NASCENT
NANOMANUFACTURING SYSTEMS FOR MOBILE COMPUTING AND MOBILE ENERGY TECHNOLOGIES
A NATIONAL SCIENCE FOUNDATION NANOSYSTEMS ENGINEERING RESEARCH CENTER

Testing Hydrophobic Materials

Subject Area(s): Algebra 1

Associated Unit: Linear Equations and Applications

Lesson Title: Testing Hydrophobic Materials

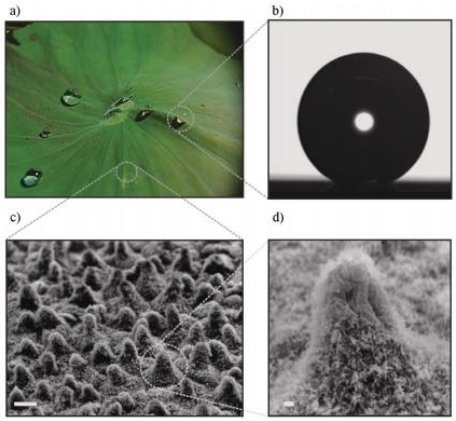

Image 1

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ADA Description: a) Picture of water droplets on a Nelumbo nucifera (Lotus) leaf. b) Static contact angle measurement of a water droplet of 0.78 mm radius on the Lotus leaf surface; the contact angle is 153. c) SEM image of the leaf surface comprising almost-hemispherically-topped papillae with sizes 5–10mm with surface density of 4.2105
cm

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2 (scale bar 10mm). d) High magnification SEM image of a single papillose depicting branch like protrusions with sizes of about 150 nm (scale bar 1mm).

Caption: Nano patterns of hydrophobic and self-cleaning Lotus Leaf

Summary

Students will learn about the behavior of surface tension of liquids at different temperatures. They will investigate these changes by planning and executing their own experimental design. To complete this, they will have to research about the practices needed to run a lab experiment. Students in a group will collaborate with other groups to obtain and give feedback on their experiment design and make improvements based on this feedback. After running the experiment, the students will model their data using algebraic models such as tables, graph, equations and verbal descriptions. Students

will test hydrophobic materials that are sold in the market against the solutions used in their lab experiment. To explain wettability of materials with the solutions used in the lab. Students will need to use the data collected and its different forms to explain the relation between contact angle of solutions on hydrophobic materials and the liquids surface tension.

Engineering Connection

Materials engineering are in constant development of creating new materials or improving existing ones. New or improved materials open doors to new technologies in civil, chemical, nuclear, aeronautical, agricultural, mechanical, biomedical and electrical engineering. With the new advancements of nanotechnology, properties of materials are being research. Many of these properties are leading way to the improvement of existing materials and to the manufacturing of new ones. For example, NeverWet is a company that specializes in the treatment of surfaces that makes them water repellent. Other companies are changing the surfaces of materials at the nano scale structure to induce hydrophobic properties. Currently, hydrophobic materials are being developed to make anti-acing, anti-corrosion, anti-wetting and self-cleaning products. Thanks to the development of hydrophobic treatments, materials engineering has lead to the development of products for construction workers such as waterproof work boots and gloves. In the field of medicine, materials have been designed to be non-wettable and self-cleaning to eliminate contamination. In sum, materials must perform their tasks in an economical and societally responsible manner. Understanding the relationships between properties, structure, processing and performance makes the job of materials engineer key for the understanding and development of materials for the improvement of society.

Educational Standards

Algebra 1 TEKS:
A.1A: Describe Independent and dependent quantities in functional relationships
A.1B: Gather and record data and use data sets to determine functional relationships between quantities
A.1D: Represent relationships among quantities using concrete models, tables, graphs, diagrams, verbal descriptions, equations, and inequalities.
A.1E: interpret and make decisions, predictions, and critical judgments from functional relationships.

ITEEA Standard
The Nature of Technology
Standard 3. Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

Technology and Society
Standard 6. Students will develop an understanding of the role of society in the development and use of technology.

Abilities for a technological world
Standard 13. Students will develop abilities to assess the impact of products and systems.

Next Generation Science Standards
Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs

Learning Objectives

After this lesson, students should be able to:

1) Represent the relationship between water's surface tension and its temperature. They will use algebraic models to interpret and make decisions about the behavior of water's surface tension as the temperature of the water changes.

2) Investigate surface tension of other liquids such as soda, cleaning products, acetone, and oils. Each group will come up with an experiment design that will be use to investigate how surface tension changes with respect to temperature of the assigned liquid.
3) Within their groups, students will complete critical friends sessions where they will get feedback from other groups about their experiment design and hypothesis to be tested.
4) Investigate how surface tension of the assigned liquid changes with respect to the concentration of another solvent.
5) Use the liquids that they worked with in class to test durability of different hydrophobic products
6) Use excel and TI-nSpire calculator app to document data and to create graphs.

Materials List

Item	Quantity
Surgauge	2
NanoTech MicroFiber Cloth	2
Magic Sand	1
Silic Shirt	2
The Innovator's DNA Book	8
Camera Lens for iPad	8
Ringstand	4
Hot Plate with Magnetic Stirrer	2
Thermometers	8

Introduction/Motivation

There are several products on the market that have been physically and chemically treated so they become hydrophobic. This lesson intends to teach students about these products and their importance on the field that they are used. Students will use knowledge about surface tension gained in the lab experiment to test several hydrophobic materials against liquids with different surface tension values.
Further, students will also learn about the application of algebra 1 with science and how algebraic representations can models real science events.

Procedure

Background

Cohesive forces between molecules inside a liquid are balanced with adjacent ones. Those on the surface of a liquid are unbalance and as an effect, they exhibit strong attractive forces upon the surfaces where the liquid rests. This unbalanced intermolecular forces at the surface of a liquid is called (causes) surface tension. Thus, the surface tension of a liquid along with external forces such as gravity are responsible for the shape of the drop of a liquid when it comes in contact with another surface. This property can be visualized through the behavior of a drop of liquid on a surface because surface tension, along with gravitation force, is responsible for the shape of the liquid. When the drop of a liquid comes in contact with a surface, three different surface tension interfaces can be found. These interfaces are surface-vapor, surface-liquid, and liquid-vapor. These three interfaces stop at the contact line where they come to equilibrium to minimize their surface energy.

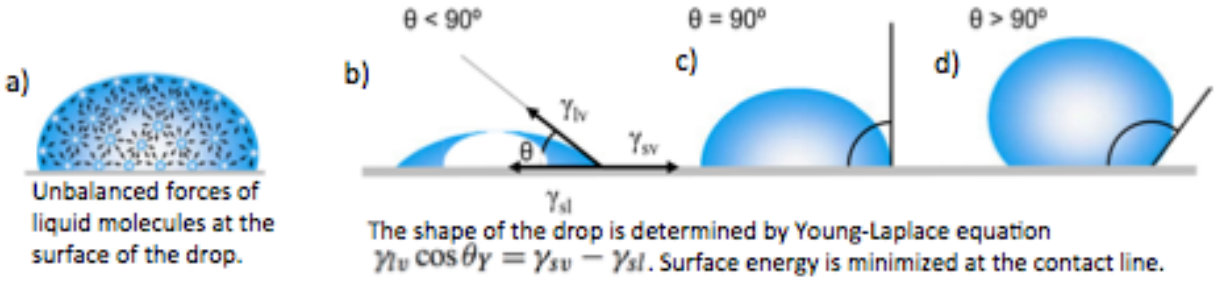

Figure 2

Image file: ___?

ADA Description: a) this image shows balanced molecules inside a water sample and unbalanced ones at the surface of the water. b) Demonstrates surface tensions interfaces in Young's contact angle. These interfaces are surface-vapor, liquid-vapor and surface-liquid. c) Shows a drop with contact angle of 90 degrees. This demonstrates poor wetting on a surface. d) Shows a drop with contact angle greater than 90 degrees, which demonstrates good wetting.

Caption: Figure 2. Young's contact angle

If the liquid-vapor surface tension is smaller than the solid-vapor surface tension, the liquid-solid interface will increase in order to minimize energy. This will cause the contact angle between the surface and the liquid to decrease. If the contact angle of the liquid is less than 30 degrees, it is then said that the surface is hydrophilic, which means that the liquid will wet the surface. This means that the surface-liquid interface will be nearly equal to the cohesive intermolecular forces inside the liquid. However, this does not necessarily mean that the water will easily drain from the surface. If the contact angle is less than 10 degrees, the surface is then said to be superhydrophilic and at this point, the liquid will be able to drain off the surface without showing resistance. On the other hand, if the liquid-vapor surface tension is greater, then the liquid-solid interface will decrease its energy resulting in a high contact angle between the surface and the liquid drop. If this contact angle is greater than 90 degrees, the surface is then hydrophobic, which means that the liquid will not wet the surface. Surfaces that display contact angle greater than 150 degrees are identified as super hydrophobic.
To attain hydrophobic properties, chemical treatments of surfaces can be used to change its surface tension, which can result in hydrophobic properties. The theoretical maximum contact angle is 120 degrees on a chemically treated surface. This equation tells us that physical treatments need to be introduced to enhance the hydrophobicity of a chemically treated surface

Vocabulary / Definitions

Word	Definition
Surface Tension	The tension of the surface film of a liquid caused by the attraction of the particles in the surface layer by the bulk of the liquid, which tends to minimize surface area.
Hydrophobicity	Is the physical property of a molecule (known as a hydrophobe) that is seemingly repelled from a mass of water.
Contact Angle	The **contact angle** is the **angle**, conventionally measured through the liquid, where a liquid/vapor interface meets a solid surface. It quantifies the wettability of a solid surface by a liquid via the Young equation.
Independent Variable	A variable (often denoted by *x*) whose variation does not depend on that of another.
Dependent Variable	A variable (often denoted by *y*) whose value depends on that of another.
Algebraic Function	A function is a special relationship between values: each of its input values gives back exactly one output value.
Experimental design	Experimental design is the process of planning a study to meet

	specified objectives. Planning an experiment properly is very important in order to ensure that the right type of data and a sufficient sample size and power are available to answer the research questions of interest as clearly and efficiently as possible.

Before the Activity

1. Floating Coins

Instructions:
Using a fork, students will place one coin at a time in the clear bucket filled with a gallon of water. Students will then move the coins around on the water surface.

After observing the coins floating on water, each group will add a different solvent to their water bucket. They will observe and explain what happens to the 'floating' coins after the solvent was introduced in the water bucket.
See video for reference.
After writing down observations, students will share them with the class and predict possible reasons for the observed events.

2. Research

Instructions:
Through online research, students will investigate the answers to the questions below. In addition to their answers, in the form of complete sentences, students will also provide citations of their research.

a) What is a molecule?
b) What is net force?
c) What is surface tension? Provide a sketch that will help you explain what surface tension is.
d) What are the units for surface tension?
e) Provide an everyday example from your life in which the surface tension property of water or another liquid is used to your advantage.

Students will be given science academic websites and other resources:
Bill Nye demonstration
Surface Tension and Water

3. What is an Experimental Design?

Students will investigate what the main components of an experimental design are.
The objective for this activity is for students to learn and understand each component of an experimental design. During this activity, students will also learn the preparation needed before carrying out an experimental design.

a) What is background research and why is it necessary during the process?
b) How do you construct a hypothesis? Provide two examples of hypotheses.
c) What is an independent, dependent and control variable?
d) What is an experimental procedure? Why is it important to repeat a science experiment?
e) Why is a materials list necessary and what information should it include?
f) What preparation needs to be done before completing the experiment?
g) What algebraic methods can you use to collect and analyze data?

h) What strategies can you use to report your experiment's results? What information needs to be included when reporting your results?

Activity: Surface Tension Lab Plan

1. After researching the different components of an experimental design, students will create a plan for their experimental design that will help them investigate the following: 1) what is the effect of temperature on the surface tension of different liquids? 2) how does the surface tension of a liquid change when adding different concentrations of solvents?

   Students will complete the following template:
   a) Identify and investigate the background research that will be needed in order to answer the questions and conduct the experiment.
   b) Identify the independent, dependent and control variables for your experiment.
   State the hypotheses. Identify what kind of data will you be collecting? How will you collect your data? How will your data be recorded?
   c) Submit a list of lab materials that will be needed during the experiment.
   d) Write down the steps for your experimental procedure in chronological order.

2. Lab Plan Critical Friends

   After drafting their experimental design plan for the surface tension lab, student groups will present their plan to the class during a critical friends session. The goal of this activity is for groups to receive and get feedback on their experimental design before conducting it.

3. Modification and Implementation of experimental design to conduct Surface Tension Lab

   After getting and receiving feedback on the student's experimental design plan, students will make any suggested modification. After this, students will conduct their Surface Tension Lab.

4. Sample for Surface Tension Lab

   Hypothesis:
   a) If the temperature of a liquid changes, then its surface tension will change too.
   b) If a solvent is added to a liquid, then the liquid's surface tension will change.

   Variables:
   a) Independent: temperature - Dependent: surface tension - Control variable: surface tension of liquid at room temperature.

   b) Independent: ratio of liquid to solvent - Dependent: surface tension - Control variable: surface tension of liquid without any solvents added.

   Experimental Procedure:

   Temperature vs. Surface Tension
   1) Divide class into lab groups (3 students per group)
   2) Students will need to have their notebook ready to record their data.
   3) Each group will begin by measuring the surface tension of their assigned liquid at room temperature.

4) Students will use the hot plate to heat up their assigned liquid at the 1st temperature. After liquid has reached the 1st temperature, they will measure the surface tension.
5) After measuring surface tension of the liquid at various temperatures, students will test the durability of hydrophobic materials (NeverWet products) against the liquids (at different temperatures).
6) Students will record surface tension data as well as observations on how the liquid (at different temperatures) wets the hydrophobic materials. Does wetting changes when the temperature of a liquid change?)
7) Students will repeat step 4 for various temperatures.

Liquid and Solvent Ration Surface Tension
1) Divide class into lab groups (3 students per group)
2) Students will need to have their notebook ready to record their data.
3) Each group will begin by measuring the surface tension of their assigned liquid before adding any solvents to the liquid.
4) Students will prepare (and label) the different liquid solutions of their liquid and solvent.
5) After preparing the different solutions (assigned liquid with various ratios of added solvent), they will measure and record the surface tension.
6) Durability of hydrophobic materials will be tested against the different liquid solutions. Does wetting change when the solution ratio changes?

8) Hydrophobicity Research
Instructions:
Through online research, students will investigate the answers to the questions below. In addition to their answers in the form of complete sentences, students will also provide citations to their research.
What is hydrophobicity and why is it important?
What causes hydrophobicity?
How is hydrophobicity measured? What is a contact angle? Provide an image and use it to explain contact angle.
What is the importance of hydrophobicity of materials in everyday products?

Analysis and Reflections
1) Students will model the data collected using tables, graphs and lines of best fit.
2) Student will reflect on their hypotheses and support their reflections and conclusions using algebraic models. Students will explain and justify if temperature affects surface tension and if the addition of solvents affect surface tension properties of a liquid. More in depth, students will explain the wettability properties of a liquid with respect to the liquid's surface tension.

Lesson Closure

Students will explain the steps of their experiment, their findings, and conclusions during the end of project presentations. During presentations, students will elaborate about their results for testing hydrophobic commercial materials against the liquids that they use for the lab experiment. Students will use the surface tension found during their lab experiment to predict and explain effects of wettability products of commercial hydrophobic products.

After presentations, students will complete a journal entry where they will reflect about how they were able to improve their experimental design based on feedback received from other groups.

Safety Issues

Students need to handle the hot plate in a careful manner to avoid getting burn. Students should not be allowed to consume any of the liquids being tested.

Assessments

Pre-Lesson Assessment

Plotting points on the coordinate plane
Identifying variables
Use of graphing calculator
Understanding correlation

Post-Introduction Assessment

Experiment design steps (rubric)
Research prompts with citations
Critical friends feedback and reflection
Surface tension lab report (individual)
Re-design or ideas for new project with supporting information
Presentation

Homework

Represent set of data using algebraic models HWK
Identify independent and dependent variables HWK
Interpret and make inferences based on algebraic models HWK

Additional Multimedia Support

What is nanotechnology? Video
NeverWet Website and Video
Power of Nanotechnology

Supporting Program

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