

Student Handout: Semiconductor Missions

Welcome! Join us on this grand mission (made up of several smaller missions) as we learn more about the world of semiconductors. There are five missions to explore. They will challenge you to dig deeper into understanding semiconductors, semiconductor technology, supply chain and its impact on our world.

Upon the completion of each mission, collect interesting words needed for the final mission! Mix in vocabulary words and interesting/fun words. As a class or team (or individually), write a short story about a particular supply chain disruption and how it impacted the world.

- [Mission \(1\) -- Materials Mission: Superhero of Electronics](#)
 - Insulator & Conductor PhET Simulation
 - Semiconductors Types PhET Simulation
- [Mission \(2\) -- Design Mission: Art Infusion](#)
 - Integrated Circuit Designer Certification - “Squishy Circuit”
 - Create the “Mask”
- [Mission \(3\) Fabrication Mission: In the Clean Lab](#)
 - Model a Microchip
- [Mission \(4\) -- Nanoscale Mission: Morse’s Law](#)
 - Graphing Moore’s Law
 - Predicting the Future
- [Mission \(5\) -- History Mission: Transistor Revolution](#)
 - Debate on the significance of transistor
- [Mission \(6\) -- Supply Chain Mission: Science Fiction Saga](#)
 - Supply chain disruption team story



Video 1

Begin the journey by watching this video to learn about what a semiconductor is, how it is made, and why it is so important! In addition, read the related e-book section.

Mission 1: Materials Mission: Superhero of Electronics

Materials Mission: Superhero of Electronics

You are **semiconductor researchers**. A semiconductor is like the superhero of electronics. It is a material that's not as good at conducting electricity as metals (like copper), but it's better than insulators (like rubber). Semiconductors are like the "Goldilocks" of materials—they're not too conductive, not too insulating, but just right for powering our tech!

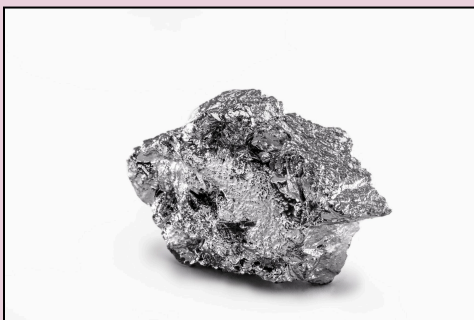
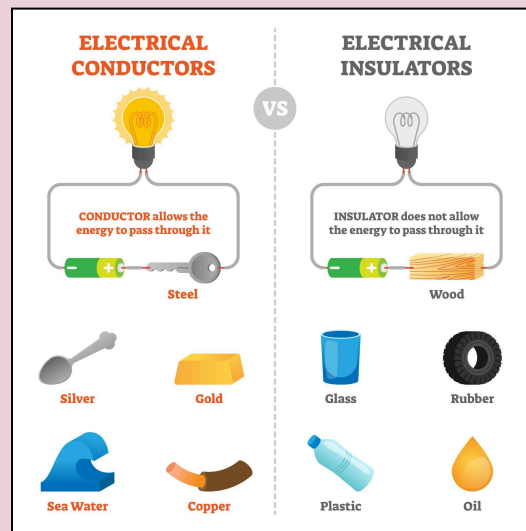
Phase 1: Explore Insulators & Conductors

To learn more about **insulators and conductors** explore the [PhET DC Circuit Simulation](#) where you can test various insulators in a circuit. Make a basic circuit with a battery, light and wires. Then have fun adding in the various materials available to determine if it will conduct electricity.

Phase 2: Semiconductor Types

Electricity is the flow of charges (electrons) through something. To dive deeper into how the electrons can move in a semiconductor, play the [PhET Semiconductor Simulation](#).

Silicon is the most common semiconductor. By adding different atoms to silicon, we can change its behavior. We create two types of semiconductors: n-type (which has extra electrons) and p-type (which has "holes" where electrons can move around).



- Zinc Oxide (ZnO)
- Silicon Carbide (SiC)
- Indium Phosphide (InP)

Other semiconductor materials are being used, as well like germanium or compounds such as gallium arsenide. See this list of semiconductors with their chemical symbol (a special shortcut for an element that scientists use when they write about chemicals.)

- Silicon Germanium (SiGe)
- Sapphire (Al₂O₃)
- Gallium Arsenide (GaAs)
- Gallium Nitride (GaN)
- Diamond

Semiconductors are just right for creating electronic magic!

Mission 2: Design Mission: Art Infusion

Design Mission: Art Infusion

A mask is a stencil of the circuit design. As the Integrated Circuit (IC) Designer, you need to create what is called a “Mask.” The circuit design is turned into a mask (or stencil). During the Fabrication Mission, you will then “stamp” your “Mask” onto your wafer (making an imprint) transferring the circuit design onto your wafer. To make the mask, the circuit design is drawn (or stamped) on the mask material and then cut out leaving the mask or stencil of the “negative of the circuit.” Light then transfers the circuit (imprinted) onto the wafer.

Chip Art: Before getting started on this next challenge read about Chip Art

When engineers design integrated circuits, they use different shapes to make a plan. This plan is sometimes referred to as ‘artwork,’ but it’s not the kind you hang on the wall. It’s a blueprint for something amazing. These shapes are like a secret code that tells the machines what to build. As we will learn, these shapes get converted into metals, insulators and semiconductors during manufacturing. But there are other



kinds of art you can find on

chips! Chip art, also known as silicon art, semiconductor art, silicon wafer art or chip graffiti refers to microscopic hidden doodles (designs, images, or messages) incorporated onto microchips during the manufacturing process. Engineers leave their creative mark on their tiny electronics canvases! One famous example was a hidden image of Waldo from the popular children’s book

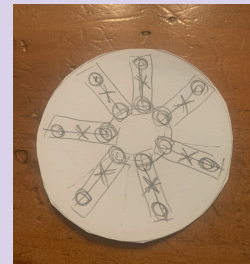
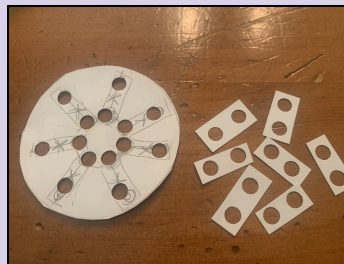
series, “Where’s Waldo?” that was found on the surface of a Texas Instruments silicon wafer in the late 1980s. Source: <https://www.devx.com/terms/chip-art/>

Go deeper by watching : To learn more about Chip Art watch this short video: [Silicondoodle Medley](#) by CPU Duke. Image Source: <https://micro.magnet.fsu.edu/creatures/pages/waldo.htm>

In honor of the “Chip Art” we just learned about. We will turn our chip layout into art.

Two constraints:

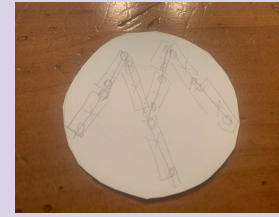
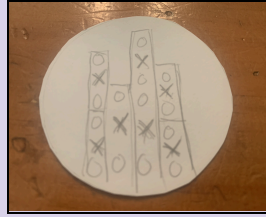
- (1) must have a minimum of 6 “chips”
(A single chip is two hole punches for the LED legs - see image of the six chips to the right)
- (2) must have a recognizable image (see image is the “sun”). Consider these other



samples (mountain and city skyline) or letters and numbers as well.

Materials

- Index Card** (Cut into a circle about 3" in diameter. You can use the bottom of a cup)
- Hole Punch
- Pencil



**A more high-tech option: If you have access to a 3D printer, you can design the "Mask" in the CAD program, Tinkercad, and then 3D print it.

Procedure

- Take the index card (cut out a 4" diameter circle as your wafer) and map out where to place 6-8 "chips" on your wafer. For this mission, chips will contain a single LED.
- There is a twist. **In honor of the "Chip Art" we just learned about**, we will turn our **chip layout into art**. Two constraints: (1) must have a minimum of 6 "chips" (2) must have a recognizable image (see image is the "sun"). Consider these other samples (mountain and city skyline) or letters and numbers as well.
- You are the quality control engineer or assign someone to this task. Explain that when quality control tests the chips they will close the circuit (using battery and wires) and if the LED lights up it counts toward your yield. If you have 7 chips and 6 light up during testing your yield will be 6 out of 7 or 86%. The goal is to have a yield of 100.

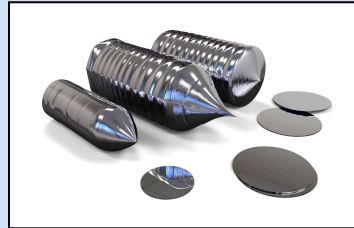
Mission 3: [Fabrication Mission](#): In The Clean Lab

Design Challenge: You are a team of **semiconductor engineers** working in a foundry or “Fab” (short for Fabrication Facilities) where you make microchips in a clean lab.

What is a clean lab? In a clean lab, everything is ultra-clean. Why? Because even a speck of dust can mess up the chips! So, semiconductor engineers wear special suits and work in air that is filtered to remove even the tiniest dust particles. It’s a high-tech space where cleanliness is king!

Materials:

- PlayDoh
- Clay
- Sandwich Bag
- Index Card
- Pencil
- Tweezers
- 4 AA Batteries (6V) or 9V
- Battery Holder or Clip
- LEDs (5mm)



Procedure:

Step 1: Wafer. Silicon is mined and then made into an ingot. The ingot is sliced into thin “wafers”

Make: Begin with one layer of PlayDoh as the wafer.



Step 2: Clean & Polish. The wafer is cleaned and polished.

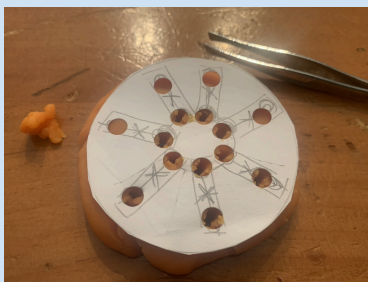
Make: Cut a sandwich bag to match the size of your wafer. Cover your wafer with it to show your wafer has been cleaned and polished.

Step 3: Photoresist Coating. After preparing the wafer, its surface is coated with a photoresist, a light-sensitive material.

Make: Add another layer of PlayDoh to model the photo resistant coating.

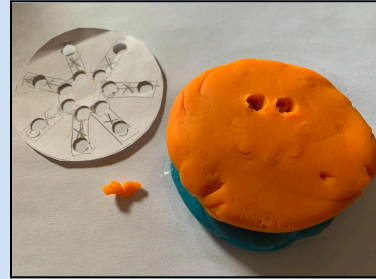


Step 4: Photo Mask. The circuit design is turned into a mask (or stencil). To make the mask, the circuit design is drawn (or stamped) on the mask material and then cut out leaving the mask or stencil of the “negative of the circuit.” Light then transfers the circuit (imprinted) onto the wafer.



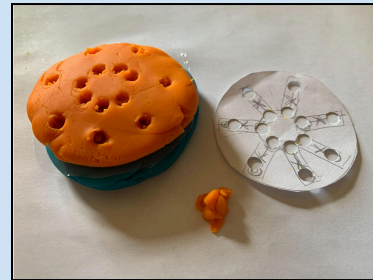
Make: Take the index card (cut out a 4” diameter circle as your wafer) and map out where to place 6-8 “chips” on your wafer. For this mission, chips will contain a single LED. There is a twist. In honor of the “Chip Art” we just learned about. We will turn our **chip layout into art**. Two constraints: (1) must have a minimum of 6 “chips” (2) must have a recognizable image (see image is the “sun”).

Consider these other samples (mountain and city skyline). When quality control tests your chips they will close the circuit (using battery and wires) and if it lights up it counts toward your yield. If you have 7 chips and 6 light up during testing your yield will be 6 out of 7 or 86%. The goal is to have a yield of 100%.



Step 5: Etching. Etching is the process of removing unwanted material to create the features of the chip by using chemicals that eat away the wafer's exposed areas, leaving behind the desired pattern. It also removes the underlying layers of silicon and other materials in the pattern of the circuit design.

Make: Use tweezers to remove the material exposed from your mask.



Step 6: Deposition. Deposition involves adding a blanket of conducting or semiconducting materials depending on the desired properties of the final product.

Make: Cut another circle (much larger than the wafer from your sandwich bag) and cover your wafer including all the areas etched away to as the coating semiconducting materials. Use the tip of a LED to press the blanket to the holes (or areas that were etched). This pulls at the sandwich bag...work your way pressing LED into blanket and smoothing (one at a time).



Step 7: Vias: Vias are little wires that let us go from one layer to another - like an elevator for the circuit, we go from one layer to another 'via' the via!

Make : Place your vias as little pieces of playdoh to connect your layers. The top of each via is a 'contact' - where we will make contact to the next device.



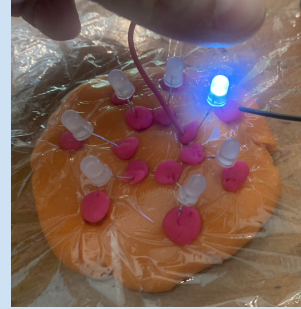
- **Step 8: Doping.** is the process of changing the properties of silicon in the wafer to create different components of the chip. This is done by introducing impurities into the silicon, which changes its conductivity. The type and amount of impurities determine whether the silicon becomes n-type, which has an excess of electrons, or p-type, which has a shortage of electrons. These are made with big machines called ion implanters, and where n and p meet (a PN junction), makes the basis of a transistor!

Make: Light emitting diodes (LEDs) are actually just a PN junction, so since we don't have a big implanter, we place our already made PN junctions (LEDs) from contact to contact to complete the circuit.



- **Step 9: Repeat.** The photolithography, etching, and doping processes are repeated multiple times to build up the complex structures of the chip. Each repetition adds a new layer to the chip, with each layer serving a specific function in the final circuit.

Make: Imagine you have repeated these steps to make multiple layers.



- **Step 10: Quality Control.** Quality Control Engineers test the chips to ensure they will actually work. This technology can be delicate and even damage not visible to the human eye can hinder its function. Therefore, clean rooms are essential to keep out any impurities and maximize the number of chips a wafer creates.

Make: Carefully add your LEDs and then the QA Engineer will test each "chip" using two wires and a battery to see if your LEDs light up.

- **Step 11: Yield.** Determine the yield. How many chips can you get out of your wafer? Typically a wafer with approximately a 12 inch diameter can **yield** 300-400 chips, depending on the amount of space between them.

Mission 4: Nanoscale Mission: Moore's Law

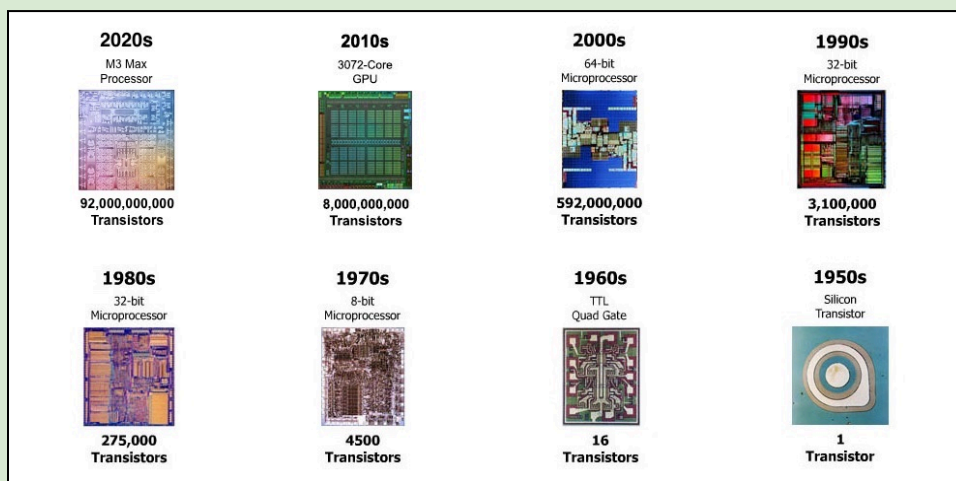
Nanoscale Mission: Moore's Law

Take on the role of a mathematician as you graph data and then make predictions.

- **Graph:** Take the information from the transistor graphic. Create a graph showing how the transistor count has changed. Discuss the exponential growth pattern and its implications.
- **Think:** Predict what computers might look like in the next decade based on this trend and imagine the features of a computer or smartphone in the year 2030.

The size of the semiconductor chip! These chips are on a **nanoscale**. Nanoscale is incredibly small – a billion times smaller than what we can see with our eyes! Your fingernails grow about a nanometer every second or 86,400 nanometres in a day, yet that's way too small for you to notice the growth. Watch the [Zoom into a Microchip](#) video by NISENet

In addition to making the chips smaller, researchers are constantly looking for new ways to increase the size of the wafer in order to increase the number of chips that can be cut from a wafer. **Wafers can range widely in size**, from 25 mm to 450 mm. Find the scale factor of your chip. What is the ratio of your Play-Doh wafer to a real wafer (3 inches in diameter, or 76 mm in diameter). What is the ratio of your Play-Doh wafer to a 25 mm chip?



Moore's Law is like a growth spurt for computers! Gordon Moore, the co-founder of Fairchild Semiconductor and Intel, predicted, in 1975, that the number of transistors (tiny switches) on a microchip would double about every two years. That means the chips get smaller and smaller. Imagine it's like your room getting twice as big every two years. This growth helps make computers faster and more powerful. Amazingly, Moore's Law has shown to be true for the last 50 years. (Image Source: <https://www.computerhistory.org/siliconengine/>)

Think & Calculate: Count the number of LEDs you got to light up this is your yield. What could you do differently to increase your yield? When quality control tests your chips they will close the circuit (using battery and wires) and if it lights up, it counts toward your yield. If you have 7 chips and 6 light up during testing, your yield will be 6 out of 7 or 86%. The goal is to have a yield of 100%. Calculate your yield.



Watch two short videos to learn more about the semiconductor industry and packaging. In addition, read the related e-book sections.

Mission 5: History Mission: Transistor Revolution

History Mission: Transistor Revolution

Take on the role of a **Technology Historian**. Watch the video that describes the history of Semiconductors and **read the section on the Transistor Revolution**. Hold a debate on the statement: "The invention of the transistor is the most significant technological advancement of the 20th century." Research to find evidence for and against this statement.

Let's Review the History of the Semiconductor Industry: The Transistor Revolution

In 1947, scientists at Bell Labs invented the transistor, a tiny electronic component made from semiconductors. Transistors replaced bulky vacuum tubes and revolutionized electronics. They're the building blocks of modern devices like computers, phones, and televisions.

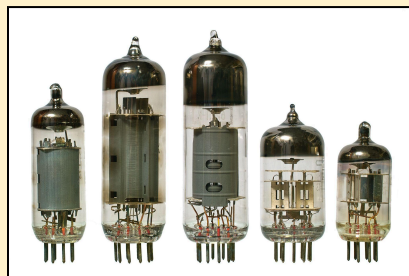
So what is a Transistor? Transistors act as a switch. When a small amount of current flows into one part of the transistor (called the gate), it allows a larger current to flow through another part (the drain). This switching capability is essential for microprocessors. **Learn** more by **watching this video**: [Transistors: Teeny Tech that Changed the World](#) by Abby Kent (Project for Science and Natural History Filmmaking from Montana State University)

In the early 1960s, the invention of the integrated circuit (commonly known as a microchip) extended the capabilities of the single transistor. To compile an integrated circuit, many transistors are manufactured at once and permanently connected within a single silicon chip. In the past 50 years, the number of transistors on a chip has grown to more than one-million on a single chip.

Think: How much smaller can a transistor be? How many might fit on the tip of an eraser in 10 years? Is there a limit to how small a transistor can be? Will Moore's Law last forever?

Source:

<https://kids.britannica.com/students/article/integrated-circuit/603797> and <https://kids.britannica.com/students/article/transistor/277411>



Mission 6: Supply Chain Mission: Science Fiction Saga

Supply Chain Mission: Science Fiction Saga

Take on the role of a **semiconductor science fiction author**. Do your research by reading about “Careers in Semiconductor Industry” and “What is the Semiconductor Supply Chain?” sections in the ebook.

Supply Chain Crisis

Imagine a serious supply chain disruption: A cataclysmic storm hits the world's biggest silicon mines now they all lie buried. This scarcity disrupts the production of phones, game consoles, and toys, disables our foundries. Society grapples with the absence of everyday electronics, underscoring the critical role of the semiconductor supply chain in our interconnected lives.

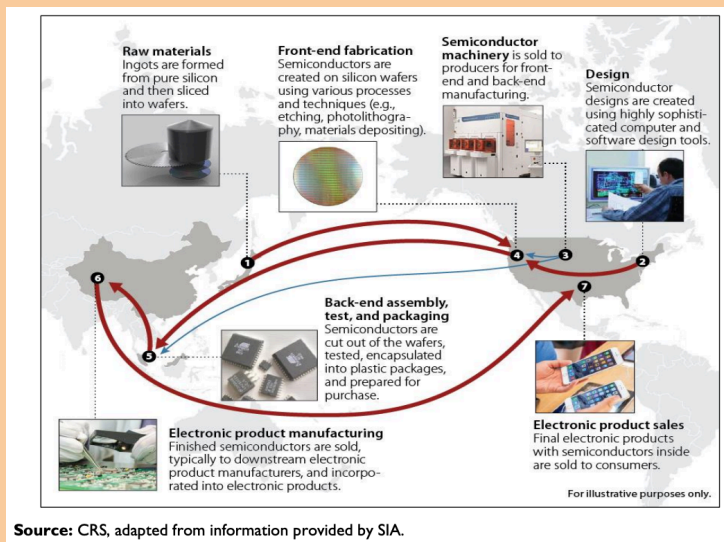
Think...What would you do?

- What creative solutions could you come up with during a supply chain disruption?

Brainstorm ideas like local production, **alternative materials**, or community support. How can we adapt when faced with scarcity?

- If you led a toy company during a supply chain crisis, what decisions would you make?

Consider balancing demand, communicating with customers, and finding alternative suppliers. How would you keep the business running?



Source: CRS, adapted from information provided by SIA.

Read the [Silicon Valley Saga](#). As a class, team or individually write a short story about a particular supply chain disruption and how it impacted the world.

How to implement team story writing: Let your students know they're about to embark on a creative adventure, crafting a story as a collective effort. Here's how it works: One student (or team) will kick off the tale with two sentences using one of the collected words appropriately. Then, they'll hand over the reins to a classmate (or team), who, after reading the opening, will contribute their own two sentences to the story also using one of their collected words. This process continues, with each student (or team)

adding to the story. Once every student has had a minimum of one turn, it's time for the grand reveal. The team (or class) will come together to read their collaborative masterpiece from beginning to end. To put the finishing touches on their creation, they'll decide on a title that captures the essence of their story and then bring it to life with some imaginative illustrations.