

# Start Your Engines!

## Teacher Guide

### Objectives

Students will compare motors and generators.

Students will identify important components of an engine.

Students will identify similarities and differences between racing engines and personal vehicle engines.

### Vocabulary

- |               |                    |                 |              |                  |                |
|---------------|--------------------|-----------------|--------------|------------------|----------------|
| • chassis     | • cylinder         | • flash point   | • piston     | • starter        | • transmission |
| • combustion  | • efficiency       | • fuel injector | • solenoid   | • suspension     | • turbocharger |
| • crank shaft | • external starter | • oxygen        | • spark plug | • thermal energy |                |

### Time

- 1-2 class periods

### Materials

- |                                 |                              |                                     |                            |
|---------------------------------|------------------------------|-------------------------------------|----------------------------|
| ▪ Assembled motor               | ▪ 4 Strong rectangle magnets | ▪ Masking tape                      | ▪ Ruler                    |
| ▪ Disassembled motor            | ▪ 1 Foam tube                | ▪ Fine sandpaper                    | ▪ Utility knife (optional) |
| ▪ Alligator clips               | ▪ 1 Small nail               | ▪ 1 Push pin                        |                            |
| ▪ 9-volt battery                | ▪ 1 Large nail               | ▪ 1 Multimeter with alligator clips |                            |
| ▪ 1 Small bottle                | ▪ Magnet wire                | ▪ Hand operated pencil sharpener    |                            |
| ▪ 1 Rubber stopper with ¼" hole | ▪ Permanent marker           |                                     |                            |
| ▪ 1 Wooden dowel (12" x ¼")     | ▪ 1 Pair sharp scissors      |                                     |                            |

### Caution

The magnets used in this model are very strong. Use caution around electronic devices, ID badges, and credit cards.

Use caution with sharp objects when puncturing plastic.

### Procedure

1. Make copies of student worksheets or prepare digital copies, as needed.
2. Gather materials for the *Science of Electricity* model.
3. Direct students to read the background information individually or as a group.
4. Students should complete the activities as a group and answer questions.

# Start Your Engines!

## Student Guide

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### 📖 Vocabulary

- chassis
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- crank shaft
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- solenoid
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- suspension
- thermal energy
- transmission
- turbocharger

### START YOUR ENGINES! *An Introduction to Internal Combustion Engines*

Most of us don't give much thought to the way the engines in our cars work. We make sure there is enough fuel, we turn the key, buckle the seat belt, and just drive. It is not until something goes wrong that we appreciate the complexity under the hoods of our cars.

No matter what fuel a vehicle uses, they all work on the same principle: **combustion**. Burning fuel releases a lot of energy. Very simply, the energy from the fuel is used to push a part of the engine, which pushes another part of the car, which turns the wheels, which propels you down the road.

### GASOLINE ENGINES

In order to burn properly, gasoline, like any other combustible substance, needs **oxygen**. In a gasoline engine, the gasoline and air are mixed together in an amount set by the car's powertrain control module, or PCM. Air is inserted into the cylinder through the air intake valve, and gas is injected through a **fuel injector** into the **cylinder**. The amount of fuel injected into the cylinder is dependent upon the degree to which the driver depresses the gas pedal (accelerator).

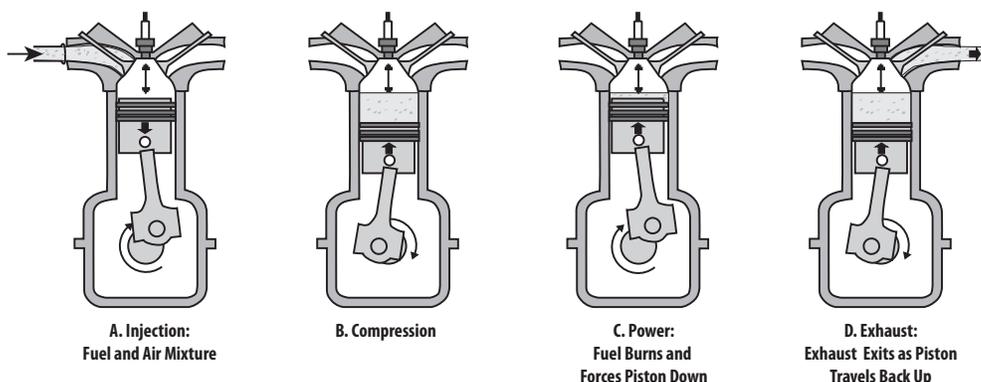
Each cylinder has its own fuel injector, **spark plug**, and **piston**. The spark plug provides an electrical spark, which is the small amount of energy, called activation energy, needed to ignite the fuel. When the gasoline burns, it releases a large amount of energy given the small amount of fuel. The energy released pushes down on the piston. The piston comes back up, more fuel is injected, and the

whole cycle repeats. A typical automobile engine will spark gasoline several hundred times a minute.

The pistons are connected to the **crank shaft**, which transforms the linear motion of the piston into circular motion that is transferred to the wheels of the car through the transmission and drive shaft. Finally, the wheels are turning and your car moves forward.

The energy from the gasoline must be transferred several times before it actually turns the wheels on the car. Every time that energy is transferred from one part to another, some of the energy is dissipated as **thermal energy** loss. The actual **efficiency** of an internal combustion engine is very low – approximately 20% of the available energy in the gasoline is used to move the car forward, and the other 80% is lost.

#### Internal Combustion Engine, Single Cylinder



## DIESEL ENGINES

Diesel engines operate under the same essential idea, but the fuel is ignited differently. Diesel engines do not have spark plugs; instead, they rely on the high temperatures generated from compression. The air is injected into the cylinder, and compressed. As the air is compressed, its temperature increases, and into this hot air the diesel fuel is injected. The high temperature of the air immediately ignites the fuel because the temperature is above the flash point of the diesel fuel.

After the diesel fuel is burned, the engine functions the same way that the gasoline engine does, with a piston being pushed down, and the energy being transferred through a series of gears and other mechanisms, until it reaches the tires.

## RACING ENGINES

Automotive racing vehicles are fundamentally no different than the vehicle you might have parked in your driveway. IndyCars, NASCARs, Formula One cars, and even go-karts have most of the same parts. They all use an internal combustion engine and have transmissions, suspensions, wheels, and brakes. However, as these high-performance vehicles are used for speed rather than leisure, this is where their similarities stop.

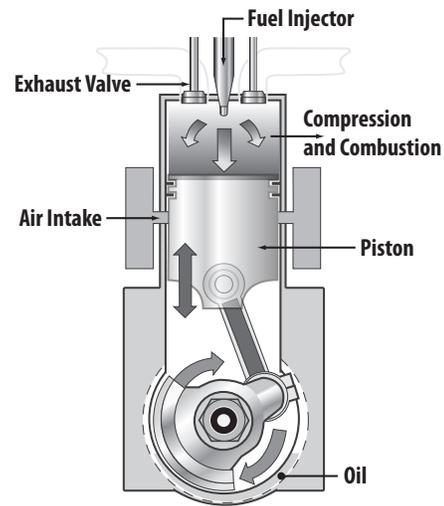
Much of the design of an IndyCar from the chassis down to the specific parts of the engine is standardized, tested, and approved by IndyCar officials. All engines used in the IndyCar Series are manufactured by Honda or Chevrolet. These engines are all 2.2 liter, V-six-cylinder, twin turbocharged engines that run on ethanol. Each cylinder has two inlet and two exhaust valves, one spark plug, and up to two fuel injectors. Turbochargers help to boost the engine's horsepower by compressing the air let into the cylinder. By doing so, more fuel can be added to the mix, creating more of an explosion in each cylinder. This enables a racing team to optimize the power to weight ratio of their vehicle.

## START THOSE ENGINES!

Starting a car is simple, right – you just turn the key, or push the button? There are actually a lot of parts involved in the starting of any car, which is something we may realize only after our car fails to start the first time. A **starter** is simply a motor or device used to rotate the internal combustion engine and also allow the engine to operate under its own power.

An electric starter motor is the most common type of starter used on smaller gasoline and diesel engines. Very simply, the starter sends electric current to crank the crankshaft and move the pistons. Before your key or starter button is activated, the circuit

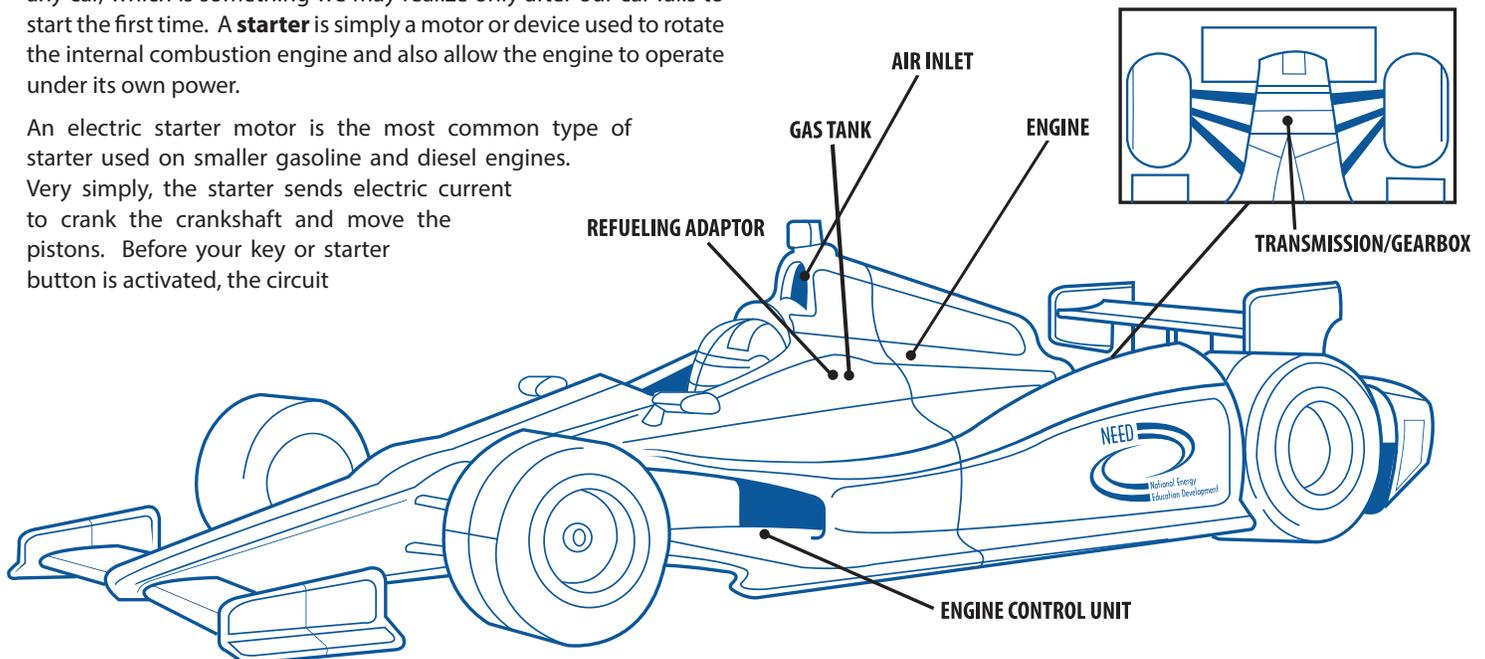
## Internal Combustion Engine, Diesel



Output  
Rotary Mechanical  
Power (20% Efficiency)

is open and current will not flow. When your key or starter button is activated, the battery sends current first to a device called a **solenoid**. This solenoid allows the circuit to be closed and current to continue to travel on to a starter motor. This motor is a DC electric motor that allows the engine to be set in motion. Electric motors use a magnetic field and a conductor to generate force. Once the engine is turned on, the starter switch (circuit) is opened, causing the starter motor to stop running and the engine to operate under its own power.

High-performance racing vehicles like IndyCars require an remote or **external starter**. This device is attached to the vehicle prior to race time by a technician and removed once the car is started, before it enters the race course. Using external starters allows teams to further control the power to weight ratio on the vehicle, as they do not need to house a heavy battery and motor.



# Start Your Engines! *ACTIVITY 1*

## Science of Electricity Model

### 🎯 Objective

To demonstrate how electricity is generated.

### ⚠️ Caution

- The magnets used in this model are very strong. Refer to page 24 of this guide for more safety information.
- Use caution with nails and scissors when puncturing the bottle.

### 📄 Materials

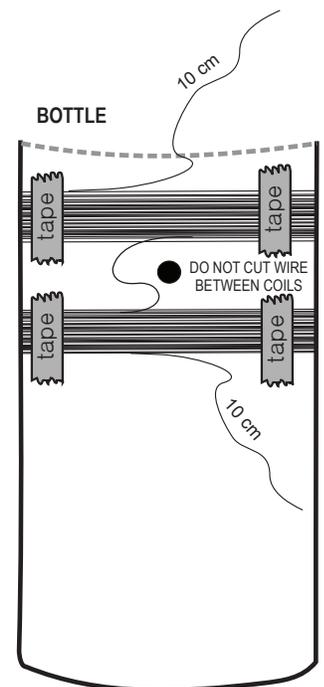
- |                                 |                         |                                     |
|---------------------------------|-------------------------|-------------------------------------|
| ▪ 1 Small bottle                | ▪ 1 Large nail          | ▪ 1 Push pin                        |
| ▪ 1 Rubber stopper with ¼" hole | ▪ Magnet wire           | ▪ 1 Multimeter with alligator clips |
| ▪ 1 Wooden dowel (12" x ¼")     | ▪ Permanent marker      | ▪ Hand operated pencil sharpener    |
| ▪ 4 Strong rectangle magnets    | ▪ 1 Pair sharp scissors | ▪ Ruler                             |
| ▪ 1 Foam tube                   | ▪ Masking tape          | ▪ Utility knife (optional)          |
| ▪ 1 Small nail                  | ▪ Fine sandpaper        |                                     |

### 🗂️ Preparing the Bottle

1. If needed, cut the top off of the bottle so you have a smooth edge and your hand can fit inside. This step may not be necessary. If necessary, a utility knife may be of assistance.
2. Pick a spot at the base of the bottle. (HINT: If the bottle you are using has visible seams, measure along these lines so your holes will be on the opposite sides of the bottle.) Measure 10 centimeters (cm) up from the base and mark this location with a permanent marker.
3. On the exact opposite side of the bottle, measure 10 cm up and mark this location with a permanent marker.
4. Over each mark, poke a hole with a push pin. Do not distort the shape of the bottle as you do this.  
**CAUTION:** Hold a rubber stopper inside the bottle behind where the hole will be so the push pin, and later the nails, will hit the rubber stopper and not your hand, once it pokes through the bottle.
5. Widen each hole by pushing a nail through it. Continue making the hole bigger by circling the edge of the hole with the side of the nail. (A 9/32 drill bit twisted slowly also works, using a rubber stopper on the end of the bit as a handle.)
6. Sharpen one end of the dowel using a hand operated pencil sharpener (the dowel does not have to sharpen into a fine point). Push the sharpened end of the dowel rod through the first hole. Circle the edge of the hole with the dowel so that the hole is a little bigger than the dowel.
7. Remove the dowel and insert it into the opposite hole. Circle the edge of the hole with the dowel so that the hole is a little bigger than the dowel. An ink pen will also work to enlarge the hole. Be careful not to make the hole too large, however.
8. Insert the dowel through both holes. Hold each end of the dowel and swing the bottle around the dowel. You should have a smooth rotation. Make adjustments as needed. Take the dowel out of the bottle and set aside.
9. With a permanent marker, label one hole "A" and the other hole "B."

### Generator Assembly: Part 1

1. Tear 6 pieces of tape approximately 6 cm long each and set aside.
2. Take the bottle and the magnet wire. Leave a 10 cm tail, and tape the wire to the bottle about 2 cm below hole A. Wrap the wire clockwise 200 times, stacking each wire wrap on top of each other. Keep the wire wrap below the holes, but be careful not to cover the holes, or get too far away from the holes.
3. DO NOT cut the wire. Use two pieces of tape to hold the coil of wire in place; do not cover the holes in the bottle with tape (see diagram).
4. Without cutting the wire, move the wire about 2 cm above the hole to begin the second coil of wraps in a clockwise direction. Tape the wire to secure it in place.



1. Wrap the wire 200 times clockwise, again stacking each wrap on top of each other. Hold the coil in place with tape (see diagram).
2. Unwind 10 cm of wire (for a tail) from the spool and cut the wire.
3. Check your coil wraps. Using your fingers, pinch the individual wire wraps to make sure the wire is close together and close to the holes. Re-tape the coils in place as needed.
4. Using fine sandpaper, remove the enamel coating from 4 cm of the end of each wire tail, leaving bare copper wires. (This step may need to be repeated again when testing the model, or saved for the very end).

## Rotor Assembly

1. Measure 4 cm from the end of the foam tube. Using scissors, carefully score a circle around the tube. Snap the piece from the tube. This piece is now your rotor.
2. On the flat ends of the rotor, measure to find the center point. Mark this location with a permanent marker.
3. Insert the small nail directly through the rotor's center using your mark as a guide.
4. Remove the small nail and insert the bigger nail.
5. Remove the nail and push the dowel through, then remove the dowel and set aside. Do **NOT** enlarge this hole.
6. Stack the four magnets together. While stacked, mark one end (it does not matter which end) of each of the stacked magnets with a permanent marker as shown in Diagram 1.
7. Place the magnets around the foam piece as shown in Diagram 2. Make sure you place the magnets at a distance so they do not snap back together.
8. Wrap a piece of masking tape around the curved surface of the rotor, sticky side out. Tape it down at one spot, if helpful.
9. Lift the marked end of Magnet 1 to a vertical position and attach it to the rotor. Repeat for Magnets 2, 3, and 4.
10. Secure the magnets in place by wrapping another piece of masking tape over the magnets, sticky side in (Diagram 3).

**WARNING:** These magnets are very strong. Use caution when handling. See page 24 for more information.

Diagram 1

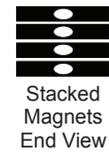


Diagram 2

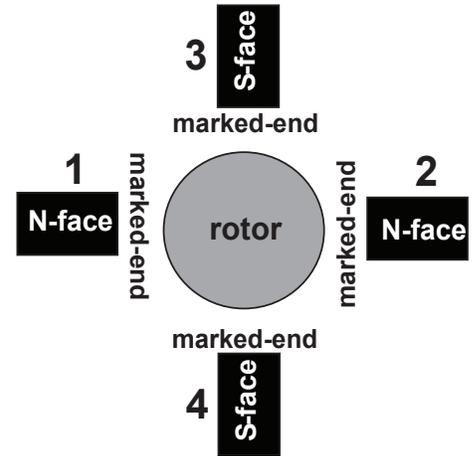
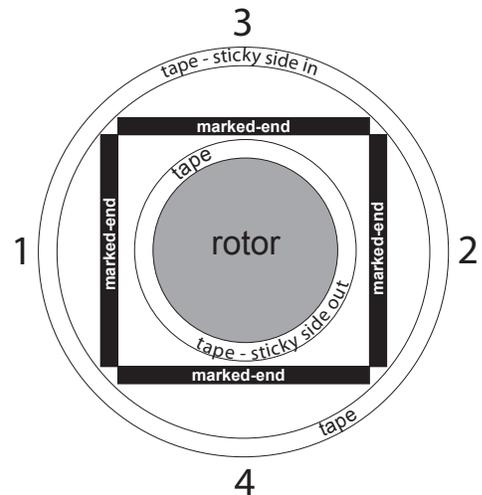
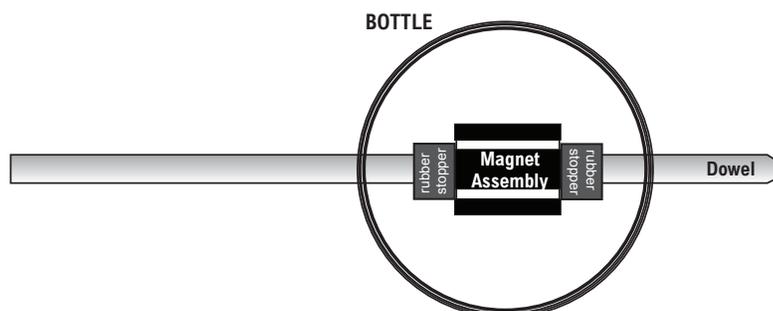


Diagram 3



## Generator Assembly: Part 2

1. Slide the sharp end of the dowel through Hole A of the bottle.
2. Inside the bottle, put on a stopper, the rotor, and another stopper. The stoppers should hold the foam rotor in place. If the rotor spins freely on the axis, push the two stoppers closer against the rotor. This is a pressure fit and no glue is needed.
3. Slide the sharp end of the dowel through Hole B until it sticks out about 4 cm from the bottle.
4. Make sure your dowel can spin freely. Adjust the rotor so it is in the middle of the bottle.





# Start Your Engines! *ACTIVITY 1*

## Observations and Conclusions

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1. Observe the science of electricity model. Draw and label the parts of the apparatus.

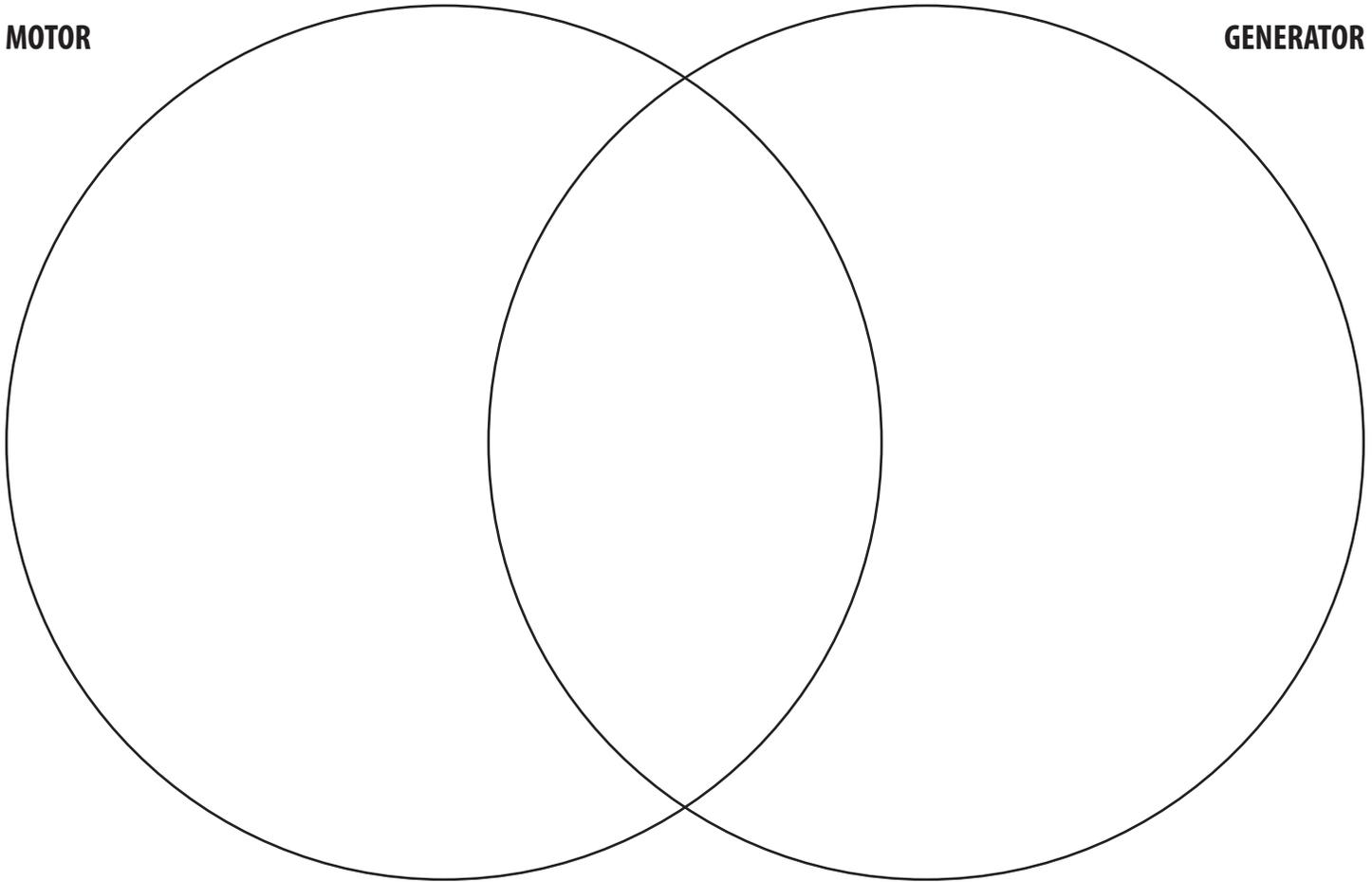
2. Explain how electricity is generated using appropriate vocabulary.



5. Complete the Venn diagram below comparing your motors to the generator you set up.

**MOTOR**

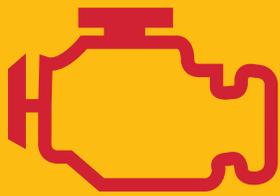
**GENERATOR**



6. Design a way to turn your science of electricity generator into a motor, like those used in appliances and electric starter motors. Describe what your design would change or incorporate. Draw a picture. Test it out if time allows.

# FAST FACTS

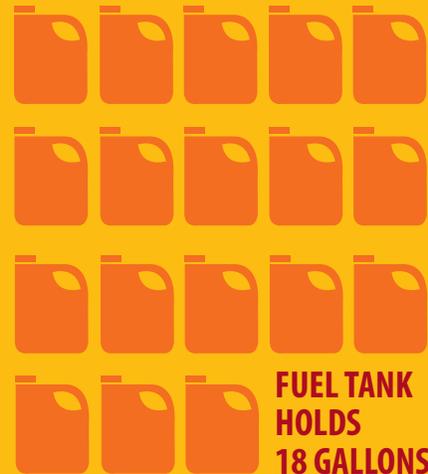
## INDYCAR RACE CARS



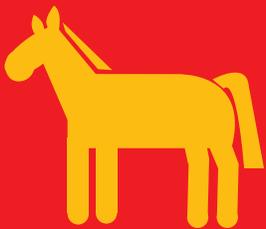
2.2L, 6-CYLINDER ENGINE



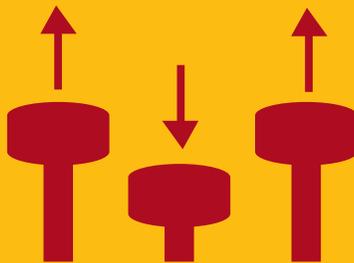
RUNS ON ETHANOL



FUEL TANK  
HOLDS  
18 GALLONS



550-700 HORESPOWER



EACH PISTON IN THE ENGINE  
MOVES SO RAPIDLY THEY CAN  
TRAVEL 1 MILE UP AND DOWN  
EACH MINUTE!



FUEL  
EFFICIENCY  
3-5 MPG

CAN GO FROM 0-100 MPH  
IN 3-5 SECONDS!



THE DRAFT CREATED BY AN INDYCAR EXTENDS  
UP TO 25 FEET BEHIND THE CAR

SOURCES: HONDA, HOW STUFF WORKS, & INDIANAPOLIS MOTOR SPEEDWAY