UNIT 2

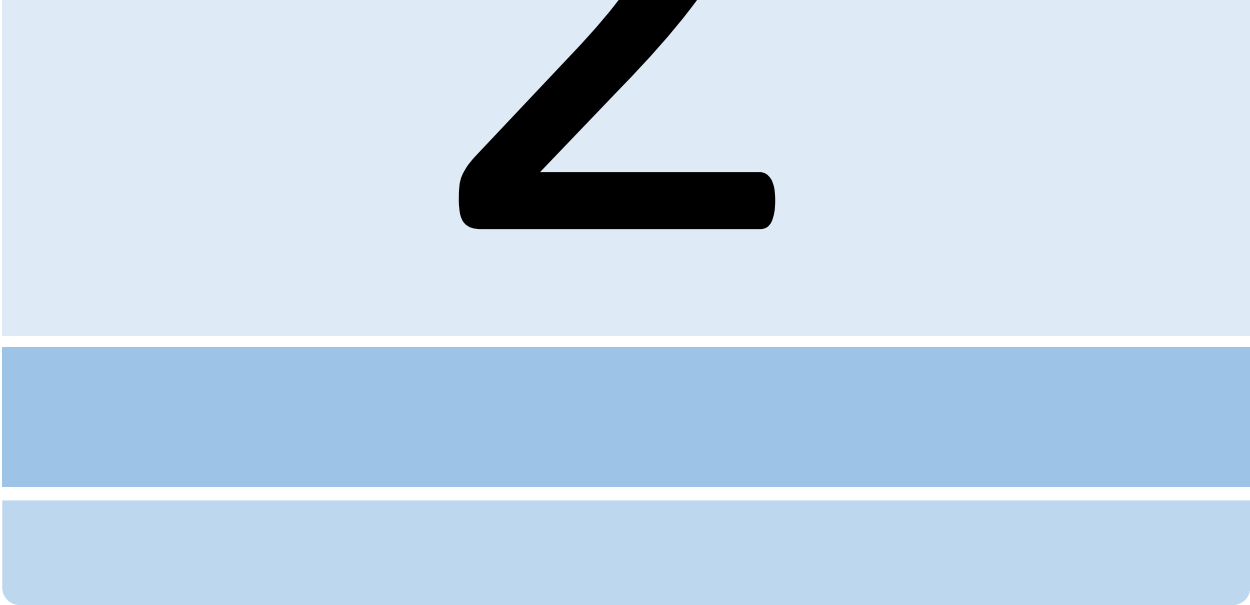## USE CASE 2

Warehouse Operations - 1 million ft² and more

In Ontario, California, bronze cow statues stand in for what had been farmland designated as a dairy preserve on acres city officials approved for a logistics center with 5,333,518 ft² of warehouses and offices across 219 acres near the Chino airport (Kaneko) ("South Ontario Logistics Center Specific Plan"). Ontario's representative on the San Bernardino County Board of Supervisors, Curt Hagman, noted local officials sign agreements with developers mandating environmentally-friendly buildings and zero-emissions transport vehicles and warned: "If we fail to keep pace with the growing demand for additional warehouse space, the result will be immediate and far-reaching throughout the Inland Empire — loss of good-paying jobs, less affordable housing, fewer environmental benefits and community infrastructure improvements, not to mention the gains other jurisdictions will make at our expense" (Hagman).
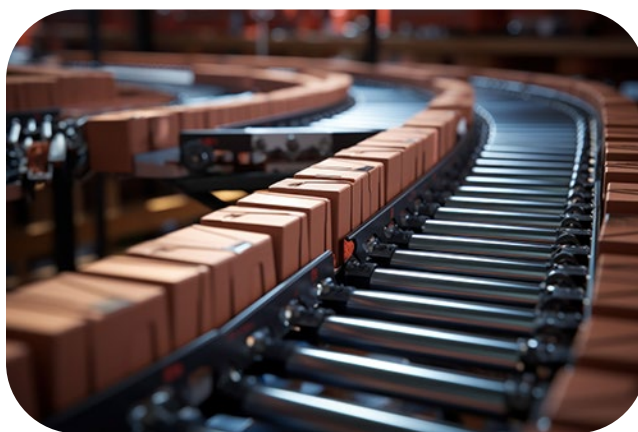
Milestone 3

Now that Builders USA identified a potential warehouse location to maximize efficient transport from The Port of Long Beach, Milestone 3 supports identifying how to efficiently plan for logistics inside the warehouse. This Milestone includes stakeholders from several departments within Builders USA such as Facilities, Engineering, Operations, and Finance.

A warehouse floor reflects the products that will move through it. For example, a warehouse that unloads, stores, and distributes cars and trucks has a different footprint than a warehouse that imports and distributes shoes and boots. A footprint is the area on a project site defined by the perimeter of the building (including everything inside the building). Parking lots, landscapes, and other non-building facilities are not included in the building footprint. You will work with the web-based application Tinkercad to apply geometric concepts that inform logistics in the Builders USA distribution warehouse.

To prototype the warehouse buildout, the Builders USA team will consistently navigate between two- and three-dimensional objects represented as shapes. Logistically, it's not feasible or affordable to install warehouse racking, aisles, docks, etc., only to find the layout ineffective for the business. Reorganizing a warehouse infrastructure of this magnitude isn't an option for Builders USA. As you prepare data to inform Builders USA layout decisions, you will learn about the mathematical common core standards:

Quick Check on Milestone 3 Mathematical Common Core Standards

- ❖ Geometric shapes, measures, and properties to describe objects
- ❖ Apply concepts of density based on area and volume in modeling situations
- ❖ Apply geometric methods to solve design problems

Common **CORE** Standards

These standards inform the Builders USA planning priority to Maximize the Cube!

Terms

Distribution warehouses

Distribution warehouses are a combination of:

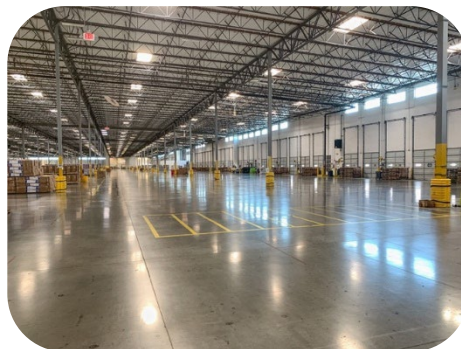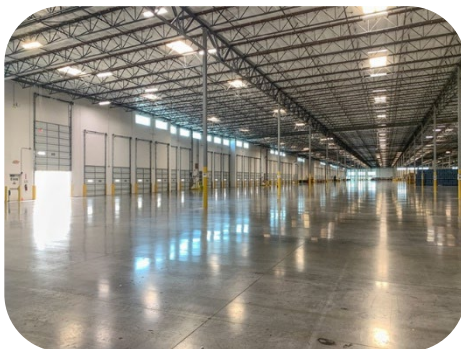Stylish front facing spaces for customer, employee, and community aesthetics-

photo credit https://www.theworldlogisticscenter.com/

Docks for efficient product movement-

Massive spaces for people, product, and robotics-

UNIT 2

The operations work that takes place in distribution warehouses encompasses:

Inbound logistics	Outbound logistics
the process of receiving and storing products	the distribution of finished products to customers

Inbound logistics bring supplies or materials into Builders USA. Outbound logistics distribute products from the Builders USA to home centers. Inbound is all about receiving, and outbound focuses on delivery.

Inbound logistics	Outbound logistics
Sourcing and Procurement	Warehousing and Storage
Supplier Selection	Packing and Packaging
Inbound Transportation	Outbound Transportation
Receiving and Quality Check	Order Fulfillment
Material Handling	Reverse Logistics
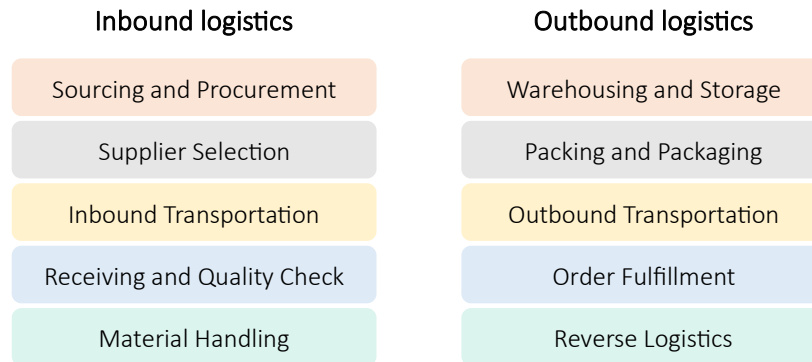
The inbound process starts with trucks arriving at the inbound docks. Outbound logistics are the final step in the warehouse workflow. Between inbound and outbound logistics, products, people, robotics, and equipment move quickly throughout the space.

Warehouse management

Warehouse management is running and overseeing the daily operations of a warehouse. Warehouse management considers everything from warehouse layout and labor management to day-to-day activities like receiving and managing inventory, fulfilling orders, and coordinating with shipping partners.

Effective warehouse management optimizes and integrates all these facets of warehouse operations to maximize productivity and efficiency. Priority is facilitating fast, accurate order fulfillment while keeping costs low. Objects you will work with in planning the distribution warehouse as intern for Builders USA include:

1 Pallets

Pallets are a portable platform for handling, storing, or moving materials and packages. Pallets are designed to move through doorways and be reused many times. There are a few different types of pallets, the most common North American pallet is the wood pallet, which is:

Affordable	Lightweight	Customizable	Repairable	Recyclable
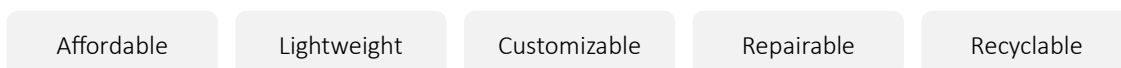
A standard wooden pallet measures 48" × 40" × 6". The simplified block pallet you will build is:

A standard wooden pallet **static load capacity** is the weight of the pallet when resting in a fixed position on a level, even surface. If pallets are stacked, for example three high, the bottom pallet is holding its own weight and the two pallets sitting on it. A static load rating refers to a pallet's load rating while the pallet is at rest, either as a single pallet or the bottom pallet of the stack.

The **dynamic load rating** is the weight the pallet can hold while moving, typically while being lifted and carried using a forklift, pallet jack, stacker crane, or conveyor system. Load distribution is critical because unevenly distributed weight can cause the pallet to tip or flip. Dynamic loading is often referred to as a **live load**, which means that it's possible for this load to be altered in **position**, **magnitude**, and **direction**. In comparison, a static load is constant, steady, and easy to calculate.

A **rackable load** is the **strength load rating** for when a pallet is placed in a racked system and stored for later access.

Builders USA primarily uses wooden block pallets with a static load capacity of 5,500 pounds, a dynamic load capacity of 4,600 pounds, and a rackable load capacity of 2,800 pounds.

When working in a distribution warehouse understanding the difference between a static load and dynamic load is essential to keeping products and personnel safe. Pallets are static and dynamic at different stages of the loading and unloading processes.

2	Pallet Jacks

Pallet Jacks are manually operated and steered with a tow bar.

> The weight capacity for a standard pallet jack is 3,000-5,000 pounds.

> The width of a pallet jack is commonly between 18-24".

> Length is typically between 48-50".

> Height is typically between 6-8".

The standard overall width across forks is 27", fork width is 6.3", and the space between forks is 14.4".

Pallet jacks are often considered the workhorses of a warehouse. They include three position hand control for lowering, lifting, and neutral positions, heavy duty hydraulic systems, tough wheels and rollers, and additional low-maintenance features.
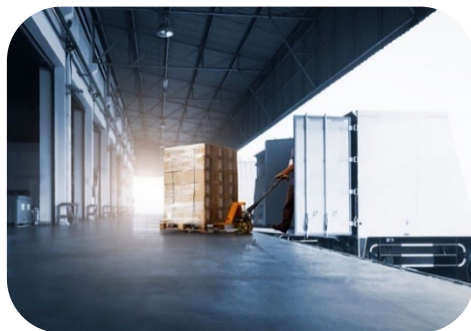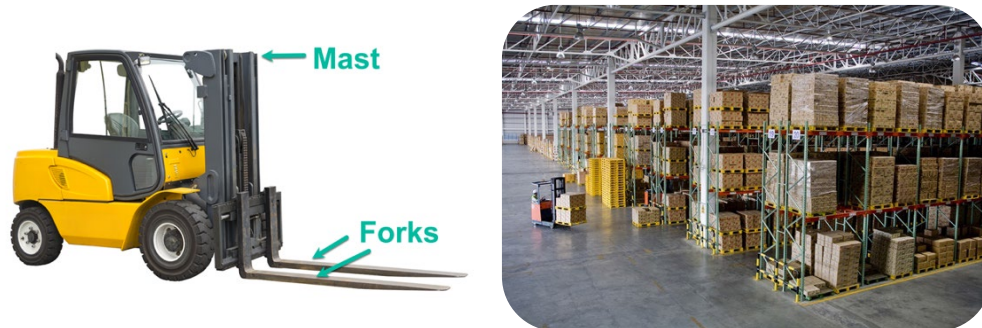
3	Forklifts

Forklifts commonly run on propane, and in some cases on electricity. The typical measurements for a standard warehouse forklift, with a 5,000-pound weight capacity, is 5' wide, 7' tall, and 10' long, with standard forks.

Five important **dimensions** include:

Overall lowered height	important for driving into trailers to unload pallets and around the warehouse
Free-fork height	from the floor to the top of the forks before the mast starts to extend- important when space is limited
Maximum fork height	is the highest the forks can go- important to make sure the forklift can reach higher racks
Overall raised height	is the highest the forks can go and includes the height of the loaded pallet
Turning radius	is how much room the forklift needs to turn around

The Occupational Safety and Health Administration (OSHA) offers seven forklift classifications:

https://www.osha.gov/etools/powered-industrial-trucks/types-fundamentals/types/classes

4	Articulated Robotic Arms

Articulated Robotic Arms, a type of pick-and-place robot, are multi-jointed limbs used to manipulate products within distribution centers and warehouses. They can be used for picking/packing, receiving/storing, and palletizing.

5	Stacker Cranes

Stacker Cranes run on electricity. The images show the stacking process. Stacker cranes increase load and height capabilities and need less space to maneuver than a forklift. Manual pallet stackers use a hydraulic system to lift pallets around. Pallet stackers aid product distribution by easily lifting, handling, and carry palletized products. Stacker cranes combine the capability of a standard pallet jack with the convenience of a motorized lifting vehicle.
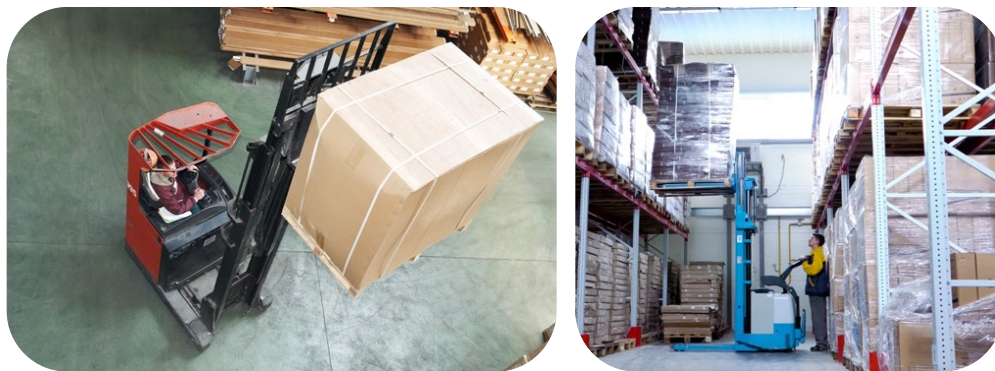

6	Automated Stacker Cranes

Automated Stacker Cranes are a type of overhead crane system that utilizes a non-hoist loading device suspended from a bridge trolley and equipped with forks or a gripper. Many stacker cranes are automated and designed for high bay warehouses. Automated stacker cranes can maneuver in 5' aisles, reach 65' high and, in advanced configurations reach 130' high. These robots move horizontally and vertically within the storage aisles. Although their function is to store goods, they also increase the flow of movements by working nonstop, supplying pick stations with products more rapidly. Automated

stackers have a lower load capacity to forklifts, a consideration for warehouses that handle bulky, heavy items.
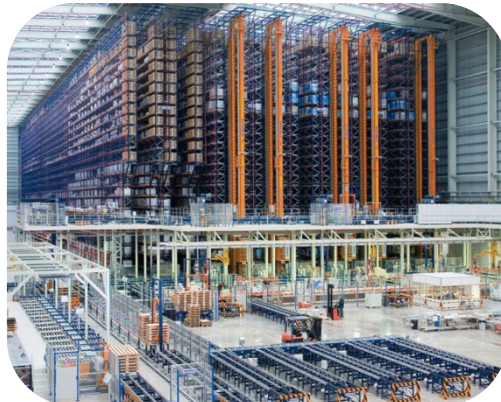
7	Conveyor Systems

Conveyor Systems move boxed and palletized products. Conveyors with belts over roller/slider beds provide better support, more precision, and stronger grip.

Additional conveyor systems

Sort and transport heavy pallets (chain-driven),

use gravity (non-powered), and

offer zero pressure (product doesn't touch the line).

Several systems are available for food grade, small products, assembly operations, etc. The Builders USA conveyor system will primarily be powered rollers and belts. These machines move, accumulate, and distribute goods to the specific positions required by the logistics operations. Conveyors can continuously supply the pick stations with the items required to fill orders.

8	Autonomous mobile robots (AMRs)

Autonomous mobile robots (AMRs) move in the environment without the need for supervision by an operator or fixed and pre-established routes. AMRs are capable of "awareness" of the surrounding environment due to sensors that enable it to:

Complete tasks efficiently, along the shortest possible route

Avoid collisions with fixed or moving obstacles

Collaborate with operators during picking and sorting operations
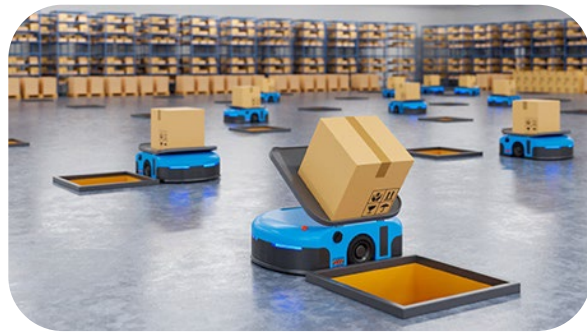
Tasks

Task 1	Tinkercad Project 1

You'll use Tinkercad to model and work with shapes as objects toward warehouse planning. Your first task is to build the simplified wooden block pallet.

Tinkercad is the web-based application (nothing to download) you will use for your Milestone 3 project.

Your teacher may have set up a direct link for you as a student. Here are the steps to set an account.

Step By Step Instruction to Set an Account

STEP 1	Go to https://Tinkercad.com/ and select the Sign Up button (top right)

| STEP 2 | If your teacher set up a Class, select the Students join a Class button. The next screen will ask you to Join Class with the code your teacher shared.

If you're setting up on your own, select the Create a personal account button. The next screen will ask you to sign up with a personal email account, your Google account, or an Apple, Microsoft, or Facebook account. is the same Google account you used for the Google Earth Milestone 1 and 2 projects. |
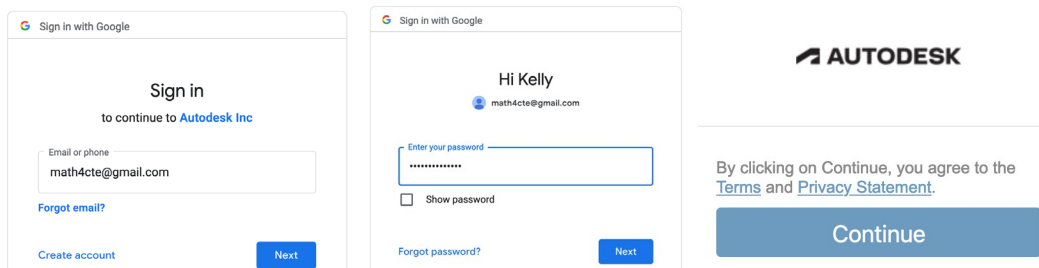|---|---|
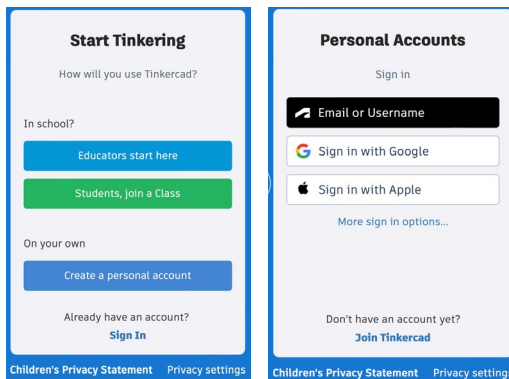
STEP 3

This example uses Sign in with Google, you will be asked to select your Google account. Or, Use another account (if you have multiple Google accounts). Select Next and Enter your password.

Select Continue to enter Autodesk, the parent company for Tinkercad.

STEP 4

You are now in Tinkercad and have the option to Create your own Designs, view Tutorials, or you can enter your class, from this screen, if your teacher provides a class login.
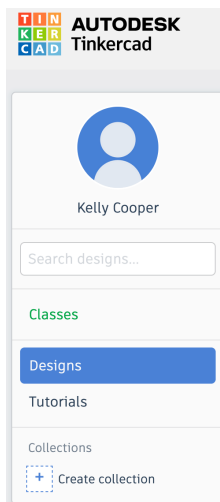
STEP 5

On the bottom of the profile window, select Create collection (1), and the settings cog button to the right of the Collections 1 label (2). Into the Properties popup window, key the Name as Builders USA and Description as Warehouse Shapes for Milestone 3 (3). Select the Save changes button.
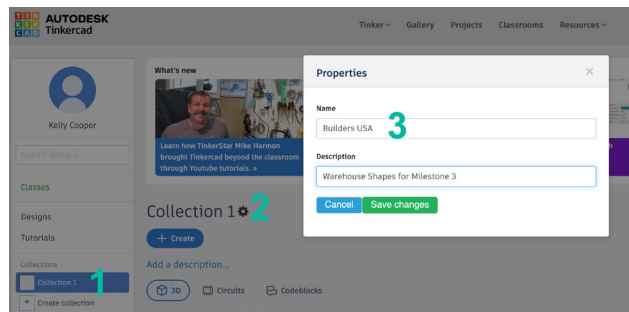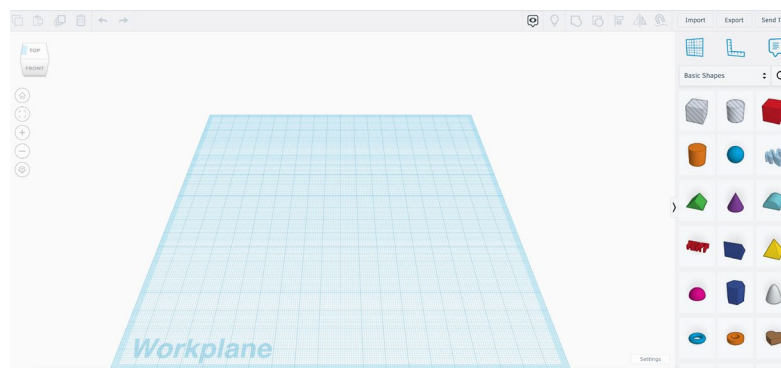

STEP 6

Builders USA is now a collection within your Tinkercad account. With the 3D icon selected, click on the + Create button to begin and select 3D Design from the popup window.
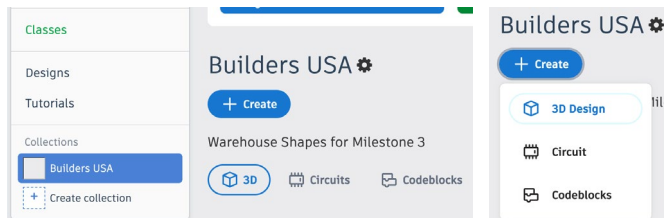
STEP 7

This is your workspace. The Basic Shapes on the right will serve as building blocks for your Builders USA shapes.

For communicating warehouse planning and layout, you will use the U.S. customary system of inch, foot, yard, and mile. Many tools used in manufacturing and warehousing utilize the metric system; however, communicating to the stakeholders in construction, transportation, building compliance, and regional governance takes place with the U.S. measurement system.

STEP 8 At the bottom right of your Tinkercad workspace, select the settings button. In the popup window, change Units to Inches, leave the Presets as they are, select Make default, and Close settings.
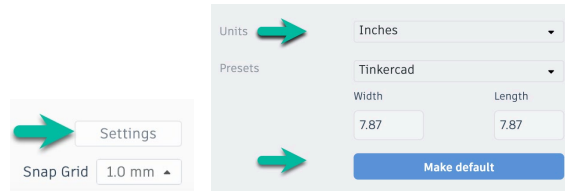
STEP 9 In the top right corner of your screen, click into the textbox and name your design Pallet.

STEP 10 Since Tinkercad and your computer are smaller than an actual pallet, the pallet will be scaled to 1:10. This means that 1" in Tinkercad represents 10" in real life. You will use one basic shape, a cube (Tinkercad notes it as Box) to create the pallet.

Millions of pounds of products are moved worldwide every day with pallets made from this one geometric shape. In the past six months, 2,119,728 containers arrived at The Port of Long Beach alone, carrying 98,069,162 metric tons (2,204.6 pounds each) for 216,203,274,245.2 pounds on pallets in containers on ships. That's a lot of shopping in six months and doesn't include another 360 ports in the U.S., products flown in, driven in, or those Made in the U.S.A. The simple wooden pallet and a few sidekick plastic pallets do a lot of work. Let's build one.
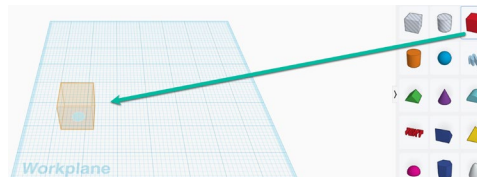
A North American wooden block pallet measures 40" (width) · 48" (length). You will start with the top deckboards. Each is 40" long, 3.5" wide, and 5/16" thick.

Step By Step Instruction to Build a Pallet in Tinkercad

STEP 1
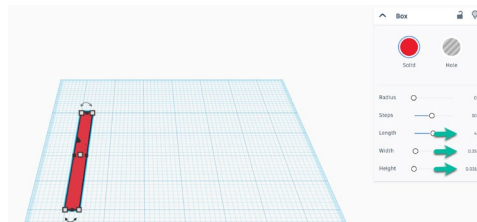
Drag a Box anywhere onto your workspace

STEP 2

Click onto your Box and a popup window appears. Keep in mind you are working on a 1:10 scale, change the Length, Width, and Height of Box:

40"	4"
3.5"	.35"
5/16 = .31"	.031"

STEP 3

This end top pallet deckboard is called the lead deckboard. From the outside edge of your lead deckboard to the outside edge of the opposite edge lead deckboard is 48".

Pallet length = 48"
Each deckboard is 3.5" wide. There are 5 deckboards to evenly space.
3.5" · 5 deckboards = 17.5" of the 48" will be deckboards.
48" - 17.5" = 30.5" of space between the deckboards.
Space will be between deckboard: 1-2 & 2-3 & 3-4 & 4-5
for a total of 5 deckboards and 4 spaces between deckboards.

30.5" of space divided by 4 spaces = 7.625" of space between each deckboard.
Since you are working on a 1:10 scale, 7.625" becomes .76"

STEP 4

Select your deckboard, key Ctrl+D on a PC or Cmd+D on a Mac, to duplicate the deckboard. It duplicates on top of your existing deckboard, use your right arrow key to move it to the right.

Note: If you have previous Tinkercad experience, you may know keyboard shortcuts. The purpose here is to work with math as you would on the job; you're thinking about numbers more than about software.
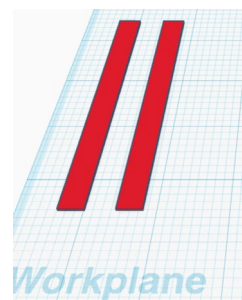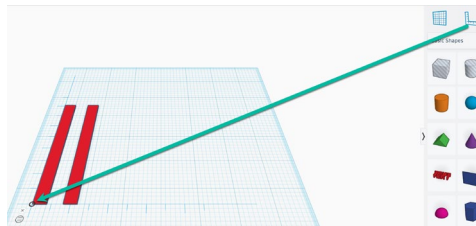
STEP 5

Select the ruler tool, above the shapes library, and position the round red circle at the outside edge of your deckboard, over the right angle the board creates.

The apex (where your ruler angle meets) rotates by clicking on the O. For each click it rotates 90°. Click until it aligns on the left and bottom of the Workplane.

STEP 6

With your shift key selected, click on both deckboards to view all measurements. Your numbers may be slightly different since you're not working with exact positioning yet.
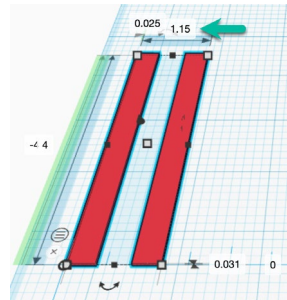
STEP 7

The number 1.15 shows it includes the width of the deckboards and the space between them. Since your deckboards are on a 1:10 scale, the values of .35" (deckboard) + .76" (space), which represent your lead deckboard plus the space before the second deckboard sums as 1.11.

You can adjust the space by keying 1.11 into the value at the top of the deckboards.
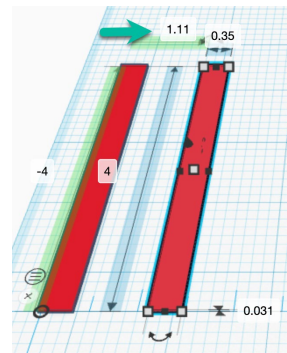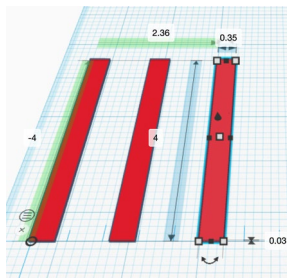
STEP 8

Click into the workspace to unselect the two deckboards.

Click to select the right deckboard and key Ctrl+D (PC) or Cmd+D (Mac).

Use your right arrow to move the duplicated board to the right. You may see the board width adjust slightly, if so, rekey .35 as the width.
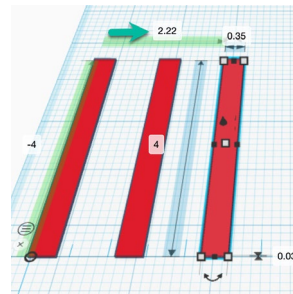
STEP 9

The highlighted green measurement encompasses the .35" of the lead deckboard, the .76" first space, the .35" of the second deckboard, and the .76 space between the second and third deckboard.

The number on the highlighted green measurement, then should be:

$$.35 + .76 + .35 + .76 = 2.22$$

Adjust the value.

STEP 10

Select your shift key and click on the two right deckboards. Since there are five deckboards total, you'll duplicate two and adjust spacing only between deckboards 3 and 4.

The number on the highlighted green measurement will be for three deckboards and three spaces:

$$(.35 \cdot 3) + (.76 \cdot 3) = 3.33$$

STEP 11

Select shift and click on the two right deckboards so that when you adjust spacing, the two move together. You spaced them correctly earlier and will move them together now.
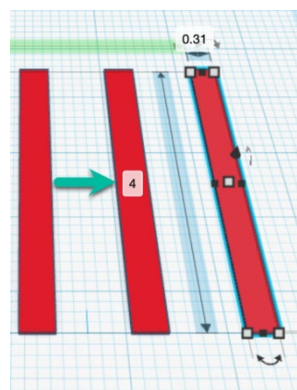
STEP 12

Adjust your green highlight spacing value to 3.33. Note that 3.33 + 1.46 = 4.79 which rounds to 4.8. at your 1:10 scale, 4.8 represents 48", the deckboards now represent 40" in width and 48" in length.

Block pallets may have 6 or 7 deckboards, depending on the use case. In this activity, you will use 5.
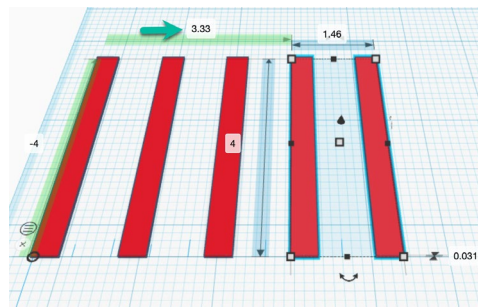
STEP 13

Click into the workspace to deselect any deckboards, select the right deckboard and duplicate. Arrow to space it to the right. This will become the first stringer board.
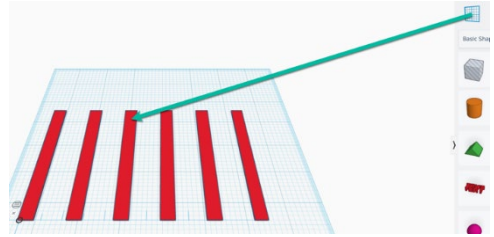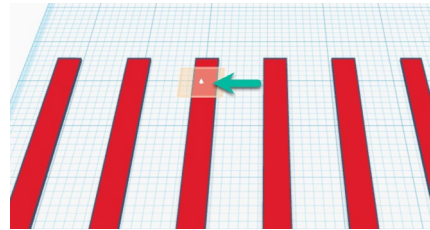
STEP 14

Click into the workspace to release any deckboards selected.

To **stack** the first stringer across the deckboards, drag the Workplane tool, located above Basic Shapes onto one of the original five deckboards.

STEP 15
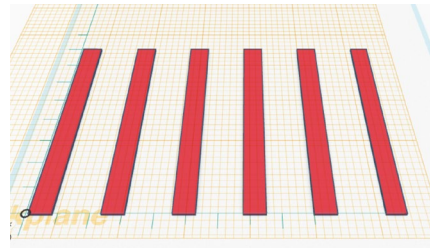
You will see a transparent yellow rectangle that represents the Workplane tool and indicates where you are dropping the new workplane onto your workspace.

STEP 16

Release and the yellow Workplane tool sets.

STEP 17

Select the right stringer and the rotate tool, to position the stringer across the deckboards.
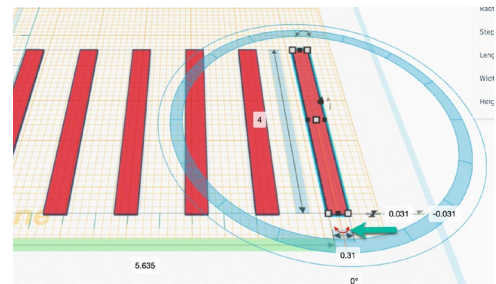
STEP 18

With your mouse, select and rotate the stringer to 90°
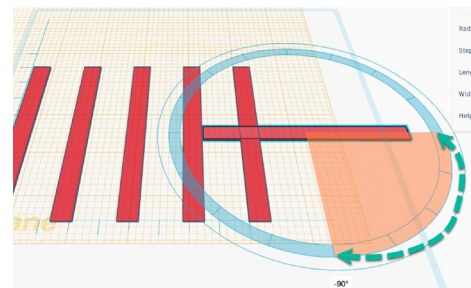
STEP 19

Select the stringer and use your arrow key to position across the deckboards.
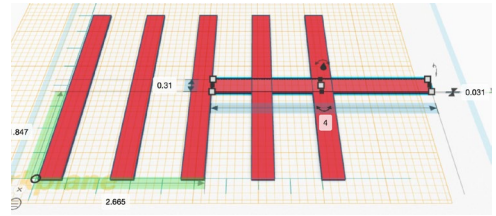
STEP 20

To center, adjust the space value from the pallet width edge to the center stringer to 1.825".

1.825" + .35" + 1.825" = 4 = the 1:10 40" width of the pallet.
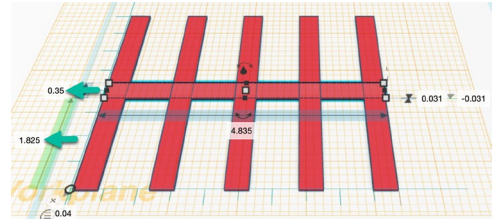
STEP 21

Duplicate the stringer and arrow it to each end of the pallet.
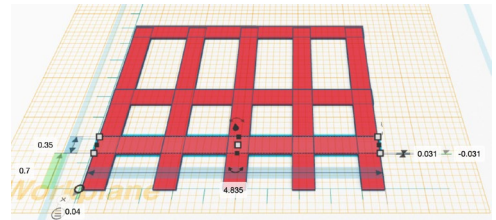
STEP 22

For each stringer: position, adjust the value to 4.8, and key a D to drop the stringer onto the pallet.
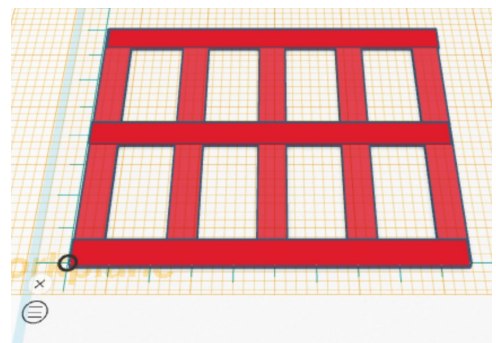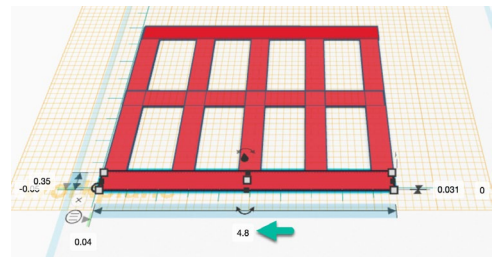
STEP 23

Next, grab the Workplane tool and drag it onto the workspace to go back to workspace mode.
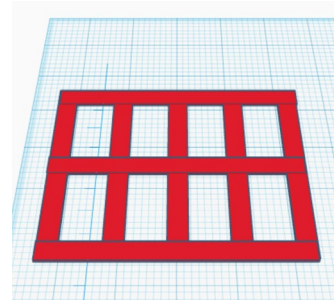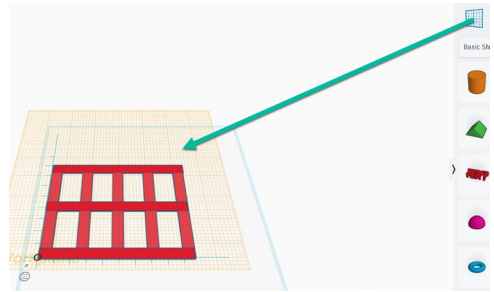
STEP 24

Next, blocks will be added at the end of each stringer. Hover over and dismiss ruler by selecting the X next to the ruler O apex.

1. Drag the Workplane tool onto a deckboard.

2. Drag a box onto the right front corner stringer

3. Adjust the values of the block to
.35" · .35" · .35
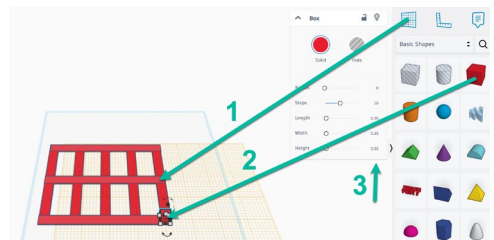
STEP 25

Duplicate the front right corner and arrow the second block up to midspan.

Repeat for the top right block.

Duplicate the left blocks, experimenting with what order to duplicate.
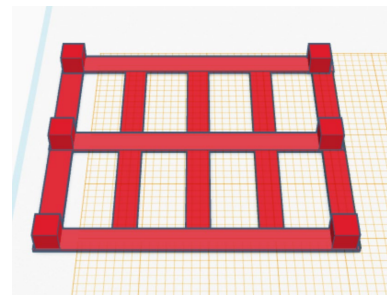
STEP 26

Left of the workspace, toggle to flat view (bottom icon) and zoom in and out to position the blocks at the pallet edge.

If you want them to line up perfectly, in the workspace right corner, below Settings, change the Snap Grid menu to Off.

If you lose your place at some point, select the home icon.
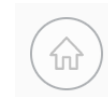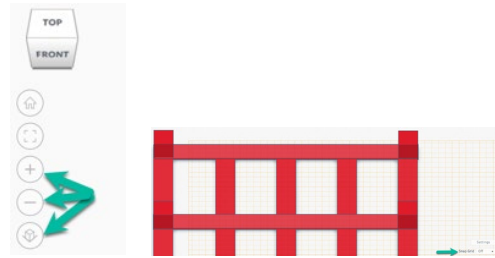
STEP 27

When you're satisfied with block placement, select each and key D.

Next, drag the Workplane tool onto the workspace.
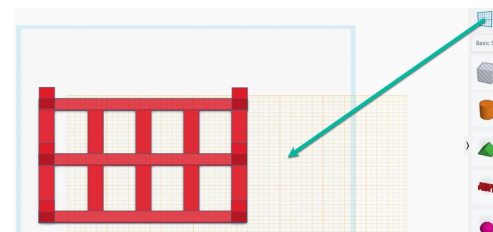
STEP 28

Toggle flat to orthographic view.
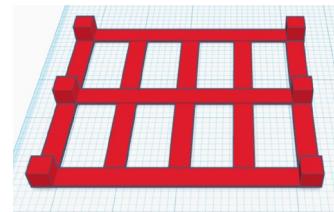
STEP 29

Add three bottom deckboards over the blocks.

a. Drag the Workplane tool to the top of one of the blocks

b. Drag a box onto one of the blocks and size it to be a 4.8" x .35" x .031" bottom deckboard

c. Rotate the bottom deckboard and position it on the blocks

d. Duplicate for the other two deckboards

e. Use Snap Grid, orthographic view, flat view, zoom in, and zoom out to detail placement

f. D to secure the bottom deckboards

g. Drag the Workplane tool onto the workspace
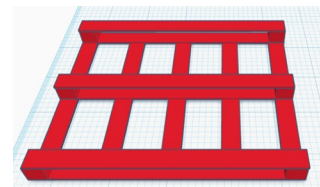
STEP 30

Drag your mouse over the entire pallet, you will see blue lines highlight the selection.

Click on the Group button in the top right navigation.
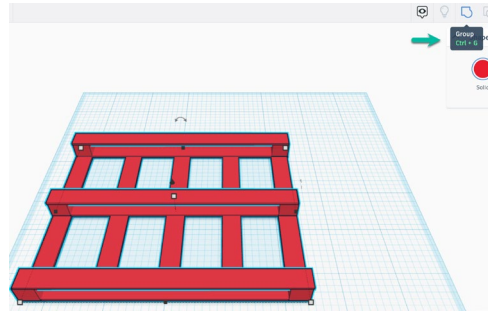
STEP 31

Select the Red Solid color icon to change the pallet's color. All boards will change since you grouped them.

Pick one color or the Custom tab to create a color or select a hexadecimal value.
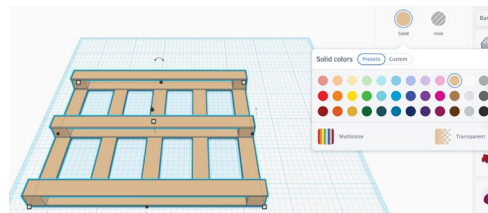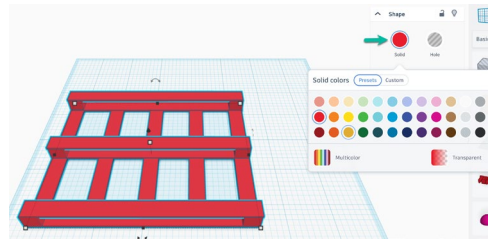
STEP 32

Select the pallet and click on the double headed arrow to flip along that line.
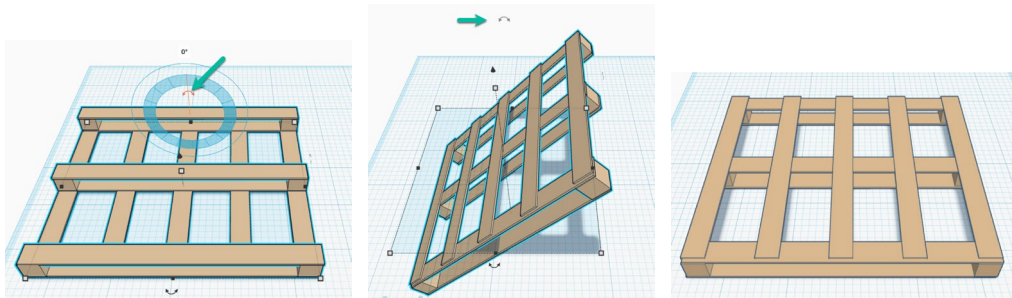
STEP 33

To fine tune your pallet (the deckboards are 4' but sit a little short from the edge), select the pallet, and click on the ungroup icon.
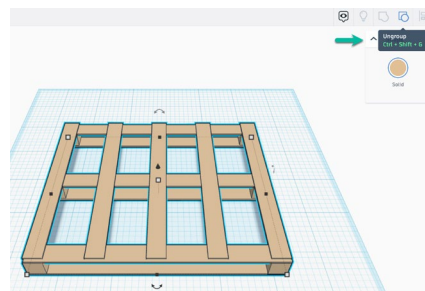
| STEP 34 | Adjust your deckboards or any other portion of your pallet with your arrow key.

You may want to turn Snap Grid off if your arrow key snaps too short or long for your preferences.

Select FRONT to view the front of your pallet. |
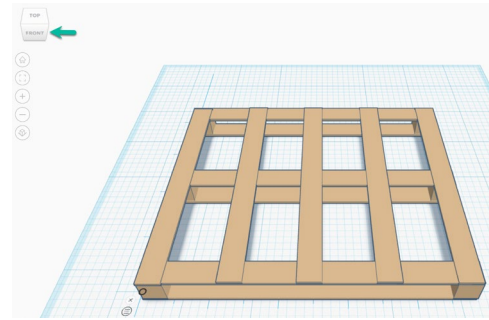
Your pallet represents how a simple geometric cube is essential to worldwide supply chains

In Unit 1, you explored the priority to Maximize the Cube! Consider this:

Area (A)	Volume (V)	packing height
the measurement of the surface of the shape	the space occupied by an object	A typical standard pallet packing height is 48 inches (includes the height of the pallet + load)
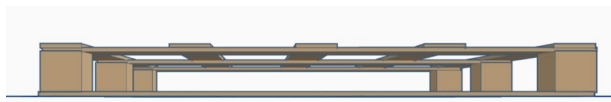
Your simplified pallet is made of

1 = .031"
2 = .031"
3 =   .35"
4 = .031"
_____
.443"

Reverse 1:10 = **4.43"**
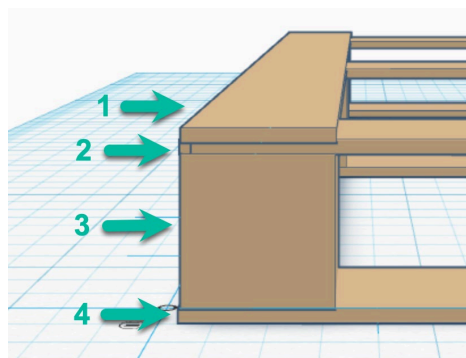
A standard pallet **average** height is close to 6", based on the thickness of each piece or additional pieces to add support for heavier loads.

STEP 35	Select Top and each of the arrows to view your pallet from all angles.

TOP

SIDE

BOTTOM

FRONT
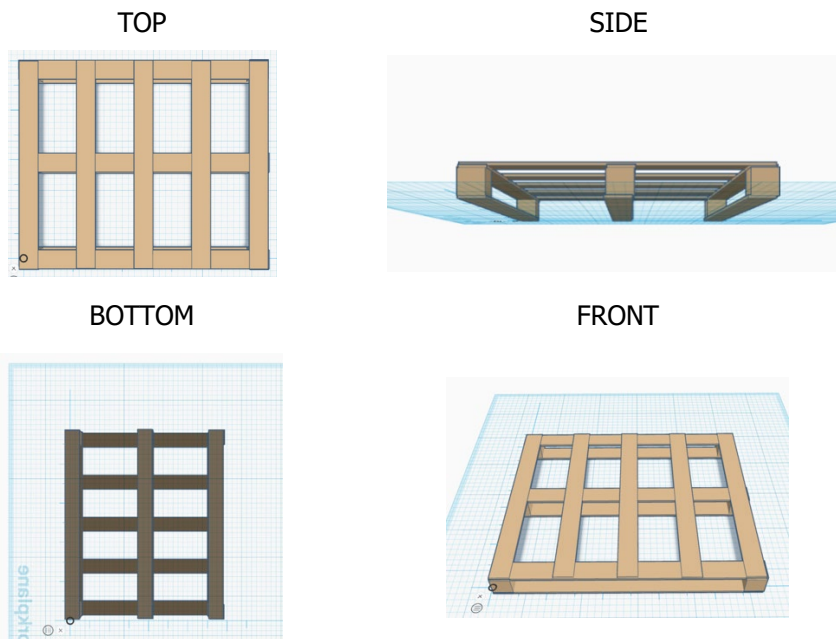
Since a standard pallet packing height is 48 inches (including the height of the pallet itself)

48"- pallet height 4.43" = 43.57"

The materials that will sit on your pallet can be 43.57" in height.

48"- pallet height 6" = 42"

The materials that sit on an average pallet can be 42" in height.

STEP 36	Drag a Workplane to your pallet
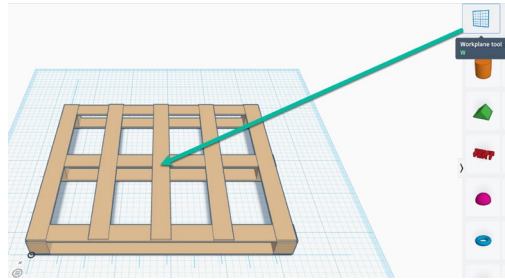
STEP 37	Drag a box to your Workplane
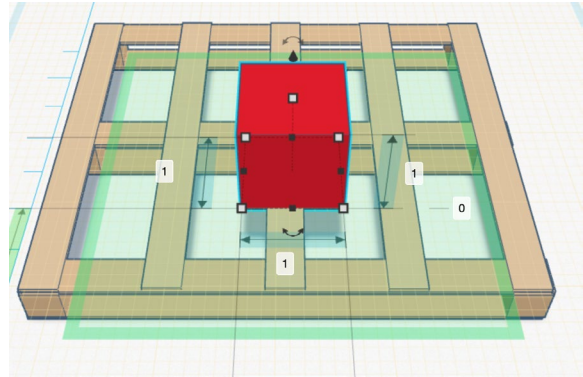
You already know a North American wooden block pallet measures 40" (width) x 48" (length). What is the largest size your box can be?

40" (width)

48" (length)

43.57" (height)

STEP 38	Keeping your 1:10 ration in play (move one decimal place to the left), key in your dimensions.

4.0" (width)

4.8" (length)

4.357" (height)

| STEP 39 | Expand your box to fit the dimensions. |

| STEP 40 | Select side views and in between views to check on placement of the box on your pallet |
| | You may need to adjust the dimension boxes. |
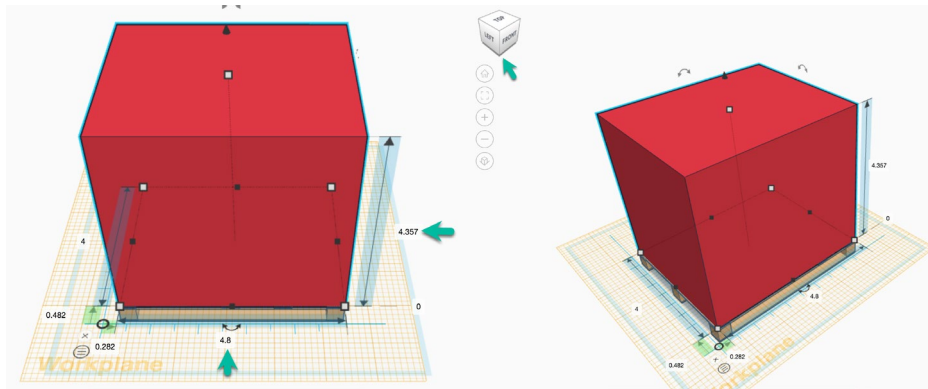
Staging, Storing, and Moving Pallets

Warehouse capacity refers to the available space for storage, inventory preparation, and order fulfillment. The physical capacity of a warehouse (the maximum number of pallets that can be stored vertically and horizontally at one time) is based on the weight and dimension of products, how much inventory you need on hand, and how much space your team needs to fill orders. Physical capacity may not equate with effective capacity, based on how much inventory is needed for customers (keeping back orders and out-of-stock in mind). More warehouse capacity and square footage are expensive (conditioned space) and tie up capital (money) when products sit on racks for weeks.

Understanding warehouse capacity is essential to optimizing the space. Considerations include:

> Footprint square footage

> Space used for non-storage purposes
> (loading area, picking and packing workspace, offices, restrooms, etc.)

> Storage space from the ground up (the maximum stack height),
> including overhead objects (lights, racks)

Usable space = footprint square footage - non-storage square footage, which is detailed below as Area (A)

Storage capacity = usable space in square feet · maximum stack height in feet, which is described below as Volume (V)

Area (A)	Volume (V)
A = (width · length)	V = (width · length · height)
Area is the region within the sides or boundaries of an object	the space occupied by an object

You have two objects: pallet and box. For Builders USA, there may be four or fewer pallet sizes throughout the warehouse. Let's assume there are two available pallet sizes for your recommendation planning:

Example pallet 1 (your pallet)	Example pallet 2 (industry average pallet)
40" (width), 48" (length), 4.43" (height)	40" (width), 48" (length), 6" (height)

You need to know the area and volume of each loaded pallet. At first, the volume difference in pallet height of 6" - 4.43" seems small at 1.57". However, you'll assess whether the difference is small or substantial in a distribution warehouse with tens of thousands of pallets. You will use the pallets' geometric shapes, measures, and properties with their loads to describe objects and their contribution to effective distribution warehouse operations. Based on that information, you will apply concepts of density (in warehouse planning) based on area and volume for Builders USA recommendations.

> Are you making the most of your available space?

To Maximize the Cube! you'll begin with calculating the area and volume of a cube. Before practicing with a formula, in the workplace you begin with industry data. Regardless of the height of example pallet 1 or 2, a standard loaded pallet measures 40" (width), 48" (length), 48" (height-pallet and load).

Oh, wait! A cube is a solid shape with six square (equal) faces. Loaded pallets are not square, they are **cuboid** (who comes up with these names?). Cubes are a specific type of cuboid.

CONE	REGULAR TETRAHEDRON	SQUARE PYRAMID	TRIANGULAR PRISM
CONICAL FRUSTUM	OCTAGONAL PRISM	HEXAGONAL PYRAMID	CUBOID
CUBE	CYLINDER	HEMISPHERE	OCTAHEDRON
SPHERE	TRUNCATED PYRAMID	PENTAGONAL FRUSTUM	HEXAGONAL PRISM
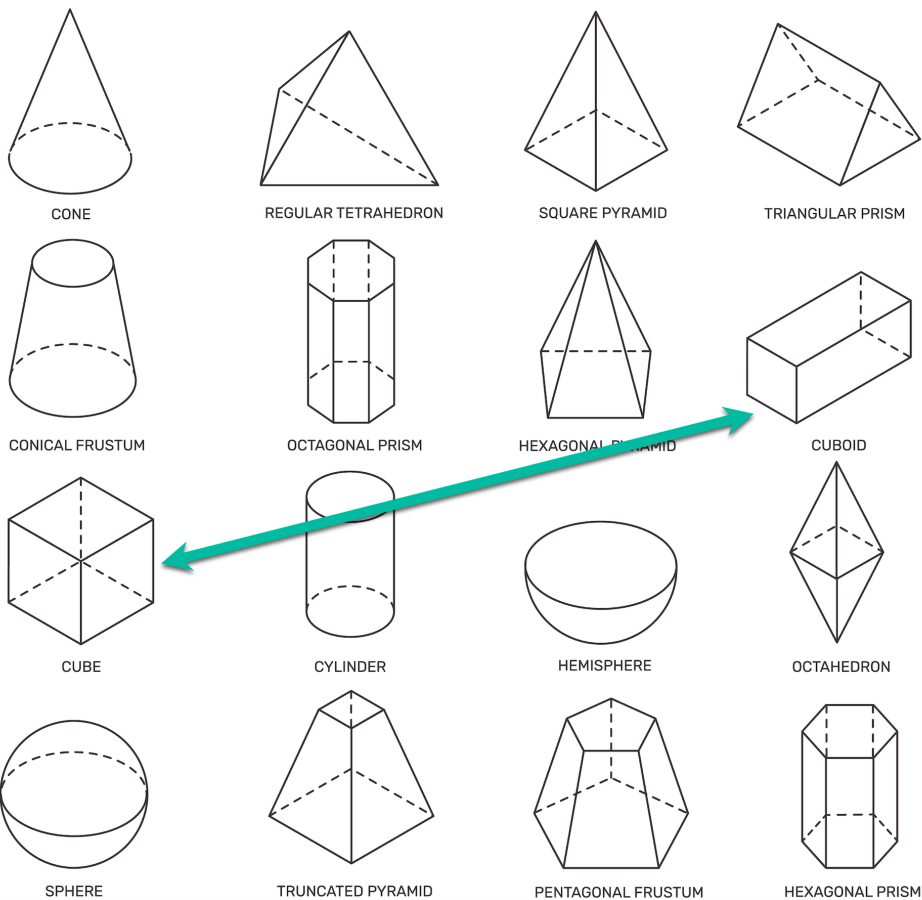
You know:

> Calculating the **area** of a cube or a cuboid is
> width · length

> Calculating the **volume** of a cube or a cuboid
> is **width** · **length** · **height**

In the case of a cube, since all sides are equal, a shortcut is

$$V = s^3$$
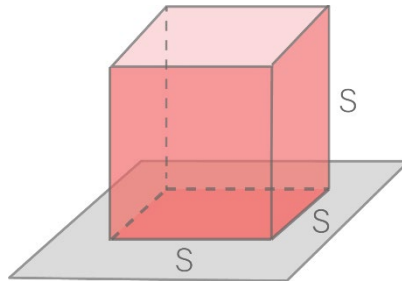
Volume of cube with side lengths s is $V = s \cdot s \cdot s = s^3$

As you work with area and volume, your role is to consider how math will support your work with Builders USA. You begin with your assignment/goal to Maximize the Cube! at every decision level of warehouse planning and then resource mathematics to inform your efforts. At this point, the mantra Maximize the Cube! applies to loading pallets, trucks, racks, and warehouses. Although the warehouse efficiency addresses different object shapes, it's doubtful that Builders USA will change its mantra to Maximize the Cuboid!

To further question naming, cuboid volume is measured in cubic units (cubic feet or cubic meters). You'll assess volume, for Builders USA, as cubic feet.

$$V \text{ (volume)} = W \cdot L \cdot H \text{ (width} \cdot \text{length} \cdot \text{height)}$$
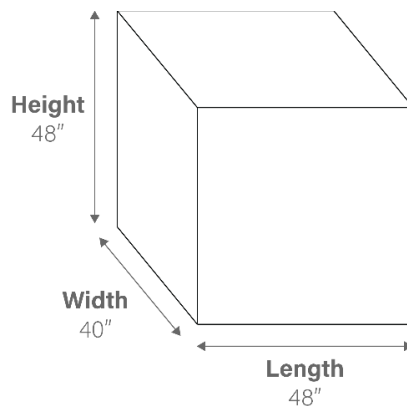
What is the **area** of a fully loaded pallet (both pallet and load)?

40" · 48" = 1,920 square inches

To convert square inches to square feet (ft^2), divide by 144.

1920/144 = 13.33 ft^2

What is the **volume** of a fully loaded pallet (both pallet and load)?

40" · 48" · 48" = 92,160"

a huge number because you're working with cubic inches.

To convert cubic inches to cubic feet, multiply by 0.0005787037 or divide by 1/1728 cubic feet (easier to remember).

Tip: Consider the order of where they keys are on a numeric keypad and think of a keyboard hack or shortcut. Mnemonics (the initial "m" is silent) are clues to help remember something, usually by associating the information with a visual image, sentence, or word.
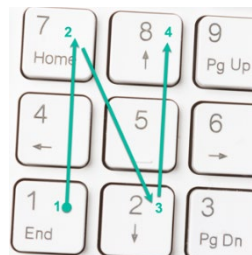
To convert cubic inches to cubic feet:

92,160/1728 = 53.333 ft^3

1. What is the **area** of example pallet 1 (without its load)?

    Example pallet 1 (your pallet):
    40" (width), 48" (length)   _____

2. What is the **volume** of example pallet 1 (without its load)?

    Example pallet 1 (your pallet):
    40" (width), 48" (length), 4.43" (height)   _____

3. What is the **area** of example pallet 2 (without its load)?

    Example pallet 2 (industry average pallet):
    40" (width), 48" (length), 6" (height)   _____

4. What is the **volume** of example pallet 2 (without its load)?

    Example pallet 2 (industry average pallet):
    40" (width), 48" (length), 6" (height)   _____

5. Is there a difference, in ft^2 between the two example pallets? If not, why?

    _____

    _____

6. What is the difference, in ft^3 between the two example pallets?

    _____

7. What is the difference in ft^3 divided by the volume of example pallet 2 (difference/example pallet 2)?

    _____

8. Convert the difference to a percentage (.xx = xx%).

_____

Although sturdier pallets are essential for heavy loads, you can see the volume difference a simpler pallet contributes to Maximize the Cube! The percentage difference equates to that much more or less ft³ of product versus pallet.

Calculate the difference across warehouse contexts:

A 40' truck holds an average of 20-24 pallets.

20 pallets · the difference in ft³ between the two example pallets = additional product per truckload.

_____

Builders USA products range from ceiling fans to sheetrock. From bricks to flower bulbs.
OSHA (Occupational Safety and Health Compliance) requires products stored in tiers to be stacked, blocked, interlocked, and limited in height so that they are stable and secure against sliding or collapse.

ROLE   As an intern for Builders USA, you will consider standard loaded pallet configurations, unusual product sizes and weights which change their warehouse movement and storage, and key factors that inform utilization of warehouse space.

UNIT 2

Task 2   Tinkercad Project 2

Next, you will work with your pallet and three additional Tinkercad files that represent important tools for your assessment. The images below include the pallet jack, forklift, and automated arm.

	Tools	Tinkercad version
Pallet jack		
Forklift		
Automated arm		
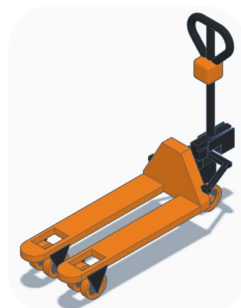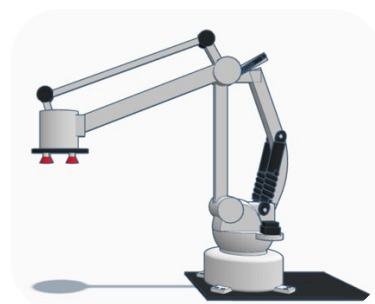
Your teacher will provide the Tinkercad tutorials for the pallet jack, forklift, and articulated robotic arm. Accessing them online keeps this book from weighing more than a loaded pallet. Build each warehouse tool per your teacher's instructions. You will also determine the area and volume for each object.

Constraints

In a distribution warehouse, pallets, pallet jacks, forklifts, and articulated robotic arms are rarely, if ever, stationary; they are in constant motion. Builders USA is looking for more than the area and volume of a standing piece of equipment. Floor space is expensive. You know about Builders USA Maximize the Cube! All the data you studied and the math you practiced inform your perspective.

Geometric constraints define relationships that force dependencies and limitations between entities. For Builders USA, considering constraints informs the warehouse object layout environment. For you, the goal is to ensure geometric and physical consistency, providing efficient workflow across the warehouse footprint. Think about the largest warehouses you have walked through, maybe Home Depot, Lowes, Costco, or others. Then, think about the safety of moving personnel and customers among the racking systems while loading and unloading products. People, equipment, racks, and products are in a constant state of constraint defining relationships.

> **Geometric Constraint Solving** is an approach for organizing shapes and objects in space using two-dimensional sketching and three-dimensional modeling.

You used Tinkercad to develop three-dimensional models representing the core objects that move products in the Builders USA distribution warehouse. In math-speak, your Tinkercad objects serve as models that inform questions of dimensions and constraints, and they can be easily modified for virtual testing purposes.

Applying geometric methods to solve design problems begins with understanding shapes, objects, area, and volume. For Builders USA, this includes addressing warehouse physical constraints, planning and modeling to maximize warehouse efficiency, and minimize costs.

Physical Constraints		Maximize Efficiency		Minimizing Costs
Physical constraints include the equipment you modeled, OSHA and Builders USA safety compliance, and the common two warehouse flow configurations.	**+**	Maximize efficiency includes Maximize the Cube! at every level of operations from optimizing product on pallets to determining aisle width to configuring stacking pallets on racks.	**+**	Minimizing costs is often reached by addressing physical constraints and maximizing efficiency; simple, fast, and safe product movement in and out of the warehouse controls costs. If an expensive articulated robotic arm requires less area and allows for very narrow aisles, it may minimize overall costs. If wasted space in building corners remains empty, costs can be staggering because any conditioned space without product or an efficient workflow does not generate revenue.

Keeping your objects in mind, here are distribution warehouse physical constraints that contribute to your assessment process.

1	Physical Constraints - types of warehouse aisles:

Conventional aisles	Narrow aisles	Very narrow aisles
Wide aisles that are typically 12'-13' wide and can accommodate a variety of equipment types. Conventional aisles work best for standard 48-inch pallets and forklifts. Conventional doesn't equate with industry standard because building age is a factor.	Typically, 8'-10' wide and support reduced size equipment. Narrow aisles maximize space and increase storage (as much as 25% of warehouse space).	Typically, 6' wide or less and can increase floor space by 40-50%. Very narrow aisles are often designed for manual order picking where the operator travels horizontally and vertically along aisles.

2	Physical Constraints - equipment in warehouse aisles:

Pallet jack

Pallet jack minimum aisle width is 9'-11'. Newer electric models may require only 4-5' of aisle space

Forklift

Forklift minimum aisle width is calculated with a formula

Right angle stack	+	Load length	+	Clearance	+	Pallet Overhang
The operator drives a forklift down an aisle, turns at a right angle, places the forks under a pallet, lifts it up, backs out, and returns to driving down an aisle. The amount of space needed is called a right angle stack.		The length of the pallet (typically 48 inches)		or Maneuvering space: Add 12 inches to head and load lengths for maneuvering space, to turn and stack		Add space for any additional overhang and an additional 6" for safety

Articulated robotic arm

The space in which a robotic arm can move is called its work envelope. The size and shape of the work envelope are determined by the size of the robot and its degrees of freedom. Articulated robots are made of several interconnected links connected through joints designed to allow the robot to move with a high degree of freedom (DOF) that allows the robot to move in various directions. The two types of joints include revolute and prismatic.

Revolt joints	Prismatic joints
Revolute joints are rotary joints that allow rotation along an axis.	Prismatic joints are linear joints that allow movement in a straight line.

In distribution warehouses, robotic arms often load and unload boxes from racks, lift and sort items of varying shapes and sizes, and perform repetitive warehouse tasks. The needed aisle and floor space is determined by the motion of the robotic arm and the safety space between robots and humans working together. For example, picking, sorting, packaging, transporting, and replenishing require differing workflows and space needs.

Stacker cranes

Stacker cranes for pallets stack items in warehouses (pallet cranes are sturdier than boxes cranes due to product weight)

Increase high load capacity by reaching heights up to 131' operating in 5' aisles	Vertical mast (single or double) with a horizontal carriage that moves up and down the mast using a motorized drive system	Uses a bottom rail track installed on a concrete slab along with an upper guide rail to stabilize the crane

Automated stacker cranes (ASC)

- Controlled by a computer system that directs movements and manages flow of materials
- Pallets can move goods up to 148' high operating in 5' aisles. The only handling equipment that can operate with racking over 131' high
- Miniload (name for box stacker crane) can reach a height of 65.6' and operate in a 2.62' wide aisle
- Uses sensors and cameras to monitor inventory levels and optimize storage and retrieval operation

Conveyor systems (five most common)

O-ring belt conveyor	uses motors and sensors to control the movement of products. Ideal for packaging and low-cost option
Belt conveyors	provide grip for slight incline or decline. Suitable for small items and allow for repeatable positioning
Heavy-duty conveyors	move up to 793 pounds, depending on roller configuration, for large items without a pallet
Heavy-duty pallet conveyors	move up to 1,100 pounds, depending on pallet configuration
Timing belt conveyors	provide flexibility for larger products with options for multiple lengths and customization of spacing between belts

Autonomous mobile robots (AMRs)

- Uses include order picking operations, zone picking, goods-to-person, and autonomous piece picking or flexible sortation
- Pick-and-place AMRs use machine vision technology to identify, grab, and move objects from one location to another while avoiding obstacles
- Complements human workers; one human operator contributes to filling orders on several AMRs, reducing operator walking time
- Use maps to dynamically navigate through the warehouse, identifying and avoiding obstacles

Tasks – Considering Constraints

Importantly, constraints balance with opportunities. For the Tasks noted, constraints are not defined as "what won't work." Instead, constraints create awareness of challenges to address during the planning phase of projects.

You consider constraints when

- ❖ thinking about traffic on a Friday afternoon versus a Saturday morning
- ❖ when you accept free shipping for an online purchase knowing your package will be slower to arrive than if paying for overnight shipping
- ❖ when you order a pizza moments before a major sporting event starts on TV
- ❖ and when you think about sleeping in on a school morning.

> Considering constraints helps you to reconsider, reroute, and adapt.

| Task 1 | Pallet Jack Constraints Example |

Calculating the area and volume of your objects, in this case a pallet jack, follows the approach you used with your pallet:

| A = W · L (width · length) | V (volume) = W · L · H (width · length · height) |

A = 2.303 · 7.248"
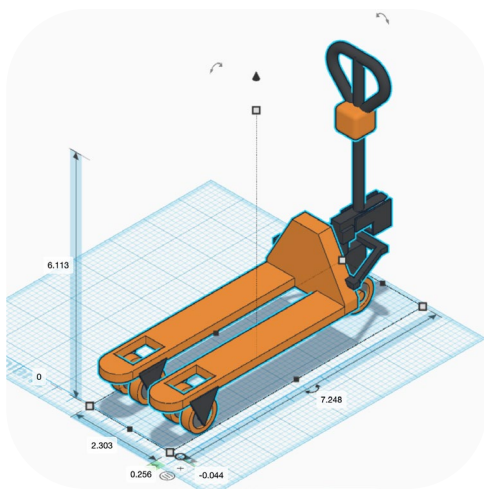
V = 2.303 · 7.248" · 6.113"

converts without 1:10 scale to

converts without 1:10 scale to

$A = 23.03 \cdot 72.48" = 1{,}669.21/144 = 11.592 \text{ ft}^2$

$V = 23.03 \cdot 72.48" \cdot 61.13" = 102{,}039.076"/1728 = 59.05 \text{ ft}^3$

Task 2	Forklift Constraints
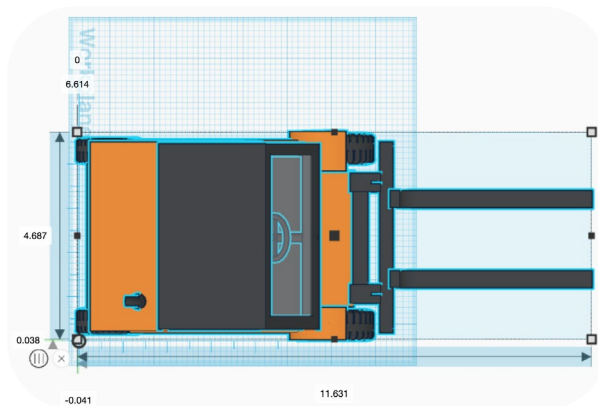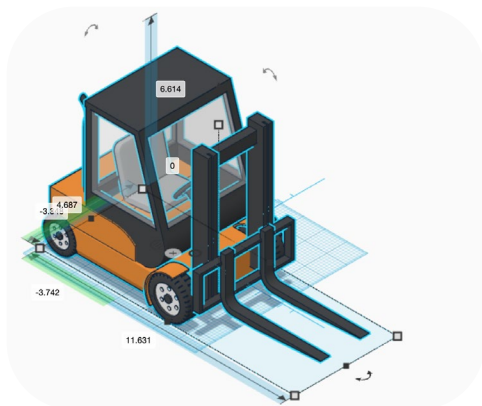
1. What is the forklift object area in ft²?

    A = _____" · _____" converts without 1:10 scale to

    A = _____" · _____" = _____" /144 = _____ft²

    > A = W · L (width · length)

2. What is the forklift object volume in ft³?

    V = _____" · _____" converts without 1:10 scale to

    V = _____" · _____" = _____" /1728 = _____ft³

    > V = W · L · H (width · length · height)

The length of your Tinkercad forklift is 11.631" at 1:10 scale.

> 116.31 " / 12 (inches per foot) = 9.69'

Right angle stacks calculations are supplied by vendors, based on forklift make and model. For this task, an estimated right angle stack calculation is based on researching 5,000-pound warehouse-style forklifts and selecting a 95.5 right angle stack.

3. What aisle minimum does Builders USA need for a 48" pallet with no additional overhang?

    _____

4. What aisle minimum does Builders USA need for a 48" pallet with 12" of overhang?

    _____

Additional Forklift Constraint

Carrying a too heavy load is one of the leading causes of forklift accidents. Operators need to consider factors like lift height, load weight, and their forklift's condition.

> **Mass** is the amount of matter an object contains.   **Volume** is how much space an object takes up.

Calculating the total **mass,** a forklift can carry begins with its rated capacity and net capacity.

> **Rated capacity** is the recommended maximum weight listed on a forklift's data plate.

> **Net capacity** (or payload capacity) is the actual weight a forklift can carry, taking into account its de-rated capacity (reductions from net capacity due to environmental challenges), mast type, and volume.

5. What constraints do you see in the following images?

    _____
    _____

Task 2   **Articulated Arm Robot Constraints**
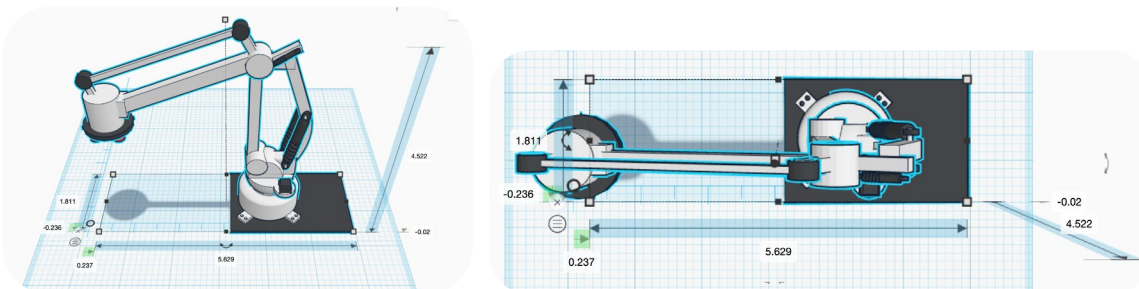
6. What is the articulated robotic arm object area in ft^2?

   A = _____" · _____" converts without 1:10 scale to

   A = _____" · _____" = _____" /144 = _____ft^2

   > A = W · L (width · length)

7. What is the articulated robotic arm object volume in ft^3?

   V = _____" · _____" converts without 1:10 scale to

   V = _____" · _____" = _____" /1728 = _____ft^3

   > V = W · L · H (width · length · height)

8. Articulated robotic arms attach to a solid surface (floor, table, etc.) with a floor-mounted or mobile pedestal. What constraints might an ARM pedestal add to warehouse workflow?

   _____

Task 3	Warehouse Flow Constraints

Now that you've practiced working with $A = W \cdot L$ and $V = W \cdot L \cdot H$, it's time to plan how the area and volume of objects do and don't inform warehouse product flow.

The **area** in square feet (ft^2) helped you to calculate the surface space needed for essential warehouse storage planning.

The **volume** in cubic feet (ft^3) helped you to understand how shapes become objects and how objects have volume, which will inform warehouse workflow planning.

The five typical components of warehouse flow:

The Receiving Area	is where incoming trucks are unloaded, product is received, and inventory is recorded
Staging Area	When products are received, the Staging Area is used to determine where they will be placed within the inventory warehouse system. Before product is shipped, the staging area prepares orders to be delivered to home centers
The Shipping Area	holds completed orders and loads them onto trucks to be delivered to home centers
Dynamic Storage	holds inventory that doesn't have a fixed warehouse location. These products are often in high demand and need to be available
Static Storage	holds inventory product that have a specific location in the warehouse. Products are usually organized on racking systems to stack and fit materials in the space provided

The following diagrams show two common warehouse flow configurations:

I-Shaped Warehouse Flow

U-Shaped Warehouse Flow
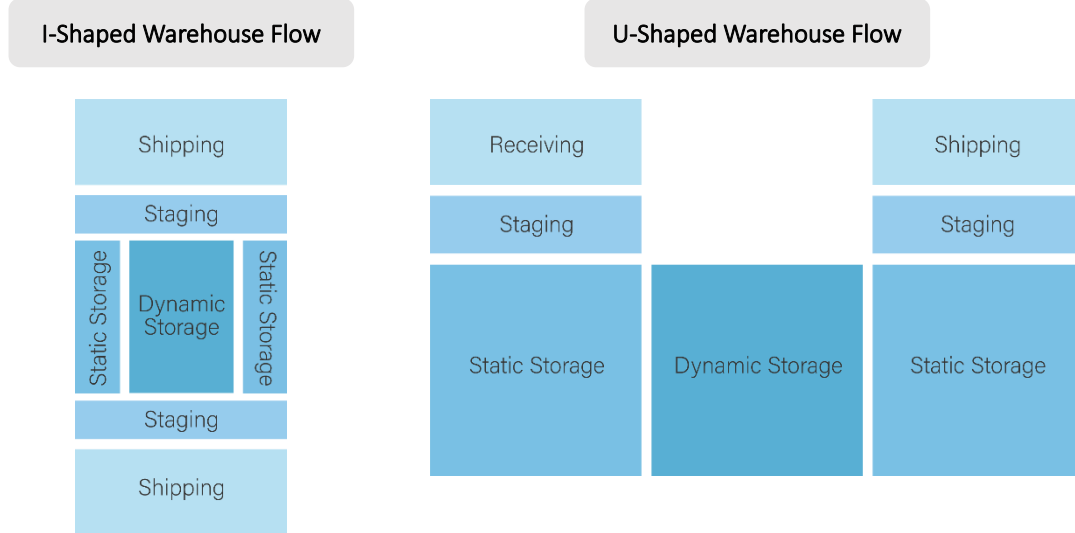
The warehouse flow configurations give you an idea of how loaded and unloaded pallet jacks, forklifts, and articulated robotic arms will move throughout the warehouse. Based on your Geometric Constraint Solving, organizing shapes and objects in space using two-dimensional sketching and three-dimensional modeling:

1. What two examples of constraints or data regarding pallet jack operations should Builders USA consider with the two warehouse flow options?

   _____

   _____

2. What two examples of constraints or data regarding forklift operations should Builders USA consider with the two warehouse flow options?

   _____

   _____

3. What two examples of constraints or data regarding articulated robotic arm operations should Builders USA consider with the two warehouse flow options?

_____

_____

Based on physical constraints data provided:

4. What example of constraints or data regarding stacker cranes and automated stacker crane operations should Builders USA consider with the two warehouse flow options?

_____

_____

5. What example of constraints or data regarding conveyor systems or autonomous motor robots' operations should Builders USA consider with the two warehouse flow options?

_____

_____

Quick Check on Milestone 3 Mathematical Common Core Standards

✓ Geometric shapes measures and properties to describe objects three-dimensional objects
✓ Apply concepts of density based on area and volume in modeling situations
✓ Apply geometric methods to solve design problems

Common CORE Standards

Task 4	Environmental Constraints

Business activity is constrained by the environment in which the business operates. Environmental constraints include physical or social conditions such as:

- ❖ Competitor actions
- ❖ Legal requirement constraints
- ❖ Social expectations and requirements (society expects business to operate ethically) constraints
- ❖ Economic constraints
- ❖ Technology constraints
- ❖ Natural resource constraints

Researching and preparing the Builders USA use case in Units 1 and 2 informed the following environmental constraints:

Across the U.S., tens of thousands of acres of land in semi-rural neighborhoods, close to interstate highways and airports but outside typically high-rent counties, have been purchased by investors looking to sell or build and lease new and massive commercial spaces to the world's biggest movers and producers of goods, including Target, Walmart, Tesla, Ikea, Boeing, Michelin, Nike, and John Deere, to name a few. Because of historic divisions by interstate in America, there is a greater likelihood of finding a warehouse in a neighborhood with more residents of color and a larger share of low-income residents than typical for the metro region nearby (Waddell).

In one Fontana, CA neighborhood with two Amazon warehouses, residents contend with 6,000 daily vehicle trips, including more than 2,300 diesel truck trips. Residents and environmental groups joined several communities to voice health concerns—increased per capita asthma and lung disease rates and chronic nosebleeds—near industrial developments with emissions from cargo traffic. Some cities restricted new construction of industrial-use spaces, and groups challenged land-use decisions with lawsuits while urging California's governor to intervene (Torres).

The Inland Empire's labor force has grown by 47.5% in the last 20 years, outpacing nearby counties and the state, which saw a 12.5% increase. The logistics sector employs more people in the two-county region than any other sector, at 17% of employed adults. At the same time, the Inland Empire tends to post relatively lower-paying jobs than surrounding counties and the nation on average. Declining housing affordability continues to hamper home buying for the 4.7 million people in the counties, with the share of households that can afford a median-priced home falling to 21% from 28% in Riverside County and to 30% from 39% in San Bernardino County in recent years ("Regional Briefing Book, December 2022").

The logistics industry's average hourly pay of about $20 per hour falls roughly $8 per hour short of the national rate for all occupations ("The U.S. Warehouse Capital Boomed During the Pandemic. Now It's Facing a Slowdown").

Builders USA considers livable wage jobs and socioeconomic justice as a mission priority. Environmental constraints data is essential to Builders USA's business activity and community acceptance. Data regarding pallets and racking differs from data regarding environmental traffic and socioeconomic hourly pay concerns; however, the success of the distribution warehouse relies on the entire ecosystem, from ships arriving at The Port of Long Beach to job and salary opportunities in the warehouse. Constraints, efficiency, and minimizing costs address success for all parties.

1. What two environmental constraints do you consider essential for Builders USA to address with the community near the distribution warehouse site?

    _____

    _____

2. How might you incorporate environmental constraints in considering Builders USA warehouse planning?

    _____

    _____

Milestone 3 Check-in Meeting

Per your teacher's instructions, meet in small teams to assess and discuss the following five Milestone 3 questions:

1. How have shapes and objects, with their area and volume, informed your perspective on distribution warehouse planning?

   _____

   _____

   _____

2. How will objects built and workflow configurations introduced inform your recommendations to Builders USA?

   _____

   _____

   _____

3. What objects and configurations will support addressing physical constraints, maximizing efficiency, or minimizing cost?

   _____

   _____

4. How can data regarding environmental constraints contribute to a successful Builders USA distribution warehouse buildout?

   _____

   _____

5. What is the role of geometry and geometric constraint solving in supporting Builders USA planning priorities?

   _____

   _____

Milestone 4 - Applying Contexts to Milestones 1-3

An essential element in understanding mathematics is **applying one concept across multiple uses or applications**. In Milestone 4 you'll remain in the warehouse industry sector; however, you will explore different geometric shapes and objects from the Builders USA distribution warehouse.

Milestone 4 reviews the mathematical common core standards:

Analyze images of

❖ two-dimensional objects
❖ three-dimensional objects

Identify relationships between

❖ two-dimensional and three-dimensional objects
❖ two-dimensional cross-sections of three-dimensional objects
❖ three-dimensional objects generated by rotations of two-dimensional objects

Geometric shapes measures and properties to describe objects

Apply concepts of density based on area and volume in modeling situations

Apply geometric methods to solve design problems

Experienced warehouse entrepreneurs and employees often contribute ideas that solve work-based problems. An old saying is, "The best inventions solve the simplest problems." In Milestone 4, you will assess United States Patent Application Publications to assess how inventor drawings extend the ideas you explored in Milestones 1-3.

Terms

Patents	An exclusive right granted for an invention. An invention is a product or process that provides a new way of doing something or a technical solution to a problem.
Trademarks	A type of intellectual property for a recognizable sign, design, or expression, such as a word, phrase, style, or logo that identifies goods and services belonging to a brand.
The U.S. Patent and Trademark	Grants U.S. patents and registers trademarks.
Google Patents	Presents the full text of selected global patents.
Patent Drawings	Illustrations of the invention and methods, or steps used to carry out the invention. The drawings follow strict rules that accurately describe and demonstrate the invention.

Tasks

You will review a series of three patents related to the warehousing industry, work with peers to assess the patents, and submit a deliverable that addresses your team and individual findings.

Each patent application is around 20 pages. Portions of the patent are included in Milestone 4. Your teacher will give you access to the full patent applications.

You will work on this set of tasks paired with another student. Talking through product objects, geometric shapes, and processes in the workplace often takes place with peers. Your goal is to utilize the patent application to understand what the product, how it works, and **the role of geometric methods in solving design problems**.

On July 4, 2023, Daniel Klinger from Avon, Indiana submitted a patent application for the Modular Pallet Rack Repair Kit. You're familiar with pallets and the racks they sit on from this book any visit you may have had to Home Depot, Lowes, or Costco. The application abstract reads:

> *A modular repair kit for repairing damaged pallet rack frames and a method of installation thereof which includes modular elements that can be customized by mechanical process such as cutting, drilling, and connecting, for example, by bolts, that avoids major modifications, such as welding, at the installation site. The modular repair kit utilizes a standard replacement post assembly that can be cut to fit into nearly any size gap that is created when the damaged portion of the pallet rack frame is removed. The remaining elements of the repair kit can then be customized to accommodate any size of the standard replacement post assembly.*

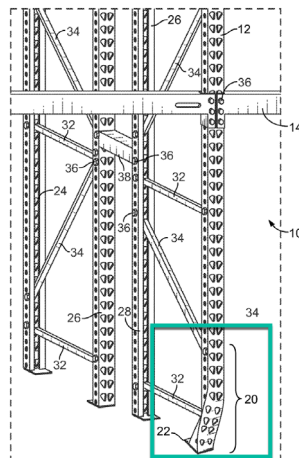From the abstract, we can expect the patent drawings to include:

> The modular repair kit utilizes a standard replacement post assembly that can be cut to fit into nearly any size gap that is created when the damaged portion of the pallet rack frame is removed.

The first patent application drawing shows the pallet with repair, the second shows a rack that has been damaged, and the third begins the demonstration of the process of repair. The purpose of reviewing the drawings ties to the Common CORE Standards, identifying two- and three-dimensional objects and relationships between them.
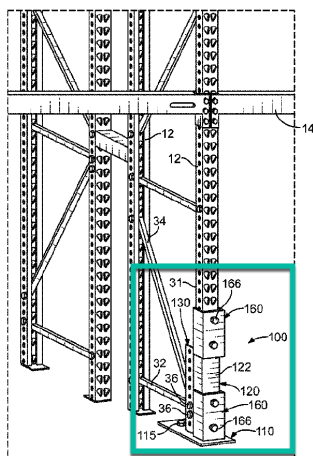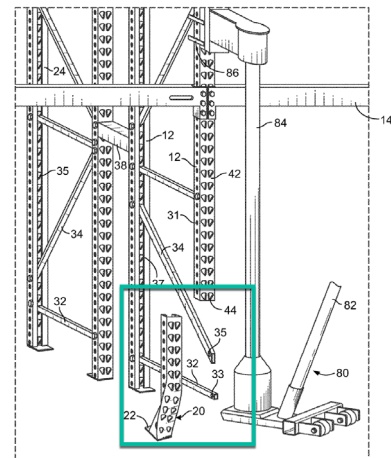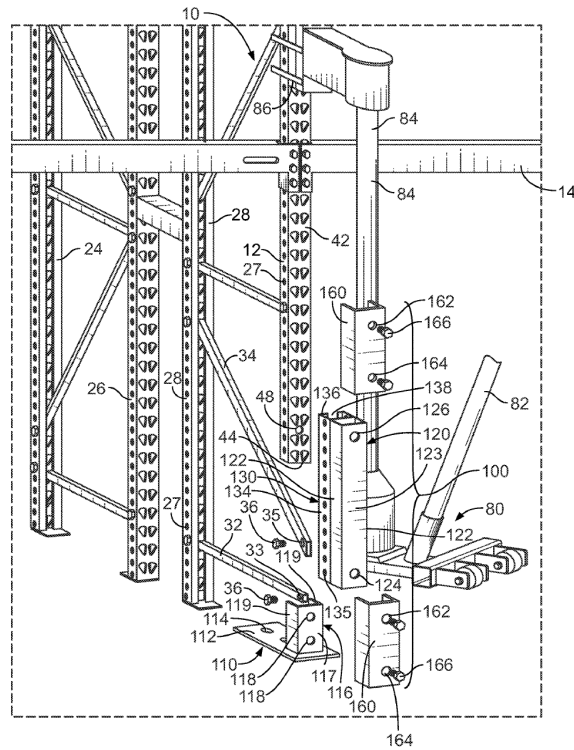

pallet with repair | a damaged rack | in process of repair

The patent application includes six additional drawings that detail the repair process and several pages of narrative text that describe each of the numbered elements in the drawings. One of the most complex drawings is Figure 3 in the patent application:

The drawing demonstrates how geometric measurements inform physical constraints. What information is presented? What is the problem asking you to find? What information might be missing? What can you interpret from the diagram?

1. On the drawing above, circle each of the numbered elements below, according to the patent application:

|	
80	is generally a standard upright jack
82	is the handle to raise the column with the jack
120	is the replacement post assembly
Replacement post 122 has a front facing wall with two connection apertures 124, 126 at either end of the section, 122 providing for connections to the base 110 and to the remaining undamaged post, 12	
The size of the post receptor pin 116 is sufficient to provide a base or anchor for supporting the U-shaped replacement post assembly 120 in a sturdy and robust connection after it is inserted into the space between receptor pin 114 and cut end 44 of post upright 12	

2. What constraint does this product address?

_____

3. How does this product improve efficiency or save cost?

_____

Task 2	Material Handling Pallet

On July 20, 2023, Venkataramu Bangalore and David Friedman from Chatsworth, California submitted a patent application for a Material Handling Pallet. The application abstract is less clearly stated than the first application. The images and detailed description better inform the product's intent. This three-dimensional image shows an improved version of the pallets you worked with earlier.
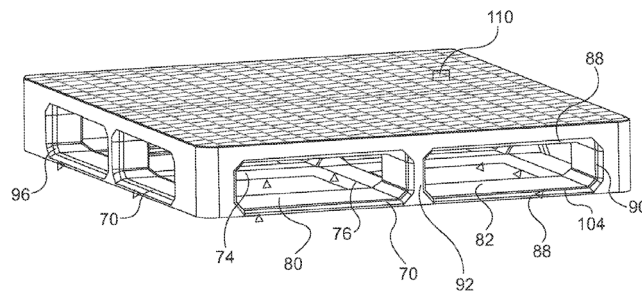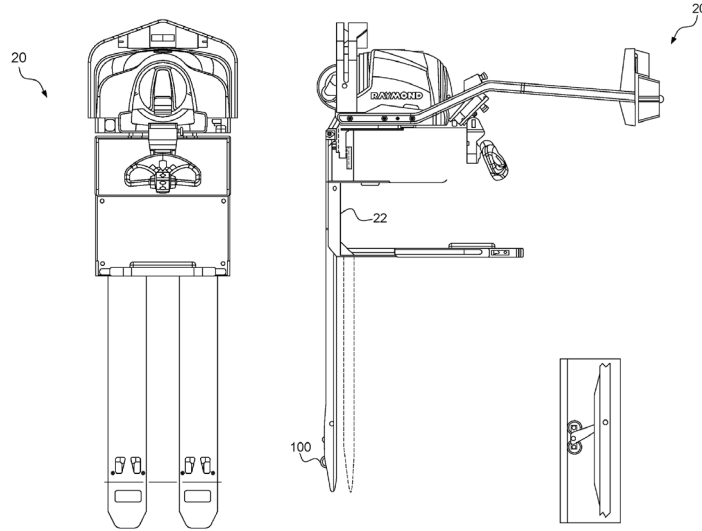

1. What geometric shape(s) in this patent application version of a pallet are different from your work with the standard wood pallet?

_____

_____

2. What two-dimensional image(s) can you create from this three-dimensional image that better inform this product design?

_____

These two-dimensional images inform the tools to be used with the material handling pallet.

3. What different shapes do you identify in the material handling pallet two-dimensional images?

_____

_____

4. Based on your previous assessment with the pallet jack and forklift, what are the physical constraints that will need to be addressed regarding aisle width?

_____

_____

5. What data would you need to determine the value of this patent be added to the Builders USA distribution warehouse?

_____

_____

Task 3	Automated Warehouse using Robotic Forklifts or other Material Handling Vehicles

On August 15, 2023, Cybernet Systems Corporation, Ann Arbor, Michigan, with inventors Charles J. Jacobus, Glenn J. Beach, Steve Rowe, and Charles J. Cohen, submitted a patent application for an Automated Warehouse using Robotic Forklifts or other Material Handling Vehicles. The application abstract reads:

Automated inventory management and material (or container) handling removes the requirement to operate fully automatically or all-manual using conventional task dedicated vertical storage and retrieval (S&R) machines. Inventory requests Automated vehicles plan their own movements to execute missions over a container yard, warehouse aisles or roadways, sharing this space with manually driven trucks. Automated units drive to planned speed limits, manage their loads (stability control), stop, go, and merge at intersections according to human driving rules, use on-board sensors to identify static and dynamic obstacles, and human traffic, and either avoid them or stop until potential collision risk is removed. They identify, localize, and either pick-up loads (pallets, container, etc.) or drop them at the correctly demined locations. Systems without full automation can also implement partially automated operations (for instance load pick-up and drop) and can assure inherently safe manually operated vehicles (i.e., trucks that do not allow collisions).

1. Based on this abstract, what is the role of geometric shape and object in this drawing?

_____

_____

_____

_____

_____
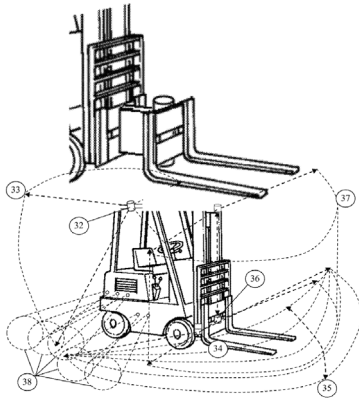
2. How do the drawings use of 38, 37, 35, and 33 benefit your interpretation of how the invention contributes to Builders USA?

_____

_____

_____

3. What is the role of geometry and geometric constraint solving in assessing this patent for Builders USA?

_____

_____

4. What is the purpose of the geometric shapes drawn into the forklift as 39, 40, and 41?
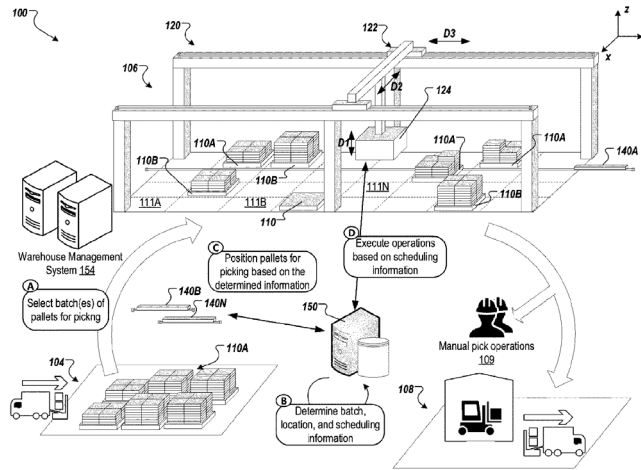

_____

_____
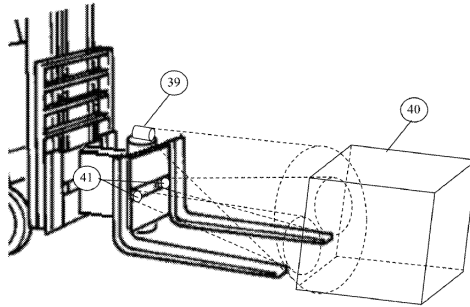
Task 4	Warehouse Workflow

Analyze the images below, note what they may represent, and explore how geometric shapes convey meaning in objects and processes.

1. What geometric shapes do you identify in the image that inform constraints, efficiency, or cost savings?
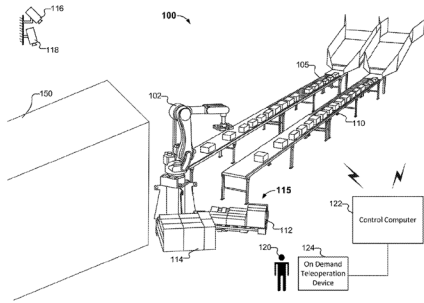

_____

_____

2. How do the geometric shapes in this image convey potential environmental constraints for Builders USA consideration?
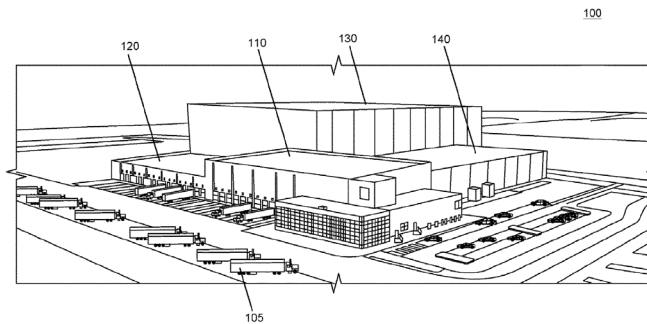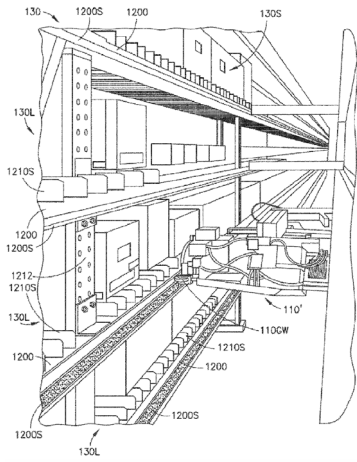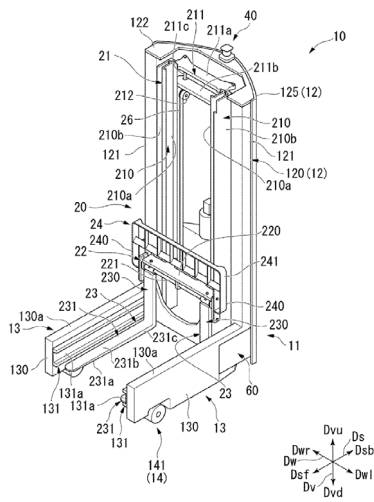

_____

_____

3. What is the role of geometry and geometric constraint solving in assessing this patent for Builders USA?

_____

_____

_____

_____

_____

4. How do these geometric shapes convey objects and processes? What's happening in the image?

_____

_____

_____

_____

_____

5. What meaning, or actions does this object convey in objects or processes?

_____

_____

_____

_____

_____

Milestone 4 Check-in Meeting

Per your teacher's instructions, meet in small teams and discuss the patent drawings, their intended use, and how geometric shapes that conveyed image meaning or process. Critically assess and discuss the following four Milestone 4 questions:

1. What geometric shapes and objects best informed product design and use?

_____
_____
_____

2. What value did the patent drawings have to support your understanding of their potential value to Builders USA?

_____
_____
_____
_____

3. Discuss your approach as you considered constraints each patent application targeted.

_____
_____
_____
_____

4. How might you utilize two-dimensional and three-dimensional drawings to demonstrate product fit to Builders USA?

_____
_____
_____
_____

Unit 2 Deliverable

Swaminathan Balasubramanian submitted a patent application August 3, 2023, for an Energy Efficient Legged Mobile Robot. The robot incorporates multiple shapes and sizes you explored in Unit 2. For this deliverable, you will apply the unit's mathematics objectives and use Tinkercad. The patent application, project information, and rubric are provided by your teacher.
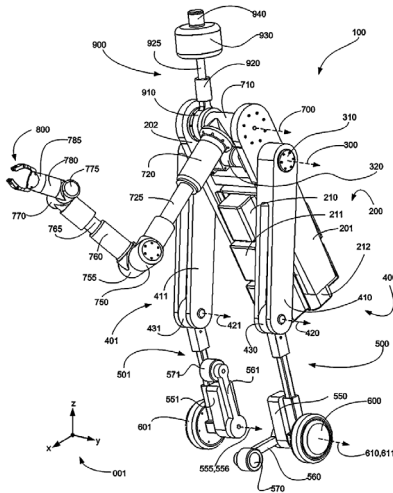
1. Select one area of the robot that contains a joint (for example, on a person what you might see as a type of elbow, knee, or wrist)

2. Create a Tinkercad model of your selected object.

3. List the area and volume of each piece of your object.

4. Using Tinkercad or creating a drawing, develop a cross-section of your object.

5. Using Tinkercad or creating a drawing, develop a two-dimensional object from your three-dimensional object.

6. Respond to the critical thinking questions in your instructions, they relate to geometric modeling and applying geometric methods to solving design problems.

In Unit 3 your use case industry sector changes to the business of online reviews and navigating how fake online reviews affect business. You will work with data and statistics to develop recommendations for the Fair Business Commission (FBC), a nonprofit social enterprise that educates businesses and the public on core themes that support ethical, equitable, responsible, and sustainable business practices.