# ANCIENT ENGINEERS TO MODERN INNOVATIONS TOUR OUTLINE GRADES 6-12

## OBJECTIVES:

When finished with this tour, the learner will be able to:

1. Describe the tools, materials, and techniques used in the ancient world and their impact on modern engineering
2. Compare and contrast ancient and modern engineering tools or practices in order to describe their use/impact
3. Analyze and discuss the role of solar observation in ancient and modern societies.

## VOCABULARY:

**Astronomy:** *the scientific study of the universe and the objects in it, including stars, planets, and nebulae. Astronomy deals with the position, size, motion, composition, energy, and evolution of celestial objects.*
**Cubit measurement:** *length of the arm from the elbow to the extended fingertips*
**Cuneiform:** *wedge-shaped characters used in the ancient writing systems of Mesopotamia*
**Digit measurement:** *width of finger as a measuring tool*
**Engineer:** *someone who designs and builds with a purpose in mind*
**Equinox:** *the time or date (twice each year) at which the sun crosses the celestial equator, when day and night are of equal length*
**Geomagnetic storm:** *a temporary disturbance of the Earth's magnetosphere. Associated with solar coronal mass ejections, coronal holes, or solar flares, a geomagnetic storm is caused by a solar wind shock wave which typically strikes the Earth's magnetic field 24-36 hours after the event.*
**Geometrics:** *straight lines and simple geometric shapes; measurement of the Earth, distances and space*
**Granite:** *a hard, crystalline igneous rock consisting mainly of quartz, mica, and feldspar*
**Greave:** *a piece of armor used to protect the shin*
**Grid:** *a framework of spaced bars that are parallel to or cross each other*
**Hieroglyphics:** *pictures or symbols representing objects, concepts, or sounds*
**Palm measurement:** *width of hand as a measuring tool*
**Plumb line:** *a cord that has a weight on one end and is used to determine vertical lines*
**Pythagorean Theorem:** *relationship among the three sides of a right triangle; the square of the hypotenuse (the side opposite the right angle) is equal to the sum of the squares of the other two sides*
**Quarry:** *a large, deep pit, from which stone or other materials are or have been removed for use*
**Relief:** *sculptural technique to give the impression that the sculpted material has been raised above the background plane*
**Renaissance:** *the time of the great revival of art, literature, and learning in Europe beginning in the 14$^{th}$ century and extending to the 17$^{th}$ century, marking the transition from the medieval to the modern world*
**Repoussée:** *a metalworking technique in which a malleable metal is ornamented or shaped by hammering from the reverse side to create a design in low relief. Most repoussée objects are also chased from the front to add fine details and sharp lines to the relief as in the case with the greave (54.2336).*

THE WALTERS ART MUSEUM

**Scribe:** *a person who learned how to read and write and was charged with writing documents*
**Solstice:** *either of the two times in the year, the summer solstice and the winter solstice, when the sun reaches its highest or lowest point in the sky at noon, marked by the longest and shortest days*
**Solar corona:** *an aura of plasma that surrounds the sun and other celestial bodies*
**Space weather:** *the state of the environment in space near the Earth*
**Stele:** *an upright stone or slab with an inscribed or sculpted surface, used as a monument or as a commemorative tablet*
**Sunspot:** *a temporary phenomenon on the photosphere of the sun that appears as a dark spot compared to surrounding regions. Sunspots correspond to concentrations of magnetic field flux that inhibit convection and result in reduced surface temperature compared to the surrounding photosphere. Individual sunspots may endure anywhere from a few days to a few months, but eventually decay. Sunspots expand and contract as they move across the surface of the sun.*
**Tablet:** *a flat slab of stone, clay, or wood, used for an inscription*
**Temple:** *a building devoted to the worship of a god or goddess*
**Trigonometry:** *the branch of mathematics that deals with the relations between the sides and angles of plane or spherical triangles*

## LIST OF HANDS-ON MATERIALS:

Baked clay cuneiform tablets
Foil with embosser cards and bronze medallions
Granite stone sample (igneous rock in docent room)
IPADS:
-Pictures of ancient Roman hand drills
-Pictures of aurora borealis
-Pictures of Baltimore exterior building reliefs
-Pictures of corona mass ejection
-Pictures of gyroscope
-Pictures of linothorax student project: https://www.uwgb.edu/aldreteg/Linothorax.html
-Pictures of solar cycle
-Picture of sunspot
-Pictures of temple alignments
- Pictures of Webb Space Telescope gold mirrors
-Picture of the stone cubit
-Satellite image of Egypt: http://www.primap.com/MapCollection/en/Free/Map%20Egypt%20Satellite%20+%20Borders%201600x1200.PNG
Laminated image of Engineering Design Process
Line level
Pre-knotted cubit rope
Reproduction of plumb line
Yard of hand-woven linen
Block of linen squares glued together
Visual of lost-wax casting technique
Wine bottle opener as an example of a t-shaped auger

## INTRODUCTION:

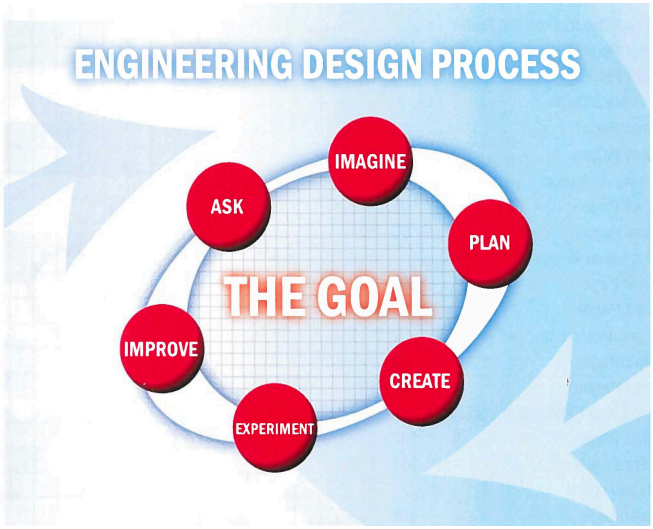
Introduce yourself and the museum while reviewing museum manners with students:
We are here today to see where art, engineering, and science cross paths. We will explore scientific, engineering, and artistic practices.

- Raise your hand if you like to make art.
- What kind of art do you like to make?
- Have you ever made an object/tool that was designed to help you do something or accomplish a specific task?
- What does an engineer do?

- Where do engineers get the materials they need to build?
- What objects do you use, on a daily basis that were designed by an engineer with a useful purpose in mind?

  The engineering design process is a series of steps that people follow to come up with a solution to a problem. Many times the solution involves designing a product that accomplishes a specific task.
- What problems do the objects you mentioned earlier solve?
- Can you think of other objects in your home or school that were created to solve problems?
- What would happen if an engineer got a measurement wrong? What would be the consequences?

Illustrate and discuss the engineering design process.




- What do you notice about the design process? Where does it start? Where does it end?

  It starts anywhere, it never ends, and there are different paths to arriving at the goal.
- Where do you see art in this process?
- Where do you see science?
- What makes you say that?
- What do you think ancient engineers, artists, and scientists created? What makes you say that?

Today we are going to explore some of the problems people in the ancient world faced, what they engineered and designed to help themselves, what advantages their projects gave them, and how those discoveries have impacted our lives today. We will examine objects from the ancient world in order to learn about our history while discussing how and why ancient civilizations solved problems, and how their solutions continue to help engineers today. When we look at the objects, we are going to focus on six questions:

- What problem does this solve?
- How was this made?
- Why do you think they designed it this way?
- What advantages did this design give?
- What do you use today that solves the same problem?
- How would you design it differently?

Keep these questions in mind as we time travel to the Ancient Near East, Ancient Egypt, and Ancient Greece.

## ANCIENT NEAR EAST

*Background information: The ancient Near East encompassed present day Turkey, Iraq, Iran, Syria, Lebanon, and Israel. The heart of this area, known as Mesopotamia, was the land surrounding the Tigris and Euphrates Rivers. The soil was fertile and the mountains surrounding the plains were rich in raw materials. Around 3000 B.C. recorded history begins, with the Sumerians in southern, Iraq, who are credited with creating one of the earliest writing systems. Show students where these objects come from while utilizing a map in your tour bag and/or the mosaic map in the Ancient World lobby.*

Protoliterate Tablet 41.219
Boundary Stone 21.10
Record of Temple Workers 48.1767
Sumerian Temple Hymn 48.1802
Copy of Victory Stele Inscription 41.109

Analyze and discuss writing tablets with students. Have students describe the object and decide on its purpose. Suggested discussion and questions:

- What do you think this is? How do you think it was made? Why do you think it was designed this way? What advantages did this design give? How would you design this differently and why?
  Compare and contrast similar challenges and solutions from our lives today?
- What information do you think was recorded on these tablets? What makes you say that? Why was the invention of a writing system so important in the ancient world? How did it change the way people lived their lives?
- Who learned to read and write in the ancient world? What is a scribe? Scribes recorded battles of defeated enemies as well as building designs for newly conquered land on some of these tablets. They also recorded hymns/songs for the mother-goddess Nintu, 20,000 names of temple workers, and grants of land on others. Below is a link to a cuneiform alphabet online translator. It requires WiFi, which will make it challenging to use in the galleries with an IPAD but you may find it useful for creating hands-on writing activities. http://www.paleoaliens.com/event/babylonian/index.html Discuss the advantages and disadvantages of stone and clay as a writing material.
- How do we use writing in our lives today? Connection to modern engineering: Discuss modern day references to symbolic writing such as smart phone emoticons used in text messages. Another example is that the development of writing systems in ANE and Egypt provided the concepts that eventually led to digital communication, a language of 1's and 0's.
- Scribes wrote on different shaped tablets depending on the type of information they wanted to record. If you were a scribe in the ancient Near East and were instructed to record a battle that took place, what tablet shape would you use to record the information? What makes you say that? The symbols used for the writing system are connected to the ideas or information represented. For example, if you wanted to convey information about a person, you might use symbols that look like body parts. What symbols would you use to represent a

battle? If you were instructed to write a poem about a sunset, what tablet shape would you use to record the information? What makes you say that? What symbols would you use to represent a sunset?

- Discuss the climate, landforms, and natural resources of the Near East. How would the climate affect what could and couldn't be designed? What makes you say that?
- Artists and craftsmen in the ancient Near East had lots of clay and wood at their disposal but stone was scarce. What did they have to consider when designing objects out of scarce material like stone? Keep in mind that outside objects did get wet. Why do you think they chose to make these objects out of stone as opposed to wood or clay? They used stone for decoration, like the Winged Genius, and for things that needed to last like boundary stones, and the cylinder seals. Why did the boundary stones need to be made out of permanent materials? They used clay for things that were disposable like instructions on how to build things or business letters. Why were these objects disposable? What would happen to the hardened clay if it got wet?

Information on boundary stones near Balitmore:
http://greatergreaterwashington.org/post/12503/boundary-stones-the-oldest-monuments-in-the-district/
http://www.boundarystones.org/
https://www.washingtonpost.com/express/wp/2014/08/29/d-c-s-historic-boundary-stones-are-being-preserved/

Model of Chariot 48.1965
Analyze and discuss the model of a chariot with students. Have students describe the object and decide on its purpose. Suggested discussion and questions:

- How do you think people moved goods and materials or travelled across long distances in the ancient world?
- What do you notice about this object? How do you think it was used?
- How do you think this object was made? Why do you think it was designed this way? What advantages did this design give? How has this design changed over time?
- What materials were needed to make a wheel and axle? How would this cart move? What would happen if the engineer got a measurement wrong? What would be the consequences?
- What tools would an ancient engineer have needed to make this chariot on a larger scale? What makes you say that?

  A t-shaped auger was a long drill bit with a pair of wooden handles for rotating it. The tool looks like an oversized corkscrew and was used to drill large and deep holes in wood. These were used by shipbuilders, bridge builders, and in wheel construction.

- Why do people make models or prototypes and how are they used?
- What steps would an ancient engineer have taken to invent the wheel?

Observe round things rolling downhill, figure out that circular things could be created to do that, most easily from tree trunks, invent a method to get it completely round. But what can you do with one wheel? (Not much without an axle.) What about two wheels? Need something to connect them. Need to make sure they rotate. Then need to place a cart on top of them.

- How do you think a cart like the one in our model would be used?
  It could be pulled by an animal. One person could balance on it. What would make it even more useful? Four wheels and a platform.

  *Background information:* *The tricky thing about the wheel is not conceiving of a cylinder rolling on its edge, it's figuring out how to connect a stable, stationary platform to the cylinder. (Wheel-and-axle concept) To make a fixed axle with revolving wheels, the ends of the axle had to be nearly perfectly smooth and round, as did the holes in the center of the wheels, otherwise there would be too much friction for the wheels to turn. The axles had to fit snugly inside the wheel's holes, but not too snugly as they have to be free to rotate. The success of the whole structure was extremely sensitive to the size of the axle. While a narrow one would reduce the amount of friction, it would also be too weak to support a load. A thick axle would hugely increase the amount of friction. Access to wide slabs of wood from thick-trunked trees to carve large, round wheels were necessary. Metal tools to chisel fine fitted holes and axle where also needed.* *https://www.scientificamerican.com/article/why-it-took-so-long-to-inv/*

Activity: Have students work in groups or pairs to experiment with one wheel, then two wheels and an axle.

- What modern innovations use wheels?
- How are these similar to early uses of the wheel?

Additional information and discussion topics:

- Sumerians developed concepts such as base 60, square root, algebra, 360 day year, 360 degree circle, 12 signs of the Zodiac
- The concept of zero, which improved the use of math in engineering applications originated in the ancient Near East.

## ANCIENT EGYPT

We are going to uncover ancient design practices and learn about the materials and techniques that were used in Egypt to make buildings and sculptures. Discuss the climate and topography of Egypt. The first questions that an ancient Egyptian architect or engineer would have to ask would be where to put the building and what materials to make it with.

Temple Relief Fragment of Ptolemy ll Offering Incense 22.176
Temple Relief of Ptolemy ll Philadelphos 22.8
Temple Relief Fragment of Ptolemy ll Offering to Osiris and Another God 22.200
Corner Relief Fragment with King Ptolemy ll Philadelphos, Mehyet, and Onuris-Shu 22.5
Temple Relief of Nectanebo II 22.119

Analyze and discuss relief sculpture with students. Have students describe the object and decide on its purpose.
Suggested discussion and questions:

- How do you think this object was used?
- How do you think this object was made? Why do you think it was designed this way? What advantages did this design give? How has this design changed over time?
  Show students granite sample and pass around to touch.

*Background information:* *These blocks came from exterior walls of temples in ancient Egypt and were constructed entirely of granite, an extremely hard and heavy stone that was brought from quarries 600 miles away. These blocks are carved in sunken relief, a technique that is better able to withstand erosion from wind-blown sand. Sunken relief also stands out better in strong, direct sunlight. Each relief shows a king presenting offerings to deities.* What decorations have you noticed on Baltimore buildings? *Show students images of Baltimore exterior building reliefs.*

- If students have already seen the cuneiform tablets, compare cuneiform with hieroglyphics using the laminated cuneiform sheet. What are hieroglyphs? What advantages did this writing system give the ancient Egyptians? How is it different from cuneiform? How is it similar to cuneiform? What makes you say that? How do you think writing was used in the ancient world?
- Ancient sun observers, like the Egyptians, built temples and pyramids to mark solar alignments that they observed at different times of the year, particularly around the solstices and equinoxes. Describe the solstice and equinox. Describe and share examples of temple alignments. Why do you think it was important for the ancient Egyptians to track when these events happened? If you were a farmer in ancient Egypt, where there are few changes in the seasons, how would you know when to plant? What would be the consequences of not knowing when to plant? *Direct students to observe map.*

*Statue of Osiris 54.551*

Describe and discuss the Statue of Osiris and connections to ancient Egyptian agriculture.
Suggested discussion and questions:

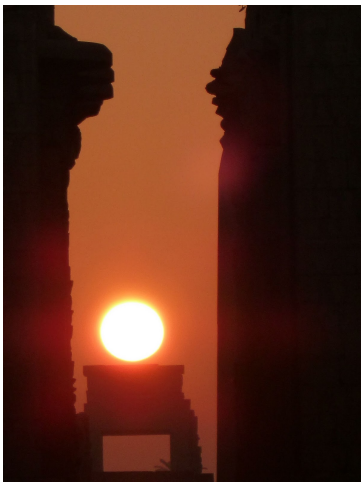
- Who do you think this person was in ancient Egypt? What did you see that made you say that?
- What do you think he is holding in his hands? How do you think those tools might have been used in ancient Egypt?

*Background information:* *The center of Egyptian civilization was the Nile River (show students satellite image of Egypt and observe the narrow band of green around the Nile and Faiyyum), which flooded every year at the same time and provided rich soil for agriculture. Understanding the cycles of the sun allowed people to know when to plant, harvest, or move to a different location. Through careful, on-going observation they were able to know that a sunny day in February was not truly the beginning of spring. They were able to recognize that the flooding of the Nile always occurred at the summer solstice, which was also when the bright star Sirius rose before the sun. Ancient Egyptians discovered the importance of the spring equinox as the start of the planting season. Astronomically, this occurs when the sun rises on the eastern horizon, halfway between its extreme winter position and its extreme summer position.*

An example of an alignment is the Hypostile Hall of the Temple of Karnak. Share and discuss images of the Hypostile Hall of the Temple of Karnak .

The solstice sunrise appears through the entryway of the temple of Karnak, one of hundreds of Egyptian sites built in alignment with celestial events. Astronomy was arguably the first science. People throughout time and across cultures have carefully observed the sky and noticed the patterns of motion in the sun, moon, and stars.

- If you were the engineer tasked with making one of these buildings in ancient Egypt, how would you figure out how to build a temple structure that aligns with the sun? Who would you go to for help? What are the experiments you would try?
- The earliest form of trigonometry was studied in Egyptian mathematics. What is trigonometry? Trigonometry helped the ancient Egyptians measure the rotation of the earth and the angles of the sun and moon risings. To build the building they probably used a type of math called geometrics. What do you think this is? They used this to measure straight lines, distances and space. Where would they have used these measurements? What would happen if the math was off on the structures made to mark the seasons? What would be the consequences?



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Additional information and discussion topics:
http://arxiv.org/ftp/arxiv/papers/1207/1207.6942.pdf

Isis with Horus the Child 54.416

The sun was incredibly important in Egyptian mythology, and the Egyptians believed in gods and goddesses they thought could control the sun.

Analyze and discuss Isis with Horus the Child sculpture with students. Have students describe the object and decide on its purpose.

Suggested discussion and questions:

- How do you think this object was used?
- How do you think this object was made? Why do you think it was designed this way? What advantages did this design give?
- What do you know about Egyptian mythology? What is a myth? Why did ancient cultures develop myths?
- Who do you think the people portrayed in this sculpture are? How do you think they relate to the sun? What did you see that makes you say that? Which gods or goddesses in Egyptian mythology represent the sun?
  The sun was represented by various gods, which one depended on its position. A rising morning sun was Horus, the divine child of Osiris and Isis. His mother Isis and Horus are portrayed in this sculpture. Isis wears a sun-disk. The noon sun was Ra because of its incredible strength. All forms of life were believed to have been created by Ra. It was believed that he wept and from his tears came man. The evening sun became Atum, the god who lifted pharaohs from their tombs to the stars. After the sun had set, it became Osiris, god of death and rebirth.
- Why do you think Egyptians worshiped the sun?
- What is astronomy?
  Astronomy played a considerable role in fixing the dates of religious festivals, planting seasons, and determining the hours of the night. How is astronomy still important to us today? How has the technology we use to make observations of the sun changed, and what have those changes allowed us to do?
  Scientists still study the sun today using satellites and sophisticated instruments not available to the ancient Egyptians. Why do we continue to make observations of the sun?
- What effects do you think Earth experiences as a result of space weather?
  Geomagnetic storms affect our technology, causing blackouts, satellite interference affecting GPS signals, avionics. Scientists study the sun and the geomagnetic storms through several satellites. A satellite called IMAGE was launched in 2000 to understand and predict space storms and their effect on power systems here on earth. Another satellite is called SOHO, which studies the internal structure of the sun, the corona, the solar wind and plasma that affects the magnetosphere. Often, scientists and engineers will work together. The scientist asks "why and how does this happen?" and the engineer thinks more big picture on how to apply scientific concepts for specific purposes.
  https://www.youtube.com/watch?v=HJfy8acFaOg
  https://www.youtube.com/watch?v=Zk09bTCY3Mw

  *<u>Background information:</u> One of the main reasons that scientists study the sun through satellite technology is space weather. Through careful observation of the sun over time, we have learned that the sun goes through an 11-year cycle of minimum and maximum solar spots. When we reach maximum sunspots the magnetic field breaks and a chunk of the solar corona is released. This blast of energy is referred to as a solar flare and travels at the speed of light. This traveling solar flare that is also known as solar wind or a corona mass ejection reaches earth a few days later. The Earth is protected from the corona mass ejection by our magnetic field, however this space weather can be seen at the poles as the aurora borealis. This is called a geomagnetic storm.*

Additional information and discussion topics:

- Egyptians erected huge obelisks exactly perpendicular
- The large pyramid at Giza was the largest man-made object until the 19th century when the Washington Monument in D.C. was built

Seated Statues of Sekhmet

Describe and discuss statues of Sekhmet.

We will examine ancient Egyptian statues, carvings, and buildings and explore ancient Egyptian tools and building techniques.

Suggested discussion and questions:

- Who do you think this person was in ancient Egypt? What did you see that made you say that?
  Sekhmet was one of the goddesses the ancient Egyptians believed could either help them or hurt them. The king, or pharaoh, erected many statues to appease the goddess and convince her not to use her negative powers, thereby delivering the king from illness and evil for a year. Based on our understanding, there may originally have been 730 statues, one seated and one standing for each day of the year.
- If you were the ancient engineer tasked with creating multiple statues, how would you measure and carve them all to look alike? Who would you go to for help? What are the experiments you would try?
- Introduce students to ancient Egyptian measuring systems. When artists and construction workers build sculptures and buildings today, what do they use to measure? What do you think the ancient Egyptians used to help them measure statues?
  Cubit: based on the length of the arm from the elbow to the extended fingertips. Go to a doorway in the gallery and ask students, how many cubits long is the doorway? Assist students in using their arms to measure the doorway in cubits. Compare arms.
  Palm: used width of hand as a measuring tool. Challenge students to measure something in the gallery using the width of their hand. (The term "hand" is still used today to measure horses. And the term "foot" is used in American measuring systems to denote a 12" length.)
  Digit: used width of finger as a measuring tool. Challenge students to measure something in the gallery using the width of their finger

  *Background information: The cubit was standardized by a royal master cubit of black granite, against which all cubit sticks or rules in use in Egypt were measured. The cubit was standardized from a pharaoh's arm. Students can search for a hieroglyphic forearm symbol in Relief with Hathor and King Necho II. Show image on iPad of cubit measuring stone from The British Museum. Note intermediate markings and introduce smaller measures.*

- What if you used different arms to measure the cubits of a statue or building as you were creating it? What would be the consequences? Why was a standard of measurement important?

Ostracon with Royal Head 32.1
Sculptor's Model 22.285
Woman Kneeling Before Offering Table 32.2

Describe and discuss models and sketches with students.
Suggested discussion and questions:

- How do you think an ancient engineer would convey instructions to all the various sculptors responsible for carving 365 similar statues? In addition to conveying measurements, ancient builders would create models and sketches. On some models or sketches we are still able to see traces of grid lines used by ancient artists to ensure the correct layout and proportion/scale of a work of art.
- How do you think ancient engineers where able to measure straight vertical lines, or specific angles to build sculptures or pyramids? What makes you say that? How do we measure vertical or horizontal lines today? Describe how ancient Egyptians used plumb lines. Demonstrate how the plumb line was used. Take students around the gallery and practice using the plumb line to measure vertical lines with them.
- How do you think ancient engineers determined if something was level horizontally? What substance or material will become level based on gravity? (Water.) Show image of puddles on iPad. Can you think of a more modern tool we use to determine level that uses water? Show plastic level with a bubble in the water.
  Ancient Egyptians developed a way of determining vertical and horizontal (plumb and level), in order to determine the position of objects. This same technology was used by modern engineers to develop gyroscopes. A gyroscope is a spinning wheel in which the axis of rotation is free to assume any orientation by itself. Useful for measuring or maintaining orientation in magnetic compasses and stabilizing flying vehicles, boats and ships, bicycles, space shuttles, yo-yos, and Frisbees . (Image on iPad) Scientists and engineers have developed a measuring system using lasers to measure distances of objects outside our solar system, which are extremely far away. What measuring system is used to measure deep space? Light-years: the distance light travels in one year, how distance is measured in space.
- How do you think people, goods, and ideas traveled throughout the ancient world?
- How do you think ancient sailors navigated and calculated distances? What do you think happened when ancient sailors miscalculated?
  Share map and discuss maritime travel in the ancient world. Many of the same observations the Egyptians used in situating their buildings were used to navigate on the sea. The Greeks developed mathematics even more than the Egyptians, and used the Pythagorean Theorem to help measure the distance between two points. Ask students if they are familiar with this term and if they can define what it is.

## ANCIENT GREECE AND ROME

Corinthian-Type Helmet 54.2303
Left Greave 54.2336
Assemblage from a Warrior's Burial 54.2456
Assemblage from a Warrior's Burial 57.1944, 57.1945, 57.1946, 57.1947
Analyze and discuss armor and burial assemblage with students. Have students describe the object and decide on its purpose.
We will explore the materials and techniques used to create ancient Greek armor.
Suggested discussion and questions:

- How do you think these objects were used in ancient Greece? What problems do they solve?

- How do you think these objects were made? Why do you think it was designed this way? What advantages did this design give? How would you design this differently and why? What body parts do you think these pieces were created for?
- How are these objects similar to things in our lives today? What do we use today that solves a similar problem?
- If you were the engineer in ancient Greece tasked with making this armor, what materials or process would you use? Who would you go to for help? What experiments would you try? What would be the consequences of getting something wrong?
- What materials were used to make these objects? How are similar materials used in our lives today? Why do you think ancient armor was made out of this material?
  Many of these objects were made out of a metal called bronze. Bronze is made up of a combination of other metals, copper and tin.
- How are these objects decorated? Why do you think the armor was decorated? What process was used to create the decorative elements?
  The armor is decorated using a technique call repoussée. Objects were most likely hammered from the reverse, with a temporary backing of pine, pitch or similar material. It was then finished by chasing from the front. Distribute materials and assist students as they practice the repoussée technique with tin foil, embosser cards, and bronze medallions.
- How do you think individual pieces of armor were attached to form a complete set that a soldier would wear? What makes you say that?
  Tiny holes lining the top and bottom edges secured a fabric lining and leather strips for attachment to the leg.

Bronze Helmet 54.2456

- How do you think this helmet was created? Compare and contrast hammering and casting techniques.
  Recent scholarship has indicated that some Corinthian helmets were cast in forms similar to their finished shapes, but they are always finished by cold working and annealing, not only to thin the metal but also to work and harden it. The decorative bauding on the helmet is incised, which is also a cold-working technique though it is possible that this object was partly cast. For a better example of the lost-wax casting process view some of the statuary in this gallery. The lost-wax casting technique became the major technique for production in bronze.
  Illustrate and discuss the lost-wax technique using visuals.
    - Step 1: Model is fashioned in solid wax.
    - Step 2: Model is surrounded with clay and then heated in order to remove the wax and harden the clay.
    - Step 3: Hot liquid bronze is poured into the hardened clay model.
    - Step 4: When metal cools the bronze-smith breaks open the clay model to reveal a solid bronze reproduction.

Assemblage from a Warrior's Burial 57.1944, 57.1945, 57.1946, 57.1947

- How do you think these objects were used? What did you see that made you say that?

These objects were found in a tomb and once adorned the body of a deceased warrior. They are made of hammered gold sheets.
Discuss the properties of gold. Gold is shiny and does not tarnish. Gold is a very soft metal and easy to bend and fold and hammer to a thin sheet. The ancient Greeks were aware of these properties and used gold for decorative items and jewelry. They became very adept at working with gold. See jewelry in Ancient Treasury.

- How is gold used in our lives today? How do modern engineers use gold?
  Gold shines without tarnishing and can be made very thin. Show image of the Webb Space Telescope, which uses microscopically thin layers of gold on its 18 large mirrors. Gold improves the mirror's reflection of infrared light.

Red-Figure Calyx Krater 48.262

Analyze and discuss the vessel with students. Have students describe the object and decide on its purpose.
The Ancient Greeks admired prowess in battle, and trained young men in the arts of war. The need for personal protection would have been very real for the Greek warrior. We've talked about forging bronze and making helmets. But the body would also need protection.
Suggested discussion and questions:

- How do you think this object was used in ancient Greece? What problems did it solve?
- How do you think this object was made? Why do you think it was designed this way? What advantages did this design give? How would you design this differently and why?
- What is illustrated on this vessel? In addition to the helmet, what is the young man wearing to go into battle? Discuss the need for body protection, but with the limitations of climate, weight and movement.
- What material could be used to create armor that was lightweight, cool, and flexible?
  Demonstrate linothorax armor. Ancient Greeks used bronze to make protective helmets and greaves, but created something lighter for body armor called the linothorax. Show students strips of linen and ask if this could protect a Greek soldier from an arrow. Ask them to brainstorm ways the linen could be made stronger. Show IPad images demonstrating how linothorax was made.
- Compare ancient armor to modern day protection. Modern hi-tech comparisons include Kevlar, Gore-Tex, and Under Armor fabrics all of which solve particular problems. NASA also has to consider materials that are both protective and light when they engineer spacecraft.

Additional information and discussion topics:

- Gregory S. Aldrete, *Reconstruction Ancient Linen Body Armor: Unraveling the Linothorax Mystery*, 2013.

Alternative locations to discuss metalworking:
Ancient Treasury or Etruscan Gallery metal objects.
Discussion Topics:

- Gold as a metal and why it was used for jewelry, why it was valued even in ancient times
- Techniques used: stamping, molding, wire twisting, and beading (granulation).
- Similar techniques were used for making and decorating armor and weaponry.
  Demonstrate repoussée, and discuss casting for helmets etc.

## CONCLUSION

We have explored materials and techniques used throughout the Ancient World. Like ancient artists, modern engineers are constantly altering designs and improving existing inventions after many trials. They don't give up when something doesn't work the first, second, or 50th time.

- How is the artistic process similar to the engineering/design process?
- How did ancient artists utilize the artistic and engineering/design process across different cultures and time periods?
- Why did ancient civilizations create structures to observe the sun?
- How and why do we continue to observe the sun today?
- What tools materials or techniques did ancient civilizations use that have impacted our lives today?

Resources for additional information:
*http://www.smithsonianmag.com/history/the-secrets-of-ancient-romes-buildings-234992/?no-ist*
*http://www.smithsonianmag.com/magazine/earliest-and-greatest-engineers-were-incans-180947976/*
*http://www.smithsonianmag.com/history/what-heck-cuneiform-anyway-180956999/?no-ist*
*http://jhupressblog.com/2013/04/24/unraveling-the-linothorax-mystery-or-how-linen-armor-came-to-dominate-our-lives/*
*https://www.ted.com/talks/sarah_parcak_archeology_from_space?language=en#t-36147*