SCIENCE, TECHNOLOGY, ENGINEERING, AND MATH

COLORADO STATE UNIVERSITY EXTENSION

# ST[EMpower]

# EARTH IN SPACE

VOLUME 8, ISSUE 2, FEBRUARY 2019

## THIS MONTH':

- EVERYTHING IS MOVING
- MILANKOVITCH CYCLES
  - OBLIQUITY
  - PRECESSION
  - ECCENTRICITY
  - SYNERGY
- CAREER CONNECTION - ORGANIZATION

## POWER WORDS

- **eccentricity**: deviation of an orbit from circular towards elliptical or egg-shaped
- **obliquity**: astronomical term describing the angle of tilt of the Earth's axis of rotation, currently at 23.5°
- **precession**: the slow movement of a spinning body's axis changing because of torque
- **torque**: a twisting force

## CAREERS

*You are collecting a lot of information as you explore career options. This issue's Career Connection provides a way to organize these data.*

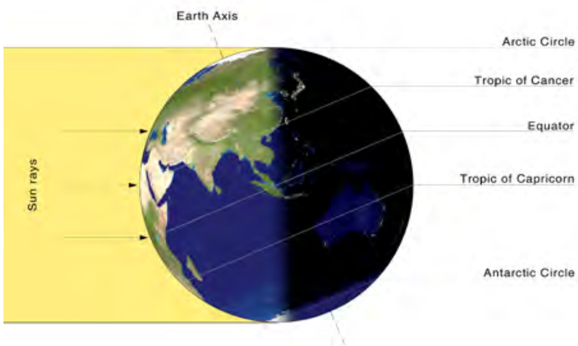
*See page 18 for careers activity on Mind Maps in this month's issue.*

## OUR EARTH IS CONSTANTLY MOVING

Last month, the activities focused on the reason for the seasons as the Earth orbits the Sun at a 23.5° angle to the plane of the Solar System. When the Earth is tilted away from the Sun, it is winter, and when tilted towards the Sun, summer. This is true for both the Northern and Southern Hemisphere, but opposite seasons. The Northern Hemisphere is tilted towards the Sun during our summer the same time the Southern Hemisphere is tilted away, so winter there.

This issue introduces very complex concepts of motion in space. Our Earth rotates on its axis. The moon rotates on its axis, and orbits the Earth. The Earth/Moon System orbit the Sun, as the Sun moves with the Milky Way Galaxy. The Galaxy moves with the Local Group, and different galaxy groups are moving.

So, with all this celestial dancing, how does that impact us on Earth? Recall that last issue touched on the Ice Ages that happened over the past 500,000 years. Before that,



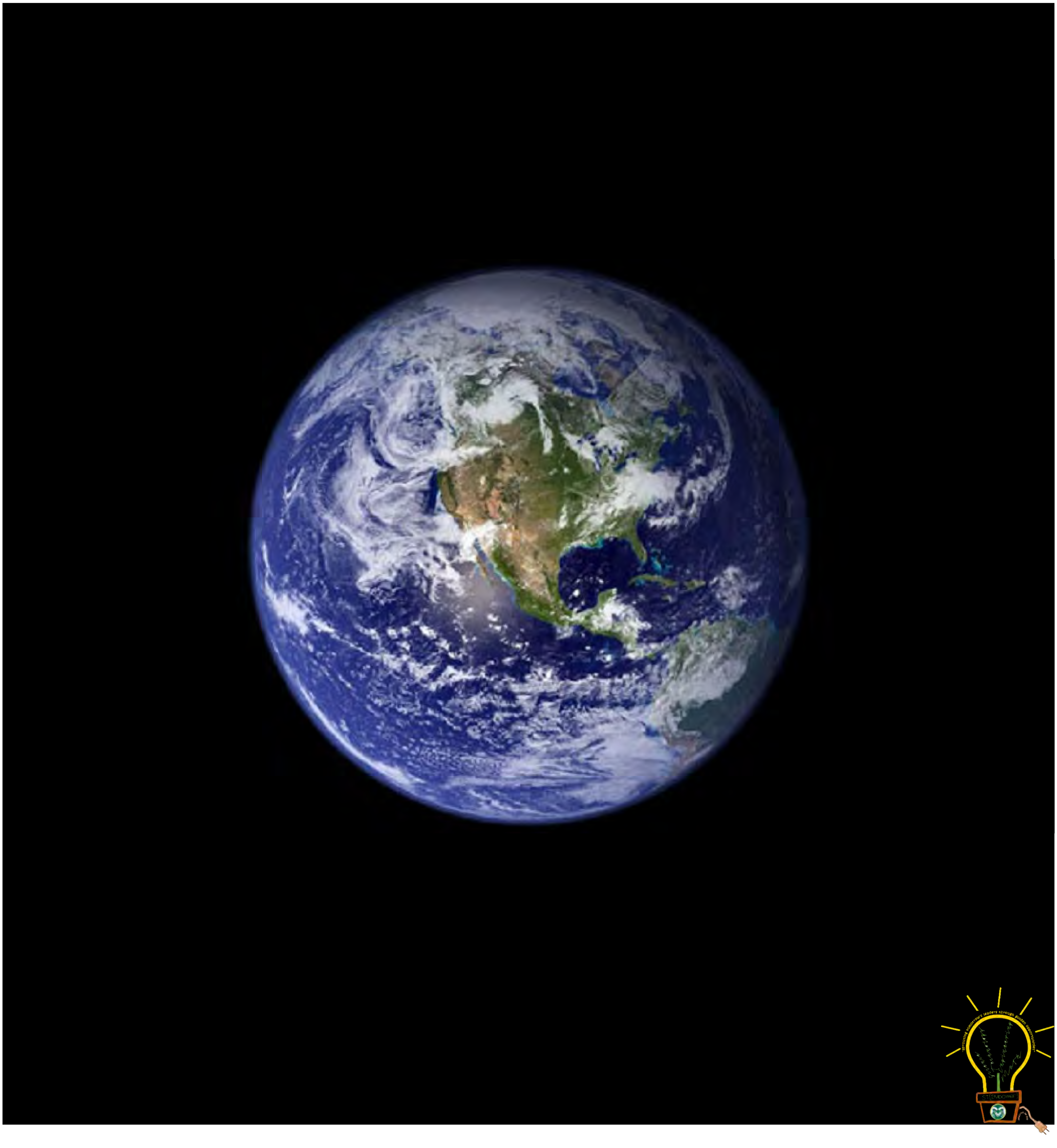

during the time of dinosaurs, the Earth was much warmer. Before that, the atmosphere trashed (as all the continents crashed together). Before that, much of the Earth was a gigantic swamp. Before that, the Earth was a gigantic Snowball.

These are very difficult concepts, but really cool to consider. Milutin Milankovitch was a Serbian astrophysicist who lived from 1879-1958. He is known for developing significant theories on Earth's long-term climate changes. He described three different motions of the Earth in relation to the sun that can help explain those long-term changes, which we now call the Milankovitch cycles.

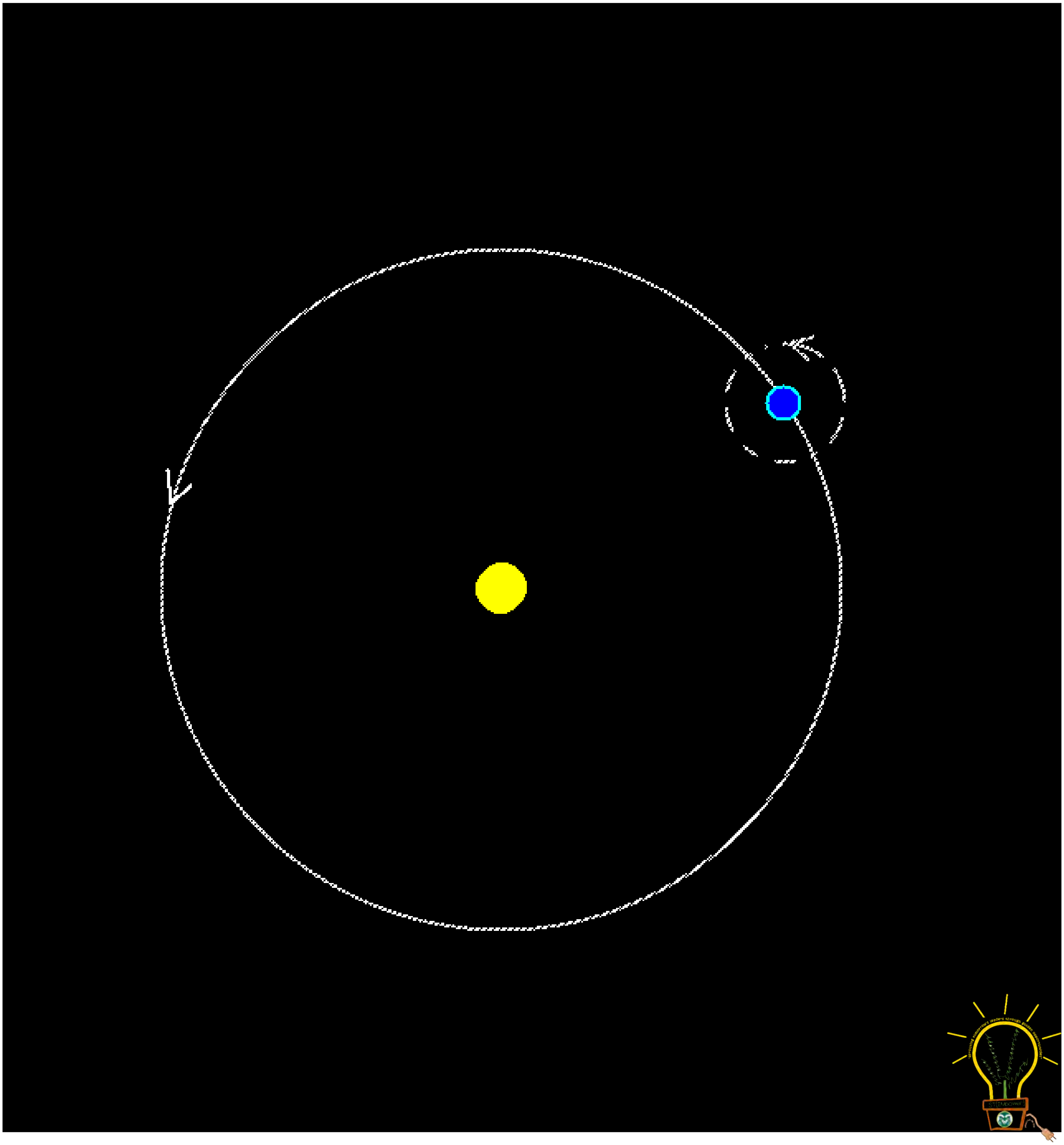
I was stopped by a police officer.  He asked, "Do you know how fast you were going?"

I replied, "That, sir, is relative..."

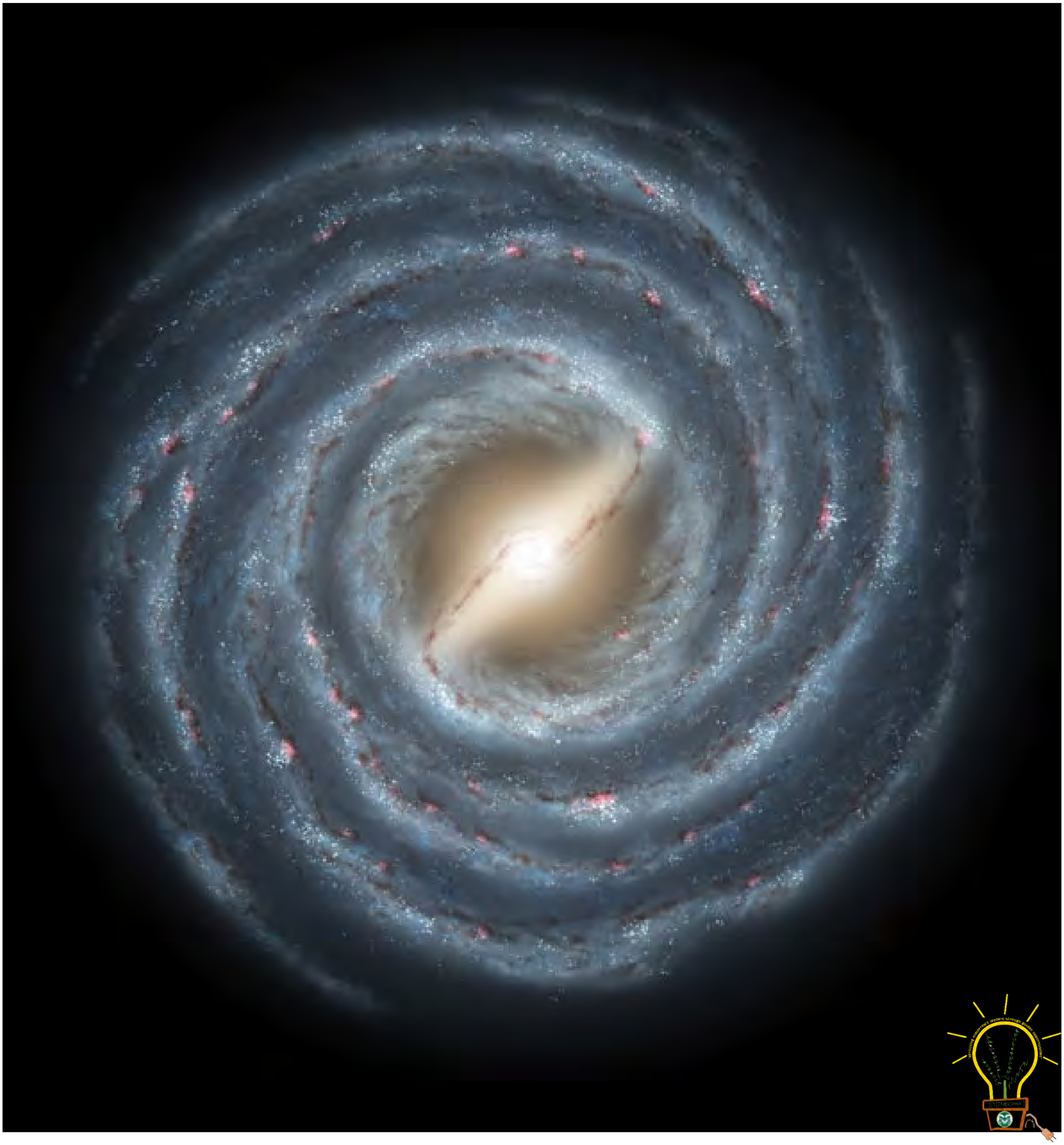
"I was driving 75 miles per hour but the Earth at the Equator is rotating on its axis at 1,040 miles per hour.  In Colorado, that is about 600 miles per hour..."



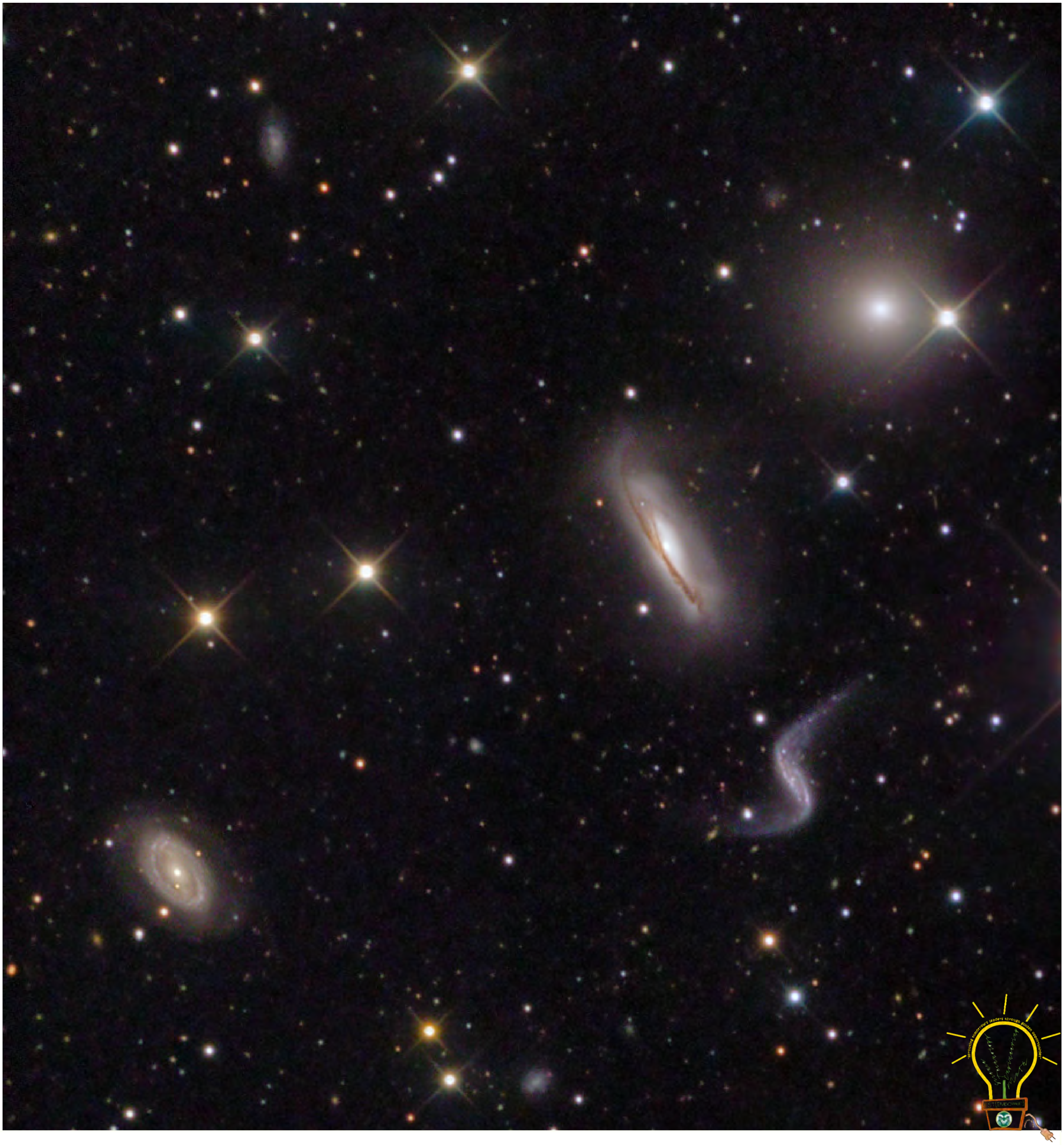
"The Earth is orbiting the Sun at 67,000 miles per hour..."



"The Solar System, with the Sun in the center, is revolving with the Milky Way Galaxy at 486,000 miles per hour..."



"The Milky Way Galaxy is moving with the Local Group towards the Constellation Hydra at 1,340,000 miles per hour..."



"So, you see sir, it is all relative."

I still got the ticket.

If the Earth is moving 1,894,040 miles per hour (1040 + 67,000 + 486,000 + 1,340,000 mph), then why can't you feel the motion?

Think about riding in a car. Can you feel the motion then? Do you feel it all the time? Why do you feel the motion sometimes but not others?

Sir Isaac Newton stated in his First Law of Motion: An object at rest stays at rest and an object in motion stays in motion with the same speed and in the same direction unless acted upon by an unbalanced force.

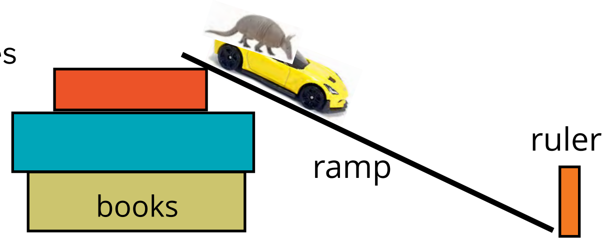
If the vehicle is constant in speed and direction, you do not feel the motion in the vehicle. You only feel the motion when the car changes direction, speeds up or slows down: the unbalanced forces.

We don't feel the Earth's motion because it is all balanced motion, constant speed and same direction. The atmosphere, trees, houses, mountains, oceans are all moving at the same, constant speed. If the Earth were to slow down or speed up, we would feel the motion then.

If you jump as high as you can, you will land in the same spot. What if you jump in a bus while the bus is traveling 50 mph? You and the bus are traveling at the same speed, so you would land is the same spot!

## Object in Motion

- Make as long a ramp as possible from a cardboard box using the scissors/box cutter.
- Stack three thick books to raise one end of the ramp.
- Measure the height of the books with the ruler, and the length of the ramp. Record in the data sheet the first column.




- Place a ruler at the bottom of the ramp and tape in place to stop the toy car suddenly.
- Place the object in the seat or bed of the toy vehicle.
- Place the vehicle at the top of the ramp with the back wheels at the edge.
- Do not push, but release the vehicle.
- Observe the object as the vehicle rolls down the ramp.
- What happens when the vehicle strikes the book at the bottom of the ramp.
- What are the different variables?
  - Height of ramp (# books)
  - Length of ramp
- Directions continue page 9.

> You never fail until you stop trying.
> Albert Einstein

### POWER WORDS

- **galaxy**: a system of millions or billions of stars, gas, and dust, held together by gravitational forces
- **local group**: a group of 54 galaxies that includes the Milky Way held together by gravitational forces
- **solar system**: the collection of eight planets and their moons in orbit around the Sun, together with smaller bodies in the form of asteroids, meteoroids, and comets
- **universe**: all existing matter and space considered as a whole; the cosmos; believed to be at least 10 billion light years in diameter and contains a vast number of galaxies, has been expanding since the Big Bang about 13 billion years ago
- **variable**: able to be changed

## MATERIALS

- Pages 2-7 to read
- copy page 9 and 10 for recording and analyzing data
- black, blue, red, and green pencils
- toy vehicle (i.e. hot wheels or matchbox) either convertible or truck with a bed)
- object: toy figure, dried bean, marble, or other small object
- ramp (recycled corrugated cardboard box)
- 3 thick books about the same thickness
- ruler
- masking tape
- sharp scissors or box cutter

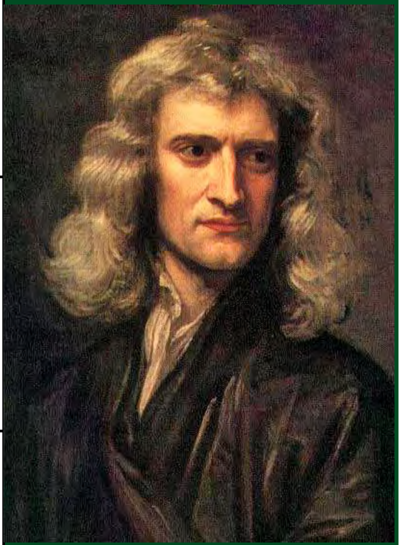
## First Law of Motion Datasheet

| Trials / Height | Trial A Distance Object was Thrown | Trial B Distance Object was Thrown | Trial C Distance Object was Thrown | Average Distance Object was Thrown |
|---|---|---|---|---|
| 3 Books: Ramp Length: | | | | |
| 2 Books: Ramp Length: | | | | |
| 1 Book: Ramp Length: | | | | |
| 3 Books: ½ Ramp Lngth: | | | | |

- Repeat 3 times (Trial A, B, and C) at each height (3, 2, and 1 book).
- Measure the distance from the end of the ramp to then landing point of the object and record.
- Calculate the average (add the three distances the object was thrown divided by 3).

## Three Laws of Motion

Newton lived from 1643 to 1727 in England. His research included motion, gravity, optics, light, and he also developed a branch of calculus.



SIR ISAAC NEWTON

- Graph the results.
- Be sure your graph has labels and a legend.

### WHAT DO YOUR DATA MEAN?

- Does that question sound funny? The word "data" is a plural word. The singular of the plural word data is datum.
- What happens to the object as it travels down the ramp on the vehicle?
- What happens to the object when the vehicle suddenly stops?
- How does this apply to Newton's First Law of Motion?
- How does the height of the ramp change the object when it is thrown from the vehicle?
- What happens with the ramp is shorter?

## Obliquity - Axial Tilt of Earth

The Earth's tilt to the plane of the solar system is 23.5°. It has not always been that way. There is a slow shift of the tilt from 22.1° to 24.5° over a 20,500 years and another 20,500 years to return (41,000 cycle).

What happens to the solar radiation's angle of incidence when the tilt is 22.1°? What about 24.5°? It is only 2.4° difference, so does it really make an impact on our climate?

Last month, you conducted an experiment on angle of incidence with the 23.5° axial tilt the Earth is currently. This tested the amount and intensity of sunlight striking the Earth during the Summer Solstice, Spring and Fall Equinoxes, and the Winter Solstice (see 48.Climate: http://tra.extension.colostate.edu/stem-k12/stem-resources/).

This activity will replicate the summer and winter solstices, during maximum and minimum axial tilt of the planet.

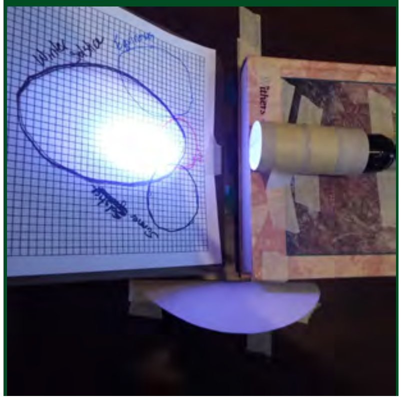
Build the experiment:

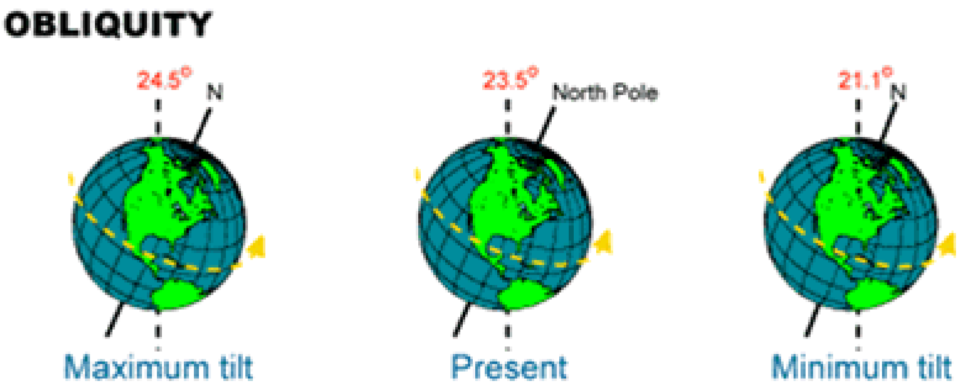
- The base for the experiment must be 5 to 8.5 cm high (2-3"). Use a corrugated thin box or a large hardcover book. Tape the TP tube on the top edge of the box/book, making sure the TP tube is aligned 90° with the box.
- Align and place the flashlight just into the TP tube, and tape the flashlight on the box.
- Print three copies of the graph paper (page 10), and attach one sheet to the clipboard. With a bit of masking tape, secure the bottom of the paper to the clipboard so it won't move.
- Set the book/box on a table. Place each ruler on either side of the box, extending in front by 1 cm. Tape the rulers in place.
- Place the clipboard in front of the box, touching the two rulers, so the clipboard is 1 cm away from the end of the TP tube. Align the protractor to the clipboard perpendicular (90°) to the table.
- *Control*: Turn on the flashlight. Keep the clipboard at the 90°, and with the red marker, draw the outline of the light circle on the graph paper.
- Question: While 2.4° difference in the axial tilt is small, how does that impact the in the solar isolation?

### POWER WORDS

- **angle of incidence**: the angle a ray of light strikes a surface
- **isolation**: the amount of solar radiation in a given area
- **radiation**: energy

**Earth's obliquity takes 41,000 years for one cycle.**






## MATERIALS

- box or book (2-3" high)
- toilet paper (TP) tube
- 2 metric rulers
- clipboard
- red, green, blue, purple and black markers
- masking tape
- scissors
- Print:
  - data sheet (page 12)
  - 4 sheets graph paper (pg 10)
  - protractor (pg 13) and cut out

Trial A:

- ***Summer Solstice@ 22º:*** Tilt the clipboard away from the flashlight, and measure to 73º on the protractor. Trace light outline with a green marker.
- ***Summer Solstice @ 24.5º***: Tilt the clipboard away from flashlight, and to 76.5º. Trace light outline with a blue marker.
- ***Winter Solstice @ 22º***: Tilt the clipboard away from flashlight, and to 30º. Trace the light outline with a black marker.
- ***Winter Solstice @ 24.5º***: Tilt the clipboard away from flashlight, and to 26.5º. Trace light outline with a purple marker.

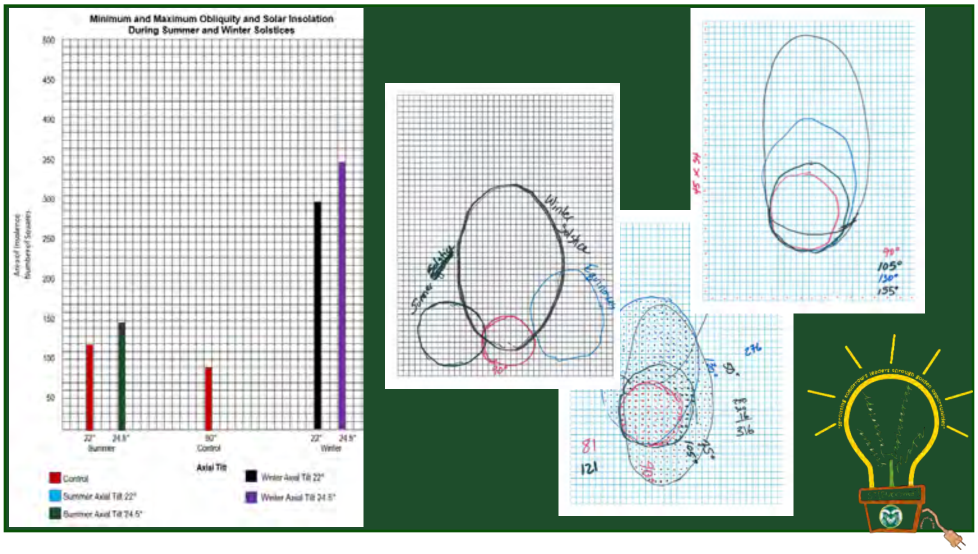
Trial B and Trial C:

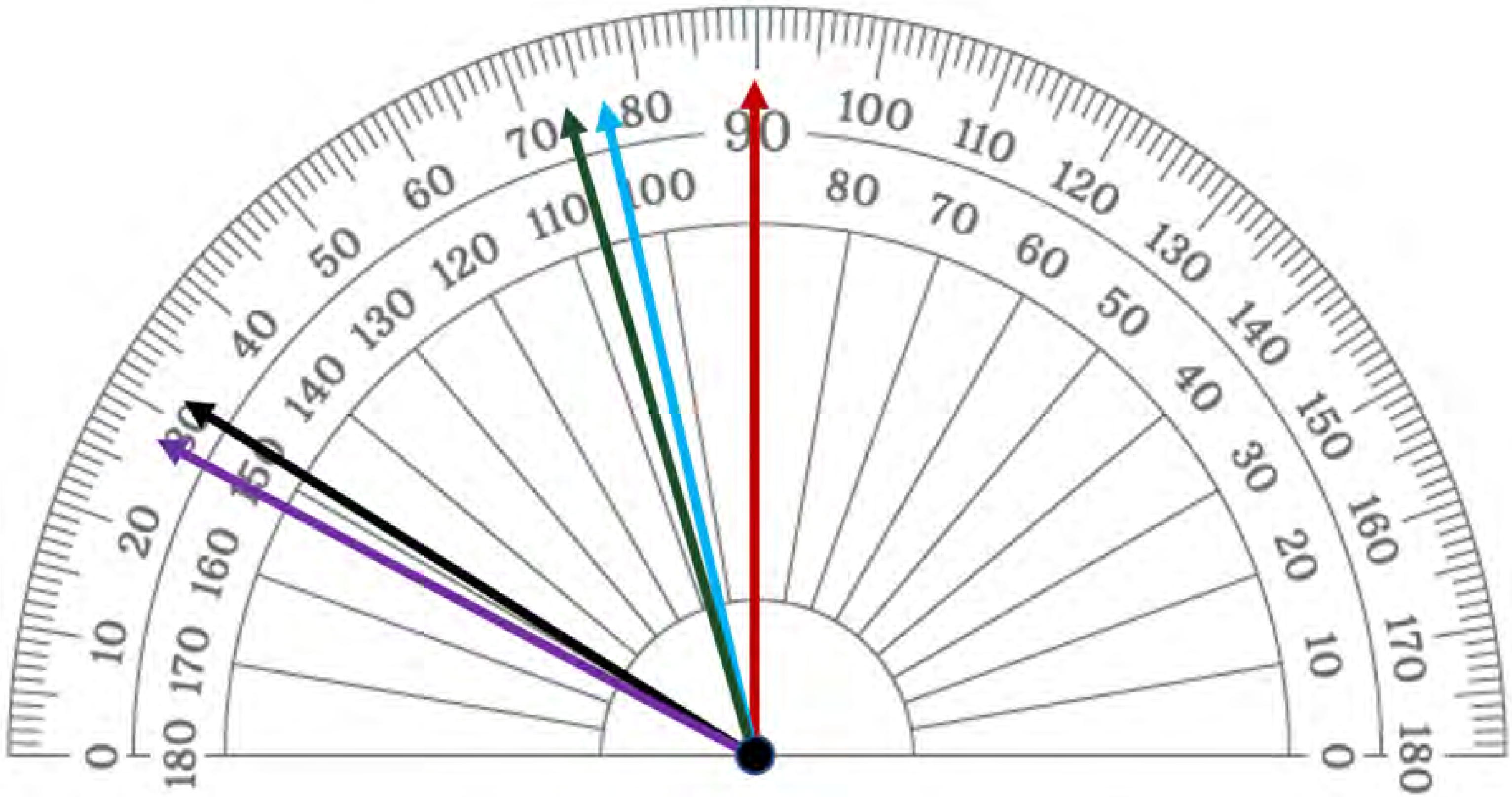
- Use the 2nd sheet of graph paper for Trial B and a 3rd sheet of graph paper for Trial C, repeating the above steps.
- Count the number of grid squares in each circle or oval (***red Control***, ***green Summer Solstice@ 22º***, ***blue Summer Solstice @ 24.5º***, ***black Winter Solstice @ 22º*** , and ***purple Winter Solstice @ 24.5º***). Record on your data sheet. If the line is more than halfway through the square, count that square. If the line is less than halfway through the square, do not count it.
- Repeat this step for Trial B and Trail C.
- Graph your results on the 4th sheet of the graph paper.
- How does the Axial Tilt change solar isolation?

## Obliquity and Solar Insolation Datasheet

| Trials / Angle | Trial A Number of Squares | Trial B Number of Squares | Trial C Number of Squares | Average # Squares (A+B+C/3) |
|---|---|---|---|---|
| Control 90º | | | | |
| Summer Solstice @ 22º Tilt set at 73º | | | | |
| Summer Solstice @ 24.5º Tilt set at 76.5º | | | | |
| Winter Solstice @ 22º Tilt set at 30º | | | | |
| Winter Solstice @ 24.5º Tilt set at 26.5º | | | | |

- For more detailed directions, please see issue 48.Climate at http://tra.extension.colostate.edu/stem-k12/stem-resources/





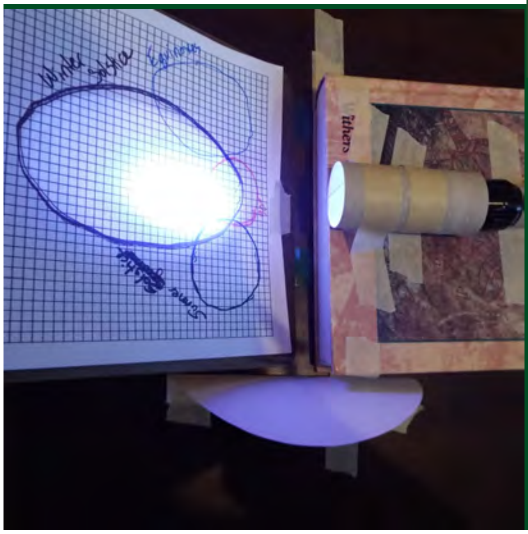
**What does this mean?**

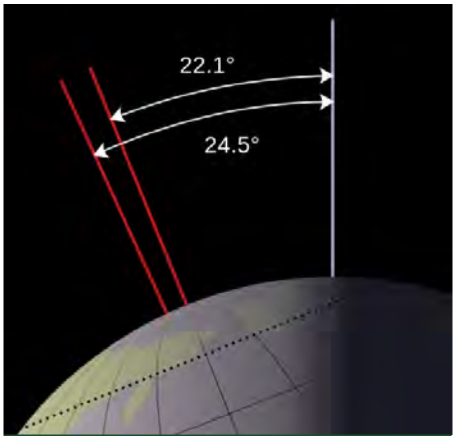
Compare these results to last month's graph of solar isolation at the current axial tilt. We are currently at 23.5° tilt to Earth's orbital plane around the sun. What do you think will happen, when that tilt is at the minimum of 22.1°? How about at the 24.5° maximum? Examine your graph. How intense was the light during Winter Solstice when the tilt was 24.5° (angle of incidence is the purple arrow). The Sun will only be 26.5° above the horizon. How intense was the light during the Summer Solstice when the tilt of the Earth is 22.1°?

If you do not remember, repeat the Winter Solstice scenarios. Look at the intensity of the light at these different angles. Look at the light as it spreads out further away from the flashlight. What happens? This simulates what happens with as the angle of incidence of sunlight spreads out across the Earth.

The short answer for this is at 22.1° tilt, there will be less temperature swings. The summers will be cooler and the winters will be warmer. When the Earth tilts 24.5°, there will be greater temperature swings. The summers will be warmer and the winters will be cooler.

The Earth's tilt is slowly decreasing towards 22.1° obliquity. What does that mean?





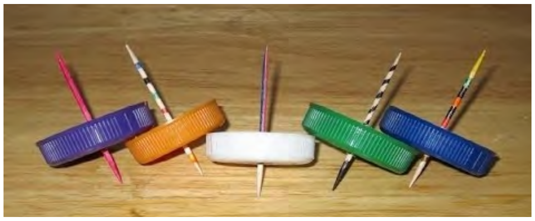

Even though the difference between 22.1° and 24.5° is slight, there is a huge impact on Earth's temperatures.

FOR ANY ANGLE OF INCIDENCE, AS LIGHT SPREADS FROM THE SOURCE (REGARDLESS FLASHLIGHT OR SUN) THE INTENSITY (ISOLATION) DECREASES.

### Precession - The Earth's Wobble

Precession is a slow wobble of the axis of a spinning object, like a planet or a top. This is very easy to observe in tops, but first, let's make tops!

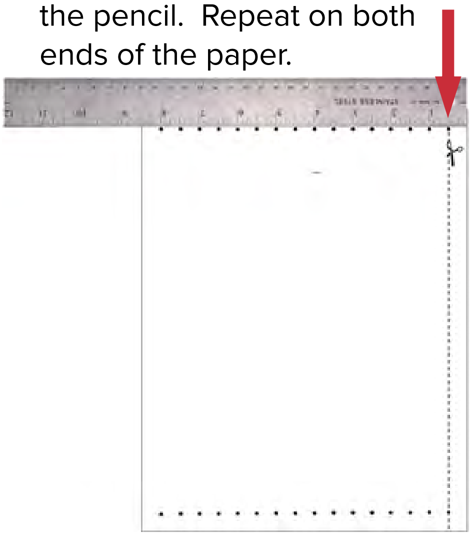
Directions Spinning Top 1



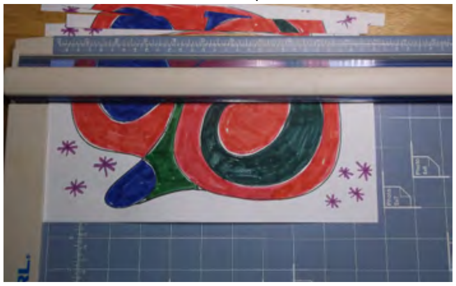
- Place the bottle cap on the cutting pad.
- Tap a hole into the center of each cap with the nail and hammer. Remove the nail.
- Carefully insert the toothpick from inside until it pokes through about 1/2 inch.
- You can decorate the toothpick and/or the inside of the cap.

Direction Spinning Top 2

- Color the paper with markers in a bold design.
- Cut your paper into 1/2" x 11" strips. Place the paper on a cutting pad. Set the ruler along the top of the 8 1/2" side of the paper.
- At every 1/2", place a dot with the pencil. Repeat on both ends of the paper.



- Align and press down the metal ruler to the first two dots running the length of the paper (red arrow on image below). With the craft knife, press the blade against the ruler, press down, and pull across the paper. to cut the strip. Repeat until you have cut the entire sheet of paper, or 17 strips total. (You can also use a paper cutter if available.)



- Glue the paper strips aligned and end to end with the glue stick until all of them are attached, and your paper string is ~14 feet long.

- Allow the glue to dry.

Continued on page 15.

### POWER WORDS

- **gyroscope:** an instrument with a heavy wheel mounted to spin rapidly so that its axis is free to turn in various directions
- **gyroscopic**: like a gyroscope
- **precession**: the slow circle traced out by the pole of a spinning top or other object (like a planet)

**Earth's precession takes 26,000 years for one cycle.**

### MATERIALS

- plastic bottle cap (e.g. milk jug)
- round toothpicks
- nail thinner than the toothpick
- hammer
- copy paper
- markers
- craft knife (box cutter or paper cutter)
- cutting pad
- pencil
- metal ruler
- glue stick
- white school glue

- Apply glue to the back side of the paper on one end. Using a toothpick as a guide, roll the end of the paper to start a coil. Once you have 10 turns of paper, remove the toothpick. Throughout the winding process, verify the toothpick still can slip into the center hole.

- I am right handed, so lefties, you will need to modify these directions. With your left hand, align the edges of the paper string with your thumb and middle finger, using your index finger to help hold down the paper to keep it tight. Turn the paper disk with your right hand.
- Add a bit of glue stick glue at every seam (10" or so) of paper to hold into place.
- Add a bit of glue stick glue to the last end, and secure into place. The disk will be about 1" in diameter. If you want a larger top, more stable top, you can repeat these steps with a second sheet of paper.

- The toothpick is 2 1/2" long. About 3/4" from one end, dab white school glue about 1/2 inch wide. Insert the toothpick into the paper disk until the school glue is completely inside the small toothpick hole in the center. Allow to dry.


- You may need to snip 1/2" on the long piece of toothpick to balance your top (leaving 1").
- Try forming a cone with your top. It may shift the balance. The larger the disk, the more you can adjust the shape.

## Precession

- Spin your tops. When you have a good spin, watch the top of the toothpick. You will notice that as the top is rotating, the axis of the top is making slow circles. That is precession, the same motion the Earth makes as it spins on its axis orbiting the Sun.
- What role does our Moon play in precession? Do you think it stabilizes the or exaggerates precession?

## EXAMPLES OF PAPER STRIP TOP

## Eccentricity - The Earth's Orbit

The Earth's orbit is almost circular around the Sun, but not exactly. This oval shape is called eccentricity.

The eccentric orbit means that the Earth is nearer to the Sun once a year, and further from the Sun six months later.

Everything is moving. Gravity holds the moon in orbit around the Earth. Gravity holds the Earth in orbit around the Sun. The planets' orbits change the gravitational pull on Earth. All these gravitation pulls oscillate the orbit of the Earth around the sun increasing and decreasing the eccentricity over long periods.

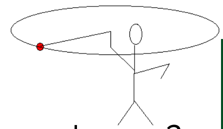
This is a quick experiment you can do to observe this eccentricity. You will represent the Sun, the elastic will represent the Sun's gravitation pull on the Earth, and the washers or hex nuts represent the Earth.

Directions:

- String the washers/hex nuts on one end of the elastic. You want to have enough mass to pull on the elastic, but not too much that if it hits someone, it could injure him/her.
- Tie the end just above the first washer with a strong knot. You don't want it to slip ( ).
- Make a loop handle on the other end to place over your wrist for safety ( ).
- Grab a partner and head outside to a large clearing.

**CAUTION: Do this activity outside!**

- Place the loop over your wrist, and swing the washers/hex nuts over your head.
- Observe that as the hex nuts orbit, they will be slightly closer and slightly further each orbit. What did your partner observe?

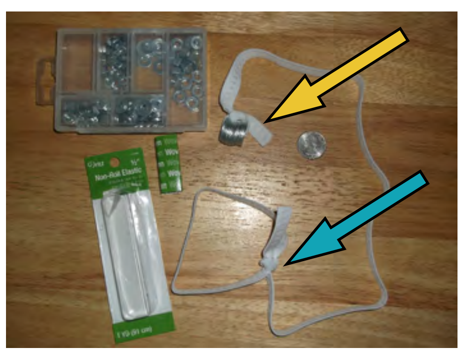


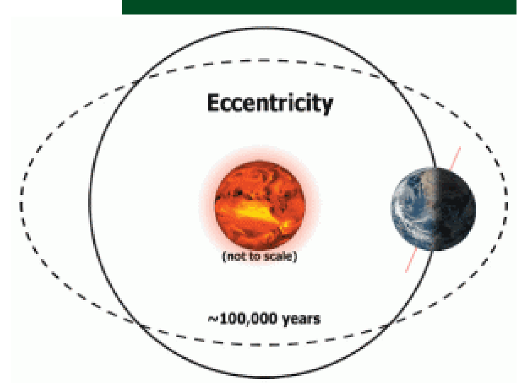
- Switch places with your partner. Have your partner swing the washers/hex nuts over his/her head. Notice that the orbit is slightly larger then smaller and each rotation, the washers/hex nuts will be sightly higher or lower in the orbit inclination.
- The Earth's orbit varies in eccentricity and orbital inclination (slightly higher or lower each cycle).
- For the Earth, what does this mean when eccentricity is low (almost circular)? How about high eccentricity (oval)?
- The slight change in tilt of the orbital inclination in relation to Earth, Moon, and Sun allow solar and lunar eclipses! Cool!

### POWER WORDS

- **circularity**: having the form of a circle
- **deviation:** departing from an established course
- **eccentricity**: deviation of an orbit from circularity
- **orbital inclination**: measures the tilt of an object (Earth) around a celestial body (Sun)
- **oscillate**: move or swing back and forth at a regular speed

**Earth's precession takes 100,000 years for one cycle.**






### MATERIALS:

- elastic band 1" x 30" (found in sewing notions)
- 1-2 ounces of washers, hex nuts, or other objects with a hole (pictured is 1 ounce)
- outside
- a partner

Everything is moving.

Milankovitch cycles are:

- Obliquity
  - 41,000 year cycle
  - Maximum axial tilt 24.5° with a greater difference between winter cold to summer hot temperatures
  - Minimum axial tilt 22.1° with a smaller difference between winter cool to summer warm temperatures
  - Currently at 23.5° axial tilt moving towards the minimum tilt of 22.1° .
- Precession
  - 26,000 year cycle
  - North Star (Polaris) has not always been aligned within 1° of the Earth's North Pole. When the pyramids in Eqypt were being built (about 5,000 years ago), the star closest was Thuban in the constellation Draco. 12,000 years ago, the closest star to Earth's North axis was Vega. We know this because many ancient cultures aligned structures to the stars.
  - This slow circle either enhances the seasonal temperatures during maximum axial tilt, or lessens the seasonal temperatures during minimum axial tilt.
- Eccentricity
  - 100,000 year cycle
  - Earth has a nearly circular orbit. The value of "0" is a circular, and "1" means the object is so elliptical that it leaves orbit. Earth eccentricity moves between 0.0034 to 0.058. Earth is currently at 0.0167.
  - We are moving towards a more circular orbit (towards the 0.0034) with less temperature extremes.

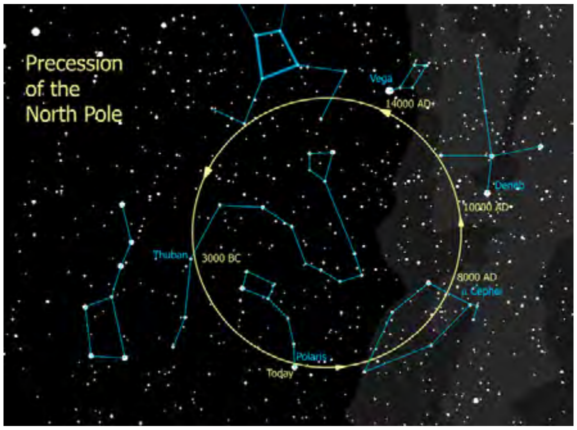
What does that mean to our long-term climate change? The interglacial and glacial periods over the past 2,600,000 (2.6 million) years are attributed to these cycles. When the Earth's orbit was near the greatest eccentricity coincided with the greatest axial tilt (obliquity), the north and south ice sheets would advance.

Long term cooling and warming over the past half billion years has been correlated to the Milankovitch cycles. These cycles are compounded by other factors. For example, plate tectonics and the continental configurations have played a big role in long-term climate.

POWER WORDS

- **eliptical**: oval-shaped
- **synthesize**: combine a number of things into a coherent whole

(Below) Earth's North Pole follows the yellow circle over the precession 26,000 cycle. Thuban was the North Star during pyramid construction.




## MILANKOVITCH YOUTUBE:

Check out these YouTube videos on Milankovitch Cycles:

- This is an interesting video tracing the North Pole over the past million years (during the ice ages) combining Milankovitch cycles: https://www.youtube.com/watch?v=hajMQpLv-YA&feature=related
- Video explaining Milankovitch cycles: https://www.youtube.com/watch?v=ztninkgZ0ws
- Fascinating video about all this movement, including Earth's plane: https://www.youtube.com/watch?v=82p-DYgGFjl

## Organizing Career Information

Over the past almost 9 years, these ST[EMpower] issues have included career exploration from highlighting different people discussing what they do to exploring career options, including taking your interests and talents survey, exploring your dream lifestyle and the income you would need, touching on starting incomes and education requirements, and interviewing people in careers you envision you would enjoy. That is a lot of information.

This issue's Career Connection will focus on organizing all this information in a way that is easy for you to review and add new ideas as they grow.

We can divide the different components of careers into five categories:

1. Your Interests and Talents
2. Evaluating your Skills
3. Work Attitude
4. Training and Education
5. Availability of Jobs

One powerful way to organize huge amounts of information is called a Mind Map. There are some rules:

- Only use key words or short phrases
- Write down everything during the first step - don't judge or filter ideas
- Write down as many key words and phrases as you can

Directions:

- List key words and short phrases on a piece of paper, one per line. At this point, do not filter or judge what you write, just keep on writing. It is okay to repeat or include silly ideas. You can add additional ideas to this list at any time.
- Review your list. You will start to see themes emerge. For example, your list may naturally fall into different interest categories. If your five favorite interests are animals, astronomy, reading, outdoors, and food, those are natural divisions.
- Identify each key word or phrase with one of the natural divisions. Work through your entire list, identifying each word to one or more of your natural divisions. Some items will fit into more than one division. Some items may not

> "Never give up on what you really want to do. The person with big dreams is more powerful than one with all the facts."
>
> Albert Einstein

## MIND MAPS

CAREER EXPLORATION

CAREER EXPLORATION

I.E. FASHION CAREER

I.E. ASTRONOMY CAREER

## MATERIALS

- scratch paper
- color pencils or markers
- post-it notes in different colors
- roll of paper at least 24" wide (i.e. postal wrap paper) or poster boards

fit in any of the divisions. You can identify those as "Other." It may help to start color-coordinating this information.

- Use the large piece of paper or poster board. If you have a paper roll, cut off 3 feet, to give yourself plenty of room.
- This Mind Map will be all the information you have collected. Later, you can do Mind Maps, one for each career. In the center of this Mind Map, write "CAREERS"
- Use a different color for each division. Write each key word or phrase on your post-it notes. You can color-code by using color pencils or markers, and/or the post-it note colors. Remember, if one of your key words fits several divisions, rewrite the word each time with its division color code.
- Group the colors on your Mind Map. They don't need to be organized further yet. That will come later.
- Review each key word or phrase in each color. Closest to the "CAREERS" label in the center, you want to identify each branch. Continuing the example from page 18 would be "Astronomy," "Animals," "Reading," "Outdoors," "Food," and "Other."
- Look at each of the remaining key words and phrases. You may have different concepts within those careers, like starting salary figures, your interest or talent that fits, etc.
- How would you organize those so that the information is easy to find in each branch of your Mind Map?
- Since your key words and phrases are on post-it notes, you can easily move them around if you think of a better way to display them.

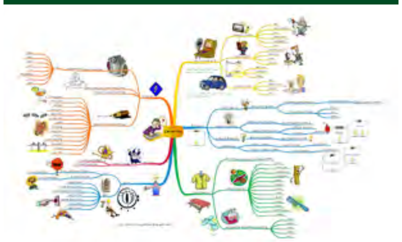
*" You cannot teach a man anything; you can only help him discover it in himself.*

*- Galileo "*

- When you are satisfied with the way that the words are grouped, draw lines to attach concepts and ideas. For example, you may see skills in different divisions that are the same. Some words will pop out as very important. You can highlight them. You can connect the lines to other divisions, not just within each division. What makes sense?
- Add images to your Mind Map for more visual tool. If you artistic, you can draw those images, or you can use images from the Internet or magazines.
- Did the "Other" division take on

CONNECT THOUGHTS

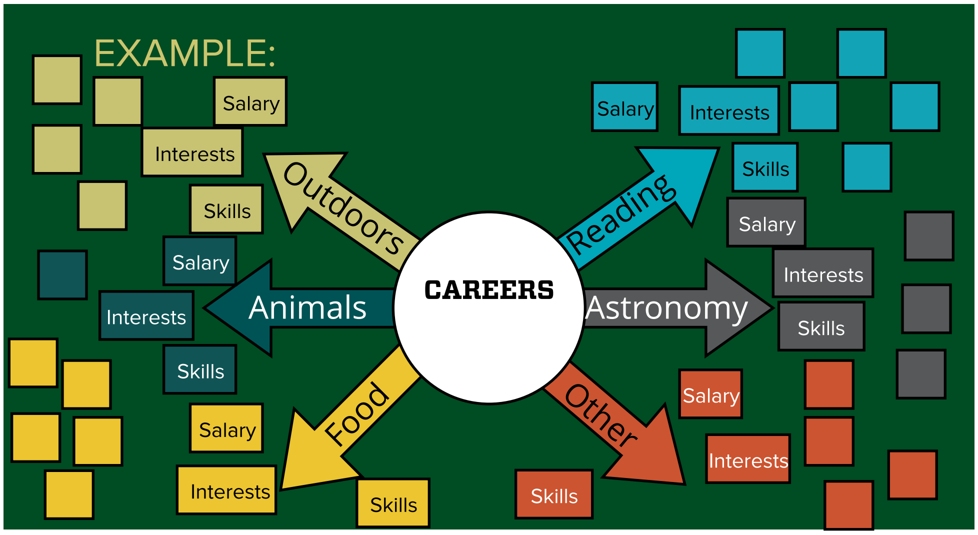
BE CREATIVE



SEE THE BIG PICTURE

a unique life of its own?

- You can develop a mind map of your interests and careers. This may clarify careers that would have high job satisfaction.



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