Investigating Stars Name:________________________________________Block:____________

**FYI: Inverse Square Law—Star Light, Star Bright: The Magnitude System** **E3:R4a**

1. Read FYI: *Inverse Square Law—Star Light, Star Bright: The Magnitude System*

   As you read use the spaces below to write down any information you find especially interesting. Also define the bold terms used in the text. If you run across any other words that you don't know the meaning of, write those down and ask your teacher to help you with them.

| **Word/Term** | Definition |
|---|---|
| Inverse Square Law | The amount of light than an object receives from a source _____________by the ___________ of the ____________ between the object and the source. In other words, light intensity follows an **inverse square law.** |
| Apparent Brightness | The brightness of an object that we perceive _______ __________ is called its **apparent brightness**. |
| Hipparchus | The _________ astronomer **Hipparchus** around the year _______ B.C.E. devised an apparent brightness scale that today we just simply call the *magnitude* scale. He divided the brightness of stars he could see with his naked eye into 6 magnitude classes with the brightest stars being _____ magnitude and the dimmest stars being _____ magnitude. |
| Limitations of Apparent Magnitude | The apparent magnitude system can't tell us whether one star is *really* brighter than another because stars vary in their ___________from Earth. A very bright star that is very far away will appear _______, while a dim star that is __________Earth may appear brighter. |
| Absolute Magnitude | When the brightness of one star is compared to the brightness of another as if they were both at the same fixed ___________ from Earth, the results give us a value called the **absolute magnitude.** (What distance do astronomers use for this comparison?) _________________ |
| Extra space for additional words or interesting information. | |

1. Which star appears brighter to an observer on Earth, a star that has *apparent magnitude* of +1 or a star that has an *apparent magnitude* of -1? Do you have enough information to answer?

2. Which star appears brighter to an observer on Earth, a star that has *absolute magnitude* of +1 or a star that has an *absolute magnitude* of -1? Do you have enough information to answer?

# FYI Inverse Square Law — Star Light, Star Bright: The Magnitude System

When electromagnetic radiation is emitted by a star, such as our sun, it can be considered to be coming from a point because of the spherical nature of the star and its immense distance from Earth. As a pulse of light spreads out in a sphere, we can imagine a spherical shell that is created by the pulse of light. This spherical shell will expand outward and will cover a surface area of $4\pi r^2$, where r is the radius of the sphere. This means that the light is spread over an area of $4\pi r^2$.

Suppose the radius of a sphere is 1 meter. Its surface area is $4\pi(1 \text{ m})^2$ or $4\pi \text{ m}^2$. If we double the radius of the sphere to 2 meters, its surface area is $4\pi(2 \text{ m})^2$ or $16\pi \text{ m}^2$. The surface area did not double as one may have expected — it quadrupled. Similarly, if we triple the radius to 3 meters, the surface area is $4\pi(3 \text{ m})^2$ or $36\pi \text{ m}^2$, a factor of nine greater than the original sphere with a 1 m radius. As the surface area of the sphere expands, the amount of light hitting a same-sized patch on the sphere will decrease. Consider a 1 $\text{m}^2$ patch on the surface of the sphere. When the sphere expands from a radius of 1 m to a radius of 2 m, the surface of the sphere becomes 4 times larger, so the amount of light hitting a 1 $\text{m}^2$ patch on its surface is reduced by a factor of 4. In other words, 1/4 of the light hits the patch on the larger sphere. Similarly, when the sphere expands to a radius of 3 m, only 1/9 of the original light will hit the patch. We can generalize this relationship by saying that the amount of light that an object receives from a source decreases by the square of the distance between the object and source, or that it follows the **inverse square law**.

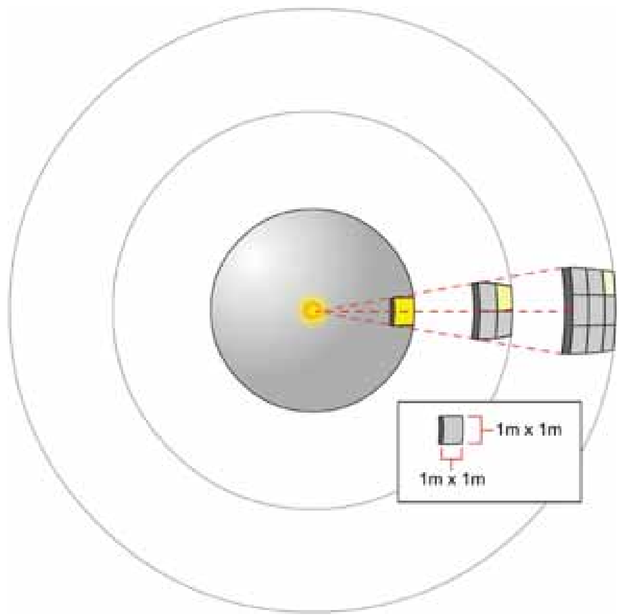

**Figure 2-10: Diagram illustrating the inverse square law**

The inverse square law applies generally when energy and forces are distributed spherically from a point source. This includes the gravitational force that a spherical planet or star exerts upon objects in its surroundings. The law even applies to the electric force that a point charge (such as an electron or proton) exerts on other charges.


**Figure 2-11: Image of a cluster of stars in Centaurus about 5900 ly from Earth. How bright a star appears to be in the night sky depends on both the star's diameter and its distance from us.**

## Star Light, Star Bright: The Magnitude System

Even a quick look at the stars in the night sky reveals that stars appear to have different brightness. The brightness of an object that we perceive from Earth is called its *apparent brightness.* We can differentiate the relative brightness of stars by using a magnitude system based on how bright a star appears to the unaided eye. The Greek astronomer Hipparchus devised this system around 150 B.C.E. He used the apparent magnitude of stars to describe their apparent brightness. He put the brightest stars into the first magnitude class, the next brightest stars into the second magnitude class, and so on until he had all of the visible stars grouped into six magnitude classes. The dimmest stars visible to the eye were sixth magnitude. The way in which Hipparchus devised his scale means that higher magnitudes relate to dimmer stars, and lower magnitudes are used to describe brighter stars.

The apparent magnitude can't tell us whether one star is really brighter than another because stars vary in their distances from Earth. A very bright star that is very far away will appear dim, while a dim star that is nearer Earth may appear brighter. Astronomers factor in the distances to stars by mentally placing each star at a fixed distance. They use a distance of 32.6 light-years, or 10 parsecs (1 parsec = 3.26 ly) from Earth. The brightness of one star is compared to the brightness of another, as if they were both at this fixed distance from Earth. The resulting value is called **absolute magnitude**. The closest star to us—the sun—has an apparent magnitude of -26.5, but from a distance of 10 pc the sun would have a magnitude of only +4.7, no brighter than the dimmest star in the Little Dipper. On the other hand, the bright star Rigel, with an apparent magnitude of +0.15, is 776 ly away from us, so placed at a distance of 10 pc, its magnitude would be -6.7.

The absolute magnitude is a measure of the star's luminosity—the total amount of energy radiated by the star every second. If you measure a star's apparent magnitude and know its absolute magnitude, you can find the star's distance using the inverse square law of light. If you know a star's apparent magnitude and distance, you can find the star's luminosity. The luminosity of a star is a quantity that depends on the star itself, not on how far away it is.