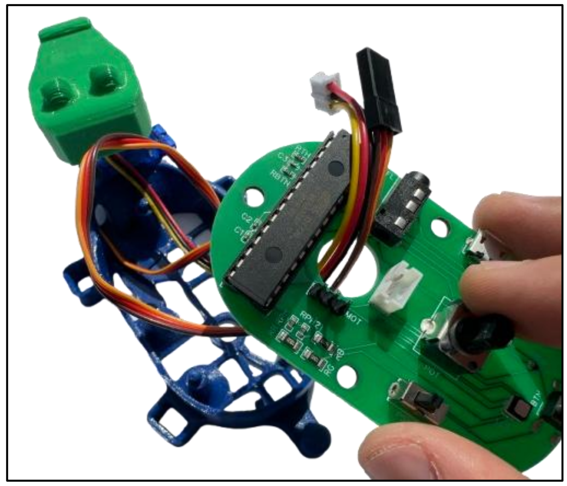
Welcome to the Introduction to Engineering Interactive Lab Kit!



This kit contains 12 hands-on activities, each representing a different branch of engineering. Engineers work together to solve complex problems, and through these activities, you'll get a taste of how that happens.

Now, imagine you're exploring the Florida Everglades, a vast and wild ecosystem home to countless alligators. With an estimated 1.3 million alligators across the state, you'd think spotting one would be easy. But they often stay hidden beneath the water's surface or deep in the marsh. How would you go about studying them?

This is where engineering comes in. Suppose we wanted to build an observation platform to safely study alligators in their natural habitat. An Environmental Engineer would ensure the structure doesn't harm the ecosystem, while a Civil Engineer would design the platform itself. A Mechanical Engineer could help with moving parts, and an Industrial Engineer would plan the assembly process. To make sure the materials hold up against water and weather, we'd need Chemical and Materials Engineers. If we wanted to attract alligators for observation, Electrical and Computer Engineers could design special lighting, and a Computer Science Engineer could program automated tracking systems. Biomedical and Biological Engineers would check that our methods are safe for both humans and wildlife. And if there happened to be any unexpected radiation in the area, a Nuclear Engineer would definitely want to investigate!

Engineers solve problems just like this by working across disciplines. This kit will introduce you to different fields of engineering and the creative problem-solving behind them. Let's get started!

BTBE Introduction to Engineering Interactive Lab Kit Parts List

---

Bag 1

Screw Clip - Top

Screw Clip - Bottom

Screw Clip - Nut

Vial + Sediment

Bag 2

Screwdriver

#4-40 Screws

Bag 3

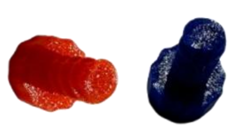
Micro USB Cable

Stereo Cable

Bag 4

RGB Lamp

Lamp Screws



Lamp Stand

Bag 5

Alligator Base

Alligator Body

Alligator Core

Alligator Feet

Bag 6

Alligator Head

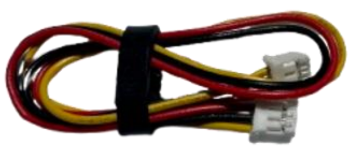
Servo Mount

Head Spacer

Head Circuit Board

Photoresistor

Head Cable



Servo Arm/Screws

Servo Motor

Bag 7

Salt Packets

Alligator Tails #1 & #2

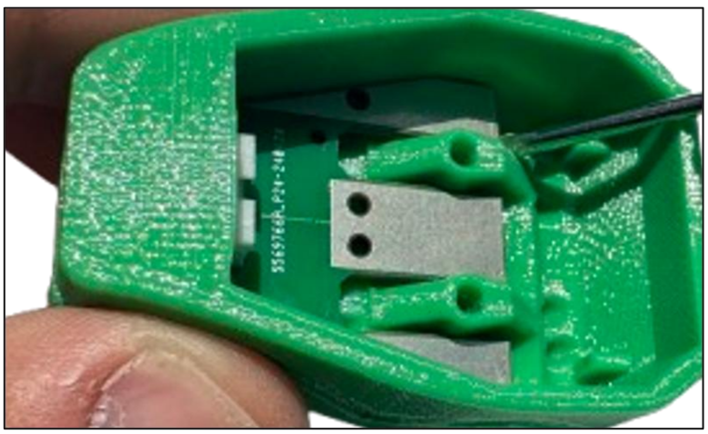
Binary Bits

Dialysis Tubing

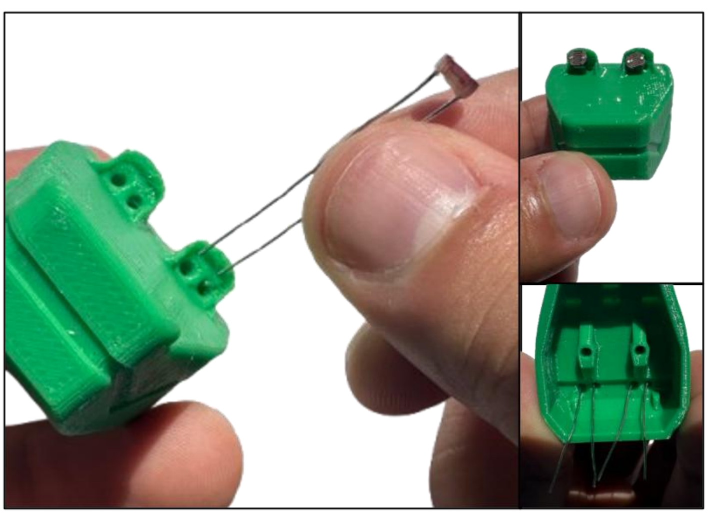
BTBE Introduction to Engineering Interactive Lab Kit
First-Use Assembly Guide

Step 1: Tear open seal at the notch and remove included bags.

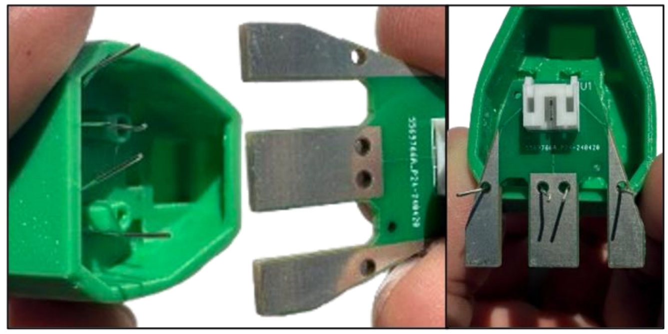
Step 2: Remove the Head Circuit Board from the Alligator Head. (may be useful to use the Screwdriver to pry underneath)



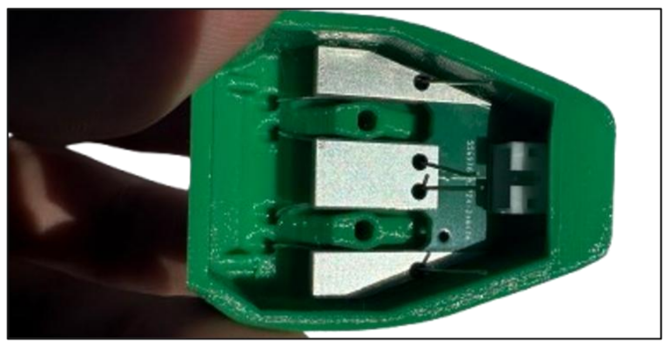
Step 3: Align each Photoresistor with Alligator Head eye sockets and push until flush.



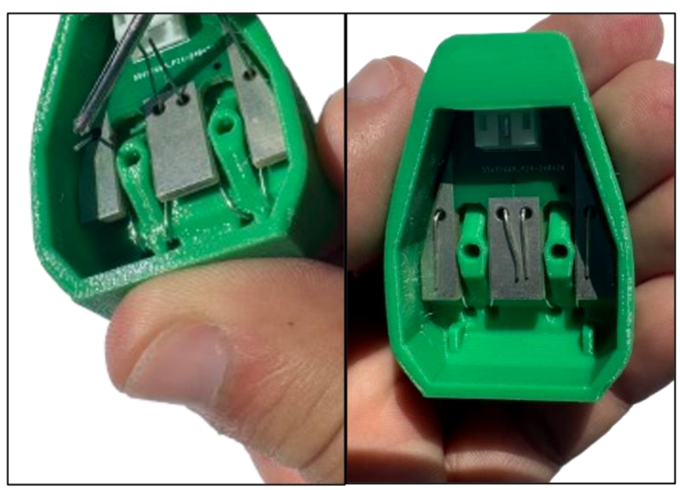
Step 4: Align the Photoresistor wires with holes in the Head Circuit Board and feed through.



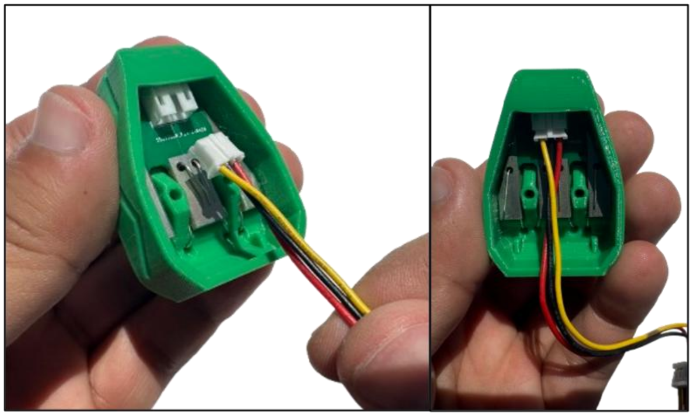
Step 5: Push the Head Circuit Board into the Alligator Head as far forward as it will go.



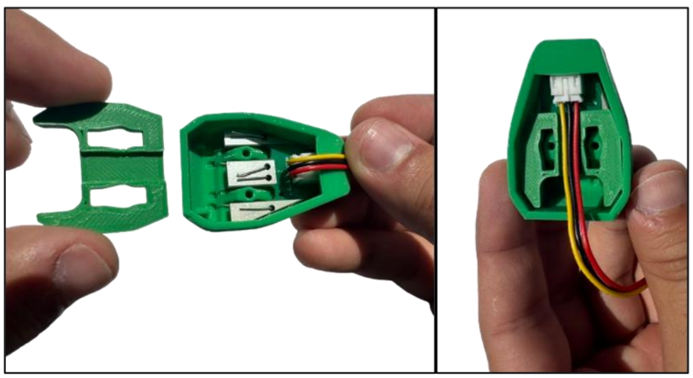
Step 6: Fold the Photoresistor wires down onto the silver pads. (may be helpful to use the Screwdriver)



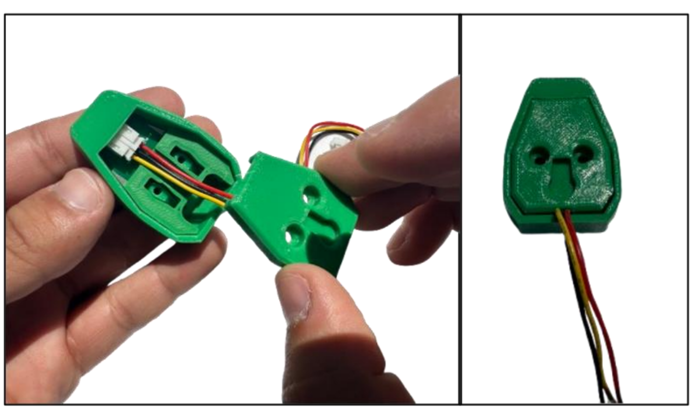
Step 7: Plug in the Head Cable into its port on the Head Circuit Board. (align the notch and push until flush or click)



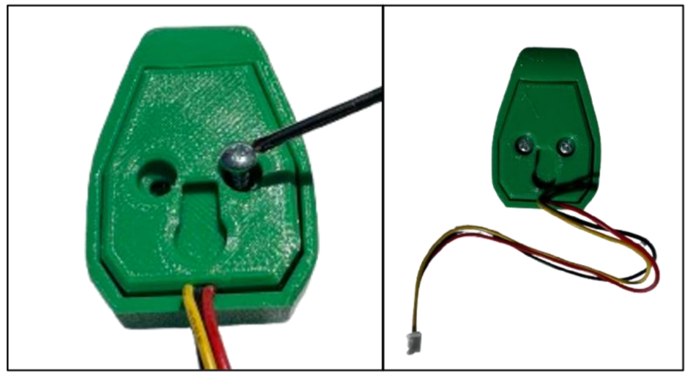
Step 8: Insert the Head Spacer underneath the Head Cable but above the Photoresistor wires.



Step 9: Align and insert the Servo Mount into its position in the Alligator Head. (align Head Cable wires with the small opening at the bottom of the Servo Mount)



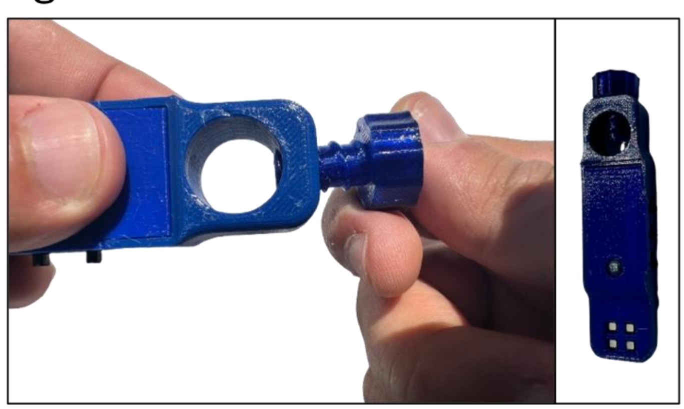
Step 10: Insert two #4-40 Screws into the holes in the Servo Mount and carefully fasten using the Screwdriver until flush.



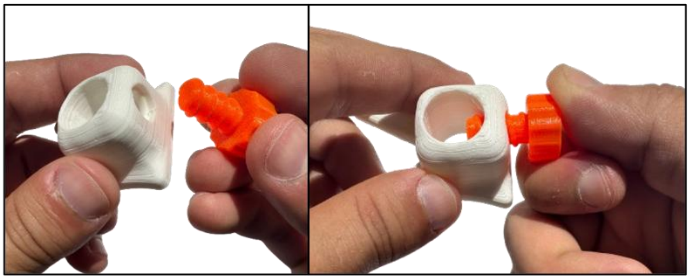
Alligator Head Assembly Complete!

Step 11: Insert a #4-40 Screw into the holes in the RGB Lamp and carefully fasten using the Screwdriver until flush.

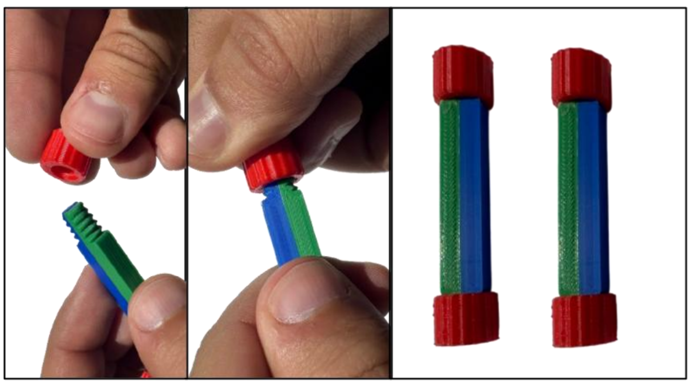
Step 12: Insert a Lamp Screw into the end of the RGB Lamp and twist clockwise by hand to tighten.



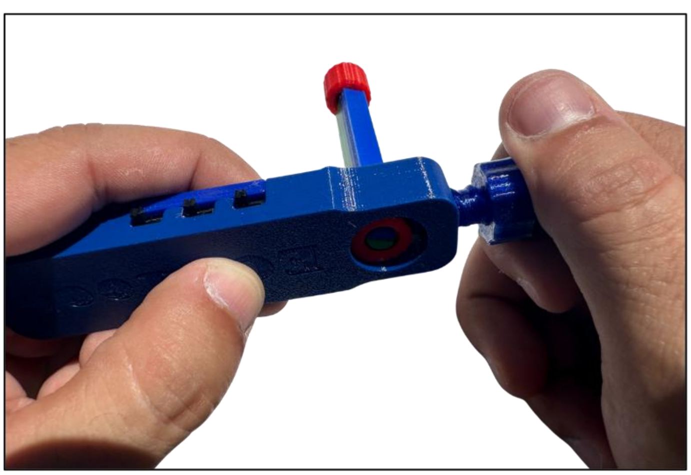
Step 13: Insert a Lamp Screw into the end of the Lamp Stand and twist clockwise by hand to tighten.



Step 14: Press together a Screw Clip – Top & Bottom and fasten with a Screw Clip – Nut. Repeat to assemble 2 total Screw Clips.



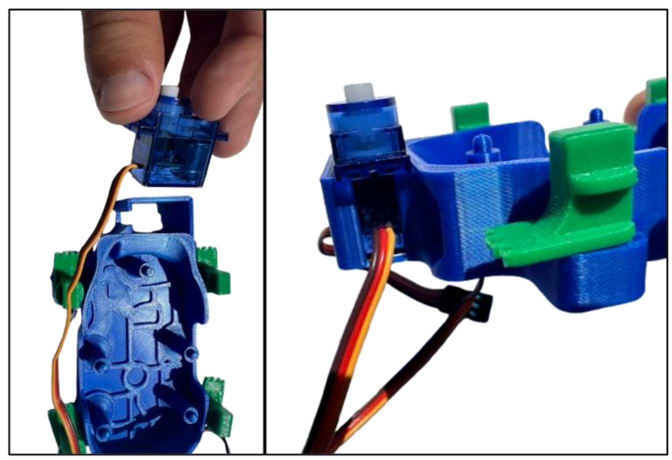
Step 15: Partially loosen the Lamp Screw from the RGB Lamp to insert a Screw Clip into the hole in the direction shown. Tighten into place.



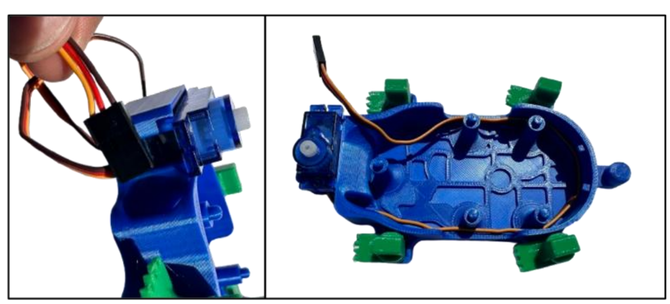
Step 16: Partially loosen the Lamp Screw from the Lamp Stand and insert the other end of the Screw Clip in the RGB Lamp as shown. Tighten into place. Ensure the assembly can stand on its own.

RGB Lamp Assembly Complete!

Step 17: Align and insert the Servo Motor with the slot in the front of the Alligator Base.

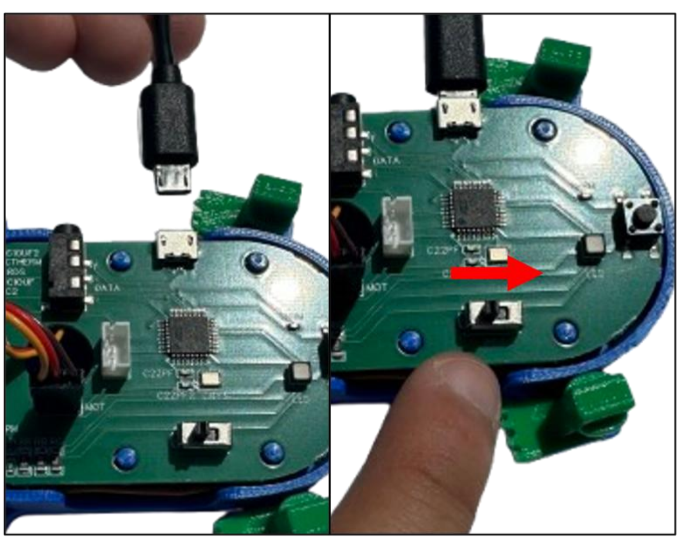


Step 18: Feed the Servo Motor wire through the hole in the front of the Alligator Base as shown.



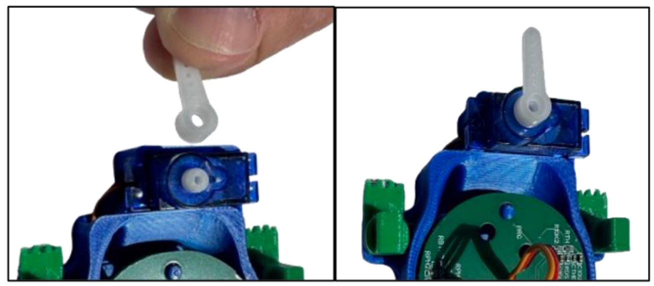
Step 19: Feed the Servo Motor wire through the largest hole underneath the Alligator Core. Align the Alligator Core with the mounting pins in the Alligator Base. Plug-in the Servo Motor cable into the 3 tallest upright pins in the orientation shown. (Orange nearest the Servo Motor)

Step 20: Plug the Micro USB Cable into its port on the Alligator Core. Move the switch to the right to turn on the kit (necessary for Servo Motor calibration). The LED on the Alligator Core should flash white 3 times and begin pulsing.

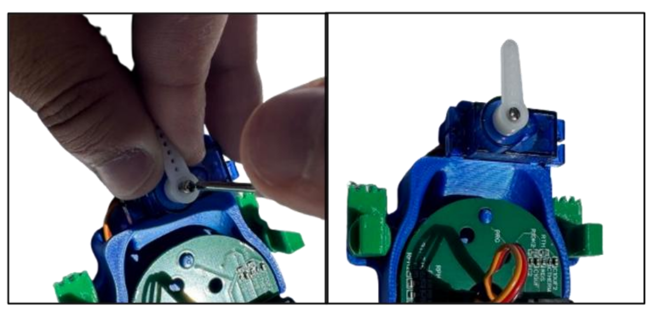


Step 21: Remove the smallest screw and the pictured Servo Arm from the Servo Screws bag.

Step 22: Align the Servo Arm with the Servo Motor pointed away from the Alligator Core and push until secure.



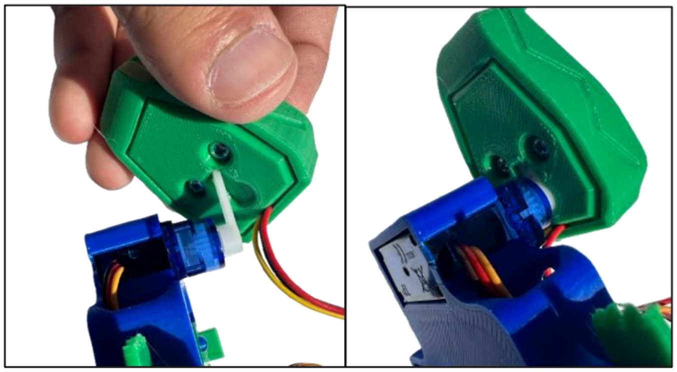
Step 23: Insert the smallest screw from the Servo Screws bag into the largest hole in the Servo Arm. Hold the Servo Arm steady and carefully screw it in with the Screwdriver until flush.



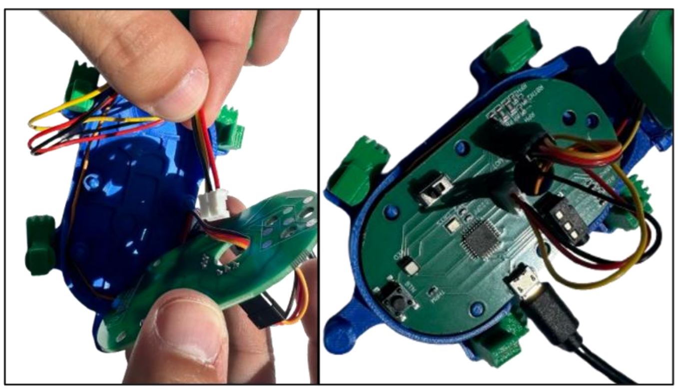
(After this point you may turn off the Alligator Core for the remainder of the assembly if the pulsing green light is distracting or unpleasant)

Servo Motor Calibration and Installation Complete!

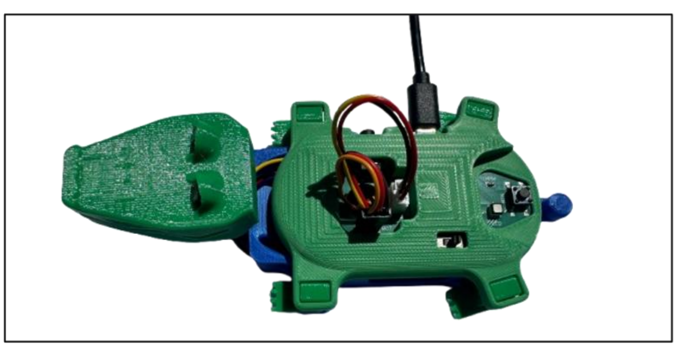
Step 24: Align the Servo Arm with the underside of the Alligator Head assembly. Insert and push until flush.



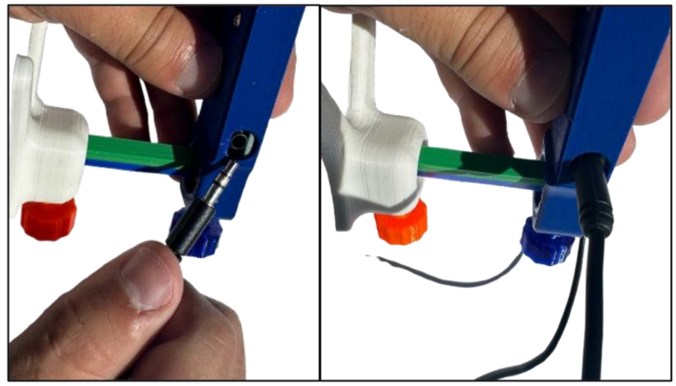
Step 25: Temporarily lift the Alligator Core and feed the Head Cable through the largest hole from the bottom. Plug into its respective port (align the notch and push until flush) on the Alligator Core.



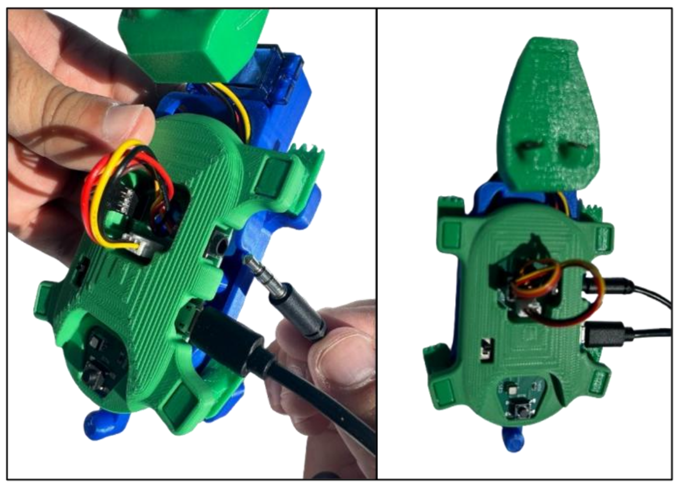
Step 26: Align the Alligator Body with the Alligator Feet and push until Flush.



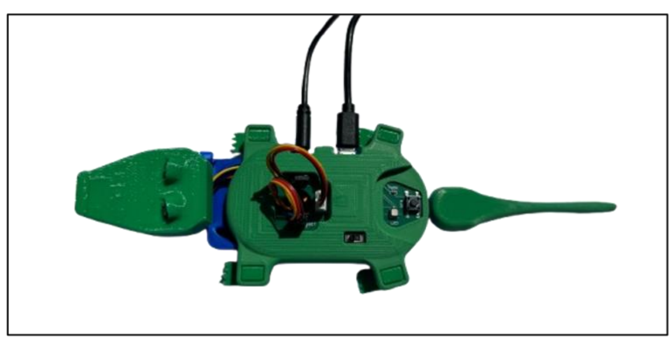
Step 27: Align one end of the Stereo Cable with the port on the RGB Lamp. Insert and push until flush.



Step 28: Align the other end of the Stereo Cable with the port on the Alligator Core. Insert and push until flush.



Step 29: Place either Gator Tail #1 or #2 on the swivel point at the back end of the Alligator Base.



Full Assembly Complete!

For disassembly and reassembly (Lab 1), please do not remove/reinstall any of the metal screws from the Alligator Head, Servo Motor, or RGB Lamp.

(skip first-use assembly steps 1-14 & 21-23)

Lab 1 – Assembly Efficiency (Industrial Engineering)

Background:

Now that you've fully assembled your kit using the instructions in the prelab, it's time to do what any good engineer would—take it apart and build it again! But this time, we're focusing on something different: efficiency.

Think about it—after assembling it once, how much faster do you think you can do it the second time? More importantly, what factors could speed up or slow down your reassembly process? Could the way your materials are arranged affect your time? Are there steps in the assembly guide that feel inefficient?

This leads us to an important concept in Industrial Engineering: workspace efficiency.

At an extreme level, imagine scattering your kit's parts across the room before reassembling—obviously, that would slow you down drastically. But even when all the parts are right in front of you, small adjustments in how they're placed can make a big difference. Grouping related parts together or orienting them in the correct direction before starting might shave seconds off your assembly time.

While this might seem trivial, small inefficiencies can add up on a large scale. In a real-world factory setting, thousands of products are assembled every day. Industrial Engineers identify and eliminate these hidden inefficiencies, saving companies valuable time and resources.

In this lab, you'll explore how workspace setup impacts assembly efficiency—just like an Industrial Engineer optimizing a real production line.

Procedure:

1.) Completely disassemble your lab kit.
2.) Place the pieces barely within arm's reach and turn all the pieces upside down.
3.) Start a stopwatch and assemble your kit according to the assembly guide. Record this time as "Scattered Layout Time"
4.) Repeat this process, but instead of initially scattering the pieces, try placing them in front of you however you choose. Record this time as "Optimized Layout Time"

Journal:

Table 1: Assembly Times of Various Part Configurations

Scattered Layout Times (Seconds)	Optimized Layout Times (Seconds)

Discussion Questions:

A.) How can small efficiency improvements in assembly processes scale up to create major time and cost savings?

B.) What other factors, beyond part placement, could impact assembly speed and efficiency?

C.) Where else in everyday life do you see opportunities for process optimization and waste reduction?

Lab 2 – Cold-Blooded (Biological Engineering)

Background:

We often hear that reptiles are "cold-blooded" while mammals are "warm-blooded"—but what does that actually mean? From a biological standpoint, cold-blooded animals (ectotherms) don't regulate their internal body temperature the way mammals do. For example, no matter where you are, a healthy human will have a body temperature close to 98.6°F. But an alligator's body temperature constantly changes, rising when it basks in the sun and dropping when it cools off in water.

Temperature doesn't just affect body heat—it also directly influences an alligator's heart rate. In warm environments, an alligator's heart beats faster, while in cold conditions, it slows down. These temperature-dependent biological changes make alligators a fascinating subject for biological engineers, who study how living organisms interact with their environments and how we can apply biological principles to engineering solutions.

Alligators are also incredibly resilient to environmental hazards, including pollution and radiation exposure. In fact, they have been used as biomarkers—biological indicators of environmental health—in areas exposed to nuclear waste. By studying the impact of extreme conditions on alligator biology, biological engineers help design safer environmental monitoring systems and develop solutions for hazardous waste management.

In this lab, you'll explore how environmental conditions impact an alligator's internal processes, just like biological engineers studying real-world ecosystems and the effects of pollutants on wildlife.

Procedure:

1.) Turn ON the Power Switch on the Gator Core by moving it to the right. The LED on the Gator Core should flash white 3 times, followed by a pulsing green light to indicate the alligator's heart rate.
2.) Begin either a stopwatch or set a timer for 60 seconds. Count how many pulses occur in 60 seconds. Document this value as "No Light".
3.) On the RGB Lamp, toggle the leftmost switch, exposing the alligator to a warm red light. Repeat step 2, and document this value as "Warm (Red) Light" and then turn off the red light.

4.) On the RGB Lamp, toggle the middle switch, exposing the alligator to a cold blue light. Repeat step 2, and document this value as “Cold (Blue) Light” and then turn off the blue light.
5.) On the RGB Lamp, toggle the rightmost switch, exposing the alligator to a toxic green light. Repeat step 2, and document this value as “Toxic (Green) Light” and then turn off the green light.

Journal:

Table 2: Gator Heart Rate Pulses in Response to External Light Conditions

No Light	Heated (Red) Light	Cold (Blue) Light	Toxic (Green) Light

Discussion Questions:

A.) How does temperature regulation in reptiles compare to how humans regulate their body temperature?

B.) How could understanding an alligator’s response to its environment inspire new technologies?

C.) What challenges might biological engineers face when using animals as environmental biomarkers?

Lab 3 – Biometric Observation (Biomedical Engineering)

Background:

Previously, you explored how external light-based temperature changes affect an alligator's heart rate. Now, let's look at another way temperature influences biological processes—direct contact heat transfer.

The THRM Temperature Sensor on the right end of the Gator Core detects changes in temperature when touched. In this lab, you'll observe how direct physical contact affects the alligator's heart rate—and compare it to changes in your own heart rate.

This ties into an important area of Biomedical Engineering: integrating the human body with technology. Biomedical engineers design medical devices like prosthetics, pacemakers, and wearable health monitors that interact with biological systems to improve health and patient outcomes.

In this activity you will be measuring your pulse—a simple but essential skill that could one day help you recognize early signs of medical conditions. Understanding how temperature affects heart rate in different organisms gives insight into how biomedical engineers develop life-saving technologies like thermal imaging devices, biofeedback monitors, and smart prosthetics.

Procedure:

1.) Turn ON the Power Switch on the Gator Core by moving it to the right. The LED on the Gator Core should flash white 3 times, followed by a pulsing green light to indicate the alligator's heart rate. (If already on from the previous activity, then no action necessary)
2.) Relax for 5 minutes to reach a resting heart rate.
3.) Place your right index finger on the small black component labeled "THRM" near the right end of the Gator Core. Wait 30 seconds for the pulsing LED to stabilize. (The pulsing LED should change color to cyan)
4.) Begin either a stopwatch or set a timer for 60 seconds. Count how many pulses occur in 60 seconds. Document this value as "Pre-Activity Gator Heartrate (BPM)"
5.) Wait at least 1 minute for the THRM sensor to return to ambient temperature. (This should cause the pulsing light to turn back from cyan to green, however if it does not after 1 minute, it is still okay to continue)

6.) Begin either a stopwatch or set a timer for 60 seconds. Feeling for your pulse on either your wrist or neck, track your own heart rate by counting the number of pulses occur in 60 seconds. Document this value as "Pre-Activity User Heart Rate (BPM)"
7.) Safely perform a short 30 second physical activity of choice. Jumping jacks, push-ups, or sit-ups are recommended for this activity.
8.) Repeat steps 3-5 to observe a new alligator heart rate. Document this value as "Post-Activity Gator Heartrate (BPM)"
9.) Repeat steps 5-7 to observe a new user heart rate. Document this value as "Post-Activity User Heart Rate (BPM)"

Journal:

Table 3: Gator Heart Rate in Response to Human Contact After Activity

Pre-Activity Gator Heartrate (BPM)	**Post-Activity Gator Heartrate (BPM)**

Table 4: User-Measured Heart Rate in Response to Activity

Pre-Activity User Heart Rate (BPM)	**Post-Activity User Heart Rate (BPM)**

Discussion Questions:

A.) How does the ability to monitor and control heart rate apply to modern medical technology?

B.) What are some ways biomedical engineers may use temperature sensors in healthcare equipment?

C.) How could wearable devices evolve to better integrate with the human body in the future?

Lab 4 – Discovering Density (Chemical Engineering)

Background:

Have you ever noticed that objects float more easily in saltwater than in freshwater? In extreme cases, like the Dead Sea, the water is so salty that people can float effortlessly. This happens because salt increases the density of water, creating a stronger upward buoyant force that can counteract gravity.

While chemistry focuses on understanding the intrinsic properties of fluids and solutions, Chemical Engineers take this knowledge and apply it to real-world challenges. From designing industrial separation processes to developing new materials and chemical solutions, their work revolves around manipulating properties like density, viscosity, and solubility to achieve specific goals.

In this lab, you'll explore how chemical engineering principles can be used to precisely control the density of a liquid to make an object float. Your kit includes a Plastic Vial with a PLA Sediment that has a carefully calibrated density of 1.17 g/cm^3, meaning it will sink in tap water. By adding just the right amount of salt, you'll adjust the density of the surrounding water, allowing the sediment to float.

Using a known water volume of 4mL, a tap water density of 1.00 g/cm^3, and a salt density of 2.16 g/cm^3, how much salt will you need to add to make the PLA Sediment float? Let's find out!

Procedure:

1.) Fill the Plastic Vial with 4mL of water. (Up to the fill line)
2.) Place the PLA Sediment into the 4mL of water in the Plastic Vial and observe the result.
3.) Calculate the mass of salt required (in grams) to increase the density of 4mL of water such that it can cause PLA to float. Document this value as "Salt Mass Required (g)". Be careful with your units!
4.) Each included packet of salt is roughly 0.5g of salt. Open a number of these packets such that the total salt is nearly equivalent to the required salt based on your calculation.
5.) Add this amount of salt to the 4mL of water in the Plastic Vial containing the PLA Sediment. Put on the cap, shake well, and observe the result.

Journal:

Table 5: Salt Calculation Table

Salt Density (D_s)	PLA Density (D_p)	Water Volume (V_w)	Water Mass (M_w)	Equation	Salt Mass Required (M_s)
$\mathbf{2.16}$ (g/mL)	$\mathbf{1.17}$ (g/mL)	$\mathbf{4.00}$ (mL)	**4.00** (g)	$M_s > \frac{(D_p * V_w) - M_w}{1 - \frac{D_p}{D_s}}$	

Discussion Questions:

A.) How could controlling a solution density be useful in an environmental or industrial process?

B.) What are some real-world applications where chemical engineers may manipulate fluid density to achieve an outcome?

C.) What are other material properties (besides density) that could be engineered to achieve specific goals?

Lab 5 – Osmotic Pressure (Environmental Engineering)

Background:

In the previous lab, we took perfectly drinkable tap water and made it undrinkable by adding salt. But can we reverse the process and extract the salt to recover fresh water?

The answer: Yes in theory, but no in practice—at least not easily. Unlike large contaminants that can be filtered out, dissolved salt particles are nearly the same size as water molecules, making traditional filtration ineffective. While boiling the water and re-condensing it would work, the process is energy-intensive and economically unfeasible on a large scale. If there were an easy way, the world wouldn't face freshwater shortages.

So instead of trying to remove salt, can we put saltwater to use in a different way? The answer lies in a fascinating natural phenomenon: Osmotic Pressure.

When saltwater and freshwater are separated by a semi-permeable membrane, the system naturally seeks equilibrium—freshwater moves across the membrane to dilute the saltwater. If we trap the saltwater in a fixed-volume container, the incoming freshwater creates pressure, which can be converted into useful energy. This concept is scalable—some power plants use osmotic pressure to generate electricity!

In this lab, you'll explore how osmotic pressure works by using the saltwater you created in Lab 2 Part A along with Dialysis Tubing included in your kit. Through this experiment, you'll see firsthand how environmental engineers study and harness natural processes to develop sustainable energy solutions.

Procedure:

1.) Remove the Dialysis Tubing from its packaging. (While dry, it looks flat)
2.) Run under a consistent, low-pressure stream of water. Gently work the tube under the stream of water until it opens.
3.) Remove the nut from the end of one of the two included Screw Clips. Place the end of the Dialysis tubing into the open section of the Screw Clip, and then reattach the nut, locking the clip in place.
4.) Holding open the tube, add a saltwater solution into the tube.
5.) Attach the second included Screw Clip to the remaining free end of the Dialysis Tube, locking the salt water inside.

6.) Submerge into a cup of fresh/tap water and let sit undisturbed for 45 minutes.
7.) After 45 minutes, remove the Dialysis Tubing and document any observed changes.

Journal:

Table 6: Dialysis Tubing Observational Documentation

Dialysis Tubing Observed Changes

Discussion Questions:

A.) If you were determined to turn the saltwater solution back into salt and freshwater, what could be some things to try?

B.) Where else in nature do we see water moving across barriers as it does in this experiment?

C.) How else might environmental engineers use natural processes to generate useful energy?

Lab 6 – Tail Testing (Materials Engineering)

Background:

So far, we've explored the intrinsic properties of liquids, but now, let's shift our focus to the properties of solid materials—specifically, how they're affected by heat.

Inside your kit, you'll find two 3D-printed alligator tails, labeled "1" and "2" on the bottom. At first glance, they look identical, but there's a key difference: they're made from two different types of plastic. The question is—which is which, and how can we tell them apart?

One of these tails is printed from Polylactic Acid (PLA), a biodegradable plastic derived from corn. PLA is known for being rigid, inexpensive, and easy to print with, but it also has a relatively low melting point. The other tail is made from Polyethylene Terephthalate Glycol (PET-G), a plastic that is more durable, slightly more heat-resistant, and fully recyclable.

Since these materials look nearly identical, we need to test their thermal properties to tell them apart. One key difference is their glass transition temperature, the point at which a solid material softens and becomes flexible. Despite the name, this doesn't mean the plastic turns into glass—it simply loses its rigidity under heat. PLA transitions at about 60°C, while PET-G requires closer to 85°C before it starts to soften.

In this lab, you'll use heated water to test these two materials and observe how each respond to temperature. If one tail deforms while the other stays rigid, you'll know exactly which is which! Materials engineers use similar testing methods to develop materials for high-temperature environments, from automotive and aerospace components to medical devices and industrial manufacturing.

Procedure:

1.) Prepare a cup of very hot (near-boiling) water.
2.) Carefully submerge the bottom (thin end) of either gator tail into the hot water. Hold for 20 seconds.
3.) Remove the tail from the water and (with care) quickly attempt to bend the tail in a shape of your choosing.
4.) Repeat steps 2-3 for the other gator tail.
5.) Observe and document the state of the tails. Use these observations to conclude which tail you believe to be PLA and PET-G.

Journal:

Table 7: Material Deformation Observations

Gator Tail #1 Observations	Gator Tail #2 Observations

Table 8: Material Test Conclusions

Gator Tail #1 Material Conclusion	Gator Tail #2 Material Conclusion

Discussion Questions:

A.) Why might two materials that look and feel very similar have very different mechanical properties?

B.) What other intrinsic properties could be examined to identify and classify different materials?

C.) How do materials science engineers decide which materials to use for different applications?

Lab 7 – Functional Artwork (Mechanical Engineering)

Background:

In Mechanical Engineering, technical drawings are a fundamental tool for designing, analyzing, and manufacturing components. Every machine, tool, or mechanical system begins as an idea, but before it can be built, it must be translated into precise visual representations that engineers, manufacturers, and machinists can all understand.

One of the most important techniques for this is orthographic drawing, which allows engineers to represent three-dimensional objects on a two-dimensional surface. To fully describe an object, engineers rely on multiple views, each showing a different perspective. The top, front, and side views provide a detailed breakdown of an object's dimensions, while the isometric view creates a more natural 3D-like representation. These drawings serve as the foundation for computer-aided design (CAD) models, technical blueprints, and engineering schematics.

Beyond just sketching an object's shape, mechanical engineers must also consider what it's made of and how it was manufactured. Every material—from metals and plastics to composites and ceramics—has unique properties that influence strength, durability, and performance. The method of manufacturing is just as important, as different processes like casting, machining, injection molding, or 3D printing determine the final product's quality and function. A well-designed component is not just one that looks good on paper—it is one that can be efficiently produced, assembled, and used in real-world applications.

Understanding technical drawing, material selection, and manufacturing processes is essential for mechanical engineers, as these skills bridge the gap between concept and reality, turning designs into functional, high-performance products.

Procedure:

1.) Select any item from the kit, any item around your room/space, any shape from either the website listed in the activity description, or any simplified 3-dimensional shape.
2.) Place the item in front of you and observe the item from a pure aerial view (looking straight down at it). In the box labeled "Top View", attempt to draw exactly what you see. (If it helps, you can take a picture of your item and reference the picture as you draw)

3.) Reposition the item such that you can only purely see the front of the item. In the box labeled “Front View” attempt to draw exactly what you see. (Try to draw this view at the same scale as your top view)
4.) Reposition the item such that you can only purely see the right side of the item. In the box labeled “Side View” attempt to draw exactly what you see. (Try to draw this view at the same scale as both the front and top views)
5.) Reposition the item such that you can see the top, front, and side all equally. Attempt to draw what you see as a 3-dimensional rendering of your item in the box labeled “Isometric View”. (Referencing your previously drawn views may help)

Journal:

Figure 1: Engineering Drawing Template

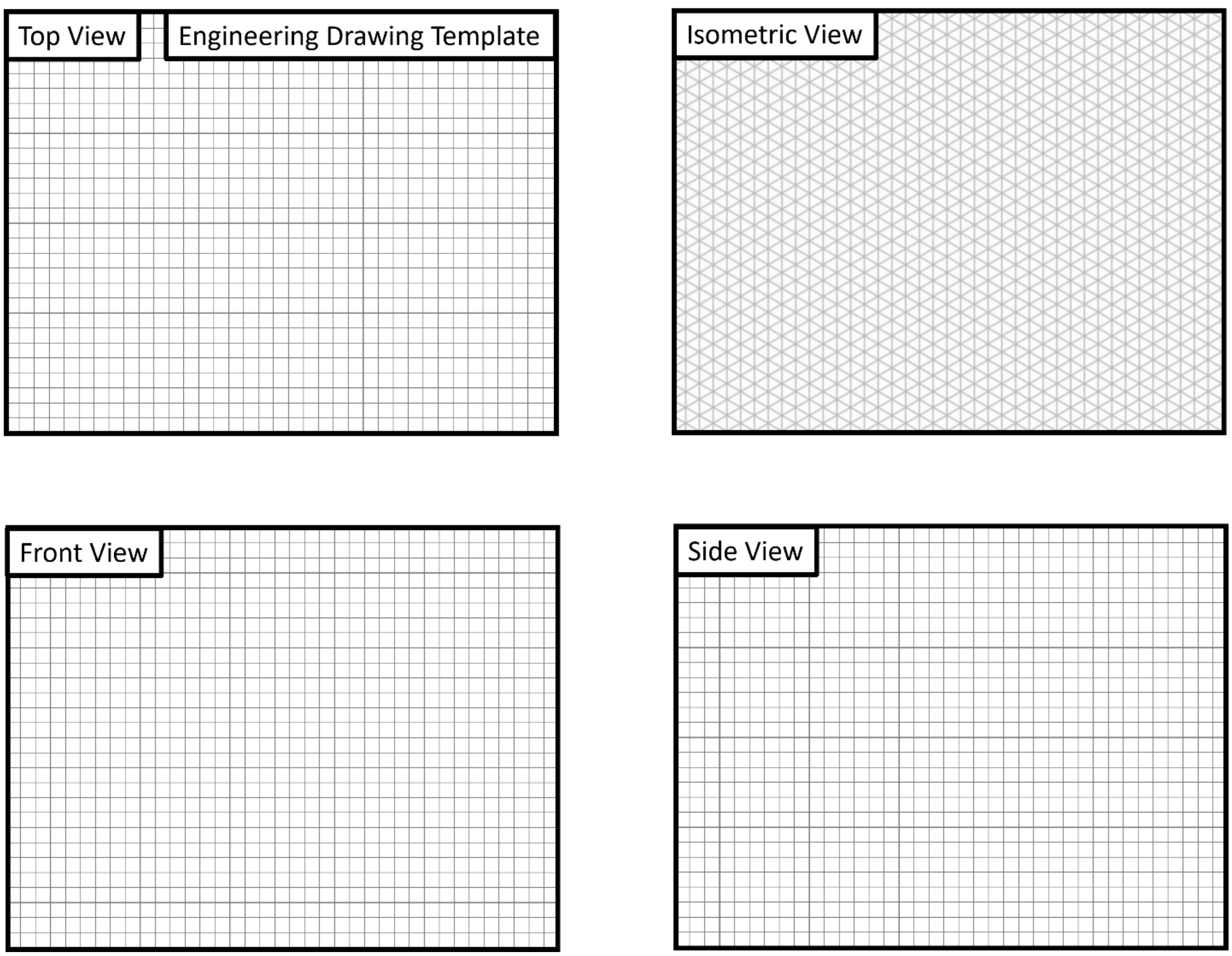


Table 9: Drawing Notes

Part Material Notes (What material is it made of?)	**Part Manufacturing Notes (How could this be manufactured?)**

Discussion Questions:

A.) Why are multiple 2-dimensional views necessary to represent a 3-dimensional object?

B.) How could material choice and manufacturing method impact the design of mechanical components?

C.) What challenges might mechanical engineers face when turning a technical 2-dimensional drawing into a real-world product?

Lab 8 – Binary (Computer Science Engineering)

Background:

As humans, we naturally count in base 10, using ten symbols (0-9) before needing to add another digit. When we run out of symbols, we repeat them in different positions—just like how 10, 11, and 12 are combinations of base 10 symbols, just in different places. But computers don't think like we do—they operate in base 2, or binary, where there are only two symbols: 0 and 1. Instead of writing numbers like 5 or 23, a computer represents them as combinations of just these two symbols, using more digits as numbers get larger.

Binary is the foundation of all modern computing because it aligns perfectly with the way computers process information. Instead of writing numbers with ink or speaking them out loud, computers represent numbers using electricity—where 1 means "on" and 0 means "off." Every piece of digital information, from the text on your screen to the music you stream, is ultimately stored and processed as patterns of 0s and 1s.

In this lab, you will perform arithmetic the way a computer does—using only binary. You'll use a set of Binary Bits, 3D-printed tokens with a 0 on one side and a 1 on the other, to set up and solve basic math problems in base 2. A binary reference sheet is provided to help you check your work by converting between binary and base 10, but the math itself will be done entirely in binary. By physically manipulating the Binary Bits, you'll gain an intuitive understanding of how computers store, add, and process numbers at the most fundamental level.

Procedure:

1.) Lets compute 3+1 in binary using Binary Bits and the Binary Cheat Sheet. From the cheat sheet, we can see that 3 in Binary is represented as "11". Place a Binary Bit with the number "1" face up in the circle labeled "C", another in circle "B". Then, the number 1 is the same in binary as it is in base 10, so put a third bit 1 face up in circle "A".
2.) Add the two numbers vertically. Normally, in Base 10, we know that 1+1=2. But in Binary, we've run out of digits – we have to represent "2" as "10". So, just like carrying the "1" in Base 10, place a new Binary Bit with the "0" side up in circle "F", and place a new Binary Bit with the "1" side up on the circle containing a star two circles above circle "B".

3.) Move one digit to the left and add vertically, carrying down any carried numbers. We have the "1" that was carried and the "1" from 11 (3). In this instance, 1+1=10. Place a new Binary Bit "0" side up in circle "E", and place a new Binary Bit "1" side up on the middle star to indicate another digit has been carried.
4.) Move to the final digit and add vertically, carrying down the carried number. In this example, it remains as the only number in its column, therefore 1+0=1. Place a new Binary Bit, "1" side up, in circle "D"
5.) The final result under the summation line should read as "100", which should convert back to "4" in Base 10.
6.) Using this process, perform a number of additional computations.

Journal:

Figure 2: Binary Cheat Sheet

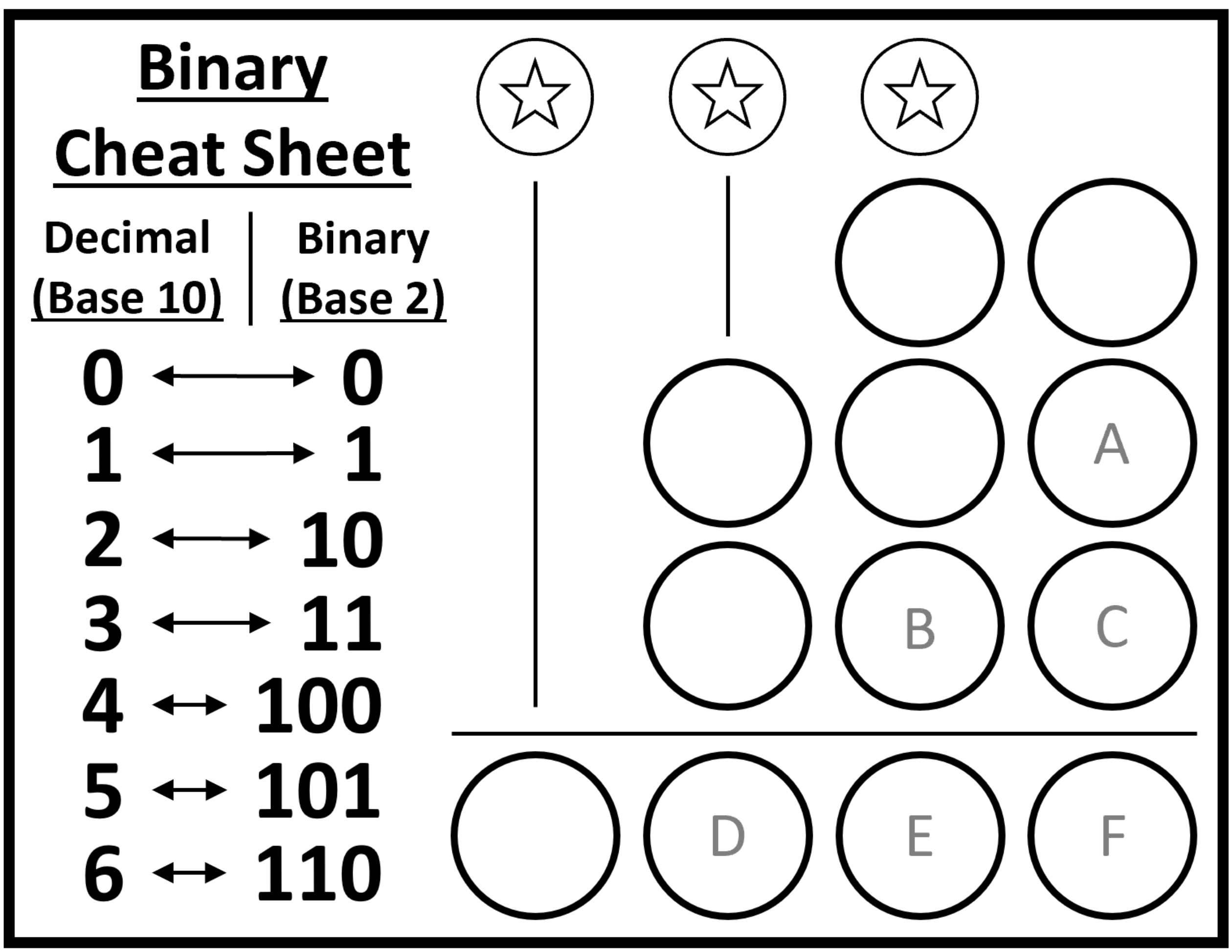


Table 10: Sample Binary Calculations Table (Binary Left, Base 10 Right). Answers in Binary Only!

Equation 1: **10 + 11 (2 + 3)**	**Equation 2:** **11 + 101 (3 + 5)**	**Equation 3:** **10 + 11 + 11 (2 + 3 + 3)**	**Equation 4:** **10 x 11 (2 x 3)**

Discussion Questions:

A.) How does the simplicity of binary allow computers to quickly perform incredibly complex tasks?

B.) If conventional computers can only store information in 1's and 0's, how could more complex numeric data (like pictures, sound, or video) be translated into binary such that it could be interpreted and stored by a computer?

C.) How might a computer process information that isn't traditionally numeric, such as letters?

Lab 9 – Radioactive Decay (Nuclear Engineering)

Background:

Nuclear engineers study the behavior of radioactive materials, including how they decay over time. One of the most important concepts in this field is half-life, which describes the time it takes for half of a sample of radioactive atoms to transform into a more stable state. This transformation is a random process—individual atoms decay unpredictably, but when observed in large numbers, their collective behavior follows a predictable pattern.

Understanding half-life allows engineers to design safer nuclear reactors, manage long-term waste storage, and determine appropriate shielding for radiation sources. It also plays a key role in assessing environmental radiation exposure and ensuring that nuclear materials remain within safe limits. While the decay of any single atom is unpredictable, the mathematical reliability of half-life makes it one of the most powerful tools in nuclear science and engineering.

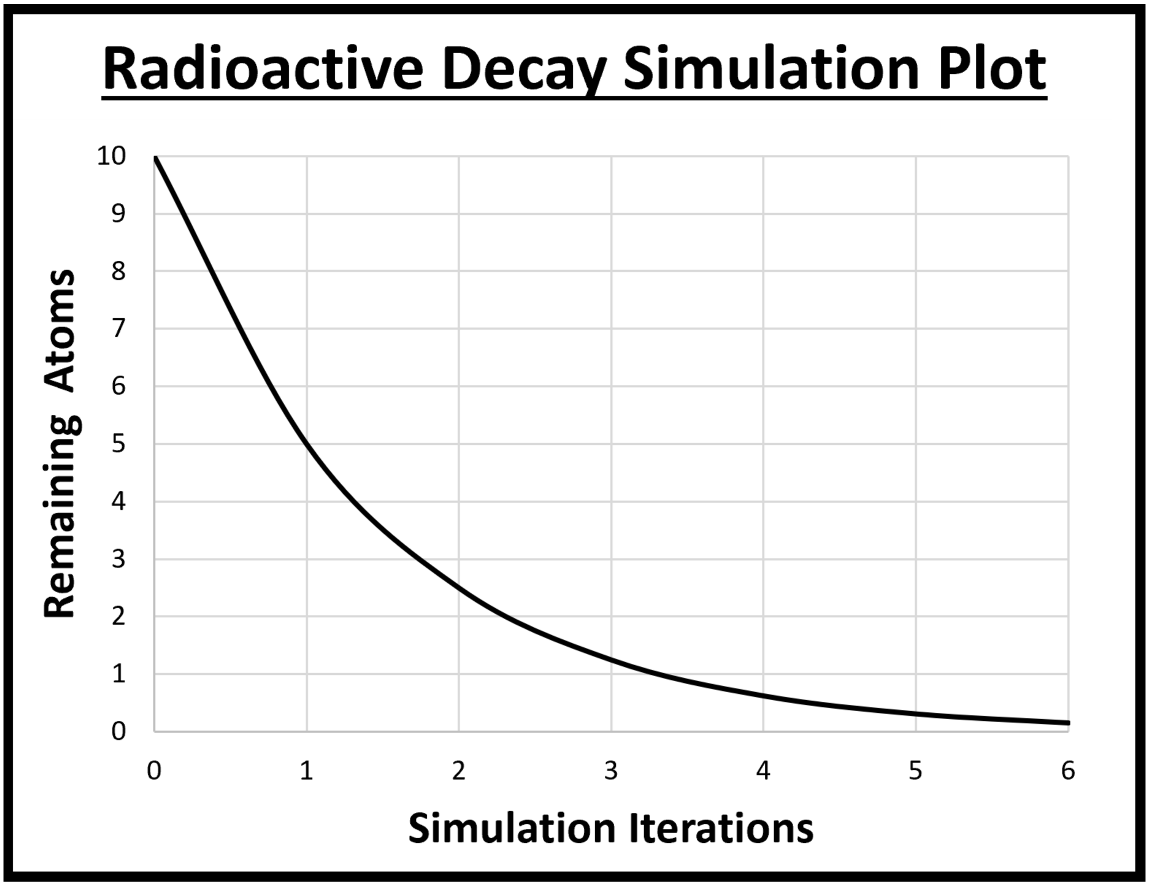
Although half-life follows a statistical pattern, it is driven by random events at the atomic level from unstable high-energy particles crashing into each other. In this activity, you will use Binary Bits to simulate this process by flipping them to represent whether an atom has decayed. As you repeat the experiment and graph your results, you'll see how seemingly random events begin to form a predictable trend—just like real radioactive decay.

Procedure:

1.) Enclose all 10 Binary Bits in your hands, shake well, and release onto a table in front of you.
2.) Count the number of face up "0's" and graph this data point on the "Radioactive Decay Simulation Plot" for Simulation Iteration 1.
3.) Pick up only face up "0's", enclose in your hands, shake well, and release into the table in front of you.
4.) Again, count the number of face up "0's", but graph this data point for Simulation Iteration 2.
5.) Repeat this process until either all "0's" have turned to "1's" or until you've run 6 Simulation Iterations.
6.) Draw a line that connects your dots on your graph.
7.) Repeat steps 1-6 10 times.

Journal:

Figure 3: Radioactive Decay Simulation Plot



Discussion Questions:

A.) How does repeating the activity multiple times help reveal predictable patterns for random events?

B.) Radioactive decay is a natural process that follows statistical rules. What other systems or technologies rely on statistical models to predict seemingly random events?

C.) How might a nuclear engineer leverage the statistical predictability of radioactive half life in applications for nuclear power and/or environmental safety?

Lab 10 – Constructing Functional Structures (Civil Engineering)

Background:

Civil engineers are responsible for designing and constructing the built environment, from roads and bridges to buildings and dams. One of their biggest challenges is creating structures that are both strong and efficient—able to withstand heavy loads while using the least amount of material possible. To do this, engineers study how forces like compression, tension, and bending act on a structure, and how different shapes and materials distribute these forces.

A common example is bridge design. Bridges must support their own weight and any additional loads, such as vehicles and pedestrians, without collapsing or deforming. Engineers use structural forms like beams, arches, and trusses to maximize strength. Even the choice of material matters—steel and concrete are strong, but their arrangement and shape play a major role in performance. Surprisingly, even a simple material like paper can demonstrate these principles. While a flat sheet is weak and flexible, folding it into shapes like ridges or layers dramatically increases its strength. This is the same idea used in corrugated cardboard, steel reinforcements, and architectural trusses.

In this activity, you'll apply these concepts using just a single sheet of paper. Your task is to fold and shape it to support your mechatronic alligator. By experimenting with different folding techniques, you'll see how structural design can transform a weak material into a stable structure.

Procedure:

1.) Open your lab kit box and remove all contents.
2.) Grab a sheet of paper (either from your own supply or this manual).
3.) Fold and construct the paper in such a way that it may (either on its own or using the edges of the open box) support your fully assembled mechatronic alligator above the sidewalls of the open box.
4.) Place your alligator on your structure and observe/document the result under "Structure 1". What does your structure look like? Did it budge or collapse?
5.) Repeat steps 1-4 three total times, creating and documenting three unique structures.

Journal:

Table 11: Structure Notes

Structure 1 Notes	Structure 2 Notes	Structure 3 Notes

Discussion Questions:

A.) What kind of real-world structures use similar design concepts to your folded structures?

B.) How could you improve the capability of your structures without simply adding more paper?

C.) What may be some challenges civil engineers face when designing and building larger scale structures?

Lab 11 – Triangulating Light (Electrical Engineering)

Background:

Electrical engineers design and build systems that sense, process, and respond to information. Whether it's an autonomous vehicle detecting obstacles, a solar panel tracking the sun, or a camera adjusting its exposure, electrical engineering plays a key role in how modern technology interacts with the world.

In this lab, you'll see these principles in action as your mechatronic alligator uses its onboard solar tracking system to detect and respond to light. Real alligators (being cold-blooded) naturally seek out warm sunlight to regulate their body temperature. Your robotic alligator mimics this behavior using two light-dependent resistors (LDRs) embedded in its eyes.

LDRs, also known as photoresistors, change their electrical resistance based on the amount of light they receive. When one eye detects more light than the other, a measurable difference in voltage is created between the two sensors. This voltage is then interpreted and processed by the circuit and used to adjust the position of the servo motor in the alligator's head, causing it to turn toward the light source. This concept of sensor-based feedback control is fundamental in Electrical Engineering and is widely used in applications like robotics, automation, and renewable energy tracking systems.

By studying how electrical signals from simple sensors can be used to control mechanical movement, you're exploring core principles of circuits, signal processing, and embedded systems—key areas of Electrical Engineering.

Procedure:

1.) Turn ON the Power Switch on the Gator Core by moving it to the Right. The LED on the Gator Core should flash white 3 times, followed by a pulsing green light to indicate the alligator's heart rate. (If already on from a previous activity, then no action necessary)
2.) Press and hold the button near the right end of the Gator Core until the LED near the right end of the Gator Core flashes white three times, and then release the button. (be advised that the Gator Head may momentarily move itself as it calibrates)

3.) Move the leftmost switch on the RGB Lamp to the left, exposing the red warm light to the eyes of the Gator Head. Move the entire Gator assembly left and right beneath the RGB Lamp and observe/document the result. Then turn off the red light.
4.) Move the middle switch on the RGB Lamp to the left, exposing the blue cold light to the eyes of the Gator Head. Move the entire Gator assembly left and right beneath the RGB Lamp and observe/document the result. Then turn off the blue light.

Journal:

Table 12: Color-Response Observations

Red Light Observations	Blue Light Observations

Discussion Questions:

A.) What other real-world applications rely on light/heat/position detection coupled with automatic adjustments?

B.) What other types of sensors can be used on robots and machines to interact with their environment?

C.) What are some challenges electrical engineers may face when integrating sensors into automated systems?

Lab 12 – Software Meets Hardware (Computer Engineering)

Background:

Randomness plays an essential role in everything from encryption and cybersecurity to artificial intelligence and video game design. But while randomness is easy to create in the real world—like flipping a coin or rolling dice—computers don't have the luxury of unpredictability. Instead, they rely on pseudorandom number generators (PRNGs) to simulate randomness using mathematical formulas.

In this lab, you will observe how computers generate and interpret randomness through your mechatronic alligator. When exposed to a toxic green light, the alligator's head will appear to jitter randomly, as if in distress. However, if you turn the light on and off multiple times, you'll notice something unusual—the motion follows the exact same pattern every time. That's because the system is using a fixed seed value, meaning the so-called "random" movement is actually predictable and repeatable.

To introduce true variability, you can press a button to reseed the system, generating a new sequence of movements the next time the toxic light is activated. This demonstrates a fundamental truth in computing: without new input, computers will always generate the same "random" sequence from the same starting conditions. Computer engineers work with these concepts when designing simulations, cryptographic security systems, and procedural generation algorithms, ensuring that randomness behaves in a controlled and useful way.

Procedure:

1.) Turn ON the Power Switch on the Gator Core by moving it to the Right. The LED on the Gator Core should flash white 3 times, followed by a pulsing green light to indicate the alligator's heart rate. (If already on from a previous activity, then no action necessary)
2.) Press and hold the button near the right end of the Gator Core until the LED near the right end of the Gator Core flashes white three times, and then release the button. (if already at this stage from the previous activity, then no action necessary)
3.) Move the rightmost switch on the RGB Lamp to the left, exposing the green toxic light to the eyes of the Gator Head. Observe the seemingly "random" movement of the head for five seconds. Then turn off the green light.

4.) Repeat step three a total of three times. Describe and document the consistent path of the movement under “Pseudorandom Movement Observations”
5.) With the green light off, quickly press and release the button on the Cator Core. The onboard LED should blink blue twice. The randomness has been seeded.
6.) Repeat step three a single time. Observe and document under “Seeded Movement Observations” how it differs from the “random” movement of the head prior to pressing the button in step five.

Journal:

Table 13: Pseudorandom Pattern Observations

Pseudorandom Movement Observations	Seeded Movement Observations

Discussion Questions:

A.) In the activity, pressing the button to reseed the system takes the amount of time that has elapsed (expressed in milliseconds) from when the power switch was flipped and uses that random number as a starting point for its internal pseudorandom algorithm. What are some other things (either manmade or that occur in nature) that computer engineers could use to generate a truly random starting seed for these random algorithms?

B.) How does the concept of pseudo randomness apply to everyday technology, such as computers, entertainment, and/or security?

C.) What real-world problems could potentially arise if a system used predictable pseudorandom numbers instead of true randomness?

Conclusion:

Congratulations on completing the Introduction to Engineering Interactive Lab Kit! Through these activities, you’ve explored a variety of engineering disciplines and seen how they work together to solve complex problems. From designing stable structures to simulating radioactive decay, each activity demonstrated how engineers use creativity, logic, and technical skills to tackle real-world challenges.

While this kit only scratched the surface of what engineers do, it hopefully gave you insight into the vast possibilities within the field. Whether you're interested in building bridges, programming smart systems, developing new materials, or even studying alligators in the Everglades, engineering offers countless ways to make an impact.

Engineering is all about problem-solving, innovation, and collaboration. No matter which path you take, the skills you've practiced—critical thinking, experimentation, and analysis—will serve you well in any technical field. So, as you move forward, keep asking questions, stay curious, and continue exploring the world through the lens of an engineer!

FAQ’s:

Q: In assembly step