

NEATEC Learning Module

Northeast Advanced Technological Education Center

Thin Films

Middle Level - Grades 6-8



**Northeast Technological Education Center (NEATEC)
Hudson Valley Community College**

STEM Introduction Topic

Thin Films

Middle Level - Grades 6-8

NEATEC Mission Statement:

“The Northeast Advanced Technological Education Center (NEATEC) is a Regional Center for Semiconductor and Nanotechnology Education funded by the National Science Foundation (NSF DUE #1003574) to serve as a critical, sustainable resource to create and maintain a skilled technical workforce for the semiconductor and nanotechnology industries in New York State and Western New England. Through an extensive network of community college, university, and industry partners, NEATEC will identify the essential technician competencies and skills required by such a workforce. NEATEC will develop curricular components and delivery methods to impart those skills to students. NEATEC will also create and disseminate educational materials to support curricula implementation at its community college and high school partners and provide professional development activities for K-12 schools and community college faculty. Lastly, through partner internships, co-ops, shadowing opportunities and outreach activities, NEATEC will educate current and future students regarding technological career pathways and expand the pipeline of K-12 students interested in semiconductor and nanotechnology career options.”

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What is STEM?

With all the acronyms that determine hundreds of different areas of education, it is easy to confuse them all. Since 2001, the letters STEM have been a normal part of educational vocabulary.

The acronym STEM stands for Science, Technology, Engineering, and Mathematics. This program was started by Judith A. Ramaley, the former director of the National Science Foundation's education and human-resources division. This approach to education is designed to revolutionize the teaching of subject areas such as mathematics and science by incorporating technology and engineering into regular curriculum by creating a "meta-discipline."

There is more; STEM Education attempts to transform the typical teacher-centered classroom by encouraging a curriculum that is driven by problem-solving, discovery, exploratory learning, and requires students to actively engage a situation in order to find its solution.

Science, technology, engineering and mathematics (STEM) education often has been called a meta-discipline, "the creation of a discipline based on the integration of other disciplinary knowledge into a new 'whole'. This interdisciplinary bridging among discrete disciplines is now treated as an entity, known as STEM (Morrison, 2006)." STEM education offers students one of the best opportunities to make sense of the world holistically, rather than in bits and pieces. STEM education removes the traditional barriers erected between the four disciplines, by integrating them into one cohesive teaching and learning paradigm. Morrison and others have referred to STEM as being an interdisciplinary approach. "STEM education is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy (Tsupros, 2009)."

What is a NEATEC Learning Module (NLM)?

A NEATEC Learning Module (NLM) is self-contained unit that can be incorporated into existing science, math, and technology classes to supplement and enhance the content and the laboratory activities of the class. Each module includes all or some of the following sections:

- Background information about the topic of the unit
- A teacher's guide
- A student's guide
- List of lab materials for laboratory activities
- A list of teacher's and student's resources
- Power Point slides

The set of modules offered by NEATEC are divided into five categories based on the level of understanding of the participants:

1. NLM K-2: These are units suitable for students in grades Kindergarten to 2nd grades.
2. NLM 3-5. These are units suitable for students in grades 3rd to 5th grades.
3. NLM 6-8. These are units suitable for students in grades 6th to 8th grades.
4. NLM 9-12. These are units suitable for students in grades 9th to 12th grades.
5. NLM for Community Colleges.

NEATEC Learning Modules include topics on Nanotechnology, Semiconductors, Photovoltaic, Alternate Energy, Mathematics, General Science and Technology.

Grade Level: Middle School Level - Grades 6-8

Essential Questions:

- How can we measure thickness without the use of a ruler?
- How do light waves and color provide clues for measuring?
- Does the structure and orientation of a thin film affect its thickness?

Objectives:

- Students will be able to understand wavelengths of light determined by color and thickness of thin film.
- Students will be able to recognize the relationship between diameter and radius, sphere and hemisphere, and calculate surface area and volume of hemisphere.

New York State Curriculum Standards

New York State Standards are subject to change and will be modified accordingly.

New York State ELA Common Core Learning Standards

Reading Standards for Informational Text

- RI.1 Cite textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text.
- RI.2 Determine a central idea of a text and how it is conveyed through particular details; provide a summary of the text distinct from personal opinions or judgments.
- RI.3 Analyze in detail how a key individual, event, or idea is introduced, illustrated, and elaborated in a text (e.g. through examples or anecdotes).
- RI.6 Determine an author's point of view or purpose in a text and explain how it is conveyed in the text.
- RI.7 Integrate information presented in different media or formats (e.g., visually, quantitatively) as well as in words to develop a coherent understanding of a topic or issue.

Writing Standards

- W.1 Write arguments to support claims with clear reasons and relevant evidence.
- W.1.a. Introduce claim(s) and organize the reasons and evidence clearly.
- W.1.c. Use words, phrases, and clauses to clarify the relationships among claim(s) and reasons.

Speaking and Listening Standards

- SL.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade level topics, texts, and issues, building on others' ideas and expressing their own clearly.
- SL.1.b. Follow rules for collegial discussions, set specific goals and deadlines, and define individual roles as needed.
- SL.1.c Pose and respond to specific questions with elaboration and detail by making comments that contribute to the topic, text, or issue under discussion.
- SL.1.d Review the key ideas expressed and demonstrate understanding of multiple perspectives through reflection and paraphrasing.
- SL.1.e Seek to understand and communicate with individuals from different perspectives and cultural backgrounds
- SL.2 Interpret information presented in diverse media and formats (e.g., visually, quantitatively, orally) and explain how it contributes to a topic, text, or issue under study.

New York State Mathematics Common Core Learning Standards

Expressions and Equations

- 6.EE.6 Use variables to represent numbers and write expressions when solving a real-world or mathematical problem; understand that a variable can represent an unknown number, or, depending on the purpose at hand, any number in a specified set.
- 7.EE.4 Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities.
- 8.EE.3 Use numbers expressed in the form of a single digit times a whole-number power of 10 to estimate very large or very small quantities, and to express how many times as much one is than the other.

For example, estimate the population of the United States as 3 times 108 and the population of the world as 7 times 109, and determine that the world population is more than 20 times larger.

Geometry

- 6.G.4 Represent three-dimensional figures using nets made up of rectangles and triangles, and use the nets to find the surface area of these figures. Apply these techniques in the context of solving real-world and mathematical problems.
- 7.G.1 Solve problems involving scale drawings of geometric figures, including computing actual lengths and areas from a scale drawing and reproducing a scale drawing at a different scale.
- 8.G.9 Solve real-world and mathematical problems involving volume of cylinders, cones, and spheres. Know the formulas for the volumes of cones, cylinders, and spheres and use them to solve real-world and mathematical problems.

New York State Science Standards

Standard 4: Physical Setting

- 4.2 Many of the phenomena that we observe on Earth involve interactions among components of air, water, and land.
- 4.3 Matter is made up of particles whose properties determine the observable characteristics of matter and its reactivity.
- 4.4 Energy exists in many forms, and when these forms change, energy is conserved.
- 4.5 Energy and matter interact through forces that result in changes in motion.

Next Generation Science Standards

MS-PS1-3 Matter and its Interactions

Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.

MS-PS3-5 Energy

Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

MS-PS4-2 Waves and Their Applications in Technologies for Information Transfer

Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

New York State Technology Standards

Standard 5: Technology Education

5.2 Tools, Resources and Technological Process

Key Idea: Technological tools, materials, and other resources should be selected on the basis of safety, cost, availability, appropriateness, and environmental impact; technological processes change energy, information, and material resources into more useful forms.

5.5 History and Evolution of Technology

Key idea: Technology has been the driving force in the evolution of society from an agricultural to an industrial to an information base.

5.6 Impacts of Technology

Key Idea: Technology can have positive and negative impacts on individuals, society, and the environment and humans have the capability and responsibility to constrain or promote technological development.

Special Education Accommodations & Modifications:

- Use provided flash drive with audio files of student **Activity Handouts** for use with struggling readers prior to beginning lab.
- Teacher may use a camera to photograph bubbles on a dark background for students to inspect.
- Dark backgrounds help students to identify colors on film.
- Floor may be covered to avoid slips or falls.

Module Guide

Thin Films

Materials supplied in kit: (Kit designed for a class of 33 students/6 groups)

33 Goggles
1 Gallon of distilled water (3.8 L)
4 Cups of Dawn® dish soap (0.95 L)
2 Cups of glycerin (0.48 L)
7 Cotton gloves
7 Pipettes
105 Straws
7 Plastic tubs for bubble solution
7 Clear trays for hemisphere Investigation
14 Cups
35 Pre-cut pieces of string (20” in length)
14 Metric rulers (clear work best)
42 Disposable absorbent pads
7 Sheets laminated paper (one side black/ one side white)
7 Sets Activity Handouts A, B, C
NEATEC Module Book
NEATEC Flash Drive

Materials **NOT** supplied in kit: (Required for a class of 33 students)

7 Sets Colored Pencils
7 Calculators (w/ π key)
7 Sheets of copier paper
Paper towels (for clean-up)

Pre-Module set-up - **24 hours in advance**

- ✓ *Prepare the Super Bubble Solution at least one day prior to use. Leave solution in an open container. It becomes more resilient if it “ages.”*
- ✓ *Super Bubble Solution may be used for Lab 1 (Flim Flam) with multiple sections throughout one school day. Bubble solution will degrade and used solution should be **DISPOSED** of at the end of the day.*

*Please refer to the “Kit Lending Supplies” sheet
for materials which must be returned (non-consumables)*

*Please complete feedback survey at
<https://www.surveymonkey.com/s/NEATECLMSurvey>*

Day 1

Materials:

- 7 sets Activity Handouts A, B, C
- Flash Drive with the electronic NEATEC Learning Module, audio files and “Thin Films” PowerPoint presentation

Pre-Lesson Set-up:

- At least one day prior to lesson. Prepare Super Bubble Solution (for use on Days 2, 3, 4)

Small batch (up to 4 students)	Large batch (class – 33 students)
1 Cup of distilled water (240 mL) <i>*Reserve small quantity (2 drops per group)*</i>	1 Gallon distilled water (3.8 L) <i>*Reserve small quantity (2 drops per group)*</i>
2 Tablespoons Dawn® dish soap (30 mL)	4 Cups Dawn® dish soap (0.95 L)
1 Tablespoon of glycerin (15 mL)	2 cups of glycerin (20 mL)

- ✓ *Prepare the above solution at least one day prior to use. Leave solution in an open container. It becomes more resilient if it “ages.”*
- ✓ *Super Bubble Solution may be used for Lab 1 (Flim Flam) with multiple sections throughout one school day. Bubble solution will degrade and used solution should be **DISPOSED** of at the end of the day.*

- Photocopy “Thin Films Preview” (1 per student)

Procedure:

1. Show PowerPoint presentation with embedded videos and discuss
2. Pre-Lab Discussion:
 - How can we measure the thickness of a bubble?
 - Will a ruler help?
 - What if it has tiny size differences?
3. Embedded Video Links
 - Intro Video: “**What is Thin Film?**”
http://www.youtube.com/watch?v=UcYSOp_g8TI (1:50 minutes)
 - “**Measuring Thin Films**”
<http://www.youtube.com/watch?v=kLqcWfft5pU> (2:35 minutes)
4. Create lab groups. Provide students **Activity Handouts A, B and C** to read and discuss.
5. Complete “**Thin Films Preview**”

Materials:

Per student:

- Goggles
- Straws (2)
- String or crochet thread

Per group (6-7 students):

- Super Bubbles Solution
- Colored pencils
- Plastic tub for bubble solution
- Paper towels
- 1-2 Disposable absorbent pads
- 7 Sheets laminated paper (one side black/ one side white)
- Activity Handouts B and C

Pre-Lesson Set-up:

- Photocopy “**Lab 1: Build your own “Thin Film Flim Flam”**” (1 per student)
- Cover work space with absorbent pad
- Distribute group materials

Procedure:

1. Complete lab activity - “**Lab 1: Build your own “Thin Film Flim Flam”**”

Teacher Note: Fluorescent lighting fixtures tend to illuminate rectangular sections of the bubble. Shade the bubble with a sheet of copy paper to reveal more dramatic colors!

2. Respond to investigative questions

Post-Activity Question:

Why did the bubble seem to change colors and surface patterns?

Answer: The bubble was not in equilibrium. The fluid was draining from the top to the bottom of the Flim Flam.

Materials:

Per student:

- Goggles
- Straws
- Glove (1 per group)

Per group (6-7 students):

- Container for bubble solution (cup)
- Super Bubbles Solution
- Copier paper
- Paper towels
- 1-2 Disposable absorbent pads
- Colored pencils

Pre-Lesson Set-up:

- Photocopy “**Lab 2: Measuring the Thickness of Bubbles**” (1 per student)
- Cover work space with absorbent pad
- Distribute group materials

Procedure:

1. Complete lab activity - “**Lab 2: Measuring the Thickness of Bubbles**”

Post-Activity Question:

By watching color patterns on the bubble, can you predict when it is about to burst?

Answer: As the water in the bubble drifts towards the bottom, and the bubble gets thinner, the colors begin to vanish, and the bubble may look speckled moments before it breaks.

Materials:

Per student:

- Goggles
- Straws

Per group (6-7 students):

- Super Bubbles Solution
- Container for bubble solution (cup)
- 1 Clear tray
- 1 Pipette
- 1-2 Disposable absorbent pads
- Metric ruler
- Calculator (w/ π key)

Pre-Lesson Set-up:

- Photocopy “**Lab 3: Hemispheres!**” (1 per student)
- Cover work space with absorbent pad
- Distribute group materials

Procedure:

1. Complete lab activity - “**Lab 3: Hemispheres!**”

Post-Activity Questions:

What happens when one distilled water droplet hits a bubble?

Answer: The bubble hemisphere walls collapse once surface tension is broken and the hemisphere walls hit the surface of the solution before the droplet hits the solution.

Teacher Note: The age of bubble solution will result in variations in time needed for the surface tension to be broken.

How can thin films help us determine where the hole is in an inflated tire tube?

Answer: If you coat the tube with a bubble solution, air will escape creating visible bubbles.

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Teacher Resources

Resources:

- <http://www.stevespanglerscience.com/lab/experiments/bouncing-bubble>
- <http://www.stevespanglerscience.com/lab/experiments/amazing-square-bubble>
- http://www.physics.mun.ca/~yakov/paperADA_soap_bubbles_AJP_2011.pdf
- http://www.exploratorium.edu/ronh/bubbles/bubble_colors.html
- <https://eee.uci.edu/programs/gchem/RDGVISSpec.pdf>
- http://www.nisenet.org/sites/default/files/catalog/uploads/5398/materialsfilm_guide_15nov10_0.pdf

Assessment:

- Students will be formatively assessed during group discussions. Students' observations and the data they record will be used as a summative assessment of students' learning and the extent to which they met the lesson objectives.

Extensions:

Have students express the thickness of the film in scientific notation.

Answers will vary.

How do different shapes affect color patterns?

Answers will vary by shape. There is no wrong "observed" answer.

Can you stop the color movement on the film?

Answer: No, you can slow the movement and/or inhibit the banding

Why does the bubble solution form into a sphere?

Answer: The surface tension of the water provides the necessary wall tension for the formation of bubbles with water. The tendency to minimize that wall tension pulls the bubbles into spherical shapes (LaPlace's Law).

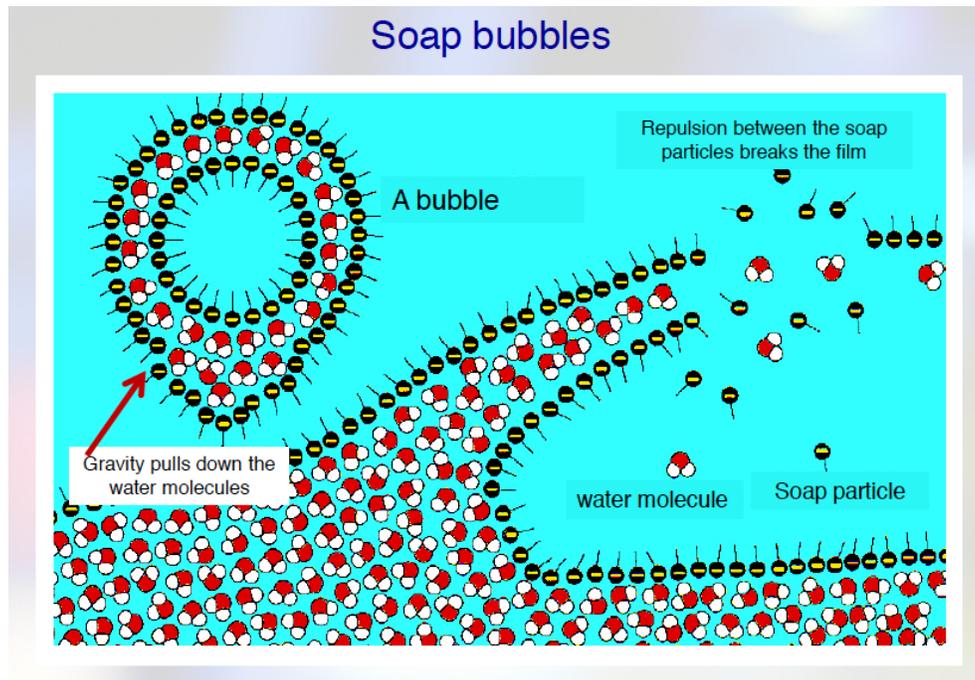
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- <http://www.gamonline.com/catalog/colortheory/visible.php>
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Thin Films - Measuring the Thickness of Bubbles! - Activity Handout - A

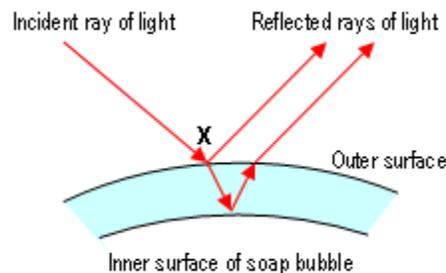
Background Information:

A thin film is a layer of a material that can be as thin as a fraction of a nanometer thick. Soap bubbles are a great example of thin films! They are a volume of air surrounded by a thin layer of soap and water. By recording our visual observations of the colors seen on the surface of the film, we are able to infer the thickness.



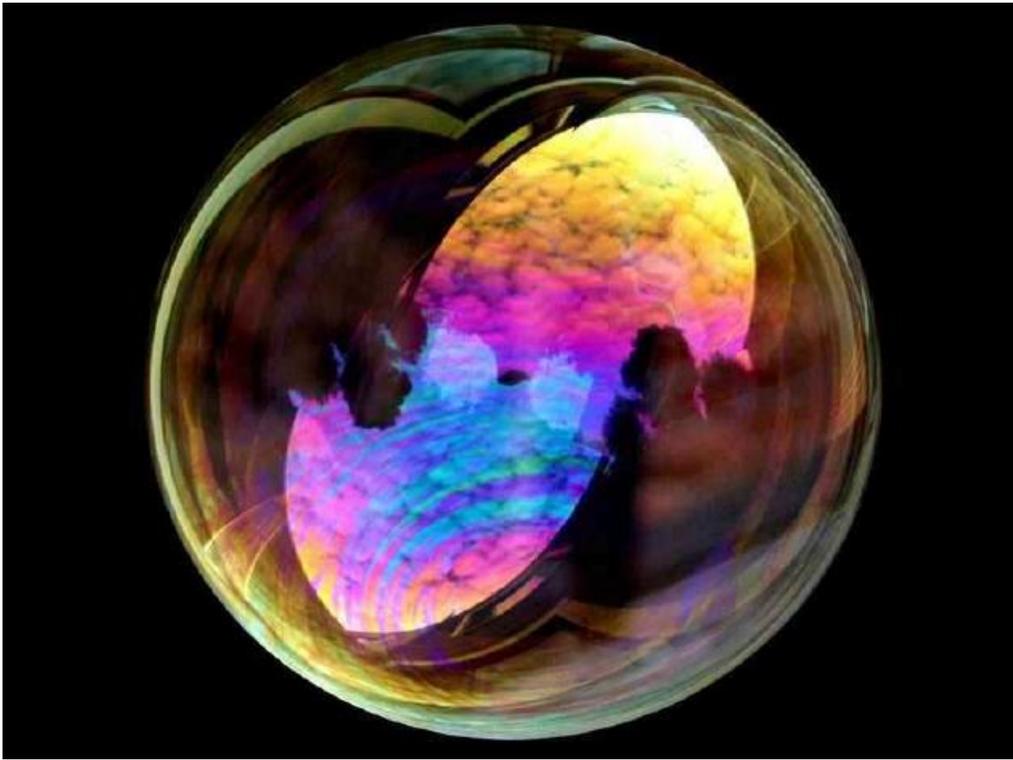
So what happens to the light waves to create these patterns? A few possibilities occur. Some waves bounce off the outside wall of the bubble, others bounce off the inner wall of the bubble, and others bounce around inside the bubble (from 1 to N times). The interference from these different paths changes our answer.

One ray of light, the incident ray, enters the bubble. When it leaves as reflected rays of light, there is more than one. That affects our results because the wavelengths of light combine to give off different colors. This is all because of the different distances traveled. Something as thin as the wall of a bubble is determining the colors we see!

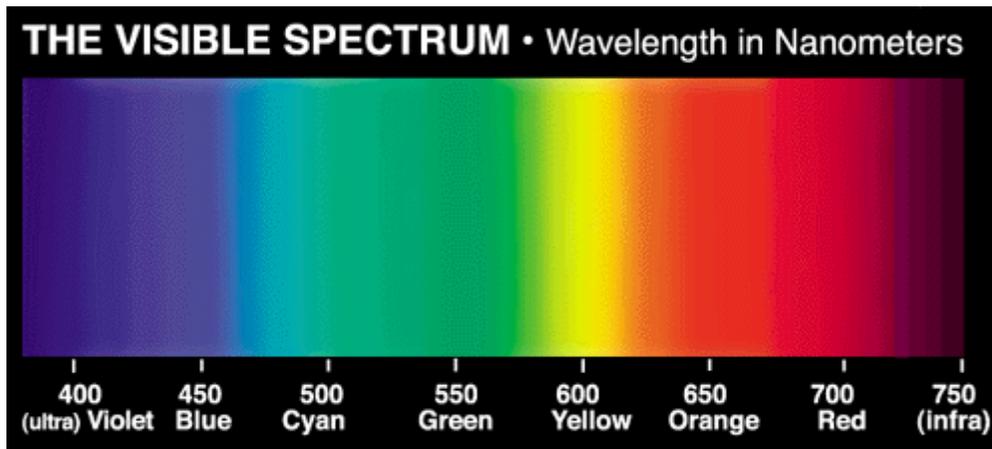


Thin Films - Measuring the Thickness of Bubbles! - Activity Handout - B

When looking at bubbles, similar to oil on water, we see swirls of color. These swirls are visible because they are thick enough to reflect visible light.



Each color of the light spectrum has a different wavelength. When light hits the bubble, it is reflected. The colors witnessed give us clues as to how thick the film is.



Thin Films - Measuring the Thickness of Bubbles! - Activity Handout - C

Watch the top of the bubble! You'll notice that after a few moments, it turns dark. This is because the surface is so thin it does not reflect visible light. At this point, the surface is only about 25 nanometers (or a millionth of an inch) thick. Guess what's about to happen.



Observe the colors of the light spectrum due to interference, and reference to the chart below. Compare the perceived color (the light you actually see) with the color that was absorbed and its wavelength.

We will use this chart on the worksheet.

Absorbed Wavelength (nm)	Absorbed Color	Perceived (Transmitted) Color
400	violet	green - yellow
450	indigo	yellow
480	blue	orange
490	blue-green	red
530	green	purple
570	yellow-green	dark blue
600	orange	blue
650	red	green

Name _____

Date _____

Period _____

Thin Films - Measuring the Thickness of Bubbles!

Thin Films Preview

Vocabulary:

Equilibrium: _____

Hemispheres: _____

Light Spectrum: _____

Sphere: _____

Thin Film: _____

Questions:

Why are equilibrium and balance important to thin films?

Where can thin films be found in nature?

Lab 1: Build your own “Thin Film Flim Flam”

Investigation Question:

What colors will you see in your Thin Film Flim Flam?

Hypothesis:_____

Materials:

- Goggles
- Super Bubbles Solution
- Straws (2)
- Colored Pencils
- Plastic tub for bubble solution
- String or crochet thread
- Paper towels
- 7 Sheets laminated paper (one side black/one side white)

Procedure:

1. Feed the string through both straws. Tie a knot in the string so it forms a loop. If you gently pull on the straws, a square/rectangle should result.
2. Pull knot inside straw.
3. Dip the entire assembly in your bubble solution. Make sure the strings, straws, and your finger tips are covered in the liquid.

Investigative Questions:

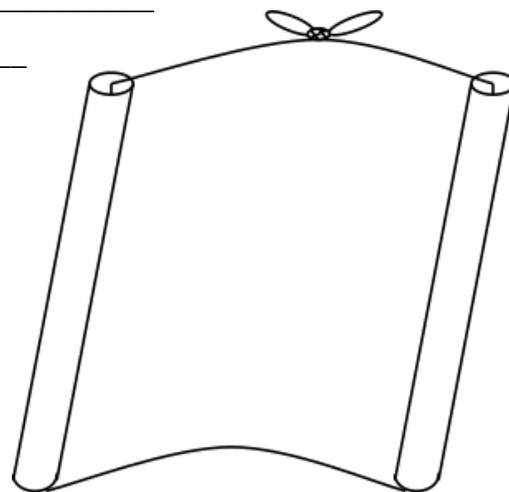
1) When you hold the Flim Flam vertically, what do you see?

2) Draw your results on the diagram to the right. Label all colors.

3) Dip your Flim Flam in the solution.

4) This time hold it horizontally, like a table top.

How do the color patterns behave?



5) What differences do you notice when holding the instrument vertically vs. horizontally?

6) How does rotating the Flim Flam affect the bubble's colors? Does it last longer?

7) Blow VERY gently into the Flim Flam. How does that change the color patterns?

Just for fun!

This instrument can be used to make giant bubbles. Apply solution to the straws and string. Using a sweeping motion, force air into the rectangle, and then trap the bubble by bringing the straws together.

- What is the biggest bubble you can make?

Lab 2: Measuring the Thickness of Bubbles

Investigative Question:



How can we measure the thickness of bubbles without using a ruler?

Hypothesis:_____

Materials:

- Goggles
- Super Bubbles Solution
- Straws (1 per student)
- Container for bubble solution (cup)
- Glove (1 per group)
- Copier paper
- Paper towels
- Colored pencils

Procedure:

In this lab we will be experimenting with bubbles! Follow the **procedures** below and complete your worksheet.
Hint: The colors are easiest to see on a black background.

1. One student in the group put on the glove.
2. Use the straw to blow a bubble.
3. Catch the bubble in the gloved hand.
4. List all of the colors that you see in the bubbles.

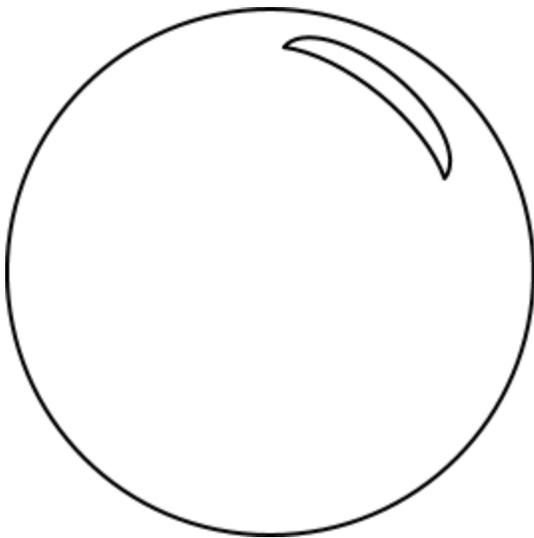


Record your observations for three separate bubbles:

Hint: Hold a sheet of tented copier paper over the bubble to shade it from the light and reveal more dramatic colors!

	Bubble 1	Bubble 2	Bubble 3
What is the most common color?			
What is the approximate diameter of the bubble in cm?			

In the bubble diagram below, use colored pencils to draw the pattern from one of your bubbles. Label the diagram's colors.



Visible Colors:	Thickness:
green-yellow	400nm
yellow	450nm
orange	480nm
red	490nm
purple	530nm
dark blue	570nm
blue	600nm
green	650nm

Does the size of the bubble determine what colors you see? _____

Where do the thicker layers occur? _____

How can you control the rate of “swirling” in the bubble? _____

Bonus:

Why does the bubble solution form into a sphere?

Lab 3: Hemispheres

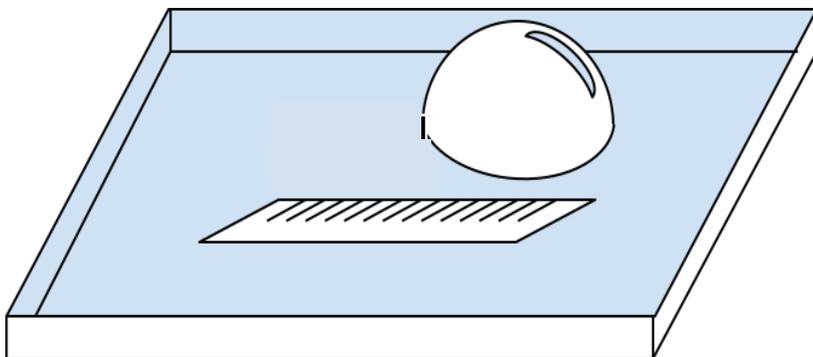
Investigative Question:

How do the sizes of a sphere and a hemisphere compare?

Hypothesis: _____

Materials:

- Goggles
- Super Bubbles Solution
- Straws
- Pipette
- Container for bubble solution (cup)
- Clear tray
- Metric ruler
- Calculator (w/ π key)



Procedure:

Now let us mathematically investigate our bubbles.

1. Put a ruler underneath the clear tray, so you can read it.
2. Dip the end of the straw into the solution, and blow one bubble onto the tray. Be sure the bubble stays on the tray. Slowly move the tray or bubble so the bubble lines up with the zero mark of the ruler.

Measure and record the diameter of the bubble. _____cm

3. Quickly, dip the ruler in solution (so it won't pop the bubble). Insert the ruler into the bubble, and measure the height of the hemisphere.

Record the height you measured. _____cm

How does the diameter of the bubble relate to the height of the bubble? Why?

How does the bubble relate to a sphere? _____

The volume of a sphere is $V = \frac{4}{3} \pi r^3$

So, the **volume** of a hemisphere is: _____

Now using your measurements, calculate the volume of your bubble.

The surface area of a sphere is $SA = 4 \pi r^2$

So, the **surface area** of a hemisphere is: _____

Now calculate the surface area of your bubble.

Using a pipette, carefully release one drop of distilled water onto the surface of the bubble.

Document your observations:

ANSWER KEY**Thin Films Preview****Vocabulary:****Equilibrium:**

The state when a substance is balanced out between two areas evenly and there is not a greater density of the substance in one area and a lower density in another.

Hemispheres:

The half of a sphere.

Light Spectrum:

The portion of the electromagnetic spectrum that is visible to humans.

Sphere:

A round solid figure, or its surface, with every point on its surface equal distance from its center

Thin Film:

A layer of material ranging from fractions of a nanometer (monolayer) to several micrometers in thickness. Electronic semiconductor devices and optical coatings are the main applications benefiting from thin film construction.

Questions:

Why are equilibrium and balance important to thin films?

If there is no equilibrium/balance you cannot control the size and thickness of the film.

Where can thin films be found in nature?

Any iridescent color found in nature, like bird feathers, sea shells, butterfly wings, and beetle shells are examples of thin films.

ANSWER KEY**Lab 1: Build your own “Thin Film Flim Flam”****Investigation Question:**

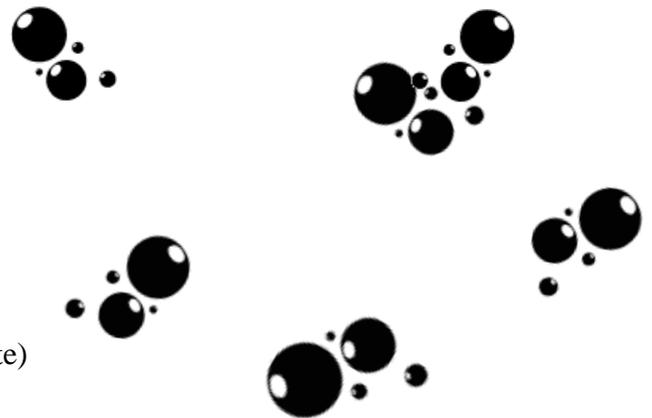
What colors will you see in your Thin Film Flim Flam?

Hypothesis:

Answers will vary, but a good hypothesis might say we will see a wide range of colors because the film thickness is going to vary from place to place

Materials:

- Goggles
- Super Bubbles Solution
- Straws (2)
- Colored Pencils
- Plastic pan for bubble solution
- String or crochet thread
- Paper towels
- 7 Sheets laminated paper (one side black/one side white)

**Procedure:**

1. Feed the string through both straws. Tie a knot in the string so it forms a loop. If you gently pull on the straws, a square/rectangle should result.
2. Pull knot inside straw.
3. Dip the entire assembly in your bubble solution. Make sure the strings, straws, and your finger tips are covered in the liquid.

Investigative Questions:

1. When you hold the Flim Flam vertically, what do you see?

The color patterns line up when it is vertical. The lines of color become wider at the top and thinner toward the bottom.

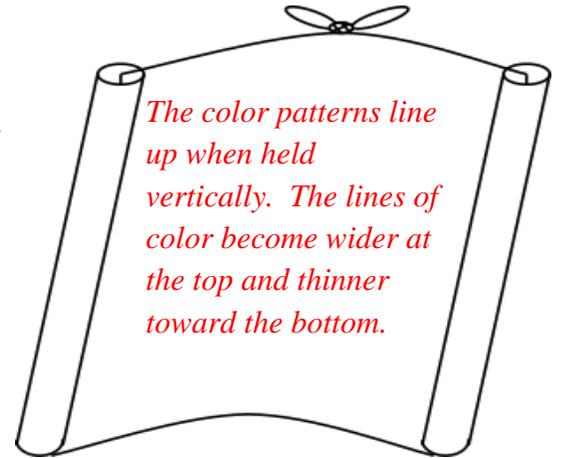
2. Draw your results on the diagram to the right. Label all colors.

3. Dip your Flim Flam in the solution.

4. This time hold it horizontally, like a table top.

How do the color patterns behave?

The color patterns swirl when it is held horizontally.



5. What differences do you notice when holding the instrument vertically vs. horizontally?

The colors swirl when the straws are horizontal (PARALLEL to the floor) and lineup when the straws are vertical (PERPENDICULAR to the floor).

6. How does rotating the Flim Flam affect the bubble's colors? Does it last longer?

It keeps them swirling. Yes (because it distributes the solution evenly without allowing any one part of it to become thinner than the rest which would result in it breaking the surface tension).

7. Blow VERY gently into the Flim Flam. How does that change the color patterns?

It pushes the swirls around the surface of the film.

Just for fun!

This instrument can be used to make giant bubbles. Apply solution to the straws and string. Using a sweeping motion, force air into the rectangle, and then trap the bubble by bringing the straws together.

- What is the biggest bubble you can make?

ANSWER KEY**Lab 2: Measuring the Thickness of Bubbles****Investigative Question:**

How can we measure the thickness of bubbles without using a ruler?

Hypothesis:

Answers will vary, but a good hypothesis might say we can observe the colors of the film that make up bubbles and infer the thickness because when light hits the bubble film, different colors are transmitted depending on the film thickness.

Materials:

- Goggles
- Super Bubbles Solution
- Straws (1 per student)
- Container for bubble solution (cup)
- Glove (1 per group)
- Copier paper
- Paper towels
- Colored pencils

Procedure:

In this lab we will be experimenting with bubbles! Follow the **procedures** below and complete your worksheet.
Hint: The colors are easiest to see on a black background.

1. One student in the group put on the glove.
2. Use the straw to blow a bubble.
3. Catch the bubble in the gloved hand.
4. List all of the colors that you see in the bubbles.



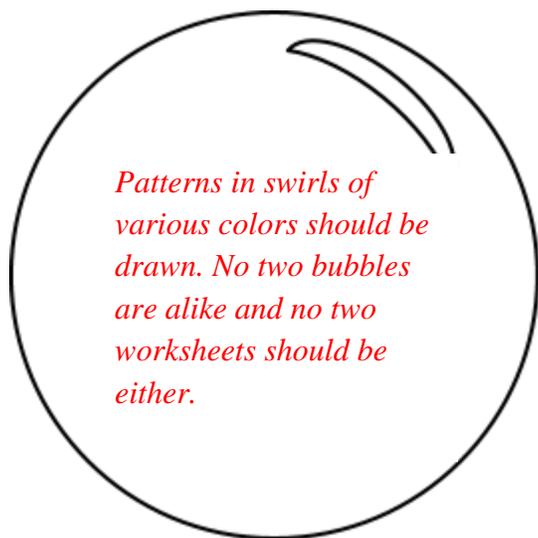
Students will notice an array of the visible color spectrum

Record your observations for three separate bubbles:

Hint: Hold a sheet of tented copier paper over the bubble to shade it from the light and reveal more dramatic colors!

	Bubble 1	Bubble 2	Bubble 3
What is the most common color?			
What is the approximate diameter of the bubble in cm?	<i>Answers will vary</i>		

In the bubble diagram below, use colored pencils to draw the pattern from one of your bubbles. Label the diagram's colors.



Visible Colors:	Thickness:
green-yellow	400nm
yellow	450nm
orange	480nm
red	490nm
purple	530nm
dark blue	570nm
blue	600nm
green	650nm

Does the size of the bubble determine what colors you see?

No

Where do the thicker layers occur?

At the bottom of the bubble

How can you control the rate of “swirling” in the bubble?

If you blow gently on the bubble, it will move more quickly. You cannot stop the swirling without it popping.

Bonus: Why does the bubble solution form into a sphere?

Answer: It has the smallest surface area to contain the largest volume

ANSWER KEY**Lab 3: Hemispheres****Investigative Question:**

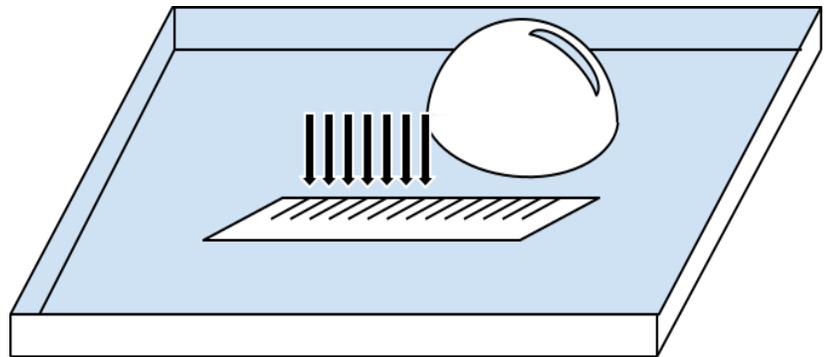
How do the sizes of a sphere and a hemisphere compare?

Hypothesis:

Answers will vary, but a good hypothesis might be the volume and surface area of hemisphere will be half that of a sphere?

Materials:

- Goggles
- Super Bubbles Solution
- Straws
- Pipette
- Container for bubble solution (cup)
- Clear tray
- Metric ruler
- Calculator (w/ π key)

**Procedure:**

Now let us mathematically investigate our bubbles!

1. Put a ruler underneath the clear tray, so you can read it.
2. Dip the end of the straw into the solution, and blow one bubble onto the tray. Be sure the bubble stays on the tray. Slowly move the tray or bubble so the bubble lines up with the zero mark of the ruler.

Measure and record the diameter of the bubble. *Answers will vary* cm

3. Quickly, dip the ruler in solution (so it won't pop the bubble). Insert the ruler into the bubble, and measure the height of the hemisphere.

Record the height you measured. *Answers will vary* cm

How does the diameter of the bubble relate to the height of the bubble? Why?

The height of the bubble will be half of the diameter of the bubble. (because there is only a half bubble on the tray)

How does the bubble relate to a sphere?

Both obtain the greatest amount of surface area with the least amount of volume.

The volume of a sphere is $V = \frac{4}{3} \pi r^3$

So, the **volume** of a hemisphere is: *Half of the volume of a sphere or $V = \frac{2}{3} \pi r^3$*

Now using your measurements, calculate the volume of your bubble.

Answers will vary based on the measurements of the bubbles above.

The surface area of a sphere is $SA = 4 \pi r^2$

So, the **surface area** of a hemisphere is: *Half of the surface area of a sphere or $SA = 2 \pi r^2$*

Now calculate the surface area of your bubble.

Answers will vary based on the measurements of the bubbles above.

Using a pipette, carefully release one drop of distilled water onto the surface of the bubble.

Document your observations:

The bubble hemisphere walls collapse once surface tension is broken (the moment the distilled water droplet hits it) and the hemisphere walls hit the surface of the solution before the distilled water droplet hits the solution

Summary

In this activity your students will have learned the correlation between color wavelengths and measurement. They will have effectively learned the formula for the volume of a sphere, and used it to solve real-world and mathematical problems.

Disclaimer

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