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| **Title** | We're ALL Engineers |
| **Introduction** | This lesson teaches students about the properties of waves.  This STEM lesson set includes:  **Science:** Students will learn about waves and wave properties including: Longitudinal, Transverse, wave anatomy (crest, trough, wavelength, amplitude), frequency, and speed.   * Assignments include:   + Pre-test (Grade not recorded, but the class average will be marked on class graph)   + Power Point Presentation with guided notes   + Slinky demonstration (In power point)   + Tuning Fork demonstration (In power point)   + Weather activity- Sine/ Transverse waves (In power point)   + Quiz   + Post-Test   **Technology:** Students will use Mac books or any other personal device (if available) for research in lessons 1 and 2.   * Assignments include:   + Research in the first lesson, “Career Day”   + Online videos     - Not only will students use technology, they will be researching technology used in engineering fields.   + Power Point   + Research in the second lesson, “Weather Activity”   **Engineering:** Students will research various types of engineers that are present in a local cable manufacturing company. Each of these engineers uses knowledge of waves daily in the creation, production, and improvement of cable. An engineering representative from the local cable company will visit and speak to the class.   * Assignments include:   + Station rotation   + Web quest   **Math:** Students will write and solve equations for wave velocity, frequency, and period.   * Assignments include:   + Questions for each (velocity, frequency, and period) in the power point. |
| **Real Science Application** | “All waves transmit energy not matter. Nearly all waves travel through matter. Waves are created when a source (force) creates a vibration. Vibrations in materials set up wavelike disturbances that spread away from the source. Wave behavior can be described in terms of how fast the disturbance spreads, and in terms of the distance between successive peaks of the disturbance (the wavelength). Sound and earthquake waves are examples. These and other waves move at different speeds in different materials. Waves are moving energy. Light waves are unique in their ability to travel through a vacuum (space). Sound is a form of energy that results when vibrating materials produce waves that move through matter. Students will compare sound waves (longitudinal waves) to light waves (transverse waves). Energy will cause materials to vibrate. These vibrations are carried as “waves” and transfer energy. Students will identify the basic characteristics of a transverse wave: trough, crest, amplitude, and wavelength. Students will also identify the basic characteristics of a longitudinal (compressional) wave: amplitude, rarefaction, and compression. " -Iredell-Statesville Schools Curriculum Guide |

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| **Curriculum Alignment** | **NC Essential Standards**   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | **Content Area** | **Grade Level** | **NC SCS** | **Lesson 1** | **Lesson 2** | **Lesson 3** | | Science | 6 | Scientific Inquiry | Career day/Choose an engineer. |  |  | | Science | 6 | 6.P.1.1  I can explain wave properties and behaviors. |  | Properties of waves notes/activities |  | | Science | 6 | Scientific Inquiry |  |  | Site visit from CommScope engineer | |
| **Learning Outcomes** | **Essential Questions:**  1. What are the characteristics of a wave?  2. How are waves created?  3. What is sound?  4. What is light?  5. What are the basic characteristics of a transverse wave?  6. What are the basic characteristics of a longitudinal wave?  **Criteria for Success:**  A.) Students will identify parts of a wave.  B.) Students will understand what a wave is  C.) Students will demonstrate behaviors of waves.  D.) Students will identify types of wave.  E.) Students will recognize that vibrations produce waves  F.) Students will understand the properties of waves. |
| **Time and Location** | **Lesson 1:** 1 class period (75 minutes)  **Lesson 2:** 3 class periods (75 minutes each)  **Lesson 3:**1 class period (75 minutes) |

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| **Materials Needed** | **Teacher List:**   * Computer * Internet access * Web quest handout * Power Point presentation * Guided notes * 1Slinky ( I recommend a large metal slinky, but any will be fine) * Projector * Smart Board (Not required) * White boards for groups (if they aren’t available, paper plates or white sheets of paper work well.)   **Student List:**   * Mac books or other personal devices (or computer lab) * Internet access * Graph paper * Pencil * Web quest handout * Guided notes |
|  | **The Safety section includes teacher and student safety precautions. Considerations for outdoor work must be described if a field site is used. Remember that even household chemicals have** [**SDS**](https://www.osha.gov/Publications/HazComm_QuickCard_SafetyData.html) **(formerly known as MSDS) sheets and they must be available.**  *None* |
| **Student Prior Knowledge** | Students should be able to name types of waves they have seen (water waves, stadium waves, etc…).  Students should know how to use computers to research.  Students should know how to create a graph with all axis labeled and have an appropriate scale. |
| **Teacher Preparations** | * Students will complete some assignments on their own (pre/post test), and some in groups. * **Lesson 1**   + Career day will involve a "Station Rotation". This needs to be set up prior to class beginning. Each station should have a computer (unless all students have devices).   + If no technology is available this can be done as a whole group assignment on the projector.   + Have tables/desks arranged into 6 stations.     - Engineering     - Product Engineer     - Materials Engineer     - Process Engineer     - Controls Engineer     - Test Engineer   + Print “Career Day” web quest handout (1 per student) OR have students download the link and complete on their device. * **Lesson 2**   + Make copies of the guided notes (1 set for each student)   + Download Power Point Presentation   + Have a slinky and a tuning fork   + Have weather history website loaded and ready to give example on the projector. * **Lesson 3**   + Classroom visit by engineer     - If possible find a local engineer to speak to the class about what they do, what education they have, and how they use waves in their job.     - Great places to look for engineers are:       * any local manufacturing plant       * a local community college or university |
| **Activities** | **Lesson 1: Career Day (One class period: 10-12 mins/station)**   * Today students will explore what kinds of engineers are involved in manufacturing facilities. * They will research several types then choose one to explore deeper. * 6 Stations should be set up around the room:   + - Engineering     - Product Engineer     - Materials Engineer     - Process Engineer     - Controls Engineer     - Test Engineer * Each station should have a computer set to the webpage that is on the web quest OR students can carry their personal devices to each station.   + \*If students do not have a personal device and there are not enough classroom computers this can be done as a whole group and the webpages can be shown on a projector. * Each student should have either a hard copy of the web quest questions OR they can download the file and complete the questions on their computer. * Students should be in small groups as the rotate around the room visiting each station. * Each station has a video or a website that provides information about a certain type of engineering.   + Students will use these sites to learn and answer questions about this type of engineer. * They will complete the short answer questions on the web quest handout as they watch the videos. * Make sure that students are on task and on the correct webpage at all times. * They should be allowed to pause videos to write and replay them (as long as time allows). * Each station will take approximately 10-12 mins to complete. * At the end of the station rotations students should choose 1 engineering type to learn more about. * **Extension- \*\*Homework\*\***    + **Writing assignment:** Students should choose a type of engineer they have learned about today to do learn more about. They will write a 5 paragraph essay about the following prompt:     - **Pretend you are a (choice of engineer) at a large company. Describe, in detail, a project that you will work on. What is the purpose of the project? What are you creating? How will you accomplish the project? Will you need help from other engineers? Will your project have a societal impact?**   **Lesson 2: Properties of Waves**   * Pass out Guided Notes handout to each student. * Turn projector on * Students should be filling in blanks on the guided notes handout throughout the entire presentation. * Open Properties of Waves Power Point (The following is on the Power Point)   \_\_\_\_\_ 5 minutes for actions listed above\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_   * + Explain the definition of waves   + Activity #1 2-5 mins: Types of waves     - Have students work as small groups/partners to quickly think of several types of waves.   + Activity #2 5 minutes: Slinky Activity     - Power Point explains activity   + Activity #3 30 minutes: Weather Activity     - Power point explains activity     - Students should get out their Mac Books or other personal devices. \*Or computer lab computer     - Go to this website:   [**http://www.wunderground.com/history/**](http://www.wunderground.com/history/)   * + - Choose a city, enter city or zip code     - Anywhere in the world! \***Global Extension**\*     - Choose April 1, 2013 as the date     - Click Monthly     - On their graph paper they should make a graph     - X axis labeled with the months     - Y axis labels with temperatures       * 0-110 degrees Fahrenheit     - Plot the point for the Average (AVG), Mean temperature.     - Click “next month”     - Continue plotting the points on your graph   + Activity #4 20 minutes: Assigning parts to the wave     - Follow along the power point     - Students will assign appropriate points to their wave, according to the presentation * Finish power point as students fill out guided notes   \*\*As a global extension students will look up average temperatures from places all over the world. Realistically places farther from the equator will have higher amplitudes and places closer to the equator will have smaller amplitudes. \*Places close to the ocean may skew results so these should be avoided since weather patterns are a 7th grade standard.\*   * As an exit ticket students will summarize their notes and what they learned including any questions they have. |
| **Assessment** | **Pre-Assessment- Page added at the bottom**  **Post-Assessment- I give the same assessment at the end to accurately show growth** |

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| **Critical Vocabulary** | **Wave**- a wave is a disturbance that travels  through a medium from one location to another.  **Transverse waves**- a wave vibrating at right angles to the direction of its propagation.  **Longitudinal waves**- a wave vibrating in the direction of propagation  **Trough**- A point on the wave is a trough if the displacement of the medium at that point is at a minimum. The bottom point of the wave.  **Crest**- A crest is a point on the wave where the displacement of the medium is at a maximum. The top point of the wave.  **Amplitude**-The height of the wave from the point of equilibrium.  **Frequency**- the number of crests of a wave that move past a given point in a given unit of time. The most common unit of frequency is the hertz (Hz), corresponding to one crest per second.  **Wavelength-**The point from one wave crest to the next wave crest.  **Rarefaction-**  A decrease in density and pressure in a medium, such as air, caused by the passage of a sound wave  compression  **Sound-** vibrations that travel through the air or another medium and can be heard when they reach a person's or animal's ear.  **Vibration-** an oscillation of the parts of a fluid or an elastic solid whose equilibrium has been disturbed, or of an electromagnetic wave.  **Medium-** An intervening substance through which something else is transmitted or carried on.  Sound travels through air, water, solid substances.  **Vacuum-** An intervening substance through which something else is transmitted or carried on.  Sound travels through air, water, solid substances**.** |

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| **Author Info** | Kenan Fellow Brittany Head   * Northview IB School, Statesville, NC -Iredell Statesville Schools * 6th grade science * four years of experience * brittany\_head@iss.k12.nc.us   Mentor:   * Doug Blew, CommScope |

**Name Date Block**

**Energy: Properties of Waves Pre-Test**

1. What do playing a guitar, banging a drum, and dropping a pebble in the water have in common? (6.P.1.1)

A.  They all produce light.

B.  They all cause vibrations.

C.  They all convert heat to energy.

D.  They all need gravity to move.

2. Sound waves, water waves, and light waves are all alike in that they all \_\_\_\_\_\_\_\_\_\_\_\_. (6.P .1.1)

1. Move energy from one place to another
2. Move at the same speed
3. Move without vibrating
4. Move the fastest in water

3. What  is the distance between two consecutive points in phase on a wave called? (6.P.1.1)

1. Frequency

B. Period

C. Amplitude

D. Wavelength

4. Which statement best explains why thunder is heard after lightning is seen? (6.P.1.1)

1. Light travels faster than sound
2. Light travels slower than sound
3. Thunder is produced by the impact of lightning against the ground
4. The eye works faster than the ear

5. Regions in a sound wave where particles are farthest apart are called \_\_\_\_\_\_\_\_\_. (6.P .1.1)

A. Compressions

B. Condensations

C. Depressions

D. Rarefactions

1. Selena stretches a rubber band across a box and lets it go. What is produced? (6.P.1.1)
2. Electrical energy
3. Magnetic energy
4. Sound waves
5. Light waves
6. How can you classify energy according to its waves? (6.P.1.1)
7. According to the waves’ frequency, amplitude, and loudness.
8. According to the waves’ wavelength.
9. According to the waves’ crest and trough.
10. According to its sound.

**Properties of Waves Guided Notes**

**What is a Wave?**

A wave is a that travels through a medium from one location to another.

A is the motion of the disturbance

**Slinky**

When the slinky is stretched from end to end and is held at , it assumes a natural position known as the  **or rest position.**

To introduce a wave here we must first create a .

We must move a particle away from its rest position.

**Slinky Activity**

One way to do this is to quickly move the slinky forward.

The beginning of the slinky moves away from its equilibrium position and then back.

The continues down the slinky.

This disturbance that moves down the slinky is called a .

If we keep pulsing the slinky back and forth, we could get a repeating disturbance.

**Slinky Activity**

This type of wave is called a wave.

The pulse is transferred through the of the slinky, but the slinky itself does not actually move.

It (moves) from its rest position and then returns to it.

**Slinky**

The metal of the slinky is the in that transfers the energy pulse of the wave.

The medium ends up in the same place as it started

It just gets disturbed and then returns to it .

The same can be seen with a stadium wave.

Let’s start the wave!

**Longitudinal Wave**

The medium particles vibrate to the motion of the pulse.

What does parallel mean?

This is the same type of wave that we use to transfer .

How does this happen?

**Transverse Wave**

Transverse waves travel to the disturbance.

What does perpendicular mean?

How is this different than longitudinal waves?

**Longitudinal vs. Transverse**

waves can be seen when we wiggle the slinky up and down.

They also occur when the source disturbance follows a motion.

A spring or a pendulum can accomplish this.

The wave formed here is a wave.

**Periodic Waves**

Think of some things that happen periodically.

Weather patterns

Temperatures

Imperfections in cable

What are some others?

**Parts of a Wave**

The points A and F are called the **\_\_\_\_\_\_\_\_\_\_\_\_**of the wave.

This is the point where the wave exhibits the maximum amount of positive or \_\_\_\_\_\_\_\_\_displacement

The highest it’s going to get!

The points D and I are called the of the wave.

These are the points where the wave exhibits its negative or downward displacement.

The lowest it’s going to get!

**Parts of a Wave**

The distance between the dashed line and point A is called the of the wave.

This is the maximum displacement that the wave moves away from the .

**Parts of a Wave**

The distance between two similar points is called the wavelength.

The easiest to see is between 2 crests.

Between what other points (pairs) can a wavelength be measured?

**Frequency**

You should know that frequency measure how often something happens over a certain amount of .

We can measure how many times a wave passes a fixed point over a given amount of time, and this will give us the .

**Frequency**

If I move a slinky up and down, and count that 10 waves pass a point in 5 seconds. What would the frequency be?

cycles / second

Hz

Use the term (Hz) to stand for cycles per second.

**Period**

The period describes the same thing as it did with a pendulum.

It is the time it takes for one cycle to complete.

It also is the of the frequency.

What does reciprocal mean?

T = 1 / f

f = 1 / T

**Wave Speed**

You can use what we know to determine how a wave is moving.

What is the formula for velocity?

Velocity = Distance / Time

What distance do we know about a wave?

Wavelength

What time do we know?

Period

**Wave Speed**

Plug these values in and get:

Velocity = Length of wave / Time for wave to move pass a fixed point

V = λ / T \*The symbol λ represents wavelength

**Wave Speed**

V= λ / T

What does T equal?

T = 1 / f

You can also write:

V = f λ

Velocity = Frequency x Wavelength

This is known as the .

**Career Day!**

**Engineering Web Quest**

**1. Engineering**

**https://www.youtube.com/watch?v=98OQpZPOnko**

**A. What is an engineer?**

**B. List the steps of the engineering process**

**1. 2. 3.**

**4. 5. 6.**

**7. 8. 9.**

**2. Product Engineer**

**https://www.youtube.com/watch?v=Llk04somtBU**

**A. List 3 things that a product engineer does.**

**B. What are the goals of a product engineer?**

**C. What are potential problems that product engineers could face? List at least 2 and explain your answers.**

**3. Materials Engineer**

**https://www.youtube.com/watch?v=DtosXFgP7C4**

**A. List 4 things that Materials Engineers work with**

**1. 2.**

**3. 4.**

**B. Name at least 3 things that Materials Engineers have created.**

**C. What are potential problems that materials engineers could face? List at least 2 and explain your answers.**

**D. What kind of education would you need to be a materials engineer?**

**4. Process Engineer**

**http://www.aboutbioscience.org/careers/processengineer**

**A. What are the 2 main responsibilities of a Process Engineer?**

**B. List at least 3 other people a Process engineer might interact with.**

**C. What are potential problems that process engineers could face? List at least 2 and explain your answers.**

**D. What kind of education would you need to be a process engineer? What high school courses could you take?**

**5. Controls Engineer**

**http://education-portal.com/articles/Become\_a\_Controls\_Engineer\_Education\_and\_Career\_Roadmap.html**

**A. What are at least 3 things that a Controls Engineer does?**

**B. What are potential problems that controls engineers could face? List at least 2 and explain your answers.**

**C. What kind of education would you need to be a Controls engineer?**

**D. What special skills might you need to be a controls engineer?**

**6. Test Engineer**

**https://www.youtube.com/watch?v=ijX7WAtjOdM**

**A. List at least 4 things that Test engineers do.**

**B. What special skills might you need to be a Test engineer?**

**C. What kind of education would you need to be a Controls engineer?**

**D. What are potential problems that controls engineers could face? List at least 2 and explain your answers.**

**Answer Keys**

**Energy: Properties of Waves Pre-Test**

1. **B**
2. **A**
3. **B**
4. **B**
5. **D**
6. **A**
7. **D**
8. **A**
9. **D**
10. **A**
11. **B**
12. **C**
13. **D**
14. **C**
15. **B**
16. **C**
17. **A**
18. **B**
19. **A**
20. **A**

**Properties of Waves Guided Notes**

**What is a Wave?**

A wave is a **Disturbance** that travels through a medium from one location to another.

A **Wave** is the motion of the disturbance

**Slinky**

When the slinky is stretched from end to end and is held at **rest** , it assumes a natural position known as the equilibrium **or rest position.**

To introduce a wave here we must first create a **disturbance** .

We must move a particle away from its rest position.

**Slinky Activity**

One way to do this is to quickly move the slinky forward.

The beginning of the slinky moves away from its equilibrium position and then back.

The **disturbance** continues down the slinky.

This disturbance that moves down the slinky is called a **pulse**.

If we keep pulsing the slinky back and forth, we could get a repeating disturbance.

**Slinky Activity**

This type of wave is called a **longitudinal** wave.

The pulse is transferred through the **medium** of the slinky, but the slinky itself does not actually move.

It **displaces**  (moves) from its rest position and then returns to it.

**Slinky**

The metal of the slinky is the **medium**  that transfers the energy pulse of the wave.

The medium ends up in the same place as it started

It just gets disturbed and then returns to it **rest position** .

The same can be seen with a stadium wave.

Let’s start the wave!

**Longitudinal Wave**

The medium particles vibrate **parallel** to the motion of the pulse.

What does parallel mean?

This is the same type of wave that is used to transfer **sound**.

How does this happen?

**Transverse Wave**

Transverse waves travel **perpendicular** to the disturbance.

What does perpendicular mean?

**Perpendicular forms a right angle to the equilibrium.**

How is this different than longitudinal waves?

**Parallel moves in the same direction as equilibrium.**

**Longitudinal vs. Transverse**

**Transverse** waves can be seen when we wiggle the slinky up and down.

They also occur when the source disturbance follows a **periodic** motion.

A spring or a pendulum can accomplish this.

The wave formed here is a **SINE** wave.

**Periodic Waves**

Think of some things that happen periodically.

Weather patterns

Temperatures

Imperfections in cable

What are some others?

**Parts of a Wave**

The points A and F are called the **CRESTS** of the wave.

This is the point where the wave exhibits the maximum amount of positive or upwards **displacement**

The highest it’s going to get!

The points D and I are called the **Troughs** of the wave.

These are the points where the wave exhibits its **maximum** negative or downward displacement.

The lowest it’s going to get!

**Parts of a Wave**

The distance between the dashed line and point A is called the **amplitude** of the wave.

This is the maximum displacement that the wave moves away from the **equilibrium** .

**Parts of a Wave**

The distance between two **consecutive** similar points is called the wavelength.

The easiest to see is between 2 crests.

Between what other points (pairs) can a wavelength be measured?

**Frequency**

You should know that frequency measure how often something happens over a certain amount of **time** .

We can measure how many times a wave passes a fixed point over a given amount of time, and this will give us the **frequency** .

**Frequency**

If I move a slinky up and down, and count that 10 waves pass a point in 5 seconds. What would the frequency be?

**2** cycles / second

**2** Hz

Use the term **Hertz** (Hz) to stand for cycles per second.

**Period**

The period describes the same thing as it did with a pendulum.

It is the time it takes for one cycle to complete.

It also is the **reciprocal** of the frequency.

What does reciprocal mean?

T = 1 / f

f = 1 / T

**Wave Speed**

You can use what we know to determine how **fast** a wave is moving.

What is the formula for velocity?

Velocity = Distance / Time

What distance do we know about a wave?

Wavelength

What time do we know?

Period

**Wave Speed**

Plug these values in and get:

Velocity = Length of wave / Time for wave to move pass a fixed point

V = λ / T \*The symbol λ represents wavelength

**Wave Speed**

V= λ / T

What does T equal?

T = 1 / f

You can also write:

V = f λ

Velocity = Frequency x Wavelength

This is known as the **wave equation** .

**Career Day!**

**Answer Key**

**Engineering Web Quest**

**1. Engineering**

**https://www.youtube.com/watch?v=98OQpZPOnko**

**A. What is an engineer?**

**An engineer is someone who “turns dreams into reality.” They follow the engineering design process to attain their goals. A person that designs, creates, or improves machines or materials.**

**B. List the steps of the engineering process**

**1. Identify a need 2. Define the problem 3.Conduct Research**

**4. Refine the research 5.Analyze Constants 6.Search for alternative solutions**

**7.Analyze possible solutions 8. Make decisions 9. Repeat**

**2. Product Engineer**

**https://www.youtube.com/watch?v=Llk04somtBU**

**A. List 3 things that a product engineer does.**

**\*\*There can be many possible answers: design new products, build the products from the design, understand how things work, test devices, reduce the time it takes to test devices.**

**B. What are the goals of a product engineer?**

**To have an efficient completed project**

**C. What are potential problems that product engineers could face? List at least 2 and explain your answers.**

**Engineers could face problems getting their ideas across to other people. They could experience design flaws or production setbacks.**

**3. Materials Engineer**

**https://www.youtube.com/watch?v=DtosXFgP7C4**

**A. List 4 things that Materials Engineers work with**

**1.Structure 2. Properties**

**3.Processing 4.Performance**

**B. Name at least 3 things that Materials Engineers have created.**

**Artificial Skin, Command strips, Prosthetics, high performance composites, sports equipment, sports apparel, adhesives (sticky stuff).**

**C. What are potential problems that materials engineers could face? List at least 2 and explain your answers.**

**They are always trying to improve a design, so they are never really finished.**

**D. What kind of education would you need to be a materials engineer?**

**Bachelor of Science degree in Chemical engineering, mechanical engineering, or materials engineering. Most continue on the get a Master of Science degree in materials engineering.**

**4. Process Engineer**

**http://www.aboutbioscience.org/careers/processengineer**

**A. What are the 2 main responsibilities of a Process Engineer?**

**Develop new industrial processes and design new process equipment.**

**B. List at least 3 other people a Process engineer might interact with.**

**Materials engineer, Product engineer, and controls engineer.**

**C. What are potential problems that process engineers could face? List at least 2 and explain your answers.**

**Is the process going to be efficient? Is the process going to work with the materials given?**

**D. What kind of education would you need to be a process engineer? What high school courses could you take?**

**One should learn the basic principals of science and math in high school by taking the highest levels of these courses offered at your school. These classes will prepare you for college where you should get a B.S. in engineering. Most will go on to get a Masters degree.**

**5. Controls Engineer**

**http://education-portal.com/articles/Become\_a\_Controls\_Engineer\_Education\_and\_Career\_Roadmap.html**

**A. What are at least 3 things that a Controls Engineer does?**

**Again, answers can vary.**

**Talks to customers, easily acquires skills, works with computers, makes machines more efficient**

**determines how things work…**

**B. What are potential problems that controls engineers could face? List at least 2 and explain your answers.**

**Some skills may be harder to learn than others. Problems can always arise when working with others.**

**C. What kind of education would you need to be a Controls engineer?**

**Strong math and science skills are required, so taking advanced classes in high school is recommended. A bachelor of science degree in engineering is recommended as well as a masters degree.**

**D. What special skills might you need to be a controls engineer?**

**Strong computer skills, attention to detail, teamwork, active learning skills.**

**6. Test Engineer**

**https://www.youtube.com/watch?v=ijX7WAtjOdM**

**A. List at least 4 things that Test engineers do.**

**Test projects for safety and efficiency. Make sure products work as they are designed. Suggest solutions if the products do not work.**

**B. What special skills might you need to be a Test engineer?**

**Oral communication skills and the ability to present in front of large groups. Problem solving skills.**

**C. What kind of education would you need to be a Test engineer?**

**Math and science classes in high school. B.S. degree in engineering and a strong background in working with customers.**

**D. What are potential problems that controls engineers could face? List at least 2 and explain your answers.**

Making sure the product is at a cost the customer can afford. Products not only have to be well made and efficient, but they also have to be affordable.