5E Integrated STEM Lesson Plan – Template

Lesson Title: Celestial Jukebox

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Topic: Developing and solving equations, Kepler's Third Law, Transits

Targeted Grade Level: 9-12

Time Needed: 110 - 115 minutes

Subject Integration: Mathematics and Science

Justification: They are using the science concepts behind Kepler's law to develop the appropriate equation to solve for certain problems. Developing the equation requires the science, solving and using the equation is where the math must be embedded. Each subject leaning on the other to accomplish the learning outcome is why this integration is logical.

Standards:

NGSS Performance Expectations (NGSS Website) & (KY Science Standards PDF)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts:
Developing and Using Models Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HSESS1-1) **Using Mathematical and Computational Thinking** Mathematical and computational thinking in 9–12 builds on K–8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. Use mathematical or computational representations of phenomena to describe explanations. (HS-ESS1-4) **Constructing Explanations and Designing Solutions** Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with	**ESS1.B: Earth and the Solar System** Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system. (HS-ESS1-4)	**Scale, Proportion, and Quantity** Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). (HS-ESS1-4)

scientific ideas, principles, and theories. Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-ESS1-2) **Obtaining, Evaluating, and Communicating Information** Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs. Communicate scientific ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS-ESS1-3)		

Common Core State Standards:

Math: (**KY Math Standards PDF**)

KY.HS.A.12 Create equations and inequalities in one variable and use them to solve problems.

KY.HS.A.15 Rearrange formulas to solve a literal equation, highlighting a quantity of interest, using the same reasoning as in solving equations.

ELA: (**KY ELA Standards PDF**) SL.11-12.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation. (HS-ESS1-3)
ITEEA Standards (PDF) Not applicable
Other Standards (KY Technology Standards PDF) (KY Computer Science Standards PDF)

Measurable Student Learning Objectives:

Students will be able to develop and use a model of the solar system to derive and explain Kepler's 3rd Law, then apply the equation to search for exoplanets in orbit around their stars.

Assessment :

Nature of STEM: This lesson addresses the nature of math and science both as it allows opportunities for students to question others ideas, evaluate their own ideas, use phenomena as a base for their learning, and has students apply multiple content areas together to reach their learning objective.

Engaging Context/Phenomena: Active Exoplanet Count We will look through the data and research being conducted currently on exoplanets and what has been accomplished thus far.

Data Integration: Data is being used at multiple times in this lesson. First students are looking at data as the phenomena that opens the lesson. It is data collected by NASA and it is live current data that initiates conversation about exoplanets. Also, students are using data collected from the rhythm made from a planet's transit. A digital scatterplot is made to collect data as a visual of this process. It first takes data from separate planets and then collects data on the planets together as a system of planets to show the difference in the graphs for observation purposes. In both of these cases, students are analyzing data.

Differentiation of Instruction: Students will be collaborating with others throughout the entirety of the lesson. They will be given assistance in the form of sentence starters and graphic organizers. They will also be given prompts and readings in their own language if needed. Students with behavioral goals will be given guidance in the form of a Never, Later, and Now structure. This is designed to help these students set small goals throughout the lesson to help them stay on task and discuss appropriately with other students

Real-life Connection: There is a real-life connection to this lesson. This lesson will have students thinking about why scientists try to discover new planets, new ways of life, and why things in our solar system and even other solar systems are the way they are. The topic is not culturally sensitive, but I have students from different cultures that need to be considered when it comes to the implementation of the lesson. Every day students are surrounded by stars and planets and now through this lesson, they will have a deeper understanding of how to learn about those things in our universe without actually going to outer space.

Possible Misconceptions: It is important to point out that even though we are using sounds to describe the orbital pattern of planets, a transit does not actually make a sound in real life.

Lesson Procedure :

5E Model	5E Objectives
Engage ***15-20 minutes***	**Procedure:** As a class we will look at the phenomena source over the active exoplanet count from NASA to open the lesson. After getting student thoughts and questions over exoplanets. I will assign them to groups of 2 or 3 depending on the number in the class. Students will then be asked to open the Eyes on Exoplanets app and will explore exoplanets. I will be walking around and assisting students with using the app as well as asking questions that will initiate students developing their own questions and ideas. The essential questions from this portion of the lesson will include: How do scientists find these exoplanets? Once they've found these exoplanets, how do they know the distances these exoplanets are from the star they orbit? The desire is for

	students to be the ones generating these questions from exploring the app. Responses will vary. This will lead into the next step of the lesson of exploring methods for discovering exoplanets. **Modifications:** In order to help those students that aren't able to develop ideas and questions as easily on their own, there will be a "Brainstorming" graphic organizer accessible for them to narrow their train of thought and have a starting point for developing their ideas. It will ask: What? Why? How? This is intended to start the thought process for those kids that have a harder time initiating it themselves. **Standards Addressed** ● *Science and Engineering Practices:* ○ **Obtaining, Evaluating, and Communicating Information** Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs. Communicate scientific ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS-ESS1-3) ○ **Constructing Explanations and Designing Solutions** Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-ESS1-2) **Formative/Summative Assessments** Students will finish their "what, why, how" graph organizer to develop and organize their ideas and questions. This will be used as their formative assessment on their ability to develop claims, and construct explanations and communicate

	possible explanations or reasons for the phenomena. **Resources** **Phenomena Source: Active Exoplanet Count** **Eyes on Exoplanets App** **Brainstorming Graphic Organizer** (Print off)
Explore ***35 - 45 minutes***	**Procedure:** Students will be asked to get out one chromebook per group/pair. Then they will access The Celestial Jukebox digital learning experience where they will perform simulations. Students will interact with one another and the simulator to explore exoplanet discovery methods. The teacher will analyze interactions among students with the educator resource associated with this lesson. On my own chromebook I will walk around observing student interactions as well as asking questions. Students will be given a large poster size sticky note. With their group they will take regular sized sticky notes and organize their thoughts in a Jot Thought structure. Each important thought that comes to mind from the Celestial Jukebox experience they will post on their poster. After they have completed the digital experience. They will walk around and skim the responses of the other groups in their class. This will provide a good starting point for discussion over the essential questions. Essential questions from this part of the lesson will include: How can sounds be used to determine the distance of a planet from the sun? How are the beats related to the orbital period of each planet? Why does the graph of data prove the orbital period and distance from the sun are not directly proportional? Since it isn't directly proportional, how could you describe their relationship? These essential questions are again, intended to be generated by students themselves after completing the activity. This will most likely lead into the end of class. **Modifications** Bracketing Distracting Thoughts: I will place a "Now, Later, Never" scale for students to focus on only the tasks at hand and to keep discussion on what is appropriate. On a piece of notebook paper, they will write down a column for now, and a column for later. Students will be told to record questions for now and questions for later. Questions for now would be questions needed to complete the exploring activity. The later questions are questions that would be good for whole class discussion after the exploring activity is complete. Off task thoughts that

	aren't appropriate for the lesson should not go on the paper and should be put aside until class is over. This method of brainstorming structure is intended to help those kids that tend to get off task and struggle with focusing on questions that really make them think. This way they can narrow down not only what is appropriate to discuss during the lesson but when it's appropriate to ask it. **Standards Addressed:** ● *Science and Engineering Practices:* ○ **Developing and Using Models** Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HSESS1-1) ○ **Using Mathematical and Computational Thinking** Mathematical and computational thinking in 9–12 builds on K–8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. Use mathematical or computational representations of phenomena to describe explanations. (HS-ESS1-4) ○ **Constructing Explanations and Designing Solutions** Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-ESS1-2) ● *Cross Cutting Concepts:* ○ **Scale, Proportion, and Quantity** Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth

	vs. exponential growth). (HS-ESS1-4)
	• *Science:*
	  ○ **ESS1.B: Earth and the Solar System** Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system. (HS-ESS1-4)
	• *Math:*
	  ○ KY.HS.A.12 Create equations and inequalities in one variable and use them to solve problems.
	• *ELA:*
	  ○ SL.11-12.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation. (HS-ESS1-3)
	
	Formative/Summative Assessments At the end of class, we will have students communicate what they learned in the digital learning experience with a Six Word Story. I will have students help us develop a brief explanation of what they learned using only six words. This will take class discussion because some students might think some words might be more important than others in the explanation.
	
	Resources
	
	Celestial Jukebox Digital Learning Experience (Student Link)
	
	Celestial Jukebox Digital Learning Experience (Teacher Link)

Explain	**Procedure:** This will be the opening discussion to start the second day of this lesson. Essential questions will be written on the board and will serve as a bellringer for the students to begin class. The students will write down the questions and fill in the missing blanks. The essential questions will be the following: The farther a planet is from a star the _______ the tones occur. In summary from yesterday, Kepler's third law states that the cube of a planet's ________ is proportional to the square of its _________. This means that planets closer to the Sun will have a _____ orbital

	period than planets farther from the Sun. Include a quick sketch to describe this. **Modifications** Before having students discuss these concepts as a whole class, I will have the students and discuss to the person next to them what they put in the blanks and describe their sketch. This will allow students to feel more comfortable with their answers and conversations in front of the whole class since they have talked with only one person about it first. **Standards Addressed** ● *Science and Engineering Practices:* ○ **Obtaining, Evaluating, and Communicating Information** Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs. Communicate scientific ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS-ESS1-3) ● *Science:* ○ **ESS1.B: Earth and the Solar System** Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system. (HS-ESS1-4) **Formative/Summative Assessments** Journaling: Students will sketch an image and fill in the blanks to make sure students are clear about what was taught in the previous day's activities. **Resources** Students just need a piece of notebook paper to answer the bellringer question.
Elaborate	**Procedure:** After answering the bellringer question to summarize the previous digital learning experience, I will tell students to get back in their groups/pairs from yesterday and each student will be given a handout for parts A, B, and C or the elaborate portion of our lesson. I will then pose the next essential question to students: What is the indicator for a transit if it isn't sound? On handout A students will write down their ideas to this question and discuss this with their group members.

	After discussing as a class what the students have brainstormed, I will guide their thinking to the idea of light. I will pose the essential question: how might the brightness of light from a star have a similar pattern as the celestial jukebox data? After discussing this question as a class, we will introduce the term light curves and watch a video to further explain this concept. After watching the video, students will look at part B of their handout and apply the concepts from the Celestial Jukebox activity to search for exoplanets using light curves. To summarize, the essential questions for this portion of the lesson should include: What is the indicator for a transit if it isn't sound? How might the brightness of light from a star have a similar pattern as the celestial jukebox data? **Modifications** I will keep a close proximity with all groups at some point but with the groups that might struggle more to offer assistance and help with generating questions and thoughts. I will also provide the handouts in the particular language needed by the ELL students in my class. **Standards Addressed** ● *Science and Engineering Practices:* ○ **Developing and Using Models** Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HSESS1-1) ○ **Obtaining, Evaluating, and Communicating Information** Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs. Communicate scientific ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS-ESS1-3) ● *Science:* ○ **ESS1.B: Earth and the Solar System** Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the

	solar system. (HS-ESS1-4) ● *ELA:* ○ SL.11-12.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation. (HS-ESS1-3) **Formative/Summative Assessments** No formative assessments will take place here as this portion will lead to the evaluate portion. **Resources** **Student Handout (Parts A, B)** **The teacher edition is at the bottom of this pdf.** **Exoplanet Light Curve Video**
Evaluate *Assess students knowledge, skills and abilities.*	**Procedure:** After students have answered the questions from part B of the student handout, we will come back together and discuss the following two questions. How do astronomers find these exoplanets? Once they've found these exoplanets, how do they know the distances these exoplanets are from the star they orbit? We will openly discuss these two questions which will lead into the application of Kepler's Third Law. I will ask students to look at part C of their handout and choose with their partner which graph would be the best for describing the relationship between distance from the star of orbit and orbital period. Students will use the graph to estimate the distance for number 2 and then for number three write out the equation that represents Kepler's Third Law. I will then have the students verify their estimate from part to by algebraically solving their equation. Students will end this lesson with an exit ticket where they must find information on two other exoplanets by using the equation from Kepler's Law. Essential Questions from this portion of the lesson: How do astronomers find these exoplanets? Once they've found these exoplanets, how do they know the distances these exoplanets are from the star they orbit? What is the equation for Kepler's Law? How can we use it to search for exoplanets? **Modifications** Students will get to refer to the example we completed and checked as a class to

	help them complete the exit ticket. **Standards Addressed** ● *<u>Science and Engineering Practices:</u>* ○ **Developing and Using Models** Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HSESS1-1) ○ **Obtaining, Evaluating, and Communicating Information** Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs. Communicate scientific ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS-ESS1-3) ● *<u>Cross Cutting Concepts:</u>* ○ **Scale, Proportion, and Quantity** Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). (HS-ESS1-4) ● *<u>Math</u>:* ○ KY.HS.A.12 Create equations and inequalities in one variable and use them to solve problems. ○ KY.HS.A.15 Rearrange formulas to solve a literal equation, highlighting a quantity of interest, using the same reasoning as in solving equations. ● *<u>Science:</u>* ○ **ESS1.B: Earth and the Solar System** Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system. (HS-ESS1-4)

	Formative/Summative Assessments: Students will be given an exit ticket which they must turn in to show they have mastered the ability to solve Kepler's Law equation. **Resources** **Student Handout (Parts C)** **The teacher edition is at the bottom of this pdf.** **Solving Kepler's Law Equation Exit Ticket**

Endeavor STEM Teaching Certificate Project
Jalyn Puckett
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Teacher Background:

Great Resources for explaining what an exoplanet is:

What is an Exoplanet?

Great visuals for Kepler's 3rd Law:

Kepler's Third Law Example 1

Kepler's Third Law Example 2

More detailed insight into this lesson:

Detailed Lesson Insight

I obtained most of my ideas, resources, and sources from this NASA lesson below:

https://etx.asu.edu/documents/lessons/celestial-jukebox/educator-docs/lesson/Celestial_Jukebox_HS_Formal.pdf