EDUCATIONAL MATERIALS

ENGINEERING: GRADES 3-5

PULLEYS: REACHING NEW HEIGHTS IN A GLOBAL ICON

Exhibit Connections: Construction, Otis Elevators

OVERVIEW OF LESSON PLAN

When looking for groundbreaking engineering challenges, the Empire State Building shines as a global icon of engineering and human design. The height, materials, construction timeline, and new building techniques all set the stage for amazing advances in skyscraper innovation and engineering. The Empire State Building took just 410 days to construct, from the setting of the tower's first steel columns on March 17, 1930. To date, no comparable structure has matched that rate of construction. When the Empire State Building opened in 1931, it was the world's first 102-story building. To help transport people and objects throughout the building, the Empire State Building's elevators were the fastest and most advanced of its day. Today, its elevators transport passengers from the ground floor to the Observation Deck and every floor in between.

One component of these elevators is a pulley. A pulley is a wheel used to transmit force or power by means of a belt, rope, or cable. It is a simple machine consisting of a string or rope wrapped around a wheel (sometimes with a groove) with one end of the string attached to an object and the other end attached to a person or a motor. Simple machines help make work easier. They are called simple because they have few or no moving parts. Pulleys may seem simple, but they can provide a powerful mechanical advantage for easily lifting very heavy objects. In this engineering lesson, students will explore how pulley systems work in elevators and in everyday life.

OBJECTIVES

Students will:

- Demonstrate how pulleys are used.
- Describe how pulleys make work easier for engineers and construction workers.
- Identify modern applications in which engineers use pulleys, such as elevators.

SUGGESTED TIME ALLOWANCE:

One hour

RESOURCES/ MATERIALS:

- Video **Impossible Science on Location**
- Pencil
- Provided handouts
- A pulley system kit is required for the post-trip activity.
    - Pulleys of varying sizes (roughly 4-10 per student group)
    - Ropes of varying lengths and thicknesses
    - Spring scales (1 per student)
    - Varying weights
    - Tape, wire, pipe cleaners, and/or other temporary fasteners

ACTIVITIES/ PROCEDURES:

PRE-TRIP ACTIVITY

Open the lesson by asking students if they have ever been to a building and ridden an elevator up to the top. Discuss how elevators can lift a lot of weight because elevators use pulleys. A pulley is an example of a simple machine. A pulley can be made up of a wheel that you loop a rope over. Pulleys make it easier to lift things, especially heavy objects. A pulley system does this by redirecting the force you need to lift something. Ask students to tie a rope to one end of an object (Ex: backpack, grocery bag filled with books, a milk or juice container with a handle. Have them lift the heavy object using their arms by pulling the opposite end of the rope straight up. Next, have students loop the rope over a doorknob and lift the object again. Have students note and discuss the differences they felt during each attempt to lift the object. Explain to students that as the force moves down, the heavy object lifts up. Ask students to brainstorm how pulleys are used in elevators to lift heavy elevator cars full of people or goods.

Know, Wonder, Learn Chart: Create a classroom KWL chart to help students organize their learning about pulleys. On a large sheet of paper, in Google Slides, or on the classroom board, create a chart with the title "Simple Machines: Pulley Systems and Elevators." Draw three columns, titled Know, Wonder, and Learn, to represent what students know, what they wonder, and what they will learn about pulleys and their mechanical advantages. Complete the Know column after their pulley exploration. Tell students that during their trip to the Empire State Building they will be experiencing how pulley systems are used in the elevators to transport people and goods over 100 floors.

Watch: **Impossible Science on Location**

After watching the video, ask students to fill in the Wonder section of the chart. Elicit wonderings by asking students, "When the Empire State Building opened in 1931, do you think their elevators worked the same way as they do today? Why or why not?". Students can use the Want to Know column to record other questions they hope to answer during their visit to the Empire State Building.

ON-SITE ACTIVITIES One hour

EXHIBIT: CONSTRUCTION (15 minutes)

The Empire State Building is being built all around you! Take a moment to observe the pieces coming together and how the workers are connecting them. Pulleys can be found all around an active construction site. Find a pulley being used at the construction site. Stop and sketch the pulley system showing what heavy object it is lifting and draw an arrow to show the direction of force.

EXHIBIT: OTIS ELEVATORS (15 minutes)

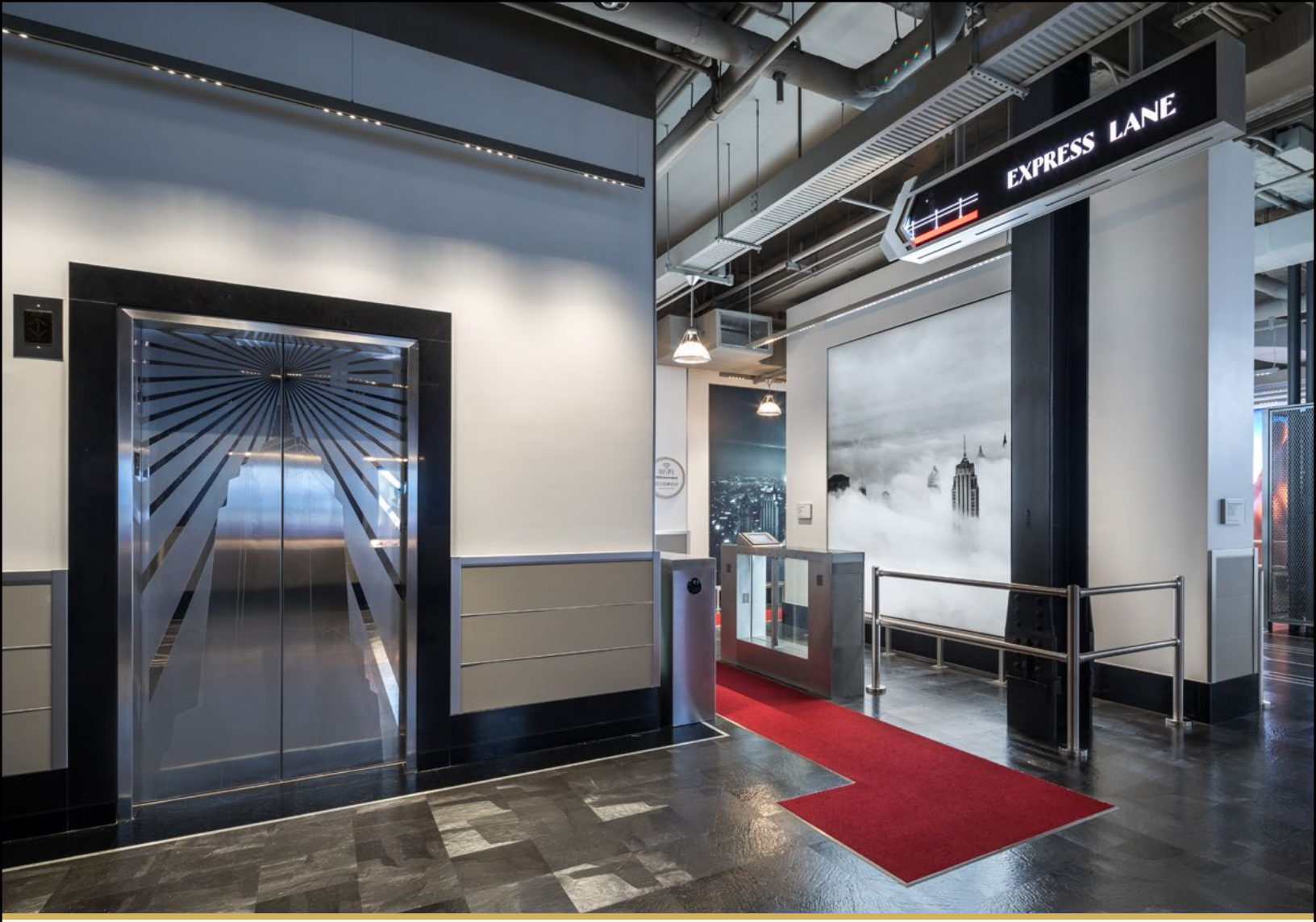
The Otis Elevator Company created an innovative and new elevator system for the Empire State Building twice—the first in 1931, then again in 2011. The Empire State Building has also made many modern improvements to the building's energy efficiency, design, and environmental impact. The building's 73 elevators use a technology called "regenerative braking," which allows them to store energy each time they slow to a stop and feed that power back into the building. How are the building's new elevator systems different from the original system?

HOMEWORK/FURTHER DISCUSSION:
Prompt students to reflect on how many types of pulleys they encountered during their field trip to the Empire State Building. Have students provide a response (written or illustrated) to the question, “How do pulleys make work easier for engineers and construction workers? Do you think the construction of the Empire State Building could have happened in record time without the use of pulleys or other simple machines? Why or why not?”

POST-TRIP ACTIVITY: OTIS ELEVATOR-INSPIRED PULLEY EXPLORATION
In this post-trip lesson, students investigate the amazing power of pulleys. For reference, teachers can explore **Pulley’ing Your Own Weight**

- Facilitate a class discussion about the Empire State Building elevators after rewatching **Impossible Science on Location**
- Have students turn and talk to their neighbors, asking them “What do you remember about the elevator ride? What difference did you notice in the 1931 Otis elevator car and the modern elevator car?”
- Allow time for the students to share what they discussed and record the students’ ideas on the board or chart paper.
- Next, introduce the pulleys, ropes, and spring scales. Have students consider how pulleys make work easier for engineers, applying what they learned and observed during their field trip.
- Separate students into small groups. Tell them they are a group of engineers who need to design a pulley system to lift heavy construction materials up to the 102nd floor of the Empire State Building. Challenge them to create their own pulley system with the given materials to lift weights or objects of varying weight. As an additional challenge, students can design and construct a pulley system to cut the weight of their load in half.
- At the end of the lesson, revisit the KWL chart and have students share what they learned in the Learned column.

EVALUATION AND ASSESSMENT
Students can be evaluated based on their exploration of the materials, teamwork, and ability to document what they learned about their successes (and failures) in their pulley system design.



CONNECTIONS TO THE STANDARDS

3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

PRE-TRIP WORKSHEET

NAME_____ **DATE**_____

PREPARING FOR YOUR TRIP TO THE EMPIRE STATE BUILDING
SIMPLE MACHINES: PULLEY SYSTEMS AND ELEVATORS

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Know	Wonder	Want to Know

TRIP WORKSHEET

NAME_____ **DATE**_____

WELCOME TO THE EMPIRE STATE BUILDING

Exhibit: Construction

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How are the building's new elevator systems different from the original system?

Observe the original 1931 Otis elevator car. Sketch the pulley system at the top of the car. Draw arrows showing how the elevator car moves up as the force moves down.

POST-TRIP WORKSHEET

NAME_____ **DATE**_____

SIMPLE MACHINES: PULLEY SYSTEMS AND ELEVATORS

Draw a diagram of your pulley design.

After visiting the Empire State Building and experimenting with your own pulley system, revisit your ideas from the pre-trip worksheet. How have your ideas changed? What have you learned? Record your ideas in the KWL chart below.

Learned	Still Wondering	Want to Know