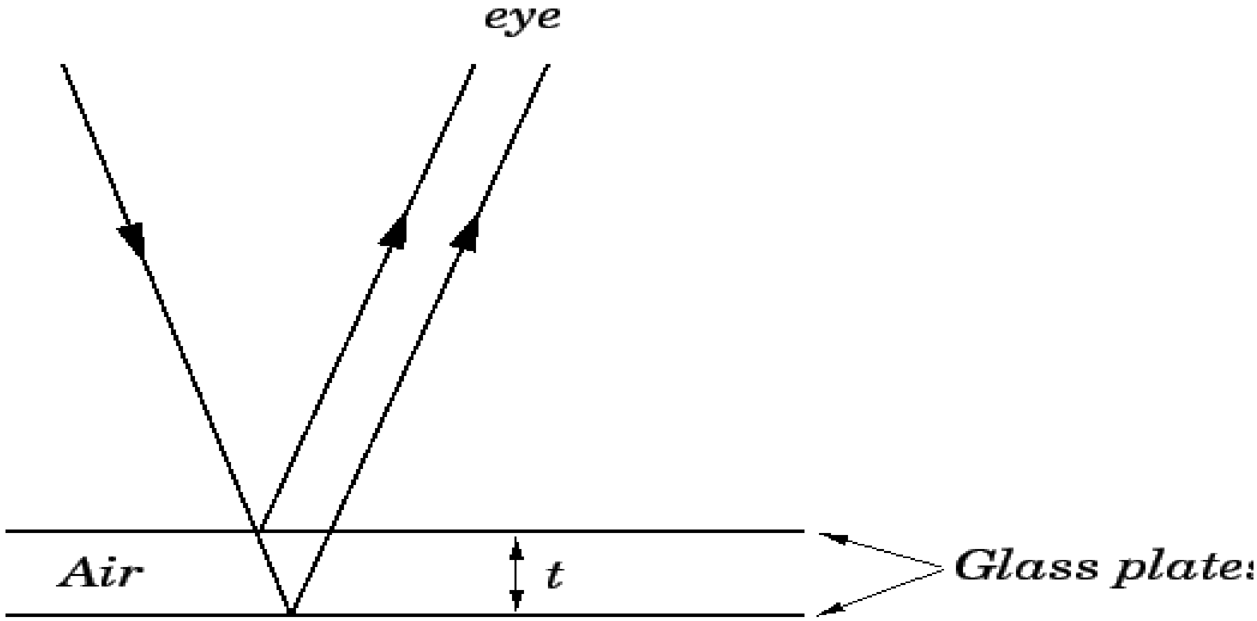
NEATEC Learning Module

Northeast Advanced Technological Education Center

Thin Films

Middle Level - Grades 6th-8th – Assessment



(Image Courtesy of:)

Northeast Technological Education Center (NEATEC)
Hudson Valley Community College

STEM Introduction Topic
Thin Films

Middle Level - Grades 6th-8th – Assessment

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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Support for this work was provided by the National Science Foundation's Advanced technological Education (ATE) Program through Grant #DUE 1003574.

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 9rd 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:

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

New York State Curriculum Standards:

Science Key Idea 4:

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.

Technology Key Idea 5:

5.2 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.
5.6 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.

Math Key Idea 8:

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.

Special Education Accommodations & Modifications:

1.) Teacher may use a camera to photograph bubbles on a dark background for students to inspect.

2.) 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!

3.) Dark backgrounds help students to identify colors on film.

4.) Floor may be covered to avoid slips or falls.

Assessment:

Student completion of worksheet.

Ability to answer both pre and post activity questions at the conclusion of the module.

Materials:

Super Bubbles Formula:

1 cup of distilled water (240 mL)
2 tablespoons of Dawn® dish soap (30 mL)
1 tablespoon of glycerin (15 mL) (may substitute sugar or corn syrup)

Pair of inexpensive cotton gloves
Small bubble wand, pipette, or straw
Black paper
A container for bubble solution (a clean, flat foam lunch or deli tray is great!)
Various wands (optional)
Straws
String

Prepare the above solution the day before you plan to utilize the activity. Leave solution in an open container. It becomes more resilient if it "ages."

Activities:

Pre-Activity Questions:
1. How can we measure the thickness of a bubble? Will a ruler help? What if it has tiny size differences?

2. Why are bubbles spherical?

3: Present videos to class prior to activity.
(links are active on .pdf)
Intro Video: "What is Thin Film?"
http://www.youtube.com/watch?v=UcYSOp_g8TI
(length 1:50)
http://www.youtube.com/watch?v=kLqcWfft5pU&feature=relmfu
(length 2:35)

Lab & worksheet completion by students in groups of 3-4.

Post-Activity Questions:
1. Why did the bubble seem to change colors and surface patterns?
2. What happens when one water droplet hits a bubble?
3. By watching color patterns on the bubble, can you predict when it is about to burst?
4. How can thin films help us determine where the hole is in an inflated tire tube?

Extensions:

How do different shapes affect color patterns?
Can you stop the color movement on the film? How?
Why does the bubble solution form into a sphere?

Resource Information for Instructor Proficiency:

(Links are active on .pdf)

http://www.stevespanglerscience.com/experiment/bouncing-bubbles

http://www.stevespanglerscience.com/content/experiment/square-bubble

http://www.physics.mun.ca/~yakov/paperADA_soap_bubbles_AJP_2011.pdf

http://www.exploratorium.edu/ronh/bubbles/bubble_colors.html

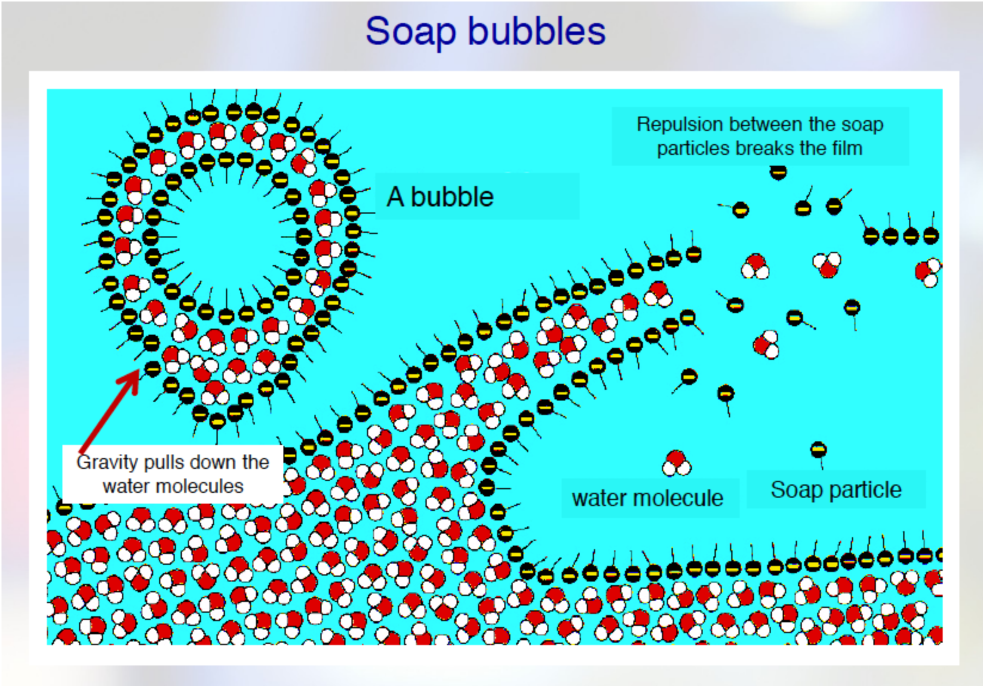
https://eee.uci.edu/programs/gchem/RDGVISSpec.pdf

http://www.nisenet.org/sites/default/files/catalog/uploads/5398/materialsfilm_guide_15nov10_0.pdf

The Following 3 Pages are for Student Handouts to discuss with your class prior to Activity and Worksheet Completion.

Background Information:

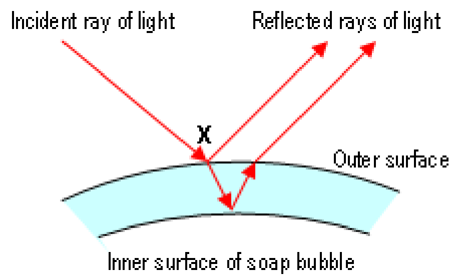
A thin film is a layer of a material that can be as thin as a fraction of a nanometer thick. Soap bubbles are a great example of thin films! They are a volume of air surrounded by a thin layer of soap and water. By recording our visual observations of the colors seen on the surface of the film, we are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



Source: http://physics.guc.edu.eg/pdfs/bubbles.pdf

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.

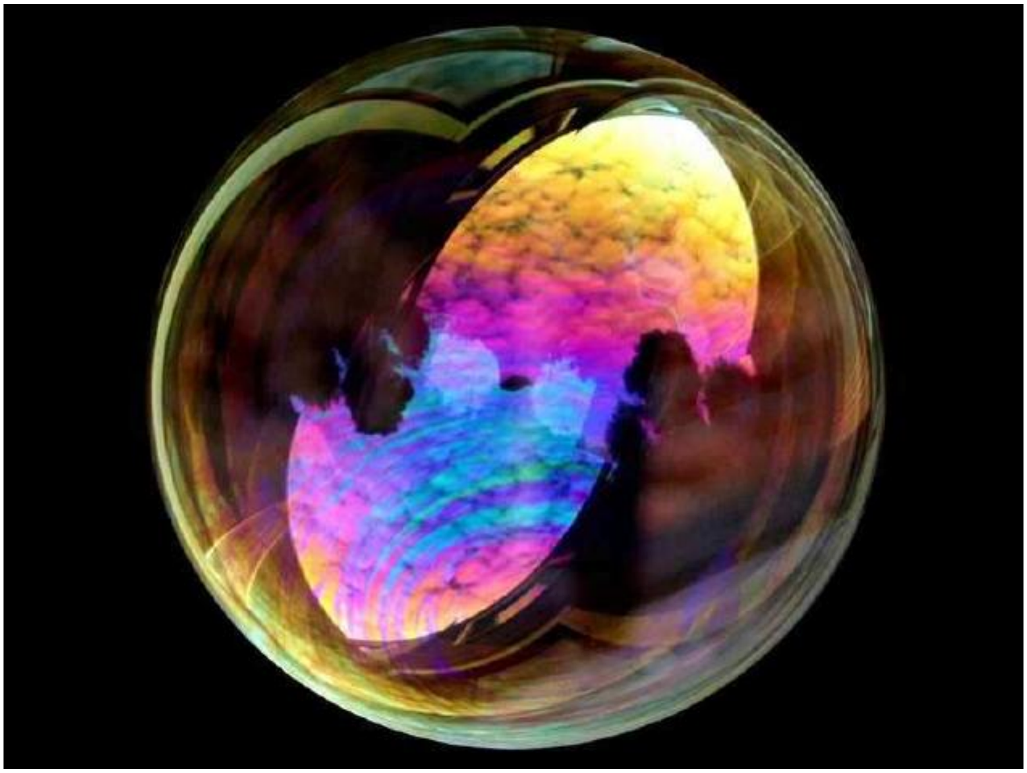
One ray of light, the incident ray, enters the bubble. When it leaves as reflected rays of light, there are more than one! That affects our results because the wavelengths of light combine to give off different colors. This is all because of the different distances traveled! Something as thin as the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



Source:http://upload.wikimedia.org/wikipedia/commons/a/a0/Reflection_from_a_bubble1.png

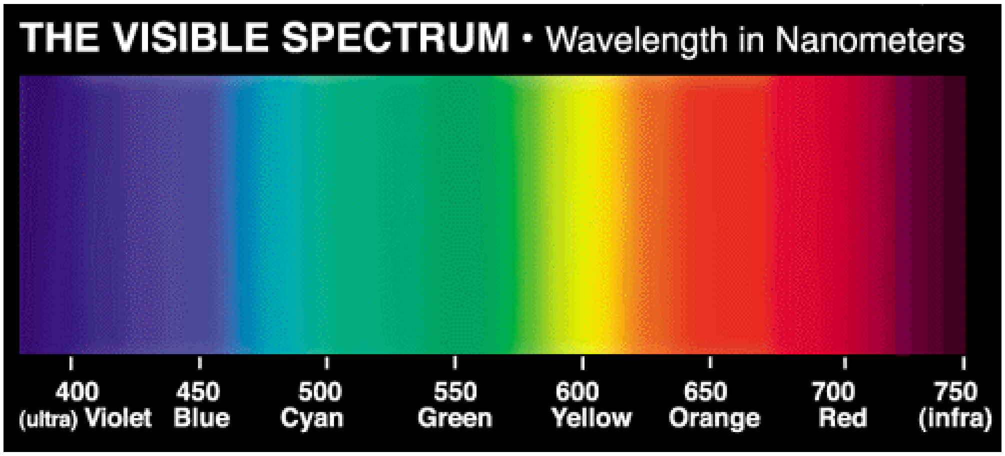
Thin Films - Measuring the Thickness of Bubbles! - Activity Handout

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.



Source: http://physics.guc.edu.eg/pdfs/bubbles.pdf

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.



Source: http://www.gamonline.com/catalog/colortheory/visible.php

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

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!

Source: http://i.telegraph.co.uk/telegraph/multimedia/archive/01442/bubble-2_1442066i.jpg

Due to the interference on the light spectrum, here is a chart to reference. 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

Source:https://eee.uci.edu/programs/gchem/RDGVISSpec.pdf

Hemispheres!

Materials:

Super Bubbles Formula:

- 1 cup of distilled water (240 mL)
- 2 tablespoons of Dawn® dish soap (30 mL)
- 1 tablespoon of glycerin (15 mL) (may substitute sugar or corn syrup)

Straws

A container for bubble solution (a clean, flat foam lunch or deli tray)

Metric ruler that starts with zero at end

Prepare the above solution the day before you plan to utilize the activity. Leave solution in an open container. It becomes more resilient if it "ages."

Name__________________________________ **Period**____________
Date___________________ **Thin Films- Measuring the Thickness of Bubbles!**

Measuring the Thickness of Bubbles

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

- ☐ Put on your cotton gloves.
- ☐ Use the pipette or wand to blow a bubble.
- ☐ Catch the bubble in your gloved hand or on the wand.
- ☐ List all of the colors that you see in the bubbles?

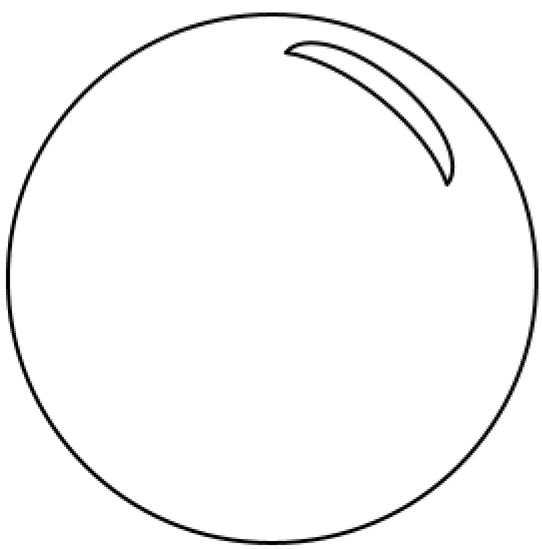
____
____

***hint:** shade the bubble with a sheet of copy paper to reveal more dramatic colors!*

Record your observations for three separate bubbles:

- ☐ What is the most common color? __________ __________ __________
- ☐ What is the approximate diameter of the bubble in cm? __________ __________ __________

Draw one of your bubbles with the color patterns below. 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

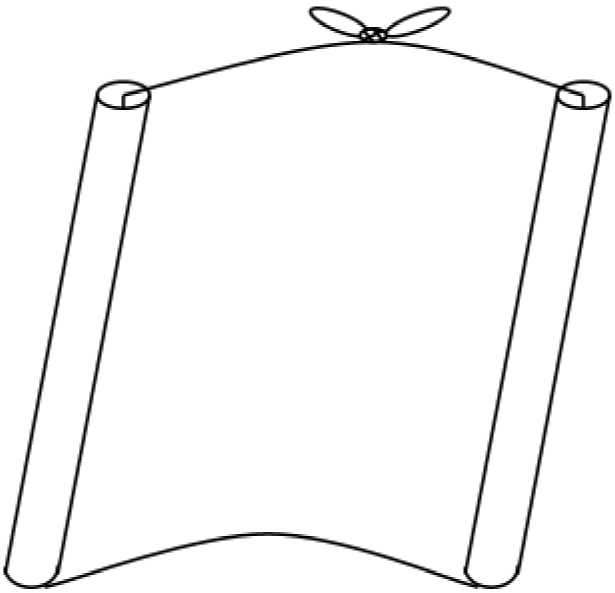
Does the size of the bubble determine what colors you see? _________________________

Where do the thicker layers occur? ____

How can you control the rate of "swirling" in the bubble? ______________________________

Name___________________________________ Period____________
Date___________________ **Thin Films- Measuring the Thickness of Bubbles!**

Build your own "Thin Film Flim Flam."



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 should result!

Dip the entire assembly in your bubble solution. Make sure the strings, straws, and your finger tips are covered in the liquid.

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

2.) Draw your results above. Label all colors.

3.) Dip your Flim Flam in the solution. This time hold it horizontally, like a table top. How do the color patterns behave? ____

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

5.) How does rotating the Flim Flam affect the bubble's colors? Does it last longer? _________
____

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

BONUS:
Giant bubbles can be made with this instrument! Apply a large amount of solution to the straws and string. Using a sweeping motion, force air into the square, and then trap the bubble by bringing the straws together. What colors do you see? Does this bubble behave the same or differently as the others? What is the biggest bubble you can make?

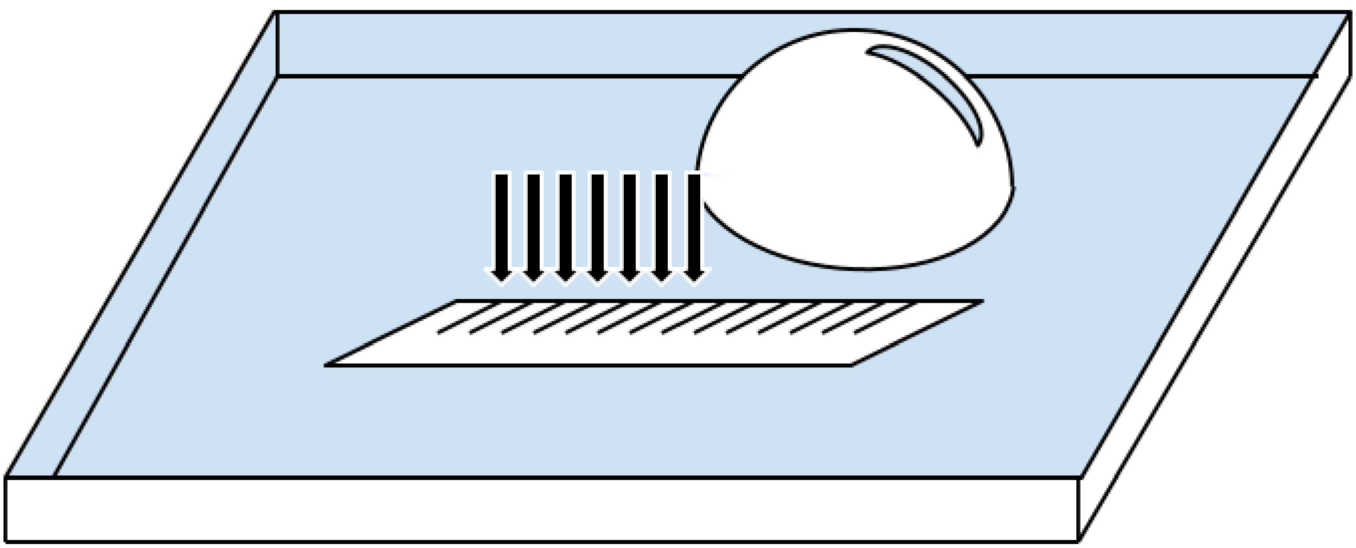
Name__________________________________ **Period**____________
Date___________________ **Thin Films- Measuring the Thickness of Bubbles!**

In this module we will be experimenting with bubbles! Follow the steps below and complete your worksheet.

Hemispheres!

Why does the bubble solution form into a sphere?

Now let us mathematically investigate our bubbles!



☐ Before adding solution, transfer 1cm marks with a ruler on a clean foam tray. You should have at least 5 -1 cm markers. The more marks you make, the more precise and easier it will be to measure!

☐ Touch the end of the straw to the solution and blow one bubble. Be sure the bubble stays on the tray. Slowly move the bubble so it lines up with the zero mark. Record the diameter you measured. ____________________cm

☐ Quickly, dip the ruler in solution (so it doesn't pop the bubble) and measure the height of the hemisphere. Record the height you measured. ________________cm

Name____________________________________ Period____________
Date____________________ Thin Films- Measuring the Thickness of Bubbles!

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 your hemisphere is

____

Now calculate the surface area of your bubble.

Name______________________________________ **Period**_____________
Date_____________________ **Thin Films- Measuring the Thickness of Bubbles!**

Why are equilibrium and balance important to thin films? _______________________________
____
____
____

Where can thin films be found in nature? ____
____
____
____

Vocabulary:

Equilibrium:
____
____

Hemispheres:
____
____

Light Spectrum:
____
____

Sphere:
____
____

Thin Film:
____
____

Activities: Teachers Guide

Pre-Activity Questions:
1. How can we measure the thickness of a bubble? Will a ruler help? What if it has tiny size differences?
Answers will vary.

2. Why are bubbles spherical?
Answers will vary.

Lab & worksheet completion by students in groups of 3-4.

Post-Activity Questions:
1. 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 sphere.
2. What happens when one water droplet hits a bubble?
Answer: The bubble hemisphere walls collapses once surface tension is broken (the moment the droplet hits it) and the hemisphere walls hit the surface of the solution before the droplet hits the solution.
3. 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.
4. 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 bubbles that are visible.

Extensions:
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: Not on a spherical bubble but yes for a flat film.
How? Answer: You can stop the movement on a flat film surface by holding it horizontally.
Why does the bubble solution form into a sphere?
Answer: It has the smallest surface area to contain the largest volume.

ANSWER KEY

Measuring the Thickness of Bubbles

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

- ☐ Put on your cotton gloves.
- ☐ Use the pipette or wand to blow a bubble.
- ☐ Catch the bubble in your gloved hand or on the wand.
- ☐ List all of the colors that you see in the bubbles?

___________Students will visibly notice an array of Spectrum colors_______________________

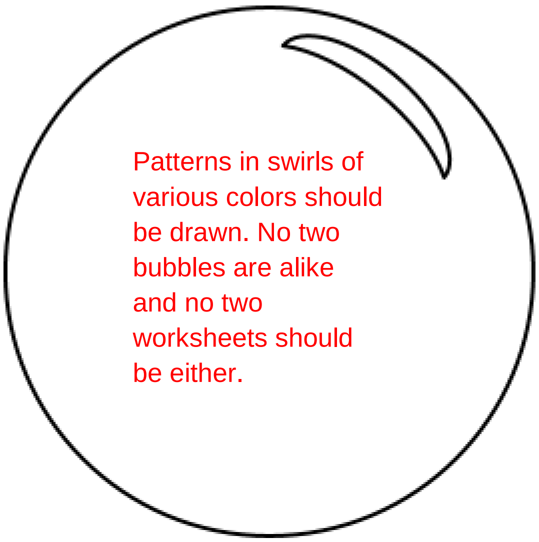
____

hint: *shade the bubble with a sheet of copy paper to reveal more dramatic colors!*

Record your observations for three separate bubbles:

- ☐ What is the most common color? ___Alll____ _Answers_ ___Vary___
- ☐ What is the approximate diameter of the bubble in cm? ___Alll____ _Answers_ ___Vary___

Draw one of your bubbles with the color patterns below. 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

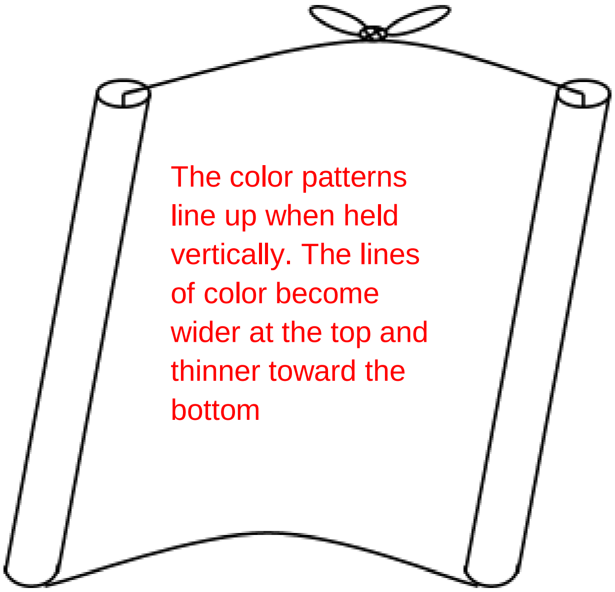
Does the size of the bubble determine what colors you see? ____No_____________________

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.______________________

ANSWER KEY

Build your own "Thin Film Flim Flam."



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 should result!

Dip the entire assembly in your bubble solution. Make sure the strings, straws, and your finger tips are covered in the liquid.

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 above. Label all colors.

3.) Dip your Flim Flam in the solution. This time hold it horizontally, like a table top. How do the color patterns behave? ___The color patterns swirl when it is held horizontally. _____________

4.) 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.) ___________________________________

5.) How does rotating the Flim Flam affect the bubble's colors? Does it last longer?
It keeps them swirling. Yes. (Because is 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.) ____

6.) Blow very gently into the Flim Flam. How does that change the color patterns?
___It pushes the swirls around the surface of the film___________________________________

BONUS:
Giant bubbles can be made with this instrument! Apply a large amount of solution to the straws and string. Using a sweeping motion, force air into the square, and then trap the bubble by bringing the straws together. What colors do you see? Does this bubble behave the same or differently as the others? What is the biggest bubble you can make?

ANSWER KEY

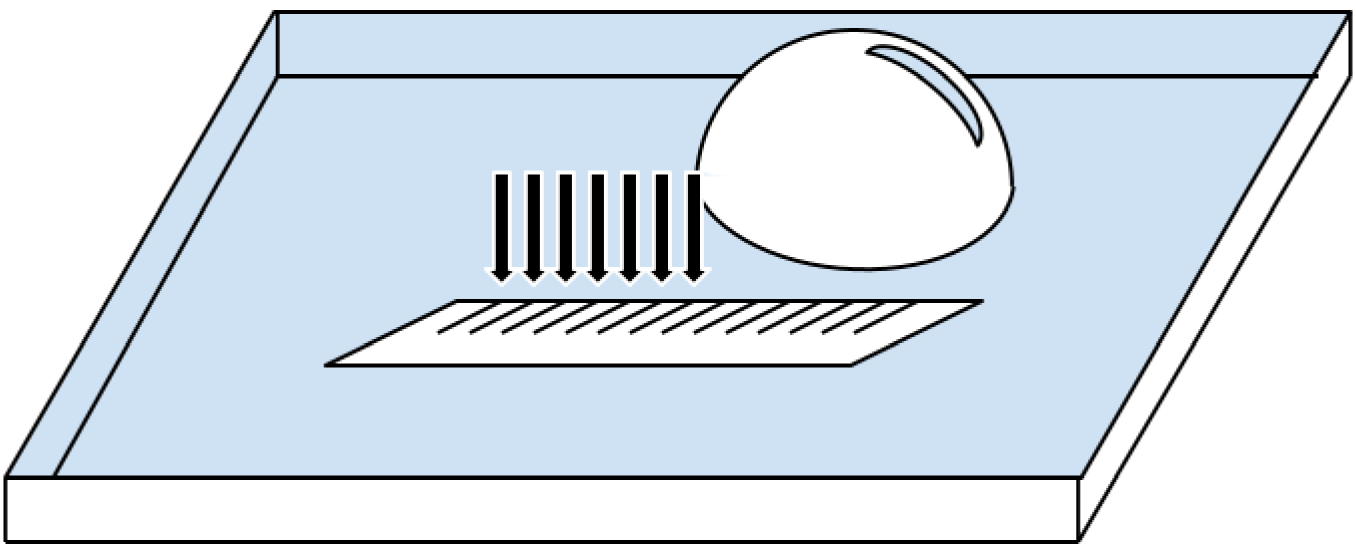
Name___________________________________ **Period**____________
Date___________________ **Thin Films- Measuring the Thickness of Bubbles!**

In this module we will be experimenting with bubbles! Follow the steps below and complete your worksheet.

Hemispheres!

Why does the bubble solution form into a sphere?
The surface tension of 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).

Now let us mathematically investigate our bubbles!



☐ Before adding solution, transfer 1cm marks with a ruler on a clean foam tray. You should have at least 5 -1 cm markers. The more marks you make, the more precise and easier it will be to measure!

☐ Touch the end of the straw to the solution and blow one bubble. Be sure the bubble stays on the tray. Slowly move the bubble so it lines up with the zero mark. Record the diameter you measured. _Answers will vary__cm

☐ Quickly, dip the ruler in solution (so it doesn't pop the bubble) and measure the height of the hemisphere. Record the height you measured. ___Answers will vary___cm

ANSWER KEY

Name____ **Period**_____________
Date_____________________ **Thin Films- Measuring the Thickness of Bubbles!**

How does the diameter of the bubble relate to the height of the bubble?
The diameter and the height of the bubble are the same. __________
____

Why? In order to obtain the least amount of volume to surface area ______________________
____

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=** $\frac{4/3 \pi r^3}{2}$

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 your hemisphere is

Half of the volume of a sphere or **SA =** $\frac{4 \pi r^2}{2}$

Now calculate the surface area of your bubble.

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

ANSWER KEY

Name___________________________________ **Period**____________
Date___________________ **Thin Films- Measuring the Thickness of Bubbles!**

Why are equilibrium and balance important to thin films?
If there is no equilibrium/balance you cannot control the size and thickness of the thin 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.

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.

Summary

In this activity your students will have learned the correlation between color wavelengths and measurement. They will have effectively learned how to solve real-world and mathematical problems involving volume of spheres. Know the formulas for the volumes spheres and use them to solve real-world and mathematical problems.

Disclaimer

Activity Evaluation

The Northeast Advanced Technological Education Center (NEATEC) would like your feedback on this activity. Your feedback allows NEATEC to maintain the quality and relevance of this activity.

To provided feedback, please email E.Crimmel@hvcc.edu

Your feedback is greatly appreciated.

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All activities have been created through developments based on learning and research provided by a variety of NEATEC Partners and National Science Foundation funded ATE Centers.

Support for this work was provided by the National Science Foundation's Advanced Technological Education (ATE) Program.