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Lighter than Air

The Tech Challenge 2016 Flight Lesson 2:
Developed by The Tech Academies of Innovation

I. Lesson Overview

Scientists often need to gather information in order to form solutions to problems. Can you design an aircraft to help scientists gather information in areas of the world that can only be observed from above?

Lesson Description:

The lesson is an exploration of how force affects the motion of an object. It includes a beginning challenge to achieve neutral buoyancy, followed by a second challenge to explore forward motion and thrust. Optional extensions might include modifying the system to carry a payload, calculating dimensions of a real-world application and/or discussing the limitations of using models at a real-world scale.

Grade Levels: 4-8

Education Outcomes:

Students will:

- utilize a helium balloon to design and create a light-as-air craft which is able to achieve neutral buoyancy.
- design and create an aircraft which, using the force of a propeller, displays forward motion.

Education Standards

Met: (Note: bolded parts of the standards are fully met by this lesson)

Next Generation Science Standards (NGSS) Performance Expectations (PE)

MS-PS2-2. Plan an investigation to **provide evidence that the change in an object's motion depends on the sum of the forces on the object** and the mass of the object**.**

NGSS Disciplinary Core Ideas (DCI)

MS-PS2-A. Forces and Motion

- **The motion of an object is determined by the sum of the forces acting on it;** if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion.

NGSS Science and Engineering Practices (SEP):

6-8 SEP 6: Constructing explanations and designing solutions

- **Optimize performance of a design by** prioritizing criteria, making trade-offs, **testing, revising, and retesting.**

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Addressed: (The following standards are practiced in this lesson but are not explicitly taught and assessed)

Next Generation Science Standards (NGSS) Performance Expectations (PE)
4-ESS3-2. Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.

5-ESS3-1. Obtain and combine information about ways individual communities use science ideas to protect Earth's natural resources and environments.

MS-PS3–5. Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

MS-ESS3-2. Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.

MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

NGSS Disciplinary Core Ideas (DCI)
3-5-ETS1.A: Defining and Delimiting Engineering Problems

- Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account.

MS-ETS1.C: Optimizing the Design Solution

- Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of the characteristics may be incorporated into the new design.
- The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.

NGSS Crosscutting Concepts (CCC):
6-8-CCC 6. Structure and Function - The way an object is shaped or structured determines many of its properties and functions.

- Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped, used and respond to forces.

Common Core Standards:
CCSS.Math 6.EE.9: Represent and analyze quantitative relationships between dependent and independent variables: Use variables to represent two quantities in a real-world problem that change in relationship to one another; write an equation to express one quantity, thought of as the dependent variable, in terms of the other quantity, thought of as the independent variable. Analyze the relationship between the dependent and independent variables using graphs and tables, and relate these to the equation. *Example: Scaling a model to real world size.*

CCSS.Math 7.RP.2: Analyze proportional relationships and use them to solve real-world and mathematical problems: Recognize and represent proportional relationships between quantities. (a)Decide whether two quantities are in a proportional relationship, e.g., by testing for equivalent ratios in a table or graphing on a coordinate plane and observing whether the graph is a straight line through the origin. (b) Identify the constant

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of proportionality (unit rate) in tables, graphs, equations, diagrams, and verbal descriptions of proportional relationships.

CCSS.ELA-Literacy.W.8.4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

English Language Development Standards:
Part 1A.1: Exchanging information and ideas with others through oral collaborative conversations on a range of social and academic topics

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II. Advanced Prep & Set-Up for Lesson

Light-as-Air Set-Up

Materials (per group of 3-4 students)

- 1 mylar balloon filled with helium, recommended diameter of at least 18”, leashed on ribbon
- 2 non-flexible ‘super jumbo’ drinking straws
- Several small (#1) paper clips
- 4 chenille stems (i.e. pipe cleaners)
- several index cards
- clear tape (about 1 foot)
- 2-4 pairs of scissors
- stop watch
- Optional: additional materials such as foam pieces or other small items to use as ballast (material that provides stability to a vehicle or structure) or as a payload. Also, wire cutters may be used to cut paper clips

Light-as-Air Set-Up

- Make sure balloons are pre-filled with helium and attached to a weighted ribbon or fishing line leash to prevent escaping to the ceiling of the classroom.
- Set up one table as a materials station where students can pick up materials to use in their groups.
- Classroom should be set up so that students can work in groups of 3 or 4.
- Time craft remain in neutral buoyancy should be collected as aircraft buoyancy is tested using the Data Collection Table (see Appendix C):

Trial #1	**Trial #2**	**Trial #3**	**Average Time**
Example: 16s	*Example: 13s*	*Example: 15s*	*Example: 14.67s*

s=seconds

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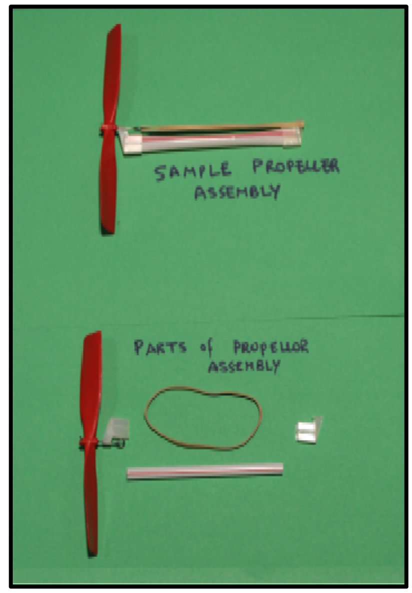
Controlled Flight Set-Up

Materials (per group of 3-4 students)

- All materials from "Light-as-Air" set-up
- 3 pony beads for payload
- 1 propeller assembly *(order kits at Delta Education, select "FOSS Middle School" and "Force and Motion, First Edition")*
  - 1 Propeller
  - 2 End-hooks
  - 1 "S1" rubber band
  - 1 4-inch piece of non-flexible "giant" drinking straw
- 3 post-its or other temporary marker to indicate distance aircraft travels on the floor
- tape measure
- masking tape to mark distances on the floor in 1 foot increments



Suggested additional materials as available:

- Additional materials such as foam, balsa wood, tubing, plastic or other lightweight material are useful for building platforms for propeller assemblies or payload carriers. These materials can be cut or torn by students based on their design needs. Size will vary based on availability and weight of material, but 2-inch by 4–inch would be adequate.

Controlled Flight Test Set-Up

- Classroom should continue to be set up so that students can work in groups of 3 or 4 with a testing station on one side of the room
- Testing station should be set up with the following:
  - A long open space of at least 15 feet.
  - Tape a marker on the floor to designate a launching starting point.
  - Using the tape measure, mark off every 1 foot for 15 total feet.
  - When teams are distance testing, place the post-it or marker at the point where the aircraft reaches on each trial
  - This lab should be conducted indoors to avoid issues with air turbulence. Also control, as possible, A/C units, fans, open doors etc.)
- Distance data should be collected as aircraft are tested using the Data Collection Table (see Appendix C)

Flight #1	**Flight #2**	**Flight #3**	**Average Flight:**
Example: 7 feet	*Example: 10 feet*	*Example: 8 feet*	*Example: 8.33 feet*

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IV. Lighter than Air Craft Design Lesson Guide

Guiding Question: How can scientists study areas of the world that can only be observed from above?

A. Introduction (20 minutes)

This section is a time to discuss the challenge with students and to activate their prior knowledge.

1. Post pictures of fish and submarines for students to observe. Ask students to brainstorm in small groups how fish and submarines are similar and different. Have them also brainstorm what they must both do in order to function under water. What characteristics do fish and submarines need that boats do not need?

2. Have the groups share out and compile a list of characteristics and functions of the fish and submarines on the Venn diagram *("Comparing Fish and Submarines" Appendix C)*.

3. Review forces by demonstrating forces on an object at rest and in motion and asking questions. Suggested questions might include:
   - When an object is at rest, what forces are acting upon it? (Gravity is pulling down. The surface it rests on is pushing up.)
   - What is the sum of the forces on this object? (Zero.)
   - When an object (like a car) is moving at a constant speed, what forces are acting on it? (Gravity is pushing down. The road is pushing up. The engine is propelling the car forward. Air resistance causes drag to push the car backward).
   - What is the sum of the forces on this object? (Zero, because the forces are balanced.)
   - If you wanted to change the motion of the car to make it accelerate or go faster, how would the forces need to change? (The engine would need to make the forward force stronger).

Facilitator Notes:
Introduction
- When brainstorming, if necessary, direct the conversation toward how both fish and submarines need to stay underwater, but not sink to the bottom.
- Venn diagrams can vary in complexity according to grade level.
- In the Venn diagram, similarities may include that both: are able to move up and down in the water, move forward (horizontally), turn and change direction, have similar body shapes, etc. Differences may include that fish are alive, submarines are man-made; fish remain underwater, submarines surface for air and supplies, etc.
- Use a document camera or an interactive whiteboard to complete the Venn diagram with the students.
- Third grade core force concepts to review include:
  - Each force acts on one particular object and has both strength and direction.
  - An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object.
  - Forces that do not sum to zero can cause changes in the object's speed or direction of motion.
  - Gravity is a force that pulls all objects down to the Earth.
- In reviewing gravity, It may be helpful to watch Defining Gravity: Crash Course Kids #4.1 (link here or see Appendix B for URL)
- See Appendix B for other buoyancy lessons.
- Students should observe that gravity pushes down on fish/submarine., Water pressure pushes up on the fish/submarine. Propulsion or pushing back on the water pushes the submarine or fish forward and water resistance or currents push the fish/submarine backward.

4. Ask students to consider what forces might be acting on a fish or a submarine as they float in the water. This information can be added to the Venn diagram using a different color pen.

5. Ask students how those forces might affect the motion of the fish or submarine and continue to add this information to the Venn diagram. Have students circle everything on their Venn diagram that has to do with forces.

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B. Light-as-Air Design Challenge (20-40 minutes)

1. Introduce the first design challenge by asking students to find a way to make the balloon float above the floor but not above 5 feet.

   Design Problem:
   - Scientists need to study ozone in our atmosphere which is located in the stratosphere. The instruments will be carried up on a helium balloon, but must stay at a particular altitude in order to study ozone. Using a helium balloon, create an aircraft that will float above floor, but not above 5 feet.

   Criteria (Design Requirements/Desired Features):
   - Use the helium balloon and materials provided
   - Balloon must be able to float between floor and the end of the tether for at least 15 seconds

> **Facilitator Notes:**
> Light-as-Air Experimental Design
> - Students should notice that if helium balloon rises toward ceiling, the lift needs to be countered with greater mass.
> - Students should notice that a sinking helium balloon will need to be balanced by reducing the mass.
> - When comparing forces acting on a fish or submarine compared to those on their aircraft, the forces will be the same; however, the fluid forces of water are of a greater magnitude than those of air. The fluid forces include **drag** (resistance) and pressure (air or water pressure). When aircraft rise, we call this force **lift**.
> - If students achieve 15 seconds, challenge them to go for 30 seconds or more.

   Constraints (Design Limitations):
   - You may not tape or otherwise permanently fix anything directly onto the balloon (allows balloons to be re-used)
   - The balloon must be free-floating (You may not touch the balloon during the test)
   - The tether itself may touch the floor as long as none of the load students added touches the floor

   Testing:
   - Buoyancy Test: have student teams demonstrate the buoyancy of their aircraft one at a time. Have students record three time trials in their Data Collection Tables handout *("Data Collection Table", Appendix C)*
   - As students work on their designs, have them document their design features, results and changes in a graphic organizer *("Light-as-Air Design Challenge Notes", Appendix C)*

2. While students are working on their designs, circulate and ask questions to encourage critical thinking and perseverance. Questions might include:
   - What changes can you make to your design to better meet the criteria?
   - What trade-offs can you think of where getting rid of one material may open up different design possibilities?
   - What have you learned from that trial? Knowing that, how will that guide your next design change?"

> **Facilitator Notes:**
> Possible sentence stems to use with students to facilitate discussion of design process and results:
> - "I think that the balloon will ________, because our design________."
> - "If we add/remove _______/from our design, then our balloon will ______."
> - "When we tested it, I think that the balloon______, because we ________."

3. Have students recall the forces acting on a fish or submarine, and have students relate these forces to the forces that would act on their aircraft. Are they the same - or are they different?

4. Run the tests and have students document their observations.
   - How do you predict each aircraft will float? Why?
   - What do you notice about the characteristics of each design? What's similar? What's different?
   - What do you notice about how each floats?
   - What do you notice about the design of each aircraft that might contribute to these flight characteristics?
   - What are the strengths and failure points or weaknesses of each design?

C. Neutral Buoyancy Content Learning (40-60 minutes)

1. Begin by reviewing the results of the first design challenge. Pair up the groups to discuss:
   - What worked? What didn't work?
   - Were you successful in the time allotted? If so, how many iterations did you try? If not, what would your next steps be?
   - How would you describe the forces acting on your balloon?
   - What did you have to do to try to balance the forces?

2. Record on a chart the general "aha's" that were found (about forces and engineering).

3. Introduce two essential vocabulary terms: for example, **neutral buoyancy** and **balanced forces**.
   - As students watch the following video, ask them to notice when the submarine is **neutrally buoyant**? What was hard about making the submarine neutrally buoyant?
   - Show the video on science project submarine: Maddy's Science Project *(link here or see Appendix B for URL).*
   - Explain that when the upward force of **lift** is balanced with the downward force of **gravity**, the submarine is **neutrally buoyant**—neither sinking nor floating.

4. Using the Frayer model *("Buoyancy Vocabulary," Appendix C)*, have students explore these vocabulary by writing a given definition, their own definition, drawing a picture and giving a non-example of the word.
   - When the force of gravity is **balanced** by lift (a force opposite to gravity), buoyancy is neutral (the object does not sink or rise). An object only sinks or rises if the forces on it are unbalanced.
   - **Buoyancy** is the tendency of an object (fish or submarine) to float in a fluid (i.e., water, air or other fluid)
   - An object that sinks has a **negative buoyancy** (gravity > lift).
   - An object that rises has a **positive buoyancy** (lift > gravity).

Facilitator Notes:
Vocabulary Learning and Supporting English Language Learners

- The Frayer Model involves drawing pictures, which helps students, especially English Language Learners comprehend the vocabulary.
- Have students create a Frayer model of 4 to 6 critical vocabulary words. Each Frayer model has the vocabulary word in the center (e.g. **buoyancy**). In the top left corner, students write a teacher-given definition in student friendly language (**The ability to float in air or water).** In the top right corner, students include examples (**A duck floats because it weighs less than the water it displaces**). After sharing and peer-discussion, students write a non-example in the bottom right (**An anchor is not buoyant, because it sinks to the bottom.**), and an in-context drawing in the bottom left.
- The discussion of submarines and fish helps connect to students' background knowledge to the concept of buoyancy.
- Consider the language students are using after conducting the neutral buoyancy portion of the challenge, and move from their language to the terms of buoyancy (Include concepts of **buoyancy, lift, gravity**, and for 8th grade students **density**.)

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5. Discuss forward motion of fish and submarines.
   - How do submarines achieve forward motion? (The engine provides energy to thrusters, which use a propeller to push against water).
   - How do fish achieve forward motion? (Fish move their bodies in a wave-like motion that pushes against the water)
   - When a fish or submarine swim or move forward, how would you describe the forces acting on them? (The forward motion is greater than the water resistance or current).
   - We call the forward motion **thrust** and air or water resistance is **drag**.

6. Using the Frayer model, have students explore two more vocabulary terms. For example: **thrust** and **drag**.

> **Facilitator Notes:**
> Neutral Buoyancy Content Learning
> - Groups should present their findings to the whole class as a way for the group to learn from their collective successes and failures.
> - Students should observe that **lift** is pushing the balloon up and that they needed to increase the mass in order to reach a point where **gravity** is equal to **lift**.
> - Possible sentence stems to use with students to facilitate discussion of buoyancy:
>   - "Our balloon achieved buoyancy when it ________."
>   - In order to make our balloon buoyant, we had to _______."

7. Show an example of a force diagram showing how force acts on an object. Have the students compare their drawings from the first challenge to the force diagram. They should add arrows to show the forces acting on their balloon if they don't already have them. *(For example, visit the force diagram here or see Appendix B for the full URL.)*

D. Controlled Flight Design Challenge (30-50 minutes)

1. Introduce the second design challenge. Explain to students that they are now going to use what they learned about making their balloon neutrally buoyant in the first experiment to control the flight of an aircraft!
   - Can you think of any places in the world that would be difficult to travel to by land?
   - How about places that would not be safe to travel to by land?

> **Facilitator Notes:**
> - Designing a lightweight aircraft is integral to this second challenge. If students were not successful in Part B, have them start by completing a neutrally buoyant craft.

2. Show students a map that shows the most remote places on Earth *(link here or see Appendix B*) pose the questions:
   - What makes these locations challenging to visit? (Allow students to make observations based on the pictures.)
   - Why might scientists need to study these places? (Scientists may study living things that only live in remote locations. They may study the geologic history, fossils, seismic faults or volcanoes in remote locations).
   - How might they do it? (Allow students to brainstorm)

3. Explain to students that their task is to design an aircraft to observe places that are hazardous to study on the ground. Students will continue their work on a light-as-air craft to achieve neutral buoyancy (maintain an altitude above the floor, but no more than 8 feet, for at least 15 seconds). In this part of the design challenge, students will design a thrust system to propel the craft in a desired direction from 5 to 15 feet.

> **Facilitator Notes:**
> Controlled Flight Design Challenge
> - Items such as paper clips may be used to attach parts of the aircraft to the balloon as they may be easily removed
> - Students will journal their work through multiple iterations of their design as they go. As you circulate, check in with groups to see that they are taking notes on what they are trying, whether it is working or not, and what changes are being made. It may be helpful to have groups decide one person who will be the 'journaler' as they work. They may rotate through this role as they work.
> - For fifth grade students, have them determine one advantage and one disadvantage of using a helium buoyancy device to watch for natural disasters

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Design Problem:

- Scientists need to study a volcano crater. They need a craft that can rise to a certain height and then move forward over the crater. Use a helium balloon to create a Lighter than Air craft to carry scientific instruments to measure temperature, gases, and pressure in a specified direction & across a target line.

Criteria (Design Requirements/Desired Features):

- Use only the provided materials
- Design a propulsion/thrust system, which can be non-permanently attached to the balloon, and can deliver a force to direct the craft in a purposeful direction carrying a payload of 3 pony beads safely.
- The aircraft must travel at least 5 feet in the desired direction with no one touching the aircraft

Constraints (Design Limitations):

- You may not tape or otherwise permanently fix anything directly onto the balloon. (allows balloons to be re-used)
- You may not touch the balloon during the test
- Tether itself may touch the floor as long as none of the load that students added touch the floor

Testing:

- Controlled Flight Test: have student teams test their aircraft one at a time. Have students record three flight distances in their Data Collection Tables handout *("Data Collection Table", Appendix C)*
- As students work on their designs, have them document their design features, results and changes in a graphic organizer *("Controlled Flight Design Challenge Notes", Appendix C)*

4. While students are working on their aircraft, walk around and ask questions to facilitate the design process.
   - What design ideas are you considering? (materials, shape, attachment location of propeller)
   - Why did you decide on that design or those materials)
   - What did you do to achieve **neutral buoyancy**?
   - What did you do to achieve enough **thrust** to overcome **drag**?
   - What did you try that didn't work?

5. Have students document their design features, results and changes in a graphic organizer – Lighter than Air Aircraft Challenge Handout *("Controlled Flight Design Challenge Notes", Appendix C)*

6. Run a whole-class test and have students document their results and observations in the Controlled Flight Design Challenge Data Table *("Data Collection Table", Appendix C)*. Lead a discussion with students about their results and designs:
   - How do you predict your aircraft will fly? Why?
   - What part of the **criteria** and **constraints** does your design meet? Which were the easiest to meet? Which were the hardest to meet?
   - What part of your design do you think caused your aircraft to ______ (some observation of their aircraft's flight)? Why?
   - What performance strengths do you notice? Where were the failure points?
   - What do you notice about the designs that travelled the furthest? What flight characteristics might contribute to this result?
   - What would you change in your next design?

Facilitator Notes:
Possible sentence stems to use with students to facilitate discussion of student designs and design process:

- "We can create/increase thrust by _______, and then our balloon will ___________."
- Right now our balloon is _________. We can solve this problem by _________."

7. Have students complete the self-reflection handout at the end of the testing and discussion *("Design Challenge Reflection" Appendix C).*
    - Remind students that as Engineers, it is important to reflect on what they tried, what worked, and especially what didn't work, so they should be honest with themselves while they reflect.

8. At the end of testing and discussion, if desired, use the Lighter than Air Challenge Rubric to evaluate student work *("Lighter than Air Challenge Rubric" see Appendix C)*

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V. Appendices

A. Vocabulary and Background Information

The following is the start of a suggested list of words to discuss as you read and discuss with students.

balanced forces	Two forces acting in opposite directions on an object, and equal in size. Anytime there is a balanced force on an abject, the object stays still or continues moving at the same speed and in the same direction.
buoyancy	Tendency of an object to float (lift) in a fluid.
center of gravity	The imaginary point where the gravity of an object is centered. For example, the center of gravity of a ball is in the center of the ball.
constraint	The limitations of a design problem which typically include budget and schedule limitations but may also include other limitations such as maximum size restrictions.
criteria	The requirements or desired features of a design problem often describing the purpose and standards that a system or device must meet.
density	Measure of mass in a given volume. Relates to how close together molecules in matter are.
design	A plan for the creation of a solution.
drag	Friction of a fluid (air or water) acting to resist motion of an object through the fluid.
engineer	Someone who finds innovative (original) solutions to real-life problems (e.g. mechanical engineer, hardware engineer, software engineer, civil engineer, electrical engineer)
failure point	The part of a system that, if it fails, will cause the entire system to stop working.
flight path	The path that an aircraft or device takes when it flies.
force	A push or a pull that changes the motion of an object or causes it to change shape.

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gravity	The force that pulls objects towards each other. (Ex: Earth pulls objects towards its center of mass)
helium	A gas that is less dense (lighter) than other gases in our atmosphere.
lift	The force that directly opposes the weight of a flying device and holds it in the air. Lift is a mechanical aerodynamic force produced by the motion of the airplane through the air.
negative buoyancy	When the gravitational pull on an object or device is greater than the buoyant force, which means that the object is being pulled and is moving downwards.
neutral buoyancy	When the gravitational pull on an object or device is equal to the buoyant force, which means that the object is moving neither up nor down and is "hovering" in the air or water.
positive buoyancy	When the buyant force on an object or device is greater than the gravitational pull, which means that the object is being pulled and is moving upwards.
propeller	A device that spins to push against air, water or other fluids.
resistance	(air/water) Results in drag which resists motion through a fluid such as air or water.
thrust	The force which moves an aircraft through the air. Thrust is used to overcome the drag of a flying device and to overcome the weight of a rocket.
trade-off	A situation that involves losing one quality or aspect of something in return for gaining another quality or aspect. Tradeoffs can occur for many reasons, including simple physics (into a given amount of space, you can fit many small objects or fewer large objects).
weight	A measure of the force of gravity (pull) the Earth has on an object.

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B. References

Ordering lesson materials:

- 1 propeller assembly *(order kits at Delta Education, select "FOSS Middle School" and "Force and Motion, First Edition")*
    - 1 Propeller
    - 2 End-hooks
    - 1 "S1" rubber band
    - 1 4-inch piece of non-flexible "giant" drinking straw

Links to use within lesson:

- Defining Gravity: Crash Course Kids #4.1. (n.d.). Retrieved August 24, 2015. https://www.youtube.com/watch?v=ljRlB6TuMOU
- Maddy's Science Project. (n.d.). Retrieved August 24, 2015. https://youtu.be/VmRItQglao0
- "Top 10 Most Remote Places in the World - Toptenz.net." Toptenz.net. 7 Jan. 2010. Web. 9 Sept. 2015. http://www.toptenz.net/top-10-most-remote-places-on-planet-earth.php
- "Forces on an Airplane." Forces on an Airplane. NASA. Web. 25 Aug. 2015. https://www.grc.nasa.gov/www/K-12/airplane/forces.html

Buoyancy:

- "Buoyancy." (Read). CK-12, 2015. Web. 28 July 2015. https://www.ck12.org/physical-science/Buoyancy-in-Physical-Science/lesson/Buoyancy-Middle-School/?referrer=featured_content
- "Exploring Buoyancy." TheTech.org. The Tech Museum of Innovation, 2015. Web. 28 July 2015. https://www.thetech.org/sites/default/files/ExploringBuoyancy.pdf

Flight:

- "The Four Forces | How Things Fly." The Four Forces | How Things Fly. Smithsonian Institute. Web. 28 July 2015. https://howthingsfly.si.edu/forces-flight/four-forces

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C. Lesson Handouts

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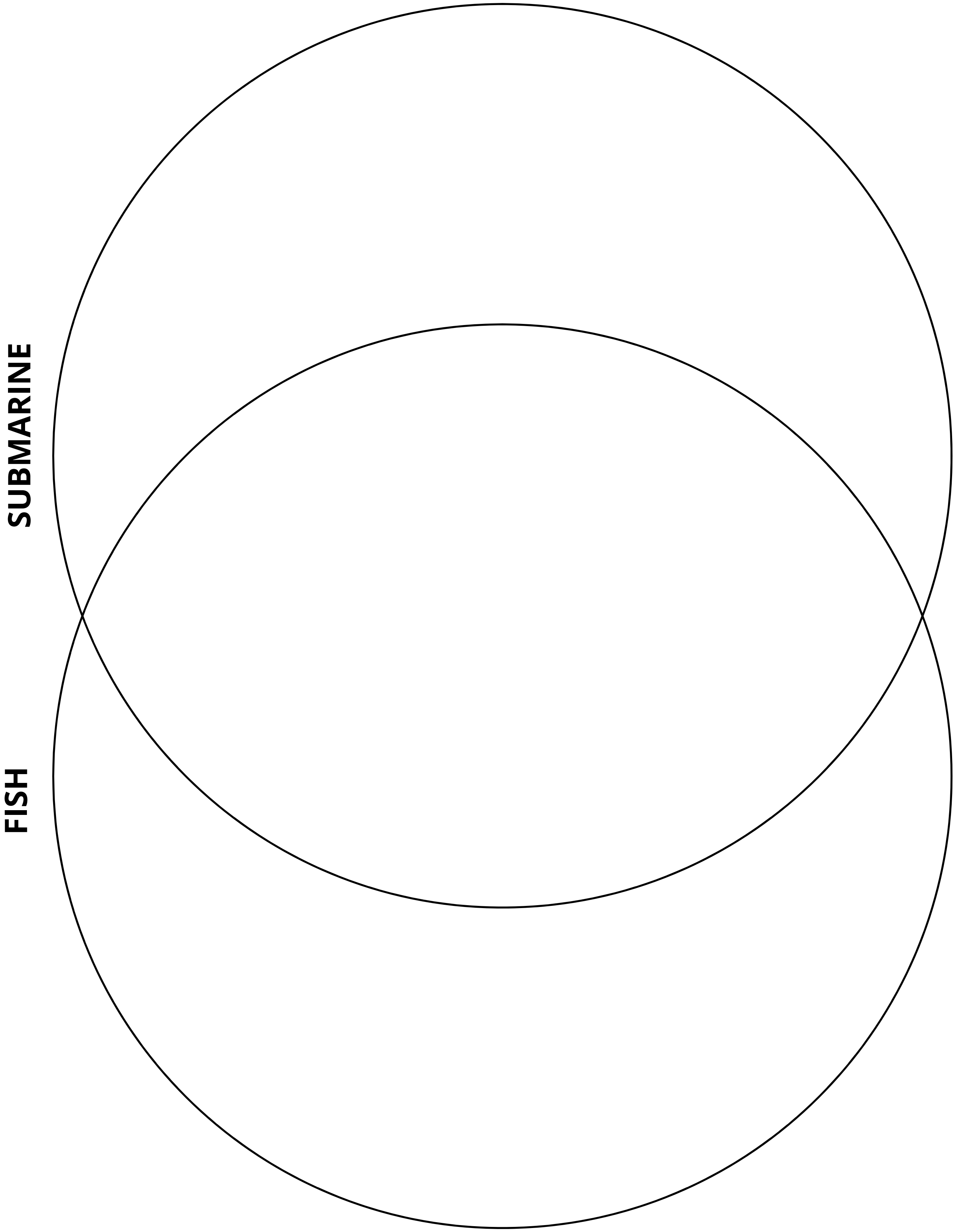
Name: ______________________________

Date: ____________ Class: ________________

Comparing Fish and Submarines



Name: ______________________

Date: __________ Class: ____________

Data Collection Tables

Part 1: Light-as-Air Design Challenge

Measured Time Aloft (between floor and 5 feet) [in seconds]

Trial #1:	**Trial # 2:**	**Trial #3:**	**Average Time:**

Part 2: Controlled Flight Design Challenge

Distance measured [to the closest foot] from launch point in required direction and short description of the flight path

Flight #1:	**Flight #2:**	**Flight #3:**	**Average Distance:**

Class Averages:

Part 1: Light as Air Design Challenge	**Part 2: Controlled Flight Design Challenge**

Name: ______________________

Date: __________ Class: ____________

Buoyancy Vocabulary (Frayer Model)

Definition:	Examples:
neutral buoyancy	
What it looks like:	What it isn't:

Definition:	Examples:
balanced forces	
What it looks like:	What it isn't:

Name: ______________________

Date: __________ Class: ____________

Definition:	Examples:
thrust	
What it looks like:	What it isn't:

Definition:	Examples:
drag	
What it looks like:	What it isn't:

Name: ____________________

Date: __________ Class: __________

Light-as-Air Design Challenge Notes

	What did you try? What are some key features of this design?	Result?	What needs to be changed?
First Attempt			
Second			
Third			
Fourth			
Fifth			
Sixth			

Name: ______________________________

Date: __________ Class: ______________

	What did you try? What are some key features of this design?	Result?	What needs to be changed?
Seventh			
Eighth			
Ninth			
Tenth			

What did you find out about gravity and other forces in this activity? (Use drawings to help explain your thinking)

Name: ______________________

Date: __________ Class: ______________

Controlled Flight Design Challenge Notes

	What did you try? What are some key features of this design?	Result?	What needs to be changed?
First Attempt			
Second			
Third			
Fourth			
Fifth			
Sixth			

Name: ___________________________________

Date: ____________ Class: _________________

	What did you try? What are some key features of this design?	Result?	What needs to be changed?
Seventh			
Eighth			
Ninth			
Tenth			

Draw a model to show how your design **used forces to achieve forward motion** or how your design was **affected by forces that prevented it from achieving forward motion**.

Name: ________________________________

Date: __________ Class: ______________

Design Challenge Reflection

Write a short reflective report to summarize your design, performance and flight path. Describe the forces acting on your aircraft and how balanced and unbalanced forces acted on your aircraft in flight. Identify the strengths and weaknesses of your design. Discuss the failure points you found, what improvements and trade-offs you made as you iterated your aircraft, and make suggestions for how to make future iterations more successful.

Name: ______________________________

Date: ___________ Class: _______________

Collaboration:
Score your own work with your team and other students throughout the design challenges. Be sure to give reasons to justify your score!

4	I was frequently and actively engaged in sharing, listening and trying ideas from my partners.
3	I was usually engaged in sharing ideas, listening to, and trying ideas from my partners.
2	I was sometimes listening and sharing, and tried to use some ideas from my partners or I took over and did most of the work which didn't allow others to participate.
1	I worked mostly by myself, did not listen or share or use ideas from my partners
My reasoning for giving myself this score:	

Engineering and Design Reflection

How well do you think your designs and engineering met the challenge? Circle the score you think your design earned in each category.

	4	**3**	**2**	**1**
Neutral Buoyancy	Float between floor and 5 feet >30 seconds	Float between floor and 5 feet 15 to 30 seconds.	Float between floor and 5 feet 5 to 15 seconds.	Floated less than 5 seconds.
Flight	Craft flew >8' in desired direction.	Flew 5' to 8' in desired direction	Flew 2' to 5' in desired direction.	Flew less than 2' in desired direction.
Payload	Payload is well controlled and arrives intact.	Loses payload on landing.	Loses payload in flight.	Unable to attach or lift a payload.

Name: ______________________

Date: ________ Class: ____________

Final Challenge Rubric

	4	3	2	1
Design	Can clearly articulate their design and the process of iterations leading to the final design.	Able to adequately articulate several features of their design, and some of the iterations leading to the final design.	Able to briefly describe a few of their design features and/or a few iterations leading to the final design.	Unable to articulate specific design features or describe any iterations leading to the final design.
Forces	Student is able to clearly articulate how both balanced and unbalanced forces affect the motion of their craft.	Student is able to articulate many aspects of how both balanced and unbalanced forces affect the motion of their craft.	Student can articulate a few aspects of the balanced and unbalanced forces affect the motion of their craft.	Student is unable to articulate how balanced or unbalanced forces affect the motion of their craft.
Gravity	Students can describe in detail how gravity pulls the craft toward the Earth.	Students can describe in general how gravity acts on their craft.	Students can only describe in very basic terms how gravity works.	Students do not describe how gravity affects the craft.
Collaboration	Student was frequently and actively engaged in sharing, listening and trying ideas from partners	Student was usually engaged in sharing ideas, listening to, and trying ideas from partners	Student was sometimes listening and sharing, and tried to use some ideas from my partners or student took over and did most of the work which didn't allow others to participate	Student worked mostly by themselves, did not listen or share or use ideas from partners