5E Integrated STEM Lesson Plan – Thomas Scharenborg

Lesson Title: *A mission to Mars!*

Author: *Thomas Patrick Scharenborg.*

Topic: *This lesson addresses the use and application of vectors for solving problems in Space Science and Engineering.*

Targeted Grade Level: *Grades 9 - 12*

Time Needed: *This lesson should take two weeks to complete.*

Subject Integration: *Physics, Mathematics, Engineering, Technology, Social Studies,* & English Language Arts

Justification: Physics is used by studying the relationships between energy and materials-science. Students will learn how matter is moved through space along vector-based pathways. Mathematics is used to solve systems of linear equations in 5 specific ways: substitution, graphing, elimination, matrices, or tabular. Engineering is used through the presentation of challenges faced by astronauts when travelling to-and-from the surface of Mars & Earth. Problems presented range from large (systems-based) to small (trajectory and displacement variations). Each scenario requires an integrated approach to setting up and solving vector-based problems by using methods presented in Mathematics, Physics, and Engineering coursework. These practices will be developed by solving actual problems presented as an assessment. Social Studies is integrated into the process by explaining how technology has reduced barriers and expanded peoples' capacity to make use of, or modify, the physical environment; Students will research the mechanical requirements necessary to construct and build structures on a different planet. English Language Arts is integrated into the lesson by helping students give free-responses to specific scenarios which require approaching the task as a researcher. Students are also encouraged to look for additional resources to gather data and facts to be presented in the APA style. The integration of these subject areas is logical when presented as a story, which has been set historically, by the endeavors of NASA sending rockets, probes, drones, and rovers to Mars to gather data and study the red planet. Further study into these areas requires a logical and historical understanding of the research, approached as a timeline, discussing that which has already been completed, the problems which have been solved, and challenging students to use inference to determine which problems need to be addressed to be more successful with the attempts we will be taking to colonize Mars in the future.

Standards: *Missouri State Learning Standards https://dese.mo.gov/college-career-readiness/curriculum/missouri-learning-standards*

Mathematics:

A2.REI.A.1 *Create and solve equations and inequalities, including those that involve absolute value. This skill will be used in the lesson to teach students how to derive and calculate the Magnitude of a vector, and to create unit vectors.*

A2.APR.A.5 *Identify zeros of polynomials when suitable factorizations are available, and use the zeros to sketch the function defined by the polynomial. This will be used to model the trajectory of a rocket booster returning to Earth.*

G.CO.A.2 *Represent transformations in the plane, and describe them as functions that take points in the plane as inputs and give other points as outputs. This will be used to study the effects of types of wind shear affecting the trajectory of objects. There will also be specific problems on the assessment to measure wind effect on airplanes travelling through Earth's atmosphere.*

G.SRT.C.7 *Use trigonometric ratios and the Pythagorean Theorem to solve right triangles. This will be used to compose vectors into their respective components on a Cartesian coordinate system.*

G.MG.A.3 *Apply geometric methods to solve & design mathematical modeling problems. This will be used to calculate volumes of payload, calculate work done by a system, and design components for the mission which will be used on Mars.*

Physics:

9-12.PS2.A.1 *Analyze data to support and verify the concepts expressed by Newton's 2nd law of motion, as it describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. [Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.] This will be used to apply free-body diagram analysis of the surface/rover interactions on Mars.*

9-12.PS2.B.1 *Use mathematical representations of Newton's Law of Gravitation to describe and predict the gravitational forces between objects. [Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of*

(MLS: Physics, con't.)
gravitational and electric fields.] This will be used to verify the known gravitational values available on NASA websites, and compare them to the calculated values using the Universal Gravitation Formula with NASA data.

English Language Arts:

9-12.W.1.A *Conduct research to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; gather multiple relevant, credible sources, print and digital; integrate information using a standard citation system. This will be used by students as they compose their responses for assessment to the introduction overview for the Mission to Mars lesson. Students will also be required to write their responses to prompted questions of inquiry during the two-week lesson.*

9-12.W.1.B *Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. This will be addressed and used for assessment in each written task throughout the lesson.*

Social Studies/World History:

9-12.WH.5.G.B *Explain how technology has reduced barriers and expanded peoples' capacity to make use of, or modify, the physical environment. This will be used as a basis for students to write a response to the history of the Mars rovers used and for assessment on the homework assignment requiring students to write a short paper on what the perfect rover could be used for on Mars.*

<u>NGSS Standards Addressed in this Lesson:</u>

HS-ESS1-4 *Earth's Place in the Universe; Use mathematical or computational representations to predict the motion of orbiting objects in the solar system. This standard is addressed as students are presented with the concept of a launch window which utilizes the Hohmann transfer orbit criteria necessary to reach Mars from Earth.*

HS-PS2-1 *Motion and Stability: Forces and Interactions*

Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. This standard will be used in the development of Free-body diagrams and vector analysis to solve systems of mathematical equations.

HS-PS2-2 *Motion and Stability: Forces and Interactions*

Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system. This standard will be emphasized in the context of deriving equations to express relationships between matter and energy.

HS-PS2-4 *Motion and Stability: Forces and Interactions*

Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects. Students will learn to calculate relationships between gravity and escape velocity on multiple planets and moons in our solar system.

HS-PS3-2 *Energy: Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects). This standard will be addressed as students learn about trajectory of spacecraft between Earth and Mars.*

NGSS Performance Expectations

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts:
Asking Questions & Defining Problems; formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. Developing and Using Models; Research problems by using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s).	Physical Science; PS2: Motion & Stability: Forces & Interactions. Engineering, Technology & The Application of Science; ETS1: Engineering Design	Scale, Proportion, & Quantity; In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change. Systems and System Models; A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems. Stability and Change; For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.

Common Core State Standards: *Missouri Learning Standards (MLS) provided.*
Math: *A2.REI.A.1, A2.APR.A.5, G.CO.A.2, G.SRT.C.7, G.MG.A.3* ELA: *9-12.W.1.A, 9-12.W.1.B*
ITEEA Standards *(NOT applicable)*
Other Standards *(NOT needed)*

Measurable Student Learning Objectives:

Students will be able to apply methods of vector analysis.

Students will be able to use matrices to solve systems of algebraic equations.

Students will be able to use trigonometry to find the angles and side lengths of a right triangle.

Students will be able to use static equilibrium theories to calculate vectors.

Students will be able to construct free body diagrams to isolate vectors.

Students will be able to calculate the escape velocity for a planet.

Students will be able to find the work done by a system.

Students will be able to create tables of data for, write equations for, and graph parabolic functions.

Nature of STEM: *This lesson addresses the nature of mathematics by giving students an opportunity to use the language and symbols of math to design a project which fits into the context of the modern world we live in. Students can walk out of math class and into the real world with a better understanding of the relationships between the numbers and equations they use in class, and how those formulas help build structures, infrastructures, and power sources they rely on in their daily lives. This lesson addresses the nature of technology as students learn more about the communication and computer-based devices they currently use. Students are challenged to further inquire into the future of these technologies in an attempt to imagine what types of technology could emerge in the future to solve or simplify the systems we use today for flight-based travel. This lesson addresses the nature of engineering by sharing a history of the innovations used to develop planetary travel vehicles, specifically remotely controlled vehicles (rovers), and teach methods of design used for the current Mars rovers. Students are also given the option to consider building scale models of their ideal next generation rover, or drone. This lesson addresses the nature of physics by helping students better understand the relationships between energy and matter as it applies to space & atmospheric science. Students will complete this lesson with an ability to calculate trajectories of projectiles, measure friction, calculate work done by a system, and use vector analysis to quantify the characteristics of a dynamic system.*

Engaging Context/Phenomena: *Students will be introduced to the most recent Mars Rover Mission, and the rover "Curiosity" as they learn what is exactly happening now on Mars. Students will be guided through a discussion using multimedia tools projected on a smartboard or projection screen as the teacher introduces MSL using the following NASA websites:*

(I.) https://mars.nasa.gov/mars2020/timeline/launch/ (II.) https://mars.nasa.gov/msl/home/

The instructor will specifically introduce the concept using the 'Spacecraft" tab on the website. Students will be informed about this site/tab and will be challenged to consider which part of the mission they would most enjoy being involved with.

They must write a short response in which they choose one of the following topics from the drop-down tabs:

1. The Rover

2. The instruments

3. The Launch Vehicle

4. Getting to/Colonizing Mars

(Students will explain why they would choose to be involved in that part of the mission for homework after Lesson 1 (see Lesson Procedure section below).

Students will also be given a preview of specific slides and quotes during the "Hook" presentation, as-well-as access to the following books for reference to write their response:

Pyle, Rod. *Curiosity. An Inside Look at the Mars Rover Mission and the People Who Made It Happen.* Prometheus Books. 2014

Bell, Jim. *Mars 3-D. A Rover's-Eye View of the Red Planet.* Sterling Publishing. 2008; Revised and Expanded 2014.

Data Integration: *NASA data for the characteristics of the planets in our solar system are used in this lesson. Students are analyzing data known about the Earth and Mars to calculate vector forces acting on objects. Data will be used from the following NASA websites to complete lessons assigned throughout the 10 day lesson plan:*

https://solarsystem.nasa.gov/planet-compare/

https://nssdc.gsfc.nasa.gov/planetary/factsheet/

https://spaceplace.nasa.gov/mars-rovers/en/

https://mars.nasa.gov/all-about-mars/facts/

https://solarsystem.nasa.gov/moons/jupiter-moons/europa/in-depth/#otp_size_and_distance

https://www.nasa.gov/returntoflight/system/system_SRB.html

Differentiation of Instruction: *This lesson can be recorded and shared remotely with students. In the classroom, presentations will be set up with digital formats to fit large-test viewing. My school also accommodates students with hearing impairment, and offers students to have a reader facilitate study sessions.*

Real-life Connection: *The real life connections to this lesson are present by helping students look at the technology in existence around them in their daily lives. Missions to the Moon and Mars, and research projects taking place on the Space Station are reported regularly on the news. People are keenly aware of the endeavors of the United States and NASA to better explore our solar system, and find ways for air travel, and interplanetary travel. This lesson is designed to* *teach all people, regardless of their social or cultural background, how to use mathematics, physics, and engineering as tools to improve the world we live in. The goal of this lesson is to inspire the next generation of scientists and astronauts to get involved in the travel, exploration, and possible colonization of Mars.*

Possible Misconceptions:

Solving systems of equations using matrices.

Defining and solving static equilibrium systems.

Lesson Procedure:

The lesson will take two weeks and should follow the timeline below:

Day 1: Introduce the Mission to Mars Project purpose and objectives. Assign writing prompt for homework. (See Prompt above in Engaging Context/Phenomena) Suggested Bonus: Watch the movie: The Martian, with Matt Damon; write a review of the movie for bonus points☺ --Due by the end of the 10 – week lesson.

Day 2: Teach Lesson on Parabolic Equations. Break students into groups to begin developing their mission plans.

Day 3: Teach Escape velocity lesson. Assign Homework for Parabolic Equations and Escape Velocity. Allow students to break into groups to work on project for the remaining class time.

Day 4: Teach Vector analysis. Give Homework (due on Day 6 at beginning of class). Allow students to break into groups to work on project for the remaining class time.

Day 5: Teach Matrices. Give Homework due on Day 7. Allow students to break into groups to work on project for the remaining class time.

Day 6: Teach Static Equilibrium Lesson 1 of 2. Allow students to break into groups to work on project for the remaining class time.

Day 7: Teach Static Equilibrium Lesson 2 of 2. Assign HW for Static Equilibrium, due on Day 9. Allow students to break into groups to work on project for the remaining class time.

Day 8: Teach Free body Diagrams Lesson. Allow students to break into groups to work on project for the remaining class time.

Day 9: Teach Calculating and Measuring Work Lesson. Assign Homework, due on Day 10. Allow students to break into groups to work on project for the remaining class time.

Day 10: Administer Test over all material. Note: Group Presentations (Recorded) or Scale Model must be submitted by each Group by the end of Day 10.

<table>
<tr><th>5E Model</th><th>5E Objectives</th></tr>
<tr><td><u>Engage</u>
.</td><td>Procedure:

Students are introduced to the concept of travelling to Mars. A History of attempts to reach Mars (failures and successes) are discussed historically. The teacher is driving the discussion using inquiry-based methods. Students are challenged to consider the who/what/when/why/how ideas of manned and un-manned travel to the red planet. The student is introduced to a list of resources to write a short paper about the aspects of going to mars. The prompt is: How were we challenged with space travel to the moon and mars 50+ years ago? What improvements have been made? What is the most important aspect to organizing a mission to Mars? Use the links and resources provided in this module to reference one research project currently in process which you feel is important for developing future missions. Explain why you think the project you picked is important.

Modifications

Standards Addressed ELA: 9-12.W.1.A, 9-12.W.1.B, Social Studies: 9-12.WH.5.G.B

Formative/Summative Assessments A Rubric will be developed to assess how students answered each prompt/question listed above.

Resources

See Books listed above in the Engaging Context/Phenomena section, in addition to the following:

Hanlon, Michael. The Real MARS. Spirit, Opportunity, Mars Express and the Quest to Explore the Red Planet. Carroll & Graf Publishers. 2004</td></tr>
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	https://www.nasa.gov/feature/nasa-selects-university-teams-to-develop-moon-mars-mission-design-ideas **Leggett, Glenn., Mead, David C., Kramer, Melinda G., Beal, Richard S., *Handbook for Writers.* Prentice Hall. Tenth Ed. 1988**
Explore	**Procedure:** *Students will be given a timeline/sequence of events which will occur in order for their mission to Mars to begin: Preparation for Launch, Launch, Near Earth trajectory, Mars trajectory, Obtaining orbit around Mars, Landing on Mars, Projects on Mars, and Preparing for Launch from Mars, Return to Earth. The teacher will be helping students to form groups (4 minimum per group) to facilitate the development of their timeline and project emphasis and development. Students are collaborating & considering how to present their timeline to other groups to clearly show the detailed plan of each phase, including the Engineering design challenges and mathematical calculations which will need to be utilized to carry out their mission.* **Modifications** *Students will need to access resources through visual, verbal, and auditory means. Students will be challenged to develop ways to interact with each group in class to critique each-others progress on the development of questions which need to be answered to solve both Engineering Design Challenges and Mathematical Models.* **Standards Addressed** *Physics:9-12.PS2.A.1, 9-12.PS2.A.2, ELA: 9-12.W.1.A, 9-12.W.1.B* **Formative/Summative Assessments** *"Gotta Have" Check sheets with teacher initials for approval will be implemented before moving to the next step.* **Resources** *NASA websites & Books listed above. Optional: Watch the movie **The Martian**, with Matt Damon*

Explain	**Procedure:** *Key concepts are presented in order to help students familiarize themselves with the nature of the science of space travel. The teacher will present lectures on vectors, vector analysis, matrices, trigonometry, static equilibrium, free body diagrams, escape velocity, work, and parabolic equations. Students will write out formula sheets, diagrams, and example problems for each concept listed above.* **Modifications** **Standards Addressed** Math: *A2.REI.A.1, A2.APR.A.5, G.CO.A.2, G.SRT.C.7, G.MG.A.3* **Formative/Summative Assessments** *Project "Gotta Have" check sheets will be used. Students will require teacher initials before they are able to move on.* **Resources** *NASA websites listed ABOVE* *Pre-calculus textbook:* **Ryan, Merilyn, S.S.J., Doubet, Marvin E., Fabricant, Mona, Rockhill, Theron D*., Advanced Mathematics. A Precalculus Approach.* Prentice Hall. First Publication: 1993.** *Physics textbook:* **Giancoli., *Physics. Principles with Applications.* Pearson Prentice Hall. 2005 Ed.**
Elaborate	**Procedure:** *Extension problems will be introduced to help students learn how to apply the ideas of travelling to Mars as an extrapolation towards making calculations for travel to the Moon and Europa. The teacher is interacting with small groups of students in rotation to facilitate progress on choosing either the Moon or Europa as a location to compare and contrast the requirements of a rover design based on the conditions of those locations. Students will either put together a 10 minute presentation on their findings, or build a scale model of the rover or drone they will use to gather data on their respective locations. Both options will require students to create "Gotta Have" Checklists.*

	Modifications *Students will have access to cameras, video cameras, and computers to complete the project. Final projects will be submitted for display in class, or uploaded to a viewable google drive folder.* **Standards Addressed:** ELA: 9-12.W.1.A, 9-12.W.1.B, Physics: *9-12.PS2.B.1* **Formative/Summative Assessments** *Rubrics will be used to grade presentations or scale model designs. Paper test will be used to assess proficiency with Extension Problems.* **Resources** *NASA Websites, slideshow presentation software, photographic and video editing software, building materials (Note: these materials will be sourced from the teacher from pre-approved sources) from science kits, Legos, Art Materials, etc.*
Evaluate	**Procedure:** *Students will be given a 10 question Test, with bonus questions.* **Formative/Summative Assessments:** *Student tests will be graded with credit given for showing work.*

Teacher Background:

Teachers must be capable of teaching Pre-Calculus, Physics, and Introductions to Engineering. Knowledge of Statistics and the ability to use a TI-84 calculator is also pre-requisite. Collaboration with an Art/Design Teacher will help students to build their rover designs based on a method used in those classes; Teachers are highly encouraged to collaborate with a fellow teacher if possible.

Endeavor STEM Teaching Certificate Project
Thomas Patrick Scharenborg
July 27, 2021

Mission to MARS TEST

NAME: DATE:

Use NASA data obtained from class to sketch diagrams, find specific data, and calculate answers to the following questions.

You must show work and reference data sources to receive partial credit!

1. Rockets launch from Earth with initial Force produced by the Thrust of their Engines to start moving along a parabolic path as discussed in class. (A). sketch a free body diagram of the forces acting on a 2-stage rocket during launch from Earth. (B) Use the Data Table from class to Sketch a graph and derive the equation for the parabolic path of a Booster – rocket (stage 1) as it launches from Earth, separates from its Mars-trajectory rocket and returns to Earth for recovery.

2. Calculate the Escape Velocity required for a 2-stage Rocket (using NASA DATA from websites used in class) to launch from (A) Earth and from (B) Mars.

Bonus: Calculate the Escape Velocity required for a Rocket to launch from Europa.

3. A 1-stage Rocket is fired at an 85-degree angle (from Horizontal) with an initial speed of 150 m/s. Sketch a free-body diagram and Find the vector-component form of the initial velocity.

4. As a rocket is launched from Earth, Mission control observes the launch from an airplane. The airplane is flying with a bearing of 170 degrees at 460 mph. A wind is blowing with a bearing of 200 degrees at 80 mph. (A) Find the component form of the velocity of the airplane. (B) Find the component form of the velocity of the wind. (C) Find the actual ground speed and direction of the airplane.

5. Rocket booster stage 1 has deployed its parachutes and is floating towards Earth. If one parachute is open at a 50 degree angle (NW) carrying 65% of the weight of the booster and the second parachute is open at a 30 degree angle (NE) carrying 35% of the weight of the booster. Sketch the vector diagram of the guide-lines connected to the booster, and calculate the Resultant Force Vector; give (A) the direction, and (B) the magnitude of the Resultant Force.

(Note: see class notes for Booster dry weight, or goto: https://www.nasa.gov/returntoflight/system/system_SRB.html)

6. The mission control airplane is tracking the progress of the booster. The airplane has airspeed of 510 mph with a bearing of S40-degrees East. Observers at the landing pad for the booster observe the actual ground speed of the plane at 500 mph with a bearing of S42-degrees East. Calculate the speed and direction of the Wind acting on the plane and the booster.

7. Astronauts have landed on Mars and are preparing to deploy a rover to the surface. Using the NASA data from class, determine the tension in each cable as the rover is lowered onto Mars with Cable 1 at an angle of 30 degrees from the floor of the ship and Cable 2 at an angle of 40 degrees from the floor of the ship.

8. The Rover has found a geologic sample and collected it from the surface of Mars. {Later, scientists measure the weight of the object on Earth and find it to be 24 pounds.} (A) Calculate the weight of the object when it was on Mars. (B) Find the work done by the rover to move the artifact in the vector direction $\langle 4,5 \rangle$ for a distance of 5 feet along a Cartesian coordinate grid with a viewing window including the points (0,0) & (5,5). Sketch a diagram of the Resultant Vector.

9. The Rover finds another strange object on the surface of Mars. The rover must drag the object to the ship for collection. Find the work done by the rover if a force of 50 pounds acts in a direction of $\langle 2,3 \rangle$ to drag the object 38 feet from the collection point (0,0) to the ship along a coordinate grid in the first quadrant along the line y=x.

10. The Rover is parked on a slope where it got stuck going up an incline at 58 degrees.

(A) Sketch a free-body diagram of the vector forces acting on the rover, including static friction.

(B) Calculate the coefficient of static friction holding the rover in place.

Bonus (A): Use information from class to calculate the coefficient of kinetic friction as the Rover wenches itself from the incline at a speed of 3 mph over the time interval of 2 seconds. Determine the percent change in the coefficient(s).

Bonus (B): Calculate the impulse required to drag the rover free. Express your answer in Kg-m-s units.