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|  | Applications of Identification Using LightTeacher Edition |
| **Subject(s)/Course(s): Geometry**  | **Grade Level: 10th**  | **Duration: ~80min** |
| **Lesson Synopsis/Narrative:** Students will utilize their knowledge of mathematics to identify the frequency of visible light through a diffraction gradient. In order to complete this lab students will need to be taught the process of how to construct a perpendicular line from a point, applications of Pythagorean Theorem and/or the law of sines.Students will construct a spectrometer to determine the wavelength of light from three different lasers. Students will use this information to design a spectrograph that is specifically designed to find two reference spectra characteristics of diamond.In 2016 the global diamond jewelry market was approximately 80 billion dollars. Diamonds are very expensive to mine and to produce gem quality specimens. Fake diamonds like cubic zirconia have been flooding the market for years, being bought and sold as real diamonds. The reason is because it is very difficult to distinguish between a real diamond and cubic zirconia. Diamonds are very unusual for a gemstone because they are composed of a single element, carbon. Virtually all other gemstones contain multiple elements, primarily significant amount of oxides. Cubic zirconia is made up of zirconium dioxide (ZrO2).  |
| **Prior Knowledge:** Pythagorean Theorem |
| **Background information:** <https://solarsystem.nasa.gov/deepimpact/science/spectroscopy.cfm> When light passes through a material, that material absorbs, reflects, or emits specific frequencies of light. In spectroscopy we can separate that light into its component parts and identify the frequencies present. These frequencies are characteristic of specific elements.Diffraction gratings used in spectroscopy diffract, or split, light periodically, meaning the light splits into several beams with a given angular separation. In this experiment, the first period, n=1, will be the brightest spot on the index card (besides the straight path of the laser, of course) after the grating splits the rays from the laser pointer. Using the formula above, you can verify the wavelength of light using what the manufacturer of the laser pointer says it is. If the room is dark enough, you may even be able to measure the 2nd and 3rd periods and plug n = 2 and n = 3 into your equation, respectively. It should yield the same result. |
| **Challenging Question or Problem:** How can we design a spectrograph that will be able to identify fake diamonds from real diamonds? Students will write a procedure to identify the frequency of the spectra of various UV visible light sources? |
| **Phenomenon and Manufacturing Application:** Spectroscopy is used to identify the elements present in a material. Medical diagnosis through magnetic resonance imaging (MRI), material identification, determining molecular structures, chemical concentration/ identification, and quality control all rely on spectroscopy. |
| **Examples (in action):**Spectroscopy in forensics has proven to be a non-destructive way to analyze different bodily fluids, drugs, or fingerprints. Analyzation of forensic materials can be on site, quick, and requires minimal to no sample preparation.By Kkmurray (Own work) [GFDL (http://www.gnu.org/copyleft/fdl.html) or CC BY-SA 3.0 (https://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia CommonsArticles that students can read at varying degrees of difficulty:Overton, G. (2012, 02). When photonics meets forensics, crime really doesn't pay. *Laser Focus World, 48*, 54-57. Retrieved from <https://search.proquest.com/docview/925657492?accountid=1771> <https://www.photonics.com/a36234/Applications_Spectroscopy_in_Forensics><https://sensing.konicaminolta.us/blog/spectroscopy-and-forensics/>  | **Vocabulary:**AngleCircleConstructionPerpendicular LineParallel LineLine SegmentLaw of SinesPythagorean Theorem |
| **State and National Standards & 21st Century Skills:****High School Common Core Math Standards:****G-CO #1**Know precise definitions of angle, circle, perpendicular line, parallel line, and line segment, based on the undefined notions of point, line, distance along a line, and distance around a circular arc.**G-CO #12**Make formal geometric constructions with a variety of tools and methods (compass and straightedge, string, reflective devices, paper folding, dynamic geometric software, etc). Copying a segment; copying an angle; bisecting a segment; bisecting an angle; constructing perpendicular lines, including the perpendicular bisector of a line segment; and constructing a line parallel to a given line through a point not on the line.**G-SRT #6**Understand that by similarity, side ratios in right triangles are properties of the angles in the triangle, leading to definitions of trigonometric ratios for acute angles.**G-SRT #8**Use trigonometric ratios and the Pythagorean Theorem to solve right triangles in applied problems.**G-SRT #11**Understand and apply the Law of Sines and the Law of Cosines to find unknown measurements in right and non-right triangles (e.g., surveying problems, resultant forces).**Geometry Practices**MP4. Model with MathematicsMP5. Use appropriate tools strategicallyMP6. Attend to precision**N-Q #3**Choose a level of accuracy appropriate to limitations on measurement when reporting quantities |
| **Learning Targets**:* Students will use geometric constructions to bisect a segment; bisect an angle; construct perpendicular lines, including the perpendicular bisector of a line segment; and constructing a line parallel to a given line through a point not on the line.
* Use trigonometric ratios and the Pythagorean Theorem to solve right triangles in applied problems.
* Understand and apply the Law of Sines and the Law of Cosines to determine an angle.
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| **Materials and Equipment Per Group:**Large PaperMeter StickThree lasers – Green Red BlueDiffraction Gradient Slit Holders/Diffraction Gradient StandPencilStringCompassStraight EdgeRulerScientific CalculatorPush Pins |
| **Materials not provided in kit, preparation/time:**Large PaperCompassStraight EdgeRulerScientific CalculatorPencil\*\*No Prep time is required; however, cutting the paper ahead of time might be helpful. |
| **Safety:**Lasers are light sources that can permanently damage the eye. They are not toys. If you stare into a laser beam for a period of time, permanent and irreparable damage to the eye can occur. The Laser Blox set provided in the kit is a Class IIIR laser product. At this power rating the human eye blink reflex will prevent any permanent eye damage. To reduce the chance of eye injury, do not completely darken the room as to prevent complete pupil dilation.**Laser safety posters should be posted around the classroom when they are in use.** Information about laser classifications and safety:<http://www.lasersafetyfacts.com/laserclasses.html> |
| Procedure and Prompts:

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| Teacher Does and Says | Student Does and Says |
| **Introduction:**  |
| <https://www.news-medical.net/life-sciences/Spectroscopy-Applications.aspx>  | Students read the article *Spectroscopy Applications* and discuss. |
| **Setup:** |
| Students should be in groups of 2 or more. Setup should match the setup as depicted in the diagram.Diffraction gratings contain thousands of very small slits, or rulings, where the light will spread out and change direction as it passes through the small openings. The laser that you are using today contains light of only one color or wavelength. Light with multiple colors or wavelengths would be broken up into their component colors or wavelengths. | 1. Using the provided poster paper, cut and tape a large sheet of paper with minimum dimensions of 30” x 24” to the table.
2. Lay the meter stick on the paper so that the edge of the stick is approximately one inch away from the edge of the paper and centered on the paper in the other direction.
3. At the far end of the paper and meter stick, place the laser pointer support block on top of the meter stick and then the laser pointer on top of the block, pointing towards the other end of the paper.
4. Place the diffraction grating in the white diffraction grating stand, making sure the stand only comes in contact with the cardboard frame. Place the diffraction grating and the stand on the meter stick between the laser and the end of the meter stick.
5. Place the push pin on the wood part of the meter stick directly underneath the diffraction grating. Do not place the push pin on the ruled tape.
6. Tie one end of the string around the push pin and the other end around a pencil at so that the string is taut and the pencil extends right to the end of the meter stick.
7. Turn the laser pointer on and align it so that it goes through the diffraction grating and is parallel to the meter stick. Use an index card or your finger to locate the laser, DO NOT LOOK DIRECTLY AT THE LASER!
8. Mark an X on the paper at the end of the meter stick in the line of the laser beam. This will become n=0 (zero order) of the diffraction.
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| **Gathering Data** |
| n=1 is where there is constructive interference from the diffraction grating. See the diagram below for where n=1 can be found. Constructive interference from the grating occurs when the path difference from two rays that are interacting with each other is a whole wavelength. Students should end up with a drawing similar to what is below. | 1. Create an arc with the pencil attached to the string and the push pin.
2. Mark an X along the arc where the laser beam is at n=1.
3. Draw a line connecting each X to the center point intersecting the diffraction grating. With the meter stick and paper removed it should look like the diagram below**.**
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| Students can determine the angle by a variety of methods.* Make geometric constructions to create a right angle triangle.
* Apply trigonometric ratios and the Pythagorean Theorem to solve right triangles in applied problems
* Apply the Law of Sines and the Law of Cosines
 | 1. Using the materials given to you, determine the angle θ between n=1 and n=0. Show all work in the box below.
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| **Deriving the Equation and Finding the Wavelength** |
| Constructive interference from the grating occurs when the path difference, λ from two rays that are interacting with each other is a whole wavelength. This path difference can be determined using geometry. | 1. Using the diagram below, come up with an expression that allows you to find the wavelength of light, λ based on the angle θ. Show all work in the box below.
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| The variable d is the distance between slits or rulings on the diffraction grating. The number of slits or rulings on the diffraction grating is written as the number of lines per mm on the diffraction grating.  | 1. Determine the distance in mm between each slit or ruling in millimeters and then convert that to inches. (there are 25.4 millimeters in an inch)
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| Students should arrive at the equation λ = d sinθ | 1. Using the angle θ you found earlier, and the distance between the slits or rulings, d, determine the wavelength of light, λ being used. Show all work below.
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| The actual wavelength of the laser being used is written on the laser. They are: Red: 6.35x10-7 m or 2.50x10-5 in, Green: 5.32x10-7 m or 2.09x10-5 in, and Blue: 4.05x10-7 m or 1.59x10-5 in. Students should use the percent error equation$\% Error= \left|\frac{\#experimental-\#theoretical}{\#theoretical}\right|x100$  | 1. Find the percent error between the value that you got and the wavelength given. Show all work below.
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| **Open Ended Question: Material Confirmation for Diamonds** |
| Material confirmation is a technique that is extensively used in the pharmaceutical industry. A pharmacy can ensure that incoming drug is labeled correctly by comparing a drugs reference spectra to the receiving drugs spectra. If there is a match of spectral absorption lines corresponding to specific wavelengths between the reference drug and the drug received, the pharmacy can confirm its authenticity. Because diamond is made up of one element (carbon) its reference spectrum is quite unique. There are two absorption lines that define a diamond due to carbon, one at 3.30x10-6 m or 1.30x10-4 in, and another at 2.85x10-6 m or 1.12x10-4 in. Using this material confirmation technique, design a spectrograph that will allow someone to quickly confirm that a diamond is authentic based on the two absorption lines found in the reference spectra characteristics.  |

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Absorption lines in diamond information:

<https://tools.thermofisher.com/content/sfs/brochures/D10278~.pdf>

<https://www.bruker.com/fileadmin/user_upload/8-PDF-Docs/OpticalSpectrospcopy/FT-IR/ALPHA/AN/AN81_Diamonds_EN.pdf>

<http://www.spectroscopyonline.com/analysis-diamonds-ft-ir-spectroscopy?id=&pageID=1&sk=&date>=