Grade Level: 6-8
Time Estimate: 3-5 days

# PHYSICS OF SHARK MOVEMENT PART 1
## / INSTRUCTOR INFO

### Summary

This lesson includes vocabulary, content, examples, and activities to help students understand basic physical forces such as lift, weight, force, and drag and learn how they relate to how sharks swim. Using real data collected from the OCEARCH Global Shark Tracker™, students will be able to achieve the goals and objectives of this lesson.

Part 1. Hydrodynamic Adaptations of Sharks
Part 2. Forces
Part 3. Potential and Kinetic Energy
Part 4. Review

### Goals & Objectives

The students will:

- learn the four main forces involved in movement – lift, weight, force, and drag;
- use fundamental physics to explore the mechanics of sharks in motion;
- learn the basics of shark anatomy and how it affects locomotion;
- learn the difference between potential and kinetic energy;
- calculate both potential and kinetic energy using respective formulas.

# // STANDARDS

**This lesson aligns with the following Common Core Math Standards:**
Grade 6: NS.B.2, NS.B.3, EE.A.1, EE.A.2a-c
Grade 7: NS.A.1a, NS.A.3, EE.B.3

**This lesson aligns with the following TEKS:**
Grade 6 Science: 2A, 2B, 2E, 3A, 4A, 8A, 8B
Grade 7 Science: 2A, 2B, 2E, 3A, 4A, 7A, 7B, 7C, 12A
Grade 8 Science: 2A, 2B, 2E, 3A, 4A, 6A, 6C

IPC: 2A, 2B, 2D, 2E, 3A, 3B, 3C, 4A, 4B, 4C

Grade 6 Math: 1C, 2C, 2D, 5, 11A, 11B, 11C, 11D, 12A, 12B, 13A, 13B
Grade 7 Math: 2A, 2B, 2C, 2E, 2F, 2G, 5A, 5B, 13A-D, 14A, 14B, 15A, 15B
Grade 8 Math: 2A, 2B, 2C, 4, 5A, 5B, 14A-D, 15A, 15B, 16A, 16B

**This lesson aligns with the following Next Generation Science Standards (NGSS):**

Framework:

1. Asking questions and defining problems
2. Developing and using models
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations and designing solutions
8. Obtaining, evaluating, and communicating information

MS. Forces and Interactions – MS-PS2-2

Disciplinary Core Ideas

*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, the larger force causes a larger change in motion. (MS-PS2-2)
- All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared. (MS-PS2-2)

MS. Energy – MS-PS3-1; MS-PS3-2

Disciplinary Core Ideas

*PS3.A: Definitions of Energy*

- Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed. (MS-PS3-1)
- A system of objects may also contain stored (potential) energy, depending on their relative positions. (MS-PS3-2)

*PS3.C: Relationship Between Energy and Forces*

- When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object. (MS-PS3-2)

Crosscutting Concepts

*Scale, Proportion, and, Quantity*

- Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes. (MS-PS3-1)

## Helpful Tips

1) The content in this lesson is related to OCEARCH and the Global Shark Tracker. Spend a few minutes getting familiar with the website and the tracker if you have not done so already. The Global Shark Tracker is also available as an app for iPhone and Android.
2) This lesson plan is designed to be adaptable to suit your specific needs. Use the entire lesson plan or just parts of it. This material can be expanded to be an entire unit or condensed for just one day in the classroom.
3) Vocabulary words will be underlined as they appear in the lesson plan. A complete list of vocabulary words is included as well.
4) Answers to questions and prompts for discussions will appear in *italics*.
5) Optional activities and content (side notes) will appear in a box. Use these to enhance your lesson and adapt it to suit your needs!
6) Have questions for OCEARCH Expedition Leader, Chris Fischer? Email info@OCEARCH.org to schedule a Skype session and let your students/child talk directly to Chris and the OCEARCH crew!
7) Email all questions about this lesson to info@OCEARCH.org.

# Vocabulary

Anal Fin – A single, small fin on the underside of the shark closest to the tail. This fin helps keep the shark upright.
Buoyancy - The power of a fluid to put an upward force on a body placed in it.
Caudal Fin – Another word for the shark's tail fin. This unpaired fin beats side-to-side to move the shark forward.
Dermal Denticles – Modified scales made of dentine that cover the shark's body. Literally translates to "skin teeth".
Dorsal Fin – The large unpaired fin located on the shark's back; maintains stability during locomotion. It keeps the shark from rolling over on its side.
Drag – The force acting on an object to slow it down.
Energy – An object's capacity for doing work.
Force – Any influence, such as a push or pull, which changes the speed or direction of an object. Force is a vector quantity that has both direction and magnitude.
Gravitational Potential Energy – The amount of energy an object possesses due to its position in a gravitational field.
Gravity - The force that attracts an object towards the center of the earth.
Heterocercal – Describes a caudal fin having the upper lobe larger than the lower with the vertebral column extending into the upper lobe.
Homocercal – Describes a caudal fin having an approximately symmetrical upper lobe and lower lobe with the vertebral column ending at or near the middle of the base.
Hydrodynamic – Pertaining to forces in liquid or motions of liquid.
Hydrofoil – Any object, design, or adaptation that provides a reaction force when in motion. For example, the hammerhead shark's flattened head acts as a hydrofoil to provide lift (an upward force), keeping the shark from sinking due to gravity (a downward force).
Joule – The unit of measurement for work and energy. Equal to the work done by the force of one Newton acting through a distance of one meter.
Kinetic Energy – Energy associated with motion.
Lift – When in motion, a force generated by hydrofoils that keeps the shark from sinking in the water. Lift works opposite of gravity.
Pectoral Fin – The large fins located on either side of the shark's body. These fins provide lift and allow the shark to change direction when in motion.
Pelvic Fins – The paired set of fins on the underside of the shark; used for stabilization.
Potential Energy – An object's stored energy.
Speed – Rate of motion; how fast an object is moving.
Swim Bladder – An air filled sac that keep boney fish neutrally buoyant. Sharks do not have swim bladders.
Thrust – A force that drives an object forward in motion. A shark's caudal fin provides thrust.
Velocity – The rate of change of position along a straight line with respect to time. Not only refers to the speed of an object, but the direction of motion as well.
Weight – The force on an object due to gravity.
Work – The energy used when a force is applied.

**Grade Level: 6-8**
**Time Estimate: 5-15 mins**

# PHYSICS OF SHARK MOVEMENT PART 1 / PRE-LESSON ASSESSMENT

Use the following true/false and multiple choice questions as an introduction/warm-up to the lesson topics. You can do this in a verbal or written format, as a game, individually, or as a whole class! A handout is provided if you wish to hand the questions out in a quiz format.

The questions do not need to be graded. They are intended to give the students an idea of what they will be learning and to see what they already know.

1) True or False A shark swims forward using lift force and thrust force.
Answer: *True*

2) True or False The caudal fin has no significance to shark movement.
Answer: *False*

3) True or False The greater the drag force, the harder the shark has to work to swim forward.
Answer: *True*

4) Which of the following helps create lift? Circle all that apply.
a. Pressure
b. The flow of water
c. Gravity
d. Thrust
Answers: *a, b, d*

5) Shark skin is made up of modified scales that are most like:
a. Fingernails
b. Teeth
c. Hairs
d. Plates
Answer: *b*

6) Buoyancy is a form of what force?
a. Drag
b. Weight
c. Lift
d. Thrust
Answer: *c*

Name: ______________________________ Date: ________________________

# Physics of Shark Movement Part I – Forces and Energy

Select the correct answer(s) to each of the following questions.

1. True or False A shark swims forward using lift force and thrust force.

2. True or False The caudal fin has no significance to shark movement.

3. True or False The greater the drag force, the harder the shark has to work to swim forward.

4. Which of the following helps create lift? Circle all that apply.
   a. Pressure
   b. The flow of water
   c. Gravity
   d. Thrust

5. Shark skin is made up of modified scales that are most like:
   a. Fingernails
   b. Teeth
   c. Hairs
   d. Plates

6. Buoyancy is a form of what force?
   a. Drag
   b. Weight
   c. Lift
   d. Thrust

**Grade Level:** 6-8

# PHYSICS OF SHARK MOVEMENT PART 1 / LESSON PLAN

## INTRODUCTION

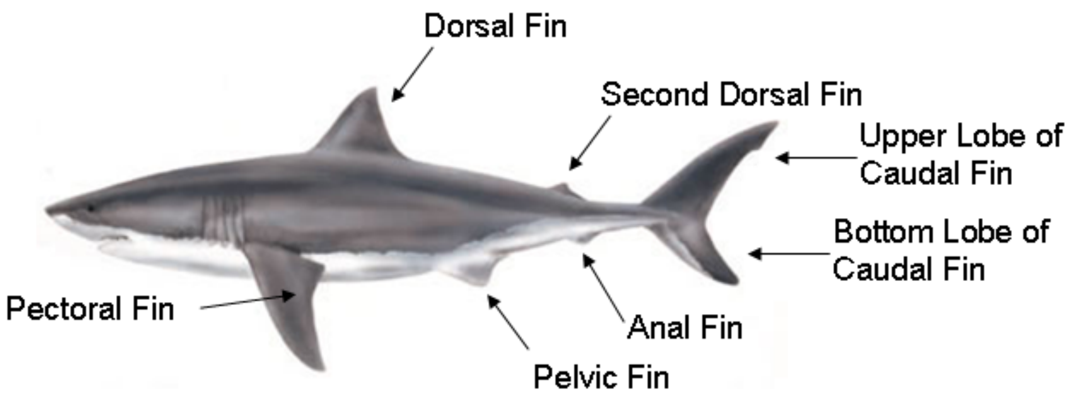
### Part 1. Hydrodynamic Adaptations of Sharks (20 – 30 minutes)

**Fins**

Great white sharks have a hydrodynamic body shape. Their torpedo shaped body reduces drag and requires a minimum amount of energy to swim. Great whites typically cruise at speeds around 2 mph (3.2 kph), but are built to quickly reach speeds of up to 30 mph (48.3 kph). So how does a great white shark swim so fast and efficiently? They have many adaptations to help them!

Just like bony fish, sharks have many fins in different shapes and sizes (Figure 1). The shape, size, and location of each fin serve different purposes in helping a shark swim. The caudal fin, another word for the shark's tail fin, beats side to side to move the shark forward though the water. Depending on where the shark lives, what it eats, how it hunts, and its body size and strength, the caudal fin is adapted to suit the shark's unique needs. Most sharks have a heterocercal caudal fin, meaning the upper lobe is significantly longer than the bottom. The great white shark is unique because it has a nearly homocercal caudal fin. The nearly symmetrical lobes allow the shark to achieve remarkable speeds for hunting, as well as the ability to cruise at slower speeds for long-distance travel while always being energy efficient.

**Figure 1. Shark Fins**




The dorsal fin and the pelvic fins are used to stabilize the shark's body as it moves (Figure 1). Without these fins, the shark would not be able to stay upright and would roll over on its side.

The second dorsal fin and the anal fin not only provide stabilization, but have a pivoting base which allows the shark to cruise more efficiently at varying speeds.

**Conservation Message and Activity**

The Issue: Every year, approximately 100 million sharks are killed for their fins in a practice called shark finning. Shark finning takes place at sea where any shark, regardless of age, size, or species is captured and all of its fins are removed. The fins are collected as an ingredient in shark fin soup, an expensive (around 100 US dollars per bowl) delicacy in many Asian cultures. Because shark meat has little value, up to 95% of the shark is wasted when the shark (often still alive) is tossed back into the water. Without its fins, the shark no longer has the ability to swim and will either drown, bleed to death, or be eaten alive by other fish. Shark finning is not only incredibly wasteful, but unsustainable, with shark populations reduced from 70% in some species to up to 95% in other species.

As a Class: Research this issue and create a way to pass this information to the rest of your grade or your school. For example, the class can decorate a poster or bulletin board in the hallway or act out a skit for the next school assembly. Be creative but make sure the issues are known, you address why sharks are important to the future of the ocean, and what others can do to help!

### Scales

*Ask student's if they know what shark skin feels like. Is it smooth or rough?* Shark skin is actually both! If you were to feel a shark from head to tail, the shark would feel smooth. If you were to feel the opposite way, the shark would feel rough like sand paper. This is because shark skin is made up of dermal denticles which are actually modified teeth made from dentine with an enamel covering. They grow with the sharp pointed tip facing towards the tail, which is why shark skin feels so rough. This streamlined arrangement reduces friction making the shark more hydrodynamic. Dermal denticles are also tough, which provide a protective armor for the shark.

### Liver

Unlike boney fish, sharks have no swim bladder. Instead, they have an oily liver. If you've ever mixed oil with water, you know that the oil is less dense than water and floats on top of water. The oily liver of a shark provides a little buoyancy which decreases the amount of energy the shark uses to swim.

## Part 2. Forces (45 – 75 minutes)

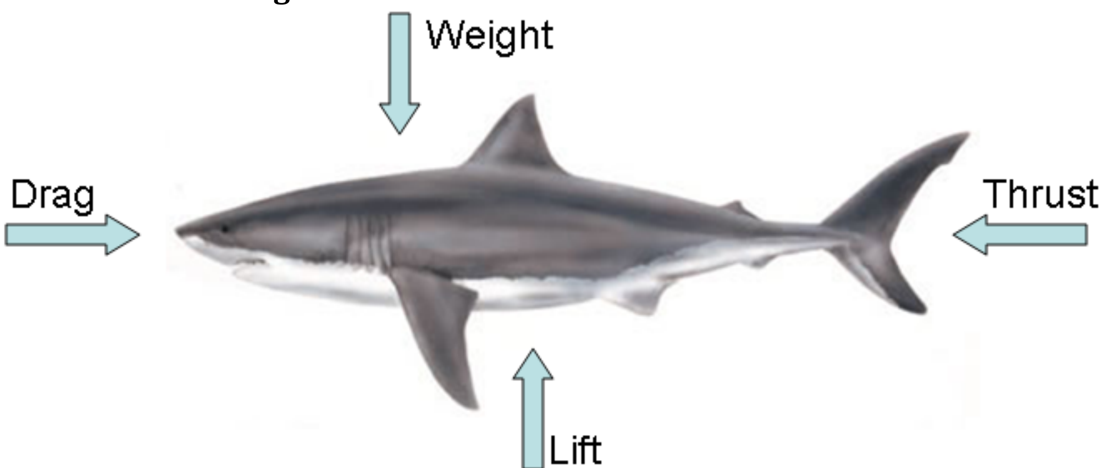
### Introduction

Understanding forces is an important part of understanding physics. A force is any influence, such as a push or pull, which causes an object to undergo a change in its state. Force is a vector quantity that has both direction and magnitude. Forces are commonly represented by diagrams in which the force is shown by an arrow, and the direction of the arrow illustrates the direction the force is acting. There are many types of forces that affect everything in the universe. Some forces we can easily observe and experience on a day to day basis, while other forces are more difficult to observe.

The four main types of forces that affect how an object moves are weight, lift, thrust, and drag. In this lesson we are going to explore these four forces and how they affect a shark in motion.

Swimming is a balance between two sets of forces: thrust and drag, and lift and weight. Referring to Figure 2, you will notice that thrust works opposite of drag while lift works opposite of weight.

**Figure 2: Forces Acting on a Shark.**




### Thrust and Drag

The great white shark's impressive speed is a result of thrust caused by the side to side movement of the shark's caudal fin. The faster the shark moves its tail, the more thrust it creates allowing the shark to swim faster. Drag reduces thrust and slows the shark down. If the drag force is greater than the thrust force, the shark will not be able to swim forward.

*Ask students what could create drag? Examples could include friction, swimming into a current, water density, waves, etc. What can human swimmers do to reduce drag? Examples could include wearing swim caps, specialized bathing suits, streamlining body position, etc.*

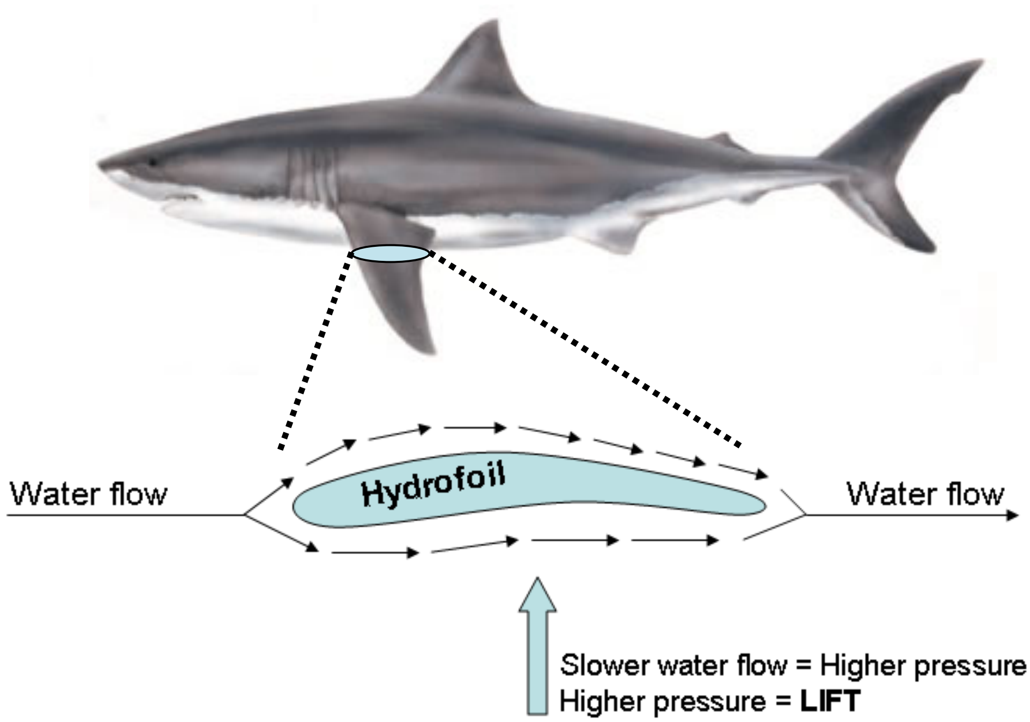
A great white shark is able to increase thrust and reduce drag with several of its adaptations. Do you remember which ones? *Caudal fin, hydrodynamic torpedo-shaped body, and dermal denticles.*

### Lift and Weight

When a shark is in motion, its pectoral fins provide lift, which keep the shark level in the water. In physics, shark fins are a hydrofoil. A hydrofoil is any object, design, or adaptation that provides a reaction force when in motion. Fins that vary in size and shape and other adaptations on sharks act as hydrofoils. For example, the hammerhead shark's flattened head acts as a hydrofoil to provide lift (an upward force), keeping the shark from sinking due to gravity (a downward force).

As a shark swims through the water, water flows above and below the fin (Figure 3). *Ask students to draw the cross section of a pectoral fin and illustrate how water would flow over the fin.* The curve on the top of the fin is longer than the curve on the bottom. This means the water flowing above the fin has to move farther than the water going below the fin. In order for the two water flows to make it to the edge of the fin at the same time, the water on top moves faster.

**Figure 3. Cross Section of Shark Pectoral Fin**

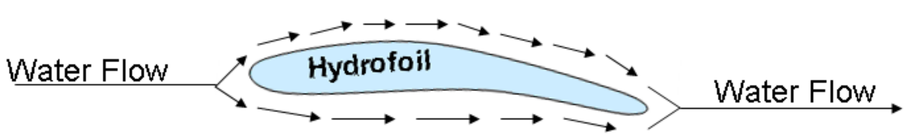



The slower water flow moving underneath the fin creates a higher pressure than the faster moving water on top of the fin. The higher pressure pushes the fin upwards to create lift. The more curved the hydrofoil is, the greater the lift (providing the degree of curve does not restrict the flow of water).

Weight is the result of gravity and causes the shark to sink. If the lift force is greater than the weight force, the shark will swim upward. If the weight force is greater than the lift force, the shark will swim downward. If the lift force and the weight force are equal, the shark will swim level.

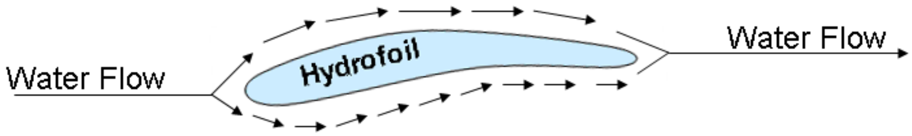
Sharks do not have as wide a range of motion in their pectoral fins as other fish do. If you observe other fish swimming, you will notice they can rotate their pectoral fins in many directions. While it may be hard to see, sharks are able to rotate their fins at slight angles. This rotation, no matter how slight, changes the path of water moving around the fins. Consider the following:

What would happen if the shark rotated its pectoral fins up?




*Water above the fin would flow faster than the water below the fin. This creates higher pressure below the fin resulting in lift. The shark will swim upwards.*

What would happen if the shark rotated its pectoral fins down?

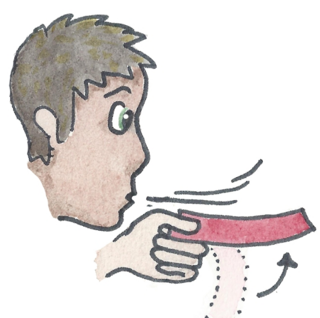



*Water below the fin would flow faster than the water above the fin. This creates higher pressure above the fin. The shark would swim downwards.*

The key thing to remember about pressure is that pressure pushes. If the pressure is higher below the fin it will push the shark up. If the pressure is higher above the fin, it will push the shark down.

**Activity. Proving Pressure (5 minutes)**

Cut a piece of letter sized paper vertically into four strips. Give each student one strip of paper. Have students hold as shown in the drawing below. Before beginning the experiment have students hypothesize what will happen when they softly blow across the top of the paper. *Will the paper move upwards, downwards, or stay still?* Now let students softly blow across the top of the paper and observe the results. What happens? *The paper moves upwards!* Blowing air across the top of the strip of paper results in faster airflow on top and higher pressure below thus causinthe paper to lift upwards. *Illustration credit: Sarah Rich-Landry's Downtown Aquarium*



Now that we understand how shark swims efficiently to conserve energy, let's learn more about energy!

## Part 3. Potential and Kinetic Energy (90 – 120 minutes)

Energy is an object's capacity for doing work. Energy occurs in many different forms, but all forms can be classified as either potential energy or kinetic energy. Potential energy is stored energy that is waiting to do work, while kinetic energy is energy in motion that is actually doing work. Any object that has motion has kinetic energy.

### Potential Energy – Gravitational Potential Energy

Gravitational potential energy is the energy an object possesses due to its position in a gravitational field, since work is required to elevate objects against Earth's gravity. It is dependent on the mass and elevation of the object, since the object has potential to fall back to Earth's surface.

If two objects with different masses are placed at the same elevation, the object that weighs more will have more gravitational potential energy. If a 1,000 lb (453.59 kg) great white shark and a 2,000 lb (907.18 kg) great white shark both leap four feet out of the water, which shark will have more gravitational potential energy at the highest point of the jump? *The 2,000 lb (907.18 kg) shark!*

If two objects with equal masses are placed at different elevations, the object at the greater elevation will have more gravitational potential energy. Consider a 300 lb (136.08 kg) sea lion laying on a rock 2 ft (0.61 m) high and another 300 lb (136.08 kg) sea lion on a rock 5 ft (1.52 m) high. Which seal lion has more gravitational potential energy? *The sea lion on the 5 ft (1.52 m) rock!*

Other examples of objects with gravitational potential energy include a ball stuck in a tree, a book sitting on a tall shelf, or a person just about to jump off a diving board.

The formula to calculate potential energy is:

$$PE = m \times g \times h$$

Where **PE** is potential energy, **m** is mass in kilograms, **g** is gravity (constant: 9.8 $m/s^2$), and **h** is height of the object in meters. The unit for energy is the joule (J).

A joule is a unit of work or energy named after physicist James Prescott Joule. If we were to keep the original units in the potential energy equation, they would look like this:

$$PE = kg \times m/s^2 \times m = kg \times m^2/s^2$$

$kg \times m^2/s^2$ is a intimidating unit to work with so scientists use the unit joule in its place.

$$1\ J = 1\ kg \times m^2/s^2$$

Example. What is the potential energy (PE) for a 300 kg sea lion sitting on a rock 2 m above the water?

Step 1. Identify the information.

Formula to calculate potential energy: $PE = m \times g \times h$

PE = unknown; what we need to solve for
$m = 300$ kg
$g = 9.8\ m/s^2$
$h = 2$ m

Step 2. Plug the known information into the formula.

PE = 300 kg × 9.8 $m/s^2$ × 2 m

Step 3. Solve the equation.

*PE = 5,880 Joules*
*The potential energy of the sea lion is 5,880 joules.*

### Potential Energy Practice Problems

1. Betsy is a 365 kg white shark that was tagged near Cape Cod, Massachusetts. During the tagging process, the hydraulic shark lift was raised 1 m out of the water. What was Betsy's potential energy while she was being tagged?
   *Set up: PE = 365 kg × 9.8 $m/s^2$ × 1 m* Answer: *3,577 J*

2. As the OCEARCH crew was packing for an expedition, someone left a 4.5 kg bag of groceries on the 1.7 m high dock. What was the potential energy of the bag of groceries?
   *Set up: PE = 4.5 kg × 9.8 $m/s^2$ × 1.7 m* Answer: *74.97 J*

3. One morning, the OCEARCH scientists were so sleepy they forgot to measure a shark's mass during the tagging process! If the hydraulic lift was raised to a height of 1 m, what would be the shark's mass in kilograms if its potential energy was 3,000 J? Round to the nearest tenth.
   *Set up: 3,000 J = kg × 9.8 $m/s^2$ × 1 m* Answer: *306.1 kg*

### Kinetic Energy

Kinetic energy is the energy of an object in motion. It is dependent on mass and acceleration. If the object has a change in velocity, it has a change in kinetic energy. The faster an object is moving, the more kinetic energy it has. Also, the more massive an object is, the more kinetic energy it creates. A small shark and a larger shark moving at the same velocity will not have the same amount of kinetic energy. Which shark has more kinetic energy? *The larger one!*

The change in an object's kinetic energy is equal to the work done by the forces acting on it. Examples of objects with kinetic energy include an airplane in flight, a rock rolling down a hill, an apple falling from a tree, or a car going down the street.

The formula to calculate kinetic energy is:

$$KE = \frac{(mv^2)}{2} \quad \text{OR} \quad KE = 1/2mv^2$$

Where **KE** is kinetic energy, **m** is mass in kilograms, and **v** is velocity (or speed) in meters per second. The unit for energy is the Joule (J).

**Example.** What is the kinetic energy of Mary Lee, a 1,571 kg great white shark cruising at a velocity of 2 m/s?

Step 1. Identify the information.

Formula to calculate kinetic energy: $KE = \frac{(mv^2)}{2}$

KE = unknown; what we need to solve for
m = 1,571 kg
v = 2 m/s

Step 2. Plug the known information into the formula.

$$KE = \frac{(1{,}571\ \text{kg} \times (2\ \text{m/s})^2)}{2}$$

Step 3. Solve the equation.

$$KE = \frac{(1{,}571\ \text{kg} \times 4\ \text{m}^2/\text{s}^2)}{2}$$ Solve the exponent then multiply the numerator.

$$KE = \frac{6{,}284\ \text{kg m}^2/\text{s}^2}{2}$$ Divide by 2.

*KE = 3,142 Joules*
*Mary Lee has 3,142 joules of kinetic energy.*

## Kinetic Energy Practice Problems

1. If 1039.6 kg white shark Genie cruises at a velocity of 1.6 m/s, what would her kinetic energy be? Round to the nearest tenth.
   *Set up:* $KE = \frac{(1{,}039.6\ kg \times (1.6\ m/s)^2)}{2}$ Answer: *831.7 J*

2. What is the mass of a shark with a kinetic energy of 900.4 J traveling at 2.1 m/s? Round to the nearest tenth.
   *Set up:* $900.4\ J = \frac{(\ kg \times (2.1\ m/s)^2)}{2}$ Answer: *408.3 kg*

3. The M\V OCEARCH has a mass of 392,811 kg. If it has a kinetic energy of 2,000,000 J, what is the ships velocity? Round to the nearest tenth.
   *Set up:* $2{,}000{,}000\ J = \underline{(392{,}811\ kg \times v^2)}$ Answer: *3.2 m/s*

## Converting Potential Energy to Kinetic Energy

A stationary object has the ability to convert its potential energy into kinetic energy as soon as it starts moving. Consider the following scenario:

A 425 kg sea lion is resting on a cliff 5 m above the water. The sea lion decides to go for a swim and jumps off the cliff into the ocean below. A hungry great white shark is swimming nearby and sees the sea lion hit the water. The 967 kg shark increases its velocity to 5 m/s in order to catch the sea lion. (a)What is the sea lion's potential energy? (b)What is the velocity of the sea lion just before it hits the water? (c)What is the kinetic energy of the shark after it increases velocity to catch the sea lion?

a.) What is the sea lion's potential energy?

Step 1. Identify the information.

Formula to calculate potential energy: PE = mgh

PE = unknown; what we need to solve for
m = 425 kg
g = 9.8 $m/s^2$
h = 5 m

Step 2. Plug the known information into the formula.

PE = 425 kg × 9.8 $m/s^2$ × 5 m

Step 3. Solve the equation.
*PE = 20,825 J*
*The sea lion has 20,825 joules of potential energy.*

b.) What is the velocity of the sea lion just before it hits the water?

Step 1. Identify the information.

In our scenario, the sea lion's potential energy is being converted to kinetic energy so we will use the following formula:

PE = KE OR $PE = \frac{(mv^2)}{2}$

PE = 20,825 J
m = 425 kg
v = unknown; what we need to solve for

Step 2. Plug the known information into the formula.

$$20{,}825 \text{ J} = \frac{(425 \text{ kg} \times v^2)}{2}$$

Step 3. Solve the equation.

$$20{,}825 \text{ J} = \frac{(425 \text{ kg} \times v^2)}{2}$$ Multiply both sides by 2.

$41{,}650 \text{ J} = 425 \text{ kg} \times v^2$ Divide both sides by 425.

$98 = v^2$ Take the square root of both sides.

*9.9 m/s = v* *The sea lion was moving at a velocity of 9.9 m/s before it hit the water.*

c.) What is the kinetic energy of the shark after it increases velocity to catch the sea lion?

Step 1. Identify the information.

KE = unknown; what we are solving for
m = 967 kg
v = 5 m/s

Step 2. Plug the known information into the formula.

$$KE = \frac{(967 \text{ kg} \times (5 \text{ m/s})^2)}{2}$$

Step 3. Solve the equation.

$$KE = \frac{(967 \text{ kg} \times 25 \text{ m}^2/\text{s}^2)}{2}$$ Solve the exponent then multiply the numerator.

$$KE = \frac{24{,}175 \text{ kg m}^2/\text{s}^2}{2}$$ Divide by 2.

*KE = 12,087.5 joules*
*The shark had 12,087.5 joules of energy.*

## Energy Conversion Practice Problems

A 71 kg man is standing on a ship 3 m above the water. The man decides to go for a swim and jumps off the boat into the ocean. A great white shark is swimming nearby and is startled when the man hits the water. The 994 kg shark swims away at a velocity of 4.5 m/s.

1. What is the man's potential energy when he is standing on the boat?
   *Set up:* $PE = 71 \text{ kg} \times 9.8 \text{ m/s}^2 \times 3 \text{ m}$ Answer: *2,087.4 J*

2. What is the velocity of man just before he hits the water? Round your answer to the nearest tenth.

*Set up:* $2{,}087.4\ J = \frac{(71\ kg \times v^2)}{2}$ Answer: *7.7 m/s*

3. What is the kinetic energy of the shark when it is swimming away? Round your answer to the nearest tenth.

*Set up:* $KE = \frac{(994\ kg \times (4.5\ m/s)^2)}{2}$ Answer: *10,064.3 J*

## Part 4. Review (15 – 20 minutes)

The students should now understand the four main forces involved in shark movement and how to apply them to everyday life. They should know how to draw a diagram showing water flow over a hydrofoil and how to create a diagram showing acting forces. Students should also understand when an object has potential and kinetic energy as well as how to calculate both.

Students should be able to answer and discuss the following:

1. What does lift do and why is it important in shark movement?
2. What is thrust and why is it necessary?
3. What are some examples of drag and how can the shark overcome it?
4. What happens to the shark if weight is the greatest acting force?
5. What does pressure do and how does it affect the shark?
6. Compare and contrast potential and kinetic energy.
7. When does an object convert its potential energy into kinetic?

Show class Figure 1.
What force(s) do the following shark adaptations affect?

1. Pectoral fin? *Lift*
2. Anal fin? *Drag*
3. Second dorsal fin? *Drag*
4. Caudal fin? *Thrust and Lift*
5. Oily liver? *Lift*
6. Dermal denticles? *Drag*

Show class Figure 2.
What should the shark do if:

1. Weight is greater than lift and thrust is greater than drag? *Swim down.*
2. Lift is greater than weight and thrust is greater than drag? *Swim up.*
3. The drag force is very high? *The shark will have to do more work to swim forward.*

Students should be able to recognize the following formulas and understand when to use them:

1. Potential Energy: $PE = mgh$
2. Kinetic Energy: $KE = \frac{(mv^2)}{2}$

Physics of Shark Movement Part I – Forces and Energy

# ACTIVITY 1. Forces and Movement

(30 – 45 minutes or take home assignment)

## Introduction

Students will use what they learned about weight, lift, drag, and thrust to compare shark movement with two similar scenarios. The students will then represent their findings in written format and as diagrams. This activity can be done individually or as a group. A worksheet is included on the following page if you wish to pass out to your students. A rubric is provided under Grading Suggestions if you want to grade this activity.

## Materials

- Computer with internet access
- Lined paper for writing
- Unlined paper for diagrams

## Instructions

Now that you have an understanding of how forces work together to create movement, consider the following scenarios:

- A human swimming laps in a pool
- An airplane flying at 36,000 feet (10,972.8 m)

Research each of these scenarios. Write out an explanation on how each scenario compares to how a shark swims. Your explanation should include how lift and thrust is created, and what causes weight and drag. Include diagrams showing water flow/airflow, and a diagram for each scenario showing the forces acting upon the moving object.

# Activity 1. Forces and Movement

Name: ______________________________

Date: ______________________________

## Instructions

Use what you have learned about weight, lift, drag and thrust to answer the following. You may have to do some research on your own.

## Activity

Consider a person swimming laps in a pool:

1. How is lift created? ____________________________________
2. How is thrust created? ____________________________________
3. What causes weight? ____________________________________
4. What causes drag? ____________________________________
5. Draw a diagram showing water flow.
6. Draw a diagram showing the forces acting on the person.

Consider an airplane flying at 36,000 feet (10,972.8 m):

7. How is lift created? ____________________________________________

8. How is thrust created? __________________________________________

9. What causes weight? ____________________________________________

10. What causes drag? ____________________________________________

11. Draw a diagram showing air flow.

12. Draw a diagram showing the forces acting on the airplane.

13. How are each of the scenarios similar to how a shark swims?

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

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# Physics of Shark Movement Part I – Forces and Energy

## Activity 2. Adaptation Creation

(multi-day or take home assignment)

## Introduction

Scientists are using what we know about sharks and their adaptations to make great technological advancements. Students will use what they learned in the lesson to research new ways we can use shark adaptations and anatomy to help us in everyday life. This activity can be done individually or as a group and be presented to the class. A rubric is provided under Grading Suggestions.

## Materials

- Computer with internet access
- Lined paper for writing
- Unlined paper or craft material for visual

## Instructions

Scientists have created a new type of swimsuit modeled after shark skin. These swimsuits give people a more hydrodynamic body shape and are made with scale-like patterns simulating dermal denticles. The swimsuits have been tested to reduce drag by as much as 7%.

Your assignment is to create a new object, or modify an already existing object, using what you have learned about shark anatomy and how forces act upon movement. To complete this assignment you should:

1. Create a visual representation of your creation. This could be a picture, animation, or 3-D object.
2. Create an infomercial to sell your product to your classmates. Your infomercial should state what your product is and how it will be used in everyday life, what adaptations you have included in the design and the physics behind your creation.
3. Present your infomercial to the class.

# Activity 2. Adaptation Creation

Name: ______________________________

Date: ______________________________

## Background

Scientists have created a new type of swimsuit modeled after shark skin. These swimsuits give people a more hydrodynamic body shape and are made with scale-like patterns simulating dermal denticles. The swimsuits have been tested to reduce drag by as much as 7%.

## Instructions

Your assignment is to create a new object, or modify an already existing object, using what you have learned about shark anatomy and how forces act upon movement. To complete this assignment you should:

4. Create a visual representation of your creation. This could be a picture, animation, or 3-D object.
5. Create an infomercial to sell your product to your classmates. Your infomercial should state what your product is and how it will be used in everyday life, what adaptations you have included in the design and the physics behind your creation.
6. Present your infomercial to the class.

# Physics of Shark Movement Part I – Forces and Energy

## ACTIVITY 3. Energy Practice Problems

(30 – 45 minutes or take home assignment)

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## Introduction

Students will practice unit conversion individually or as a small group using the OCEARCH data based problems provided.

## Materials

Lined Paper
Writing utensil
Calculator

## Instructions

Have the students work individually or small groups. The practice problems can be handed out, written on a board, or shown on a projector.

Students should show their work and remember to make sure all numbers have the correct unit. Round answers in Joules to nearest whole number. Round answers in m/s to nearest tenth.

## Answers

1.) 32,487 J

2.) a. 1,688 J

 b. 9,188 J

 c. 1,890 J

3.) 866,148 J

4.) a. 1,000 J

 b. 5.4 m/s

 c. 9,008 J

5.) 285 J

# Activity 3. Energy Practice Problems

Name: ________________________________

Date: ________________________________

## Instructions

Round your answers in Joules to the nearest whole number and answers in m/s to the nearest tenth. If you need more space, use an extra sheet of blank paper.

1. What is the potential energy for a 1,105 kg great white laying on the hydraulic lift of the M/V OCEARCH 3 m above the water?

2. Philip is a 375 kg great white with an average speed of 3 m/s. When Philip spots a seal he increases his velocity to 7m/s. After he eats the 45 kg seal, Phillip's returns to his average velocity. What is Phillip's kinetic energy:
   a. Before he spots the seal?
   b. After he spots the seal?
   c. After he eats the seal?

3. The M/V OCEARCH is traveling at a speed of 2.1 m/s. If the ship weighs 433 tons, what is the ship's kinetic energy? *Hint: what units does the formula call for?*

4. A 68 kg man is standing on a boat 1.5 m above the water. The man decides to go for a swim and jumps off the boat into the ocean. A great white shark is swimming nearby and is startled when the man hits the water. The 1,126 kg shark swims away at a velocity of 4 m/s.
    a. What is the man's potential energy when he is standing on the boat?
    b. What is the velocity of man just before he hits the water? (Round answer to nearest tenth)
    c. What is the kinetic energy of the shark when it is swimming away?

5. Nixie, the OCEARCH crew's 16 lb dog, likes to lie out on the deck of the ship. If the deck is 4 m above the water line, what is Nixie's potential energy? *Hint: what units does the formula call for?*