MIDDLE SCHOOL

STEM PROJECT

SCIENCE 3D

SEA TURTLE 360

In this packet, sample student answers are provided in red and notes to teachers are in blue.

In this **STEM Project**, students will explore the concept of density in both life science and as a characteristic of matter. They will gain insights into buoyant force and use this understanding to develop their own designs for scientific tags worn by sea turtles. They will also learn about trade-offs in engineering in the process.

DENSITY

Density is an important concept in science and engineering. There is more than one way to use the idea of density. When dealing with organisms, density can be the number of individuals in a particular area. For example, Dr. Beth calculated the number of turtles per square kilometer in her study areas.

The mathematical formula is:

$$p = \frac{n}{A}$$

where p = density, n = the number of individuals, and A = the area measured.

Density is also a concept used to describe matter. Density is a physical property of matter that is a measure of the mass per unit volume. Other physical properties can include melting or boiling point, odor, color, texture, and how well it conducts heat and electricity. In the sea turtle study, the density of the 360-degree camera and the density of the foam tail were very different. And, the differences were important for getting the camera to float to the surface once it fell off the turtle.

The mathematical formula is:

$$p = \frac{m}{V}$$

where p = density, m = the mass of the object, and V = the volume of the object.

ACTIVITY I: WORKING WITH DENSITIES

Let's start by calculating some densities.

1. Fill out Tables 1 and 2 to determine the densities. Include the units in your answer.

Table 1. Counts of turtles on transects

Location	Number of turtles	Area surveyed (km^2)	Density of turtles
A	10	0.5 km^2	20 turtles/km^2
B	100	10 km^2	10 turtles/km^2
C	17	1 km^2	17 turtles/km^2
D	36	6 km^2	6 turtles/km^2
E	24	2 km^2	12 turtles/km^2

Table 2. Mass of water at different temperatures

Object	Mass (g)	Volume (cm^3)	Density of water
Ice (solid)	91.5g	100 cm^3	0.915 g/cm^3
Freshwater at 4°C	100g	100 cm^3	1.00 g/cm^3
Freshwater at 20°C	99.8	100 cm^3	0.998 g/cm^3
Freshwater at 40°C	99.2	100 cm^3	0.992 g/cm^3
Saltwater at surface	126.0	100 cm^3	1.26 g/cm^3
Water vapor (gas)	<0.1	100 cm^3	<0.001 g/cm^3

2. Look at the data in Table 2. **Describe** the pattern in density of freshwater as temperature changes.

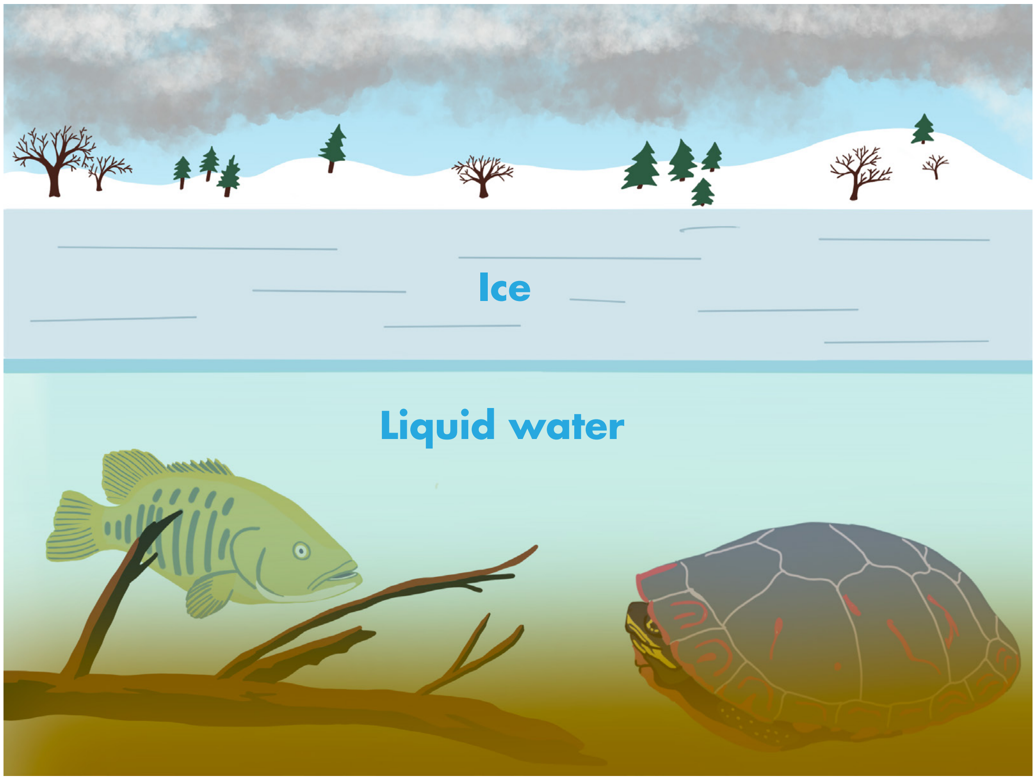
The density of liquid water increases as temperature decreases.

3. Look at the data in Table 2. **Describe** the pattern in density of water as it changes state from solid to liquid to gas.

The density of water is very low when it is a gas. The density of liquid water is greater than that of water vapor. The density of ice, a solid, is less than that of water.

Misconception Alert: Be sure to discuss with students that for most matter, solids have higher density than liquids. Water is special because of the way the molecules of water form a crystal lattice structure when ice forms. Questions below explore why it is beneficial to organisms that ice is less dense than liquid water.

Objects that have a lower density than liquid water will float. Objects that are denser than water will sink.



Pond turtles that live in areas where it freezes in winter can hibernate. They dig into the mud in the bottom of the pond. They can hold their breath all winter and get some oxygen from the water around them.

4. Most solids have higher density than the liquid form of the same matter. However, that is not the case for water! Look at the diagram above. **Describe** why you think it is beneficial for turtles and fish that ice has a lower density than water. **Predict** what would happen to the water in the pond and to the turtles if ice was denser than water. Note: Consider having a class discussion to answer this question. Extend the conversation by asking about different steps. For example, ask whether or not the ice will float or sink and why.

It is good for turtles that ice is less dense than water, because ice floats. That means there is water at the bottom of the pond where they can live through the winter. If ice was denser than water, it would sink. Then, the pond would freeze from the bottom up and there would be no place for fish or turtles to hibernate. They would die.

5. Look at the data in Table 1. **Describe** why an object with a density of 1.1 g/cm³ will float in saltwater but sink in freshwater.

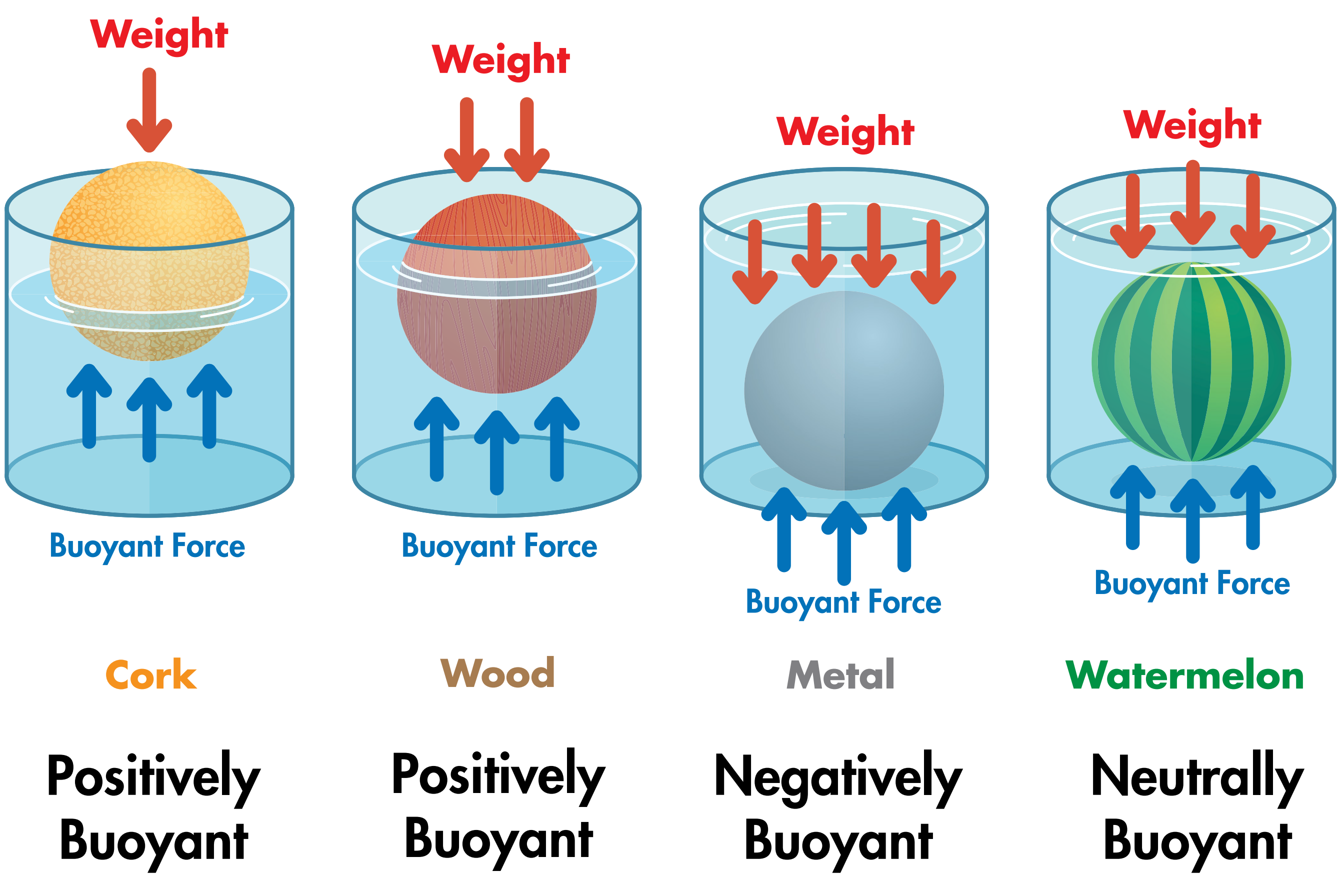
The object will float in saltwater, because it has a density that is less than saltwater. It will sink in freshwater because its density is greater than freshwater.

Extend the Lesson: Tell students that the density of canola oil is 0.915 g/cm³. Ask them to predict whether oil will float on water or sink. You can have students do the experiment for themselves by pouring water and oil into a container. This is a way to bridge to standards related to solutions and mixtures.

ACTIVITY 2: TO FLOAT OR NOT TO FLOAT

When engineers are designing systems to measure the oceans or ride along on animals, making sure that they have the right buoyancy is critical. Buoyancy is the ability to float in a liquid.

Objects may fit into one of three basic categories of buoyancy. A **neutrally buoyant** object neither floats nor sinks. An object that is **positively buoyant** floats. It can even lift another object. A **negatively buoyant** object sinks.



Fill in the statements below with the words *the same*, *a higher*, *a lower*, *increases*, or *decreases*.

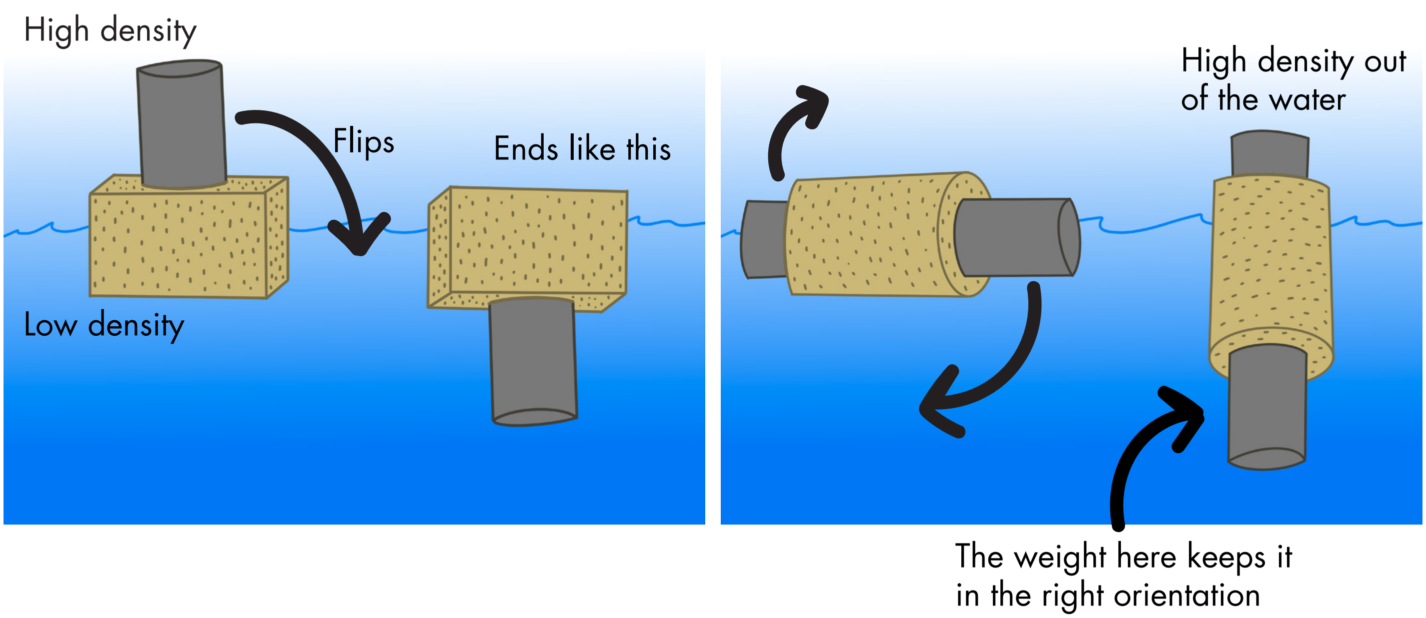
1. The buoyancy of an object ____increases____ as its density decreases.
2. A negatively buoyant object has ____a higher____ density than the liquid it is in.
3. A neutrally buoyant object has ____the same____ density as the liquid it is in.
4. A positively buoyant object has ____a lower____ density than the liquid it is in.

ACTIVITY 3: DESIGNING A CAMERA AND FLOATATION SYSTEM

Designing a camera system that records video, collects data about the environment, and releases from the sea turtle when it is supposed to is only part of engineering a solution. For use on a sea turtle, the instrument has to satisfy a few other important criteria. There are also several constraints that have to be kept in mind. Let's work on a design!

One important consideration is the stability of the system. Objects rotate in the water so that the heaviest parts of the object face down. That means the instrument the turtle wears has to be balanced properly when it releases from the turtle. Here is how it works:

HOW DO YOU GET AN OBJECT TO FLOAT PROPERLY? REDISTRIBUTE THE WEIGHT!



Other considerations include the distribution of foams, which help the system float, and weights which can counterbalance the foam or change the way the instrument floats.

1. Think about designing a camera system for a sea turtle. You will need to add foam to the camera to make it float because cameras are a lot denser than water. You will also need to add a tracking device to find the camera when it releases from the turtle. **Complete** the table below. First, read the criteria or constraint. Second, read the details about that criteria and constraint. Then, **fill in** the final column with some ideas on how you might address that criteria or constraint. One row is filled in for you as an example. These notes may help you later!

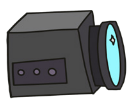
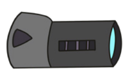
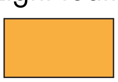
The first part of this exercise is more about coming up with multiple ideas and less about identifying correct answers. You might read this table with a group or the whole class and collectively brainstorm ideas.

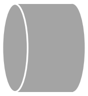
Table 3. Criteria and constraints

#	Criteria or Constraint	Details	How to address?
1	The camera must be neutrally buoyant when it is on the turtle.	If the camera is negatively buoyant, it will sink to the bottom when it falls off. If the camera is positively buoyant, the turtle will have to work too hard to stay underwater while it is wearing it.	Add flotation or weight to make the system neutrally buoyant.
2	The instrument needs to be positively buoyant when it releases from the turtle.	If the system doesn't float to the surface when it comes off the turtle, the team will never find it.	Add weights that release when the camera falls off. The weights need to match the amount of buoyant force of the flotation.
3	The radio antenna for tracking must be above the water when the system floats.	If the instrument floats but the antenna is underwater, there will be no tracking signal. Without the signal the team will never find the instrument	Distribute the foam and weights correctly.
4	The camera system needs to be as small and streamlined as possible.	If the system is too big or not streamlined, it will be too difficult for the turtle to swim.	Make the system the right size and shape.
5	The foam used to float the camera can't crush at the depths the turtles dives.	Foams that are used as flotation have small bubbles of air in them, but these bubbles can be crushed by the weight of water. Foams that crush at more shallow depths have more buoyancy (they can lift more weight for a particular volume of foam) than foams that crush at deeper depths.	Use the right foam.

Table 4 shows the buoyant force of each component that you will use in the activity on the following pages. Positive numbers mean the object will float. Negative numbers mean the object will sink. If you add all the buoyant forces of an object, it will float if the sum is positive, sink if the sum is negative, and be neutrally buoyant if the sum is 0.

Table 4. Potential components for building a turtle camera

Description	Shape	Buoyant Force (+ = floats; – = sinks)	Notes and Specifications
Camera with sensors: Three different types of camera systems can be mounted on sea turtles.			
Regular Camera 1		–40	Gets 20 hours of video; regular frame; will work only on large turtles in Abaco
Regular Camera 2		–10	Gets 4 hours of video; regular frame; will work on all sizes of turtles in Abaco
360 Degree VR Camera		–20	Gets 40 min of video; 360-degree VR footage; will work on medium and large turtles
Flotation: Calculate the amount of foam you will need. You can shape it however you want.			
Light foam 	Sculpt to the shape you want; each block is 5 cm × 5 cm × 5 cm	+5 per block	Crushing depth where buoyancy is lost: 20 m
Medium foam 	Sculpt to the shape you want; each block is 5 cm × 5 cm × 5 cm	+4 per block	Crushing depth where buoyancy is lost: 100 m
Heavy foam 	Sculpt to the shape you want; each block is 5 cm × 5 cm × 5 cm	+2 per block	Crushing depth where buoyancy is lost: 3,000 m

Transmitter with antenna for tracking		–1	Must be used to track package down; must be out of water when package releases from turtle.
Weights: They can be set to drop off when camera releases or to remain attached to balance the package when it pops off.			
Small		–1	Weights dissolve in seawater but last for days, so they maintain their weight during the camera deployment.
Large		–3	

1. **Design** a camera to deploy on small green turtles that dive to at least 15 meters deep. **Choose** which camera you need to use to fit the criteria.

   The camera I choose is Regular 2.

2. **Describe** why you chose this camera.

   It is the only camera that is small enough for small turtles.

3. **Complete** Table 5 below to select the flotation and weights that you will need to build the complete instrument package. Remember, it needs to be *neutrally buoyant* while it is on the turtle **and** *positively buoyant* when it falls off the turtle. Fill in what type of flotation and weights you will use in the Number/Type column.

   Make sure students remember that the package needs to be neutrally buoyant on the turtle, meaning the sum of the buoyancies must equal 0. Have them think about what the buoyancy needs to be when the package releases, so it floats to the surface with the antenna out of the water.

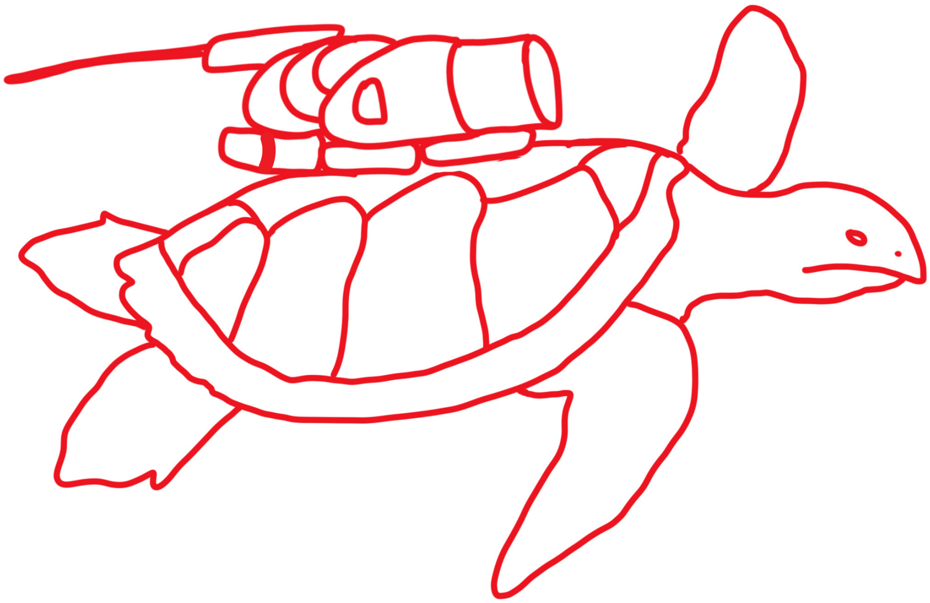
Table 5. Camera buoyancy calculations for turtles that dive to 15 meters

	Type/Number	Buoyancy per Item	Total Buoyancy
Camera	2	–10	–10
Flotation	Light/3	5	15
Transmitter with antenna	1	–1	–1
Droppable weights	Small/4	–1	–4
Total (while attached)	________	________	0
Total (after release)	________	________	4

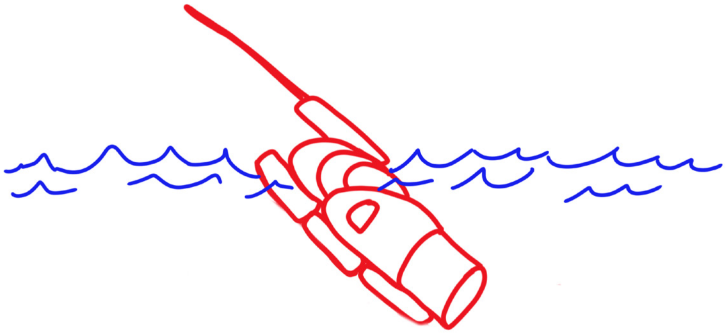
4. **Draw** your camera design attached to the turtle below. **Write** notes that show the ways your design addresses the criteria and constrains listed in Table 3 and the functions of the different components.

I added 3 light foam pieces near the antenna to help that part stay near the surface.

I added 4 small weights near camera bottom to keep it neutrally buoyant on the turtle's back.



5. **Draw** your camera design floating at the surface. Use notes to show why it floats in the orientation you drew.



The foam pieces near the antenna keep it at the surface but still allow the device to float.

The weights are towards the bottom under the water surface.

6. **Describe** how you would test your design.

A sample answer includes: floating the camera in saltwater or in water where it is going to be deployed.

7. Design a camera for deploying on large green turtles that dive 50 meters deep. In your design, be sure to address the criteria and constraints mentioned in the Table 5. Hint: size doesn't matter here. You can be creative!

The camera I choose is Camera 3 (answers will vary)

8. **Describe** why you chose this camera.

Accept reasonable answers. Students may say a small camera because it will minimize the impact on the turtle. They may choose the large camera because it will record more video. They may choose the 360-degree camera to get video from all angles!

9. **Complete** the table to select the flotation and weights that you will need to build the complete instrument package. Remember, it needs to be *neutrally buoyant* while it is on the turtle **and** *positively buoyant* when it falls off the turtle. Be sure to fill in what type of flotation and weights you will use in the Number/Type column.

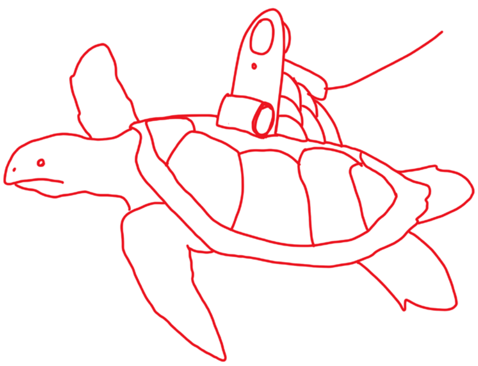
Make sure students remember that the package needs to be neutrally buoyant on the turtle, meaning the sum of the buoyancies must equal 0. Have them think about what the buoyancy needs to be when the package releases, so it floats to the surface with the antenna out of the water.

Table 6. Camera buoyancy calculations for turtles that dive to 50 meters

	Type/Number	Buoyancy per Item	Total Buoyancy
Camera	3	–20	–20
Flotation	Medium/6	4	24
Transmitter with antenna	1	–1	–1
Droppable weights	Large/1	-3	–3
Total (while attached)	______________	______________	0
Total (after release)	______________	______________	3

10. **Draw** your camera design attached to the turtle below. **Write** notes that show the ways your design addresses the criteria and constrains listed in Table 3 and the functions of the different components.

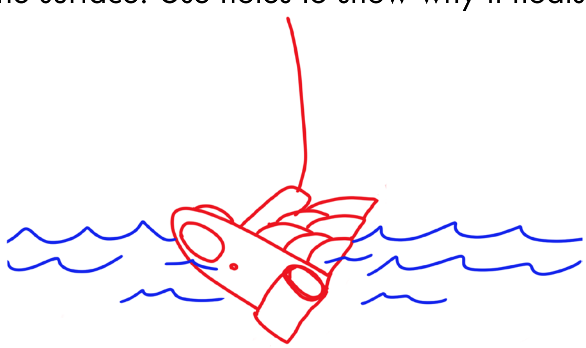
Different camera choices are acceptable. Make sure they get the foam and design correct for each camera.



I chose the 360-degree camera. I chose 1 large weight to keep it neutrally buoyant while on the turtle and attached 6 medium floats near the antenna to make sure that floats when detached.

11. **Draw** your camera design floating at the surface. Use notes to show why it floats in the orientation you drew.

The antenna is attached near the floats so that part stays above the water surface for collection. The weight is attached near the bottom of the camera to keep only that part underwater.



Extend the Lesson 1: Have students repeat the exercise for a leatherback turtle that dives 800 meters deep and is much bigger than a green turtle. You could also give students/groups different scenarios (or make different assumptions about camera capabilities) and have them present their designs to the class.

Extend the Lesson 2: Have students present their designs. Have other students critique the designs and then have students who chose the same camera types work together to optimize the design as a group. Alternatively, have individual students optimize their designs after getting feedback.

Extend the Lesson 3: Have students think about and discuss the importance of density in their everyday lives.

Extend the Lesson 4: Give students physical materials with different buoyancies to build packages that float in different orientations. Have them recreate a "camera with an antenna."