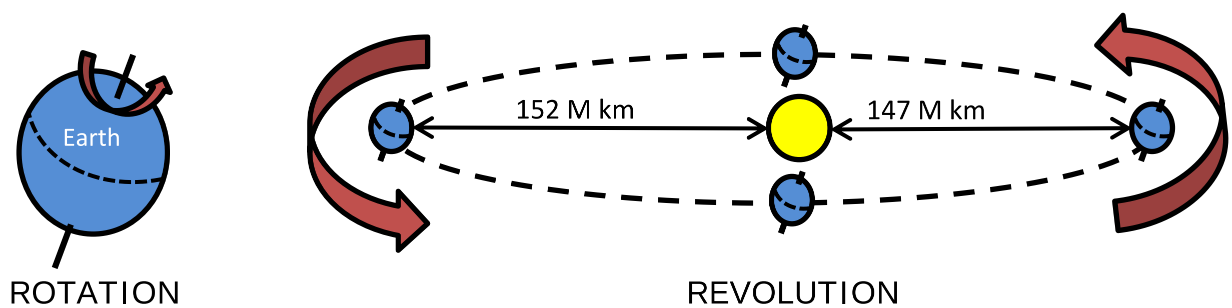
Name: ____________________ Teacher: _______________ Pd. ___ Date: ________

STAAR Science Tutorial 27
TEK 8.7A: Earth's Seasonal & Day-Night Cycles

TEK 8.7A: Model and illustrate how the tilted Earth rotates on its axis, causing day and night, and revolves around the Sun causing changes in seasons.

The Earth spins, or rotates, on its axis once a day. This is the cause of the day—night cycle on Earth. In fact, the Earth's counter-clockwise rotation, not any motion of the Sun, is what makes the Sun seem to rise in the East and set in the West.

The Earth orbits, or revolves, around the Sun once in a year (365.25 days), also in a counter-clockwise direction, as viewed from over the North Pole. The shape of that orbit is almost a perfect circle, but is slightly "elliptical" (oval) in shape. The Earth is slightly closer to the Sun (147 million km) on about January 3rd each year, and slightly further away from the Sun (152 million km) on about July 4th each year. This 3% difference in the Earth to Sun distance during the year does NOT make any real difference in the temperature of our seasons.



The real cause of the seasons is the tilt of the Earth's axis, about 23.5 degrees. If the Earth's axis was not tilted, there would be no seasons on Earth—every day would be about the same temperature in any one place. Without tilt, every day and every place on Earth (except the poles) would have exactly 12 hours of daylight and 12 hours of night. It is the tilt that causes seasonal differences in the length of night and daylight—longer nights in winter and longer days in summer. It is the tilt that causes the Sun to be high in the sky in summer and low in the sky in winter. It is the combination of longer daylight hours and more direct sunlight that causes the heat of summer, and the combination of shorter daylight hours and less direct sunlight that causes the cold of winter.

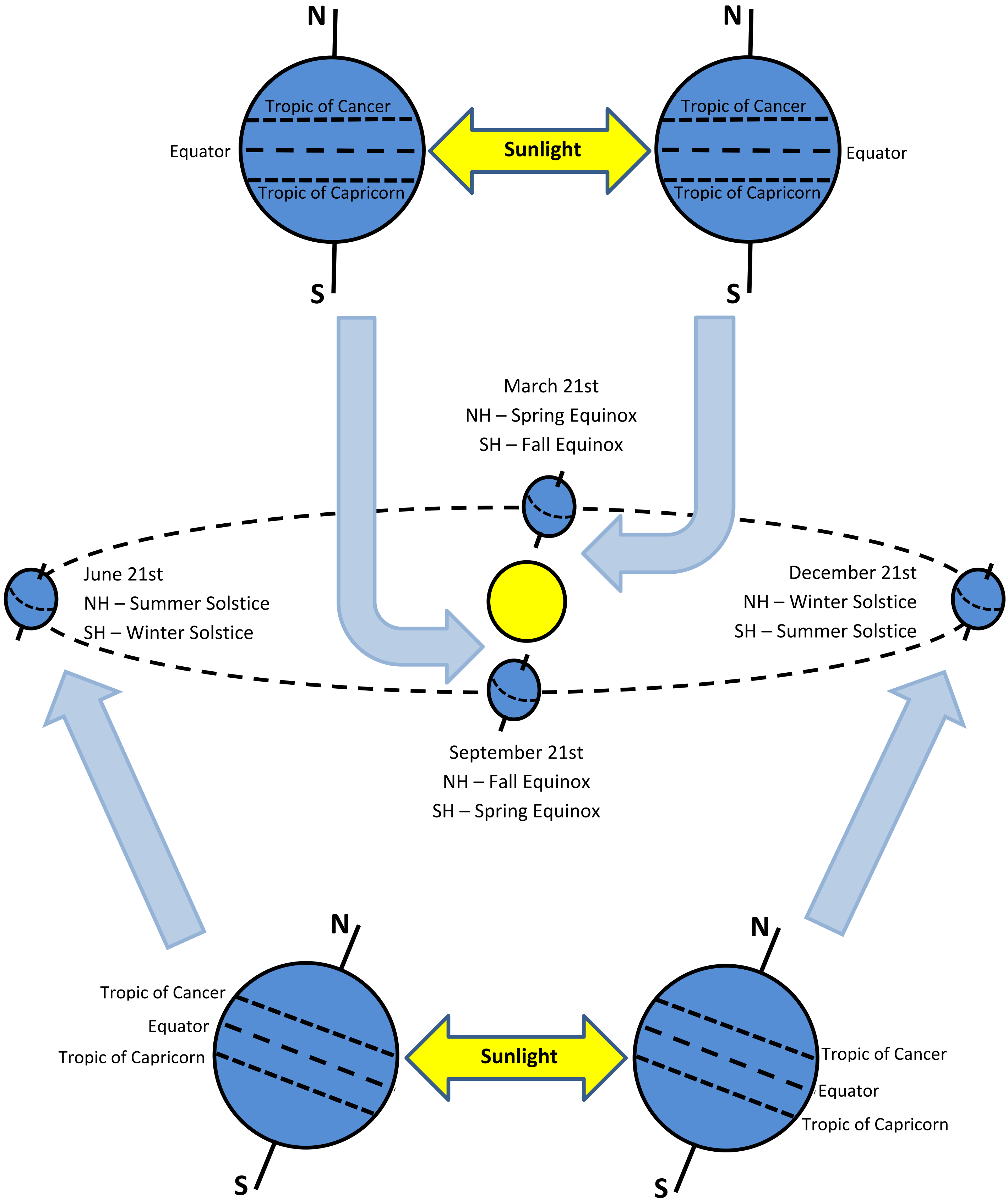
The angle of the Earth's tilt does not change during the year. The Earth's North Pole axis always points to Polaris, the North Star. But the hemisphere of Earth that faces the Sun more directly DOES change during the year, as the Earth orbits around the Sun. On one day a year (the summer solstice, June 21st), the northern hemisphere is tilted directly towards the Sun, and the Sun is directly overhead at the Tropic of Cancer, 23.5 degrees north latitude. Six months later (on the winter solstice, December 21st), the northern hemisphere is tilted directly away from the Sun, and the Sun is directly overhead at the Tropic of Capricorn, 23.5 degrees south latitude. On the two days halfway between those dates, both hemispheres face the Sun equally, the Sun is directly over the equator, and the length of day and night everywhere on Earth is exactly 12 hours each. These are called the spring (or "vernal") equinox (on March 21st in the northern hemisphere) and the fall (or "autumnal") equinox (on September 21st).

The seasons in the north and south hemispheres are the opposite of one another. In January, when it is winter in the northern hemisphere, it is summer in the summer hemisphere. In April, when it is spring in the northern hemisphere, it is fall in the southern hemisphere. In July, when it is summer in the northern hemisphere, it is winter in the southern hemisphere. In October, when it is fall in the northern hemisphere, it is spring in the southern hemisphere. Likewise, summer solstice in the northern hemisphere is the winter solstice in the southern hemisphere.

Between the Arctic Circle (66.5 degrees north latitude) and North Pole, and the Antarctic Circle (66.5 degrees south latitude) and South Pole, the apparent movement of the Sun across the sky daily and seasonally is different from the rest of Earth. At each pole, the Sun rises on the spring equinox and sets six months later on the fall equinox. Each 24 hour day during the summer, the Sun completely circles the horizon. At the Arctic or Antarctic Circles, the Sun does not set at all on one day, the summer solstice. In other words, on the summer solstice there is 24 hours of daylight and no night. Between 66.5 degrees latitude and the pole, the number of 24 hours days without a sunset increases as one moves towards the pole. In winter, the opposite occurs, with one or more 24 hour days with no sunrise, and 24 hours of darkness.

The greatest seasonal variation in daylight and night hours occurs at the North Pole and South Pole, and the lowest seasonal variation in daylight and night hours occurs in the tropics, between the Tropic of Cancer and Tropic of Capricorn, including the equator. In the tropics, the longest daylight period is 13 hours and shortest is 11 hours. In Dallas, the longest daylight period is about 14.5 hours and the shortest 9.5 hours. In southern Alaska, the longest daylight period is 19 hours, and shortest 5 hours.

The diagram on the next page shows an angled view down on the Earth's orbit, with the Sun in the center. (The shape of the orbit is not really this elliptical (oval)—the low angle of view needed to show the tilt in each season just makes it seem elliptical.) A close-up of the Earth in each position shows the latitude where the Sun's light is directly overhead. (A side view of Earth at the two equinox positions is used to show the angle of sunlight falling on Earth.) The solstice or equinox at each location is noted, as well as the season starting at that position and date.


N
S
Tropic of Cancer
Equator
Tropic of Capricorn
Sunlight
N
S
Tropic of Cancer
Equator
Tropic of Capricorn
March 21st
NH – Spring Equinox
SH – Fall Equinox
June 21st
NH – Summer Solstice
SH – Winter Solstice
December 21st
NH – Winter Solstice
SH – Summer Solstice
September 21st
NH – Fall Equinox
SH – Spring Equinox
N
S
Tropic of Cancer
Equator
Tropic of Capricorn
Sunlight
N
S
Tropic of Cancer
Equator
Tropic of Capricorn

Practice Questions

1. The day and night cycle on Earth is caused by the Earth's ____________ or r________________ on its axis.
2. The yearly cycle of seasons on Earth are caused by the __________ of the Earth's axis and the ____________ or r_________________ of the Earth around the Sun.
3. On January 3rd of each year, the Earth is ________________ **(closest / farthest)** from the Sun, _______ million kilometers.
4. On July 4th of each year, the Earth is _________________ **(closest / farthest)** from the Sun, ________ million kilometers.
5. The varying distance from the Sun to the Earth ___________ **(is / is not)** the reason for the seasons.
6. On about December 21st, the ______________ hemisphere is tilted directly towards the Sun, and it is their ________________ solstice.
7. On about December 21st, the ________________ hemisphere is tilted directly away from the Sun, and it is their ____________________ solstice.
8. On about December 21st, the Sun is directly overhead at the Tropic of ______________, 23.5 degrees ___________ latitude.
9. On about March 21st, the Sun is directly overhead at the ________________, 0 degrees latitude, and it is the _________________ equinox in the northern hemisphere and the ______________ equinox in the southern hemisphere. On this day, there are _____ hours of daylight and _____ hours of night everywhere on Earth.
10. On about June 21st, the ______________ hemisphere is tilted directly towards the Sun, and it is their ________________ solstice.
11. On about June 21st, the ________________ hemisphere is tilted directly away from the Sun, and it is their ____________________ solstice.
12. On about June 21st, the Sun is directly overhead at the Tropic of ______________, 23.5 degrees ___________ latitude.
13. On about September 21st, the Sun is directly overhead at the ________________, 0 degrees latitude, and it is the _________________ equinox in the northern hemisphere and the ______________ equinox in the southern hemisphere. On

this day, there are _____ hours of daylight and _____ hours of night everywhere on Earth.

14. The Sun is highest in the sky during the ____________ season, and lowest in the sky during the _______________ season.

15. The number of daylight hours is the greatest during the _________________ season, and the lowest during the __________________ season.

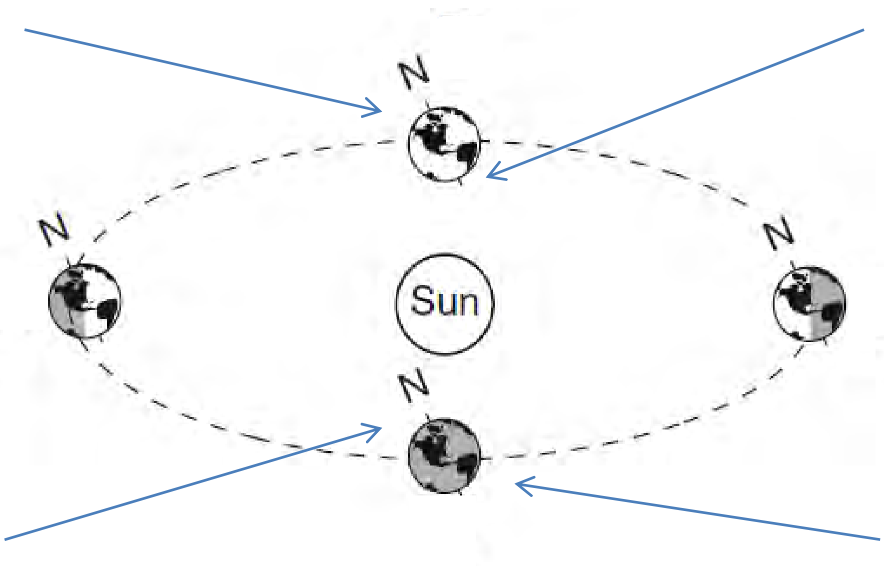
16. The greatest seasonal variation in daylight and night hours occurs at the _________________ and __________________, and the lowest seasonal variation in daylight and night hours occurs at the ____________________.

17. In the diagram below, label the position of Earth at the start of each season for each hemisphere, in the blanks provided. (NH = northern hemisphere; SH = southern hemisphere) Also label with arrows the direction of Earth's spin (rotation) and orbit (revolution). <u>Note that this diagram has a different viewpoint than the one in the explanatory text above—it is shown from the opposite side, reversing the direction of the Earth's tilt.</u>

NH______________ SH_____________

NH______________ NH____________

SH_______________ SH____________

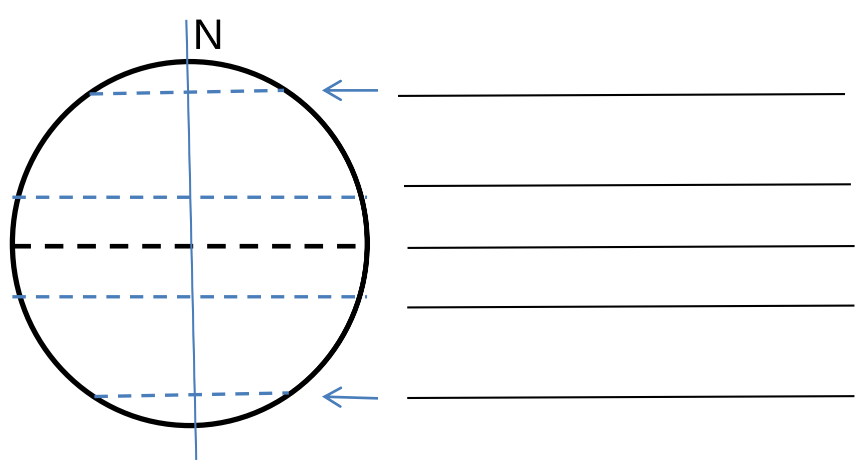


NH______________ SH_____________

18. Label the Equator, Tropic of Cancer, Tropic of Capricorn, Arctic Circle and Antarctic Circle on the diagram below.

__________ Hemisphere

__________ Hemisphere



Name: ____________________ Teacher: _______________ Pd. ___ Date: ________

STAAR Science Tutorial 28
TEK 8.7B: Moon Phases

TEK 8.7B: Demonstrate and predict the sequence of events in the lunar cycle.

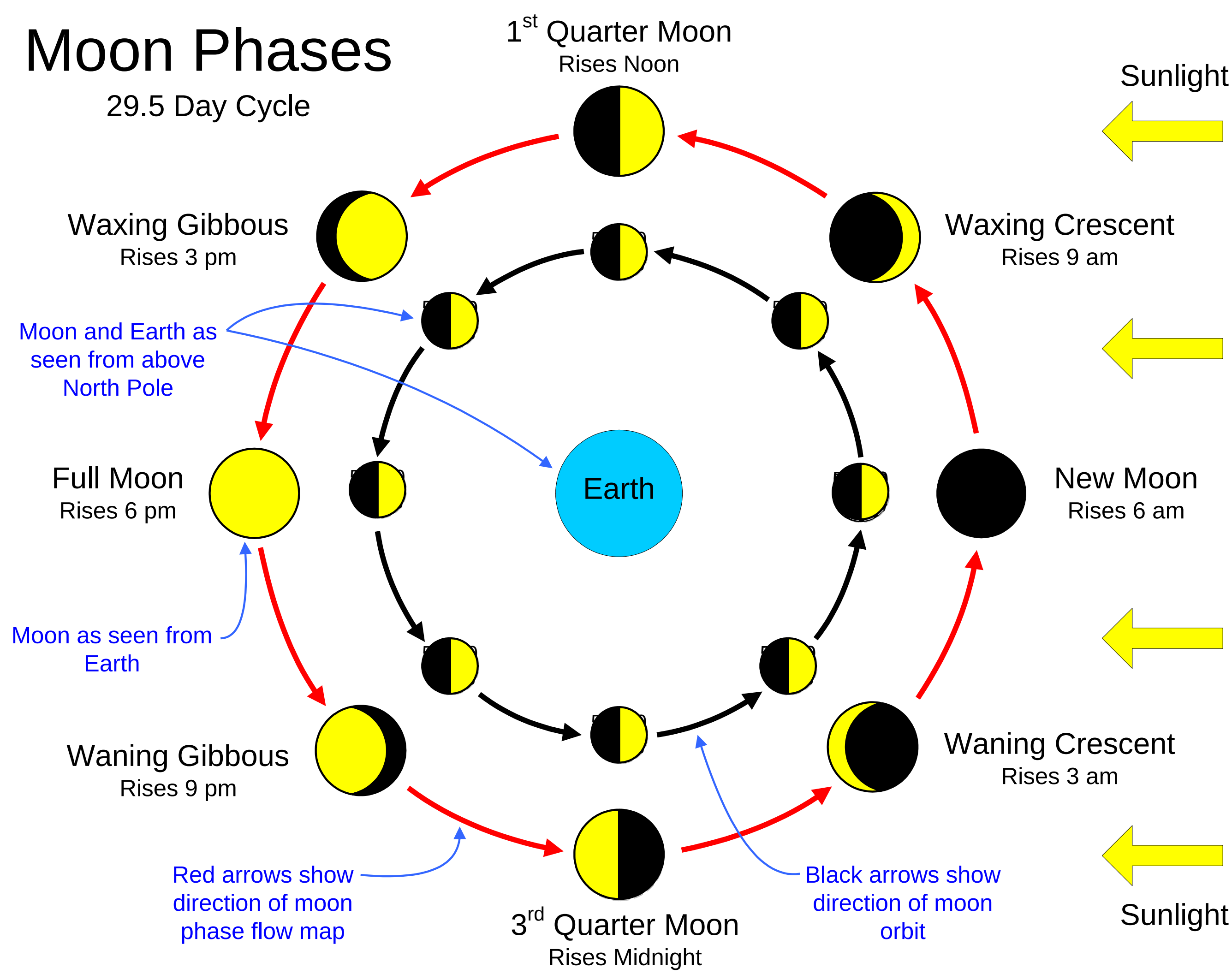
At any point in time, half of the Moon is lit (illuminated) by the Sun, and half is not lit. However, for a viewer on Earth at any given time, the Moon may appear to be completely lit, completely dark, or somewhere in between. These varying appearances of the Moon are known as "Moon Phases," and have been used by humans for thousands of years to keep track of time, even before calendars were invented. It takes 29.5 days for the Moon to cycle through all of its phases, and return to the same starting point. Our current calendar system used this fact to establish months of about 30 days.

The Moon takes about 27.3 days to orbit (revolve) once around the Earth. It takes the same amount of time, 27.3 days, for the Moon to spin (rotate) once around its axis. This means that the one side of the Moon, known as the "near side", is always facing Earth, and the other "far side" is always facing away from the Earth. The reason that the rotation and revolution periods of the Moon are different from the time it takes to complete one cycle of Moon phases is that the Earth is also orbiting around the Sun, and the Moon thus has to revolve more than 360 degrees around the Earth for the Sun, Earth and Moon to all align again at the same starting point.

The direction of the Moon's rotation and revolution is counter-clockwise, when viewed from above the Moon's (and Earth's) North Pole. This is the same direction as the Earth rotates and revolves.

During a complete 29.5 day cycle of the Moon Phases, the Moon <u>as seen from Earth</u>, goes from being completely dark, called a "New Moon" to completely lit, called a "Full Moon", and then back to a completely dark New Moon again. During the first half of the cycle, a bit more of the Moon facing Earth is lit each night. These are called the waxing (brightening) phases of the moon. During the last half of the cycle, a bit less of the Moon facing Earth is lit each night. These are called the waning (darkening) phases of the Moon.

Each phase of the Moon has been given a name. When less than a quarter of the Moon facing earth is lit, it is called a "Crescent Moon". When about half of the Moon facing Earth is lit, it is called a "Quarter Moon." When about three-quarter's of the Moon facing Earth is lit, it is called a "Gibbous Moon". The complete cycle of Moon Phases, with their full names, are shown in the flow map diagram on the next page. Note that there are two quarter moons, two crescent moons and two gibbous moons, one each in the waxing side of the cycle, and one in the waning side of the cycle.



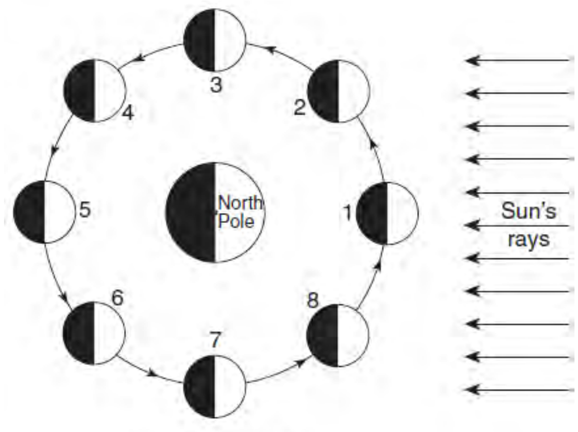
Note that during the waxing (brightening) phases, light first appears on the right edge of the Moon and moves across the entire Moon facing the Earth until a Full Moon is reached. Thus, any waxing phase moon is lit on the right edge and dark on the left edge. During the waning phases, a dark edge first appears on the right edge, and moves across the entire Moon facing Earth until a completely dark New Moon is reached, completing the cycle. Waning phase moons are lit on the left edge and dark on the right edge. The Moon rises about 50 minutes later each night, and each moon phase rises at a particular time. For example, a full moon rises about when the Sun sets, about 6 p.m.

Questions on the STAAR test about moon phases will likely require you to interpret a diagram of the Sun-Earth-Moon system, and predict what moon phase would be visible on Earth when the Moon and Sun are at certain positions. A typical diagram of this type is shown in practice question #1 on the next page. You may also be asked to place a sequence of moon phases in the correct order.

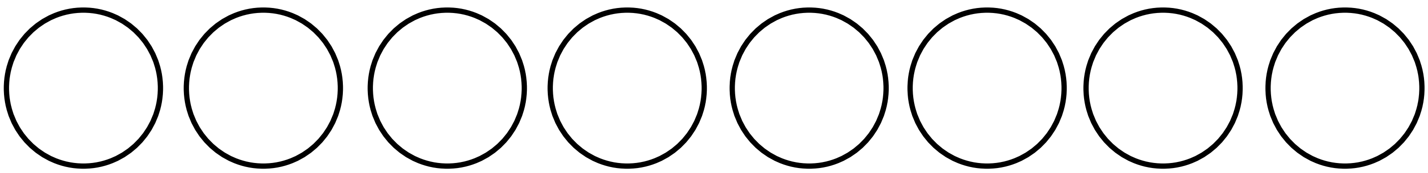
You should try to visualize yourself on the side of the Earth facing the Moon, and study the diagram to see what sides of the Moon would be lit by the Sun. If you have trouble doing this, you may need to memorize the phases of the Moon and where each phase occurs in its orbit around the Earth.

Practice Questions

1. Draw in the labeled circles below the moon phase visible from Earth in each of the eight moon positions shown in the diagram to the right. Label each moon phase with its name.



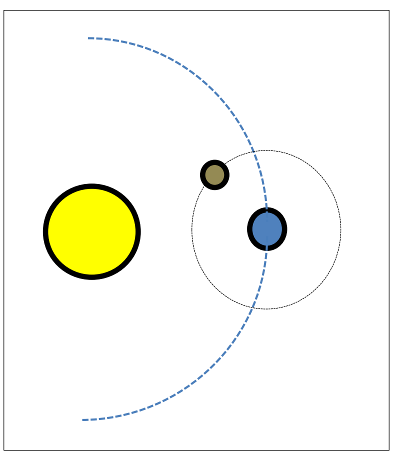
(Not drawn to scale)

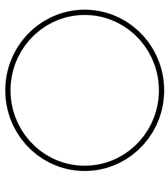


1	2	3	4	5	6	7	8
________	________	________	________	________	________	________	________
________	________	________	________	________	________	________	________

For questions 2-7, draw and name the moon phase visible from Earth for each of the following Sun-Earth-Moon diagrams. Note that the Sun is on the opposite side of the Earth, compared to the diagram above!

2.

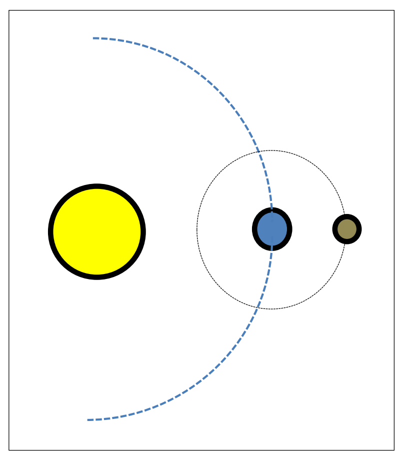


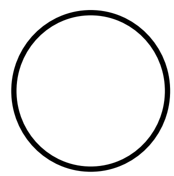


____

____

3.

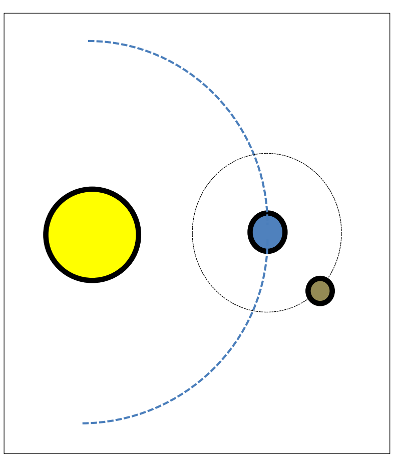


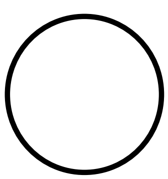


____

____

4.

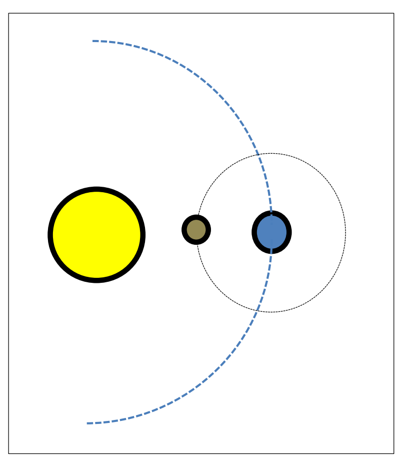


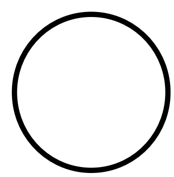


____

____

5.

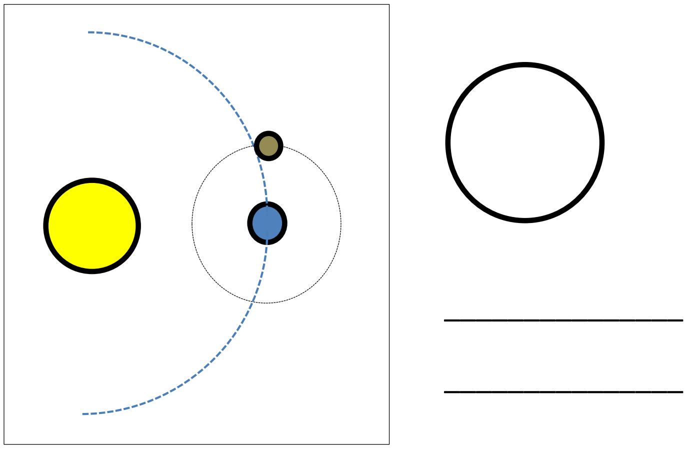




____

____

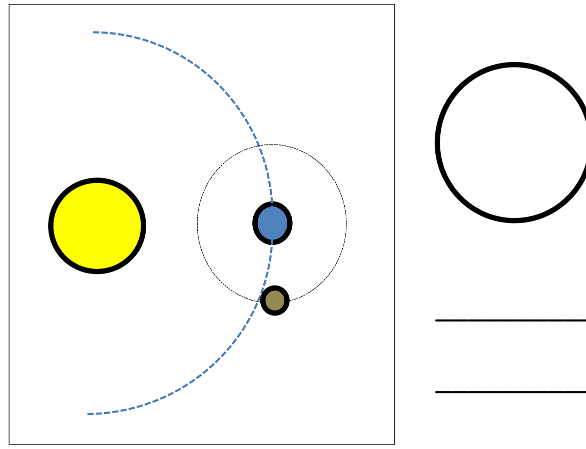
6.



____

____

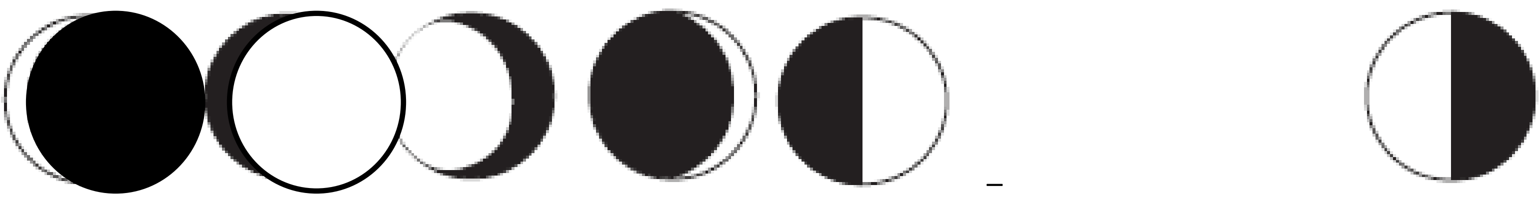
7.



____

____

8. Label the following moon phases in the correct order, starting with the New Moon.



_____ _____ _____ _____ _____ ____ _____ _____

9. How much of the Moon, as seen from Earth, is lit during a crescent moon? ______

10. How much of the Moon, as seen from Earth, is lit during a gibbous moon? ______

11. How much of the Moon, as seen from Earth, is lit during a quarter moon? ______

12. How much of the Moon, as seen from Earth, is lit during a full moon? ______

13. How much of the Moon, as seen from Earth, is lit during a new moon? ______

14. Is more or less of the lit side of the Moon visible from Earth each night during the <u>waxing</u> phases of the Moon? ____________________

15. Is more or less of the lit side of the Moon visible from Earth each night during the <u>waning</u> phases of the Moon? ____________________

16. In what direction does the Moon revolve around the Earth? ___________________

17. How long does it take to complete a cycle of Moon phases? ___________________

18. Which side of the Moon is lit during the waxing phases? __________________

19. Which side of the Moon is lit during the waning phases? __________________

20. What moon phase reflects the most light back to Earth? ___________________

Name: ____________________ Teacher: _______________ Pd. ___ Date: ________

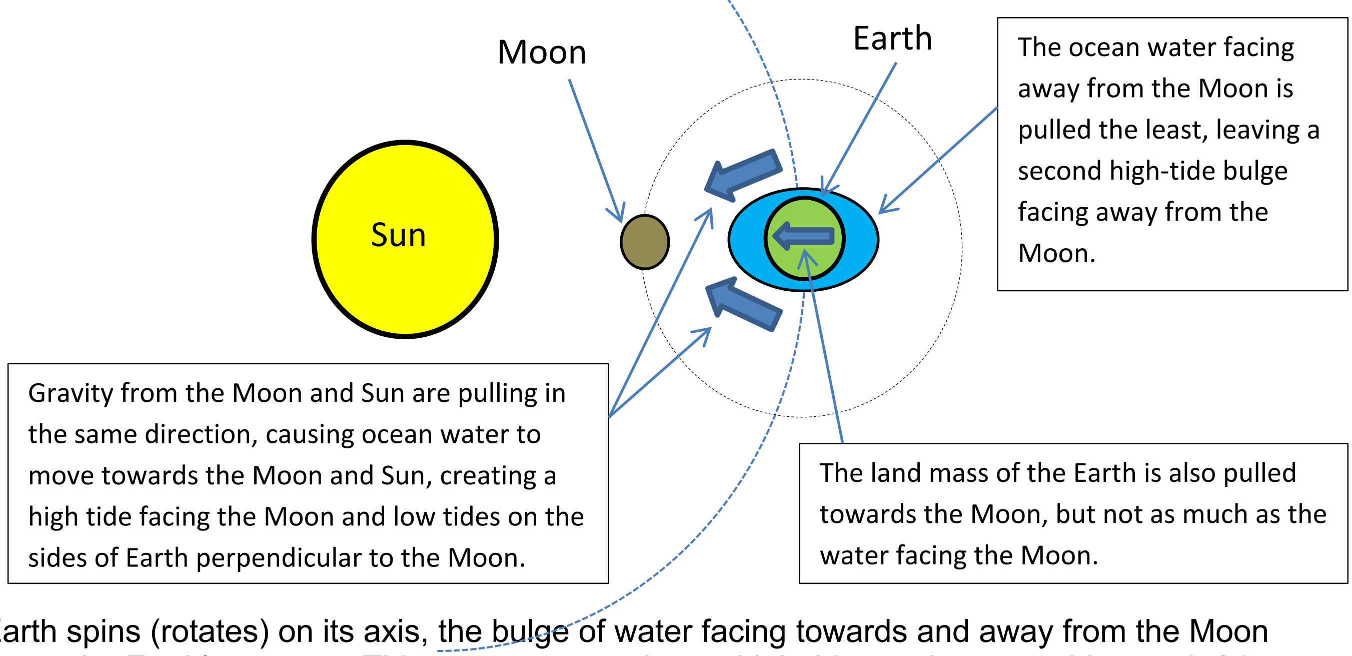
STAAR Science Tutorial 29
TEK 8.7C: Earth's Tides

TEK 8.7C: Relate the position of the Moon and Sun to their effect on ocean tides.

Gravity is a long-range (non-contact) force between any two objects with mass. The greater the combined mass of the two objects, and the closer that the two objects are to one another, the greater the pull of gravity. The Moon orbits (revolves) around the Earth because the Moon and Earth have a strong gravitational attraction on one another. Similarly, the Earth orbits around the Sun because the Earth and Sun have a gravitational attraction on one another.

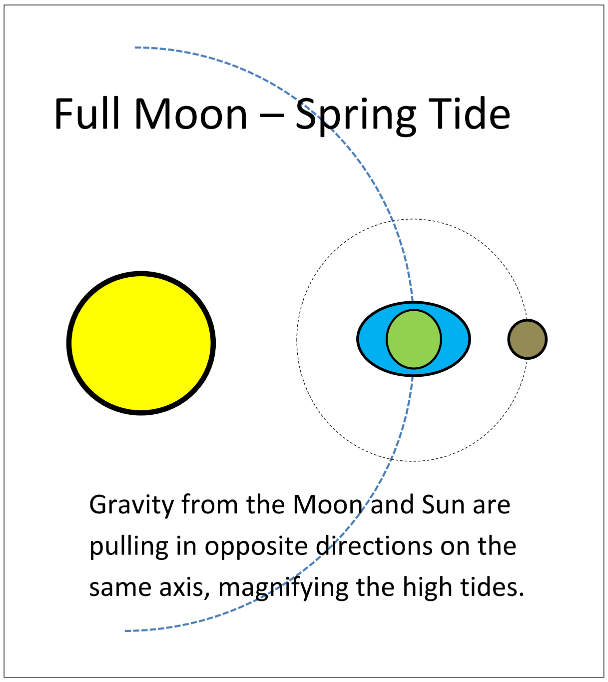
The strength of the gravity force depends more on the closeness of the two objects than their mass. Because the Moon is much closer to the Earth than the Sun, the Moon's gravitational pull on Earth is much stronger than the Sun's, even though the Sun has much more mass.

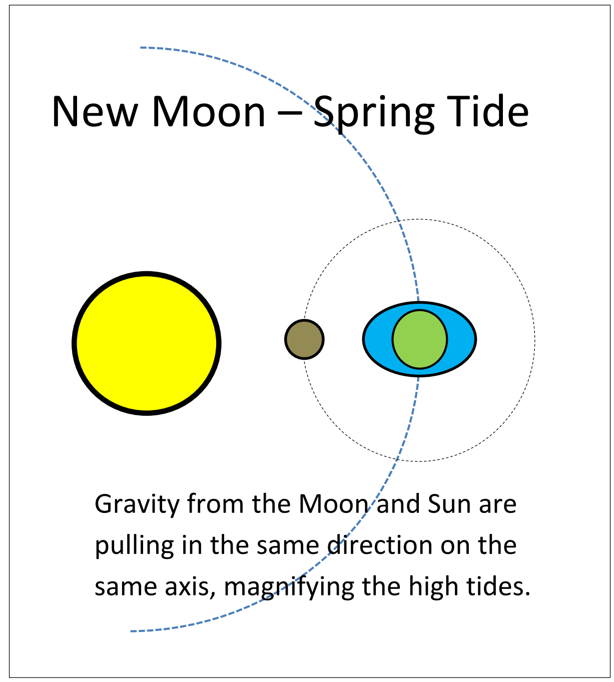
The Moon's gravitational force not only pulls on the solid mass of Earth as a whole, but on the water in the Earth's oceans. This causes the water in the oceans to flow towards the point directly under the Moon, and bulge outward towards the Moon. Water in the Earth's oceans also flows to and bulges toward the Sun, but to a lesser extent than the Moon. These bulges in the Earth's oceans are called tides. At any one moment, there is an ocean bulge (high tide) facing directly towards the Moon, and another bulge facing directly away from the Moon. The reason for the high tide facing away from the Moon is that the land mass of the Earth is also pulled towards the Moon, but the water facing away from the Moon is "left behind" (inertia holds it in place), as shown in the diagram below.



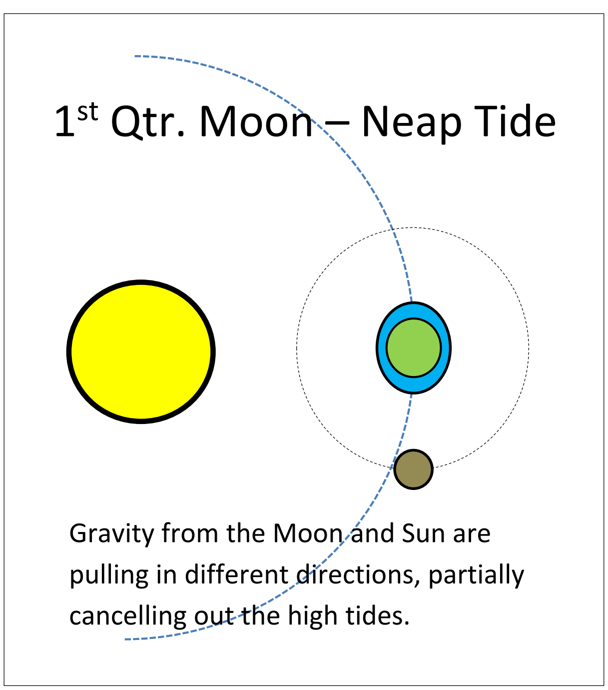
As the Earth spins (rotates) on its axis, the bulge of water facing towards and away from the Moon move across the Earth's oceans. This usually results in two high tides and two low tides each 24 hour day at each place on Earth. The tidal bulges have to flow around continents and other land masses. This can result in tides that are magnified in height and range in some places, and low and high tides that almost cancel each other out in other places. Partially enclosed water bodies such as the Gulf of Mexico often have very little range (one meter or less) between low and high tides. Funnel-shaped bays such as the Bay of Fundy in Canada can have a tidal range of almost 20 meters.

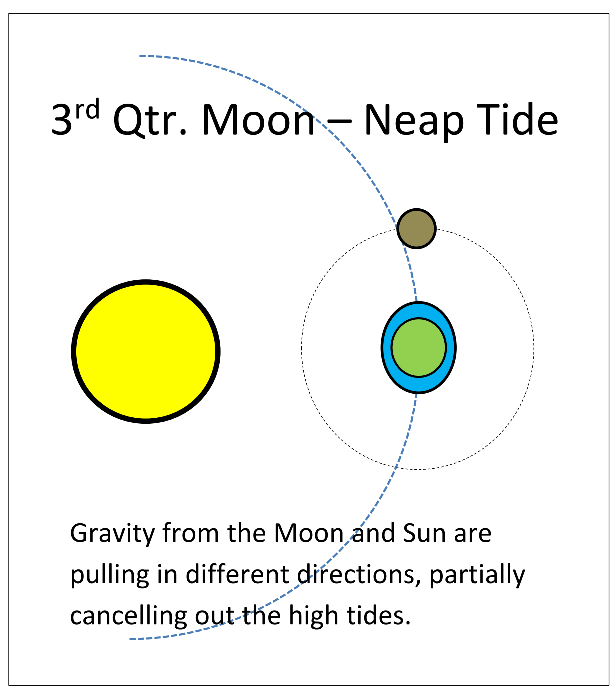
The relative position of the Earth, Moon and Sun control the height and timing of tides. When the Sun and Moon are in line with one another, such as during a full moon or new moon, the tidal range is magnified, because the gravity from both the Moon and Sun are pulling in the same direction or axis. These are called “spring tides”, though they happen twice per the 29.5 day long lunar cycle, not just in the spring season. Spring tides have a very high tidal range—the high tides are very high, and the low tides are very low. The diagrams below show the two Moon positions for spring tides.





When the Moon and Sun are at right angles (90 degrees or ‘perpendicular’) to one another, relative to Earth, during a 1st quarter or 3rd quarter moon, the tidal range is reduced because the gravity from the Moon and Earth partially cancel one another. These are called “neap tides”. Again, they occur twice in each 29.5 day long lunar cycle. Neap tides have a low tidal range—there is less difference between high tides and low tides, compared with spring tides. The diagrams below show the two Moon positions for neap tides.



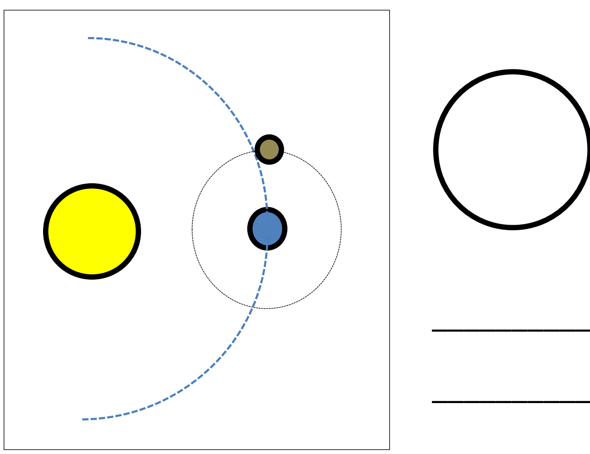


Practice Questions

1. Tides are mainly caused by the force of ______________________ from the ______________________.
2. At any point on Earth's oceans, there are ______________ high tides and ______________ low tides each 24 hour day.
3. High tides face either directly towards or directly away from the ______________.
4. Low tides face at _________________________ (90 degrees) to the Moon.
5. The tides that have the greatest tidal range are called ________________ tides.
6. The tides that have the lowest tidal range are called _________________ tides.
7. Spring tides occur during the ____________________ and _________________ moon phases.
8. Neap tides occur during the ____________________ and ______________________ moon phases.

For questions 9-12, label each of the following diagrams with both the moon phase name and type of tide, draw a picture of the moon phase in the blank circle, and draw the two high-tide bulges in proper size and direction in relation to the Moon.

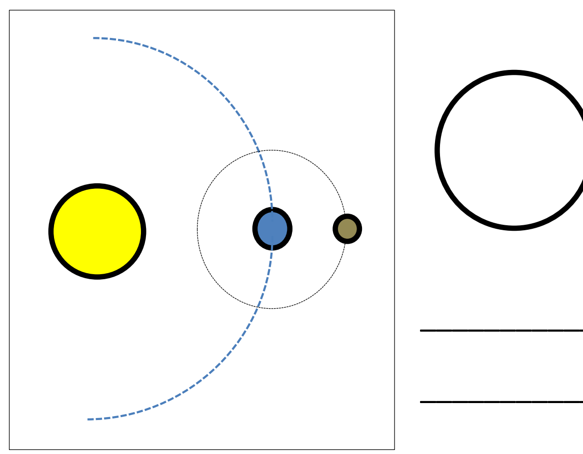
9.



____

____

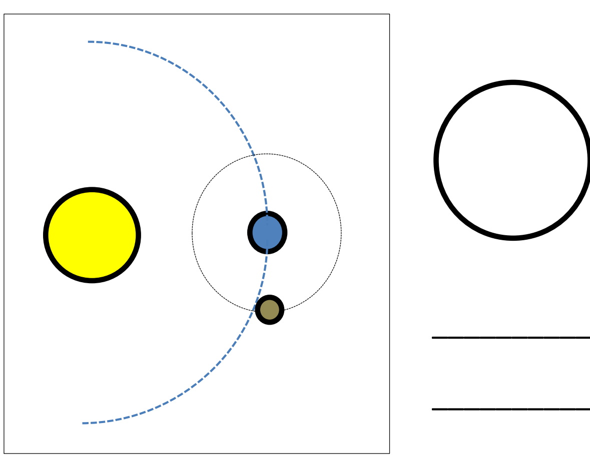
10.



____

____

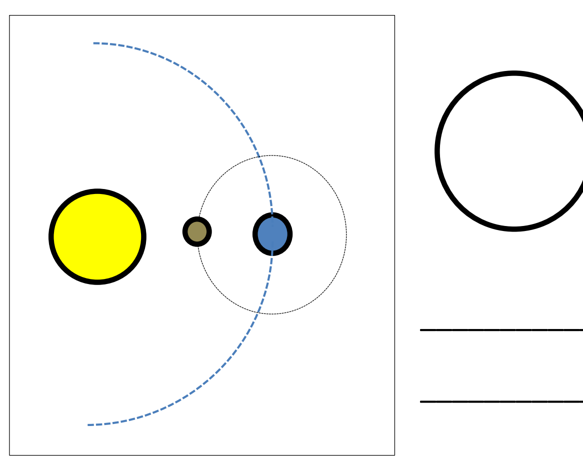
11.



____

____

12.



____

____

Name: ____________________ Teacher: _______________ Pd. ___ Date: ________

STAAR Science Tutorial 28
TEK 8.8A: Stars, Galaxies and the Universe

TEK 8.8A: Describe components of the universe, including stars, nebulae, and galaxies, and use models such as the Herztsprung-Russell diagram for classification.

Big Bang Theory of Universe Creation

- Scientists believe that the universe as we know it was created about 13.7 billion years ago in an event popularly known as the "big bang." According to the big bang theory, all of the energy and matter of the universe was once packed into a single point of space called the singularity. When this singularity exploded, the outward expansion of the universe began, a process that continues today. The first matter to condense out of this cooling, expanding universe were sub-atomic particles. As the expansion continued, hydrogen atoms were able to form. Clouds of these atoms (nebula) began to be pulled together into stars about a billion years after the big bang. Large groups of these first stars formed the first galaxies. See *Tutorial 30: Electromagnetic Waves* for a discussion of the evidence supporting the big bang theory.

Universe Components

- The **universe** contains all of the matter and energy known by humans to exist. Some scientists have hypothesized that there may be parallel universes that we cannot detect, but there is no evidence to support their existence. The universe is known to contain billions of galaxies, though it is impossible to actually count the number.
- A **galaxy** is a very large group of stars held together by gravity. It may contain as few as a 100,000 stars, or as many as several trillion stars. Our Sun is one star in our **Milky Way Galaxy**, which may contain about 200 to 400 billion stars and measure about 100,000 light years in diameter. (A light year is the distance that light travels in one year, about 9.5 trillion kilometers.) While we have never seen our own Milky Way Galaxy from the outside, we do look out to the rest of the universe from a point about 26,000 light years from its center. On a dark, clear night away from city lights, the dense band of stars crossing the sky, which to the ancients looked like spilled milk, are the stars of the Milky Way Galaxy.
- Galaxies are usually grouped into **galaxy clusters**. Our own "local group of galaxies" contains about 30 galaxies which are gravitationally locked in an inward-moving spiral. The largest of these galaxies is the Andromeda Galaxy, a spiral galaxy located about 2.5 million light years from Earth, which may contain as many as one trillion stars.
- The three main types of galaxies are spiral, elliptical and irregular galaxies, each named from its general shape.

- **Spiral galaxies** have "arms" of stars that spiral outward from the center. The overall shape is round and flat like a plate, but the dense center of a spiral galaxy is spherical. Younger stars are more likely found in the arms of the spiral, and older stars are most likely found in the center sphere. Scientists believe that the center of all spiral galaxies contains a massive **black hole**, an extremely dense area from which light cannot escape. Our galaxy is believed to be a barred spiral galaxy, similar in appearance to the Andromeda Galaxy.
- **Elliptical galaxies** are spherical or elliptical (oval) in shape. They may be older than spiral galaxies, because they do not seem to have as many nebulae and dust clouds, and thus cannot form as many new stars.
- **Irregular galaxies** are so named because they do not have a regular or defined shape. They may be the result of merged galaxies still being reorganized by gravitational forces.

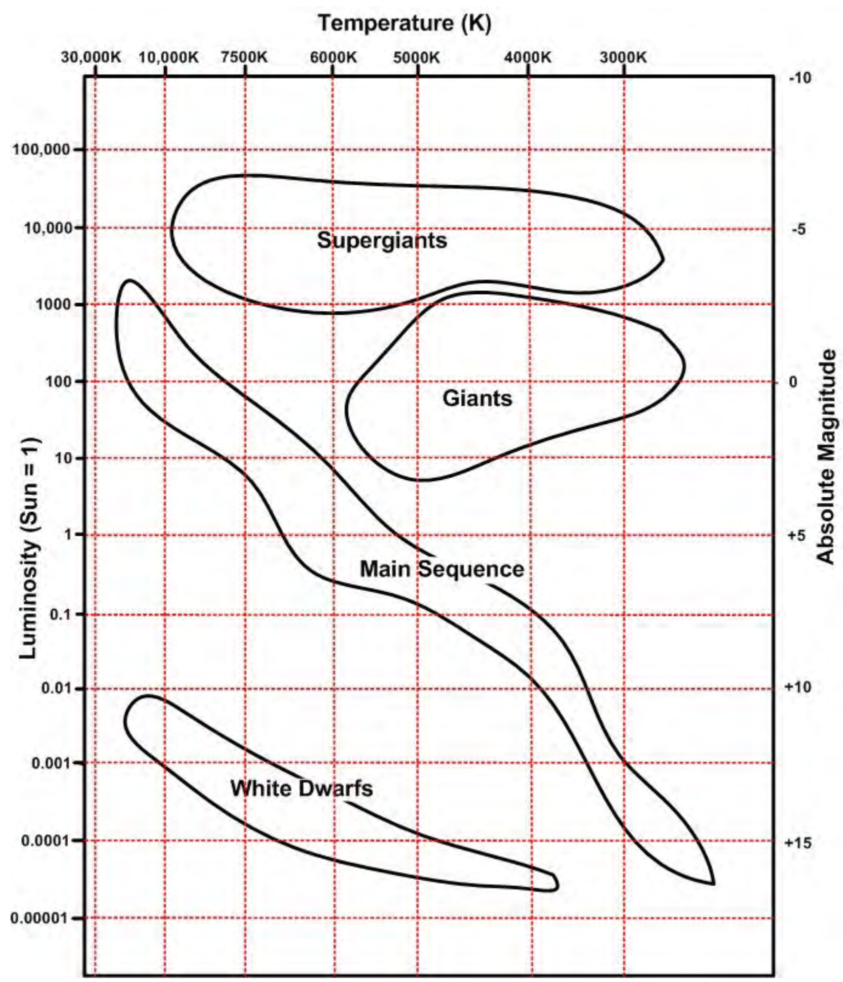
- Within the galaxies are **star clusters** containing between 10,000 and a million stars, held together by gravity. Most star clusters were likely formed at about the same time from the same nebula. Globular clusters are more tightly packed, and may contain older stars. Open clusters are more loosely packed and may contain younger stars.
- A **star** is a single, dense mass of matter that is hot enough at its core to support nuclear fusion. Stars vary greatly in size, temperature and color, as further discussed in the next section on the Hertzsprung-Russell Diagram. Most stars are found in pairs (binary stars) or small multiple-star groups. Our own star, the Sun, is unusual in that it is not part of such a group. For a detailed description of our star the Sun, see *Tutorial 29: The Sun*.
- **Nebulae** are diffuse clouds of gas and dust loosely held together by gravity. Scientists believe that new stars form in nebulae when compression waves from nearby supernova begin a consolidation and star formation process known as the Nebular Hypothesis. Diffuse nebulae may be the remnants of supernova explosions, the end of life of very large stars.
- **Planetary nebulae** are shaped like a sphere, ring or disc. They are believed to be the remnants of smaller stars like our Sun that explode outward at the end of their lives.

Hertzsprung – Russell Diagram

- During the late 1800s and early 1900s, many scientists were using telescopes to catalog and classify all of the stars and other objects visible from Earth. Scientists noticed that there was great variation in the brightness and color of stars. Spectroscopes, which split white light into its component colors like a rainbow, were used to further classify the stars into **spectral classes** (patterns of color distribution). Eventually, it was discovered that the color or spectral classes directly related to the **surface temperature** of the star, which seemed in some cases to also relate to the brightness of the star. For example, most blue-white stars were also very bright.
- Scientists during this time developed methods of estimating how far away a star was from Earth. By measuring the **apparent magnitude** (brightness) of the star,

its brightness as seen from Earth, and factoring in its distance from Earth, scientists could calculate their **absolute magnitude**, their actual brightness as judged from a standard distance. Another measure of absolute magnitude is **luminosity**, which compares other stars to our Sun—the luminosity of our Sun is 1, so luminosity states how many times brighter or dimmer another star is, as compared to our Sun.

- In the early 1900s, two scientists, **Ejnar Hertzsprung** in Denmark and **Henry Russell** in the United States, independently analyzed the relationship between absolute brightness and surface temperature in stars. The process that both used was to create a graph of absolute brightness or luminosity on the y-axis, and surface temperature or color on the x-axis. The immediate discovery that they made was that 90% of the stars they graphed had a direct relationship between absolute brightness and temperature: the hotter the surface temperature, the brighter the star. This graph, called the **Hertzsprung-Russell Diagram** or **H-R Diagram**, is still used by scientists today.



- These stars that had the direct relationship between absolute magnitude and temperature were called the **main sequence stars**, because the band on the graph contained 90% of the stars. Main sequence stars can range in luminosity from 1/10,000 of our Sun to 1000 times brighter. There is a direct relationship between luminosity and temperature, with brighter stars being hotter and the least bright stats being cooler.
- There were two concentrations of stars on the H-R Diagram that were generally brighter but cooler. These were named the giants and supergiants.
- On the H-R Diagram, **supergiants** have a luminosity of 1000 to 60,000 times brighter than our Sun, with surface temperatures ranging from 3000 K to 10,000 K.
- **Giants** have a luminosity of 10 to 100 times that of our Sun, with surface temperatures ranging from 3000 K to 6000 K.

- The fourth concentration of stars were generally low in brightness, but somewhat hotter. These **<u>white dwarfs</u>** are between 1/100 and 1/10,000 as bright as our Sun, with temperatures ranging from 4000 K to 20,000 K.
- Just as the patterns of the periodic table of the elements led to the discovery of the relationship between atomic structure and chemical properties, so too has the patterns of the H-R Diagram led to the discovery of the life-cycle of stars and four named stages.
- Based on analysis of the data contained in the H-R Diagram, scientists concluded that about 90% of a star's life is spent in a main sequence stage, the part of a star's life when it fuses hydrogen into helium.
- About 10% of the stars fell into two adjacent areas of stars that were generally brighter but cooler (redder). Scientists eventually concluded that these stars were in the last stages of their life, in which a series of elements heavier than hydrogen were being fused into still heavier elements.
- The hot but dim "stars" at the bottom of the H-R Diagram were eventually identified as the burned-out remains of small stars, called white dwarfs, no longer powered by fusion, but just a glowing ball of carbon. When a white dwarf eventually stops glowing and has become cold, it is called a **<u>black dwarf.</u>**

<u>Life Cycle of Stars</u>

- All stars begin their life when the gases (mostly hydrogen) and dust of a nebula are pulled together by gravity into a **<u>protostar</u>**. As the protostar collapses further, the center becomes hot enough to begin the fusion of hydrogen into helium. A main sequence star has now been born, and will spend the next 90% of its life in this stage. When all of the hydrogen has been fused, the star initially collapses, but then gets hot enough in its core to fuse helium into carbon. It is now a giant.
- Larger stars can go through this collapse and expansion process several times as a supergiant, fusing even heavier elements until iron is created. When no more fusion is possible, the star collapses and then explodes as a supernova, a massive explosion that spreads most of the star's mass over a huge area.
- From that point, the life-cycle of stars varies with the size (mass) of the star. Generally, small to average mass stars like our Sun follow a path that ends as a white dwarf and black dwarf. Larger stars having a mass of about 8 to 40 times that of our Sun end as **<u>neutron star</u>**, an extremely dense but small sphere made only of neutrons, about the size of Dallas but containing mass three or more times that of the Sun. The very largest stars, having a mass of more than 40 Suns, end as a **<u>black hole</u>**, which have so much mass compressed into such a small space that its gravity keeps even light from escaping.
- The life cycle of the three star sizes can be summarized as follows:
    - <u>Small to Medium Star Life Cycle</u>: (1) Nebula; (2) Main Sequence Star; (3) Giant; (4) White Dwarf; (5) Black Dwarf.
    - Large Star Life Cycle: (1) Nebula; (2) Main Sequence Star; (3) Supergiant; (4) Supernova; (5) Neutron Star.

- Very large Star Life Cycle: (1) Nebula; (2) Main Sequence Star; (3) Supergiant; (4) Supernova; (5) Black Hole.

Practice Questions

1. Scientists believe that the universe was created about ___________ billion years ago in an event known as the ______________ ___________________.
2. The _________________________contains all of the matter and energy known by humans to exist.
3. A ___________________is a very large group of stars held together by gravity.
4. The galaxy in which we live is known as the __________________ _________ galaxy, which contains about ___________ to ___________ billion stars.
5. The three types of galaxies are (1) _______________________, (2) ______________________ and (3) _______________________________.
6. A ___________________ is a very large cloud of gas and dust.
7. The ______________________ magnitude of a star is the brightness of the star as seen from Earth.
8. The ______________________ magnitude of a star is its actual brightness, if viewed from a standard distance. This is also called _____________________, which compares the actual brightness to that of the Sun.
9. The _______________________ - _____________________ Diagram is a graph that compares ___________________________, plotted on the y-axis, with ____________________ or _____________________________, plotted on the x-axis.
10. There are four groups of stars on the H-R Diagram. About 90% of the stars are in the ______________________ ________________________. The other 10% are in two areas, called the ________________________ and ______________________________. The fourth area at the bottom of the H-R Diagram contains the _________________ _______________________, which are former stars that have stopped fusion but are still glowing from their left-over heat.
11. When white dwarfs stop glowing and become cold, they are called _______________ ___________________.

12. A ________________________ is a large explosion of a collapsing supergiant star which occurs when fusion stops.

13. A ________________________ ___________________ is a very dense but small sphere made of neutrons.

14. A ___________________ ___________________ is an extremely dense area with gravity so intense that even light cannot escape.

15. The five life cycle stages for a small to medium star, no bigger than 8 times the mass of our Sun, are: (1) _______________________; (2) ________________ ___________________ _____________; (3) __________________________; (4) ________________________ and (5) _____________________________.

16. The five life cycle stages for a large star, between 8 to 40 times the mass of our Sun, are: (1) _______________________; (2) ________________ ___________________ _____________; (3) __________________________; (4) ________________________ and (5) _____________________________.

17. The five life cycle stages for a very large star, over 40 times the mass of our Sun, are: (1) _______________________; (2) ________________ ___________________ _____________; (3) __________________________; (4) ________________________ and (5) _____________________________.

Name: ____________________ Teacher: _______________ Pd. ___ Date: ________

STAAR Science Tutorial 29
TEK 8.8B: The Sun

TEK 8.8B: Recognize that the Sun is a medium-sized star near the edge of a disc-shaped galaxy of stars and that the Sun is many thousands of times closer to Earth than any other star.

Our Sun is a star, much like all of the other stars that are visible in the night sky. What makes our Sun different than other stars in the sky is that it is so much closer to Earth, and thus so much brighter. The next nearest star to Earth (other than our Sun) is Proxima Centauri, which is about 4.2 light years away from Earth. This is 263,000 times further away from Earth than our Sun. (Our Sun is 0.000016 light-years away from Earth.) While there are 11 stars within 10 light-years of Earth, most of the other stars visible in the night sky are many thousands of times further away. With a telescope, stars many millions of times further away from Earth are visible. See *Tutorial 31: Light-Years* for a detailed discussion of distance measurement in space, and the distances between Earth and other objects in the Universe.

Compared with the other stars in our galaxy, the Sun is a medium-sized star. Typical main-sequence stars in our galaxy vary in size from 0.1 times less massive than our Sun, to about 40 times more massive, with a radius range of 0.1 to 18 times that of the Sun. The luminosity or absolute brightness of main-sequence stars in our galaxy varies from 0.0008 times as bright to 500,000 times brighter. Giant and supergiant stars near the end of their life can become much, much larger in diameter and brightness.

The surface temperature of our Sun, 5,500°C, is about average when compared with other stars. About half of the stars in our galaxy are cooler, and about half are hotter. The surface temperature of stars ranges from 3000°C to 30,000°C, though very few stars are over 10,000 C. The color of our Sun, yellow, is at about the middle of the star spectrum, with red at the cool end and blue-white at the hot end.

One characteristic of our Sun that is a bit unusual is that our Sun is not part of a binary (double) or multiple-star system. Our Sun has no star partner.

Our Sun is expected to have a total life span of about 10 billion years. It is currently about 4.6 billion years old, in the middle of its "main sequence" phase of life. During this phase, it fuses hydrogen into helium in its core, with a temperature of about 15 million degrees Celsius. When all of its hydrogen has been fused into helium, the fusion process will temporarily stop, and the Sun will begin to collapse under the force of gravity. This compression at the core will increase the temperature. When the core temperature reaches about 100 million degrees Celsius, the fusion of helium will begin, and the Sun will expand to become a red giant. Once all of the helium has been fused to carbon, the Sun will collapse into a white dwarf, a very hot glowing ball of carbon. Eventually, the Sun will finally cool into a black dwarf. See *Tutorial 28:*

Stars, Galaxies, Universe for a detailed discussion of the life cycle of stars and the H-R Diagram, which is a graph showing the brightness and temperature of all stars.

The Sun is located in the Milky Way Galaxy, which is shaped like a flat disk with outwardly spiraling arms. The overall diameter of the Milky Way Galaxy is about 100,000 light-years. Our Sun and solar system is about 27,000 light-years from the center, in one of the spiral arms. There are about 200 to 400 billion stars in the Milky Way. They are seen from Earth as a milky white band of stars (hence the name) crossing the sky, but is visible only on very clear, dark nights away from city lights.

Practice Questions

1. Our Sun is so much brighter than the other stars visible in the sky because it is so ____________________ to the Earth. The next closest star to Earth is ____________________________ times further away than the Sun.
2. The size of the Sun is _______________________, compared to the size of other main-sequence stars.
3. The surface temperature of our Sun is _________________ degrees Celsius, which gives a surface color of ________________________. Stars range in surface temperature from ________________ to __________________°C.
4. The one thing about our Sun that is not average is that it is not part of a ________________ or ____________________ star system.
5. Our Sun is currently about ______________ billion years old, and is expected to have a total life span of about ________________ billion years.
6. During the main-sequence of a star's life, it fuses _____________________ into _________________________ and has a core temperature of ___________________________ degrees Celsius. In the beginning of the giant or supergiant phase, a star fuses ___________________________ into __________________________, and has a core temperature of ________________________________ degrees Celsius.
7. Our Sun is located in the ____________________ ______________ Galaxy, which has a diameter of _______________________ light-years. Our Sun is located about ______________________ light-years from the center of the galaxy.

Name: ____________________ Teacher: _______________ Pd. ___ Date: ________

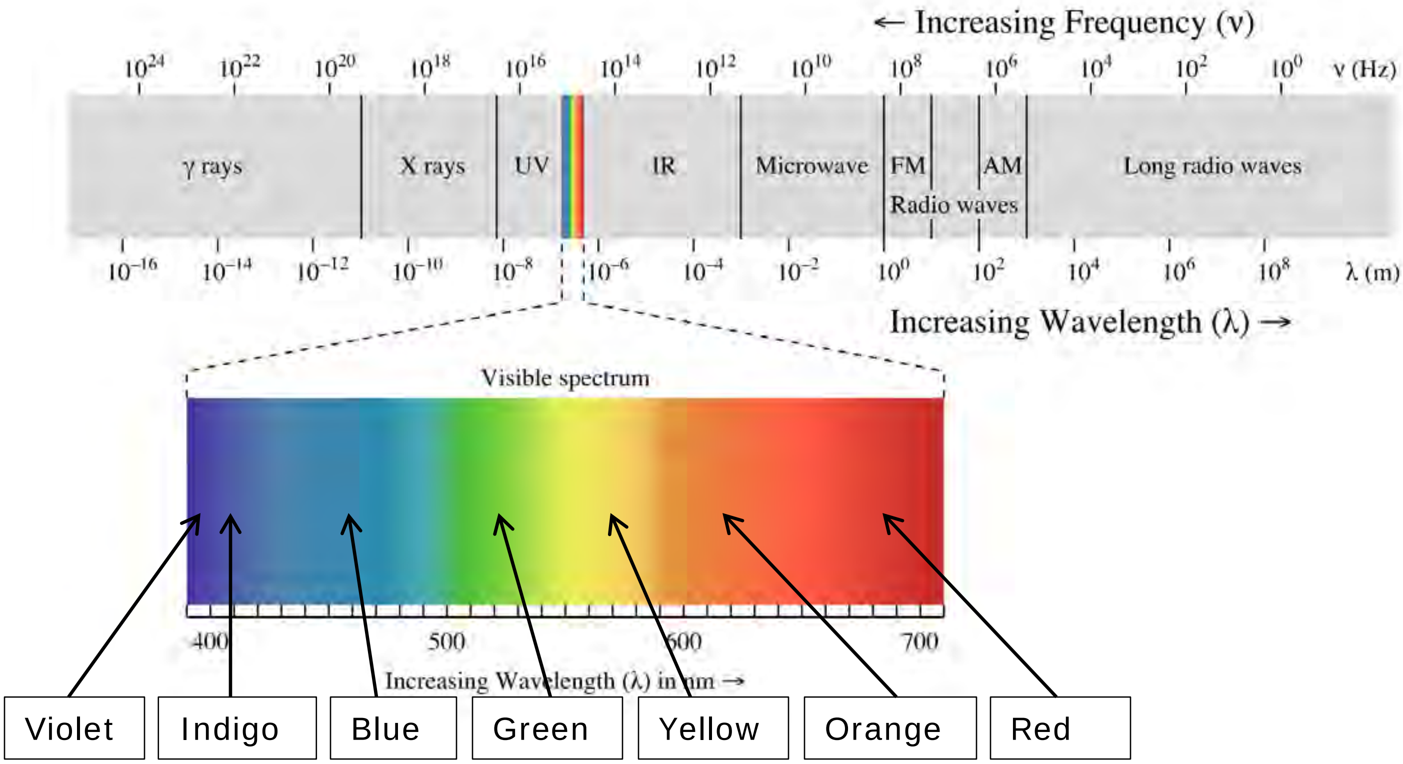
STAAR Science Tutorial 30
TEK 8.8C: Electromagnetic Waves

TEK 8.8C: Explore how different wavelengths of the electromagnetic spectrum such as light and radio waves are used to gain information about distances and properties of components in the universe.

The Electromagnetic Spectrum

- Electromagnetic energy is a form of energy that can move through both matter such as air or water, as well as the vacuum of space. The model that scientists use to best describe electromagnetic energy is a transverse wave (shaped much like a non-breaking ocean wave), though it also behaves somewhat like a particle, because it comes in packets of energy of a particular size.
- Each form of electromagnetic energy has a particular range of wavelengths and frequencies. **Wavelength** is the distance between one wave crest and the next. **Frequency** is a measurement of how many waves passes a point in one second. The shorter the wavelength of the electromagnetic energy, the greater the frequency, and the greater the energy contained in the wave.
- The forms of electromagnetic energy that we are most familiar with are light and radio waves. We use our eyes to see and interpret light, the only part of electromagnetic energy we can sense directly. Humans have developed many instruments to create, use and detect the other forms of electromagnetic energy. We use radio waves to transmit television and telephone signals. We use microwaves to cook food and detect storms (radar). We use x-rays to see inside our bodies.
- All electromagnetic energy travels at a constant speed when moving through a particular "medium"—a kind of matter. The so-called "speed of light" is the speed of any electromagnetic wave in a vacuum, without interference with matter. That speed is very fast, about 300,000 kilometers per second. This constant speed allows scientists to use light to measure distance. See *Tutorial 31: Light-Years*. As the medium becomes denser, the speed becomes slower. Some mediums block parts of the electromagnetic energy spectrum completely, while others do not. For example, light cannot pass through the cover of a book, but radio waves and x-rays can.
- Humans rely on our ability to see light to interpret and understand our world. Using technology, scientists have extended their ability to see the Universe, by turning the other forms of electromagnetic energy, called the electromagnetic spectrum, into either light or sound.
- The diagram below shows the entire electromagnetic spectrum, with the visible light portion near the center of the spectrum magnified below. (For those reading this on a black-and-white copy, the color names are labeled.) The waves at the left side of this diagram have the most energy and shortest wavelengths, while the

waves at the right side have the longest wavelengths and least energy. The main categories of electromagnetic waves, from left to right, are gamma rays, x-rays, ultraviolet rays, visible light, infrared waves, microwaves and radio waves.



Optical Telescopes

- While many stars and other objects in the sky are visible to the "naked" eye, scientists use telescopes to magnify the visible-light image of objects in the sky, and to increase the apparent brightness of the objects by gathering more light with a large lens or mirror.
- The first telescopes used a pair of glass lenses, a large objective lens at the sky-pointing end, and a smaller eyepiece lens at the viewing-end. The larger the objective lens, the more light is gathered and the greater the number of dimly-lit objects that can be seen.
- Modern telescopes use a large concave mirror to gather light, and usually have a lens connected to an electronic sensor like in a digital camera to see and capture images. The very largest observatories actually use multiple telescopes to look at the same object, and combine the images with computers to get even more detail.
- Telescopes on Earth are usually located on the tops of mountains away from city lights and pollution. Even then, air movement and clouds limit how much can be seen from Earth. The very best telescope images are taken from space, with telescopes such as the Hubble Space Telescope.
- The Hubble Space Telescope has been able to photograph galaxies over 13 billion light-years away from Earth. All of our current estimates of the age of the Universe, and the number of galaxies in the Universe, are based on images and measurements from the Hubble Space Telescope.

- Scientists have launched other space telescopes using infrared waves, ultraviolet waves and even X-rays instead of visible light, to better study objects in space.

Spectroscopes and Light Measurement

- A spectroscope is an instrument that splits white light, which is really a blend of all the separate colors of light, into its individual wavelengths so that they can be each be measured. The overall color of light emitted by stars is directly related to the surface temperature of the star. For this reason, scientists use spectroscopes to determine the surface temperature and color of stars.
- Because each element emits specific bands of colored light unique to that element when it absorbs electromagnetic energy —a color "fingerprint" of the element—scientists can determine what elements are contained in a star.
- The total amount of light emitted by a star, as seen from Earth, is called the star's **apparent magnitude** or apparent brightness. Scientists use this apparent brightness, along with its distance from Earth, to calculate the star's **absolute brightness or luminosity**. The size of a star, and thus its mass, can be calculated from its luminosity.

Star Distance Measurements

- When scientists view the pattern of stars in the sky over time, some appear to shift positions slightly as the Earth moves around the Sun. These stars shift because they are closer to Earth—this **parallax** effect can be used to determine the distance to our nearest stars.
- There are a variety of methods that scientists can use to estimate the distance to more-distant stars. For example, some variable stars (stars that vary in brightness over a period of time) are known to have a constant absolute magnitude. By measuring their apparent magnitude (the brightness as seen from Earth), the star's distance from Earth can be calculated.

Doppler Shift

- When electromagnetic waves are emitted from a very fast moving object, the distantly-viewed waves are either compressed or stretched out, depending on whether the object is moving towards the viewer or away from the viewer. If the object is moving towards the viewer, they are compressed into shorter wavelengths. If the object is moving away from the viewer, the waves are stretched out, making the wavelengths longer. In visible light, the light appears to shift towards the blue side of the spectrum ("blue-shift) if moving towards the viewer, and towards the red side of the spectrum (red-shift) if moving away from the viewer. This is called the Doppler Shift or Doppler Effect.
- Scientists use Doppler shift to determine whether distant stars and galaxies are moving towards us or away from us. In the late 1920s, astronomers Georges Lemaitre and Edwin Hubble separately proposed that all distant galaxies are moving away from Earth (red-shifted), and that the further away a galaxy was, the faster it was moving. From this discovery, scientists began to accept that the Universe is expanding. Scientists now believe that the Universe began to expand

from a single point in space some 13.7 billion years ago—the "Big Bang Theory." See *Tutorial 28: Stars, Galaxies, Universe* for a more detailed discussion of this theory.

- Unlike the distant galaxies observed by Hubble, galaxies in our local group are moving towards us (blue-shifted). Scientists believe that all of the galaxies in our Local Group will eventually merge together.
- The revolution rate of the Milky Way Galaxy around its center has been measured by Doppler Shift methods. It takes about 200 million years for the stars in the Milky Way Galaxy to revolve once around the galaxy's central black hole.

Radio Telescopes

- Scientists can also use telescopes to "see" images of radio waves and microwaves, by using arrays of widely spaced dish antennas (similar to those used by Dish TV, but much bigger) to receive the signals. A computer is used to translate the varying signal strength into false colors representing the signal strength, and thus "see" an image of the radio waves.
- Radio and microwave images have the advantage of being able to see through clouds of dust that block visible light, and see objects that are too cool to emit the other kinds of electromagnetic waves. The biggest disadvantage of radio telescopes is that the long wavelength of the radio waves cannot capture as much detail as shorter wavelength visible light. This is why scientists today use multiple widely spaced antennas—to increase detail.
- Using radio-telescopes, scientists have been able to get a whole-sky microwave image of space, and capture the background radiation left over from the "big-bang" creation of the Universe.

Practice Questions

1. Electromagnetic energy has properties of both ______________________ and ____________________________.
2. The ____________________________ of a wave is the distance from one wave crest to the next, while its ___________________________ is the number of waves that passes a point in one second.
3. The longer the wavelength of an electromagnetic wave, the more __________ that it contains.
4. The speed of all electromagnetic waves in space is _____________________ kilometers per second.
5. The seven different parts of the electromagnetic spectrum, stated from the shortest wavelength to the longest, are (1) ____________________________ ______________; (2) __________________; (3) _______________________

_______________; (4) ____________________ ___________________;

(5) ___________________ ___________________; (6) ____________________;

and (7) ______________ ____________________..

6. Scientists use __________________________________ to measure the color of light.

7. The _______________________________ of the surface of a star can be determined from a star's color.

8. Bands of light in a star's spectrum allow scientists to determine what ______________________ are in the star.

9. The brightness of a star as seen from Earth is its __________________________ ____________________________. The actual brightness of a star, calculated by knowing its distance from Earth and apparent brightness, is its ______________________ _____________________ or ____________________.

10. The distance to stars that are close to Earth can be measured by ____________________.

11. The ______________________ ____________________ allows scientists to determine whether a star is moving towards or away from Earth. If the light from the star is ______________-shifted, it is moving away from Earth. If the light is ___________________-shifted, it is moving towards Earth.

12. One of the main pieces of evidence supporting the Big Bang Theory is the fact that all distant galaxies are ___________________-shifted, meaning that they are moving ___________________ from Earth.

13. Another piece of evidence supporting the Big Bang Theory is the _____________________________ background of space, which was measured with radio telescopes.

Name: ____________________ Teacher: _______________ Pd. ___ Date: ________

STAAR Science Tutorial 31
TEK 8.8D: Light Years

TEK 8.8D: Model and describe how light years are used to measure distances and sizes in the universe.

Generally, we pick a measurement unit that is close to the size of the object we are measuring. To measure the size of a leaf, we use centimeters. To measure a room we use meters. To measure the distance between cities, we use kilometers.

Because distances in space are so large, the metric units of distance measurement that we use on Earth, such as kilometers, are too small to be convenient. The closest object to Earth in our solar system is the Moon, which is about 375,000 kilometers away. While a large distance, we can still comprehend or visualize how far away that is.

The distance from the Sun to Earth is about 149,600,000 kilometers. To make measurement within our solar system more convenient, scientists created a new measurement called the **astronomical unit (au)** to match this average distance from the Earth to the Sun. This makes it easier to compare the distances between other planets and the Sun, since the Earth-Sun distance is 1 au. The distances from the Sun to each of the eight planets is as follows: Mercury: 0.4 au; Venus: 0.7 au; Earth: 1.0 au; Mars: 1.5 au; Jupiter: 5.2 au; Saturn: 9.5 au; Uranus: 19.6; Neptune: 30 au. This means that Neptune is 30 times further away from the Sun than is the Earth.

Outside of our solar system, the astronomical unit is too small to measure the distances to even the nearest stars. For these distances, scientists use the **light-year**, which is the distance that light travels in one year, about 9.5 trillion kilometers, or about 63,241 au.

The light-year is a unit of distance, not time, but it does have the added advantage of also stating how long it will take light to travel that distance. For example, Proxima Centauri, the closest star (other than our Sun) to Earth, is 4.2 light-years away from Earth, which also means that it takes 4.2 years for its light to reach Earth. When you look out into space, you are also looking back in time.

Our galaxy, the Milky Way, is about 100,000 light years in diameter. The Sun is about 26,000 light years away from the center of the Milky Way galaxy. The nearest galaxy outside of our own, the Large Magellanic Cloud, is 165,000 light years away. The largest galaxy in our local group of galaxies, Andromeda, is 250,000,000 light years away. Using the largest telescopes, scientists can see galaxies over 13 billion light years away.

For distances much less than one light-year, it is sometimes useful to measure in light-minutes or light-seconds. When astronauts visited the Moon, their radio signal took about 1.2 seconds to travel from the Moon to Earth, because radio waves travel at the speed of light, and the Moon is about 1.2 light-seconds away. Light from the Sun takes about 8.3 minutes to travel to Earth, because the Sun is about 8.3 light-minutes away from Earth. If the Sun has a coronal mass discharge, it takes us on Earth about 8.3 minutes to find out.

Practice Questions

1. Why are kilometers not a good unit of measurement in space? ______________

   ____

2. What distance measurement unit is used for objects within our solar system?

   ____

3. How many kilometers are in one astronomical unit? ______________________

4. What distance measurement unit is used for objects outside of our solar system? ____

5. How many kilometers are in one light-year? ____________________________.

6. How far away is the nearest star to Earth other than our Sun?

   ____

7. How far away is the center of the Milky Way Galaxy from Earth?

   ____

8. What is the diameter of the Milky Way Galaxy?

   ____

9. How far away is the Andromeda Galaxy from Earth?

   ____

10. How long does it take for light from our Sun to reach Earth?

    ____

11. What is the distance from the Sun to the Earth, in light-minutes?

    ____