SCIENCE 3D

SHARK WORLD

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 different types of energy and apply it to how sharks, scientists, and technology are used to study shark energy consumption. Then, they will use data on power consumption to propose camera tag designs and programs to turn sensors on and off to optimize sampling with shark cameras.

ENERGY AND MOTION IN STUDYING SHARKS

Energy is the ability to cause changes in matter or do work. Energy comes in many forms and is critical to blacktip sharks when they migrate. It is also critical for the scientists studying them. Let's investigate! Step 1: Energy Review!

ACTIVITY I: TYPES OF ENERGY

Energy is the ability to do work. There are two major kinds of energy: kinetic energy and potential energy. Kinetic energy is the energy of an object in motion. Potential energy is the energy stored within an object because of its position (like a rollercoaster at the very top of a hill) or its condition (like the chemical bonds in a molecule). Some objects may have both potential and kinetic energy. A flying squirrel that has jumped out of a tree and is gliding has kinetic energy from its motion and potential energy from its height above the ground.

For each of the types of energy below, use online resources or books to define it and decide whether it represents kinetic or potential energy.

1. Chemical energy – Energy stored in chemical bonds; potential

2. Electrical energy – Energy carried in moving electrons; kinetic

3. Electromagnetic energy - The energy in electromagnetic waves (like light); kinetic

4. Elastic energy – Energy stored in an object when its shape is changed; potential

5. Gravitational energy – Energy based on the position of an object and gravity acting on it; potential

6. Mechanical energy – The sum of the kinetic and potential energy in an object; potential and kinetic

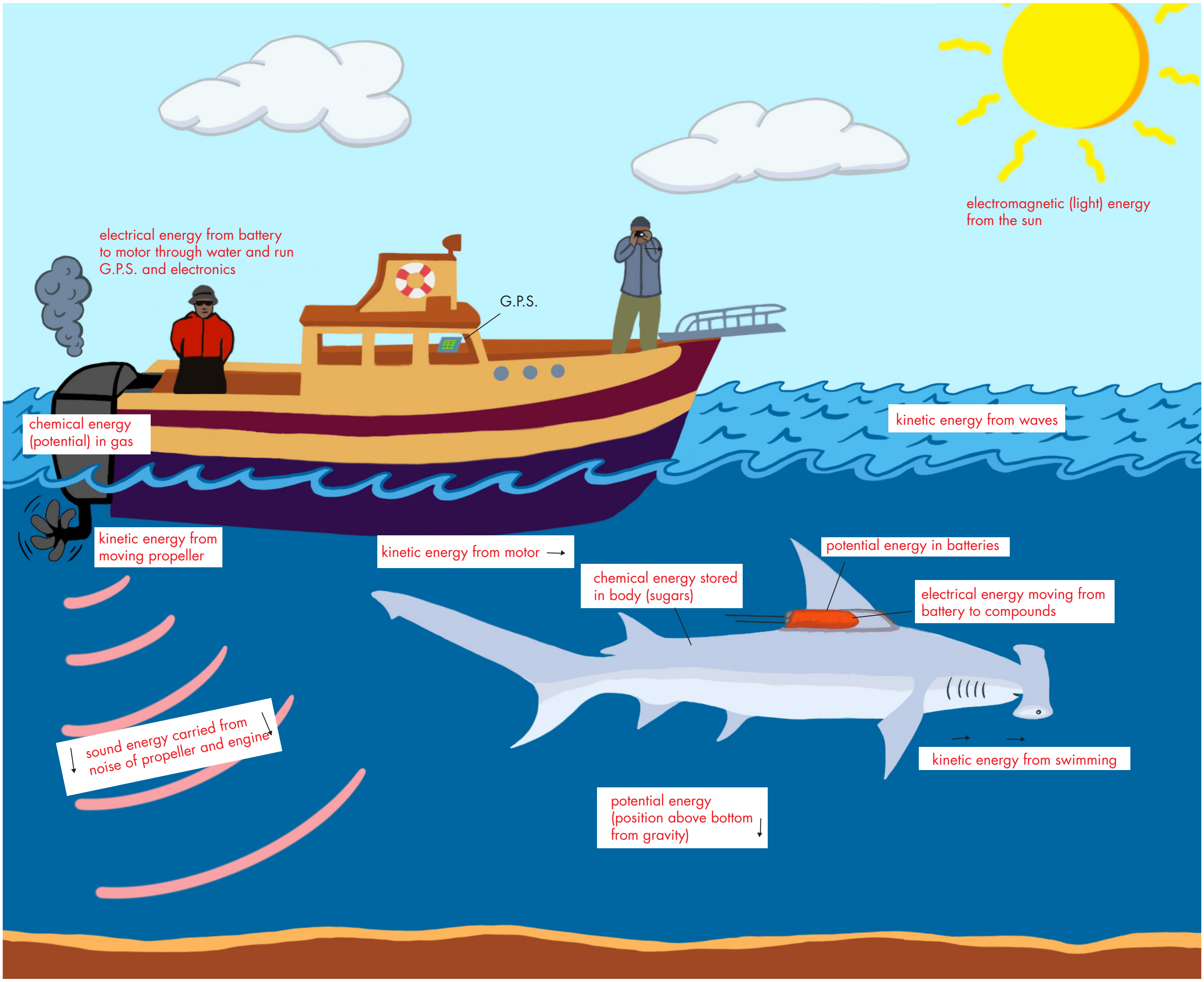
7. Nuclear energy – Energy in the nucleus of an atom; potential

8. Sound energy – Energy created by vibration of particles; kinetic

9. Thermal energy – Energy of particles in an object; kinetic

ACTIVITY 2: ENERGY AND THE GREAT SHARK MIGRATION

1. Make a poster or illustration that shows the different aspects of the study of blacktip and hammerhead sharks. Show the sharks, the research team, and the research tools. Include labels that describe the different types of energy and how they are used by the animals and researchers. Include at least two types of energy that are important for each shark and the research team!



ACTIVITY 3: ENERGY AND SHARK-CAM

There are many challenges gathering data from the back of an animal. The weight, or drag, needs to be minimized to ensure the animal is not affected by the tag. The amount of data needs to be as large as possible. And, running the sensors and onboard computer takes energy. That means, the bigger the battery the more data that can be collected. But, too big of a battery means the tag is too big or heavy for the animal. So, scientists and engineers must make sure that the energy use is as efficient as possible and that sensors are only running when they are needed.

To be able to effectively program the cameras, it is important to know how much energy a battery holds. This is measured in watt hours. You also need to know how much power each part of a system uses. Watts is a measure of power. It tells how much energy is used per unit of time. A device that uses 2 watts would use 4-watt hours of energy if left on for two hours. If left on for 8 hours, it would use 16-watt hours of energy.

Extend the Lesson: Have students create a graph of how many watt hours a device that uses 3 watts would use after 1, 3, 6, and 10 hours of use.

Table 1 provides information on how much power different components of the shark-cam need. These measurements represent how many watts each component uses every hour it is turned on. Table 2 provides information on how much total energy is available in the battery of four different shark-cams. Since bigger batteries make the tag bigger, the minimum size of the shark that can be tagged is included in the table. Use these tables to answer the questions on the next page.

Table 1. Energy draw of different components of the Shark-cam

Component	Function	Can turn on and off during deployment?	Power (Watts)
Computer	Processes data	No	0.5 W
Accelerometer	Records swimming behavior (speed, direction, acceleration, roll, etc.)	Yes	0.2 W
Time-depth-recorder	Records time and depth of tag every second	Yes	0.1 W
Hydrophone	Records sound	Yes	0.1 W
Camera	Records video	Yes	1W

Table 2. Energy stored in different sizes of Shark-cams batteries and the size of sharks that can safely wear them

Shark-cam battery size	Length of smallest shark able to carry the tag	Total battery power (Watt hours)
Small	100 cm	5.4 W • h
Medium	150 cm	18 W • h
Large	200 cm	40 W • h
Extra Large	300 cm	75.6 W • h

1. The team is planning to catch blacktip sharks that range in size from 140-180 cm in length. They are planning to study hammerhead sharks that are a threat to blacktips. Only hammerhead sharks larger than 300 cm can catch blacktip sharks. If the team can only take four cameras with them, what sizes and how many of each size should they take? Explain your choices.

   Accept well-reasoned answers. In general, there should not be a large camera included in the answer because animals between 200-300 cm are not being targeted. Some students might say they want a smaller camera for the hammerheads, but they must have a good reason. Instead, students should say they will take an extra-large for hammerheads because of the large battery and greater data collection ability. They should also select at least one small (for sharks between 140-150 cm) and one medium camera (for the blacktips between 151-180 cm) to get more data than they could from a small camera.

2. You need to determine how to get the maximum amount of data from a medium camera about to be deployed on a blacktip shark. You want to know how deep and fast they swim and collect the longest possible video. You are not concerned about hearing what is happening underwater.

   A. **Complete** Table 3.

Table 3. Hourly power draw for your camera deployment on a blacktip shark

Sensor	Item needed for this deployment? (yes/no)	Power (Watts)	Power used in first hour
Computer	yes	0.5 W	0.5 W • h
Accelerometer	yes	0.2 W	0.2 W • h
Time-depth recorder	yes	0.1 W	0.1 W • h
Hydrophone	no	0.1 W	0 W • h
Camera	yes	1.0 W	1.0 W • h
			Total: **1.8** W • h

Total battery power (in Watt hours) for medium camera: 18 W • h

B. How many hours can your shark-cam run with the sensors you choose to use in Table 3?

Show your work.

18 W•h / 1.8 W•h = 10 hours

C. How many fewer hours would you have been able to record if you only had a small shark-cam? Show your work.

5.4 W•h / 1.8 W•h = 3 hours for the small camera.
10 hours (medium camera) – 3 hours (small camera) = 7 hours of data lost

3. You need to determine how to optimize the amount of data you can get from an extra-large shark-cam for deployment on a large hammerhead shark. You want to have data on their swimming depth and speed. You also want to collect as much video as possible. You are not concerned about hearing what is happening underwater. There are 12 hours of daylight when video can be recorded. You are deploying the tag at the very beginning of the day.

A. Fill out Table 4 to determine how much power you will use during daylight hours.

Table 4. Total power draw from the first 12 daylight hours of deployment

Sensor	Power (Watts)	Hours used	Total power used in first 12 hours
Computer	0.5 W	12	6 W • h
Accelerometer	0.2 W	12	2.4 W • h
Time-depth recorder	0.1 W	12	1.2 W • h
Hydrophone	0.1 W	0	0 W • h
Camera	1.0 W	12	12 W • h
			Total: **21.6 W•h**

Total watt hours for extra-large camera 75.6 W • h

B. How many watt hours will you have remaining after the first 12 hours? Show your work.

75.6 W•h — 21.6 W•h = 54 W•h remaining

This answer assumes students decided to turn off the hydrophone and leave everything else on. If they made other decisions, then they could have another answer that is mathematically correct. Make sure they can support their answers.

C. Fill out Table 5 to determine how much power you will use during nighttime hours.

Table 5. Total power draw from 12 hours of deployment at night

Sensor	Power (Watts)	Hours used	Total power used in first 12 hours
Computer	0.5 W	12	6 W • h
Accelerometer	0.2 W	12	2.4 W • h
Time-depth recorder	0.1 W	12	1.2 W • h
Hydrophone	0.1 W	0	0 W • h
Camera	1.0 W	0	0 W • h
			Total: **9.6 W•h**

D. How many watt hours will be left after running the camera for 24 hours using the program you developed in Tables 4 and 5? Show your work.

75.6 W•h — 21.6 W•h = 54 W•h remaining
54 W•h — 9.6 W•h = 44 W•h This answer assumes students decided to turn off the hydrophone and leave everything else on. If they made other decisions, then they could have another answer that is mathematically correct. Make sure they can support their answers.

E. How many days (where a day is 24 hours) could you run the camera, based on the total energy in the battery? Show your work and round to the nearest 0.01 days.

9.6 W•h at night + 21.6 W•h during day = 31.2 W•hr per day

75.6 W•h in battery / 31.2 W•h per day = 2.42 days

F. How many hours could the camera record if you ran all sensors except the hydrophone continuously? Give your answer in numbers of 24-hour days. Show your work.

75.6 W•h / 1.8 W•h = 42 hours
42 hours / 24 hours per day = 1.75 days

G. Based on your calculations, argue why it is important to program the camera correctly.

Complete answers should identify that turning off the camera allowed them to collect data for more than half a day longer than if they had run the camera continuously. If they had turned the hydrophone on for the whole time, then it would have run out of battery even sooner and important behaviors or data might have been missed.

Extend the Lesson: More advanced students can make graphs of how many hours of data they can gather with different suites of sensors on and off and with different camera types to further explore tradeoffs. It is also possible to create a spreadsheet to automate the process.

4. **Compare** how scientists programming camera tags and engineers building cell phones are similar to sharks when it comes to using energy and energy efficiency.

Complete answers should include that scientists need to be efficient to gather as much data as possible (or in the case of using gas, minimize their ecological footprint). This is also driven by the need to keep tags as small as possible to not impact the animals. Engineers need to cram many different components on fairly small batteries, so they have to be efficient. For sharks, the more efficient they are with energy, the more energy they will have available for reproduction. Greater efficiency also means they would need to catch and eat less food to survive and migrate.

If students are interested in how much power their phones use, here are some estimates:

1. CPU: 500-2,000 mW
2. Display: 400 mW
3. Cell phone call: 800 mW
4. Bluetooth: 100 mW
5. Accelerometer: 20 mW
6. Gyroscope: 130 mW
7. Microphone: 100 mW
8. G.P.S.: 175 mW
9. Using the camera viewfinder: 1,000 mW
10. Recording video: up to 1,000 mW in addition to viewfinder
11. Apps: can vary greatly; check phones to see how much power their apps use

Extend the Lesson: Have students conduct a basic energy audit of their classroom or their homes. Then discuss how they could be more energy efficient or what energy tradeoffs they face in everyday life.

Some interesting articles that could be used to launch a discussion of energy efficiency in students' homes or schools include:
https://www.cnet.com/news/got-big-power-bills-blame-dumb-electronics/
https://www.cnet.com/news/the-skinny-on-gadgets-growing-energy-appetite/