the gravity of Earth, 9.8 m/s^2.

$$F = ma$$
$$= (5500\ kg)(4.0\ m/s^2 + 9.8\ m/s^2)$$
$$= (5500\ kg)(13.8\ m/s^2)$$
$$= 75{,}900\ \text{Newtons}$$

Name Key Date _____

Aviation: Newton's Laws of Motion

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2. The equal and opposite reaction is thrust.

3. According to Newton's third law, every force is accompanied by an equal and opposite *reaction* force. Explain why these forces do not cancel each other out.

The two forces act upon different objects; only forces on the same object can balance each other