**🧲 Station 4: “Field Forces” – Electromagnetic Arm Assist**

**Standard:** HS-PS3-5
**Objective:** Investigate how **electric or magnetic fields** interact with objects.

**Goal:**

You will **build a simple electromagnet**, explore how well it can lift or move magnetic objects, and **measure its electrical properties** using a multimeter. Then, you’ll reflect on how electromagnets could help move parts in a robotic arm.

**Materials Needed:**

* Iron nail (3–4 inches)
* Insulated copper wire (about 3 feet)
* AA battery (or 9V battery for stronger field)
* Electrical tape or alligator clips
* Paperclips, small metal objects
* Compass (optional)
* Multimeter (for voltage and resistance)

📝 **Student Directions:**

**Step 1: Build Your Electromagnet**

1. **Wrap the Wire**
	* Tightly coil the wire around the nail, leaving about 3 inches of wire free on each end.
	* Try to make the coils neat and close together (this increases the strength).
2. **Connect to Power**
	* Tape one wire end to the positive (+) terminal of the battery.
	* Quickly touch and hold the other wire end to the negative (–) terminal.
	* ⚠️ **Only connect for short intervals (10–15 seconds)** to prevent the wire from overheating!
3. **Test It**
	* Try to pick up paperclips or attract small metal objects.
	* Move a compass near your electromagnet—does the needle react?

**Step 2: Measure the Electromagnetic Properties**

1. **Voltage Across Your Coil**
	* Set your multimeter to DC Voltage (V⎓).
	* Connect probes to both wire ends *while connected to the battery*.
	* Record the voltage:

🔋 Coil Voltage: \_\_\_\_\_\_\_\_\_\_\_ V

1. **Resistance of the Coil**
	* Disconnect the battery.
	* Set the multimeter to resistance (Ω).
	* Connect probes to each wire end of the coil.
	* Record resistance:

🔌 Coil Resistance: \_\_\_\_\_\_\_\_\_\_\_ Ω

**🧠 Engineering Reflection**

💭 What variables seemed to make your electromagnet stronger?
→ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

💭 How could a robotic arm use this kind of electromagnetic system to pick things up?
→ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

💭 What might limit how strong your electromagnet can be?
→ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**🔬 Extension Challenge (Optional)**

Can you increase the strength of your magnet by:

* Adding more coils?
* Using a larger nail?
* Using more batteries?

Test and compare results—record your changes and findings below.

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**NGSS Standard:**
**HS-PS3-5** – *Develop and use a model of two objects interacting through electric or magnetic fields.*

**✅ ITEEA STEL Standards – High School**

**STEL 1E** – *Technological systems use inputs, processes, outputs, and feedback to solve problems.*
→ Students create and test a system (electromagnet) where the **input** is electric current, the **process** is magnetic field generation, and the **output** is mechanical movement (lifting objects).

**STEL 2E** – *Technological systems are made up of interactive parts.*
→ Students explore how energy, materials, and tools work together in a simple electromagnet—a core concept in mechatronics and robotic assist devices.

**STEL 7F** – *Technological products and systems can be used to apply energy in a variety of ways.*
→ Students apply electrical energy to create a magnetic field, demonstrating **energy transfer and transformation** in engineered systems.

**STEL 8F** – *Design involves a set of steps that can be performed in different sequences and repeated as needed.*
→ Students revise and improve their electromagnets by changing the number of coils, wire length, and battery power.

**STEL 11F** – *Modeling, testing, evaluating, and modifying are used to transform ideas into practical solutions.*
→ Students test electromagnetic strength and measure system behavior using multimeters, making adjustments for real-world function (e.g., robotic graspers).

**✅ Common Core Math Standards – High School**

**CCSS.MATH.CONTENT.HSN.Q.A.1** – *Use units to understand problems and guide the solution.*
→ Students interpret volt (V) and ohm (Ω) measurements from the multimeter and relate them to system behavior.

**CCSS.MATH.CONTENT.HSN.Q.A.3** – *Choose a level of accuracy appropriate to limitations on measurement.*
→ Students estimate changes in electromagnetic strength with more or fewer coils, more batteries, or longer wires—understanding practical constraints in testing.

**CCSS.MATH.CONTENT.HSF.IF.C.7** – *Graph functions expressed symbolically and show key features of the graph.*
→ (Optional extension) Students may graph changes in voltage, resistance, or number of paperclips lifted, helping visualize the relationship between coil properties and field strength.

**CCSS.MATH.PRACTICE.MP2** – *Reason abstractly and quantitatively.*
→ Students apply reasoning to understand how physical properties like wire resistance or voltage impact magnetic field strength.

**CCSS.MATH.PRACTICE.MP5** – *Use appropriate tools strategically.*
→ The multimeter becomes a critical tool for students to **diagnose**, **measure**, and **refine** their engineering system.

**✅ Summary:**

This high school activity allows learners to **engineer and evaluate real-world electromagnetic systems**, blending:

* **NGSS** physical science energy and fields content
* **ITEEA STEL** systems thinking and engineering design standards
* **Common Core Math** standards focused on **measurement**, **units**, and **data analysis**