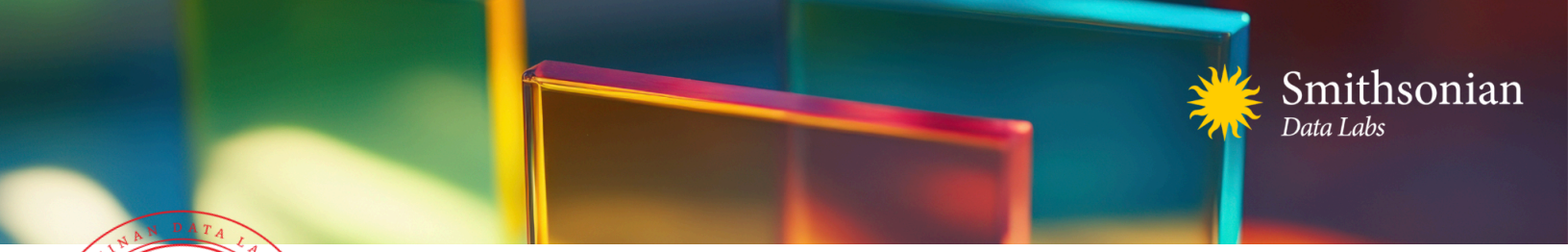


SPECTRUM LAB

Final Project: Lighting Design for a Saltwater Aquarium ANSWER KEY

Create and light a saltwater reef aquarium that is healthy, and looks great too. For this project, you'll first learn about how a lighting designer at the Smithsonian American Art Museum uses light to make exhibits pop! Then you can begin your own adventure using light to design a unique habitat for fish, coral and plants. You'll explore the spectra of a Regal Angelfish and then dive into the project by investigating a variety of plants, fish and coral that live in saltwater aquaria. You'll choose a few to live in your tank. Based on what you've learned in this unit, you'll decide how to light the tank so all of its inhabitants thrive.

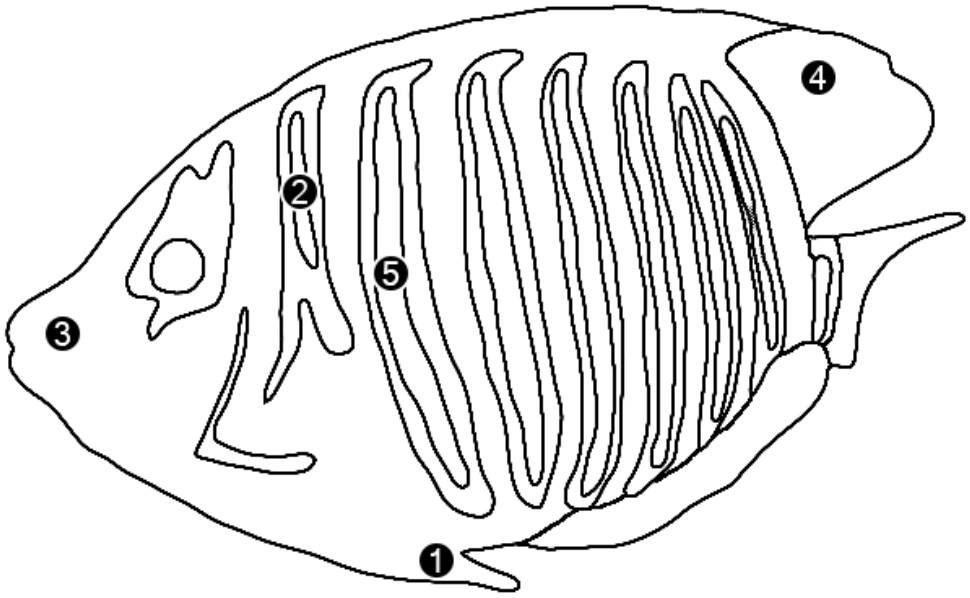
Explore Lighting Design

First, watch the Museum Lighting Design video to find out how lighting can be used to make artworks "look as good as they can."

Reflection Spectra and Colors

Explore more about the reflective spectra of different parts of a Regal Angelfish.

Choose any of the mystery spectra and see if you can guess which color it represents. Fill in the chart below.



	Color we see based on reflection spectrum	Region on fish that corresponds to each spectrum
Spectrum A	dark blue	4
Spectrum B	white	5
Spectrum C	yellow	1

Now that you've practiced interpreting reflection spectra, you are ready to start thinking about lighting your fish tank to optimize the health of the plants and make your fish look great.

Plant Reflection Spectra

Answer the following questions about the reflection spectrum of the Shaving Brush Plant

1. Within the visible part of the spectrum, at what wavelength does the plant reflect the most amount of light? Is this in line with your expectation? Why or why not?

   In the visible part of the spectrum, the algae reflects the most light at between 500 - 600 nm, which is green/greenish yellow. We would expect an object that appears green to reflect more green light than any other color.

2. Chlorophyll is the most important pigment in most green plants, and it absorbs sunlight to make food for the plant through photosynthesis. Based on the shaving brush plant's reflection spectrum, what color photons do you think are the ones that the plant needs to perform photosynthesis to keep it healthy?

   The algae reflects the least at around 445 nm (violet, indigo, and blue), and it also reflects less around 675 nm (red), so these are the wavelengths of light that the algae is absorbing for use in photosynthesis.

Now that you've practiced interpreting reflection spectra, you are ready to start thinking about lighting your fish tank to optimize the health of the plants and make your fish look great.

Your Saltwater Aquarium

Part 1: Choosing plants (algae) and animals (fish and coral) to live in your tank

For this task, you should select **at least 2 fish**, **2 plants** and **1 type of coral** from the **attached charts**. Think about the needs of the entire system. Which animals and plants can live together? Do all of your plants and corals have the same lighting needs? If not, you'll have to find a way to keep them all healthy. Which color combinations of plants and animals will look the best in the tank?

1. Use this chart to keep track of the needs of your organisms.

Name of fish, plant or coral	**Color(s)** of organism	**Light intensity needed** (low, moderate, high, any)	**Other needs** (hiding places, etc.)

EX 1. Sea Goldies	Yellow	Any	Multiple fish
Longfin Bannerfish	White, Black, Yellow	Any	Need lots of room
Red Gracilaria	Pink	Moderate	Eaten by fish
Dragon's Tongue	Red	Low to moderate	Eaten by fish
Yellow Tube Coral	Yellow	Low	not photosynthetic

2. Explain why you chose these plants and animals:

Student answers will vary - at this point, they are choosing plants and animals that are interesting to them. The above collection was chosen because they all are warm in color (reds, pinks, and yellows).

Part 2: Lighting the needs of your inhabitants

Lighting not only enhances the appearance of your tank, it also helps keep the inhabitants healthy. When deciding on which lights to use for your tank, you should try to recreate the conditions in which your aquarium plants and animals would live naturally.

1. First look at the information charts for coral and algae you picked for your tank. What are the best colors and intensities of light to keep each of them healthy? Look at the reflection spectrum for each organism - **what colors are reflected? Absorbed?**

Name of plant or coral	**Color(s)** of organism	**Pigment** (if present)	**Reflected color** of pigment	**Wavelengths** reflected by pigment, if present (in nm)	**Wavelengths** absorbed by pigment, if present (in nm)
Dragons Tongue	Red	Photocoerythrin	Purple/ Red	Purple: 400 nm Red: 625 nm	green 525 nm yellow 580 nm

Red Gracilaria	Pink	Phycoerythrin	Purple/Red	Purple: 400 nm Red: 625 nm	green 525 nm yellow 580 nm
Yellow Tube Coral	Yellow	no algae so no pigment	Animal will reflect yellow (might be green and red or yellow)	@580 nm for yellow or 550 (for green) and 650 (for red)	blue 400-500 nm

2. Now it's time to add your fish into the mix.

Name of fish	**Reflected color(s)** of fish	**Wavelength(s)** of reflected by fish (in nm)
Ex: Sea Goldies	Yellow and orange	580 nm yellow (high intensity) 600 nm orange (medium intensity)
Longfin Bannerfish	White, Black, Yellow	Yellow: 580 nm White: 380 – 700 nm Black: N/A

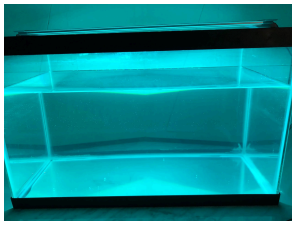
Lighting your aquarium

Part 1: Choose your light colors

You can choose from 3 LED light colors to light your tank: red, blue and green. You will need to decide the intensity (light level) of each color (low, moderate or high). Each combination will give

your tank a different look. For example, a tank with equal parts red, green and blue will appear white (remember the simulation from Day 1) but by adjusting the percent of each color, your tank's light can enhance the colors of your fish, and keep your plants and coral healthy. Remember what you learned from the land plants about reflected light.

For example, to get a tank with a teal hue, you could use high green and low blue



Or, for a tank which appears orange, you could use medium red and low green

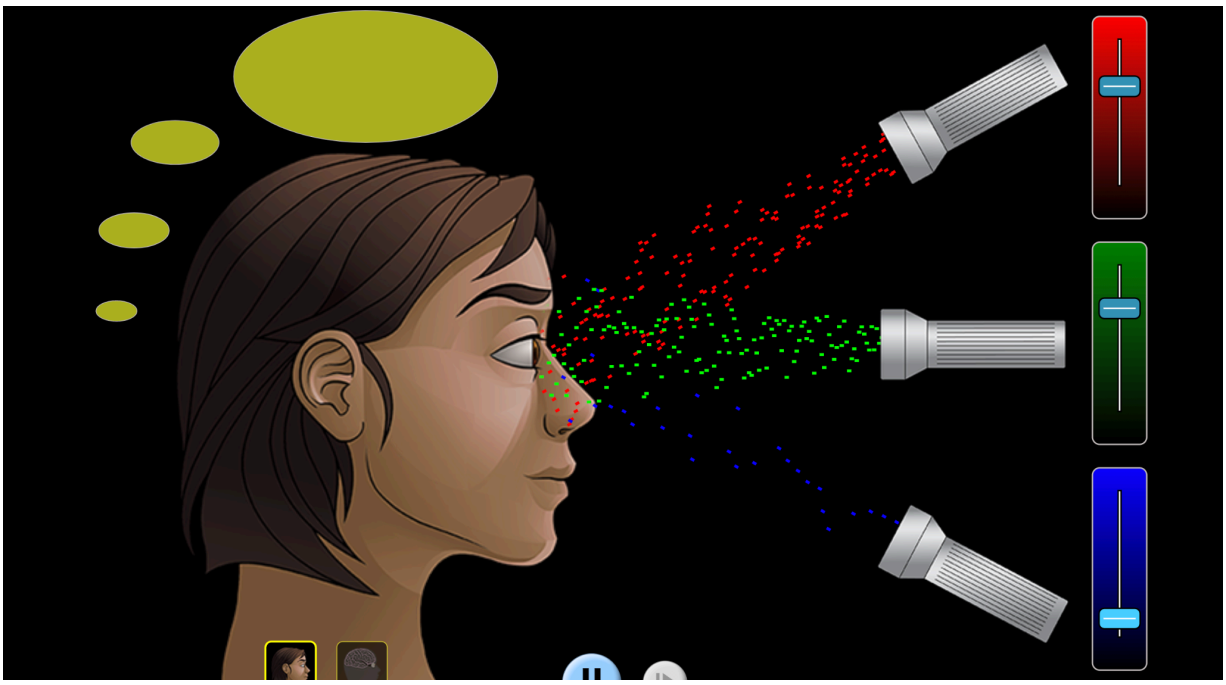
1. Use the **PheT simulation** (RGB bulbs) to see lots of color combinations.

Color Vision

2. Color of my tank:

Answers will vary - for this example tank color is yellow

3. Take a screenshot from the simulation of the color combination you'd like to use for your tank and paste it here:



4. Colors mixed to create my tank color – describe the level of each color (high, medium or low):

Red	medium (moderate intensity)
Green	medium (moderate intensity)
Blue	low (low intensity)

In terms of the health of your organisms and your aesthetic goals, explain why you chose this color combination:

Answers will vary - for this example, yellow-dominant fish and yellow-dominant corals require equal amounts of red and green light to show their true yellow colors. Likewise, reddish-pink plants will look best under red light with a hint of blue to elicit their purplish hues. This hint of

blue will also help achieve the white stripes present on the Longfin Bannerfish.

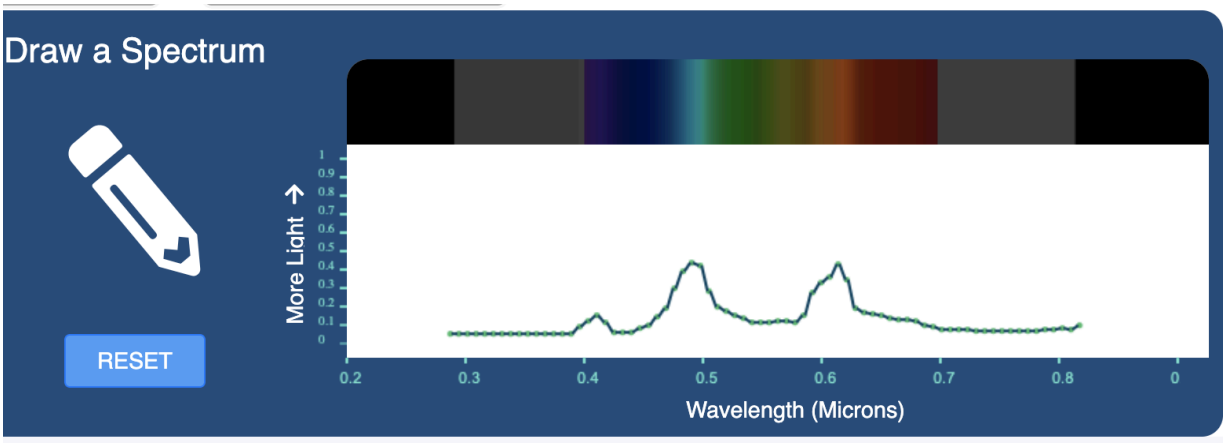
These plants absorb green light to make energy; this need is accounted for by the moderate levels of green light. Overall, the light intensity of the tank is low-to-moderate, which suits all of the plants and corals.

Part 2: Draw Your Tank's Spectrum

Return to the Spectrum Tool to view sample spectra showing various percentages of red, green and blue light.

https://waps.cfa.harvard.edu/microobservatory/spectrum/fishtank.html

With these as guides, use the drawing tool to create the overall spectra of an empty tank with your lighting design. Take a screenshot and paste it here:



Inhabitants Under Your Lights

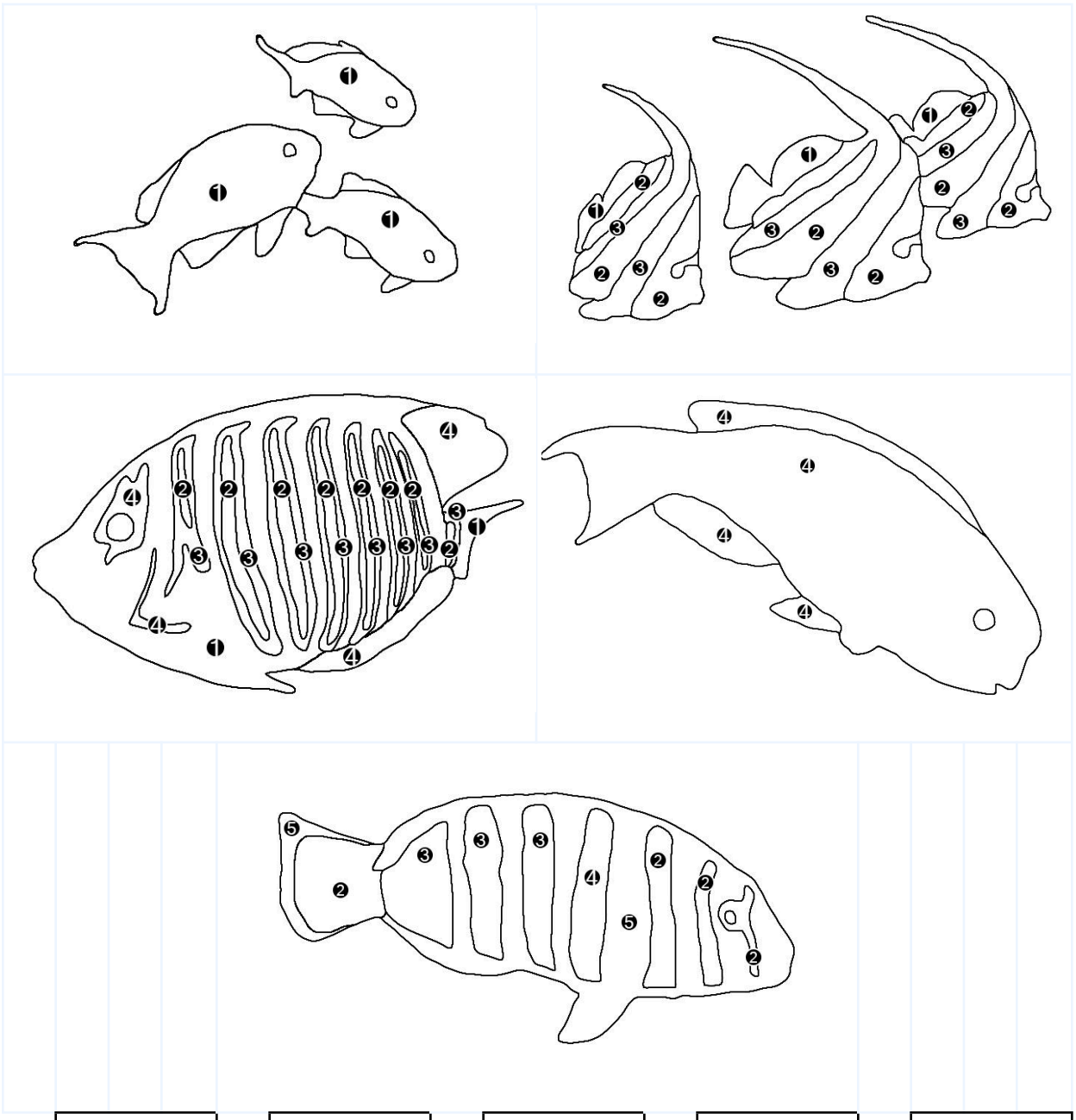
1. Now imagine adding the fish, coral and plants to the tank. If you need help thinking about this, use this stage lighting simulation.

https://www.physicsclassroom.com/Physics-Interactives/Light-and-Color/Stage-Lighting/Stage-Lighting-Interactive

2. What colors do you think your plants and coral appear with your lighting scheme?

Name of plant or coral	**Actual color(s)** of organism	**Color organism appears** under my lights
Dragons Tongue	Red	Red
Red Gracilaria	Pink	Pink
Yellow Tube Coral	Yellow	Yellow

Color the fish you chose as they would appear with your lighting scheme (or type in the colors that correspond to the numbered sections of the fish in the boxes below):



1	2	3	4	5
yellow	black			

Put it all together

Using all the data you've collected in Parts I-IV, write a paragraph that describes the set-up of your tank including what creatures you've chosen to live in the tank, what lighting scheme you have chosen for the tank and why you made these choices.

In this paragraph you should:

a. Identify the inhabitants you've chosen to live in the tank and the optimal lighting scheme (the tank's color) you've chosen for the well-being of these plants and animals and for your visual enjoyment. (**your claim**)
b. Review the data you gathered above in Sections I-IV. Include here the most relevant data (from the Project Data Charts, the PheT and Stage Lighting simulations, or the Spectrum Tool) that support your claim. (**your evidence**)
c. Using what you have learned about light and color throughout this Spectrum Lab, explain *why* you chose each type of plant and animal and *why* your lighting scheme works to meet the needs of the tank's creatures and allows them to look great. You should be able to justify how the data supports your claim. For example, how do the colors you chose support the well-being of your tank's inhabitants; and how does the appearance of the inhabitants under your lighting scheme meet your aesthetic goals for the tank? (**your reasoning**)!

Students' answers will vary. They can pick any combination of organisms and tank colors. The key is for them to explain why they chose each type of plant or animal and how they chose to light the tank.

In the example above two yellow-dominant fish (Longfin Bannerfish and Sea Goldies) as well as a yellow-dominant coral (Yellow Tube Coral) were chosen. Sticking to the long-wavelength end of the visible light spectrum (575-625), Dragon's Tongue and Red Gracilaria were also included in the tank.

The tank was lighted primarily with a combination of green and red lights (moderate to keep the plants and coral healthy). This combination created a yellow light which worked for both the yellow and red organisms. Under yellow light, the yellow fish and yellow coral appear yellow and the red/pink plants appear red (tested with Stage Lighting simulation). Some low blue light was added to bring out the purple colors of the plants and to improve the appearance of the white bands on the Longfin Bannerfish.

This set of animals was chosen because their needs are highly complementary. By utilizing mainly two primary light colors (red and green), the needs of the tank's inhabitants are fully met.