Using Proportion to Determine Scale

Name: ____ Period: _____________

In this activity, you will convert the actual height of skyscrapers or the actual length of bridges and tunnels into a reduced scale of inches. The scale you will use is 50 feet = 1 inch; this is the ratio of 50/1. Round all answers to the nearest hundredth. To find the actual height or length, see the following pages. Remember to keep the order of the terms the same in both proportions.

Name of structure	Actual height or length	Scale
John Hancock Center		
Chrysler Building		
Petronas Tower		
Sears Tower		
Citicorp Center		
Sunshine Skyway Bridge		
Firth of Forth Bridge		
Golden Gate Bridge		
Akashi Kaikyo Bridge		
New River Gorge Bridge		
Channel Tunnel		
New York Third Water Tunnel		
Central Artery/Tunnel Project		
Seikan Tunnel		
Underground Canal		

Bonus: Using the data for either skyscrapers, bridges, or tunnels, create a graph comparing all the structures in the category.

John Hancock Center

Vital Statistics:

Location: Chicago, Illinois, USA
Completion Date: 1969
Height: 1,127 feet
Stories: 100
Materials: Steel
Facing Materials: Aluminum, glass
Engineer(s): Skidmore, Owings & Merrill

Today, the John Hancock Center in Chicago, Illinois, is affectionately known as "Big John," but it was not always this way. Located on North Michigan Avenue along Chicago's "Magnificent Mile," the skyscraper was controversial from the start for its enormous bulk and dark metal exterior. Eventually, it was celebrated for its very brashness, and today it remains one of Chicago's best-loved icons.

Currently, the John Hancock Center is the twelfth tallest building in the world. But to keep such a tall building standing in the "Windy City," engineers had to make the enormous structure super stiff. How did they do it? The John Hancock Center is actually a super-tall **steel** tube. Steel **columns** and beams are concentrated in the skyscraper's **perimeter**, and five enormous diagonal **braces** on the exterior walls of the skyscraper give it extra **strength** in the wind. The skyscraper also rises from 40,000 square feet at the base to 18,000 square feet at the summit. This tapered design provides additional structural **stability** against wind forces.

In order to reach the whopping height of 1,127, engineers knew that the enormous 384-million-pound tower needed **caissons** to prevent it from sinking into the soft ground. Today, the John Hancock Center rests on several caissons that extend down to **bedrock**. One of the caissons actually reaches 191 feet below the ground -- the deepest ever sunk in Chicago!

Chrysler Building

Vital Statistics:

Location: New York, New York, USA
Completion Date: 1930
Cost: $20 million
Height: 1,046 feet
Stories: 77
Materials: Steel
Facing Materials: Brick
Engineer(s): Ralph Squire & Sons

In the summer of 1929, a "race for the sky" broke out on the island of Manhattan. Automobile tycoon Walter Chrysler battled Wall Street powerhouse Bank of Manhattan Trust Company for the title of world's tallest building in what many historians consider to be the most intense race in skyscraper history. In the spring of 1930, just when it appeared that the bank might capture the coveted title, a small crew jacked a needle-thin **spire** hidden in Chrysler's building through the top of the crown to claim the title of world's tallest at 1,046 feet.

Not only was the Chrysler Building the world's tallest structure, it was also one of the most decorated office buildings in the world. Chrysler wanted "a bold structure, declaring the glories of the modern age" -- and he got it. He decorated his skyscraper with hubcaps, mudguards, and hood ornaments, just like his cars, hoping that such a distinctive building would make his car company a household name. Today, the Chrysler Building is recognized as New York City's greatest display of Art Deco, a decorative style characterized by sharp angular or zigzag surface forms and ornaments.

Only four months after the completion of the Chrysler Building, the world's tallest championship title would be claimed by a new structure, the Empire State Building.

Petronas Towers

Vital Statistics:

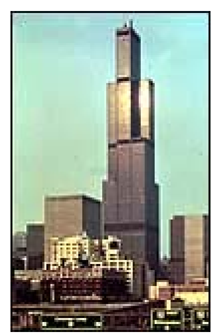
Location: Kuala Lumpur, Malaysia
Completion Date: 1998
Cost: $1.6 billion
Height: 1,483 feet
Stories: 88
Materials: Concrete, Steel
Facing Materials: Aluminum, Stainless Steel
Engineer(s): Thornton-Tomasetti and Ranhill Bersekutu

Until 1998, the world's tallest skyscraper had always been in the United States. But that year, Malaysia's Petronas Towers laid claim to this distinction.

Squeaking past the Chicago Sears Tower by 33 feet, the **spires** atop the Petronas Towers peak at an impressive 1,483 feet. Yet there's a controversy. The highest occupied floor in the Sears Tower is actually 200 feet higher than the top floor of the Petronas Towers, and its antennae stretch higher still.

So why are the Petronas Towers considered the world's tallest buildings? According to the Council on Tall Buildings and Urban Habitat, spires count, but antennae don't. Spires do not contain floors, but they are counted in the

Sears Tower



Vital Statistics:

Location: Chicago, Illinois, USA
Completion Date: 1973
Cost: $150 million
Height: 1,454 feet
Stories: 110
Materials: Steel
Facing Materials: Black aluminum
Engineer(s): Skidmore, Owings & Merrill

The Sears Tower is an example of the revolutionary bundled-tube structural design.

Tube buildings gain most of their structural support from a **rigid** network of **beams** and **columns** in their outer walls. The rigid outer walls act like the walls of a hollow tube. The Sears Tower is actually a bundle of nine tubes, and is considered one of the most efficient structures designed to withstand wind. This is a great design for a skyscraper in Chicago, the "Windy City," where the average wind speed is 16 miles per hour. As the building climbs upward, the tubes begin to drop off, reducing the wind **forces** on the building. The Tower's heavy weight -- more than 440 million pounds -- is also supported by 114 **piles** sunk deep into the earth so that they stand firmly on hard, solid **bedrock**.

world's tallest building race for one architectural reason: they're nice to look at.
Built over a former racetrack, the Petronas Towers reflect a unique blend of religion and economic prosperity. The $1.6 billion towers contain more than eight million square feet of shopping and entertainment facilities, underground parking for 4,500 cars, a petroleum museum, a symphony hall, a mosque, and a multimedia conference center.
Each tower's floor plan forms an eight-pointed star, a design inspired by traditional Malaysian Islamic patterns. The 88-**story** towers, joined by a flexible skybridge on the 42nd floor, have been described as two "cosmic pillars" spiraling endlessly towards the heavens.

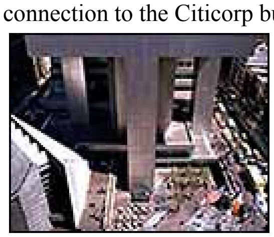
In 1974, the Sears Tower in Chicago assumed the coveted title of world's tallest building, at 1,454 feet. It held this title for 22 years until 1998, when the decorative **spires** atop the Petronas Towers in Malaysia surpassed the Sears Tower by 33 feet. Today, the Sears Tower still boasts the tallest occupiable floor and the tallest skyscraper roof in the world.

Citicorp Center

Vital Statistics:

Location: New York, New York, USA
Completion Date: 1977
Cost: $175 million
Height: 915 feet
Stories: 59
Materials: Steel
Facing Materials: Aluminum, reflective glass
Engineer(s): William LeMessurier and Associates

From the very beginning, the Citicorp Center (today, the Citigroup Center) in New York City was an engineering challenge. When planning for the skyscraper began in the early 1970s, the northwest corner of the proposed building site was occupied by St. Peter's Lutheran Church. The church allowed Citicorp to build the skyscraper under one condition: a new church would have to be built on the same corner, with no connection to the Citicorp building and no **columns** passing through it.



How did the engineers do it? They set the 59-story tower on four massive columns, positioned at the center of each side, rather than at the corners. This design allowed the northwest corner of the building to **cantilever** 72 feet over the new church.
In 1978, the skyscraper's chief structural engineer, William LeMessurier, discovered a potentially fatal flaw in the building's design: the skyscraper's bolted **joints** were too weak to withstand 70-mile-per-hour wind gusts. With hurricane season fast approaching, LeMessurier took no chances. He convinced Citicorp officers to hire a crew of welders to repair the fragile building. For the next three months, a construction crew welded two-inch-thick **steel** plates over each of the skyscraper's 200 bolted joints, permanently correcting the problem.

Sunshine Skyway Bridge

Vital Statistics:

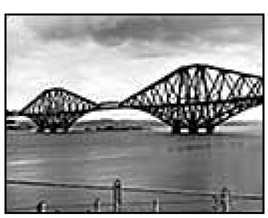
Location: St. Petersburg and Bradenton, Florida, USA
Completion Date: 1987
Cost: $244 million
Length: 29,040 feet
Type: Cable-Stayed
Purpose: Roadway
Materials: Steel, concrete
Longest Single Span: 1,200 feet
Engineer(s): Figg & Muller Engineering Group

Completed in 1987, the Sunshine Skyway is the world's longest cable-stayed **concrete** bridge. It is probably the best known of the several dozen **cable-stayed bridges** that have been built in the United States since the late 1970s. Its popularity may be due to its unique color -- its **cables** are painted a bright taxicab yellow -- but the bridge also boasts an interesting history.

The Sunshine Skyway isn't the first bridge to span the broad mouth of the Tampa Bay. In fact, a four-mile **steel** **cantilever** bridge used to live where the new Sunshine Skyway now stands. But during a violent thunderstorm on the morning of May 9, 1980, the freighter *Summit Venture* plowed into the cantilever bridge. More than 1,000 feet of the bridge fell into the bay, killing 35 motorists and bus passengers instantly.
The Florida Department of Transportation began construction on a safer Sunshine Skyway Bridge only days later. more than 300 precast concrete segments were linked together with high-strength steel cables to form the roadway. Protecting the new bridge from ships was a big priority, so they installed large concrete islands, called dolphins, around each of the bridge's six piers to absorb unwanted impact. Since it opened to traffic in 1987, the sleek, new Sunshine Skyway has won dozens of engineering and design awards.

Firth of Forth Bridge

Vital Statistics:



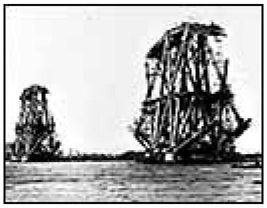
Location: South Queensferry and North Queensferry, Scotland
Completion Date: 1890
Cost: $15 million
Length: 8,276 feet
Type: Cantilever
Purpose: Railway
Materials: Steel
Longest Single Span: 350 feet (center span)
Engineer(s): Benjamin Baker, John Fowler

Golden Gate Bridge

Vital Statistics:

Location: San Francisco and Sausalito, California, USA
Completion Date: 1937
Cost: $27 million
Length: 8,981 feet
Type: Suspension
Purpose: Roadway
Materials: Steel, concrete
Longest Single Span: 4,200 feet
Engineer(s): Joseph B. Strauss

In the late 1800s, a railway bridge across Scotland's Firth of Tay swayed and collapsed in the wind. Seventy-five passengers and crew on a passing night train died in the crash. It was the worst bridge disaster in history. So when engineers proposed bridging the even wider Firth of Forth, the Scottish public demanded a structure that looked like it could never fall down. They got it.



Chief engineers Sir John Fowler and Benjamin Baker came up with the perfect structural solution: a **cantilever** bridge. The Firth of Forth Bridge is made of a pair of cantilever arms, or **beams** "sticking out" from two main **towers**. The beams are supported by diagonal **steel** tubes projecting from the top and bottom of the towers. These well-secured **spans** actually support the central span. This design makes the Firth of Forth Bridge one of the **strongest** -- and most expensive -- ever built.

But not everyone liked the design. The poet and artist William Morris declared it "the supremest specimen of all ugliness." Ugly or not, the Firth of Forth is a safe bridge. Even today, the highest winds barely shake this enormous structure. This is exactly what the people of Scotland needed after the Tay Bridge disaster. Unfortunately, a cantilever of this size comes with a hefty price tag. This is why very few like it have ever been built again.

Today, some call it the "most spectacular bridge in the world." But a century ago, building the Golden Gate Bridge seemed like an impossible task. Any bridge in this location would have to withstand brutal winds, tide, and fog. It would also sit less than eight miles from the epicenter of the most catastrophic earthquake in history. Only one engineer was willing to gamble that his bridge could withstand such destructive power. His name was Joseph Strauss.

Strauss used more than one million tons of **concrete** to build the **anchorages** -- the massive blocks that grip the bridge's supporting cables. The north **pier**, which supports the **tower**, was built easily on a **bedrock** ledge 20 feet below the water. But on the southern San Francisco side, Strauss had to build his pier in the open ocean, 100 feet below the surface. He built a huge water-tight cofferdam -- big enough to enclose a football field -- and pumped in hundreds of tons of concrete. By 1935, the towers were complete, and cable-spinning began. Two years later, the bridge was finished.

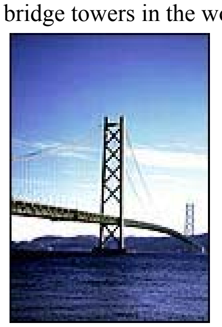
Strauss completed the $27 million bridge only five months after the promised date and $1.3 million under budget. For his efforts, Strauss received $1 million and a lifetime bridge pass.

Akashi Kaikyo Bridge

Vital Statistics:

Location: Kobe and Awaji-shima, Japan
Completion Date: 1998
Cost: $4.3 billion
Length: 12,828 feet
Type: Suspension
Purpose: Roadway
Materials: Steel
Longest Single Span: 6,527 feet
Engineer(s): Honshu-Shikoku Bridge Authority

In 1998, Japanese engineers stretched the limits of bridge engineering with the completion of the Akashi Kaikyo Bridge. Currently the longest spanning **suspension bridge** in the world, the Akashi Kaiko Bridge stretches 12,828 feet across the Akashi Strait to link the city of Kobe with Awaji-shima Island. It would take four Brooklyn Bridges to **span** the same distance! The Akashi Kaikyo Bridge isn't just long -- it's also extremely tall. Its two **towers**, at 928 feet, soar higher than any other bridge towers in the world.



The Akashi Strait is a busy shipping port, so engineers had to design a bridge that would not block shipping traffic. They also had to consider the weather. Japan experiences some of the worst weather on the planet. Gale winds whip through the Strait. Rain pours down at a rate of 57 inches per year. Hurricanes, tsunamis, and earthquakes rattle and thrash the island almost annually.

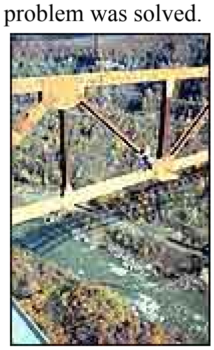
How did the Japanese engineers get around these problems? They supported their bridge with a **truss**, or complex network of triangular braces, beneath the roadway. The open network of triangles makes the bridge very **rigid**, but it also allows the wind to blow right through the structure. In addition, engineers placed 20 **tuned mass dampers** (TMDs) in each tower. The TMDs swing in the opposite direction of the wind sway. So when the wind blows the bridge in one direction, the TMDs sway in the opposite direction, effectively "balancing" the bridge and canceling out the sway. With this design, the Akashi Kaikyo can handle 180-mile-per-hour winds, and it can withstand an earthquake with a magnitude of up to 8.5 on the **Richter scale**!

New River Gorge Bridge

Vital Statistics:

Location: Fayetteville, West Virginia, USA
Completion Date: 1978
Cost: $37 million
Length: 4,224 feet
Type: Arch
Purpose: Roadway
Materials: Steel
Longest Single Span: 1,700 feet
Engineer(s): Michael Baker, West Virginia Department of Highways

The New River carves a deep gorge through southern West Virginia. For years, in order to cross the New River Gorge, drivers were forced to take a 40-mile detour or carefully wind down narrow mountain roads. Despite its scenic beauty, the New River Gorge was a major obstacle. It wasn't until the completion of the New River Gorge Bridge in 1977 that this problem was solved.



The New River Gorge was an ideal location for a **steel arch bridge**. The solid rock on both sides of the gorge would resist the outward thrust of the arch, making tall **towers** and deep **piers** unnecessary. In June 1974, **cables** were strung between temporary towers located on each side of the gorge. The steel sections of the arch bridge were pieced together over the gorge by trolleys running on these cables. After three years of construction and $37 million, the new bridge reduced a 40-minute drive around one of America's oldest rivers to less than one minute.

Today, the New River Gorge Bridge is the world's longest spanning, steel single-arch bridge. Soaring 876 feet above the rugged whitewaters of West Virginia's New River, it is also the second tallest bridge in the United States.

Channel Tunnel (Chunnel)

Vital Statistics:

Location: Folkestone, England, and Sangatte, France
Completion Date: 1994
Cost: $21 billion
Length: 163,680 feet (31 miles)
Purpose: Railway
Setting: Underwater
Materials: Steel, concrete
Engineer(s): Transmanche Link Engineering Firm

When England and France decided to link their two countries with a 32-mile rail tunnel beneath the English Channel, engineers were faced with a huge challenge. Not only would they have to build one of the longest tunnels in the world; they would have to convince the public that passengers would be safe in a tunnel this size. Tunnel fires, like the Holland Tunnel disaster, were common at this time. How did the engineers resolve this problem? They built an escape route.

The Channel Tunnel, also called the Euro Tunnel or Chunnel, actually consists of three tunnels. Two of the tubes are full sized and accommodate rail traffic. In between the two train tunnels is a smaller service tunnel that serves as an emergency escape route. There are also several "cross-over" passages that allow trains to switch from one track to another. Just one year after the Chunnel opened, this engineering design was put to the test. Thirty-one people were trapped in a fire that broke out in a train coming from France. The design worked. Everyone was able to escape through the service tunnel.

It took just three years for **tunnel boring machines** from France and England to chew through the chalky earth and meet hundreds of feet below the surface of the English Channel. Today, trains roar through the tunnel at speeds up to 100 miles per hour and it's possible to get from one end to the other in only 20 minutes!

New York Third Water Tunnel

Vital Statistics:

Location: New York, New York, USA
Completion Date: 2020
Cost: $6 billion
Length: 316,800 feet (60 miles)
Purpose: Water supply
Setting: Rock
Materials: Concrete
Engineer(s): Grow, Perini & Skanska; Lehiavone & Shea

Six hundred feet below the busy streets of New York City, engineers are boring a 60-mile-long tunnel -- the largest tunnel in America. This tunnel won't carry cars, trains, or even people, but it will deliver 1.3 billion gallons of water daily to nine million area residents. New York City's $6 billion Third Water Tunnel is one of the nation's largest and most complex public works projects ever attempted.

In 1954, New York City recognized the need for a new tunnel to meet the growing demand on its 150-year-old water supply system. Construction began in 1970 on the Third Water Tunnel, a tunnel designed to improve the dependability of New York City's entire water supply system. The majority of the tunnel is being carved with a 450-ton, 19-foot diameter rock-chewing device called a **tunnel boring machine**. Unlike the older water supply tunnels in New York City, water control valves in the Third Water Tunnel will be housed in large underground chambers, making them accessible for maintenance and repair.

When completed in 2020, the size and length of the Third Water Tunnel, its sophisticated valve chambers, and its depth of excavation will represent the latest in state-of-the-art tunnel technology.

Central Artery/Tunnel Project (Big Dig)

Vital Statistics:

Location: Boston, Massachusetts, USA
Completion Date: 2004
Cost: more than $10 billion
Length: 18,480 feet (3.5 miles)
Purpose: Roadway
Setting: Soft ground
Materials: Steel, concrete
Engineer(s): Bechtel, Parsons Brinckerhoff, Quaide Douglas

Some call the Central Artery/Tunnel Project in Boston, Massachusetts, the "largest, most complex and technologically challenging highway project in American history." Others consider it one of the most expensive engineering projects of all time. Locals simply call it the "Big Dig." By the time it's finished in 2004, the tunnel will be eight lanes wide, 3.5 miles long, and completely buried beneath a major highway and dozens of glass-and-**steel** skyscrapers in Boston's bustling financial district. What does it take to dig a tunnel like this? A lot of hard work and a handful of engineering tricks.

Today, engineers use special excavating equipment, called "clamshell excavators," that work well in confined spaces like downtown Boston. These special machines carve narrow trenches -- about three feet wide and up to 120 feet deep -- down to **bedrock**. In Boston, engineers are pumping liquid slurry (clay mixed with water) into the trenches to keep the surrounding dirt from caving in. Huge reinforcing steel **beams** are

Seikan Tunnel

Vital Statistics:

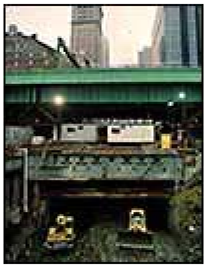
Location: Honshu and Hokkaido, Japan
Completion Date: 1988
Cost: $7 billion
Length: 174,240 feet (33 miles)
Purpose: Railway
Setting: Underwater
Materials: Steel, concrete
Engineer(s): Japan Railway Construction Corporation

In 1954, a typhoon sank five ferry boats in Japan's Tsugaru Strait and killed 1,430 people. In response to public outrage, the Japanese government searched for a safer way to cross the dangerous strait. With such unpredictable weather conditions, engineers agreed that a bridge would be too risky to build. A tunnel seemed a perfect solution. Ten years later, work began on what would be the longest and hardest underwater dig ever attempted.

Engineers couldn't use a **tunnel boring machine** to carve the Seikan Tunnel because the rock and soil beneath the Tsugaru Strait was random and unpredictable. Instead, tunnel workers painstakingly drilled and blasted 33 miles through a major earthquake zone to link the main Japanese island of Honshu with the northern island of Hokkaido. Today, the Seikan Tunnel is the longest railroad tunnel in the world at 33.4 miles in length, 14.3 miles of which lie under the Tsugaru Strait.

Three **stories** high and 800 feet below the sea, the main tunnel was designed to serve the Shinkansen, Japan's high-speed bullet train.

lowered into the soupy trenches, and **concrete** is pumped into the mix. Concrete is heavier than slurry, so it displaces the clay-water mix. The side-by-side concrete-and-steel panels form the walls of the tunnel, which will allow workers to remove more than three miles of dirt beneath the city.



As if tunneling beneath a city isn't hard enough, the soil beneath Boston is actually landfill -- it's very loose and soggy. Engineers had to devise a few tricks to keep the soggy soil from collapsing. Their solution: freezing the soil! Engineers pump very cold saltwater through a web of pipes beneath the city streets. The cold pipes draw heat out of the soil little by little. Once frozen, the soil can be excavated without sinking. Engineers also inject glue, or grout, into pores in the ground to make the soil stronger and less spongy during tunnel construction.

Unfortunately, the cost of extending the Shinkansen service through the new tunnel proved to be too expensive. In fact, air travel today between Honshu and Hokkaido is quicker and almost as cheap as rail travel through the tunnel. Despite its limited use, the Seikan Tunnel remains one of the greatest engineering feats of the 20th century.

Underground Canal

Vital Statistics:

Location: Lancashire County and Manchester, England
Completion Date: 1776
Length: 274,560 feet (52 miles)
Purpose: Canal
Setting: Rock
Materials: Brick
Engineer(s): John Gilbert, James Brindley

Beneath the old county of Lancashire, England, lie miles and miles of underground canal -- 52 to be exact. Considered an engineering masterpiece of the 18th century, the "Navigable Level," as it was known in its day, serves as a monument to the area's industrial past.

Francis Egerton, the third Duke of Bridgewater, wanted a canal to transport coal from his mines at Worsley to Manchester, a distance of 10 miles. He commissioned John Gilbert and James Brindley to build the Bridgewater Canal, a gravity-flow canal crossing the Irwell valley on an elevated structure supported by arches. Completed in 1761, the highly successful canal extended deep into the coal field and became a much more efficient way to transport coal from the country to the city. The Bridgewater Canal cut the cost of coal in Manchester in half.

Work started in 1759 as small teams of skilled miners cut into rock by hand, using only picks, hammers, shovels, and drills. Later on, they used **gunpowder** to blast through the hard ground. The canal was carved at a downward sloping angle, a design that allowed gravity to pull mining boats through the majority of the long, underground chambers. In 1776, the canal was extended an additional 30 miles, from Manchester to Liverpool. Years later, numerous side-branching canals were added, creating the longest underground canal system in the world.