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WELCOME, ENERGY SYSTEMS ENGINEER!

ARE YOU READY TO MAKE ENERGY WORK?

Plan → Build → Test → Measure → Improve

Energy is working all around you. It moves vehicles, lifts objects, spins machines, launches rockets, and powers systems that complete useful tasks. But where does energy come from? How can it be stored? What happens when it is released? How does energy travel from one part of a system to another? These are the kinds of questions energy engineers investigate.



In this book, you will build working systems that capture, store, release, and transfer energy. You will:

- 🚀 Explore how compressed air can launch an object.
- 🚙 Store elastic energy and use it to power a car.
- 🏗️ Use gravitational energy to operate a lifting system.
- 🌬️ Transfer wind energy through rotation to lift a load.
- ⚙️ Connect several energy transfers in a chain-reaction system.

Each project begins with an engineering challenge. You will build a first design, test it through repeated trials, measure its performance, and use evidence to improve it.

YOUR ENERGY SYSTEMS ENGINEERING MISSION

Complete five engineering projects and discover how energy moves through systems to perform useful work.

1. Capture Energy
Build a compressed-air launcher and investigate how an energy input creates stored air pressure and motion.

2. Store Energy
Build an elastic-powered car and explore how twisted elastic material stores energy before releasing it as movement.

3. Release Energy
Build a gravity-powered lift and discover how stored height energy can lift an object.

4. Transfer Energy
Build a wind-powered lifting system and investigate how moving air produces rotation and useful motion.

🚀 Build a Compressed Air Launcher

Get ready to think like an engineer and build your own **energy-powered launching system**! In this activity, you will design and build a **compressed air launcher** that stores energy and releases it to launch a rocket.

Instead of just launching an object, you will build a **complete system** — including an energy source, a storage method (air pressure), and a release mechanism that creates motion.

When you squeeze the bottle, air is compressed and energy is stored inside the system. When the air is released, that stored energy pushes the rocket forward, creating motion.



👉 **This is how real engineering systems work**:
They don't just create motion — they **store, control, and release energy to perform tasks**.

❓ What problem are we solving?

Compressed air can store energy—but that energy is useful only when a system releases it in the right direction at the right time. If air leaks through a connection, the rocket fits poorly, or the launcher shifts during release, part of the stored energy is wasted. The rocket may travel only a short distance, move sideways, or fail to launch.

Engineers design compressed-air systems that:

➜ contain air until it is needed;
➜ release energy safely and quickly;
➜ direct the moving air toward a useful output;
➜ produce reliable and repeatable motion.

Your task is to transform a simple squeeze bottle into a controlled energy system.

🚀 ENGINEERING CHALLENGE

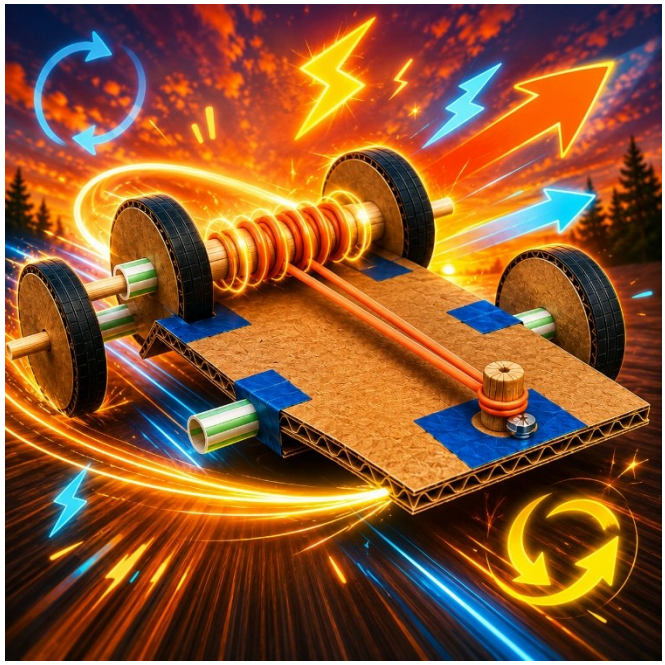
How can you design and build a compressed-air launcher that safely sends a lightweight paper rocket forward, keeps it inside a marked testing lane, and works reliably in repeated trials?

🚙 Create a Rubber Band-Powered Car

Get ready to think like an engineer and build your own energy-powered moving system! In this activity, you will design and build a rubber band-powered car that stores energy and releases it to create motion.

Instead of simply building a toy car, you will create a complete engineering system — including an energy input, an elastic-energy storage system, and a motion system that transfers energy to the wheels.

When you twist the rubber band, energy is stored inside the system. When the rubber band is released, the stored energy turns the axle and wheels, causing the car to move forward.



👉 **This is how real engineering systems work:**
They don't just move — they store, transfer, and release energy to perform tasks.

❓ What problem are we solving?

Vehicles need energy to move—but storing energy is only the first step. That energy must also transfer efficiently through the axles and wheels. If the rubber band slips, the axles are crooked, or the wheels rub against the frame, some stored energy is transferred into friction, wobbling, and unwanted motion. The car may move only a short distance, turn sideways, or fail to start. Engineers design motion systems that store energy until it is needed; transfer energy smoothly to the wheels; reduce unwanted friction and slipping; and produce straight, stable, and repeatable motion.

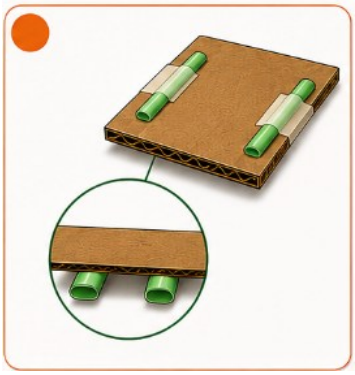
💡 Engineering Challenge

How can you design and build a car system that stores energy in a twisted rubber band, transfers it through the axle-and-wheel system, and travels forward reliably?

🌍 Where do we see this in real life?

This same idea is used in many real engineering systems:

🟠 Step 2 — Create the Axle Supports



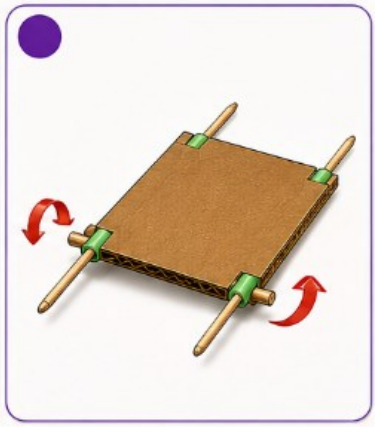
→ Cut two short pieces of drinking straw
→ Tape one straw near the front underside of the cardboard
→ Tape the second straw near the back underside

👉 **The straws will act like axle guides**

→ Make sure both straws are:
✓ straight ✓ parallel ✓ securely attached

👉 **Crooked axles will make the car turn or wobble**

🟣 Step 3 — Insert the Axles



→ Slide one wooden skewer through the front straw
→ Slide the second skewer through the back straw
→ Spin the skewers gently with your fingers

👉 **The axles should rotate freely**

✓ If they stick: adjust the tape → straighten the straws → reduce friction

👉 **Smooth rotation helps transfer energy efficiently**

🔴 Step 4 — Attach the Wheels



→ Create a small hole in the center of each bottle cap or cardboard wheel
→ Push the wheels onto both ends of each axle

👉 **Push each wheel onto its axle and secure it so the wheel and axle rotate together. Leave a small gap between each wheel and straw to prevent rubbing**

👉 Check that:
✓ all wheels touch the ground evenly
✓ the car rolls smoothly
✓ the wheels spin without rubbing the frame

🟡 Step 5 — Add the Elastic Energy System

Core Test Results

Trial	Moved Successfully?	Distance	Sideways Drift
1	Yes / No	___ cm	___ cm
2	Yes / No	___ cm	___ cm
3	Yes / No	___ cm	___ cm

❑ **Calculate Average Distance**

Average Distance = Total Distance ÷ 3

⊙ Average Distance = _____ cm ÷ 3 = _____ **cm**

❑ **Calculate Movement Reliability**

Reliability = Successful Trials ÷ 3 × 100

⊙ Reliability **=** _____ ÷ 3 × 100 = _____**%**

Think Like an Engineer

⊙ **Which trial produced the best combination of distance and low sideways drift**?

⊙ **Was the car reliable? Use your measurements as evidence.**

⊙ **Where might energy have transferred into friction, vibration, or unwanted movement**?

⊙ **What should you improve first: stored energy, car mass, or the wheel system**?

🔬 How It Works (Science Background)

🚗 Your Car is an Energy System

Your rubber band-powered car is a system made of:

👉 **Energy Storage**: Twisted rubber band
👉 **Transfer System**: Axles and wheels
👉 **Release**: Rubber band untwisting
👉 **Output**: Car motion

👉 **All parts must work together for the car to move effectively.**

🔴 How Elastic Energy is Stored

When you twist the axle: The rubber band stretches and twists → Energy is stored inside the rubber band → The twisted rubber band wants to return to its original shape

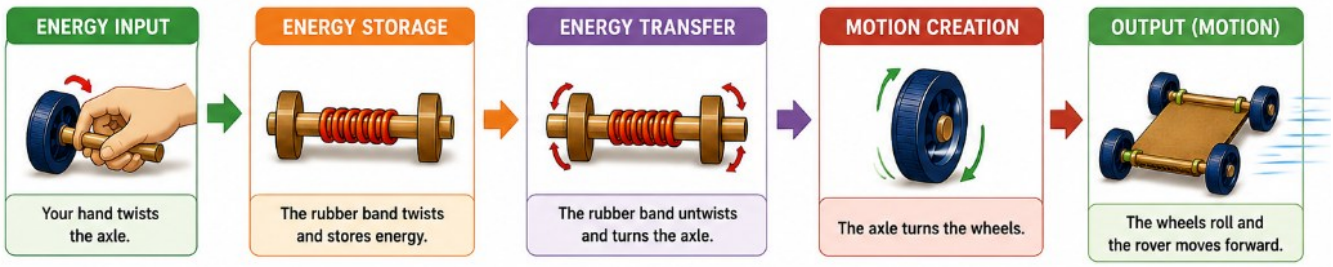
👉 This stored energy is called: **Elastic Potential Energy**
💡 **Think of it like: A stretched spring storing energy and waiting to snap back.**

🔄 How Motion is Created

When you release the car:

✓ The rubber band untwists
✓ The axle begins to rotate
✓ The wheels turn
✓ The car moves forward

👉 Stored energy changes into motion.

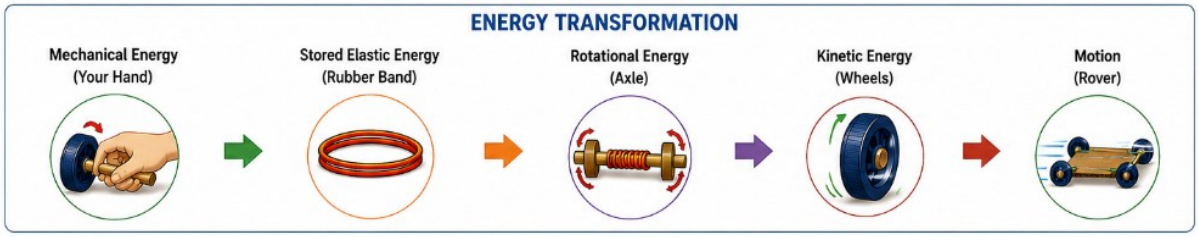


⚙️ Energy Transformation

In your car system, energy changes form:

👉 Mechanical energy (your hand twisting) → becomes stored elastic energy (rubber band) → becomes rotational motion (axles and wheels) → becomes car movement

👉 **This is called: Energy Transformation**



What's Happening?

Larger wheels travel farther during one complete rotation, but they may require more turning force. Smaller wheels rotate more easily but cover less distance per rotation. Wheel alignment, mass, traction, and friction also affect performance. Engineers select wheel systems by balancing: **Distance + Speed + Stability + Energy Efficiency**

Troubleshooting

Problem	What to Check and Fix
Car does not move	✓ Check that the rubber band is hooked securely to the paper clip and cinched around the rear drive axle. ✓ Make sure the rear axle and wheels rotate freely.
Car moves backward	✓ Wind the rear wheels in the opposite direction.
Car moves only a short distance	✓ Check for wheels rubbing against the frame or straws. ✓ Straighten the axle guides and test again before adding more turns.
Car turns sideways	✓ Make sure the front and rear axles are straight and parallel. ✓ Check that all four wheels are centred and touch the floor evenly.
Wheels wobble or slip	✓ Secure each wheel firmly to its axle. ✓ Make sure the wheel holes are centred.
Rubber band slips	✓ Reattach it securely to the paper-clip hook. ✓ Retighten the cinched loop around the centre of the rear axle.
Rubber band rubs the frame	✓ Centre the paper-clip anchor and rear connection. ✓ Make sure the band runs straight down the middle of the car.
Rubber band snaps or becomes damaged	✓ Stop testing and replace it with a fresh rubber band. ✓ Use fewer turns and do not overwind it.
Results are inconsistent	✓ Use the same five turns, start line, floor surface, and release method each time. ✓ Check the car after every trial for loose or rubbing parts.

REFLECT & EXPLAIN

① **System Pathway: Which pathway best describes the rubber band-powered car?**

☐ A. Hand turns axle → Rubber band stores energy → Rubber band untwists → Axle and wheels rotate → Car moves
☐ B. Wheels move → Rubber band disappears → Axle stores distance → Car stops
☐ C. Car moves → Wheels create energy → Rubber band becomes heavier
☐ D. Cardboard stores motion → Straws release energy → Wheels stop

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② **Stored Energy: Where is energy stored before the car is released?**

☐ A. In the twisted rubber band
☐ B. Inside the cardboard base
☐ C. In the measuring tape
☐ D. Under the wheels

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③ **Energy Transfer: What causes the car to move forward?**

☐ A. The rubber band untwists, rotates the axle, and turns the wheels.
☐ B. The cardboard base pulls the wheels forward.
☐ C. The wheels create energy without receiving any force.
☐ D. Gravity stretches the rubber band while the car moves.

---

④ **Match Each Part to Its Function**. Write the correct letter beside each part.

Part	Answer	Function
1. Rubber band	___	A. Support the car's components
2. Axles	___	B. Guide the axles and allow them to rotate
3. Wheels	___	C. Store elastic potential energy
4. Straws	___	D. Transfer rotational motion to the wheels
5. Cardboard base	___	E. Roll against the floor and move the car

---

⑤ **A young engineer tests the same car using two numbers of axle turns.**

Energy Setup	Average Distance	Reliability
5 axle turns	125 cm	100%
10 axle turns	190 cm	67%

Which conclusion is best supported?

☐ A. Ten turns produced greater average distance, but five turns were more reliable.
☐ B. Five turns prevented the car from moving.
☐ C. Both setups produced exactly the same result.
☐ D. More turns always guarantee the best-performing car.

🏗️ Build a Gravity-Powered Lift System



Get ready to think like an engineer and build your own **gravity-powered machine!** In this activity, you will design and build a **lift system that stores energy using height and releases it to create motion and perform work**. Instead of simply dropping a weight, you will create a complete engineering system — including an **energy source, a storage method (gravitational potential energy), and a rotational motion system that transfers energy through an axle and lifting mechanism.**

When you raise a weight, energy is stored in its position above the ground. When the weight is released, gravity pulls it downward, causing the axle to rotate and transfer motion through the system.

👉 **This is how real engineering systems work**:

They don't just move — they store, transfer, and release energy to perform useful tasks.

❓ What problem are we solving?

Engineers often need to lift, lower, or move objects safely without relying only on direct human force. Large systems such as elevators, cranes, winches, and counterweight machines use **stored energy, gravity, rotating axles, cables, and balanced loads** to control movement and perform useful work. These systems must transfer energy smoothly while reducing friction, slipping, instability, and wasted motion.

This activity creates a simple model of those larger engineering systems. It helps you understand how:

→ raising an object stores gravitational potential energy;
→ gravity can produce controlled movement;
→ an axle can transfer motion between two sides of a system;
→ one moving load can lift another load;
→ engineers improve lifting systems through balance, alignment, and reduced friction.

💡 Engineering Challenge

How can you design and build a gravity-powered lifting system that uses a raised weight, rotating axle, and two strings to lift a small load smoothly and reliably?

⚙️ Design an Energy Transfer Chain Reaction



Get ready to think like an engineer and build your own **multi-stage energy transfer system**! In this activity, you will design and build a **chain-reaction system where energy moves through several connected stages to create a final action**.

Instead of creating just one moving object, you will build a **complete engineering system — including stored energy, rolling motion, collision transfer, trigger stages, and a final output action.**

When the marble is released from the top of the ramp, gravity pulls it downward. The moving marble transfers energy through collisions and triggers new motion throughout the system until the final stage is reached.

> 👉 **This is how real engineering systems work:**
> They don't just move — they transfer energy through connected stages to perform useful tasks.

❓ What problem are we solving?

Many machines depend on several connected stages working in the correct order. One moving part must transfer energy to the next part until the system completes its final task. However, a chain-reaction system can stop when:

✓ a ramp is rough or misaligned
✓ the first marble misses the dominoes
✓ dominoes are spaced incorrectly
✓ a collision is too weak
✓ the second marble leaves its path
✓ the final target is positioned poorly

Engineers must design every stage so that energy and motion transfer **smoothly, accurately, and reliably**. In this activity, you will solve the same engineering problem.

💡 Engineering Challenge

How can you design a reliable chain-reaction system that transfers energy through connected stages to move a final target?

🟢 Step 6 — Add the Final Output Target

→ Place a large domino, block, or target object at the bottom of the final ramp
→ Aim the second marble toward the target

👉 **Engineers design systems to perform a final useful action.**



🔵 Step 7 — Test the Full System

→ Hold the first marble at the top of the starting ramp
→ Release it gently with your finger
→ Watch each stage carefully

👉 **Energy should transfer through every stage until the final output happens.**



🔍 Test and Record Your Results

Setup: Complete three trials using the same setup: a 3-book starting level, a flat platform supported by two 2-book stacks, 8 dominoes spaced 2 cm apart, a final ramp leading to a movable target, and a 10-second limit. Mark the starting positions of the marbles, dominoes, and target with tape so each trial begins the same way. Reset the system, release the first marble without pushing, and record whether each stage succeeds before the target moves or time runs out.
Measure spacing as the clear gap between the nearest edges of two adjacent dominoes.

🧪 Test and Measure

Trial	1. First Marble Hits Dominoes	2. All Dominoes Fall	3. Second Marble Moves	4. Target Moves/Falls	Completion Time
1	✓ / ✗	✓ / ✗	✓ / ✗	✓ / ✗	_____ s / NR
2	✓ / ✗	✓ / ✗	✓ / ✗	✓ / ✗	_____ s / NR
3	✓ / ✗	✓ / ✗	✓ / ✗	✓ / ✗	_____ s / NR

→ Write **NR** when the system does not complete all four stages.

→ A successful trial completes all four stages and moves the target within 10 seconds. Write N/A for average time if no trials are successful.

❑ **Successful Trials**

⊙ Number of successful trials that completed all four stages = _____ **out of 3**

Average Time = Total Successful Times ÷ Number of Successful Trials

REFLECT & EXPLAIN — ANSWER KEY

🚀 ACTIVITY 1 — COMPRESSED-AIR LAUNCHER

① **A** ② **A** ③ **A**

④ **Matching:** 1–C 2–D 3–E 4–B 5–A

⑤ **A**

⑥ **C** — **67%** (Two successful launches ÷ three trials × 100 ≈ 67%.)

⑦ **B** ⑧ **A**

⑨ **Correct checks:**

✓ Check for air leaks around the cap and tube.

✓ Check whether the rocket has a snug sliding fit.

⑩ **Suggested Response:**

Mechanical energy from the hand compresses the air and stores energy inside the bottle. When the compressed air is released, it produces a force that pushes the rocket forward and creates motion.

🚙 ACTIVITY 2 — RUBBER BAND-POWERED CAR

① **A** ② **A** ③ **A**

④ **Matching:** 1–C 2–D 3–E 4–B 5–A

⑤ **A** ⑥ **A** ⑦ **B** ⑧ **A**

⑨ **Correct checks:**

✓ Check whether the axles are straight and parallel.

✓ Check whether the wheels rub against the cardboard frame.

⑩ **Suggested Response:**

Mechanical energy from turning the axle twists the rubber band and stores elastic potential energy. When the rubber band untwists, it rotates the axle and wheels, transferring the stored energy into car motion.

🏗️ ACTIVITY 3 — GRAVITY-POWERED LIFT SYSTEM

① **A** ② **A** ③ **A**

④ **Matching:** 1–C 2–D 3–E 4–A 5–B

⑤ **A** ⑥ **A** ⑦ **B** ⑧ **A**

⑨ **Correct checks:**

✓ Check whether the axle rotates freely inside the straw bearings.

✓ Check whether the strings are wrapped in opposite directions and are not slipping.