Lesson Plan

Spin Art and Atomic Layer Deposition

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Science Practices:

Science Practice 2: The student can use mathematics appropriately.

Science Practice 3: The student can engage in scientific questioning to extend thinking or to guide investigations within the context of the AP course.

Science Practice 4: The student can plan and implement data collection strategies in relation to a scientific question.

Science Practice 5: The student can perform data analysis and evaluation of evidence.

Science Practice 6: The student can work with scientific explanations and theories

Content Area 7: Torque and Rotational Motion

Big Idea 3: The interactions of an object with other objects can be described by forces.

Big Idea 4: Interactions between systems can result in changes in those systems.

Big Idea 5: Changes that occur as a result of interactions are constrained by conservation laws.

Enduring Understanding 3.A: All forces share certain common characteristics when considered by observers in inertial reference frames.

> 3.A.1.1: The student is able to express the motion of an object using narrative, mathematical and graphical representations.
>
> > 3.A.1: An observer in a particular reference frame can describe the motion of an object using such quantities as position, displacement, distance, velocity, speed, and acceleration.
> >
> > > a. For rotational motion, there are analogous quantities such as angular position, angular velocity, and angular acceleration.
> > >
> > > b. For uniform circular motion of radius r, v is proportional to omega (for a given r), and proportional to r (for a given omega). Given radius r and a period of rotation T, students derive and apply $v = (2\pi r)/T$.

Enduring Understanding 3.F: A force exerted on an object can cause a torque on that object.

> 3.F.1.1: The student is able to use representations of the relationship between force and torque.
>
> 3.F.1.2: The student is able to compare torques on an object caused by various forces.

3.F.1.3: The student is able to estimate the torque on an object caused by various forces in comparison to other situations.

3.F.1.4: The student is able to design an experiment and analyze data testing a question about torques in a balanced rigid system.

3.F.1.5: The student is able to calculate torques on a two-dimensional system in static equilibrium, by examining a representation or model.

3.F.2.1: The student is able to make predictions about the change in the angular velocity about an axis for an object when forces exerted on the object cause a torque about the axis.

3.F.2.2: The student is able to plan data collection and analysis strategies designed to test the relationship between a torque exerted on an object and the change in angular velocity of that object about an axis.

3.F.3.1: The student is able to predict the behavior of rotational collision situations by the same processes that are used to analyze linear collision situations using an analogy between impulse and change of linear momentum and angular impulse and change of angular momentum.

3.F.3.2: In an unfamiliar context or using representations beyond equations, the student is able to justify the selection of a mathematical routine to solve for the change in angular momentum of an object caused by torques exerted on the object.

3.F.3.3: The student is able to plan data collection and analyze strategies designed to test the relationship between torques exerted on an object and the change in angular momentum of that object.

Enduring Understanding 4.D: A net torque exerted on a system by other objects or systems will change the angular momentum of the system.

4.D.1.1: The student is able to describe a representation and use it to analyze a situation in which several forces exerted on a rotating system of rigidly connected objects change the angular velocity and angular momentum of the system.

4.D.1.2: The student is able to plan data collection strategies designed to establish that torque, angular velocity, angular acceleration, and angular momentum can be predicted accurately when the variables are treated as being clockwise or counterclockwise with respect to a well-defined axis of rotation, and refine the research question based on the examination of data.

4.D.2.1: The student is able to describe a model of a rotational system and use that model to analyze a situation in which angular momentum changes due to interaction with other objects or systems.

4.D.2.2: The student is able to plan a data collection and analysis strategy to determine the change in angular momentum of a system and relate it to interactions with other objects and systems.

4.D.3.1: The student is able to use appropriate mathematical routines to calculate values for initial or final angular momentum or change in angular momentum of a system or average torque or time during which the torque is exerted in analyzing a situation involving torque and angular momentum.

4.D.3.2: The student is able to plan a data collection strategy designed to test the relationship between the change in angular momentum of a system and the product of the average torque applied to the system and the time interval during which the torque is exerted.

Enduring Understanding 5.E: The angular momentum of a system is conserved.

5.E.1.1: The student is able to make qualitative predictions about the angular momentum of a system for a situation in which there is no net external torque.

5.E.1.2: The student is able to make calculations of quantities related to the angular momentum of a system when the net external torque on the system is zero.

5.E.2.1: The student is able to describe or calculate the angular momentum and rotational inertia of a system in terms of the location and velocities of objects that make up the system. Student are expected to do qualitative reasoning with compound objects. Students are expected to do calculations with a fixed set of extended objects and point masses.

Questions for Students:

1. Does the distance the ink moves depend on the speed of rotation?
2. Does the curvature of the lines depend on speed of rotation?
3. Does the coverage area depend on the speed of rotation?
4. Does the coverage area depend on the amount of paint applied?
5. Can you produce a desired pattern?

Materials:

Drill

Bolt

Washers

Plastic containers

Drill bit

Paper

Cardboard

Paint

Camera-cell phone video will do

Blue tape

Masking tape

Scissors

Lazy Susan

Velcro

Background

The goal of producing electronics with graphene instead of silicon has proven to be very difficult. Researchers have spent more than a decade looking for ways to produce significant band gaps in the material. It has been shown that the first epitaxial graphene layer grown on silicon carbide, SiC, (the buffer layer) is semiconducting. So far, no theory explains the band gap observed. (1) Material characterization will help determine the reasons for this property of the buffer layer. Using Surface X-Ray Diffraction, SXRD, an understanding of the structure of graphene on SiC can be obtained. Aluminum Oxide is deposited on a layer of graphene to improve its electronic characteristics. However, what this coating of Aluminum Oxide does to the graphene needs to be determined. The reflectivity data from SXRD can be used to determine the roughness of the surface and interface along with the thickness of the Aluminum Oxide deposited on the surface of the sample. Growth of armchair and zigzag graphene has also been shown to have improved properties. Growth of zigzag graphene is done using Atomic Layer Deposition and etching. A more thorough characterization of graphene's structure will propel the development of graphene based electronics.

During this summer's work, we have done spin coating on small silicon carbide samples. This produces a thin film on the surface to allow for etching. After etching zigzag graphene will be grown along the trenches. The process of spin coating uses rotational motion along with drops of a solution to thoroughly coat the sample. The coating is meant to be uniform. This is accomplished through material placed on the sample, ramp speed and time at rotational velocity. The sample is then etched to produce a desired pattern. In our case to grow zigzag graphene ribbons. This activity can be mimicked in the classroom. I will model this activity using spin art in my AP Physics 1 classroom.

Plan

This lesson is designed as an open-ended inquiry based activity for AP Physics 1 students. During the school year the students are taught how to do inquiry based lab work. When we study rotation, they are able to perform inquiry lab work with guided instructions or without. After some study of rotation and rotational quantities will be the time to introduce the following activities.

Part I:

Observing Paint in Rotation

Set up the lazy Susan with the bowl on top.

Place your paper in the bowl.

Drop a drop or two of paint. Spin slowly. Then faster until the paint moves. Record the direction of the rotation on the paper and the direction of the paint's movement.

Repeat spinning first one direction then reversing direction. Record the first direction on the paper and the second. Be sure the label which one was first.

Video the rotation of the paper and ink spot. Use Tracker software to determine the speed of rotation.

Part II:

Coverage of Entire Paper

Now you need to cover the entire sheet of paper provided by your teacher.

There are two things to consider here, speed of rotation and amount of paint.

The object is to cover the sheet with the least amount of paint required.

Plan your approach to this problem. Record all data necessary and results.

Part III:

Masking

Now your job is to produce the desired pattern on the paper. See teacher for pattern.

You may use blue tape and paint for this part. Record all data and results.

Additional Activity:

During part I the students can measure or calculate the rotational speed of the lazy Susan.

They can count 20 rotations and time it. Another option is to video the rotation and use software to map its motion.

Free software for video analysis can be found at http://physlets.org/tracker/ or use Vernier rotation sensors to measure the rotational velocity, which can be found at

Grading Rubric for Lab Report

Students will write a lab report for this activity. The lab report will contain a title, objective, materials list, procedure, data/observations, data analysis and conclusion.

A rubric will be used to grade this lab report.

Rubric for Lab Report

Title *2 4 6 8 10*

Describes lab content concisely, adequately, appropriately

Objective *2 4 6 8 10*

Effectively defines the research problem and states the research question

Successfully establishes the scientific concept of the lab

States hypothesis and provides logical reasoning for it

Materials *2 4 6 8 10*

Lists all materials used for the lab

Procedure *2 4 6 8 10*

Gives enough details to allow for replication of procedure

Data/Observations *2 4 6 8 10*

Opens with effective statement of overall findings

Presents visuals clearly and accurately

Presents verbal findings clearly and with sufficient support

Successfully integrates verbal and visual representations

Data Analysis/Lab Analysis	*5*	*10*	*15*	*20*	*25*

Opens with effective statement of support of hypothesis

Backs up statement with reference to appropriate findings

Provides sufficient and logical explanation for the statement

Gives answer to the research question and solution for unknowns

Effectively links answer of research question to solution of problem

Sufficiently addresses other issues pertinent to lab

Conclusion	*5*	*10*	*15*	*20*	*25*

Convincingly describes what has been learned in the lab

Has successfully learned what the lab is designed to teach

Demonstrates clear and thoughtful scientific inquiry

Accurately measures and analyzes data for lab findings

References:

https://link.springer.com/chapter/10.1007%2F978-3-211-99311-8_11

Coating

http://www.housingaforest.com/homemade-spin-art-machine/

Making a spin art device

https://www.youtube.com/watch?v=FF0U7YIwm4M

making a spin art device

https://www.stevespanglerscience.com/lab/experiments/is-black-black/

chromatography with spin art

https://www.teachingchannel.org/blog/2017/05/19/spinner-science-in-six-steps/

lesson plan with spinners

http://www.housingaforest.com/homemade-spin-art-machine/

drill spin art device

http://physlets.org/tracker/

Free software for video analysis

http://www.chematscientific.com/UploadFiles/2016/11/Fundamental-understanding-and-modeling-of-spin-coating.pdf

spin coating

https://www.vernier.com/products/sensors/rmv-btd/

Vernier sensor for measuring rotational motion

https://www.ncsu.edu/labwrite/instructors/excelsheets.htm

lab rubrics in Excel