

Compiled Engineering Level 1 (Week 1-8)

INK AND METAL 2020-2021

Engineering Principles Syllabus (Weeks 1-8)

Introduction to Engineering

Grades 5-11

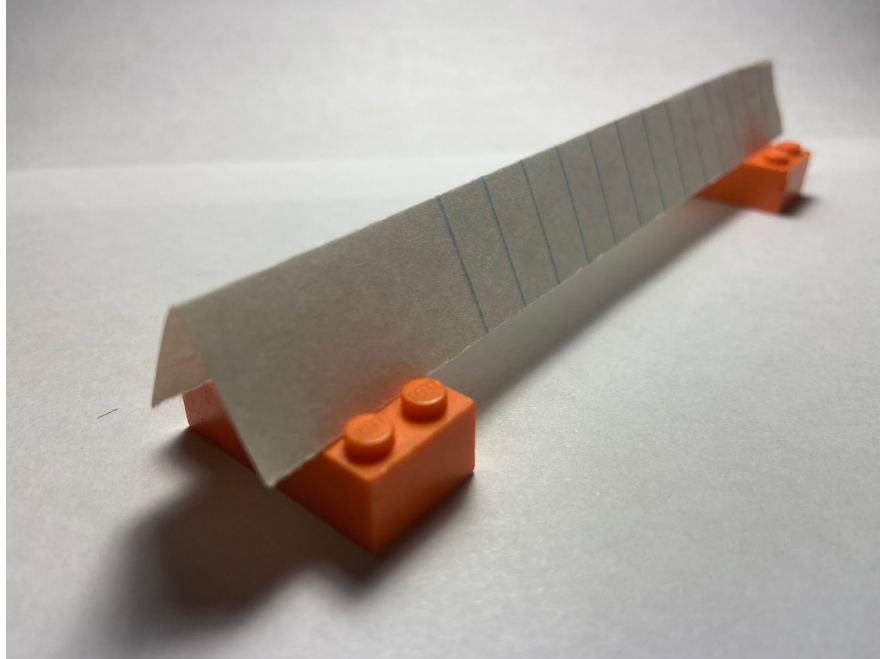
- **Class 1**
 - **Goal:** Students will discover and be introduced to engineering through a challenge where a paper bridge is being built (**Goal is to have the longest bridge**).
- **Class 2**
 - **Goal:** Students will understand the Design Process and Design Brief (Documentation Process), in relation to the paper bridge activity from week 1.
- **Class 3**
 - **Goal:** Students will learn how to design a bridge in an online platform used by industrial professionals. This will expand on the paper bridge built in the previous class. (**This will also build on documentation classes**)
 - <https://bridgedesigner.org/download/>
 - 1 common bridge - holding 1000lbs
 - 1 unique creative bridge - holding 1000lbs
- **Class 4**
 - **Goal:** Students will learn the functions and significance of simple machines (levers, wheel, wedges, etc.) and their applications in our lives and the industrial world.

- **Class 5**
 - **Goal:** Students will learn and understand the basics of gearing, gear mechanics, the background, and real-world applications of gears. (This will give an example of a commonly utilized and crucial mechanism used in the real world of engineering)
 - <https://geargenerator.com/>
 - **Class 6**
 - **Goal:** Students will understand the layout and uses of a chassis. A small preview of the FTC Ink and Metal 2019-2020 robot will be shown, and how torque and speed play a role in the robot and its functions will be taught. Students will also understand how different mechanisms are used to perform different tasks.
 - **Rahul Ravi**, the captain of **FTC Ink and Metal 5773**, is going to give a tour of the FTC Robot
 - **Class 7**
 - **Goal:** Students will learn about CAD, and will utilize TinkerCAD, a free online CAD tool to design and develop various objects.
 - **Class 8**
 - **Goal:** Students will learn the basics of electricity. Everything from history, to concepts, and even applications.
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Paper Bridge Activity (Week 1)

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- **Google Classroom Signup**
 - Make Google Classroom and you should be given a code
 - EX: "et56dh"

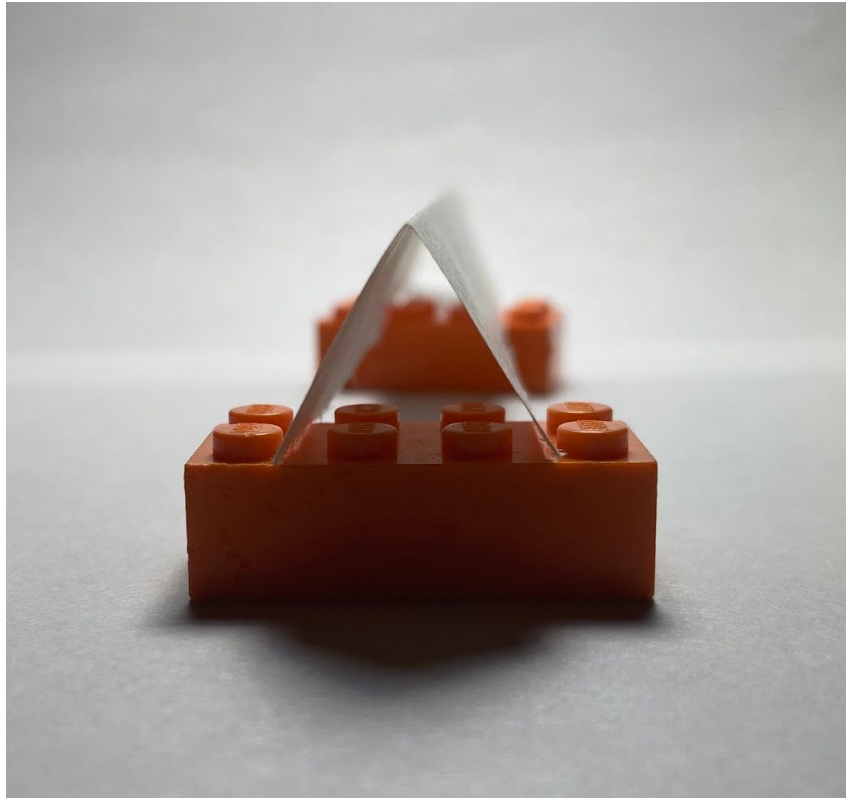
- Share this code with your class/target audience so that they can join and access assignments
- **Assist students that still need help signing up for the classroom (5 minutes)**
- **Explain to the students what the class will be about and the major concepts in addition to FIRST and FTC (5 minutes)**
 - **EX:** This class serves as an introductory class to engineering. It will go through many fundamentals in what goes into building and mechanizing a robot and beyond. You will also learn the many steps it takes to design and come up with a producible product. You will not only learn about gears and motors, but also the many different values of FIRST that are used in robotics teams such as in FTC. FTC is a robotics competition in which every year a different challenge is given in which your team has to make a robot that will attempt to gain the maximum amount of points possible.
- **Students in this class will partake in an activity Known as the Paper Bridge Activity**
 - Materials Required (Have students acquire these before class)
 - 11 inch by 8.5 inch paper (Quantity: 1)
 - Scotch Tape (Quantity: ∞)
 - Ruler/Measuring Tape (Quantity: 1)
 - This activity will require students to make a bridge in **15 minutes** that is able to hold its own weight while resting afloat only held up two points. (As seen in **FIGURE 1**)
 - The goal of the bridge is to be the longest than any other in the class
 - Make an assignment on Google Classroom that is titled "Length and Picture of Paper Bridge"
 - **FIGURE 1**



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- Explain this challenge and its goal to the students before having them attempt it. (10 minutes)
- Allow students to accomplish this challenge while letting them know how much time is left in 5 minute intervals. (15 minutes)
- Give students a few minutes to display their bridge over 2 points. Have them record the length and take a picture of their bridge. (5 minutes)
 - Using the assignment previously named “Length and Picture of Paper Bridge” have them turn both the picture and length in on an attached google document.
- Have students present each of their bridges explaining their thought process and procedure. (15 minutes)
 - This will teach them to be open and think about multiple solutions to the same problem.

- One of the easiest and strongest designs out there is the triangular prism design in which the paper creates a “V” shape as seen in FIGURE 2.

- FIGURE 2



- Last few minutes ask them this question: What were some common steps in the procedure?
 - This will prompt them to think about a common set of steps followed indirectly introducing them to the design process.

Design & Documentation Process (Week 2)

- Google Classroom Troubleshooting

- Students should have joined the Google Classroom during Week 1, if any students experience any difficulty with Google Classroom or have any questions regarding how to turn in assignments, etc., now is the time to take care of those to prevent confusion later on during the classes.
- Google Classroom is important to the flow of these classes, it is an excellent tool for any educator.

- **Leading Questions for this Week**

Leading Questions are an excellent method to prepare students for what they are about to learn. Students should be able to answer these questions perfectly by the end of the class.

What is the Design Process?

What is the Design Brief?

Why are the Design Process & Design Brief (Documentation Process) essential to an engineer?

Where is the Documentation Process applied in the real world?

- **Quick One-Minute Recap of Last Class to Refresh the Students' Minds**

Last week, students participated in a paper-bridge activity, where they only had one piece of paper, and as much tape, and were told to build the longest bridge possible, spanning from one book to another.

The students followed the steps of the **Engineering Process** without knowing they were doing so.

- **The Instructor should open Google Classroom, and Review Paper Bridge Submissions with the class**

- Screen share (on Zoom/Cisco Webex) each submission with your class.
- Students will view each submission and point out what is good about each design and what could be improved.
- Students should be active and engaged in this class discussion activity

- **The Design Process (6 steps)**

- 1. **Define** a Problem
 - The problem provided last week was that you had to construct the longest bridge possible between two textbooks using only one sheet of paper and as much tape as needed.
- 2. **Gather Information** regarding the Problem
 - This would be the act of collecting their materials and discovering/coming up with initial ideas.
- 3. **Generate and Analyze** possible ideas
 - At this point in the paper bridge challenge, the students would have thought of a few designs they could use to solve their problem.
- 4. **Develop** Solutions
 - This would be the act of the students actually building the bridge with their materials, and DEVELOPING the idea/design that they came up with in step 3.
- 5. **Gather** feedback
 - This is the activity we did at the beginning of the class, where students gave feedback on each others' designs.
- 6. **Improve** your design
 - Based on feedback, students would improve their designs and use a better design. However, they will not actually do this as it would require time, and we must move on with the class.
- **The Design Brief**
 - The Design Brief is a documentation method used in many professional engineering fields.
 - It is simply like a "profile" or "biography" for a design.
 - Students will fill in the Design brief (**Text is in the Last Page of this Curriculum**) according to the Paper Bridge Activity from Last Week.
 - Students will be provided 10-15 minutes to fill out this document and turn it in via Google Classroom.
 - One **example** of the application of the design brief in a professional environment would be in the field of architectural engineering.

- Architects use this whenever proposing a design, whether it is a bridge or a skyscraper, stating constraints/budget
- One **example** of the application of the design brief in a professional environment would be in the field of automotive engineering
 - Automotive Engineers use this when designing a new vehicle, and they state the features/capabilities of the vehicle.

DESIGN BRIEF DOCUMENT IS ON NEXT PAGE, PLEASE COPY & PASTE ONTO A DOCUMENT AND ASSIGN IT TO YOUR CLASS VIA GOOGLE CLASSROOM

FTC Ink and Metal

Design Brief

Client Info

- Your Name
- Your Street (Use Imaginary Address)
- Your City
- Your Country
- Email Address

Project Info

- Your Project
- Your Future Goals (Add-ons to the prototype)
- Your Build Budget (Constraints and estimated cost to build prototype)

Building Details

- What sort of building do you want? (i.e. house, store, workshop, pub) Specify type of bridge
- How do you want the building to feel in the environment? (Different design types in a city, beach, and forest)

What is the Design Process?

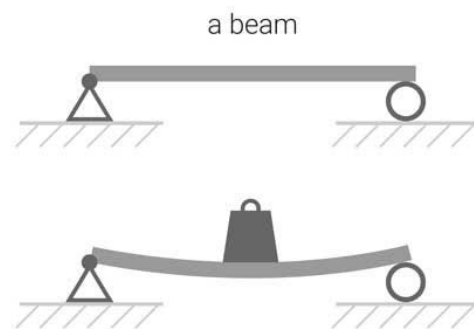
What is the Design Brief?

**Why are the Design Process &
Design Brief
(Documentation Process)
essential to an engineer?**

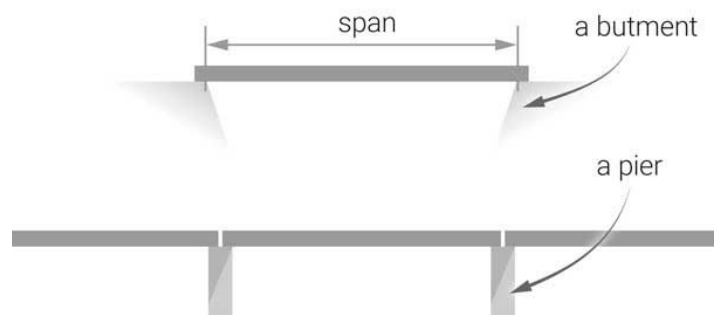
**Where is the Documentation
Process applied in the real
world?**

Beam Bridges

A beam bridge is one of the simplest types of bridge. A perfect example being a basic log bridge – something you may see while out on a country walk.



The deck area traditionally consists of wood plank or stone slabs (often referred to as a clapper bridge). These are supported either side by two beams running between abutments/piers.



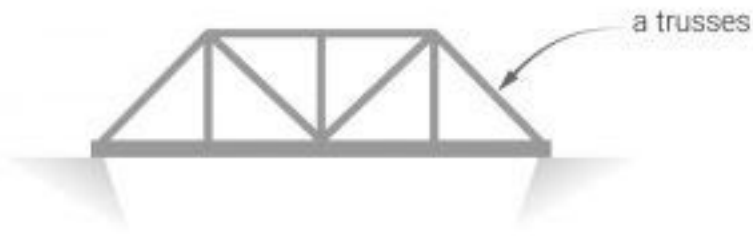
Very often you will find other beams, positioned in between the main beams, offering additional support and stability.

The area over which people or vehicles travel will be a simple decking positioned vertically across the underlying beams. This is often referred to as a “simply supported” structure. There is no transfer of stress which you see in arch structures and other types of bridges.

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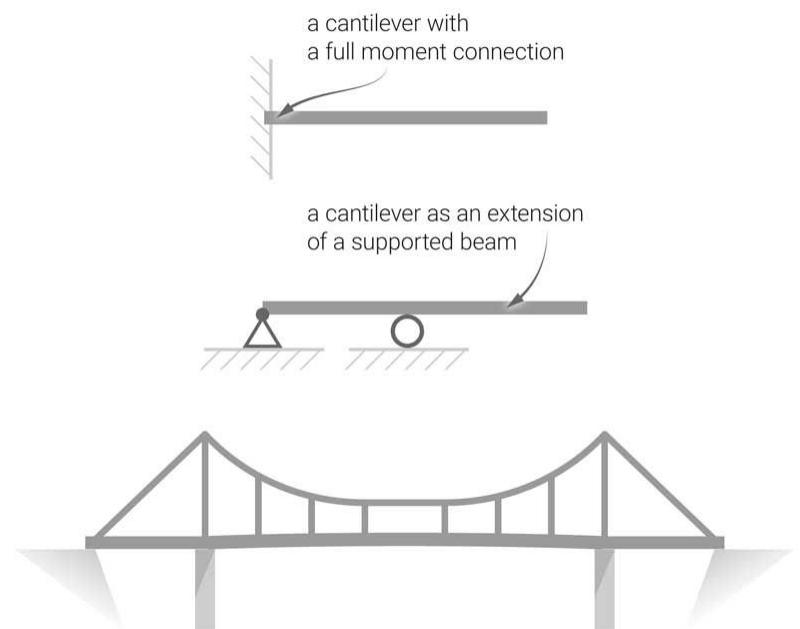
Truss bridges

The truss bridge has been around for literally centuries and is a load-bearing structure which incorporates a truss in a highly efficient yet very simple design. You will notice an array of different variations of the simple truss bridge but they all incorporate triangular sections. The role of these triangular elements is important because they effectively absorb tension and compression to create a stressed structure able to accommodate dynamic loads. This mixture of tension and compression ensures the structure of the bridge is maintained and the decking area remains uncompromised even in relatively strong winds.



Cantilever bridges

When the first cantilever bridge was designed it was seen as a major engineering breakthrough. The bridge works by using cantilevers which may be simple beams or trusses. They are made from pre-stressed concrete or structural steel when used to accommodate traffic. When you consider that the horizontal beams making up the cantilever arm are only supported from one side it does begin to sound a little dangerous. However, the two cantilever arms are connected by what is known as the “suspended span”



which is effectively a centrepiece which has no direct support underneath. The bridge load is supported through diagonal bracing with horizontal beams as opposed to typical vertical bracing. Extremely safe and very secure, the design of cantilever bridges is one which still lives on today.

Arch Bridges



Example of an Arch Bridge: Gaoliang Bridge of The Summer Palace.

There are many different types of arch bridge but they all have central elements in common. Each bridge has abutments, which are used to support the curved arch structure under the bridge. The most common type of arch bridge is a viaduct, a long bridge made up of many

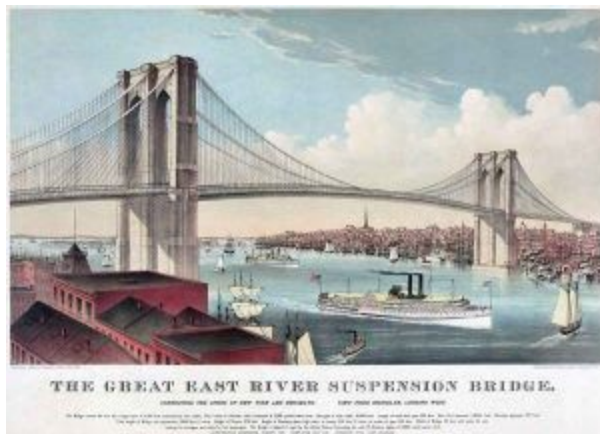
arches. The lateral pressure created by the arch span is transferred into the supporting abutments. It is therefore essential that these parts of the bridge remain solid, intact and well founded. You will see many arch bridges with decorative brickwork which is an integral part of the design. Simple yet so very effective an arch bridge can carry everything from pedestrians to heavy rail.

Suspension Bridges

The structure of a stereotypical suspension bridge looks very simple but the design is extremely effective. The deck of the suspension bridge is the load-bearing element of the structure. This is held in place by vertical suspenders which support the cables. The suspension cables extend out beyond each side of the bridge and are anchored firmly into the ground. It will depend upon the size of the bridge but a number of towers will be installed to hold up the suspension cables. Any load applied to the bridge is transformed into tension across the suspension cables which are the integral part of the structure. As there is some “give” in the suspension cables this can translate into slight, but measured, bridge movement in difficult weather conditions.



Cable-stayed bridges



Example of a Cable-stayed Bridge: Chromolithograph of the “Great East River Suspension Bridge”, (Brooklyn Bridge), by Currier and Ives, 1883.

A cable stayed bridge is dependent upon towers/pylons which are the load-bearing element of the structure. Cables are connected from the pylons to the deck below.

Either directly from the top of the tower or at different points of the column. When connected at different points of the column this creates a fan like pattern. This is the feature many people associate with cable stayed bridges. This type of structure tends to be used for distances greater than those achieved with a cantilever bridge design but less than a suspension bridge. One of the main issues with this type of bridge is that the central connection of the cables can place horizontal pressure on the deck. Therefore, the deck structure needs to be reinforced to withstand these ongoing pressures.

What is the strongest type of bridge and why?

Even though the truss bridge design has been around for literally centuries it is widely regarded as the strongest type of bridge. The design itself looks extremely simple, so what makes it the strongest type of bridge and why?

This is a load-bearing bridge which consists of an array of triangular structures. Interestingly, the triangular beam structures are pinned in place rather than rigidly connected which is important when spreading the load. The vibrations caused by traffic moving over the bridge or even weather conditions are not isolated; instead they are spread right across the bridge structure, moving between triangular sections. As the load is spread right across the bridge this also increases overall stability and reduces flexing.

What is the most expensive type of bridge to build?

If you look at the vast majority of expensive bridges you will see a pattern, they tend to be **suspension bridges**. So, the answer to the question, what is the most expensive type of bridge to build is simple, a suspension bridge!

There are a number of reasons why they tend to be so expensive. Firstly they offer the ability to span huge distances (up to 7000 feet) – a span which is out of the reach of other bridge designs. The size of the towers, materials used and the installation of what is known as a deck truss beneath the bridge deck all add to the significant costs. We have come a long way from the first suspension bridges which were apparently made of twisted grass. The cost of today's larger suspension bridges will regularly exceed \$1 billion!

Bridge Designing (Week 3)

- Students will learn how to design a bridge in an online platform used by industrial professionals. This will expand on the paper bridge built in the previous class. (**This will also build on documentation classes**)
<https://bridgedesigner.org/download/>
- **Leading Questions for this Week**
 - Leading Questions are an excellent method to prepare students for what they are about to learn.

- Students should be able to answer these questions perfectly by the end of the class.
 - **What is a bridge?**
 - **Where are bridges used?**
 - **Why are bridges used?**
 - **What types of bridges are utilized in the 21st century?**
 - **What are the pros and cons of different bridges?**
 - **How are different bridge designs similar to others?**
- **Quick One-Minute Recap of Last Class to Refresh the Students' Minds**
 - Last week, students learned about the design and documentation process through the medium of the prototype paper bridge. Students compared their bridges in order to learn from their "mishaps," and they learned how to collaborate and constructively criticize.
- **The Instructor should tell the students to download the Bridge Designing software before the class starts, as the download will take a while to finish.**
 - Screen share (on Zoom/Cisco Webex) how to open the application
 - Students will view the user interface of the application, and will learn how to use the designer.
 - Students should be active and engaged in this class discussion activity
 - Before this starts, the leading questions should be put forth.
- **The instructor should make sure EVERY student has a thorough understanding of how to use the software**
 - *If the Instructor wants to learn beforehand, this [video](#) is extremely helpful*
 - *A "GOOD" bridge is a bridge that incorporates different elements commonly utilized in bridge design, i.e. triangles, etc., and the bridge is an innovation of an idea of a "bridge." The bridge also has to be structurally sound, and be visually appealing.*

- **Assign a project for the students on Google Classroom**
 - ONE Unique Bridge
 - ONE Common Bridge
 - *Both bridges should be structurally adept, and the instructor can test this by using the simulation in the software*
 - **This assignment is due in two weeks time.**
- **After two weeks, the students should look at each others' designs, and find two pros, and two cons for their partner. (Partner up students)**
 - This activity reinforces the creative design process, collaboration, intuition, constructive criticism, and "non conventional thinking." These are widely utilized in the engineering world, and will ultimately make you a better designer.

Simple Machines

(Week 4)

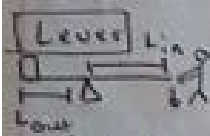
Simple Machines

$$AMA (\text{Actual Mechanical Advantage}) = \frac{F_{out}}{F_{in}} \quad \frac{\text{Force Output}}{\text{Force Input}}$$

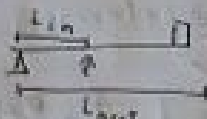
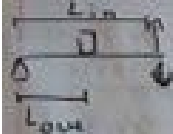
$$IMA (\text{Imaginary Mechanical Advantage}) = \frac{D_{in}}{D_{out}}$$

↳ "perfect world"

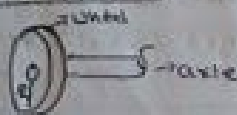
ie. no friction, unaccounted forces.



$$\frac{L_{in}}{L_{out}} = \frac{D_{in}}{D_{out}} = IMA$$



Wheel & Axle



$$IMA = \frac{2\pi R}{2\pi r} = \frac{R}{r} \rightarrow \text{If I turn the wheel}$$

$$\frac{r}{R} \rightarrow \text{If I turn the axle}$$

Pulley

IMA = # of string (not including one pulled)

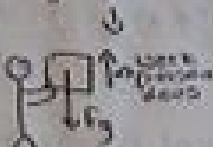


Incline Plane



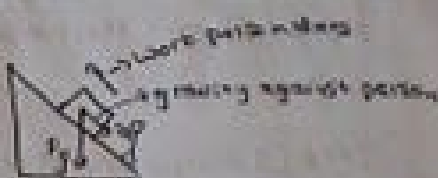
$$IMA = \frac{L}{h} = \frac{D_{in}}{D_{out}}$$

Why is it easier?

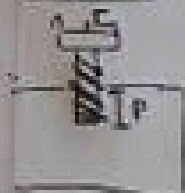


F_g (Force of gravity)

on an incline plane, less gravity resisting motion

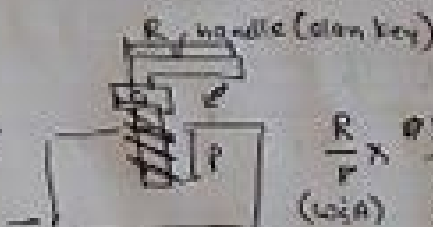


Screw



$$IMA = \frac{2\pi R}{P} = \frac{D_{in}}{D_{out}}$$

or



$$\frac{R}{r} \times \frac{2\pi r}{P} = \frac{2\pi R}{P}$$

(W/A) (Screw)

Simple Machines

1. Wheel and axle
2. screw

When two simple machines work together, multiply indiv IMA, to get total IMA

Wedge



if wedge fully in

$$IMA = \frac{\text{width of wedge}}{\text{height of wedge}} = \frac{w}{h}$$

if partially, use similar triangle
IMA, $\frac{w \text{ of small } \Delta}{h \text{ of small } \Delta}$



Mechanical Advantage: measure of the machine's tendency
towards strength or speed
→ how the system transfers energy

$MA > 1$
↳ towards strength (less force over a longer amount of time)

$MA < 1$ → towards speed (more force, over ^{but} faster, shorter time)

$MA = 1$ → transfer of energy → change of direction



$$D_{in} = D_{out} \text{ so, } MA = 1$$



→ force change direction

Gears

(Week 5)

Why are gears used?

- To transfer energy
- Change direction of motion
- Make something spin faster (RPM)
- Make something spin with more strength (torque)

Types of Gears

- **Normal Gears**



- **Bevel Gears** - used to change the plane of motion
 - (first gear spinning on the vertical plane and second gear is spinning on the horizontal plane)



- **Worm gears** - Rotational motion to linear motion



Gear Ratios

Out → output gear (the last gear in the chain or the gear that you want to move)

In → input gear (first gear or the gear that you physically move)

$$\text{GR} = \frac{\text{number of teeth of } \mathbf{output} \text{ gear}}{\text{Number of teeth of } \mathbf{input} \text{ gear}} = \frac{\text{diameter(or radius) of } \mathbf{output} \text{ gear}}{\text{diameter(or radius) of } \mathbf{input} \text{ gear}} = \frac{\mathbf{w-in}}{\mathbf{w-out}}$$

w stands for angular speed

- Can be simplified to the time the gear take to complete one rotation (360 degrees)
- Measured in degrees per second

If GR = 1 → transfers energy across distance

If GR > 1 → the output gear has more torque (strength), which means it can spin even with more resistance

If GR < 1 → the output gear spins faster than input gear, more speed but less strength, meaning it can be stopped easily

When is torque useful?

- When you want to spin a gear which is attached to something heavy, it make be slow but it will be able to lift it

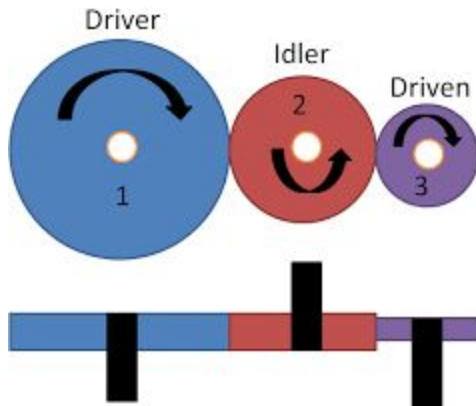
When is speed useful?

- When you want something to go faster, like wheels on a robot

When would you want GR=1?

- When you only want to transfer energy from one place to another

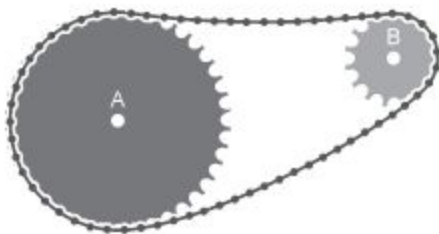
Use intermediary gears to increase the distance the rotational energy travels



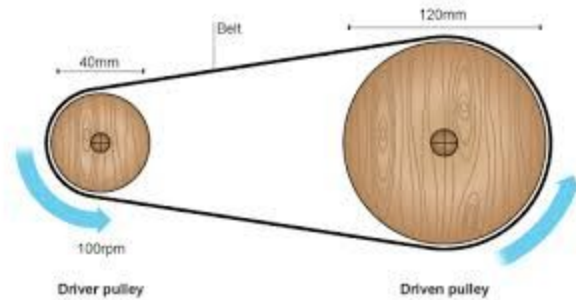
- Second gear is intermediary (or idler) because it only increases the distance and ensures that the other two gears spin in the same direction
- Notice how it is not included in Gear Ratio calculations

Special Types of Gear Systems

- **Chain and Sprocket System**



- **Belt and Pulley System**



	Pulley	Sprocket
Method of Transmitting Force	Belt	Chain
Advantages	Quiet, no lubrication needed, inexpensive	No slip, greater strength
Disadvantages	Can slip	Higher cost, needs lubrication, noisy

Examples of Gears In Real Life

- **Bicycle**

- Use higher gear for flat surface (higher gear ratio), since there is not that much resistance, less pedalling makes you travel farther
 - On slopes, you use a lower gear ratio because there is resistance to the wheels (gravity). You need more turns to travel the same distance, each turn of the wheel requires more pedaling, so it has sufficient energy to overcome gravity
-

Robot Presentation

(Week 6)

- **Before the class begins, edit the following slideshow to fit your needs and prepare your presentation about your 2019-2020 Skystone robot or other STEM achievements that your team would like to show students.**
 - Go to the following link:
<https://tinyurl.com/sksytonerobot>
 - Make a copy of the file and edit the slides to resemble your robot from the past season
 - Make sure to include CAD files of various parts of your robot since this part of robotics may intrigue other students, possibly because they have had prior experience with 3D-modeling or if they would like to try gaining a new skill
 - Include videos of your autonomous code in your slideshow so that students who are interested in code will be able to understand how code that they learn in the classes is applied in the real world as well as clubs in high school
 - Pictures will most definitely appeal to the students more than text on slides, so try to keep the text on the slides minimal and have more pictures/videos so that they can understand the different mechanisms and their functions better
- **When the class begins, go through the slideshow that was prepared and explain the various mechanisms of your previous robot and answer any questions on the way (35 minutes)**

- Ensure that the presentation you give is interactive so that students will definitely ask questions → one person from your team lecturing will end up being a boring presentation while students asking questions helps the presenters understand that the students are interested in the topic
- If the classes are being held in person after COVID-19, give the students an opportunity to drive the robot because that will make the experience much more interactive and pique their interest in robotics
- **Have one member of your team show the students the various CAD files of the robot (10 minutes)**
 - Go through the CAD files and show the students the immense detail that is put into the 3D modeling and the purpose of it **(as seen in Figure 1 below)**
 - **Ex:** 3D modeling a part or mechanism of the robot will make the building process of that mechanism easier. For instance, 3D modeling the chassis ahead of time and knowing which parts will be used to build it can not only help save money as the parts only need to be bought once but will also help save time as all team members will know how the parts fit together with an assembly file in the 3D modeling software.

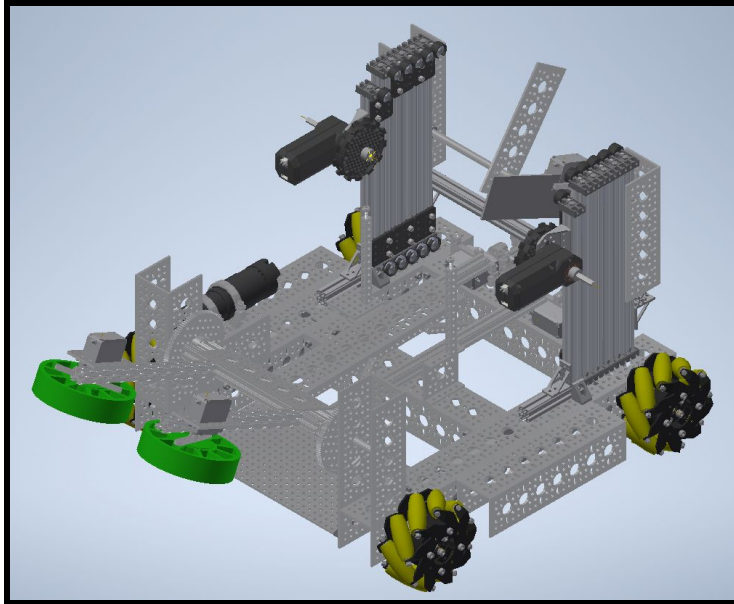


Figure 1: 5773 Robot CAD File

- **Have one member of your team 3D model any real-world item (5 minutes)**
 - The goal of this part of the curriculum is to ensure that students are interested in the next class, which will revolve around TinkerCad and the students getting a hands-on experience with 3D modeling
 - **Ex:** A traffic signal is something that can be 3D modeled in 5 minutes by an experienced individual. This is something that students see throughout their day, and seeing it 3D modeled will inspire them to do the same as they will be able to visualize something on their computer that they will see if they go outside. The color feature, which will make a visual appeal to the students, will also have a profound effect if a traffic signal is 3D modeled during the class.
 - The individual who is going to 3D model the item during the class should have prior experience with doing so that this can be accomplished in 5 minutes.

- Gauge the interest of the students in either starting an FLL or FTC team after the FTC robot presentation that they were given (5 minutes)
 - The easiest way to take care of this would be by making a simple Google Form that takes care and gets the responses of the necessary information
- The homework for this week will be to ask the students to design their own robot for the 2019-2020 Skystone Challenge
 - Make an assignment on Google Classroom that will ask students to sketch a robot that could be used to solve the problem given in the Skystone season
 - At the beginning of the next class, evaluate the different robot designs by discussing the advantages and disadvantages of each

TinkerCAD Tutorial

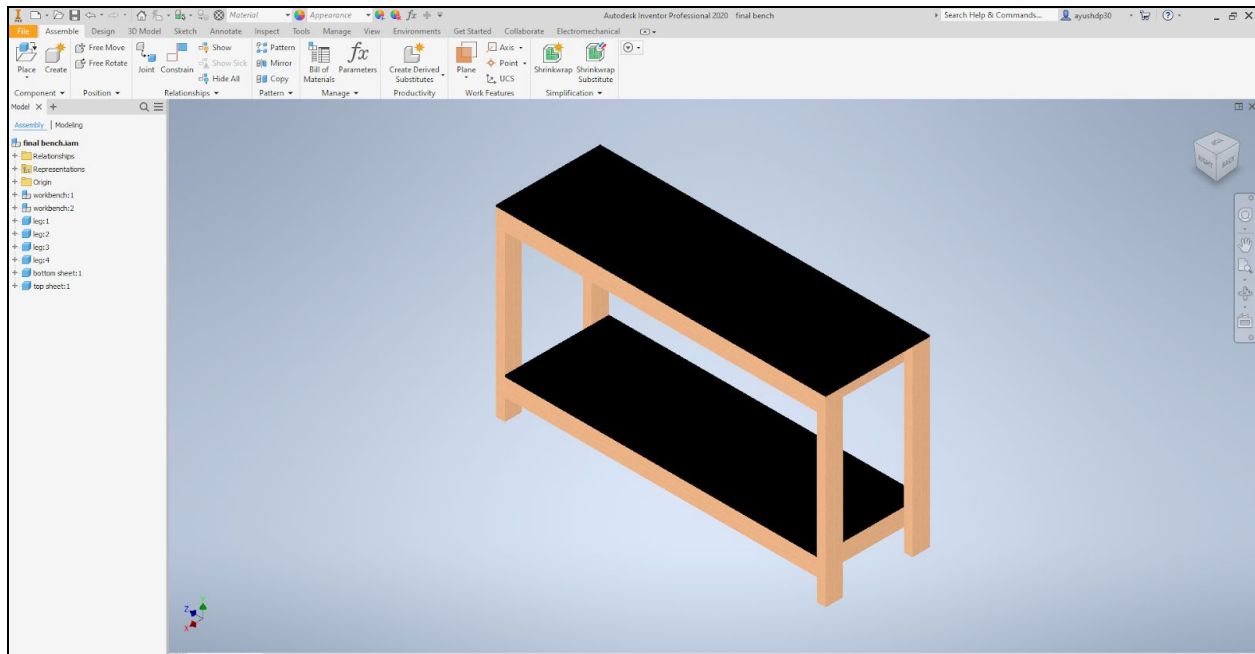
(Week 7)

- TinkerCAD Sign Up (5 minutes)
 - Go to [TinkerCAD](#) and have the students click **JOIN NOW**
 - Then tell them to **CREATE A PERSONAL ACCOUNT** and then **SIGN IN WITH GOOGLE**
 - This should redirect the students to their dashboard
- Then have the students **CREATE NEW DESIGN (5 minutes)**

This should redirect them to their workplane in which the students will be able to CAD their first project

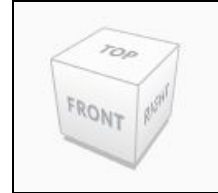
- If they are unable to get into their workplane have them refresh or sign into TinkerCAD again
- **Explain to the students the purpose of CAD (5 minutes)**
 - The purpose of CAD is to visualize a product or a part of a project to see how and if it will work with other components of the project. This will also be used in order to custom make parts using a 3D printer or a CNC machine. An example is shown in **Figure One** in which a workbench is made in a software called Inventor 2020. There are many other softwares such as **Fusion 360** and **Solidworks**.

Figure One:



- **Explain and teach the students how to navigate in TinkerCAD (5 minutes)**

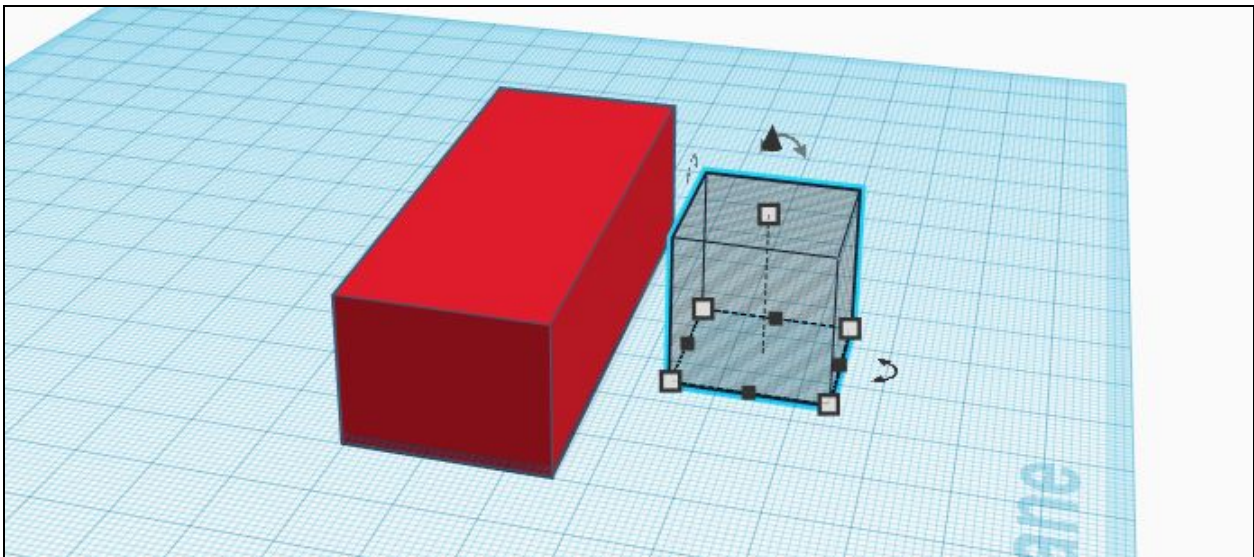
- Holding down right click allows you to pivot your screen.
- Use the cube to navigate and look at the different views of your workplane



- You can right click or go to the cube to change the views
- The house symbol below the viewcube will bring you to the home view of your workplane.
- The [] button below that fits all objects you have highlighted to your entire screen.
- The + and - symbols below that respectively allow you to zoom in and out. You can achieve the same with the scroll wheel on your mouse.
- Finally, the last button on the left will display a flat view of your workplane. Click it again to return to an Orthographic view.

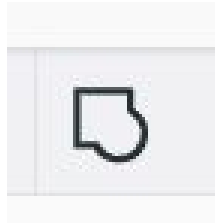
- Explain to the students how to add and change the variety of shapes present on the right of their screen. Have them do it along with you so that they understand the concepts and know how to do them independently (15 minutes)
 - Click on the shape and then drag it to the workplane and left click to place it
 - The size can be changed by clicking on the shape and dragging the smaller boxes on the shape out in the wanted direction
 - The exact dimensions can be changed by going to the box with the dimension and editing it to the wanted length
 - **To cut** a given shape take the shape that you want to cut and place it on the workplane. Next take another shape that you want to cut with and place it so that it touches the first shape in the way you want it to. Then take the shape you want to cut with and click the option that says Hole. Example in figure 2

■ **Figure 2**



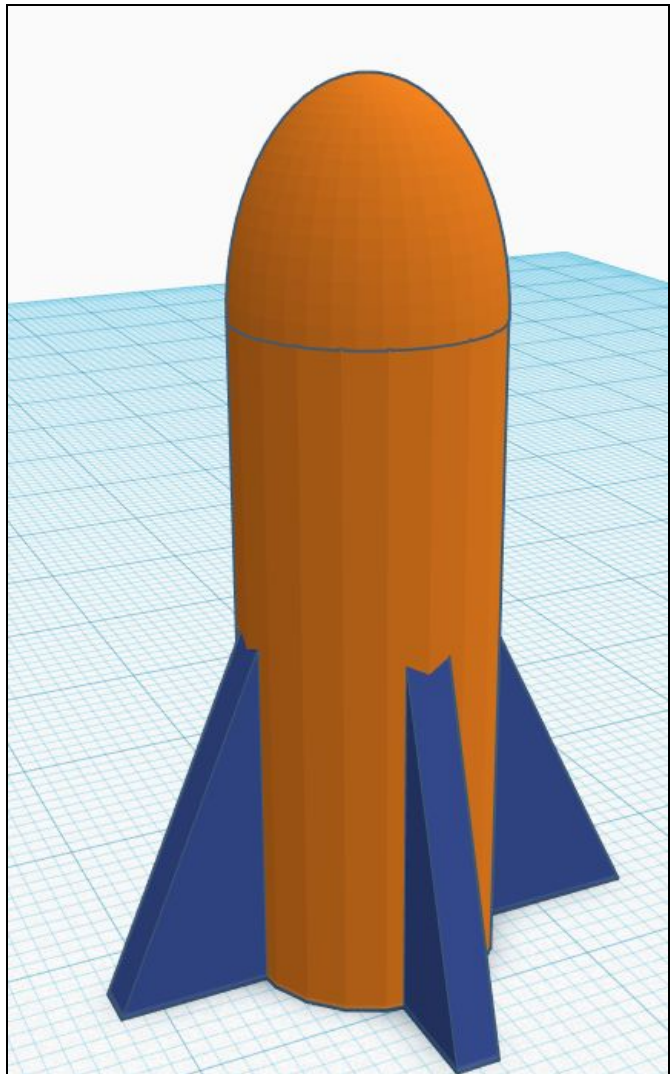
- Then left click and select both the shapes that are incorporated in your cut and then click the button as shown in figure 3

■ **Figure 3**



- **Explain to students their homework assignment (5 minutes)**
 - Assignment is to build a rocket with at least three different shapes.
 - Turn it into **Google Classroom**
 - Example shown in **Figure 1:**
 - Students also have the option to create and submit any other TinkerCAD object they make.
- Have the students start their projects during class so that they can ask questions and clarify before they are due next week.

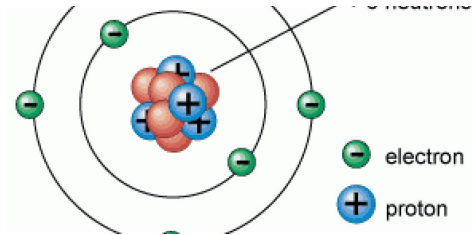
(5 minutes)



Electricity

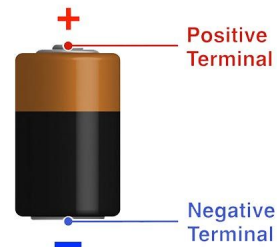
What is a battery?

In an atom, there are positive and negative charges.



The **protons** at the center of the atom (nucleus) have a positive charge.

The **electrons** which orbit the nucleus have a negative charge.



Similarly, in a battery, there are positive and negative charges.

The charges want to come together but chemical energy in the battery separates them.

Voltage

“How much” do the charges want to come together - with how much “pressure” - how hard the electricity flows

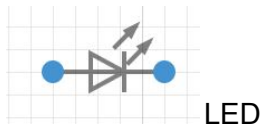
Current

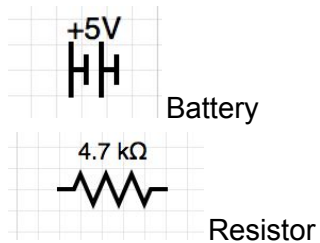
How fast the electricity flows

Resistance

How much the electricity is blocked or dissipated

Circuit Diagrams



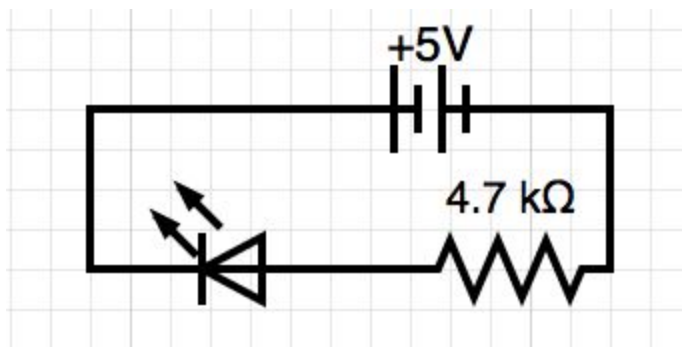


Battery

Resistor

***NOTE:** all components have resistance, like the battery, resistors, LED, and even the wire. But to make it simple, we will only work with the resistance in resistors and LEDs.

****NOTE:** resistance means that energy is lost, resistor dissipate energy through heat, LED loses energy through light



Basic Circuit

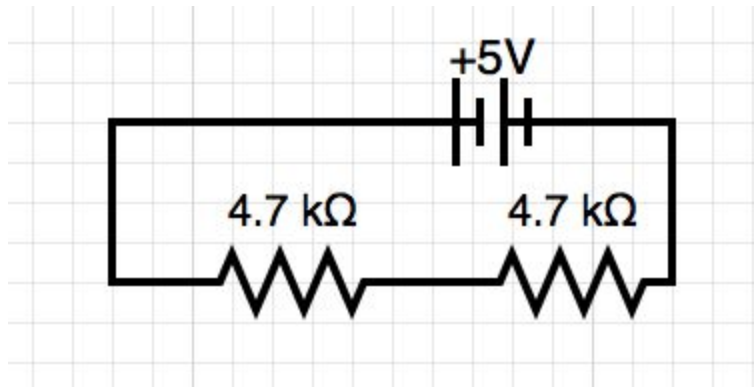
Math

$V = IR$ $V = \text{Voltage}(V)$ $I = \text{Current}(A \rightarrow \text{Amperes})$ $R = \text{Resistance}(\Omega \rightarrow \text{Ohms})$

If a batter has 5V and circuit has a resistance of 2Ω , what is the current?

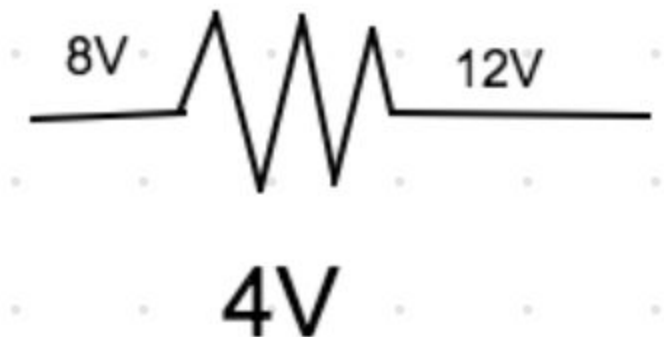
$$V=IR \quad 5V = I * 2\Omega \quad I = 2.5A$$

Series Circuit



Resistors are in series

- When electricity travels across a resistor, the voltage drops
- Since some of the energy is dissipated, the force with which electricity moves is lower



Voltage of the resistor is 4V. The difference in voltage at the start and the end is 4V.

When electricity reaches the battery again, it should have lost all of its energy, going to 0V. The energy in the battery gives the electricity back 12V, and the cycle starts again.

Math (Only for Series)

$$V_T = V_1 + V_2 + V_3 + \dots$$

Add up voltage of resistors to get the total voltage of the circuit (battery voltage)

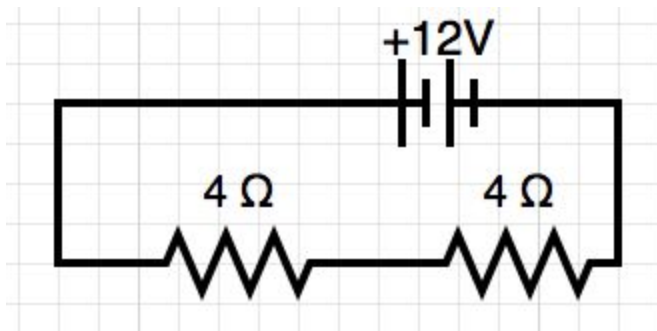
$$R_T = R_1 + R_2 + R_3 + \dots$$

Add up resistance of each resistor to get total resistance

$$I_T = I_1 = I_2 = I_3 = \dots$$

Current stays the same at each resistor, and same in the circuit overall

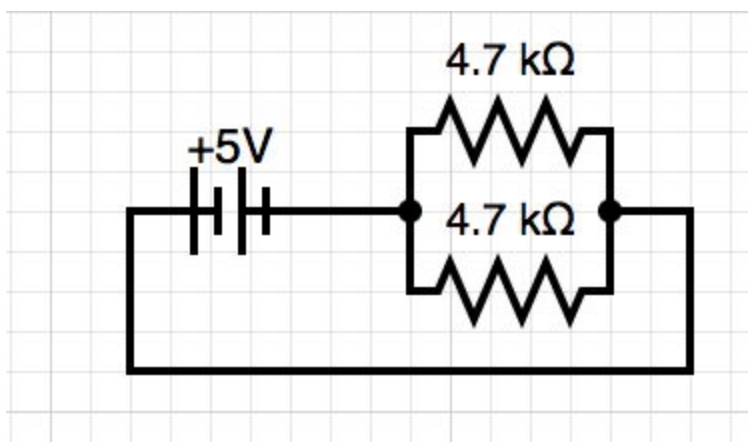
What is the current of the circuit?



$$\begin{aligned} V_T &= R_T \cdot I_T \\ 12V &= R \cdot I \quad 12/R = I \\ R_T &= R_1 + R_2 = 2\Omega + 4\Omega = 6\Omega = R \\ 12V/6\Omega &= 2A = I \end{aligned}$$

$$I = 2A$$

Parallel Circuit



Resistors are in parallel

Math (Only for Parallel)

$$V_T = V_1 = V_2 = V_3 = \dots$$

Voltage is the same through both parallel resistors

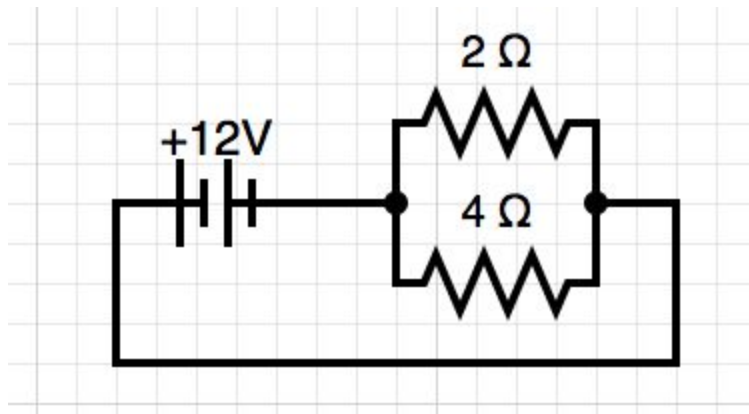
$$I_T = I_1 + I_2 + I_3 + \dots$$

Add up currents of parallel resistors to get total current

$$1/R_T = 1/R_1 + 1/R_2 + 1/R_3 + \dots$$

Use this equation to find total resistance

Find total current



$$V_T = R_T * I_T$$

$$V_T/R_T = I_T$$

$$R_T = 1 / (1/R_1 + 1/R_2) = 1 / (1/2 + 1/4) = 1 / (3/4) = 4/3 \Omega$$

$$12V / (4/3 \Omega) = 9A$$

$$I_T = 9A$$

Combination Circuit

