Transformation 2013
Design Challenge
Planning Form
Guide

Design Challenge Title: Space Elevator – Fact or Fiction?

Teacher(s): Abel Gonzalez

School: Taylor High School

Subject: Physics

Abstract: In this lesson, students will be asked to study and assess the feasibility of building and deploying an elevator system that would carry cargo and people into space without the use of rockets. Specifically, the students will investigate the properties of tethered bodies in terms of linear and angular velocity, mass, gravity, and mechanical energy and momentum.

MEETING THE NEEDS
OF STEM EDUCATION
THROUGH DESIGN CHALLENGES

Step 1: Begin with the End in Mind

- ***Does this design challenge meet the criteria for STEM student needs (21st century skills, TEKS, TAKS)?***

Section 1
Summarize the theme or "big ideas" for this design challenge.

What are the essential ideas, essential questions, major concepts that students should take away from this experience?

Students will investigate the possibility of building a space elevator system, beginning with a study of how present-day elevators work, and how those concepts would translate when applied to the motion of cargo along a rotational tethered body system.

Section 2
Identify the TEKS/SEs that students will learn in the design challenge (two or three).

What are the targeted TEKS student expectations (planned)?

Physics
(2) Scientific processes. The student uses scientific methods during field and laboratory investigations.
The student is expected to:

(A) plan and implement procedures including asking questions, formulating testable hypotheses, and selecting equipment and technology

(3) Scientific processes. The student uses critical thinking and scientific problem solving to make informed decisions

(A) analyze, review, and critique scientific explanations, including hypotheses and theories, as to their strengths and weaknesses using scientific evidence and information;

(4) Scientific processes. The student knows the laws governing motion.
The student is expected to:

(B) analyze examples of uniform motion and accelerated motion including linear, projectile, and circular;
(C) demonstrate the effects of forces on the motion of objects;
(D) develop and interpret a free-body diagram for force analysis;

(6) Science concepts. The student knows forces in nature:
The student is expected to:

(A) identify the influence of mass and distance on gravitational forces;

Section 3
Identify key performance indicators students will develop in this design challenge.

What are the targeted TEKS student expectations (planned)?

1. Create a graphic organizer showing the information links with the Space Elevator as the center point.
2. Research the space elevator concept on the Internet and write a 2-page report on the pros and cons of building one.
3. Develop and draw a diagram of the components of a space elevator.
4. Build a scale model/prototype (1in = 1000 miles) of what a space elevator might look like and how it might work.
5. Prepare a project portfolio.

Section 4
Identify the 21st century skills that students will practice in this design challenge (one or two).

Critical thinking
Initiative & Self-Direction
Communication & Collaboration
Leadership & Responsibility

Section 5
Identify STEM career connections and real world applications if content learned in this design challenge.

What are the elements of STEM integration that are involved in this design?
How is the integration of math, science, engineering principles, and technology achieved?
Are STEM career connections included in the design challenge?

STEM integration elements - critical to the design of a working space elevator:
- Large-scale multilayer nanotube production
- Cable design and production using carbon nanotube composite ribbons
- Power beaming propulsion systems for payload delivery

Career connections
- Engineers
- Physicists
- Mathematicians

Step 2: Craft the Design Challenge

- ***Have you posed an authentic problem or significant question that engages students and requires STEM knowledge to solve or answer?***

State the essential question or problem statement for the design challenge.

Essential question or problem statement includes the content, outcomes, and focus for inquiry for the design challenge. Capture the theme in the form of a problem or a question that cannot be easily solved or answered.

Guidelines for crafting the question – Driving Questions:

- ❒ *are provocative.*
- ❒ *are open-ended.*
- ❒ *go to the heart of a discipline or topic.*
- ❒ *are challenging.*
- ❒ *can arise from real-world dilemmas that students find interesting.*
- ❒ *are consistent with curricular standards and frameworks.*
- ❒ *may have to be drafted and re-drafted.*
- ❒ *can be created with students.*

NASA has demonstrated that access to space utilizing a reusable container such as the Space Shuttle is a reasonable expectation. However, the cost of each mission runs about $10,000 per pound of cargo. What if a system could be designed such that the cost of cargo could be reduced to around $100 – $400 per pound, and would work similar to an elevator system in a multi-storied building?

Your design team has been asked by The Spaceward Foundation to create a design and model/prototype of a space elevator including all the working components and power systems. All designs, drawings, and justifications for such a design will be included in a complete portfolio which should include conclusions and recommendations on the feasibility of building such a system.

All aboard on the Space Elevator to the future and have a great climb!

Step 3: Map the Design Challenge

Look at the *major* product for the design challenge and analyze the tasks necessary to produce a high-quality product. What do students need to know and be able to do to complete the tasks successfully? How and when will they learn the necessary knowledge and skills?

Product: Graphic organizer showing the information links with the Space Elevator as the center point.	**Already Learned**	**Taught before the project**	**Taught during the project**
1. How to create a graphic organizer		x	
2. Identify links between the Space Elevator and sources of information			x
3. Make task assignments based on previous learning experience related to sources of information		x	

Step 3: Map the Design Challenge

Look at the *major* product for the design challenge and analyze the tasks necessary to produce a high-quality product. What do students need to know and be able to do to complete the tasks successfully? How and when will they learn the necessary knowledge and skills?

Product: Two-page typed and double-spaced report on the pros and cons of building a space elevator.	**Already Learned**	**Taught before the project**	**Taught during the project**
1. Reading comprehension	x		
2. Use clear grammatically correct writing to describe the space elevator.	x		
3. List the factors against building a space elevator			x
4. List the factors in favor of building a space elevator			x

Step 3: Map the Design Challenge

Look at the *major* product for the design challenge and analyze the tasks necessary to produce a high-quality product. What do students need to know and be able to do to complete the tasks successfully? How and when will they learn the necessary knowledge and skills?

Product: Diagram of the components of a space elevator	**Already Learned**	**Taught before the project**	**Taught during the project**
1. Measurement of the radius of the earth		x	
2. Shortest length of tether necessary to hold the space elevator in orbit			X
3. How a carbon nanotube composite ribbon is made			X
4. What a power beam system is and how it can be used for propulsion			X
5. Size and shape of possible ribbon climbers, including traction systems			X
6. Ribbon anchor design			X

Step 3: Map the Design Challenge

Look at the *major* product for the design challenge and analyze the tasks necessary to produce a high-quality product. What do students need to know and be able to do to complete the tasks successfully? How and when will they learn the necessary knowledge and skills?

Product: Scale model/prototype (1in = 1000 miles) of what a space elevator might look like and how it might work.	**Already Learned**	**Taught before the project**	**Taught during the project**
1. Newton's First Law of Motion – force and motion of an object			X
2. Newton's Second Law of Motion – relationship of force, acceleration and mass			X
3. Newton's Third of Motion – equal and opposing forces			X
4. Linear velocity			X
5. Angular velocity			X
6. Centripetal Force			X
7. Centripetal Acceleration			X
8. Free particle motion			X
9. The influence of mass and distance on gravitational forces			X

Step 3: Map the Design Challenge

Look at the *major* product for the design challenge and analyze the tasks necessary to produce a high-quality product. What do students need to know and be able to do to complete the tasks successfully? How and when will they learn the necessary knowledge and skills?

Product: Project portfolio containing all project documents	**Already Learned**	**Taught before the project**	**Taught during the project**
1. Reading comprehension	x		
2. Use clear grammatically correct writing to describe the space elevator.	x		
3. List the factors in favor of building a space elevator			x
4. List the factors against building a space elevator			x
5. Diagram of the components of a space elevator			x
6. Conclusions and recommendations			x

Step 4: Plan the Design Challenge 5E Lesson

Design Challenge Title: Space Elevator – Fact or Fiction?
TEKS/TAKS objectives: Physics 2A, 3A, 4B,4C,4D,6A
Engage Activity: Identify/focus on instructional task, connect between past & present learning experiences, lay groundwork for activities (ex. Ask a question, define a problem, show a surprising event, act out a problematic situation) **The particular subject area is introduced to the students with common examples that have meaning in their lives.**

Introduce your students to the design challenge:
"NASA has demonstrated that access to space utilizing a reusable container such as the Space Shuttle is a reasonable expectation. However, the cost of each mission runs about $10,000 per pound of cargo. What if a system could be designed such that the cost of cargo could be reduced to around $100 – $400 per pound, and would work similar to an elevator system in a multi-storied building?

Your design team has been asked by The Spaceward Foundation to create a design and model/prototype of a space elevator including all the working components and power systems. All designs, drawings, and justifications for such a design will be included in a complete portfolio which should include conclusions and recommendations on the feasibility of building such a system."

Please take notes on chart paper as we watch the Space Elevator video from YouTube: Space Elevator on YouTube. You may watch the video several times to make sure you get all the information you think is necessary for this project.

All aboard on the Space Elevator to the future and have a great climb!

Engage Activity Products and Artifacts:

1. ***Artifacts (KWL charts, journal entries, etc) are evidence of the student's thinking.***
2. ***Products (flow charts, data tables, models, etc) include checkpoints for progress through a design challenge.***

Notes on the Space Elevator video

Engage Activity Materials/Equipment

Computer Lab, Internet Access, Large Chart Paper, Markers, Project Folder

Engage Activity Resources

Space Elevator on YouTube

Explore Activity: Students get involved with phenomena and materials; students work in teams to explore through inquiry.

Directed laboratories are conducted so the students can experience the principles in a controlled manner. This experience is crucial to success in solving design challenges.

Working in teams of 4, the students will create a Graphic Organizer to map out their information links with the Space Elevator as the center point. The students will also develop a time table for doing the Internet research related to the Space Elevator and make task assignments based on group member choices.

Then they will access the computer lab to research the Spaceward Foundation, read about carbon nanotubes, and review the CNN Space Elevator Report on the resource links listed below. Students will then complete the attached Research Worksheet #1.

All notes and task assignments produced will be kept in the project folder along with all other portfolio documents.

Explore Activity Products and Artifacts:

1. ***Artifacts (KWL charts, journal entries, etc) are evidence of the student's thinking.***
2. ***Products (flow charts, data tables, models, etc) include checkpoints for progress through a design challenge.***

Graphic organizer
Time table
Task assignment list
Project folder
Research Worksheet #1

Explore Activity Materials/Equipment

Computer Lab, Internet Access, Large Chart Paper, Markers, Project Folder

Explore Activity Resources

Graphic Organizer
The Spaceward Foundation
Carbon Nanotubes
CNN Space Elevator Report

Explain Activity: Students discuss observations, ideas, questions and hypotheses with peers, facilitators, groups. Learners apply labels to their experiences – thus developing common language, clarification/explanation of key concepts

Delivery of the content begins with a discussion of the principles illustrated by the Hands-On examples. In this way, the participants' intuition is tapped to introduce terms and concepts that they may have heard. This approach leads naturally to an in-depth discussion of the science and mathematics concepts underlying the particular subject area.

Working as a class, have the groups sit together and discuss how elevators work, why people use them, and limitations in terms of cargo. Use these topics to explain the concept of lifting mass and working against the pull of gravity. Introduce the use of electric motors as propulsion systems and inherent limitations of using direct cable connections as the lifting mechanisms. Explain the use of cable anchor points and why they are necessary.

At the Earth's surface, all objects experience a downward force due to gravity. This force depends on the object's mass: the greater the mass, the greater the force. Explain the role gravity plays on how much cargo an elevator can carry and the dependence on cabling systems.

Introduce the concept of centripetal force and the role it plays on an object on a merry-go-round. Using a hollow tube with a string running though the middle, demonstrate the use of circular motion to deploy an object (small rubber ball) away from the center of rotation. Show how the length of the string plays a role on how fast the object must rotate in order to stay in a fixed plane of rotation.

Again, using a similar hollow tube with a 12 inch disk attached to it, show how the disk must rotate at the same rate as the string so that the ball reminds in a stationary orbit with respect to the disk. Explain to the students that this is one of the critical requirements of a space elevator – it must remain in a stationary orbit with respect to the earth's rotation in order to work. This then defines the angular rotation of the Space Elevator's anchor point out in space. It must remain stationary with respect to the Space Elevator's anchor point on the surface of the earth. Let the students know that this feature must be included in their design of Space Elevator model/prototype.

(Note: a ceiling fan may be used here to further illustrate the principle. Also, see Materials section for alternatives)

Explain Newton's First, Second, and Third Laws of Motion and the role each one of them plays on the small rotating ball at the end of the string. Introduce the relationship of linear velocity, angular velocity, and centripetal force by using free-particle force diagrams. Students will draw diagrams of the ball in motion, describing the dependence of angular velocity on linear velocity.

Students will then access the computer lab to review **The Physics Classroom Tutorial** website and access the information on Newton's Laws of Motion.

After reading the material and viewing the illustrations, the students will work with the teacher in completing the Check Your Understanding exercises on the tutorial. Upon completion of the tutorial exercises, students will complete attached Worksheet #2.

Explain to the students how the ball breaking free from the string is similar to an extended application of the Space Elevator in serving as a launching pad for space exploration vehicles.

Explain Activity Products and Artifacts:

1. ***Artifacts (KWL charts, journal entries, etc) are evidence of the student's thinking.***
2. ***Products (flow charts, data tables, models, etc) include checkpoints for progress through a design challenge.***

Diagrams showing motion of the rubber ball on the string, with and without the 12 inch disk.
Completed attached KWL chart
Check Your Understanding exercises from the physics tutorial
Completed Worksheet #2

Explain Activity Materials/Equipment

Hollow tube with string running though it and attached to a small rubber ball on one end. An alternative to this would be an old-fashioned yo-yo on a string.
Twelve inch disk attached to the hollow tube and the string and ball combination. An alternative to this would be a Frisbee attached to a small block of wood by a nail through the center, but free to rotate. The string would run through the same hole as the nail, and is attached to the Frisbee along the radius of the disk.
Ceiling fan if available
Paper and pencil
Calculators
Dry erase board and markers
KWL chart
12-inch Cardboard disk cut from any grocery store box
Frisbee
Yo-yo

Explain Activity Resources

The Physics Classroom Tutorial
At the Earth's surface, F_g = mg, where F_g = force due to gravity, m = mass, and g = gravitational acceleration.
Newton's First Law of Motion = every object will remain at rest or in uniform motion in a straight line unless compelled to change its state by the action of an external force
Newton's Second Law of Motion = For an object with a constant mass **m**, the force **F** is the product of an object's mass and its acceleration **a**: (F = m * a)
Newton's Third Law of Motion = for every action (force) in nature there is an equal and opposite reaction.
Angular velocity is a measure of angular displacement per unit time. If the small ball rotates at 30 times per minute, then the angular velocity is 30*2Pi = 60Pi radians per minute.
The linear velocity = angular velocity (radians)*radius of the string.
Mass of the rubber ball
Length of the string
Speed of rotation

Elaborate Activity: Expand on concepts learned, make connections to other related concepts, apply understandings to the world. (ex. Extend & apply knowledge).

At its heart, engineering is the application of science and mathematics to design solutions to problems for humanity. Thus, providing design opportunities to students is a key component of STEM education.

Opportunities to be creative in open-ended situations peak the interest of many students, providing an answer to the ubiquitous question: "Why do we need to know this?"

Students work to gather all information they think necessary to solve the problem. This may include viewing the YouTube video again to get a better understanding of what is required. The groups discuss how the concept of lifting cargo on a standard elevator may be extended to the Space Elevator concept. The teacher will constantly monitor each group to ensure that they are looking in the right direction, providing redirection clues as necessary, but making sure that no redirection takes the form of a task. Each group must decide for themselves which direction to take in determining how they are going to construct a solution to the challenge.

Engage the students in a discussion of the role of nanotubes in the construction of the tethering cable required by the Space Elevator. Discuss the properties of carbon nanotube composite ribbons as compared to steel cables used in conventional elevator systems.

Engage students in discussions of the project status using the Storyboard as a guideline for where they need to be on their research and products.

A related activity which the teacher may encourage (if no group takes this step) is to solve the same problems of rotation for the Space Elevator by using proportions based on the calculations for the rubber ball. When doing so, the teacher should encourage the students to generate ideas about what they need to know about the earth and its rotation. For example, if the Earth rotates on its axis once every 24 hours, then this complete circle is 2π radians. Therefore, the angular velocity of the Earth's rotation is $2\pi / 24$ hours. If the radius R of the Earth is about 4000 miles, then the distance traveled in one hour on the surface of the Earth is $\pi / 12$ = 180 degrees/12 = 15 degrees.

Using the formula for the circumference of the Earth as $2\pi r$, then we can use the proportion of

$15° / 360° = \frac{1}{24} \bullet 2\pi(4000) = 1047 miles$. That means **Your** linear velocity, standing on the surface of the Earth, is 1047 miles per hour!

What keeps you from flying off the Earth?

Another related activity that the students should undertake is to create a materials list for the model/prototype including what materials are needed, in what quantities, and the purpose for each item. The students can start by creating drawings of what their model/prototype would look like, labeling and identifying the purpose of each part of the model/prototype.

Once the material list is compiled, the students should work on how they are going to use the materials to construct their model/prototype and compile assembly instructions.

Students will then create a prototype of their space elevator using the materials that they requested. You might find that students will need a supply that they did not originally request. Based on their justification as to what they will use the supply for, you may or may not decide that they can have the material.

Elaborate Activity Products and Artifacts:

1. ***Artifacts (KWL charts, journal entries, etc) are evidence of the student's thinking.***
2. ***Products (flow charts, data tables, models, etc) include checkpoints for progress through a design challenge.***

Calculations for the Space Elevator anchor point in space rotating in a stationary orbit
Drawings of the scale model/prototype
Materials list
Proposed model/prototype assembly instructions

Elaborate Activity Materials/Equipment

Computer Lab, Internet Access, Large Chart Paper, Markers, Project Folder, Paper and pencil
Calculators, Dry erase board and markers

Elaborate Activity Resources

None

Evaluate Activity: Ongoing diagnostic process to determine if the learner has attained understanding of concepts & knowledge (ex. Rubrics, teacher observation with checklist, student interviews, portfolios, project products, problem-based learning products, assessments). Leads to opportunities for enrichment through further inquiry and investigation.

What is the culminating task?

The students will lead the presentation of models/prototypes and portfolio contents to their peers and interested members of the Faculty and Administration. The students will discuss the project process in detail, starting with the development of the graphic organizer and taking the audience through each phase of the project development. Each student-led discussion will include observations, ideas, questions and hypotheses, concluding with recommendations on the feasibility of building a Space Elevator.
Students reflect on and evaluate the project through:

- Class discussion
- Student-facilitated formal debrief
- Teacher-led formal debrief
- Individual evaluations
- Group evaluations

The teacher will evaluate each project based on the Rubrics (see below).

Upon completion of all presentations, have the students complete the KWL chart that was begun in the Explain phase of the lesson.

Evaluate Activity Products and Artifacts:

1. ***Artifacts (KWL charts, journal entries, etc) are evidence of the student's thinking.***
2. ***Products (flow charts, data tables, models, etc) include checkpoints for progress through a design challenge.***
3. ***What is the final product (working model, portfolio, presentation, etc) you will require?***

Rubrics (see below)
- Student-facilitated formal debrief
- Teacher-led formal debrief
- Individual evaluations
- Group evaluations

Completed KWL Chart

Evaluate Activity Materials/Equipment

Model/prototype of the Space Elevator
Portfolio
Rubrics (see below)
Completed KWL Chart

Evaluate Activity Resources

None

Step 5: Plan the Assessment

State the criteria for exemplary performance for each artifact/product of each section of the 5E lesson.

- ***Do the products and criteria align with the standards and outcomes for the design challenge?***

Engage Artifact(s)/Product(s Notes on the Space Elevator video – comprehensive notes detailing the concept of a Space Elevator and how it is expected to function
Explore Artifact(s)/Product(s): Graphic organizer – complete with all information links relative to the Space Elevator Time table - accounting for all time necessary to complete research Task assignment list – student names and tasks assigned to each Project folder – folder containing all these and previous documents. Completed Research Worksheet #1 Completed attached KWL chart
Explain Artifact(s)/Product(s): Diagrams showing motion of the rubber ball on the string, with and without the 12 inch disk – complete with explanations Completed attached KWL chart Check Your Understanding exercises from the physics tutorial Completed Worksheet #2
Elaborate Artifact(s)/Product(s): Calculations for the Space Elevator anchor point in space rotating in a stationary orbit – complete and mathematically correct Drawings of the scale model/prototype – complete and to scale Materials list – complete and with intended purpose Proposed model/prototype assembly instructions – step-by-step assembly instructions
Evaluate Artifact(s)/Product(s): Student-facilitated formal debrief – formal presentation of project results between groups Teacher-led formal debrief – formal presentation of project results between groups Individual evaluations – individual evaluation of group results Group evaluations – group evaluation of project results between groups Completed KWL Chart

Step 6: Create Rubrics

Space Elevator Rubrics

Product	20 points	15 points	10 points	5 points	0 points
1) Graphic organizer showing the information links with the Space Elevator as the center point.	Clear, grammatically correct written description of information links required to gather and assemble the Space Elevator project	Somewhat clear, grammatically incorrect written description of information links required to gather and assemble the Space Elevator project	Unclear, grammatically incorrect written description of information links required to gather and assemble the Space Elevator project	Missing links in the description of information links required to gather and assemble the Space Elevator project	No graphic organizer
2) Two-page typed and double-spaced report on the pros and cons of building a space elevator.	Clear, grammatically correct written description of the pros and cons of building a Space Elevator	Somewhat clear, grammatically incorrect written description of the pros and cons of building a Space Elevator	Unclear, grammatically incorrect written description of the pros and cons of building a Space Elevator	Unclear, grammatically incorrect and incomplete written description of the pros and cons of building a Space Elevator	No report
3) Diagram of the components of a space elevator	Clear scale drawing with correct dimensions with key	Clear scale drawing with correct dimensions without key	Clear scale drawing with incorrect dimensions with key	Clear scale drawing with incorrect dimensions without key	No scale drawing
4) Scale model/prototype (1in = 1000 miles) of what a space elevator might look like and how it might work.	Clear scale model/prototype with correct dimensions with key	Clear scale model/prototype with correct dimensions without key	Clear scale model/prototype with incorrect dimensions with key	Clear scale model/prototype with incorrect dimensions without key	No scale model/prototype
5) Project portfolio containing all project documents	Clear, grammatically correct written description of information links required to gather and assemble the Space Elevator project Clear scale drawing with	Somewhat clear, grammatically incorrect written description of information links required to gather and assemble the Space Elevator project Clear scale drawing with	Unclear, grammatically incorrect written description of information links required to gather and assemble the Space Elevator project Clear scale	Missing links in the description of information links required to gather and assemble the Space Elevator project Clear scale drawing with incorrect	No graphic organizer No written description No scale drawing No scale model/prototype No project

	correct dimensions with key Clear scale model/prototype with correct dimensions with key Clear, grammatically correct project conclusions and recommendations	correct dimensions without key Clear scale model/prototype with correct dimensions without key Somewhat clear, grammatically correct project conclusions and recommendations	drawing with incorrect dimensions with key Clear scale model/prototype with incorrect dimensions with key Somewhat clear, grammatically incorrect project conclusions and recommendation	dimensions without key Clear scale model/prototype with incorrect dimensions without key Unclear, grammatically incorrect project conclusions and recommendation	conclusions or recommendations

Step 7: Space Elevator Storyboard (block schedule)

	Day 1 **90 minutes**	**Day 2**	**Day 3** **90 minutes**	**Day 4**	**Day 5** **50 minutes**
Week 1 Activities	Engage Activity: Identify/focus on instructional task, connect between past & present learning experiences, lay groundwork for activities (10 mins) Space Elevator video (10 mins) Graphic organizer concepts (10 mins)		Explore Activity: Product 1 Due Graphic organizer showing the information links with the Space Elevator as the center point. Students review Internet resources and work in teams to complete graphic organizer and Worksheet #1 (60 minutes)		Evaluate Activity: Ongoing diagnostic process to determine if the students have attained understanding of concepts & knowledge to include: Review of Graphic Organizer (15 mins) Review of Worksheet #1 (10 mins) Review of project status by teams (25 mins)
	Day 6 **90 minutes**	**Day 7**	**Day 8** **90 minutes**	**Day 9**	**Day 10** **50 minutes**
Week 2 Activities	Explore Activity: Students work in groups to complete The Physics Classroom Tutorial on Newton's Laws of Motion (60 mins) Explain Activity: Students discuss observations, ideas, questions and hypotheses with teacher and peers. (20 mins)		Explore Activity: Product 2 Due Report on pros and cons of building a Space Elevator Students work in teams to put finishing touches on report (10 mins) Students work in teams to complete the Check Your Understanding questions on The Physics ClassroomTutorial website (20 mins)		Evaluate Activity: Ongoing diagnostic process to determine if the learner has attained understanding of concepts & knowledge Review of pros/cons report (15 mins) Review of Check Your Understanding answers from the tutorial (10 mins) Review of project status by teams (25 mins)

	Day 11 90 minutes	Day 12	Day 13 90 minutes	Day 14	Day 15 50 minutes
Week 3 Activities	Elaborate Activity: Expand on concepts learned, connect and apply understandings to the world. Teacher-led presentation of the concepts of linear velocity, angular velocity, centripetal force, and free body diagrams (45 mins)		Explore Activity: Product 3 Due Diagram of the components of a space elevator Students work in teams to complete diagrams (20 mins) Students work in teams to complete Worksheet #2 (20 mins)		Evaluate Activity: Ongoing diagnostic process to determine if the learner has attained understanding of concepts & knowledge Review of the diagram of the components of a space elevator (15 mins) Review of Worksheet #2 (10 mins) Review of project status by teams (25 mins)
	Day 16 90 minutes	**Day 17**	**Day 18 90 minutes**	**Day 19**	**Day 20 50 minutes**
Week 4 Activities	Elaborate Activity: Expand on concepts learned, connect and apply understandings to the world. Teacher-led review of tethered body motion and application to Space Elevator (20 mins) Students work on model assembly instructions (30 mins)		Explore Activity: Product 4 Due Scale model/prototype (1in = 1000 miles) of what a space elevator might look like and how it might work. Students work in teams to complete their model of the space elevator, using their pre-prepared assembly instructions (45 mins)		Evaluate Activity: Ongoing diagnostic process to determine if the learner has attained understanding of concepts & knowledge Review of the model of a space elevator (15 mins) Review of Worksheet #2 (10 mins) Review of project status by teams (25 mins)
	Day 21 90 minutes	**Day 22**	**Day 23 90 minutes**	**Day 24**	**Day 25 50 minutes**
Week 5 Activities	Explore Activity: Students work in teams to organize and reflect on portfolio contents, and write conclusions and recommendations (45 mins)		Explore Activity Product 5 Due Project portfolio with all project documents Students work in teams to complete portfolio contents, and review conclusions and recommendations (90 mins)		Evaluate Activity: Ongoing diagnostic process to determine if the learner has attained understanding of concepts & knowledge Preliminary review of team portfolio contents (40 mins) Students reflect on reasons behind conclusions and recommendations (15 mins)

	Day 26 90 minutes	Day 27	Day 28 90 minutes	Day 29	Day 30 50 minutes
Week 6 Activities	Evaluate Activity: The students will lead the presentation of models/prototypes and portfolio contents to their peers and interested members of the Faculty and Administration. The students will discuss the project process in detail, starting with the development of the graphic organizer and taking the audience through each phase of the project development. Each student-led discussion will include observations, ideas, questions and hypotheses, concluding with recommendations on the feasibility of building a Space Elevator. (45 mins)		Evaluate Activity: The students will lead the presentation of model/prototypes and portfolio contents to their peers and interested members of the Faculty and Administration. The students will discuss the project process in detail, starting with the development of the graphic organizer and taking the audience through each phase of the project development. Each student-led discussion will include observations, ideas, questions and hypotheses, concluding with recommendations on the feasibility of building a Space Elevator. (45 mins)		Evaluate Activity: The students will lead the presentation of model/prototypes and portfolio contents to their peers and interested members of the Faculty and Administration. The students will discuss the project process in detail, starting with the development of the graphic organizer and taking the audience through each phase of the project development. Each student-led discussion will include observations, ideas, questions and hypotheses, concluding with recommendations on the feasibility of building a Space Elevator. (45 mins) The students will spend the remaining 5 minutes of the period completing the KWL Chart that they began in the Explain phase of the lesson. (5 mins)

Worksheet #1 – Space Elevator Research

Please complete the following worksheet using your Internet research relating to the Spaceward Foundation, the Space Elevator, and the CNN Space Elevator Report.

1. What is the recommended length of the cable required for the Space Elevator?
   ____

2. What is used to "anchor" the end of the cable in space?
   ____

3. What keeps the cable tight so that it will not "fall" down back to earth due to gravity?
   ____

4. What new material can be used to make the cable so that it will not break?
   ____

5. What are the "electric cars" used to carry cargo called?
   ____

6. What do the electric cars use for power to climb the cable?
   ____

7. What is a "buckyball"?
   ____

8. Draw what a nanotube looks like.
   ____

9. What is the name of the Russian engineer who first proposed the Space Elevator in the 1960s?
   ____

10. Should the Space Elevator cable be round or more like a ribbon? Why?
    ____
    ____
    ____

Worksheet #2– Tethered bodies

Please complete the following worksheet using your notes from our previous lecture on tethered bodies in motion.

1. Suppose an object moves around in a circle of radius R at a constant speed V. If S is the distance traveled in T time around this circle, what is the mathematical relationship of V to T and S?

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2. Suppose that Theta (measured in radians) is the central angle swept our time T. What is the mathematical relationship between the angular velocity Omega and Theta and T.

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3. An object is traveling around a circle with a radius of 2 meters. If in 20m/second the object travels 5 meters, what is its angular speed?

   ____

4. In the problem above, what is its linear speed?

   ____

5. If the earth completes one revolution, and you are standing still, what is your linear speed?

   ____

6. What is your angular speed?

   ____

7. Assuming a telephone pole is 100 feet tall, what is the linear speed of the top of the telephone pole?

   ____

8. What is the angular speed of the top of the telephone pole?

   ____

9. What would be the linear speed of the top of the pole if it was 62,000 miles tall?

   ____

10. And the angular speed of this 62,000 mile tall pole?

    ____

Name: ____ **Date:** _________

KWL Chart

Before you begin your research, list details in the first two columns of this chart. Fill in the last column after completing your research.

Topic: ____		
What I Know	**What I want to Know**	**What I learned**