Ocean Landing: High School Digital Lesson Educator Guide

Lesson Overview:
Students will investigate how pilots launch and land high-speed jets on the flight deck of an aircraft carrier. They will explore how weather phenomena can impact the approaches and how pilots, flight-deck operators, and engineers work together to safely land in various conditions. Students will apply relative motion/velocity, acceleration, thrust, drag, and projectile motion to explain how adjustments are made.

Content Areas: Physics/Physical Science

Grade Level: Grades 9-12

National Standards:

Next Generation Science Standards
Physics

PS2.A: Forces and Motion

- Newton's second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2-1)
- Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. (HS-PS2-2)
- If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system. (HS-PS2-2), (HS-PS2-3)

Essential Questions:

1. What are the forces of flight and what factors affect these forces?
2. What are the key factors involved in achieving a successful aircraft launch from the flight deck?
3. How do weather phenomena impact the launch and landing of high speed jets on an aircraft carrier?
4. How do pilots, flight deck operators, and engineers work together to safely land high-speed jets in various conditions?

Materials:

For Introductory Lesson/Demos:
Access to the Internet
Paper
Two empty soda cans
Straw

For Airplane Landing Challenge:
Sheets of copy paper
Standard paper clips
Scotch tape and blue painter's tape
Glue sticks
Staples

Free Body Diagram Student Activity Sheet (one per student)
Free Body Diagram Teacher Key (teacher resource)
Forces of Flight Student Activity Sheet (one per student)
Forces of Flight Teacher Key (teacher resource)
Flight Scenarios: Is Take off a "Go" or No Go"? Student Activity Sheet (one per student group)
Flight Scenarios: Is Take off a "Go" or No Go"? Teacher Key (teacher resource)
The Airplane Landing Challenge Student Activity Sheet (one per student)
Rubric for The Airplane Landing Challenge Student Activity Sheet (one per student)

Objectives:

- Represent the four forces of flight using a free-body diagram and explain the factors that affect each of these forces
- Determine whether the conditions for the takeoff of a jet from an aircraft carrier are met by calculating airspeed
- Calculate the average force of a catapult system by applying the impulse-momentum theorem
- Design and successfully land a paper airplane within a designated target zone
- Justify modifications made to the airplane design based on a video analysis of two-dimensional motion and summarize the results in a Flight Analysis Report.

Background Information:

Throughout modern military history, aircraft carriers have played a central role in executing the mission of the U.S. Navy. Without a doubt, their versatility as mobile military bases make them instrumental in projecting power across the world and performing timely defensive and offensive tactics. However, launching and landing jets successfully in a limited amount of space takes a tremendous amount of resources and ingenuity. To compensate for the relatively short runways of an aircraft carrier, engineers have developed steam-powered catapult systems to launch planes at high speed. In addition, Navy pilots and flight deck operators work together to land the aircraft safely and ensure that it decelerates before approaching the end of the short runway. Various weather phenomena, such as strong and unpredictable winds, thunderstorms, and temperature fluctuations contribute to the uncertainty and make this a particularly formidable task. It is important to understand the role each crew member plays and the considerations they have to take into account to ensure a safe takeoff and landing.

This guide was created to provide educators with resources and strategies for presenting the content in the digital lesson. It provides slide-by-slide details and notes so that educators can effectively facilitate the discussions and hands-on activities associated with this unit. The presentation is designed to cover four 45-minute class sessions. As an introduction to this topic, students will observe two demonstrations dealing with Bernoulli's Principle so they learn how differences in air pressure can produce a force. Furthermore, they will conduct their own research to learn about the four forces of flight. In the second lesson, students will participate in an activity in which they will evaluate various takeoff scenarios in small groups to determine whether or not to authorize the takeoff of a jet from an aircraft carrier at sea. They will also calculate the how much average force a traditional catapult system generates as compared to a proposed new electromagnetic system to help decide whether to invest in this new technology. During the third day, students will watch a video that shows the landing process and review key points to ensuring a safe and successful landing. This will prepare them to complete their group-based project, in which they build and successfully land a paper airplane within a target zone. By capturing and analyzing videos of two initial landing trials, students will be prepared to make any necessary adjustments to their design for their final trial. During the last phase, students will work in small groups to communicate their conclusions by completing the Flight Analysis Report.

Procedure:

Day 1

Explore (Slides 1-5)

*Overview: In this section, students will experience two demonstrations led by student volunteers to explore the four forces of flight: lift, thrust, drag, and weight. Then, students will conduct independent internet searches to study the four vectors of flight in conjunction with aircraft carriers to successfully complete the **Free Body Diagram** and **Forces of Flight: Graphic Organizer**.*

Slide 1

- Review objectives and inform students that they will participate in two demonstrations to illustrate lift force.
- Ask for a student volunteer and guide students through the first demonstration.
- The student will be instructed to hold a sheet of paper from the front edges and let the front edge hang down. Then, the student will blow across the top of the paper.
- After the class observes the demonstration, ask them to explain why the paper surprisingly moves upward toward the stream of air instead of moving downward away from the stream of air.
- Explain to the class that this demonstrates Bernoulli's Principle, which states that fluids in an area moving faster than the surrounding area possess less pressure. In the demo, the slower moving air (fluid) underneath the paper has a higher pressure and pushes the paper up toward the area of lower pressure.

Slide 2

- For the second demonstration, ask for another student volunteer.
- Ask the student to lay two empty soda cans sideways on a table so that they are positioned about an inch apart and parallel to each other. Then instruct the student to blow through a

straw that is placed between the cans and parallel to them. Ask the class to observe what happens to the cans.

- Ask the class: *Why do the cans move closer together?*
- Correct any misconceptions by telling the class that the reason for the cans moving together has to do with a change in fluid (air) pressure. The air speeds up to pass between the cans and this causes a drop in pressure. However, the atmospheric pressure on the outside of the cans remains higher than that between the cans and this pressure differential forces the cans to move closer to the area of lower pressure.
- Differences in pressure also explain why an airplane wing moves up. The curvature of the wing causes air to move faster over the top producing an area of lower air pressure. At the same time, the bottom of the wing experiences higher pressure. The difference in air pressure between the top and bottom surface create lift.

Slide 3

- In order to understand the four force vectors of flight in conjunction with jets and to ask meaningful questions, students will conduct independent, internet background research focused on lift, thrust, drag, and weight. (Students can work individually, in pairs, or in small groups depending upon the number of devices with internet connections available.) The following is a list of resources that may be used:
    - https://www.grc.nasa.gov/www/k-12/airplane/lift1.html
    - https://www.nasa.gov/audience/foreducators/k-4/features/F_Four_Forces_of_Flight.html
    - http://www.kids.ct.gov/kids/cwp/view.asp?q=330926

Slide 4

- Direct students to complete the **Free Body Diagram** based upon their research. Students should label the FOUR force vectors acting on the jet during flight. All force vectors should be represented with a capital letter F and a subscript naming the type of force vector (e.g. F_{lift}). Students should then answer the questions underneath the Free Body Diagram:
    - Which force pairs have equal magnitude and opposite direction assuming the jet flight is in equilibrium (level with constant velocity)?
      Thrust Force = Drag Force
      Force Due to Lift = Force Due to Weight
    - Explain how the free body diagram would change, if the plane flies straight up.
      If the jet flies straight up (ADD) at a constant speed, thrust is no longer equal to the drag. Thrust would equal the combination of weight and drag.
- Lead students through a class discussion of the answers to the **Free Body Diagram**, based upon the answer key. Click to reveal each correct answer (in red above), following the brief discussion.

Slide 5

- Direct students to complete the **Forces of Flight: Graphic Organizer** by listing each force of flight and the direction of each force vector from the **Free Body Diagram**. Then, students should describe the factors that affect each force using their earlier internet research.
- Lead students through a class discussion of the answers to the **Forces of Flight: Graphic Organizer**, based upon the answer key. Click to reveal each correct answer, following the brief discussion. Ensure that students have acknowledged the effects of changes to air temperature and pressure, altitude, airspeed, the size and shape of the object, the motion of the object

through the air and properties of the air (such as mass, velocity and compressibility), the wing span-to-wing area ratio, the flow resistance of air, and the weight of the aircraft (which decreases during flight due to fuel usage). Instruct students to add any missing information to their **Graphic Organizer**.

Day 2

Explain and Elaborate (Slides 6 - 9)

Overview: Students will be introduced to the calculations required and necessary adjustments that may be necessary in deciding whether or not to authorize the takeoff of a jet from an aircraft carrier at sea. Then, they will investigate a specific scenario (in small groups) to determine whether their scenario is a "Go" or "No Go" for takeoff and report out their decisions with justifications to the class. As an extension, students will then calculate how much <u>average force</u> a traditional catapult system generates as compared to a proposed new system to help decide whether to invest in this new technology.

Slide 6

- Explain that students will participate in an activity in which they will evaluate various takeoff scenarios in small groups to determine whether or not to authorize the takeoff of a jet from an aircraft carrier at sea. Click to reveal the basic assumptions for all groups and the formula to be used (below) as you describe the activity: *Imagine you're on board the USS-Discovery Aircraft Carrier. Your crew has been tasked with coordinating the safe takeoff of a jet from the flight deck of the aircraft carrier. Since the runway length on your aircraft carrier is only a few hundred feet, your crew has engineered a steam-powered catapult to quickly launch the aircraft to the desired minimum takeoff speed (at least 170 mph). You know that airspeed depends on the ship's velocity, the catapult's velocity, and wind velocity through the following formula:*

$$\textbf{Airspeed} = V_S + V_C + V_{HW}$$

V_{ship} = ship speed, V_C = catapult speed, and V_{HW} = headwind speed

Note: assume positive wind velocity is in the opposite direction of ship's motion (tailwind = negative)

- Divide students into at least 4 groups. Hand out one **Flight Scenario** to each group (one handout should be given to each student, but inform students that only one, final group handout will be collected). Instruct students to complete the calculations and make their "Go" or "No Go" determinations as a group for their unique scenarios, as well as to describe the adjustments needed ensure that the minimum airspeed is reached if their scenario is a "No Go".

Slide 7

- Randomly choose one group of students per scenario to report out their calculations and conclusion: "Go" or "No Go". Lead students through a class discussion following each report out to correct and/or add missing points to each conclusion, based on the **Flight Scenarios: Is Take Off a "Go" or "No Go"? Answer Key**. Click to share the correct answers during the discussion.

Slide 8 - 9

- Describe the extension activity to the students as a full class: *Your crew is interested in upgrading the steam driven catapult system on the aircraft carrier to an Electromagnetic Aircraft Launch system (EMALS), which uses less energy, is more precise, and delivers more average force. Let's assume the Electromagnetic system is capable of delivering 810,000 N of average force. Before deciding to invest in this new technology and as a point of comparison, your crew wants to calculate how much average force (in Newtons) the old catapult system generated. You know that the catapult can launch a 20,000 kg plane from rest to 170 mph (76 m/s) in a matter of 2 seconds. Assume the jet engines provide a thrust force of 140,000 N (this should be added to the left side of the equation). Use the change in momentum of the plane-catapult system and the impulse-momentum equation shown below to calculate the maximum force exerted by the steam-driven catapult and determine whether switching to the new technology is a smart decision.*
- Click to reveal the equation:

For this situation, Newton's Second Law: $F_{net} = ma$ can be rewritten in terms of momentum as:

$$F_{net} = (F_{avg.})_{catapult} + F_{thrust} = \Delta p / \Delta t$$

$$(F_{avg.})_{catapult} = [\Delta p / \Delta t] - F_{thrust}$$

Note: Δp = final momentum (mv_f) - initial momentum (mv_i)

Δt = final time (t_f) – initial time (t_i)

Solution:

$$F_{avg.} = [(mv_f - mv_i) / \Delta t] - F_{thrust}$$

F_{thrust} = 140,000 N

m = 20,000 kg

v_i = 0 m/s (rest condition)

v_f = 76 m/s

t_i = 0 s

t_f = 2 s

Δt = 2 seconds

- After allowing time for independent work, lead students through a full class discussion of the results of their calculations and their conclusions about whether to invest in the new technology. Click to reveal the solution (in red above). Click to advance to Slide 9 for the conclusions:
    - **Plugging into the equation and solving for average force gives: Average Force = (20,000 kg) (76 m/s) / 2 s = 760,000 kg*m/s^2 - 140,000 kg*m/s^2 = 620,000 kg*m/s^2 which is equivalent to 620,000 N. This force is significantly less than that generated by the electromagnetic system (810,000 N). So the improved average force and other advantages associated with the Electromagnetic Aircraft Launch system (EMALS) technology make this a smart decision.**

Day 3

Engage (Slides 10-14)

Overview: In this section, students will be presented with a video showing the landing process and review key points to ensuring a safe and successful landing. This will prepare them to complete their own project in small groups to build and successfully land a paper airplane within a target zone during Days 3 and 4 of the lesson.

Slides 10-11

- Click the play icon on Slide 10 to watch the video together as a class. This video depicts the process of landing a jet on an aircraft carrier at sea. The video can be stopped at :33, which is at the point one complete landing has occured. You may wish to pause frequently for students to take notes, or plan to watch the video several times as a class. As there is no voiceover narration, you will need to describe to students what is happening as the video plays. Key points to cover include:
    - The video shows what is known as an "arrested" landing of a jet on an aircraft carrier.
    - During an "arrested" landing the jet is decelerated on the runway using a tailhook that snags one of four sturdy wire cables (spaced 50 feet apart), which span the carrier's deck. The wires are attached to a hydraulic system that absorbs the energy of impact and brings the plane to a halt. The pilot aims for the third wire which is the safest and most effective target. If the plane comes in too low on the first wire it could cause it to crash into the stern of the ship.
    - It is also important to point out the concerted effort of all the crew members on board the carrier. The Landing Signal Officers (LSOs) assist in guiding the plane in through radio communication and a collection of lights on the deck of the aircraft carrier. A Flight Deck Commander provides final instructions.
- From watching the video, students should be prepared to have a full class discussion about the salient factors in achieving a safe and successful landing, including the roles and responsibilities of different team members. Click to Slide 11 to reveal the key points during the discussion. Inform students that this information will be used to complete their own project in small groups to build and successfully land a paper airplane within a target zone during Days 3 and 4 of the lesson.

Slide 12

- Instruct students that, in groups of 2-3, they will construct a paper airplane that flies accurately toward a target zone and onto a runway based on internet background research focused on airplane designs. The following is a list of resources that may be used:
    - https://www.grc.nasa.gov/www/k-12/airplane/glidpaper.html
    - https://www.exploratorium.edu/exploring/paper/airplanes.html
    - http://howthingsfly.si.edu/activities/paper-airplane/gallery
    - There are multiple Smartphone applications that allow you to craft multiple paper airplane designs.

Slide 13

- As a class, review **The Airplane Landing Challenge** handout, including the required and optional materials, the goal of the challenge (Group's plane must land within the designated runway with these dimensions: length = 460 cm, width = 80 cm during at least one trial), and how to prepare the Flight Analysis Report (especially Background, Results, Video/Graphical Analysis, and

Conclusions sections). Briefly review the grading rubric to ensure that students understand the scoring criteria and the availability of 2 Bonus Points for groups whose plane lands within the runway during all THREE trials.

- Note: The dimensions for the target zone are based on the aspect ratio for length and width of an actual aircraft carrier runway and jet:

  Dimensions of Runway for Airplane Landing Challenge
  -Average length aircraft carrier runway = 1,092 ft. (332.85 m)
  -Flight deck width = 256 feet (78 m)
  -Average length of jet = 20 m
  -Length Ratio: 333/20 = 16.65 to 1
  -Width Ratio: 78/20 = 3.9 to 1
  -Length Paper Airplane = 28 cm
  -Width of Paper Airplane = 21 cm
  -16.65 x 28 cm = 466 cm runway = make runway length 460 cm (4.6 m)
  -21 cm x 3.9 = 81.9 cm → make width about 0.80 meter (80 cm)
  -Use blue tape on floor to map out rectangular area measuring L x W = (4.6 m x 0.8 m).

Slide 14

- Instruct students to break into their groups of 2-3 to build their plane and complete Trials #1 and #2 of their landings, videoing each for later analysis on Day 4. Set up the landing areas before class by marking the space with tape on the floor in the hallway or another area large enough to allow for students to stand up to at least 25 feet away and include vertically placed meter sticks in the background for height measurements.

  - There are two options for the video analysis of the paper airplane landing:
    Option #1: Use a Video Analysis application to capture a video of the paper airplane landing. Applications allow the user to analyze the two-dimensional projectile motion frame-by-frame and make markings relative to a set scale that can be directly graphed in the program. Graphs of trajectory, x/y position, and velocity versus time will be particularly useful for this activity.

    Option #2: Capture a video using a digital camcorder or USB camera and import the movie clip directly into a graphical analysis software.

    Note: Check with your school's technology specialist to see if your school already has a site license for software, which allows school use or free download for home use.

- In the time remaining, students should work on their Flight Analysis Reports in their groups based upon their internet research, their selected design, and the results of their first two trials.

<u>Day 4</u>

Evaluate (Slides 15 - 18)

Overview: In this section, students first summarize their learning by completing the video/graphical analysis of their first two trials, making any necessary modifications to their design, and completing the third and final trial. Then, students communicate their conclusions by completing the Flight Analysis Report in their small groups.

Slide 15

- Instruct students to break back into their Flight Analysis groups from the previous day to complete the video/graphical analysis of their first two flight trials using a video analysis app. (such as Vernier Video Physics) to analyze a video of their group's plane approaching and landing on the runway. Students should focus on the plane's apex, time of flight, angle of approach, and linear displacement on the runway to determine possible modifications that should be made before completing the third and final flight trial.

Slide 16

- After making the airplane modifications, students should note in their Flight Analysis Report any additional optional materials used and the results of the third trial (added to the data table).

Slide 17

- Instruct students to discuss as a group their results and complete the conclusion section of their Flight Analysis Report: *Was the goal met during the first two trials? If not, what modifications or changes in design were made for the final trial? How did the video analysis inform your decisions? Which conditions yielded optimal results for landing on the runway?*

Slide 18

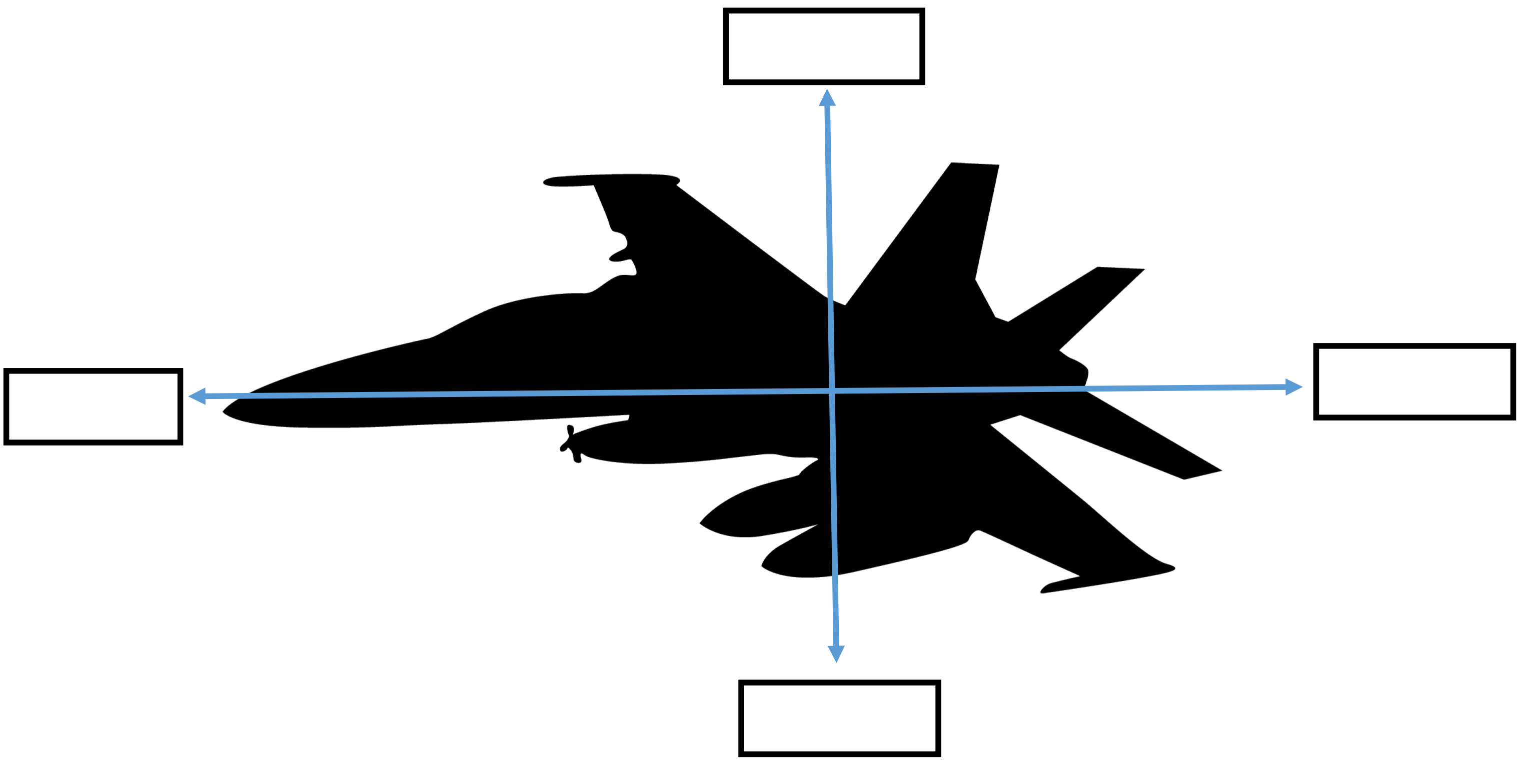
- Summarize the following key aspects of the entire lesson:
    - Various factors affect the four forces of flight (lift, drag, thrust, weight) and lift is created by a difference in pressure. A free-body diagram is used to represent the relative magnitude and direction of these forces from the center of the object.
    - Airspeed calculations are used to predict safe conditions for launching an aircraft from an aircraft carrier. Weather phenomena require adjustments be made to the calculations so that the required minimum safe speed is achieved.
    - Takeoff and landing of an aircraft on an aircraft carrier involves the coordinated effort of engineers, pilots, flight deck operators and landing signal officers all taking into account the plane's trajectory, angle of approach, velocity, and landing spot on the runway.

Additional Online References

http://www.onr.navy.mil/Home/Science-Technology/Departments/~/media/Files/35/NNR-Sea-Based-Aviation.ashx
https://www.grc.nasa.gov/WWW/k-12/VirtualAero/BottleRocket/airplane/shortr.html
http://illumin.usc.edu/142/taking-off-and-landing-on-an-aircraft-carrier/

FREE BODY DIAGRAM

Directions:
Label the FOUR force vectors acting on the jet during flight. All force vectors should be represented with a capital letter F and a subscript naming the type of force vector.



Questions:

- Which force pairs have equal magnitude and opposite direction assuming the jet flight is in equilibrium (level with constant velocity)?

- Explain how the free body diagram would change, if the plane flies straight up?

FREE BODY DIAGRAM
(ANSWERS)

Directions:
Label the FOUR force vectors acting on the jet during flight. All force vectors should be represented with a capital letter F and a subscript naming the type of force vector.
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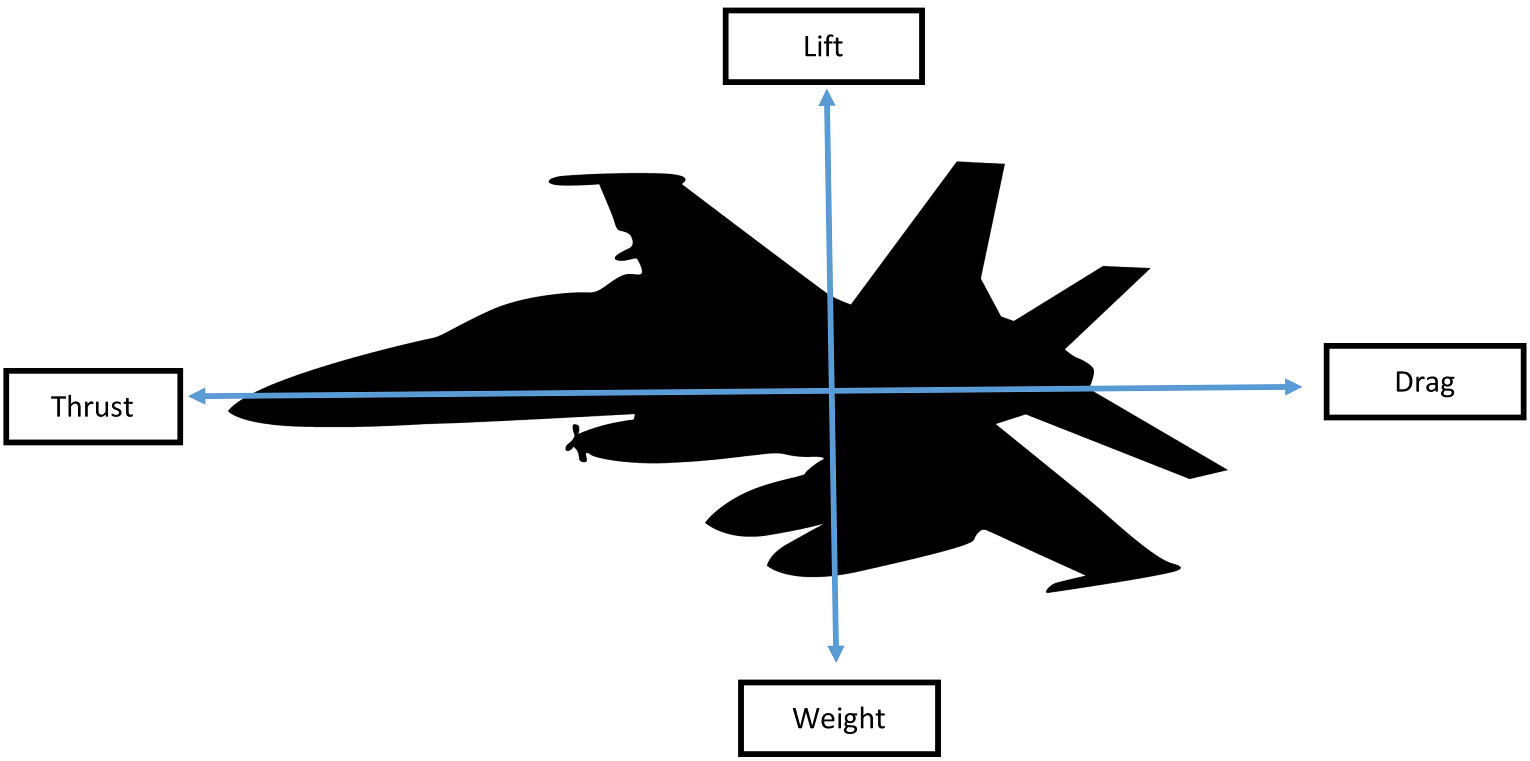

Questions:

1) Which force pairs have equal magnitude and opposite direction assuming the jet flight is in equilibrium (level with constant velocity)?
   Thrust Force = Drag Force
   Force Due to Lift = Force Due to Weight

2) Explain how the free body diagram would change, if the plane flies straight up.
   If the jet flies straight up (ADD) at a constant speed, thrust is no longer equal to the drag. Thrust would equal the combination of weight and drag.

FORCES OF FLIGHT: GRAPHIC ORGANIZER

Directions:
Complete the graphic organizer by listing each force of flight and the direction of each force vector from the free body diagram. Then describe the factors that affect each force.

Name of Force	Direction of Force Vector (From Free Body Diagram)	Factors Affecting This Type of Force

FORCES OF FLIGHT: GRAPHIC ORGANIZER (ANSWER KEY)

Directions:
Complete the graphic organizer by listing each force of flight and the direction of each force vector from the free body diagram. Then describe the factors that affect each force.

Name of Force	Direction of Force Vector (From Free Body Diagram)	Factors Affecting This Type of Force
Thrust	**Direction of Motion (In this case, left.)**	**Any factor that changes the density of air will affect thrust. Temperature and pressure change at various altitudes and climates, and these change the density of air, which in turn affects thrust. For instance, at higher altitudes air becomes colder and denser causing the thrust to increase. Also, as airspeed increases, the overall thrust tends to decrease**
Drag	**Opposite Direction of Motion (In this case, right.)**	**Drag is affected by the size and shape of the object, the motion of the object through the air and properties of the air (such as mass, velocity and compressibility). Drag depends directly on the mass of the air flowing past the aircraft. Also a smooth surface produces less drag than a rough surface.**
Lift	**Upward**	**The shape and size of a wing will affect the lift force. The wing span-to-wing area ratio also affects the amount of lift. In addition, lift depends on the velocity of the air and the mass of the flow. Lastly, the flow resistance of air and its compressibility also affect lift.**
Weight	**Straight Down**	**Weight is a force caused by Earth's gravitational attraction. It depends on inertia (mass) and the magnitude of gravity. Although weight is distributed throughout the jet, we tend to think about it as being concentrated at the center of gravity. Its direction is always toward the center of the earth. As the jet burns up its fuel during flight, mass (and therefore**

		weight) decreases. This disrupts the jet's equilibrium state and therefore the pilot has to make adjustments to bring it back to a balanced state.

FLIGHT SCENARIOS: IS TAKE OFF A "GO" OR "NO GO"?

Scenario #1

Imagine you're on board the USS-Discovery Aircraft Carrier. Your crew has been tasked with coordinating the safe takeoff of a jet from the flight deck of the aircraft carrier. Since the runway length on your aircraft carrier is only a few hundred feet, your crew has engineered a steam-powered catapult to quickly launch the aircraft to the desired minimum takeoff speed (at least 170 mph). You know that airspeed depends on the ship's velocity, the catapult's velocity, and wind velocity through the following formula:

$$\text{Airspeed} = V_s + V_c - V_w$$

V_{ship} = ship speed, V_c = catapult speed, and V_w = wind speed
Note: assume positive wind velocity is in the direction of the ship's motion

Your ship is moving with a velocity of 20 mph and the wind speed at the time of launch is 30 mph in a direction that is opposite the direction of the ship. The jet is launched upward from the catapult with a velocity of 150 mph. Given these values, determine whether takeoff will be a "Go" or a "No Go". Explain the steps in your decision-making process. If your decision is to not takeoff, what adjustments need to be made to ensure that the minimum airspeed is reached?

Equation/Calculations	Decision ("Go or No Go"?) With Justification	Adjustments (If Necessary)

Adapted from Glenn Research Center NASA (Airspeed Activity)
https://www.grc.nasa.gov/WWW/k-12/BGA/Dan/airspeed_act.htm

FLIGHT SCENARIOS: IS TAKE OFF A "GO" OR "NO GO"?

Scenario #2

Imagine you're on board the USS-Discovery Aircraft Carrier. Your crew has been tasked with coordinating the safe takeoff of a jet from the flight deck of the aircraft carrier. Since the runway length on your aircraft carrier is only a few hundred feet, your crew has engineered a steam-powered catapult to quickly launch the aircraft to the desired minimum takeoff speed (at least 170 mph). You know that airspeed depends on the ship's velocity, the catapult's velocity, and wind velocity through the following formula:

$$\text{Airspeed} = V_s + V_c - V_w$$

V_{ship} = ship speed, V_c = catapult speed, and V_w = wind speed
Note: assume positive wind velocity is in the direction of the ship's motion

Your ship is moving with a velocity of 20 mph and the wind speed at the time of launch is 10 mph in the same direction as the ship. The jet is launched upward from the catapult with a velocity of 150 mph. Given these values, determine whether takeoff will be a "Go" or a "No Go". Explain the steps in your decision-making process. If your decision is to not takeoff, what adjustments need to be made to ensure that the minimum airspeed is reached?

Equation/Calculations	**Decision ("Go or No Go"?) With Justification**	**Adjustments (If Necessary)**

Adapted from Glenn Research Center NASA (Airspeed Activity)
https://www.grc.nasa.gov/WWW/k-12/BGA/Dan/airspeed_act.htm

FLIGHT SCENARIOS: IS TAKE OFF A "GO" OR "NO GO"?

Scenario #3

Imagine you're on board the USS-Discovery Aircraft Carrier. Your crew has been tasked with coordinating the safe takeoff of a jet from the flight deck of the aircraft carrier. Since the runway length on your aircraft carrier is only a few hundred feet, your crew has engineered a steam-powered catapult to quickly launch the aircraft to the desired minimum takeoff speed (at least 170 mph). You know that airspeed depends on the ship's velocity, the catapult's velocity, and wind velocity through the following formula:

$$\text{Airspeed} = V_s + V_c - V_w$$

V_{ship} = ship speed, V_c = catapult speed, and V_w = wind speed
Note: assume positive wind velocity is in the direction of the ship's motion

Your ship is moving with a velocity of 25 mph and the wind speed at the time of launch is 10 mph in a direction that is opposite the direction of the ship. The jet is launched upward from the catapult with a velocity of 150 mph. Given these values, determine whether takeoff will be a "Go" or a "No Go". Explain the steps in your decision-making process. If your decision is to not takeoff, what adjustments need to be made to ensure that the minimum airspeed is reached?

Equation/Calculations	**Decision ("Go or No Go"?) With Justification**	**Adjustments (If Necessary)**

Adapted from Glenn Research Center NASA (Airspeed Activity)
https://www.grc.nasa.gov/WWW/k-12/BGA/Dan/airspeed_act.htm

FLIGHT SCENARIOS: IS TAKE OFF A "GO" OR "NO GO"?

Scenario #4

Imagine you're on board the USS-Discovery Aircraft Carrier. Your crew has been tasked with coordinating the safe takeoff of a jet from the flight deck of the aircraft carrier. Since the runway length on your aircraft carrier is only a few hundred feet, your crew has engineered a steam-powered catapult to quickly launch the aircraft to the desired minimum takeoff speed (at least 170 mph). You know that airspeed depends on the ship's velocity, the catapult's velocity, and wind velocity through the following formula:

$$\text{Airspeed} = V_s + V_c - V_w$$

V_{ship} = ship speed, V_c = catapult speed, and V_w = wind speed
Note: assume positive wind velocity is in the direction of the ship's motion

Your ship is not moving and the wind speed at the time of launch is 15 mph in the positive direction. The jet is launched upward from the catapult with a velocity of 150 mph. Given these values, determine whether takeoff will be a "Go" or a "No Go". Explain the steps in your decision-making process. If your decision is to not takeoff, what adjustments need to be made to ensure that the minimum airspeed is reached?

Equation/Calculations	Decision ("Go or No Go"?) With Justification	Adjustments (If Necessary)

Adapted from Glenn Research Center NASA (Airspeed Activity)
https://www.grc.nasa.gov/WWW/k-12/BGA/Dan/airspeed_act.htm

FLIGHT SCENARIOS: IS TAKE OFF A "GO" OR "NO GO"?
Answer Key

Equation/Calculations	Decision ("Go or No Go"?) With Justification	Adjustments (If Necessary)
Scenario #1: V_c = 150 mph, V_s = 20 mph, V_w = -30 mph Airspeed = 20 + 150 – (-30) = 200 mph	GO The speed of 200 miles per hour is above the minimum required speed.	N/A
Scenario #2: V_c = 150 mph, V_s = 20 mph, V_w = +10 mph Airspeed = 20 + 150 – (10) = 160 mph	NO GO Since the airspeed (160 mph) is less than the required minimum speed for takeoff. Adjustments will need to be made.	The following adjustments can be made to reach the desired speed: -Increase the ship speed -Increase jet engine throttle to maximize forward thrust -Turn the ship into the wind to maximize lift
Scenario #3: V_c = 150 mph, V_s = 25 mph, V_w = -10 mph Airspeed = 25 + 150 – (-10) = 185 mph	GO The speed of 185 miles per hour is above the minimum required speed.	N/A
Scenario #4: V_c = 150 mph, V_s = 0 mph, V_w = +15 mph Airspeed = 0 + 150 – (15) = 135 mph	NO GO Since the airspeed (135 mph) is less than the required minimum speed for takeoff. Adjustments will need to be made.	The following adjustments can be made to reach the desired speed: -Set the ship in motion with a speed greater than or equal to 35 mph -Turn the ship into the wind to maximize lift -Increase jet engine throttle to maximize forward thrust

THE AIRPLANE LANDING CHALLENGE

CHALLENGE:
In groups of 2-3, you will construct a paper airplane that flies accurately toward a target zone and onto a runway based on your research of paper airplane designs.

REQUIRED MATERIALS:
1-2 standard-size sheets of copy paper (required)

ADDITIONAL MATERIALS (OPTIONAL):
***Use of one or more of these materials will result in point deductions (see rubric)**
-One standard paper clip
-Three inches of tape
-A dab of glue
-Three staples

FLIGHT TRIALS:
Goal: Group's plane must land within the designated runway (Dimensions: length = 460 cm, width = 80 cm) during at least one trial.

FLIGHT ANALYSIS REPORT PREPARATION:
Include the following information in a <u>visually appealing</u> flight analysis report (can be front and back, one report submitted per group):

1) Names of group members
2) Title
3) Background – How background research was used to construct the plane. Rationalize your design - include steps used to design and build the paper airplane. Also include terms such as weight, lift, thrust, drag, and a description of how Newton's Laws apply.
4) Results of Flight Trials – Include data table
5) Video/Graphical Analysis – Use Video Analysis app. (such as Vernier Video Physics) to analyze a video of your group's plane approaching and landing on the runway. Include vertically placed meter sticks in the background for height measurements. Focus on the plane's apex, time of flight, angle of approach, and linear displacement on the runway.
6) Conclusion - Was the goal met during the first two trials? If not, what modifications or changes in design were made for the final trial? How did the video analysis inform your decisions? Which conditions yielded optimal results for landing on the runway?

BONUS (+2 Points)
Groups with a plane that lands within the runway during all THREE trials will receive the bonus points.

RUBRIC – THE AIRPLANE LANDING CHALLENGE

NAMES: ____ SCORE: __________________

	Excellent (4 Points)	**Very Good (3 Points)**	**Fair (2 Points)**	**Inconsistent (1 Point)**
Background Research	Specific terms are expanded beyond simple definitions and the steps of the design are clearly delineated. Includes thorough explanation of airplane design choice and how Newton's Laws apply	All steps of the process have been thoroughly explained, but definitions of terms are not expanded. Includes adequate explanation of airplane design choice	Not all steps of the process have been thoroughly explained and some terms are unclear. Includes adequate explanation of airplane design choice but does not include an explanation of how Newton's Laws apply	Definitions are incomplete and the design process has not been explained. Does not include an explanation of airplane design choice. Does not include an explanation of how Newton's Laws apply
Use of Approved Materials	Used only 1-2 standard size sheets of copy paper	Used one optional material	Used two optional materials	Used three or more optional materials
Flight Analysis Report	Report includes all flight trial results, projectile video analysis of motion, and conclusions. Report is visually appealing	Report includes all required components but is not visually appealing	Report includes essential knowledge but information is not in-depth and the report is not visually appealing	Report includes inadequate amount of information and is missing requirements
Flight Distance	Paper airplane flies at least 25 feet toward the target zone	Flies approximately 20 feet toward the target	Flies approximately 15 feet toward the target	Flies less than 15 feet toward the target
Landing	Plane lands within the target zone and does not slide out	Plane strikes the target zone but then slides out either lengthwise or sideways	Plane's trajectory is consistently aimed at the target zone but either falls short or overshoots the runway	Plane consistently strikes a wall or nose dives prematurely, missing the target zone

Bonus Points (+2) awarded for THREE successful trials ____________________________