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Math in/and Physics [11th-12th grade]

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UNDERSTANDING BY DESIGN

Unit Cover Page

Unit Title: Math in/and Physics

Grade Level: 11th and 12th

Subject/Topic Area(s): AP Physics

Designed By: Penny Whetstone

Time Frame: The first two weeks of the course

School District: Northside ISD, San Antonio

School: John Jay High School, Science and Engineering Academy

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Brief Summary of Unit (Including curricular context and unit goals):

This unit is written to be taught during the first two weeks of the physics course. In any physics course, from conceptual physics up through graduate studies, there is a unique and significant dependence on the mathematical concepts and skills required to succeed in the course. A keen understanding of mathematics, as well as knowing how to apply the tools, is an important piece of the physics course.

Math in/and Physics is designed to answer the question, "If this is a physics class, why do I have to do so much math?" The goals of this unit are designed to allow the students to discover for themselves the answers to this question. This unit takes the students through the entire year, by way of a physical survey of the math skills needed. They will audit the year according to math milestones that will help them achieve confidence and strength in physics. Students will create a Physics/Math Survival Guide that will contain the math concepts, examples of when to use these concepts, and a "how-to" page that walks to reader though the problem-solving protocols for the physical concepts. The Survival Guide is a product that students will continue to add to and build as the year progresses, and, in many cases, this Guide can follow the high school students through to college.

In addition to the goal of academic success, the Physics/Math Survival Guide also serves as a model in organization, scaffolding, and interdisciplinary studies. It teaches the students to go beyond the individualization of class and subject and make connections. The Guide will help students realize the value of mathematical reason and logic beyond the math classroom, and into their lives as learners and doers.

Unit: Math in/and Physics
Grade: AP Physics B and C (11th and 12th grades, as well as post-high school)

Stage 1: Desired Results

Understandings

Students will understand that…

The relationship between math and physics is necessary to understand physical properties, laws, and theorems.

Essential Questions

What is the relationship between math and physics and why is it important?

or

If this is a physics class, why do we have to do so much math?

Knowledge & Skill

TEKS 3 (B) Express laws symbolically and employ mathematical procedures including vector addition and right-triangle geometry to solve physical problems.

Beyond the TEKS, the students in a college-level physics course must be successful and confident with their math skills in order to have a strong self-efficacy and content knowledge for the physics course. Listed below are the mathematic applications that students will be expected to perform during the course.

AP Physics B	AP Physics C
• Vector Operations • Trigonometry (SOH-CAH-TOA) • The slope and area under a graph • Manipulation of equations	• Calculus • Trigonometry (SOH-CAH-TOA) • Dot Product • Cross Product • Manipulation of equations

Stage 2: Assessment Evidence

Performance Task:

While trying to write a logical theory of gravitation, Sir Isaac Newton could go no further in proving his theory with the mathematics that were currently known and available to him at the time. Published in 1687, the Philosophiea Naturalis Principia Mathematica is the venue in which Newton described the laws of motion and laws of gravity. It was while trying to solve problems with gravitation that Newton is credited with discovering Calculus and other "new" mathematics. Newton's fear that he would be ridiculed for his new-found math made him reluctant to publish any work until a decade later.

Since the dawn of physics, mathematics has served a tool to help scholars and physicists better understand specific physical concepts as well as gain global understanding of the science. This relationship between math and physics may have begun in the 17th century, but the ties that bond the two are ever as strong today. The relationship is not only felt in our physics class, but also at Southwest Research Institute, and in an engineering office at MIT, or a laboratory at the College of Physics at Texas A&M University.

The product that you will create during this unit will serve as a tool for this year, next year, and beyond. You will create an interactive Physics/Math Survival Guide [**PSG**]. There are many pieces of math that are helpful and beneficial, and the importance of knowing *how* and *when* to use specific math tools is just as necessary as knowing the techniques themselves.

The **PSG** that you create will be a tool box that can be carried throughout the entire course, and even into college. I will provide you with the mathematic concept and a timeline of when we will use this concept throughout the year. You will finish the **PSG** by filling in the following parts of the **PSG**:

- The physical concept(s) that requires the mathematical concept.
- The chapter and section of the book that contains the physical concept.
- A "How To" flow chart, or other graphic organizer, that explains the mathematic concept.
- A solved example of the mathematic concept as applied directly to a physics problem.

Disclaimer:
There will be some "boxes" left unfilled until you have developed an even better understanding of both math and physics, and I will let you know which "boxes" can be left unfilled. These boxes will be revisited and developed throughout the year.

Upon the completion of this unit, you will assess your progress, product, and your potential for success.

Just like Sir Isaac Newton, you will find that the better understanding you have of mathematics, the more complete understanding you will have of physics. We are taught the two disciplines as separate fields (i.e. separate courses), yet my desire is that you will discover that math and physics enhance and enrich one another. From Ms. Whetstone, ***"Success in math leads to success in physics; the desire to know physics more deeply will lead to relevance in math."*** *From Albert Einstein, "Do not worry about your problems in mathematics. I can assure you that mine are far greater."*

Other evidence:

- INTERVIEW ~ Sir Isaac Newton
- EXAM ~ Math Pre-test and Self Reflection
- EXAM ~ Final Mathematics Applications exam and Self-Reflection
- HOMEWORK ~ Various independent practice assignments
- QUIZZES ~ mini-quizzes to connect prior material with new material
- VENN-DIAGRAM ~ individual Venn Diagrams comparing vectors and scalars
- VECTOR MANUFACTURING ~ students create their own vectors, labeling the parts of the vector and writing instructions for vector operations on the vector
- EXIT QUESTIONS ~ each day the students will answer and exit question on a note card
- INFORMAL CHECKS FOR UNDERSTANDING ~ mainly "Which Road?[1]"

Stage 3: Learning Activities

Day One: Math in/and Physics Introduction

To introduce the importance of math in physics, the unit will begin with a historical account of Sir Isaac Newton's development of mathematics. The students will receive informational text and read the historical account, writing down their "first thoughts" about the Newton, mathematics, and physics. The students will brainstorm what they believe is the purpose of the reading. In groups of four, the students will engage in a Pizza Talk about the reading. The purpose of the Pizza Talk[2] is come up with questions that they students would like to ask Isaac Newton about his discoveries in mathematics. The students will be sent off with the intended purpose for the unit, which is to construct value and meaning of mathematics and its purpose in a physics course.

Exit Question: When, in your real life, have you had to use any type of math outside of math class to solve a problem?[3]

Activity	Concept	Homework	Materials
• Reading of informational text. • Pizza Talk Discussion of "what's the point"	• The students will be introduced to the relationship between math and physics.	• Write ten questions that you would ask Isaac Newton about Math and Physics	• Newton's historical account • Pizza Talk Handout

[1] Students describe their current understanding of material as a type of road, such as dirt road, gravel road, paved street, or highway. If the material seems hard to understand, murky, or if the student feels like he is going through it slowly with many road bumps, he might choose to say that he is "on a dirt road." If a student feels like she can fly through the material with not pit stops, she might describe herself as "on a highway."

Day Two: Interviewing a Mastermind

The students will bring their ten questions to class, and be put in previously-determined pairs and write an "interview" of Sir Isaac Newton. Together the pair must script five questions for Isaac Newton, as well as possible answers that he might have provided. The completion of this is for homework. The students will be sent off with a complete description of the performance assessment, a rubric, and expectations for their work. The rubric, schedule, and performance assessment will be discussed, and any answers about the unit will be entertained.

Exit Question: What are your initial thoughts about the **PSG**? How useful do you think this might be?

Activity	Concept	Homework	Materials
• Working in pairs to create a hypothetical interview with Isaac Newton • Explanation and introduction of the performance assessment	• The students will begin to internalize the importance of math in physics by stepping into the shoes of Isaac Newton	• Complete the interview of Isaac Newton • Outline Chapter 1	• Interview Template • Performance Assessment Packet (Introduction, rubric, expectations, timeline, etc.)

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[2] A Pizza Talk is a guided written discussion where students designed for groups of four. The groups are given one large sheet with circle drawn in the middle of the paper. The circle is equally divided into four "pieces." Students begin by each writing a thought, question, or observation in the "top" of the piece that is facing them. (This would be the point of the pizza that is eaten first, if the circle was a real pizza.) After a minute, the "pizza" is then rotated once. Now the students each have an opportunity to respond to what was written before them. They may ask a question, respond, or make a connection. The pizza will rotate after one minute until the pizza has made one complete revolution. Then each student reads their entire piece of pizza and reflects on what is written. This exercise is intended to be a silent exercise; all communication is done via the pizza.

[3] The Exit Questions are presented as questions written on the board that students reply to via a half sheet of paper. This paper is available to the students as they enter the class room. The "Exit Question" procedure is a quick way to monitor immediate understanding and effectiveness of the lesson. Exit Questions are kept in the student's binder and collected at the end of the six weeks.

[4] Students can communicate with the instructor directly by holding up one, two, three, or four fingers. One finger would correspond to a "dirt road", whereas four fingers would indicate a "highway."

[5] Groups during the Round Robin experience should be heterogeneous groups, in terms of strength with material. Each group should be evenly distributed with students ranging for "Highway" to "Dirt Road."

[6] Concept Attainment is an inductive teaching strategy where students come to understand a definition by seeing examples and non-example of the idea. It is usually used in the form of two un-titled columns. In the first column might be "45 mph East," "10 m/s^2 toward the ground," or "50 m/s at 30° North of West." In the second column might be "75 inches," "24 hours," or "88 kg." Students would talk about what is different about the columns, come up with examples and place the examples in the proper column. As a culminating action, the titles of "Vector" and "Scalar" would be revealed, and students now can associate they own, internalized, definitions of those words as well as having the book definition.

Day Three: Celebration of Knowledge

To assess the student's current knowledge and ability to apply math concepts, a math pre-test will be given to check for prior knowledge. The students will have about 30 minutes to complete the exam, and then ten minutes to analyze their exam and write questions that they have about the material covered on the exam. These questions will then be posted on post-it notes and posted on a work sheet. The students will order their post-it notes in order of "most challenging" to "least challenging." At this time, students will show their level of understanding by selecting a "road.[4]" The students will be given a sheet of hints on how to perform operations that were on the pre-test. The students will leave class with encouragement and assurance that after this unit there will be much growth in their knowledge and understanding; this is a pre-test.

Exit Question: Tell me about a time when you got better at something. What did you do to get there?

Activity	Concept	Homework	Materials
• Math Pre-Test • Self Reflection Post-it Activity • "Which Road?"	• The students will review the knowledge that they know and assess what they do not know.	• Finish the "hints" worksheet • Prioritize their mis-undertandings via the post-it worksheet	• Math pre-test • Post-its • Post-it worksheet • Hint worksheet

Day Four: Gallery Walk

Today the students will use their post-it notes from Day Three to evaluate the progress, strengths, and improvements of the class as a whole. The students will discover that many of their classmates, much like themselves, would like to have a better understanding of the mathematical concepts. Around the classroom will be large whiteboards with different areas in which students may find misunderstandings. On the board is written the titles of each of the whiteboards, and the students are given three minutes to assign each of their post-it questions a "genre" or whiteboard title (e.g. "Opposite or Adjacent?" "Solving for the Unkown"). Then the students will walk around the classroom and place their post-it question on the appropriate white board. After the placing of post-its, students will have about 20 minutes to complete the "Gallery Walk Observation" survey. This survey allows students to list their questions and analyze the appearance of other questions on the white boards. Students are then prompted to find trends and develop common questions. The class will close by looking at the most common areas of strength and weakness. They will also pick up a Math Skills worksheet to finish for homework.

Exit Question: What was one trend that you saw from the gallery walk today? What was the frequency of your most challenging question? Did anyone else ask your question? What do you think that means?

Activity	Concept	Homework	Materials
• Gallery Walk	• The students will discover trends in common areas of improvement in the class.	• Math Skills Worksheet • Begin to complete the **PSG**.	• Large whiteboard with titles • "Gallery Walk Observation" trend survey • Math Skills Worksheet

Day Five: SOH-CAH-TOA and Equations

Today's direct instruction will cover trigonometry, SOH-CAH-TOA, and manipulating equations. The purpose of today is to give the students a succinct, direct, and deliberate lesson, and to examine the expectations of their performance. An example will be performed of the task first, then a guided instruction example, followed by independent practice. A quick "Which Road" will be performed after the guided practice. Students will have an assignment sheet, so that students who can confidently and correctly complete the sheet have the opportunity. This also serves as a facility in which students can teach and show other students how to perform the operation during guided practice.

Exit Question: What are three things outside this class that you think are made up of one or more triangles that could be SOH-CAH-TOA-ized?

Activity	Concept	Homework	Materials
• DI Lesson covering SOH-CAH-TOA and manipulating equations. • "Which Road?"	• SOH-CAH-TOA and manipulating equations	• Math Skills Assignment Sheet • Begin the SOH-CAH-TOA and Manipulating Equations pages in the **PSG**.	• Math Skills Assignment Sheet

Day Six: Graphing Round Robin

Today we will begin with a mini-quiz as the students come into class. The quiz will cover the skills that we went over in Day 5, moderately challenging and similar to the homework. After the quiz, the students will be put into groups of four[5], and we will have a "round robin" activity where the students look at graphs and analyze how units are used and important in graphs. Each station with an envelope with a question, problem, and solution. The groups will stay at their current station for 6 minutes. Four minutes will be spent working on the question and finding a solution to the problem. Two minutes will be given for the students to consult the solutions and check their own work. This collaborative learning activity will serve as a review, as well as an opportunity to gain new understanding of math, as it applies to physics.

Exit Question: What are two things that you can conclude by simply looking at the units of a graph?

Activity	Concept	Homework	Materials
• Round Robin Collaborative Learning	• Slope of a graph (units rise/run) • Area under the curve of a graph (multiply units)	• Graph/Unit Worksheet • Begin the Slope and Area pages in the **PSG**.	• Mini-Quiz • 6 envelopes with note cards (question, problem, solution) • Graph/Unit worksheet

Day Seven: Vectors and Scalars

Today I will introduce the concept of a Vector. As a class we will learn the difference between a vector and a scalar using concept attainment[6]. After the activity, students will create individual Venn Diagrams comparing vectors and scalars. Students make their own vectors out of card-stock and magnets. Students will measure the lengths of their vectors, and we will use them throughout the class.

Exit Question: Write down two examples of a scalar quantity and two examples of a vector quantity.

Activity	Concept	Homework	Materials
• Example/Non-Example • Venn-Diagram • Making your own vector	• Differentiating between scalar and vector • Categorizing quantities into Vectors and Scalars	• Begin the Vector Operations page in the **PSG**.	• Card Stock • Scissors • Magnetic tape • Rulers

Day Eight: What's Your Vector, Victor?

Using the vectors that the students created in the Day Seven, we learn how to break the vectors into x- and y-components using trigonometry. With this new knowledge, we will learn how to add and subtract vectors [tip to tail]. Groups of four students will then practice adding, subtracting, and deconstructing vectors using their own vectors. For this activity, students can choose their own groups, building ownership and comfort within their groups.

Exit Question: How you can get the Zero vector if you have the following: one vector, two vectors, and three vectors?

Activity	Concept	Homework	Materials
• Vector Deconstruction, Addition and Subtraction in groups.	• Vector Operations.	• Cutnell and Johnson Book Problems • Continue working on the Vector Operations page in the **PSG**.	• Student-crafted vectors. • Large white boards

Day Nine

Today we will explicitly use the mathematical concepts that we have been discussing. Three examples from chapter will guide the students through the completion of their **PSG**. A take-home exam over the mathematical concepts will be given to each student. Any pages left unfinished will be fully covered by the end of this class period. Students will work in groups of four and ask one another for help. If help from the instructor is required, every member of the group must raise their hand. This indicates that each person has considered the question and is still lacking a complete answer. The unit will come to fruition in Day Ten, when students turn in their **PSG**'s, take-home exam, and complete the in-class exam. The take home test will be written such that the students can complete the **PSG** using the questions and problems found in the take-home test. The students will be able to see an exemplar **PSG** and a **PSG** that could be improved, and the rubric will be revisited.

Exit Question: What is one thing that you have learned and become proficient in with which you were not familiar last week?

Activity	Concept	Homework	Materials
• Math Review • Collaborative Learning • Completion of **PSG**	• Vector Operations • SOH-CAH-TOA • Graphing • Manipulation of Equations	• Complete take-home exam • Complete **PSG** • Study for post-exam	• Take home exam

Day Ten: Celebration of Learning and Growing

Today students will take the post-exam covering the mathematical concepts. The post-exam will have the same structure (number of problems and same type of problems), but will not be identical to the pre-exam. Students will have the same thirty minutes to complete the exam, as per the pre-exam. After thirty minutes, the students will turn in their exam and receive a self-reflection and progress sheet. They will also receive a rubric with which to assess their **PSG**, according to content, process, quality, and result. As students leave, they will receive a Unit Audit, which is a place for the students to give feedback for the instructor about the unit. This will help control the quality of the unit. Students will be allowed to respond to the unit with anonymity and authenticity. The Audit will not be collected until after the **PSG**'s have been returned to the students.

Exit Question: **If this is a physics class, why do we have to do so much math?**

Activity	Concept	Homework	Materials
• Celebration of Learning • Self-assessment	• Vector Operations • SOH-CAH-TOA • Graphing • Manipulation of Equations • Self-Reflection	• Unit Audit	• Post-Exam • Self-Assessment • Unit Audit

Name: Date:

Math in/and Physics

Rationale:

Whether in a middle school science classroom, AP Physics course, Advanced Theoretical Physics course in college, or doctoral study of astronomy there is a thread that is seen in all physics courses. That thread, whether loved or loathed, is an inter-dependence on mathematics. The author of Calculus is debated, but it is known that Sir Isaac Newton is distinguished as publishing the first work that mentions the Fundamental Theorem of Calculus.

As a student of physics, as well as your instructor, I have observed and experienced a strong correlation between success in deeply understanding mathematical concepts and computations and success in physics. It is important to understand that there a few significant mathematical understandings and skills that must be mastered in order for one to have a confidence in physics. My expectation for this experience is that you, through your own discovery and development, learn for yourself the importance of having a working and lasting understanding of math, logic, and problem-solving. Even if your current skills and knowledge of mathematics is not where you would like it to be, through the creation of this Physics/Math Survival Guide [**PSG**], you can pinpoint exactly what you need to know as well as where, when, and how you will be responsible for using certain, specific mathematical tools.

Unit Goals:

At the end of this unit, I expect you to have discovered and learned how to do the following:

- Find relevance in knowing how and when to use mathematical concepts in physics
- Build a tool-box and become confident with each tool as it is applied to various problems and ideas in physics that you can continue to use in your future courses and experiences
- Create a flexible, effective **PSG** that not only will help you in physics class, but will also model the importance of knowing what you need to use and how to use it
- Possess pride and confidence in a piece of work with much personal investment
- Evaluate, asses, and reflect on your own areas of strength and weakness and to monitor growth through the unit

Assessment Overview:

Building your own Physics/Math Survival Guide

While trying to write a logical theory of gravitation, Sir Isaac Newton could go no further in proving his theory with the mathematics that were currently known and available to him at the time. Published in 1687, the Philosophiea Naturalis Principia Mathematica is the venue in which Newton described the laws of motion and laws of gravity. It was while trying to solve problems with gravitation that Newton is credited with discovering Calculus and other "new" mathematics. Newton's fear that he would be ridiculed for his new-found math made him reluctant to publish any work until a decade later.

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