Balanced And Unbalanced Forces

4th Grade

Physical Science | Lesson Guide

Photo Description

This image shows a large construction machine called a backhoe loader with its mechanical arm (bucket) raised high in the air. A person stands beside the machine on a grassy property with trees and a house in the background. The backhoe is using hydraulic power to lift heavy materials—demonstrating how machines can apply forces to move and lift objects that would be too heavy for humans to move alone.

Scientific Phenomena

Anchoring Phenomenon: A backhoe loader lifting heavy loads using applied force and simple machines.

Why This Happens: The backhoe uses hydraulic pressure (fluid pushed through cylinders) to create a large force that moves the mechanical arm. This is an example of an applied force—a push or pull created by the machine's engine. The backhoe's arm acts as a lever (a simple machine), which multiplies the force applied, allowing the operator to lift objects much heavier than a human could lift. Without this applied force, gravity alone would keep the heavy materials on the ground. The machine works by converting engine power into hydraulic pressure, which then creates the force needed to overcome gravity and move the load.

Core Science Concepts

* Applied Forces: A force is a push or pull. The backhoe's engine creates an applied force through hydraulic pressure that moves the bucket and lifts materials against gravity.

* Simple Machines (Levers): The backhoe's arm works like a lever—a simple machine with a fulcrum (pivot point) that multiplies force. This allows a smaller effort to lift a much larger load.

* Gravity and Weight: Gravity constantly pulls objects downward. The backhoe must apply an upward force greater than the weight of the materials to lift them off the ground.

* Work and Energy: The backhoe does "work" by applying a force over a distance (lifting the bucket). This requires energy from the engine.

Pedagogical Tip:

When introducing this lesson, ask students to first try lifting a heavy object themselves (like a textbook stack), then discuss how the backhoe does the same job with less effort. This concrete experience helps them understand why simple machines matter in real life. This builds from their personal experience to the abstract concept.

UDL Suggestions:

Provide multiple means of representation: Show the photo, then show a simple diagram of a lever with labels. Allow students to choose between drawing, building with blocks, or role-playing to demonstrate their understanding of how the backhoe works. Some students may benefit from manipulating a simple lever tool (like a ruler on a pencil) to feel the mechanical advantage firsthand before discussing the backhoe.

Zoom In / Zoom Out

Zoom In: Inside the Hydraulic Cylinder
When you look very closely inside a backhoe's hydraulic system, you'd see tiny oil molecules being pushed through metal tubes by the engine's pump. These molecules are so small you can't see them with your eyes, but when billions and billions of them are pushed together under high pressure, they create an enormous force that can lift tons of dirt and rocks. It's like if you tried to push one marble—easy! But if you pushed a million marbles all at once in a tube, that would be very hard to do. The oil molecules work the same way: individually tiny, but together incredibly powerful.

Zoom Out: Construction Sites in Community Development
A single backhoe like the one in the photo is part of a much larger system that helps build and maintain our communities. Construction machines work together on job sites to dig foundations for houses, clear land for roads, build parks, and create safe communities. These machines are connected to the people who operate them, the engineers who design buildings, the city planners who decide where to build, and the families who eventually use these new spaces. When you see construction happening in your town, you're watching a small piece of how communities grow, change, and improve over time.

Discussion Questions

1. What force is the backhoe using to lift the bucket full of dirt? (Bloom's: Understand | DOK: 1)

2. Why do you think the backhoe's arm is shaped like a long stick instead of being short and thick? How does the shape help it lift heavy objects? (Bloom's: Analyze | DOK: 2)

3. If a person tried to lift the same bucket of dirt that the backhoe lifted, what would happen? Why? (Bloom's: Analyze | DOK: 2)

4. If the backhoe's engine broke and couldn't pump hydraulic fluid anymore, what would happen to the bucket? Explain using what you know about gravity and forces. (Bloom's: Evaluate | DOK: 3)

Potential Student Misconceptions

Misconception 1: "The backhoe is just really strong, like a superhero."
Clarification: The backhoe isn't strong by itself—it's smart! It uses simple machines (levers) and hydraulic power to multiply the force from its engine. A human is strong, but a backhoe multiplies that strength many times over. It's not magic or superhero power; it's good engineering. The backhoe's arm works like a seesaw (lever), which makes lifting easier and lets the machine do work that would take 100 people to do by hand.

Misconception 2: "The bucket stays up in the air by itself because the machine is holding it."
Clarification: The bucket only stays up as long as the hydraulic system is actively pushing it upward. The moment the engine stops pumping hydraulic fluid, gravity immediately pulls the bucket back down. Gravity is always working—the machine must keep working too, or gravity wins. It's like holding a heavy book over your head: you have to keep pushing up, or it falls down.

Misconception 3: "Bigger machines can lift anything no matter how heavy."
Clarification: Even the biggest backhoe has limits to what it can lift safely. Engineers have to calculate the maximum weight each machine can handle based on its size, the strength of its parts, and how the lever system is designed. Trying to lift something too heavy could break the machine, just like bending a toy car too hard could snap it. Every machine has a "weight limit."

Extension Activities

1. Build a Lever Machine: Provide students with rulers, pencils, and small objects of different weights (erasers, blocks). Have them create a simple lever by placing a ruler across a pencil (fulcrum) and experiment with lifting objects from different distances along the ruler. Students should discover that the farther the load is from the fulcrum, the harder it is to lift—and the closer it is, the easier. They can draw diagrams showing their findings.

2. Design a Lifting Machine: Provide students with building materials (straws, string, paper clips, plastic cups). Challenge them to design and build a simple machine that can lift a toy object (marble, small block) at least 6 inches off the ground using only these materials and a human hand for power. This requires them to apply their understanding of levers and simple machines. Students should sketch their design first, test it, and explain how their machine works using vocabulary from the lesson.

3. Compare Effort and Load: Set up stations where students use different tools (spoon, shovel, stick) to scoop sand or soil into a bucket. Have them record which tool required the least effort and which required the most. Discuss how the shape and length of each tool affects the force needed—introducing the concept that different simple machines require different amounts of effort depending on their design.

Cross-Curricular Ideas

Math Connection: Measuring Force and Weight
Students can measure objects in the classroom and estimate their weight in pounds, then calculate how many students would need to work together to lift what the backhoe lifts in one scoop. Create a chart comparing the weight of classroom objects (pencil, textbook, chair) to the weight of dirt a backhoe bucket can hold (typically 1-2 tons). This builds understanding of scale, multiplication, and real-world measurement applications.

ELA Connection: Writing How-To Guides and Procedural Text
Have students research how a backhoe works and write step-by-step instructions titled "How to Safely Operate a Backhoe" or "How a Backhoe Lifts Heavy Objects." This requires them to sequence information logically, use technical vocabulary correctly, and explain cause-and-effect relationships. Students could also read and discuss construction-themed picture books, then write their own short story about a day in the life of a backhoe operator.

Social Studies Connection: Community Helpers and Construction Careers
Invite a local construction worker or heavy equipment operator to visit the classroom (virtually or in person) to discuss what they do. Students can create a "Community Helpers" poster showing different jobs on a construction site and how they work together. This connects to understanding how communities are built and maintained, and introduces students to the diverse careers needed to make neighborhoods thrive.

Art Connection: Designing Machines and Blueprint Drawing
Provide students with large paper and ask them to design their own "dream construction machine" that could do multiple jobs. They should sketch it from the side, label the parts, and explain what forces and simple machines they would use. Advanced students could try creating a simple blueprint-style drawing with measurements and annotations, learning how engineers and architects communicate their ideas visually.

STEM Career Connection

Heavy Equipment Operator

A heavy equipment operator is the person who sits in the cab of machines like backhoes, bulldozers, and excavators and controls them to dig, move, and lift materials on construction sites. They use joysticks, pedals, and levers to precisely move the machine's arms and buckets. It's like playing a video game, but in real life with real construction happening! These operators need to understand forces, be very precise and careful, and work as part of a team. Average Annual Salary: $48,000–$65,000 USD

Mechanical Engineer
A mechanical engineer designs and builds machines like backhoes. They use math and science to figure out how to make machines work better, lift heavier loads, and run more safely. Engineers draw plans on computers, test new ideas, and solve problems when machines don't work right. If you like building with blocks, creating inventions, and solving puzzles, this job might be for you! Average Annual Salary: $68,000–$92,000 USD

Construction Supervisor / Site Manager
A construction supervisor oversees all the work happening on a construction site, including the heavy equipment operators and their machines. They plan what needs to be dug, when to use each machine, and make sure everyone stays safe. This job requires understanding how machines work, being a good leader, and solving problems when things don't go as planned. Average Annual Salary: $65,000–$85,000 USD

NGSS Connections

Performance Expectation: 4-PS3-1: Use evidence to construct an explanation relating the speed of an object to the energy of that object.

Related PE: 3-PS2-1: Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

Disciplinary Core Ideas:
- 3-PS2.A Forces and Motion
- 4-PS3.A The Relationship Between Energy and Forces

Crosscutting Concepts:
- Cause and Effect
- Energy and Matter
- Systems and System Models

Science Vocabulary

* Force: A push or pull that can make something move, stop, or change direction.

* Applied Force: A push or pull made by a person or machine to move something.

* Lever: A simple machine made of a stiff bar that pivots on a point (called a fulcrum) to lift or move heavy objects.

* Gravity: The invisible force that pulls objects downward toward Earth.

* Hydraulic: A system that uses liquid (usually oil) pushed through tubes under pressure to create power and movement.

* Work: Using force to move an object over a distance.

External Resources

Children's Books:

- Simple Machines: Levers by David Adler (illustrated explanations of how levers work in everyday machines)
- Machines Go to Work by William Low (colorful pictures of construction machines and what they do)
- The Way Things Work by Macaulay (engaging diagrams explaining simple machines, especially levers)