# UV Investigations

## Lesson Plan

ART INSTITVTE CHICAGO

### LESSON OVERVIEW

**Grades:** 6–12 **Duration:** 100–125 minutes

The **RLC Presents: Art + Science** video series and related curriculum supports middle and high school students in exploring science concepts and careers in museum conservation. This material is based upon work supported by the National Science Foundation under Grant No. OISE 1743748.

***In the Lab: UV Investigations***

In this video, museum conservator Lisa Ackerman discusses her career path and provides a demonstration of how museum scientists use ultraviolet light to investigate what the human eye can't see and discover new stories and understandings in works of art. Students will watch the video and respond to a brief set of reflection questions.

**UV Investigations Lesson Plan Summary**

Students investigate the electromagnetic spectrum and why some materials fluoresce under ultraviolet (UV) light. Through modeling, inquiry stations, and reflection, students begin to understand how different types of electromagnetic radiation cause some materials to fluoresce. Optional activities invite students to explore related concepts using the museum's collection. Engage your students in all of the activities provided, or select those most relevant to your teaching.

**Driving Question**

Why do some things appear to glow (fluoresce) under UV light?

**Anchoring Phenomenon**

Students look at images of objects from the museum's collection and use that experience to help them determine why the objects look different under UV light than they look in standard light.

**Lesson Objectives**

Students will:

- Make observations and inferences and ask questions
- Create models based on observed phenomena, experience, and prior knowledge
- Complete inquiry stations to learn electromagnetic spectrum vocabulary, make hypotheses, collect data, and explain a phenomenon
- Revise their initial models
- Reflect on their learning

**Table of Contents**


1. **Lesson Overview (page 1–3)**
2. **Preparing the Materials, Set Up the Lesson (page 3–6)**
3. **Facilitation Instructions (page 6–8)**
4. **Ongoing Learning (page 8–9)**
5. **Answer Key and Additional Terms (page 10–12)**
6. **Resource Handouts (page 13–16)**


**Key Vocabulary**

- Electromagnetic spectrum
- Electromagnetic radiation
- Visible light
- Ultraviolet light
- Fluorescence
- Frequency
- Wavelength

**Lesson at a Glance**

1. **Video Viewing and Reflection (20 minutes)**
   Students watch a video of a museum conservator at work in her lab and reflect by responding to questions.

2. **Opening Activity: "See, Think, Wonder" (10 minutes)**
   Students make observations, inferences, and ask questions about how they see two images of objects from the museum's collection under different lighting.

3. **Initial Model: Why do you think some things appear to glow (fluoresce) under UV light? (10-15 minutes)**
   Students create an initial model of why certain objects or substances glow under UV light.

4. **Inquiry Stations: Electromagnetic Spectrum (40-60 minutes)**
   Students complete four activity stations focused on electromagnetic spectrum vocabulary and the phenomena of fluorescence.

5. **Final Model: Why do you think some things appear to glow (fluoresce) under UV light? (10 minutes)**
   Students revise their initial model using their updated knowledge and understanding of UV light and fluorescence.

6. **Learning Reflection (10 minutes)**
   Students choose from a variety of questions to reflect on what they learned within the lesson.

7. **Possible Extensions**
   This includes creative response, further study, and exploring the collection.

**Next Generation Science Standards**

- **MS-PS4** Waves and Their Implications in Technology and Information Transfer (Waves and Electromagnetic Radiation)
    - **MS-PS4-2** Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.
- **MS-LS1** From Molecules to Organisms: Structures and Processes
    - **MS-LS1-8** Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.
- **NGSS Science and Engineering Practices**
    - Developing and Using Models
    - Constructing Explanations
- **NGSS Cross Cutting Concepts**
    - Cause and Effect
    - Energy and Matter

## UV INVESTIGATIONS LESSON PLAN

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## PREPARING THE MATERIALS

**Materials**

- The following resources are at the end of this document:
    - Image of art objects under standard light
    - Image of art objects under UV light
    - Vocabulary cards (1 set per group of four students)
    - Electromagnetic Spectrum Text (1 printout per group)
- Small sticky notes (1 set per group)
    - 6 in one color
    - 6 in another color
- Pieces of yarn or string (2 per group)
- Ruler (1 per group)
- Desk or clip lamp with a black light bulb (1 per group)

  **Note: Black light bulbs that fit a standard light socket can be ordered online for less than $10.00.*

  **Note: If supplies are limited, student groups can take turns with 1 black light station.*
- At least 3 materials from the “Will Fluoresce” list and at least 3 from the “Will Not Fluoresce” list below (per group)

  **Note: Fluorescence will vary. Test the samples you will use prior to giving them to students.*

| Will Fluoresce | Will Not Fluoresce |
|---|---|
| White Paper | Rock |
| Laundry Detergent | Darker Colored Paper |
| Tonic Water | Plain Water |
| Highlighter Pen Ink | Permanent Marker |
| Whitening Toothpaste | Wood |
| Vaseline | Soda (Pop) |
| Turmeric | Lotion |

**Worksheets**

**1 Per Student**

- UV Investigation Student Resource
  - "See, Think, Wonder" Chart (page 2)
  - Model/Explanation (page 3)
  - Electromagnetic Spectrum Inquiry Stations (page 4–10)
  - Reflection on My Learning (page 11)
- Notebook, paper, and pencil for reflection

## SET UP THE LESSON

1. Print the UV Investigations Student Resource for each student or provide them with electronic access.
2. Prepare the stations.

**Station 1: Electromagnetic Spectrum Vocabulary**

Cut out the Electromagnetic Spectrum Vocabulary Cards. There should ideally be two sets: one with only the terms and another with the definitions. This will allow students to match the cards during the activity.

**Tip: If possible, color-code the cards so terms are on a card of one color and definitions are on a card of another.*

Vocabulary:

- Electromagnetic Spectrum: The complete range of all types of radiation that include both electric and magnetic fields that travel in waves
- Electromagnetic Radiation: A type of energy wave that transfers energy
- Visible Light: A form of electromagnetic radiation that humans can see
- Ultraviolet Light: A form of electromagnetic radiation, that humans cannot see, with wavelengths shorter than visible light

- Frequency: The number of times an electromagnetic wave has a complete set of back and forth vibrations in a specific amount of time
- Wavelength: The distance between two identical points on back-to-back waves

**Station 2: Electromagnetic Spectrum**

Gather materials for the stations. Each group of 4 students should have:

- Electromagnetic Spectrum Text
- Small sticky notes with names of the parts of the electromagnetic spectrum (all one color)
    - Radio
    - Infrared
    - Visible
    - Ultraviolet
    - X-ray
    - Gamma ray
- Small sticky notes with just the wavelength ranges for each section (all another color)
    - Gamma ray = Less than 0.01 nm
    - X-ray = 0.01 nm–10 nm
    - Ultraviolet = 10 nm–400 nm
    - Visible = 400 nm–740 nm
    - Infrared = 780 nm–0.1 mm
    - Radio = 30 cm–100 km

**Station 3: Wavelength: Creating Waves**

Gather materials for the station. Each group of 4 students should have:

- Pieces of yarn or string (2)
- Ruler (1)

**Station 4: What will fluoresce under UV light?**

Gather materials for the station. Each group of 4 students should have:

- A desk or clip lamp with a black light bulb (1)
  **Note: If supplies are limited, student groups can take turns with 1 black light station.*
- At least three materials from the "Will Fluoresce" list and at least three from the "Will Not Fluoresce" list

| Will Fluoresce | Will Not Fluoresce |
|---|---|
| White paper | Rock |
| Laundry Detergent | Darker Colored Paper |
| Tonic Water | Plain Water |
| Highlighter Pen Ink | Permanent Marker |

| | |
|---|---|
| Whitening Toothpaste | Wood |
| Vaseline | Soda (Pop) |
| Turmeric | Lotion |

**Note: Teacher should test all materials with your specific black light to ensure consistent and noticeable fluorescence. We have found that laundry detergent with whitener, highlighter ink, white paper and tumeric provided the most noticeable result.*

## FACILITATION INSTRUCTIONS

**Video Viewing and Reflection (20 minutes)**

1. Ask the students to answer the following questions in a whole class discussion, small group, or pairs:
    - Did you know that scientists work in some museums?
    - What do you think they might do?
2. Have students watch the video, *In the Lab: UV Investigations* (runtime: 6 minutes 39 seconds) as a class or individually.
3. Ask students to reflect on the following questions in writing, whole class discussion, or in pairs, sharing with a partner:
    - How does Lisa Ackerman's work relate to both art and science?
    - What did you learn about her career path? What advice did she offer?
    - What else did you learn that is new or surprising?

**Opening Activity: See, Think, Wonder (10 minutes)**

1. Review the sections of the "See, Think, Wonder" chart (page 2) as a class.
   **Recommendation: Give students a concrete number of items to put in each column.*
2. Project images of objects under standard light and the objects fluorescing under UV light for the students.
3. Allow students 3 to 5 minutes to independently observe the images and complete the chart. Once completed, ask for volunteers to share one thing they noted.
   **Opportunity for differentiation: To simplify, complete this in pairs or small groups.*
4. Students can share their observations, inferences, and questions with an elbow partner, small group, or whole class.

**Initial Model: Why do some things appear to glow (fluoresce) under UV light? (10-15 minutes)**

1. As a class, review the instructions (page 3).
2. In pairs or small groups, students explain why some objects look normal under standard light, but appear to glow under UV light. Students can use words, pictures, or a combination of both to explain as thoroughly as they can, but ultimately, this is intended to be an educated guess.

**Opportunity for differentiation: To simplify, begin a model together as a class and let students finish it in smaller groups.*

3. Student groups share their ideas with the class. Models will be revised later.

**Electromagnetic Spectrum Inquiry Stations (40-60 minutes)**

- **Student UV Investigation Inquiry Stations** (page 4–10)

**Station 1: Electromagnetic Spectrum Vocabulary**

1. At this station, students have a set of cards with terms and a set of cards with the definitions for each of the terms.
2. Students match each term to a definition.
3. Students then record the definition of each term in the appropriate place on their student document and draw an image or memory clue.

   **Opportunity for differentiation: To simplify, match a few terms with their correct definition.*

**Station 2: Electromagnetic Spectrum**

1. Students start with a copy of the Electromagnetic Spectrum Text, which includes an unlabeled electromagnetic spectrum, and sticky notes with the names of the sections and the wavelength ranges. The names of the sections will all be on one color of sticky note and the wavelength ranges will be on another color of sticky note.
2. Students read the descriptions of each section and move the sticky notes to the correct spots on the electromagnetic spectrum on the Electromagnetic Spectrum Text document. Each section should have a name and a wavelength range.

   **Opportunity for differentiation: Have some sections already labeled.*
3. Students label their copy of the electromagnetic spectrum in their student document and answer the questions before moving on to the next section.

**Station 3: Wavelength—Creating Waves**

1. Students look at their copy of the electromagnetic spectrum diagram. Using one string on their desk, students recreate waves that show high energy. With the second string, students recreate waves that show low energy.

   **Opportunity for differentiation: Create one of the waves for them to start or draw sets of waves on cards and have students choose.*
2. Students draw each set of waves on their student document.
3. Using the ruler, and either their string wave creation or drawing, students will measure from the top of one wave to the top of the next for the high energy wave and record the number. This is the wavelength. Students measure from the top of one wave to the top of the next for the low energy wave and record the distance.
4. Students answer the questions about the relationship between wavelength and energy.

**Station 4: Fluorescence**

1. Students write down the names of the items at the station on their data table.
2. Students describe the color and appearance of the items in normal light in the “Under Standard Light” column

of their data table.

**Opportunity for differentiation: Give students options of items to choose from.*

3. The teacher turns off the lights and turns on the lamp with the black light bulb. Students describe the color and appearance of the items in the "Under UV Light" column of their data table.
4. Students read the explanation of fluorescence and determine which items fluoresced.

**Final Model: Why do some things appear to glow (fluoresce) under UV light? (15 minutes)**

1. In the same pairs or small groups from the initial model stage, students revise their model to explain why the object looks normal under standard light, but appears to glow under UV light (page 11). Students can use words, pictures, or a combination of both to explain as thoroughly as they can.

   **Opportunity for differentiation: Review as a class what was learned in each section of the lesson before students begin their revisions.*

**Reflection on My Learning (10 minutes)**

1. Students complete a written reflection about their learning, selecting and responding to one question from each column (page 12).

## ONGOING LEARNING

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### About the Conservator

Lisa Ackerman is an Associate Conservator of Objects at the Art Institute of Chicago. In this role she condition checks and treats works of art that are three dimensional. She specializes in wooden artifacts and furniture and uses science to investigate objects in the museum's collection to uncover their history and prepare them for exhibition and storage. This includes learning about the object's past treatments, such as repairs and coatings that may have been applied, fixing breaks and sometimes removing harmful substances.

Ackerman advises students to expect to change paths a few times as they decide on a career. She began as an athlete–a figure skater–and decided to pursue science and conservation work when she wasn't selected for a professional skating show because she was told she was too tall. At first she was nervous about the advanced science classes she would need to take. She worked with a tutor to improve her skills and eventually graduated from the Art Conservation MA/CAS program at the State University of New York College at Buffalo. She hopes that more young people also consider pursuing science and find a career that they love.

## Possible Extensions

**Creative Expression**

- Create a drawing with highlighters. Once completed, look at what you drew under a black light bulb.

**For Further Study**

- Research other types of luminescence found on the electromagnetic spectrum chart to see how they work and how they are used.

## Explore the Collection

Explore the artworks featured in this lesson by clicking on the titles below. Access the museum's full collection by browsing the collections page at https://www.artic.edu/collection.

- Roman and Egyptian, *Jar*, unknown date
- Persion; Tepe Siyalk, *Beaker*, 2nd half of the 4th millennium BCE
- Italian, Rome, *Medal Cabinet with the Barberini Arms*, 1630-1634
  **Note: This piece is under conservation and has yet to go on view at time of writing.*

**Video Viewing and Reflection**

1. Ask the students to answer the following questions in a class discussion, small group, or in pairs:
    - Did you know that scientists work in some museums? *Answers vary*
    - What do you think they might do? *Answers vary*
2. *N/a*
3. Ask students to reflect on the following questions in writing, whole class discussion, or in pairs, sharing with a partner.
    - How does Lisa Ackerman's work relate to both art and science? *Answers vary but may include: Lisa uses UV light to identify the history of an object so that she can treat and repair artwork.*
    - What did you learn about her career path? What advice did she offer? *Answers vary*
    - What else did you learn that is new or surprising? *Answers vary*

**See, Think, Wonder Opening Activity**

*Answers vary but may include: Cracks or select areas in the objects are glowing under the UV light, which may indicate where an object has received conservation treatment.*

**Initial Model: Why do some things appear to glow (fluoresce) under UV light?**

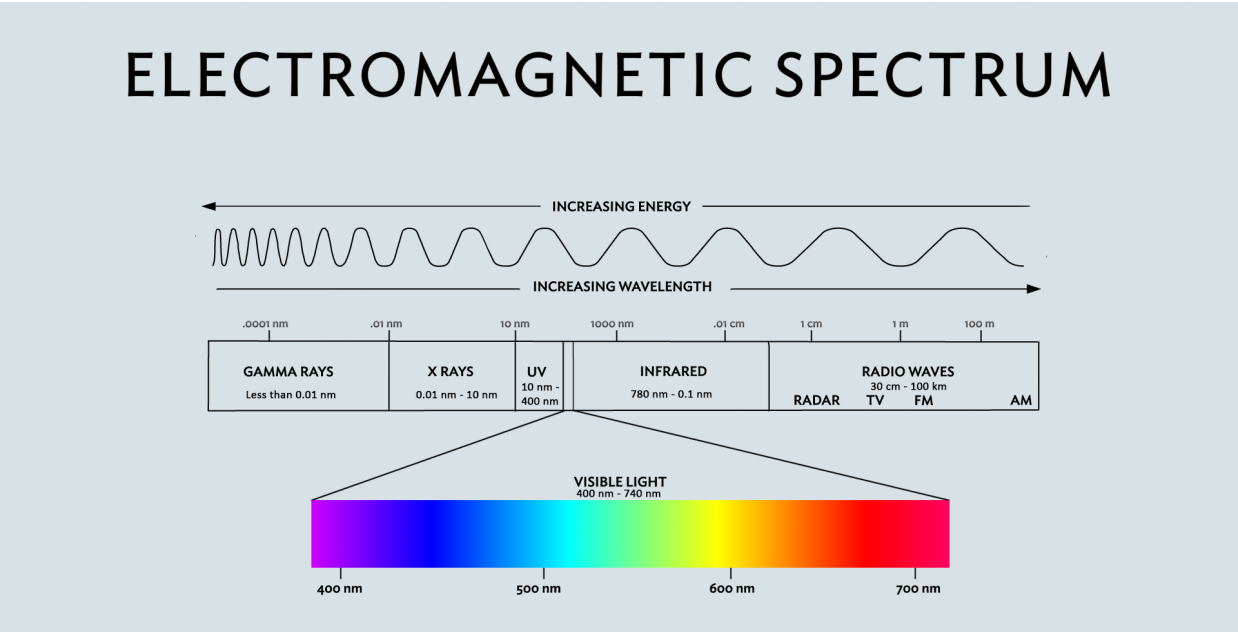
*Answers will vary as this is intended to be an educated guess. Answers will be revised later.*

**Station 1: Electromagnetic Spectrum Vocabulary**

*See preparation notes for Station 1.*

**Station 2: Electromagnetic Spectrum**

1. *N/a*
2. Match the correct name and wavelength range to each section of the document. *See preparation notes for Station 2 or the electromagnetic spectrum diagram below.*



3. Record the name and wavelength range on your electromagnetic spectrum below. *Answers should align with the electromagnetic spectrum diagram above.*
4. What types of electromagnetic radiation had you heard of before doing this activity? Explain how or where you encountered them. *Answers vary but may include: experiences with/at the doctor's office, sunglasses, sunscreen, radio, sci-fi movies, etc.*
5. What patterns do you notice on the electromagnetic spectrum as the energy changes? *Answers may vary but may include: As the energy increases, the waves become smaller.*
6. Write two questions you still have about the electromagnetic spectrum. *Answers vary*

**Station 3: Wavelength: Creating Waves**

1. *N/a*
2. *N/a*
3. Draw the waves you created in the appropriate box below. *Answers vary but should show waves close together in the high energy box and waves further apart in the low energy box.*
4. Scientists measure the distance between waves to determine wavelength. Using a ruler and either your string creation or drawing, measure the distance from the top of one wave to the top of the next wave in centimeters. *Answers vary but should show a shorter distance between waves in the high energy box and a longer distance between the waves in the lower energy box.*
5. What differences do you notice in how the high energy and low energy waves look? *Answers vary but may include: The distance between the high energy waves is shorter and the distance between the low energy waves are longer.*
   What similarities do you notice between the waves? *Answers may vary but may include: The waves are the same height.*
6. Wavelength is the distance from the top of one wave to the top of the next wave.
   Which type of wave has the longest wavelength? *Low Energy Waves*
7. Gamma Rays have the shortest wavelength on the electromagnetic spectrum.
   Do you think they are high energy or low energy waves? *High Energy Waves*
   Why did you choose this answer? *The higher the energy, the shorter the wavelength.*
8. Radio waves have the longest wavelength on the electromagnetic spectrum.
   Do you think they are high energy or low energy waves? *Low Energy Waves*
   Why did you choose this answer? *The lower the energy, the longer the wavelength.*
9. What do you notice about the waves as you move from Gamma rays to Radio waves? *The wavelength becomes longer.*

**Station 4: Fluorescence**

1. Write down the names of the items at the station in the first column of the data table. *Answers vary depending on the materials provided, but three should fluoresce and three should not.*
2. Look at all of the materials at the station under standard light and describe their colors and appearance. *Answers vary depending on the materials provided.*

3. Your teacher will turn off the standard lights and turn on the black light. Look at the materials and describe their colors and appearance. *Answers vary depending on the materials provided, but three should fluoresce and three should not.*
4. Fluorescence or the appearance of glowing happens when materials absorb radiation with short wavelengths, like UV light, and give off light with longer visible wavelengths.
   Which items did you see fluorescing under UV light? *Answers vary depending on the materials provided.*
5. UV light is 10 nm–400 nm. If an item fluoresces, what wavelength of light will it give off?
   *400 nm–740 nm*
   Why did you choose this answer? *The wavelength of light the fluorescing item will give off will be longer, so the answer is 400 nm–740 nm as those wavelengths are longer than the UV light.*

**Final Model: Why do some things appear to glow (fluoresce) under UV light?**

*Revisions may vary but should include: Some things appear to glow (fluoresce) under UV light because they are absorbing the shorter wavelengths of the UV light and emitting light with longer wavelengths.*

**Reflection on My Learning**

*Answers vary*

## ADDITIONAL TERMS FROM THE VIDEO

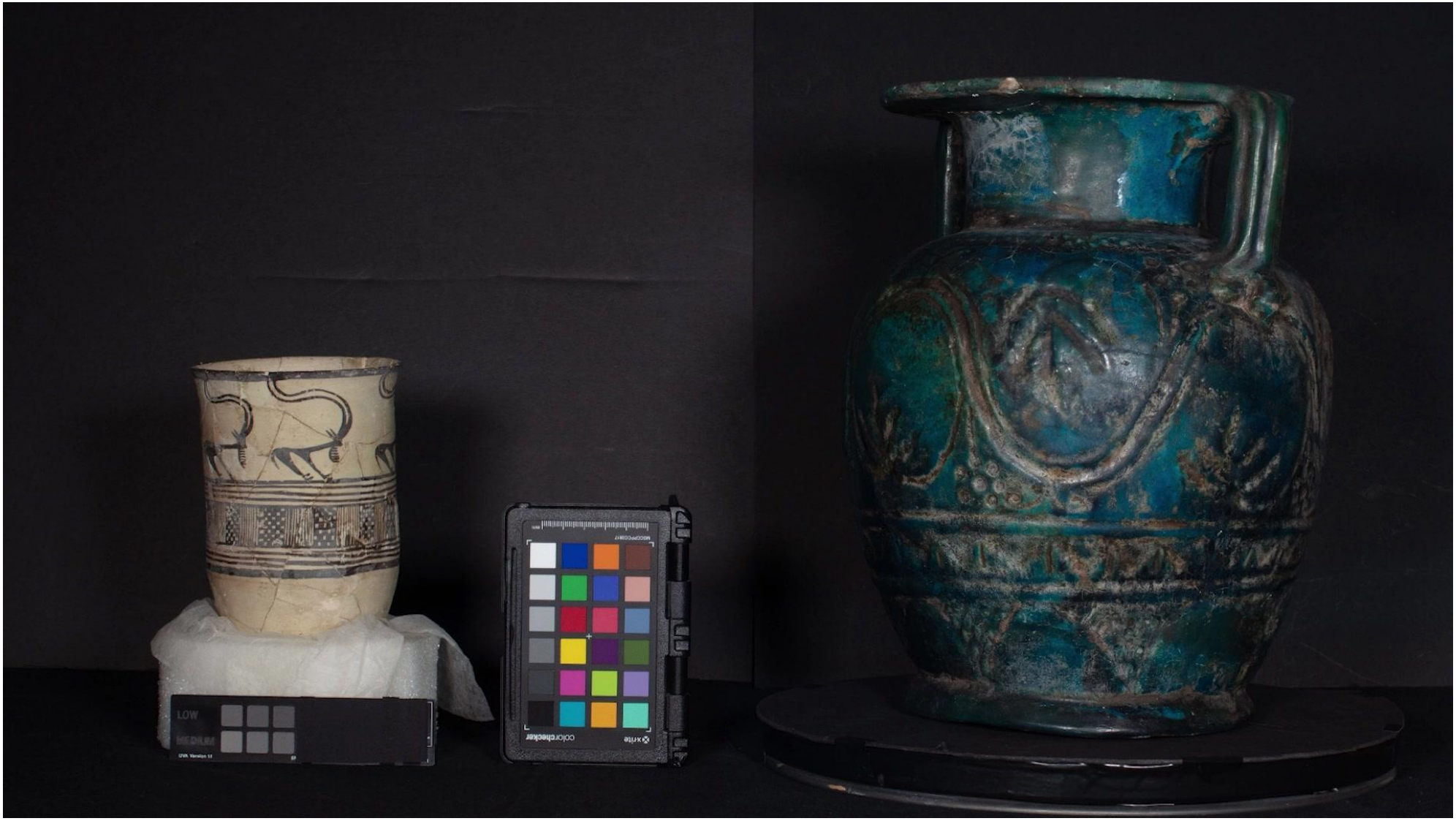
**Fluorescence:** Occurs when a material absorbs radiation with short wavelengths (like ultraviolet light) causing it to emit radiation with longer wavelengths (visible light or glow).

**Shellac**: A natural coating that fluoresces orange.

**Ultraviolet Radiation:** A form of electromagnetic radiation with wavelengths shorter than visible light.

**Visible Spectrum**: The part of the electromagnetic spectrum the human eye can see.

UNDER STANDARD LIGHT

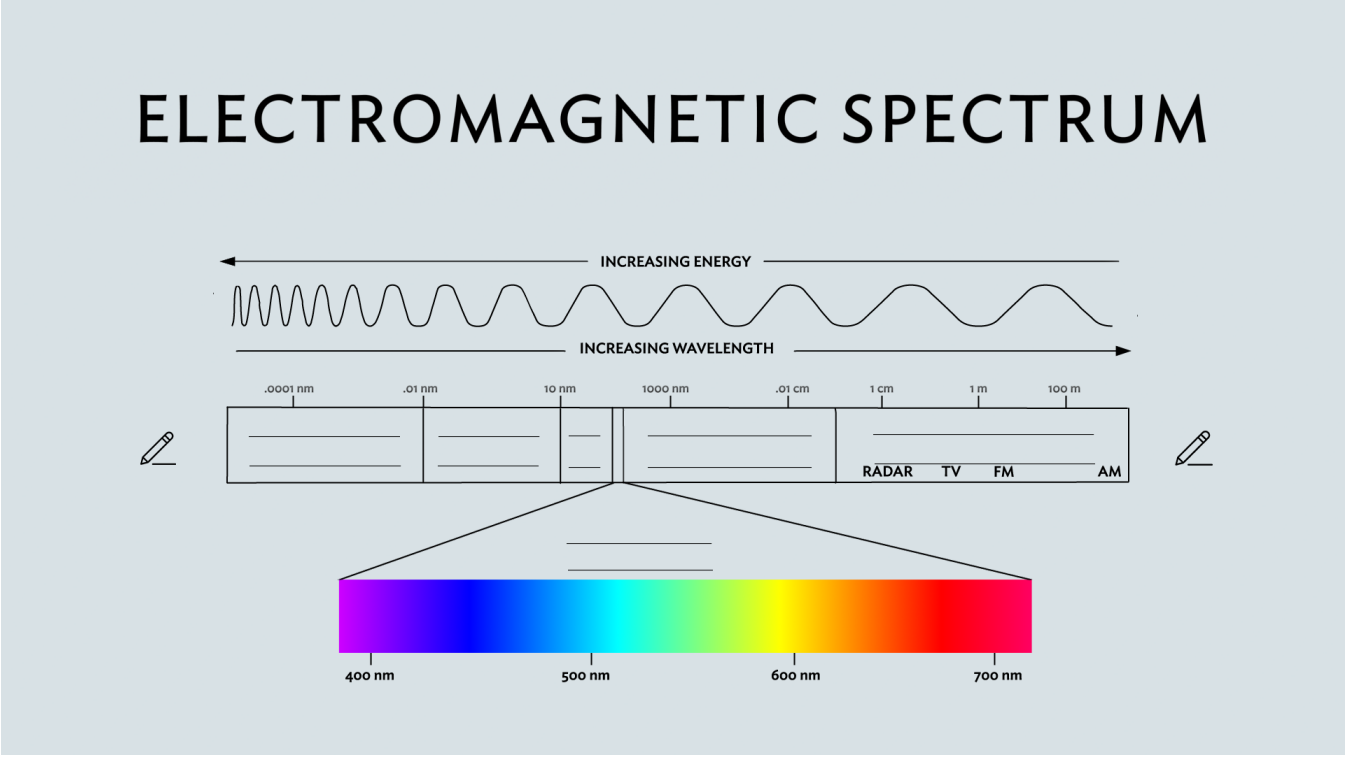


UNDER UV LIGHT

ELECTROMAGNETIC SPECTRUM VOCABULARY

| | |
|---|---|
| **Electromagnetic Spectrum** | **All types of electromagnetic waves placed in order of increasing frequency/energy.** |
| **Electromagnetic Radiation** | **A type of energy wave that transfers energy.** |
| **Visible Light** | **A form of electromagnetic radiation that humans can see.** |
| **Ultraviolet Light** | **A form of electromagnetic radiation with wavelengths shorter than visible light that humans cannot see.** |
| **Frequency** | **The number of times an electromagnetic wave has a complete set of back and forth vibrations in a specific amount of time.** |
| **Wavelength** | **The distance between two identical points on back-to-back waves.** |

# ELECTROMAGNETIC SPECTRUM TEXT




- **Radio:** Electromagnetic radiation with the lowest energy on the spectrum and longest wavelength that humans cannot see. Humans use this type of electromagnetic radiation for communication.
- **Infrared:** Electromagnetic radiation with the second lowest energy on the spectrum and wavelengths from 780 nanometers to 0.1 millimeters that humans cannot see. Humans use this type of electromagnetic radiation for heat sensors and night vision.
- **Visible:** Electromagnetic radiation with wavelengths from 400 nanometers to 700 nanometers that humans can see. This type of electromagnetic radiation is visible to humans in many colors.
- **Ultraviolet**: Electromagnetic radiation with wavelengths from 10 nanometers to 400 nanometers that humans cannot see. Humans use this type of electromagnetic radiation to kill bacteria. This is the type of electromagnetic radiation that causes skin damage in humans.
- **X-ray:** Electromagnetic radiation with second highest energy and wavelengths from 0.01 nanometers to 10 nanometers that humans cannot see. Humans use this type of electromagnetic radiation to see bones and other parts inside the body.
- **Gamma ray:** Electromagnetic radiation with the highest energy and shortest wavelength that humans cannot see. Humans use this type of electromagnetic radiation for treating disease and creating nuclear energy.