Lesson: Hacking 3D Printers by Stealing Sound Waves

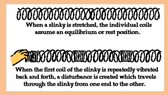
Toni McDonough, Dr. Shamik Sengupta, Dr. David Feil-Seifer

Introduction & Justification

The purpose of this lesson is to introduce students to computer science principles that are associated with cybersecurity, and how cyber security meshes with the political and the business worlds. Students should understand that cybersecurity, science, and the real world are interconnected. Students will be able to describe sound properties, model them, and set up sound experiments where they can convert sound waves into visual patterns.

Lesson Vocabulary:

Air Molecules-Electrically neutral group of atoms. Contains Nitrogen (N2) and Oxygen (O2).
Density-Mass divided by Volume=Density. Which is more dense? A handful of rocks or a handful of feathers?
Hertz-How many back and forth cycles per second the air molecules will move back and forth.
Acoustics-A science that deals with the production, control, transmission, reception, and effects of sound.
Side Channel Hacking-Capturing and decrypting signal emissions coming from a device (acoustical (sound/electromagnetic or mechanical).
Black Hat Hacker-A person who attempts to find computer security vulnerabilities and exploits them for personal gain or other malicious reasons.
Grey Hat Hacker-A computer security expert who may violate laws or typical ethical standards, but does not have a malicious intent.
White Hat Hacker-A computer security expert, who specializes in penetration testing and in other testing methodologies that ensures the security of an organization's information systems. Named after White Mage who served a Defensive/Protective Role in game *Final Fantasy.*
Ethical Hacker-They break into systems legally and ethically (often hired by a company to check how secure their own computers are).
Sound-A pressure wave caused when something vibrates, making particles bump into each other and then apart. The particles vibrate back and forth in the direction that the wave travels but do not get carried along with the wave.
Sound Frequency-Measures the number of waves passing a certain point in a given period of time.
Sound Waves-A traveling compression wave makes air molecules move fast (761 miles per hour), always pushing against the air molecules in front, causing the space in front to have a higher density of air molecules. Sound waves are compression waves. They are also called longitudinal waves because the air vibrates along the same direction as the wave travels; as a sound wave moves forward, it makes the air bunch together in some places and spread out in others. This creates an alternating pattern of squashed-together areas (known as compressions) and stretched-out areas (known as a rarefactions). A wave is like a slinky.
Sine Wave-A mathematical curve that describes a sound.



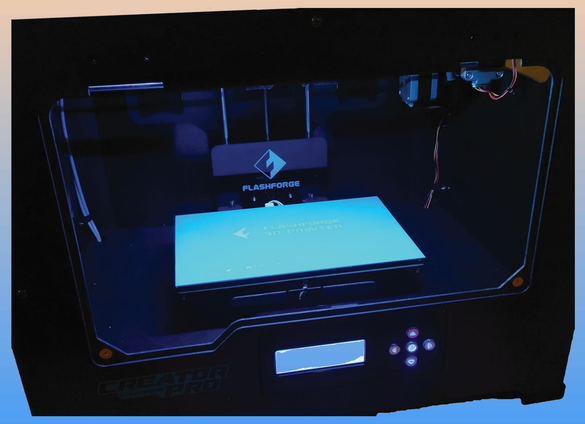
Engage: Students see 'side channel' Hacking done by sound recordings stolen from 3D printers; experiments are set up to see sound.

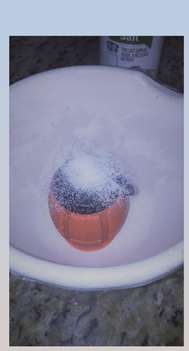
Explore: Students: see stolen sound files reconstructed into objects.; design experiments to 'see' sound; draw models of specific 'points in time' of sound using sine wave models.

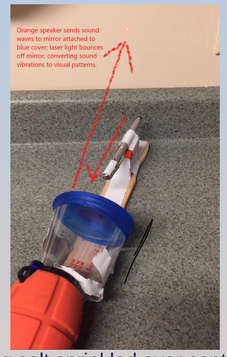
Explain: Black hats can record sound and reconstruct printing objects—even corrupt prints as corporate/political espionage; Sound wave patterns can be converted into what object is being printed.

Elaborate: Sound can be reconstructed to objects by analyzing its patterns by a phone call to an innocent party standing next to the machine, in order to capture that 3D machine's acoustical signature

Evaluate: Students can communicate 3D printer vulnerabilities, model sound waves, create experiment.







Left image is experiment using salt sprinkled over container enclosing a speaker will display patterns of sound waves.
Right two pictures are experiment showing sound patterns will be displayed by connecting a system of a laser bouncing speaker sound from mirror to wall.

Objectives & Standards

Objectives:
Students will be able to:
- Use Engineering Design Cycle to create models showing evidence that sound is a wave.
- Discuss Cyber Security concepts extending to Side Channel hacking and vulnerabilities of 3D printing.
- Understand sound waves and how to mathematically describe the energy and amplification with a sine wave model.
- Create and use models and experiments as evidence. Develop/use a model to describe that waves are reflected, absorbed, or transmitted through various materials.
- Analyze graphs and patterns of sound waves to identify patterns.

Science Standards NGSS:
- Technologies extend the measurement, exploration, modeling, and computational capacity of scientific investigations. (MS-PS4-3)

Nevada Computer Science Standards
- Explain security issues that might lead to compromised computer programs. (P7.2)
- Evaluate the ability of models and simulations to test and support the refinement of hypotheses. (P4.4)
- Compare ways software developers protect devices and information from unauthorized access. (P7.2)
- Predict how computational innovations that have revolutionized aspects of our culture might evolve. (P7.2)

Common Core ELA-Literacy-Math- Science and Technical Informational Text
- Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions. (MS-PS4-3)
- Model with mathematics. (MS-PS4-1)
- Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, energy). RST.9-10.5
- Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text. .9-10.3

Performance Expectations
- Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials. (MS-PS 4-2)
- Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave. MS-PS4-1
- Engineering Design Cycle:

(1) Inquire and Analyze (2) Develop Ideas (3) Create the Solution (4) Evaluate/Reflect.

Disciplinary Core Ideas
Wave Properties-A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude PS4.A
Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

Crosscutting Concepts:
Graphs and charts can be used to identify patterns in data(MS-PS4-1)
Science and engineering complement each other in the cycle known as research and development (R&D). (HS-PS4-5)

Reference Avesta Hojjati, Anku Adhikari, Katarina Struckmann, Edward Chou, Thi Ngoc Tho Nguyen, Kushagra Madan, Marianne S. Winslett, Carl A. Gunter, and William P. King. 2016. Leave Your Phone at the Door: Side Channels that Reveal Factory Floor Secrets. In *Proceedings of the 2016 ACM SIGSAC Conference on Computer and Communications Security* (CCS '16). ACM, New York, NY, USA, 883-894. DOI: https://doi.org/10.1145/2976749.2978323

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