PROTOTYPE

Sunny Solar Farm
Activity

Grades
K-12

Career Pathways
Agricultural Engineer
Irrigation Technician
Energy Systems Engineer
Solar Technician
Hydroponics Farmer

Academics
Math: Volume, Angles, Measurement
Science: Energy, Chemistry, Health, Structure, Function, Systems

Professional Career Skills
Analysis
Creativity
Teamwork
Perseverance

Materials
Photovoltaic (PV) Solar Panel(s)
Hydro Pump
Hot Glue Gun/Tape
Scissors
Waterproof/recyclable supplies (cups, containers, straws, Ziploc bags)

Optional –
Molecular Modeling Set
Bean Seeds/Small Plant
Ruler/Protractor
Autodesk TinkerCAD Accounts
Autodesk Fusion 360 Accounts
3D Printer

Team Goal

Level 1
Design a hydroponics planter! Construct a structure that will support a growing plant while circulating water across it's roots using a solar panel and hydro pump.

Level 2
Design a hydroponics planter and develop a way to secure the solar panel to take advantage of solar energy. Your prototype will need to support a growing plant while circulating water across it's roots using a solar panel and hydro pump. Explain how the system works/supports plant growth.

Level 3
Use CAD to design and 3D print a hydroponics planter that will circulate water using solar energy while supporting a growing plant. This design could be mass printed! Explain how the system functions and ultimately may provide nourishment for humans.

Think like an Agricultural Engineer

Iterative Design

As you create your design, continue to think of new ideas and make improvements so it works better and looks great! Engineers and designers are always improving and modifying their ideas and models by cycling through the engineering design process.

Motor

A motor uses electrical energy to move molecules. In this case, it moves water molecules! A motor for hydroponics uses electrical energy to move water molecules to create a flow or current of water across the roots of a plant. Energy can be converted from one form to another, but cannot be created or destroyed!

Renewable Solar Energy

The sun can be a source of renewable energy. It is a source of energy that will not run out. Solar panels use the sun's energy to generate electricity. Solar photovoltaic (PV) panels create renewable energy from the sun. Light energy becomes electrical energy!

Precision

Engineers pay attention to the details of how components are shaped and connected. Measurements have to be precise so the final product they design works well. When you design and construct your hydroponics planter, you need to be precise! Precision in design and construction can help with reducing energy loss and increasing efficiency.

Criteria

You will know if your hydroponic planter design is successful by how well it works. One criteria for success is designing a planter that supports a plant as it grows. Test your design and use feedback to improve and modify your prototypes.

Constraint

All designers and engineers are limited by resources or time. You may have a limited number of supplies or a limited amount of time to construct a design. You'll need to work with what you have to make the best hydroponics planter that is possible. Designing and engineering are very creative work!

Hydroponics

Hydroponics is a way of growing food without soil. In hydroponic systems, nutrients need to be added to the water as the plant matures. In an aquaponics system, the nutrients may not need to be added, since fish might fertilize the water that is used.

Prototype or Model

Before putting too many resources, like time or money into a final product, you should sketch a plan and build a small model of your product first. Use orthographic or isometric drafting techniques to draw a model. Or develop a drawing in CAD. Then, build a physical prototype.

Troubleshoot

When you assemble your prototype, it may not work as well as you expected. Designers and engineers always test, modify and refine their designs so they work! Troubleshoot and modify your hydroponic planter so it supports a growing plant!

Component

Your hydroponic planter has many parts that are needed to make it function and work. You might need to modify different components so they fit or work together better. Having modular components that can be altered, fixed, or replaced are good for the environment and a future budget!

Irrigation

All plants need water to survive. In soil, irrigation is used to spread water to each plant. But much of the water drains or evaporates before a plant can use it. In a hydroponics system, the plant is constantly being irrigated with a flow of water, but this water can recirculate. The system must be set up to keep the water flowing and recirculating, which saves water.

Assembly

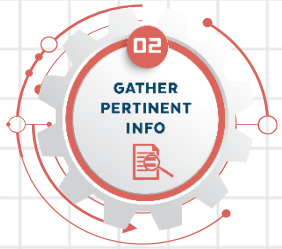
You need to be precise as you put all the components together. It is helpful to assemble a model in a certain order otherwise putting it together may be difficult or even impossible! If you are designing a model in CAD, you may need to consider the order of assembly when constructing pieces that fit together!

Engineering Design Process Directions:

Define the Problem

Choose a goal to tackle with your team!

Gather Pertinent Information



Take some time to research hydroponics. How are plants held in place? Can plants drown? Explore the supplies you have to use for this project. How does the solar panel work? How does the hydro pump work? Explore **How do Solar Hydroponics Work?** and learn about the chemistry and nutrition with **Elements for Plants & People**. You might even want to explore aquaponics!

Generate Multiple Solutions

Draft ideas for a model. How much water (volume) will your design need to hold? Does your design have enough space for a growing plant? Are the materials strong enough? How will the mechanical parts be secured or supported? Communicate with your team about the strengths and weaknesses of ideas to make predictions about what might work best.

Choose a Solution

Combine ideas from the multiple solutions that your team created. Use the **Orthographic Drafting Template**, **Isometric Projection Template** or CAD to create an accurate representation of your design. Include dimensional measurements for scale and size.

Design a Culturally Responsive Solution

As you build your solution, be sure to help your team. Assembly requires many helping hands, taking turns, and being patient with the time that building each step can take. Help each other manage construction responsibilities, supply needs, and material testing.

Test and Optimize

Test your hydroponic planter. Does it work as well as predicted? What data can be collected to confirm that your design meets, or does not meet, the goal? Analyze how your design compares to your draft; adjust the measurements that would lead to improvements. Use the feedback you gained from testing and from sharing with others to improve your solution.

Share & Reflect

How did you use feedback to improve your solution? How did your team's communication help improve your design? How did your creativity develop? Talk to your team: What went well? What could have gone better?

How do Solar Hydroponics Work?

Star Energy Powers your Solar Hydroponic Planter!

STEM works RESEARCH

Silicon

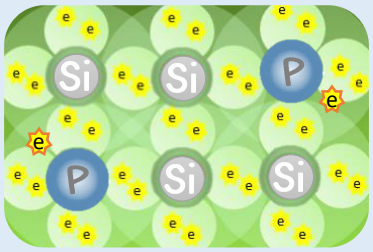
Silicon (Si) is a very common element, 28% of the Earth's crust is made from silicon!

Silicon's properties make it useful for solar panels. It has four valence electrons and wants to bond with other atoms to have a complete valence shell of eight electrons. When bonded to other atoms, silicon forms a crystalline structure, used to create the semiconductive layers in solar cells.

In solar cells, impurities are added to create layers that either have extra electrons or lack electrons. Adding these impurities to the silicon layer is called doping.

Phosphorus

One layer has phosphorus (P) added to silicon atoms to Form a crystalline layer (see below). Phosphorus has five valence electrons, one more than needed. The extra electrons give this a negative charge. This is the n-type layer.



In the solar cell, another layer may have boron (B) added to silicon atoms. Boron has only three valence electrons. A lack of electrons in this layer creates electron holes.

Boron

That means this layer is positively charged. It is called the p-type layer.

The top layer of a solar cell is often silicon (Si) with phosphorus (P) added. In this crystalline layer, there are some free electrons because phosphorus has one valence electron that isn't bonded. Silicon is doped with phosphorus to have extra free electrons. Electrons have a negative charge. So the extra electrons create a negatively charged top layer!

When photons of energy hit the solar panel they excite electrons. Electrons flow through the circuit as electricity.

Earth's Sun

Radiant Energy

Radiant (solar or light) energy travels in packets of energy called photons.

Negative Charge

Electron Hole

Photovoltaic Solar Panel

n-type semiconductor (extra electrons)

p-type semiconductor (needs electrons)

Positive Charge

The bottom layer is often silicon (Si) with boron (B) added. In this crystalline layer, boron does not have enough electrons, so there are vacant electron holes. Silicon is doped with boron, so there are electron holes. A lack of electrons creates a positively charged p-type layer. This positively charged layer attracts electrons flowing in the circuit.

Electron

Water output!

PV Panel Mount

Hydro Pump

Water input!

Water Reservoir

3D Printable Tinkercad Drawing

The movement of electrons is electricity! The hydro pump's motor is powered by the flow of electrons (electrical energy). If the pump isn't running check if enough energy is flowing through your circuit.

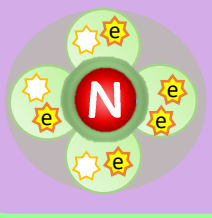
Elements for Plants & People

People need to eat nutrients and minerals to be healthy. We can get nutrition we need from plants because plants are able to absorb minerals and nutrients into their roots. Plants primarily need nitrogen, phosphorus, and potassium, followed by calcium, magnesium, and sulfur. To be healthy, plants also need much smaller amounts of boron, copper, iron, chloride, manganese, molybdenum and zinc. Humans need these too, and plants can rearrange these elements into molecules that humans can digest!

Elements

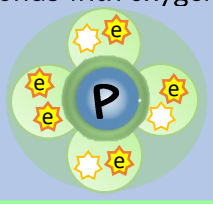
Nitrogen

Nitrogen (N) is a very common element with five valence electrons available for making bonds. 78% of the air we breathe is Nitrogen gas!



Phosphorus

Phosphorus (P) has a valence shell of 5 electrons and is unique because it's valence shell can forms bonds to hold more than 8 electrons! In nature, phosphorus often forms bonds with oxygen.



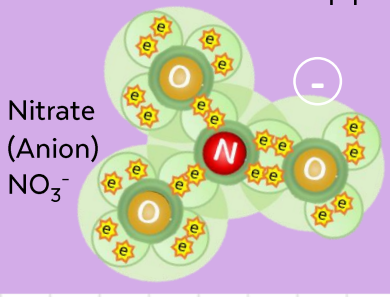
Potassium

Potassium (K) is important for living things. It has one valence electron available for bonding. If potassium loses the valence electron, it becomes a cation.

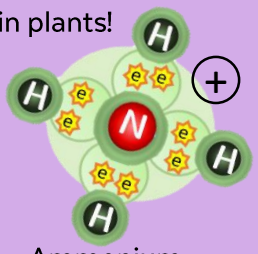
Plants

Nitrogen

Nitrogen in the air is not useful for plants; it needs to be in molecules in the soil, as nitrate (NO_3^-) or ammonium (NH_4^+). Plants need nitrogen to grow and make amino acids. Amino acids make up proteins in plants!



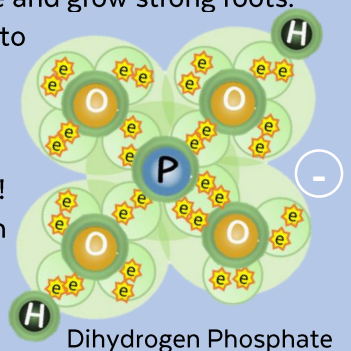
Nitrate (Anion) NO_3^-



Ammonium (Cation) NH_4^+

Phosphorus

Phosphorus helps plants in many ways. It helps the plant's cells divide so the plant can grow into a mature plant at the right time and grow strong roots. The plant needs phosphorus to help make energy and move nutrients to all areas of the plant. It keeps the plant healthy and disease resistant! Plants can absorb dihydrogen phosphate (H_2PO4^-) or hydrogen phosphate (HPO_4^{2-}) from the soil.



Dihydrogen Phosphate (Anion) H_2PO4^-

Potassium

Potassium is absorbed by plants as the cation, K^+. This mineral helps a plant regulate water (osmo-regulation). Plant leaves have small pores called stomata that open and close. Potassium helps the plant open and close it's stomata to release water vapor. Oxygen and carbon dioxide also pass through stomata, so this helps the plant photosynthesize too! Potassium also helps plant cells hold water so they won't wilt; it helps a plant be more resistant to drought! It also helps the plant create and move carbohydrates.

Potassium ion (Cation) K^+

People

Nitrogen

Humans need nitrogen to make amino acids for our muscles, hair and skin. We even need it to make our DNA! So when people eat plants, the nitrogen atoms from the plants are used to build human protein too!

Phosphorus

About 1% of your body weight is phosphorus! We need phosphorus for our skeleton! It binds with calcium to make strong bones and teeth. Phosphorus helps your metabolism give you energy! It is also an important part of DNA and found in every cell of your body!

Potassium

Potassium is commonly known as one of the many electrolytes that help your body balance proper hydration. It also helps nerves fire so your muscles contract. It's essential for movement, including your heart beat!

Orthographic Drafting Template

During design, engineers pay attention to measurements in their designs. This includes the angles, edges, surface area, volume and more. An orthographic drawing shows several 2-dimensional flat views of surfaces in a 3D model. Draw four orthographic views of your design. In the template below, each quadrant has 100 square units. Label your model with dimensions and create a scale.

= 1 square unit

Front View

Top View

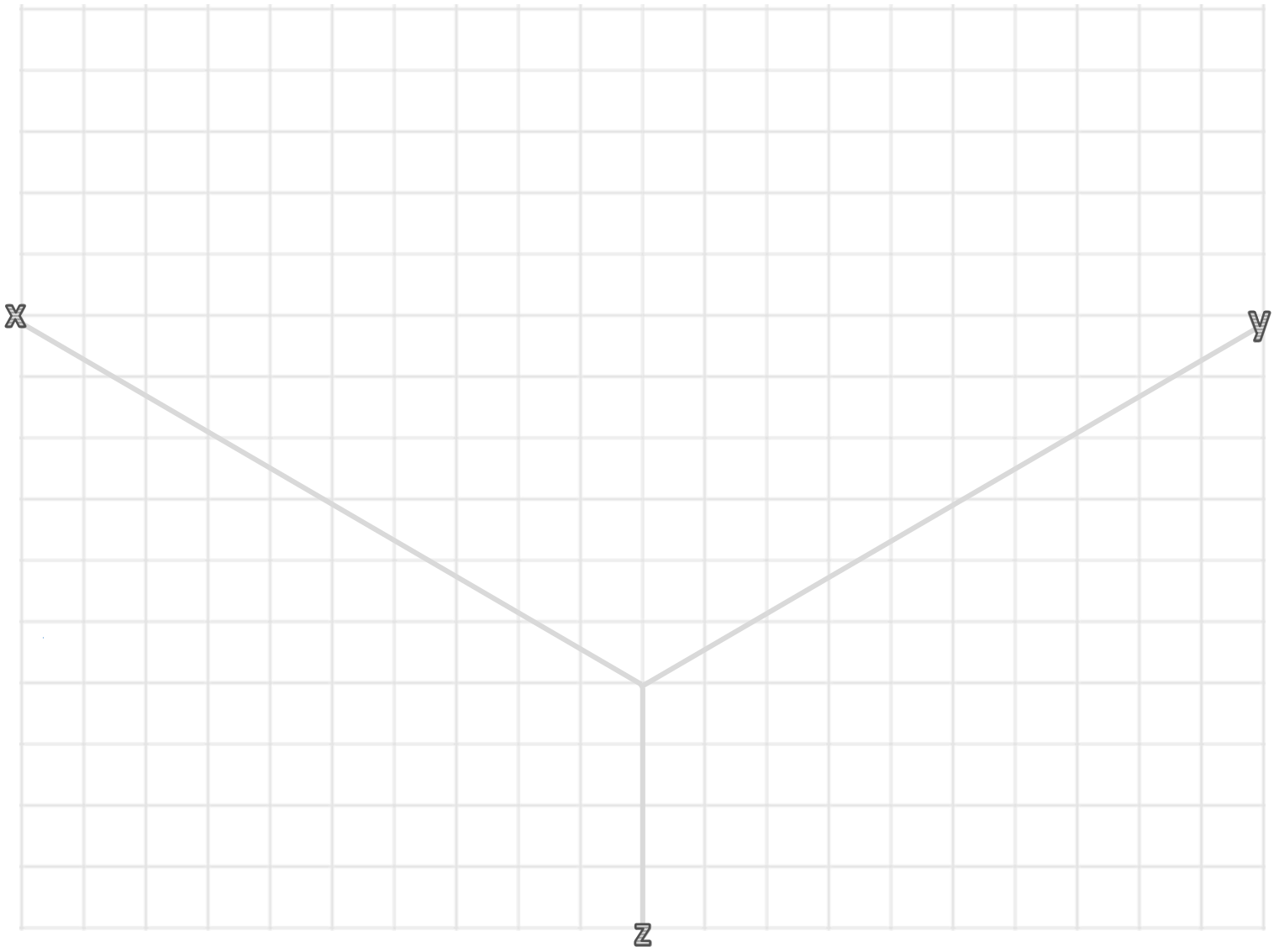
Left Side View

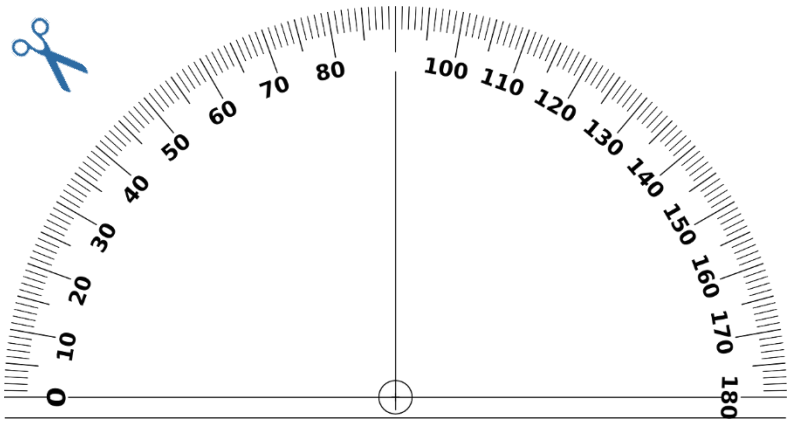
Right Side View

Isometric Projection Template

During design, engineers pay attention to measurements in their designs. This includes the angles, edges, surface area, volume and more. Draft an isometric projection of your design in the template below. Each square is 1 square unit. Label your model with dimensions and create a scale.

= 1 square unit





An isometric projection is a three dimensional representation (model) where each axis (x, y, and z) meet at exactly 120°. Tip: Many of the major lines in your design will be parallel to one of the three axis in the template above. Cut out the protractor and use this tool to measure angles and as a ruler to keep lines parallel to the x, y or z axis.