Oceanic Circulation:

What Keeps the Ocean in Motion?

Name: ______________________________

Date: ______________________________

Student worksheet

Directions: Follow the directions below to prepare for and conduct the experiment.

1. **Before the Experiment**

   To prepare for the experiment, answer these questions.

   a. In your own words, explain briefly what the video said about the global ocean conveyer belt. What drives this ocean circulation system?

   b. Write down your hypothesis about how lower temperature differences affect the movement of water and the ocean conveyor belt.

2. **Experiment**

   Follow these steps to conduct your experiments. Before you start your experiment, skip down to step f below and practice the cup flipping technique. This will make your experiment go much more smoothly!

   <u>Experiment 1: High temperature difference (30-40°C)</u>

   a. Label one cup "hot" and the other one "cold."
   b. Fill the cup you labeled "hot" with hot water.
   c. Fill the other cup with *ice water*. Add 5 drops of food coloring to the cold water and mix.
   d. Remove ice cubes and add cold water to fill the cup.

Oceanic Circulation: What Keeps the Ocean in Motion?—Page 2

Name ___________________________

Directions: Follow the directions below to continue your investigations.

e. Measure the temperature of each solution. Aim to have a *temperature difference of about 30-40°C* between the hot and cold water. Adjust temperatures with hot or cold water or ice if needed. Record the measured temperatures in the table below.

		Water temperature in top cup [°C]	**Water temperature in bottom cup [°C]**	**Water temperature difference between both cups [°C]**
Experiment 1	Start			
	End			
Experiment 2	Start			
	End			
Experiment 3	Start			
	End			
Experiment 4	Start			
	End			

f. Now the tricky part begins. You are going to invert one cup (turn it upside down) and put it on top of the other without spilling, as shown in the image on the next page. Do this step on top of the aluminum tray to capture any spills.

i. Use the CD to cover the top of the cup with cold water. Place the plastic strip on the CD so that it covers the hole and sticks out beyond the CD a little, as shown below.

ii. Hold the cup near the base with one hand while holding the CD with the plastic strip against the opening with the other hand.

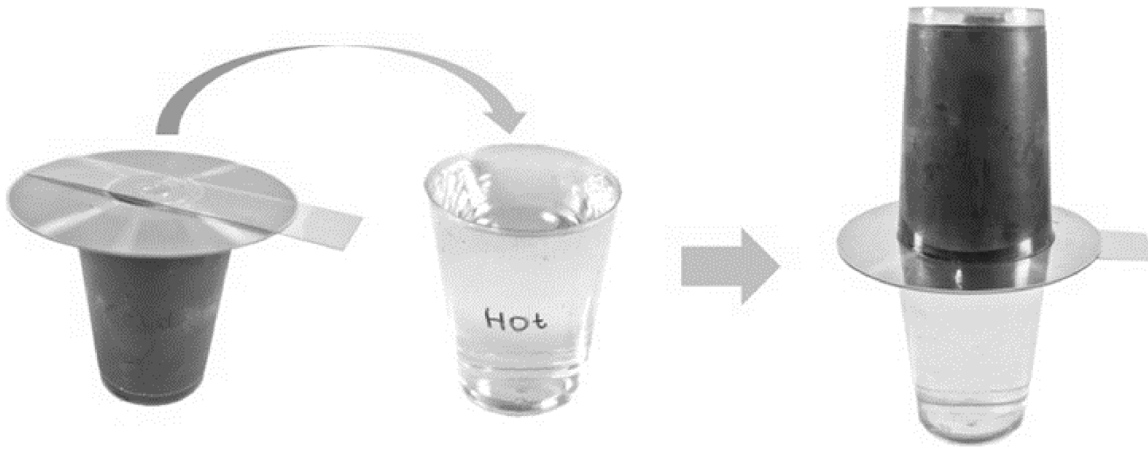
iii. Slowly and carefully flip the cup over, keeping the CD pressed tightly against the opening.

iv. Place the inverted cup on top of the other cup. The plastic strip remains in place, so it is between the openings of both cups. See image on the next page.

Oceanic Circulation: What Keeps the Ocean in Motion?—Page 3

Name ___________________________

Directions: Follow the directions below to continue your investigations.



g. Open the phyphox app on the phone and select the light sensor.

h. Lean your phone against a book with the light sensor facing sideways towards the bottom cup with hot water. Then place the stacked cups in front of the light sensor. Put the flashlight in front of the bottom cup so it shines through the solution directly into the light sensor as shown in the image below.

Note that the light sensor reading will be dependent on the position of the flashlight with respect to the phone. You might want to try different positions to get the highest readings. However, you should *not* move the flashlight or the phone while recording data.

Oceanic Circulation: What Keeps the Ocean in Motion?—Page 4

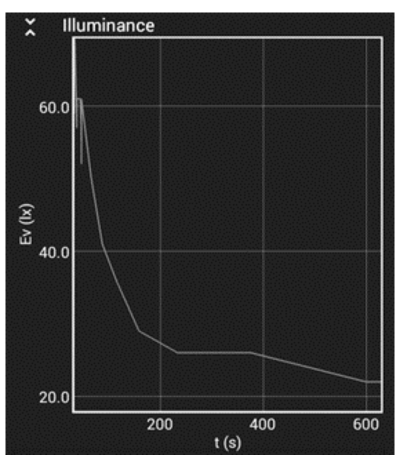
Name ___________________________

Directions: Follow the directions below to continue your investigations.

i. Press the play button in the phyphox app to start the recording. Note that on some devices the light sensor is only updated when there is a coarse change of illuminance. This means that you might not see data being recorded if the light intensity does not change significantly. Slowly and carefully pull out the laminated paper or plastic strip that covers the hole of the CD while holding the upper cup in place. In case your light intensity readings do not change significantly and you don't see the data recording move forward anymore, you can wiggle the flashlight slightly to activate the sensor again.

j. Write down your observations:

k. The food color will mix into the bottom cup while the app will record the color change over time. An example graph is shown below. Note that your graph might not exactly look like this one. Stop recording after about five minutes and save your data. You will analyze your data once you have completed all your experiments.



Oceanic Circulation: What Keeps the Ocean in Motion?—Page 5

Name ___________________________

Directions: Follow the directions below to continue your investigations.

l. Separate both cups again by first carefully sliding the laminated paper or plastic strip back in between both cups so it covers the hole of the CD. Then hold the upper cup near the base again with one hand while holding the CD with the plastic strip against the opening with the other hand.

m. Slowly and carefully flip the cup over, keeping the CD pressed tightly against the opening, and set it down next to the other cup on the aluminum tray.

n. Measure the temperature of both of the cups and record the readings in the table above.

o. Dispose of your water in the sink and rinse out both cups. Then continue with the next experiment.

Experiment 2: Low temperature difference (10-20°C)

p. Repeat steps a-o using hot water and *room temperature water* instead of ice water. For this experiment, aim to have a *temperature difference of about 10-20°C* between the hot and cold water. Adjust temperatures with hot or cold water if needed and record your temperatures in in the table above.

Experiment 3: No temperature difference (0°C)

q. Repeat steps a-o using *room temperature water* in both cups. For this experiment, aim to have *no temperature difference* between both cups. Record your measured temperatures in in the table above.

Experiment 4: Reverse layering

r. Repeat steps a-o, but this time, reverse the water layer and stack the *hot water on top of the cold water*. Record your measured temperatures in the table above.

Oceanic Circulation: What Keeps the Ocean in Motion?—Page 6

Name ___________________________

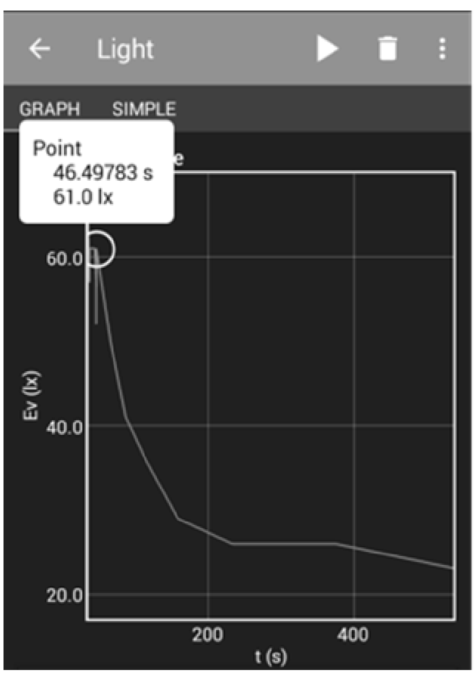
Directions: Based on your results, answer the questions below.

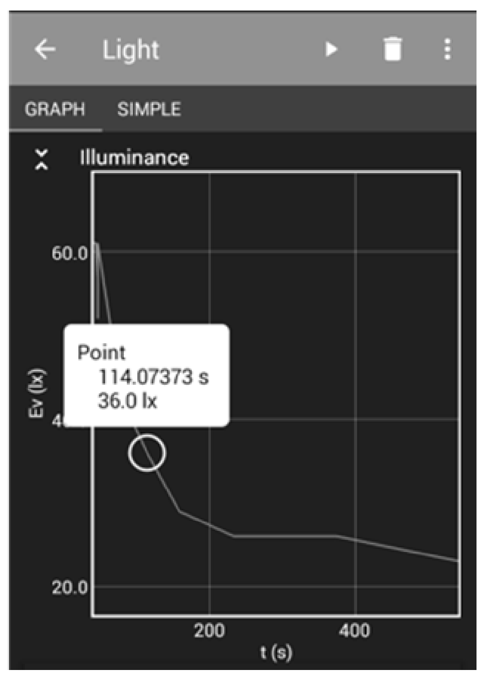
3. After the Experiment

Analyze your data following the steps below.

a. Calculate the temperature difference between both water layers for each of your experiments before and after the experiment. Record your results in the table above.

b. Determine the initial mixing rate from your recordings. To do this, find the light intensity values at the very beginning of your experiment (when you actually started the mixing reaction) and closest to one minute after (60 seconds after, or the next closest possible data point). Use the pick data function of the app to view the time and light intensity values for each individual time point as shown in the graph below. Make sure to account for the delay between pressing the record button and starting the mixing reaction. You can either pan and zoom into the relevant part of your graph or pick the actual data point when the mixing reaction started. In this (zoomed-in) graph, the light intensity values at the beginning (46 seconds) and about 60 seconds later (114 seconds) are 61 lux and 36 lux, respectively.





Oceanic Circulation: What Keeps the Ocean in Motion?—Page 7

Name ___________________________

Directions: Based on your results, answer the questions below.

Record your results in the data tables below and calculate the average reaction times from all your trials for each temperature average.

Experiment	Water temperature difference [°C]	Light intensity start of mixing	Light intensity about 1 min after start	Rate of color change (mixing rate)
1				
2				
3				
4				

c. Calculate the initial rate of color change, or the "mixing rate," using the equation given below. Record the results in your data table.

$$Rate\ of\ color\ change\ (mixing\ rate) = -\frac{\Delta\, Light\ intensity}{\Delta\, Time}$$

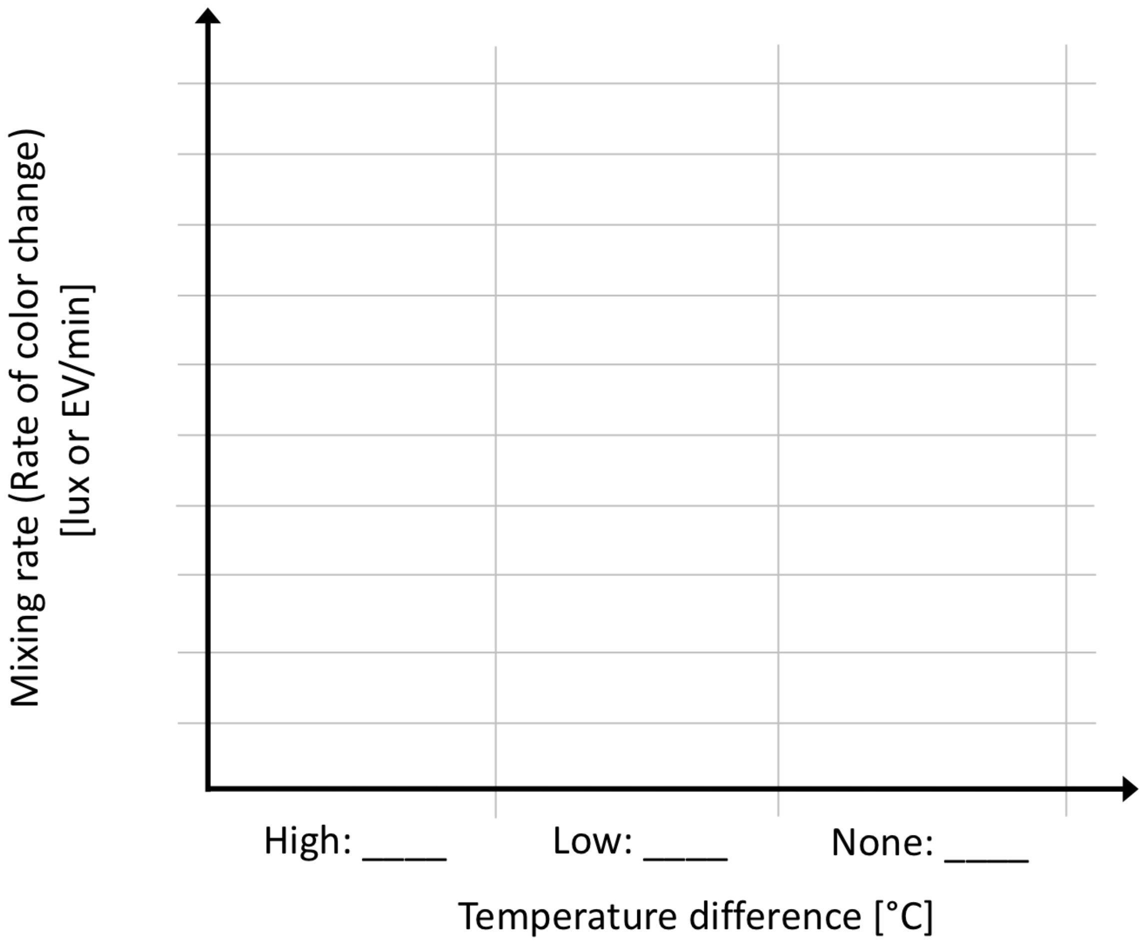
- Change in (∆) Light intensity = Light intensity about 60 seconds after the start − Light intensity at the start. In the example above, this would be 36 lux − 61 lux.
- Change in (∆) Time = Time interval between the two data points. In the example above, this would be 114 seconds − 46 seconds.

Oceanic Circulation: What Keeps the Ocean in Motion?—Page 8

Name ___________________________

Directions: Based on your results, answer the questions below.

d. To visualize your data, display your results in the graph below. Fill in the temperature differences and label the y-axis to fit your data.



Oceanic Circulation: What Keeps the Ocean in Motion?—Page 9

Name ___________________________

Directions: Based on your results, answer the questions below.

e. Looking at your data, what happens to the mixing rate as the temperature difference gets smaller?

f. Considering your answer in question e, how do your results relate to ocean currents and the global conveyor belt?

g. Based on your results, what would you expect to happen if there were lower temperature differences in the ocean water between the poles and the equator due to climate change? Was your initial hypothesis correct?