ClassAction: Stellar Properties Module
Instructor's Manual

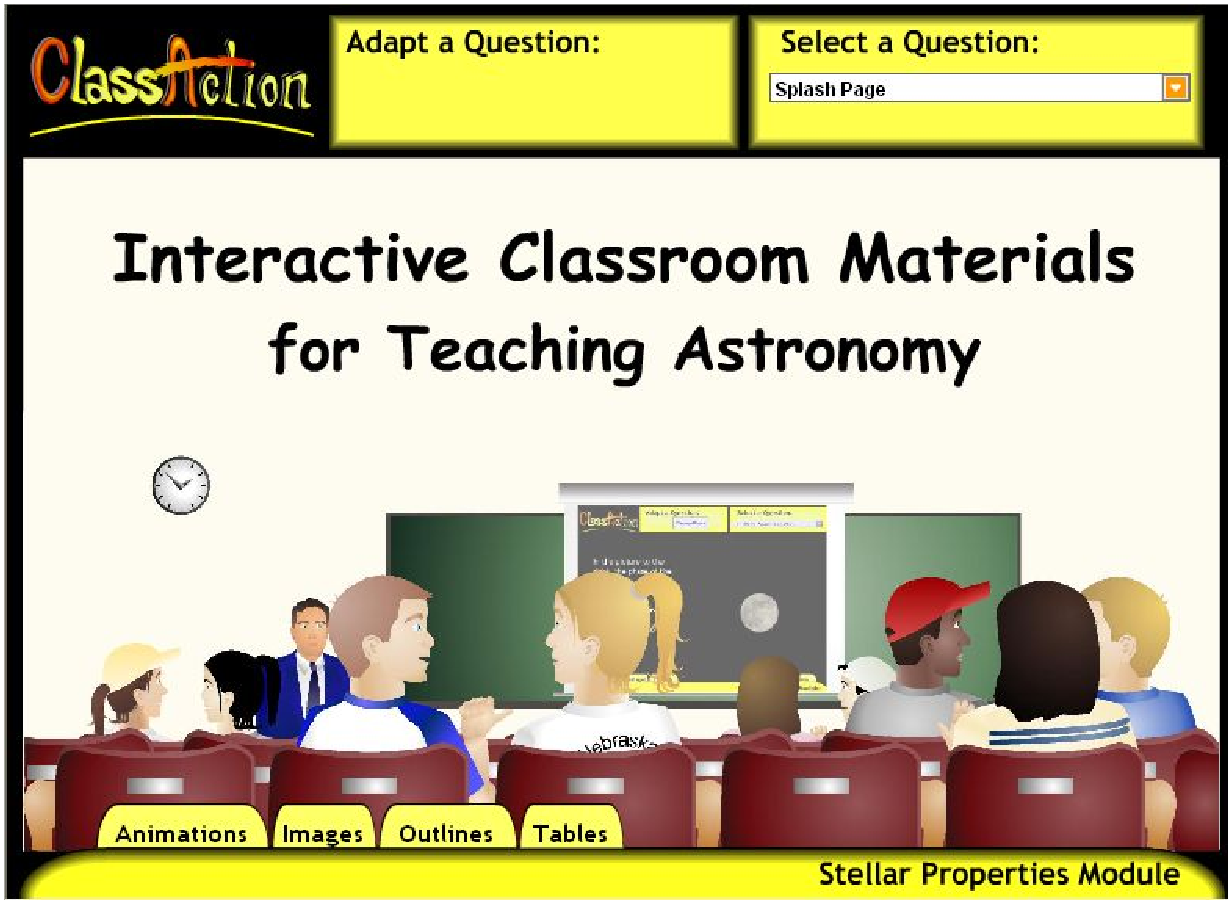


Table of Contents

Section 1: *Warm-up Questions*

This section contains warm-up questions. These questions are single concept based and therefore generally straightforward to answer.

It is recommended that these questions be projected during the few minutes immediately preceding class.

Teaching suggestions, and possibly hints, are provided for every question.

A degree of difficulty (1 – 5; 1 being easy and 5 being difficult) is also provided for every question.

Temperature and Color

Key Concept: Temperature

Secondary Concepts: Blackbody radiation

Description:
The image above displays automobile controls for the air conditioner and heater. For the control knob on the right, cool/cold is the "blue" range and warm/hot is the "red" range. Students should determine how this may or may not differ from how an astronomer might relate a certain temperature range and colors.

Answer:
An object acting like a blackbody radiator (like a star) will emit more light towards the blue end of the visible spectrum when at a higher temperature, and will emit more light towards the red end of the visible spectrum when at a lower temperature. Thus:

An astronomer associates the color blue with high temperature (hot) objects and the color red with low temperature (cool) objects.

The color / temperature relationship as depicted on the automobile controls more than likely stems from a hot fire being red and cool water / ice being blue.

Suggestions:
Recommended images: Colors of Stars.

Recommended tables: Stellar Colors & Temperatures.

Difficulty: 2

Section 2: *General Questions*

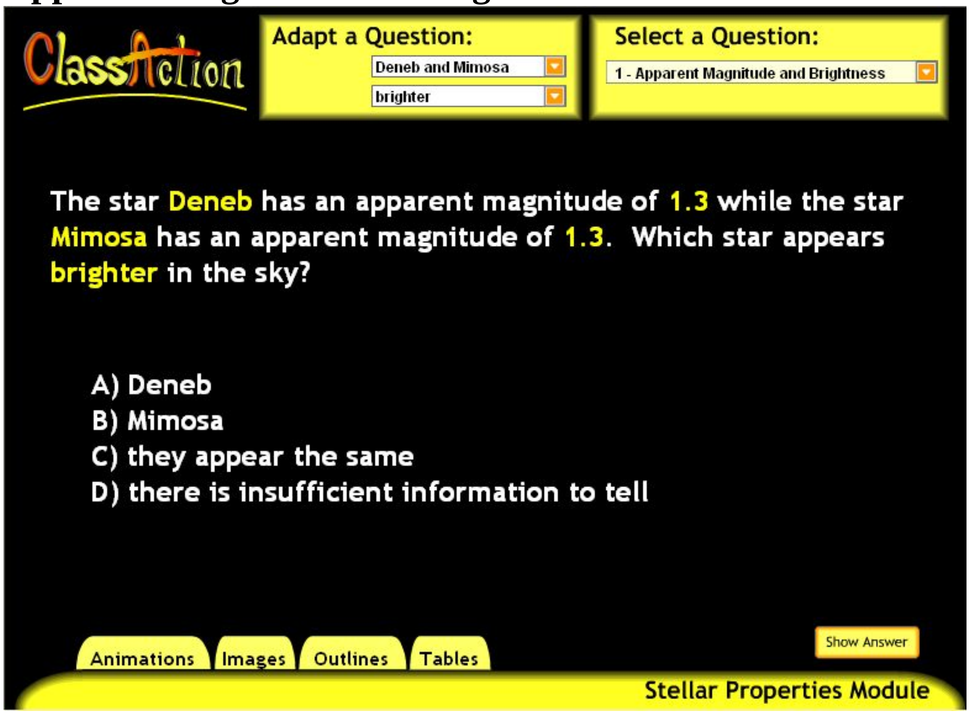
This section contains general astronomy questions that are straightforward applications of the material. These questions are designed to basically test 1 – 2 astronomical concepts, and while not necessarily easy, the concepts being tested are in the same context in which they are generally covered in a lecture and/or textbook.

It is recommended that the think-pair-share method be employed for these questions.

Teaching suggestions, and possibly hints, are provided for every question.

A degree of difficulty (1 – 5; 1 being easy and 5 being difficult) is also provided for every question.

Apparent Magnitude and Brightness

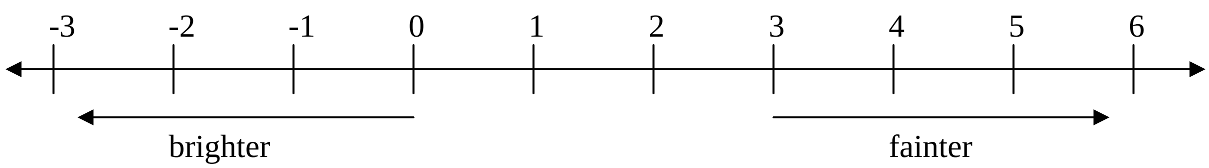


Key Concept: Magnitude System

Secondary Concept: Apparent magnitude

Description:
A question is presented that provides apparent magnitude values for two stars in the night sky. Students should determine which star appears brighter or fainter.

Answer:
The magnitude numbering system is designed as follows:



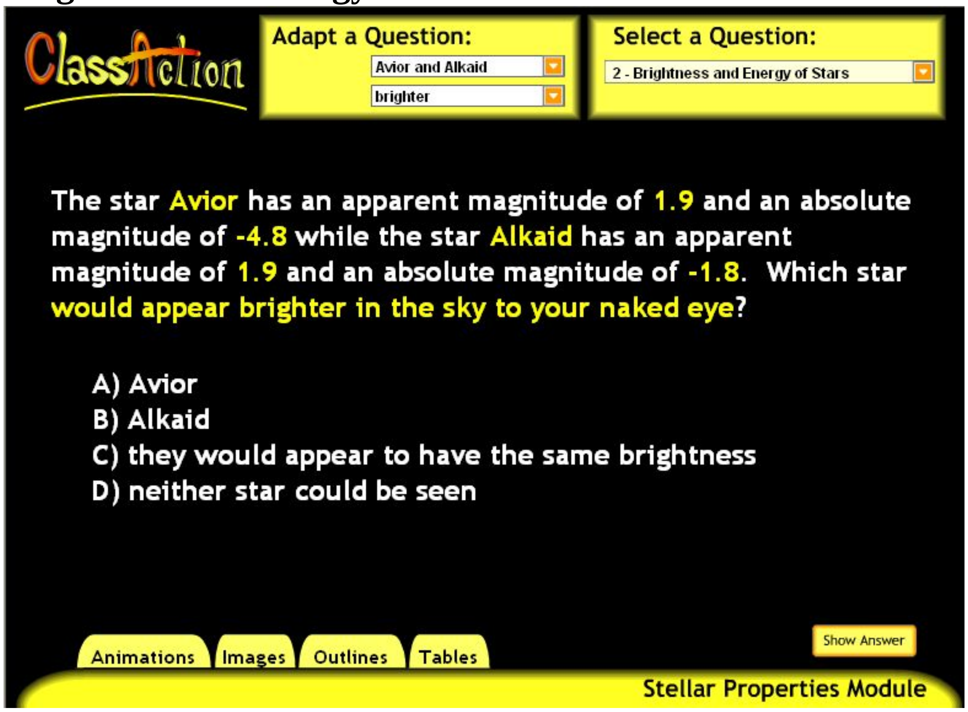
Thus:

Deneb (m = 1.3) and Mimosa (m = 1.3) appear to be the same brightness.
Altair (m = 0.8) appears brighter than Polaris (m = 2.0) (or, Polaris appears fainter than Altair).
Sirius (m = -1.5) appears brighter than Merak (m = 2.4) (or, Merak appears fainter than Sirius).

Suggestions:
There are 3 different adaptations to the question, therefore the instructor could talk through and present the solutions to one of the adaptations and use the think-pair-share method with the remaining adaptations.

Difficulty: 1

Brightness and Energy of Stars

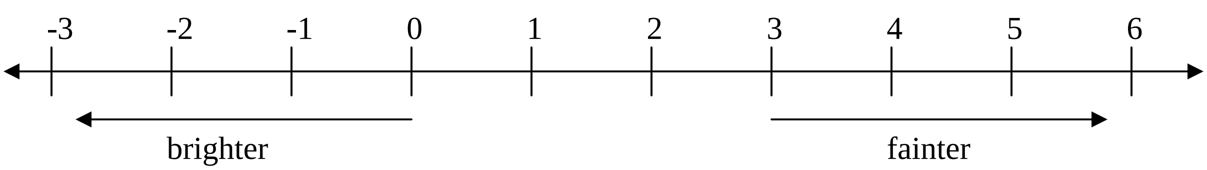


Key Concept: Magnitude System

Secondary Concepts: Apparent magnitude; Absolute magnitude

Description:
A question is presented that provides apparent magnitude and absolute magnitude values for two stars in the night sky. Students should determine which star appears brighter or which star is emitting more energy.

Answer:
The magnitude numbering system is designed as follows:



Apparent magnitude (m) is measure of how bright a star appears to be in the night sky. Absolute magnitude (M) is measure of how bright a star actually is when it is placed a distance of 10 parsecs from the Earth, which means that absolute magnitude is also an implicit measure of intrinsic brightness <u>and</u> how much energy a star is releasing per second (luminosity). Thus:

Avior (m = 1.9) and Alkaid (m = 1.9) appear to be the same brightness, but Avior (M = -4.8) emits more energy than Alkaid (M = -1.8).

Barnard's Star (m = 9.5) appears brighter than Wolf 359 (13.4), and Barnard's Star (M = 13.2) emits more energy than Wolf 359 (M = 16.6).

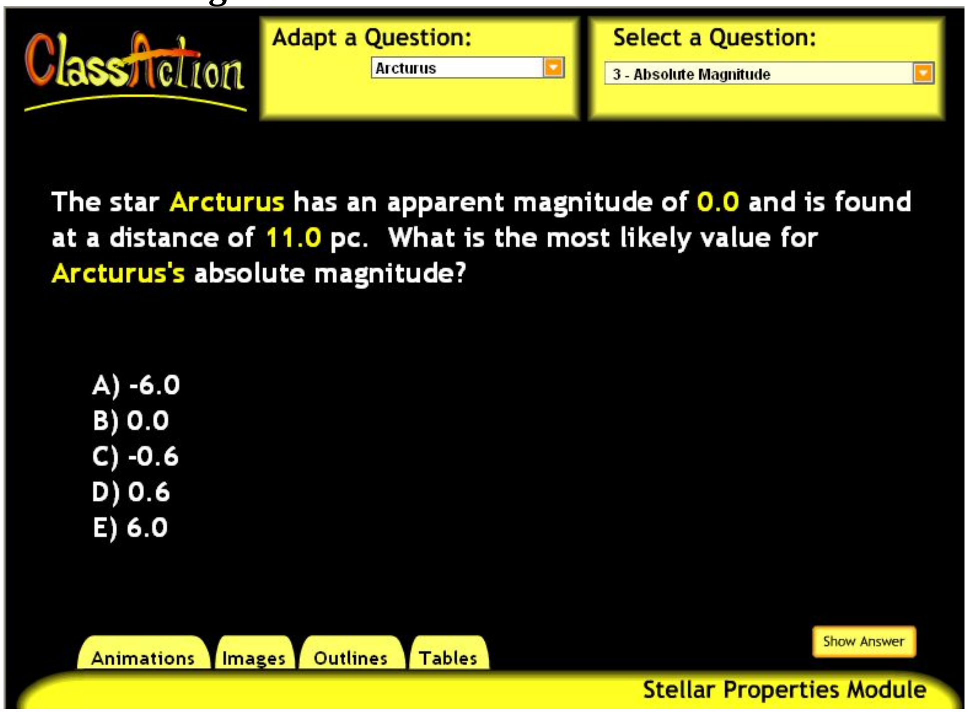
Aldebaran (m = 0.9) appears brighter than Acrux (m = 1.6), but Acrux (M = -4.0) emits more energy than Aldebaran (M = -0.8).

Arcturus (m = 0.0) appears brighter than Deneb (m = 1.3), but Deneb (M = -7.5) emits more energy than Arcturus (M = -0.6).

Suggestions:
There are 8 different adaptations to the question, therefore the instructor could talk through and present the solutions to one or two adaptations and use the think-pair-share method with the remaining adaptations.

Difficulty: 2

Absolute Magnitude

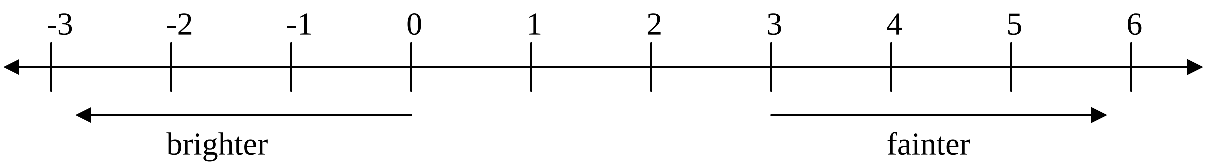


Key Concept: Magnitude System

Secondary Concepts: Apparent magnitude; Absolute magnitude

Description:
A question is presented that provides the apparent magnitude and the distance from the Earth for a selected star in the night sky. Students should determine a mostly likely value for the absolute magnitude of the star.

Answer:
The magnitude numbering system is designed as follows:



Apparent magnitude (m) is measure of how bright a star appears to be in the night sky. Absolute magnitude (M) is measure of how bright a star actually is when it is placed a distance of 10 parsecs (pc) from the Earth. If a star happens to be located at an actual distance of 10 pc, its apparent and absolute magnitude will have the same value. If a star is located beyond 10 pc, its absolute magnitude value will be less than its apparent magnitude; and if a star is located closer than 10 pc, its absolute magnitude value will be greater than its apparent magnitude. Also, the amount of the difference between the magnitude values reflects the star's distance from 10 pc. Thus:

Arcturus (m = 0.0; d = 11.0 pc) would have an absolute magnitude of M = -0.6.
HIP (m = 11.7; d = 10.0 pc) would have an absolute magnitude of M = 11.7.
Rigel (m = 0.2; d = 237 pc) would have an absolute magnitude of M = -6.6.

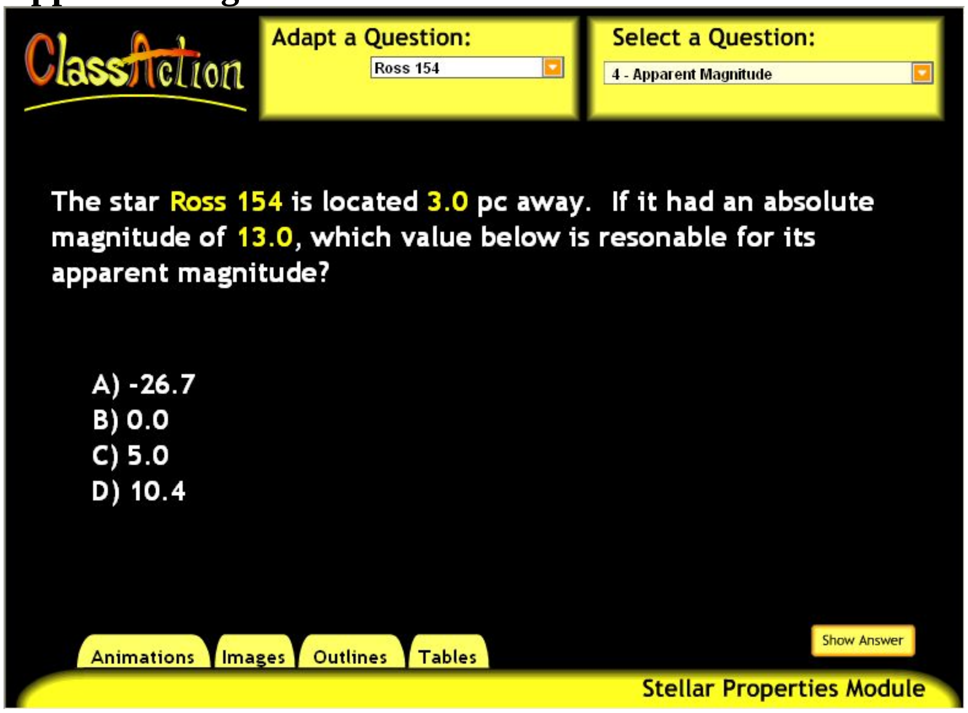
Suggestions:
There are 3 different adaptations to the question, therefore the instructor could talk through and present the solutions to one of the adaptations and use the think-pair-share method with the remaining adaptations.

Recommended animations: Distance Modulus Explorer.

Recommended outlines: Distance Modulus.

Difficulty: 3

Apparent Magnitude

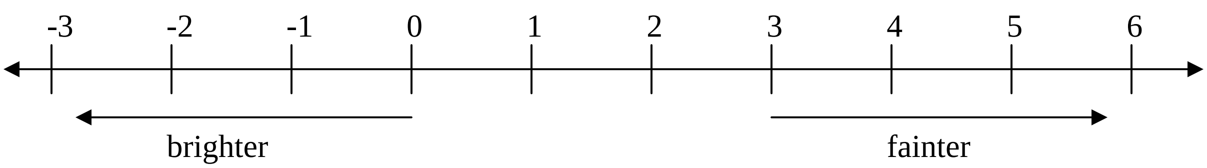


Key Concept: Magnitude System

Secondary Concepts: Apparent magnitude; Absolute magnitude

Description:
A question is presented that provides the absolute magnitude and the distance from the Earth for a selected star in the night sky. Students should determine a mostly likely value for the apparent magnitude of the star.

Answer:
The magnitude numbering system is designed as follows:



Apparent magnitude (m) is measure of how bright a star appears to be in the night sky. Absolute magnitude (M) is measure of how bright a star actually is when it is placed a distance of 10 parsecs (pc) from the Earth. If a star happens to be located at an actual distance of 10 pc, its apparent and absolute magnitude will have the same value. If a star is located beyond 10 pc, its absolute magnitude value will be less than its apparent magnitude; and if a star is located closer than 10 pc, its absolute magnitude value will be greater than its apparent magnitude. Also, the amount of the difference between the magnitude values reflects the star's distance from 10 pc. Thus:

Ross 154 (M = 13.0; d = 3.0 pc) would have an apparent magnitude of m = 10.4.
Sol (M = 4.8; d = 4.8 x 10^{-6} pc) would have an apparent magnitude of m = -26.7.
HD 6658 (M = -2.5; d = 32.2 pc) would have an apparent magnitude of m = 5.0.

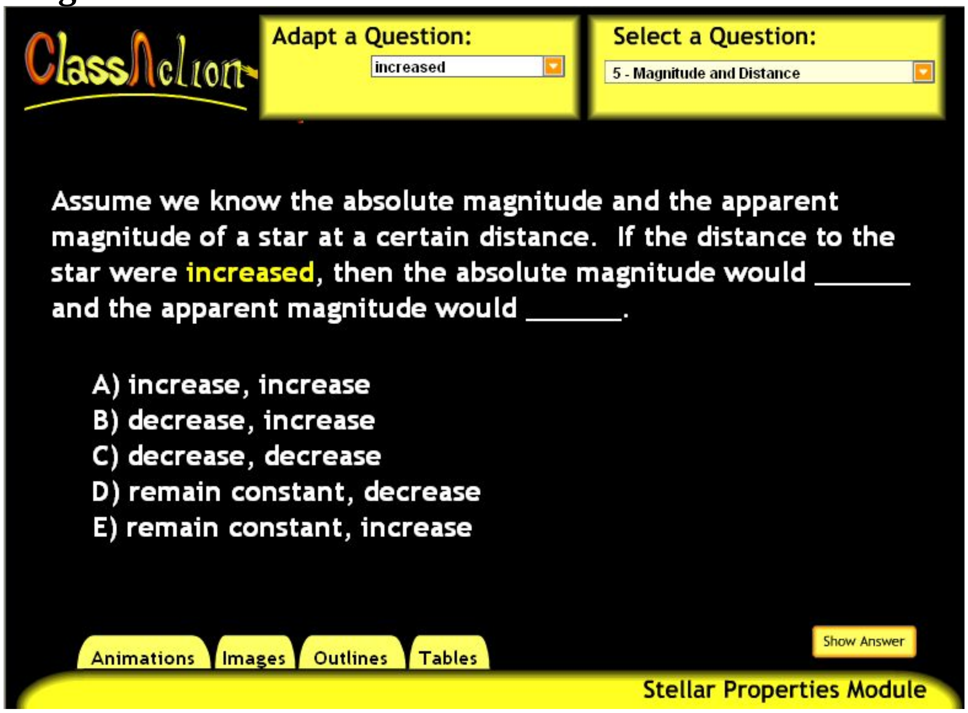
Suggestions:
There are 3 different adaptations to the question, therefore the instructor could talk through and present the solutions to one of the adaptations and use the think-pair-share method with the remaining adaptations.

Recommended animations: Distance Modulus Explorer.

Recommended outlines: Distance Modulus.

Difficulty: 3

Magnitude and Distance

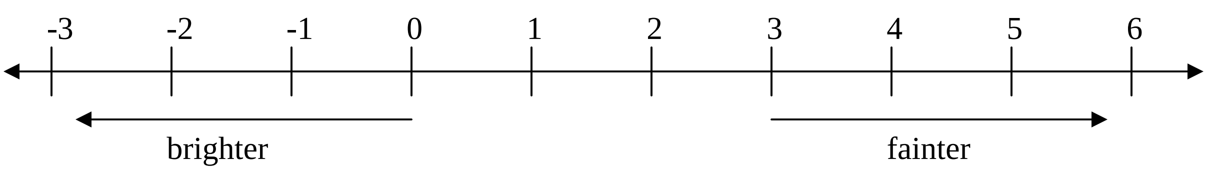


Key Concepts: Magnitude System

Secondary Concepts: Apparent magnitude; Absolute magnitude

Description:
A question is presented that states that the absolute and apparent magnitude values of a star are known. Students should determine how these values would change (increase, decrease, remain constant) if the distance to the star from Earth changed.

Answer:
The magnitude numbering system is designed as follows:



Apparent magnitude (m) is measure of how bright a star appears to be in the night sky. Absolute magnitude (M) is measure of how bright a star actually is when it is placed a distance of 10 parsecs (pc) from the Earth, which means that absolute magnitude is also an implicit measure of intrinsic brightness. Thus:

If the distance to a star increased, it would appear to be fainter (apparent magnitude increases), but its intrinsic brightness is unchanged (absolute magnitude remains constant).

If the distance to a star decreases, it would appear to be brighter (apparent magnitude decreases), but its intrinsic brightness is unchanged (absolute magnitude remains constant).

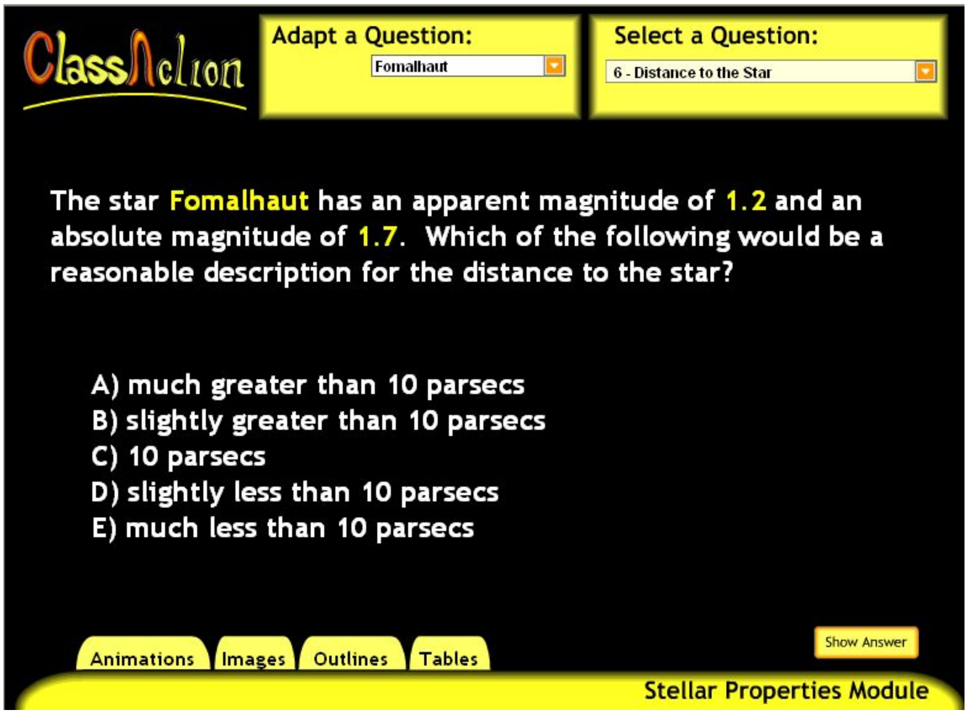
Suggestions:
There are 2 different adaptations to the question, therefore the instructor could talk through and present the solutions to one of the adaptations and use the think-pair-share method with the remaining adaptation.

Recommended animations: Distance Modulus Explorer.

Recommended outlines: Distance Modulus.

Difficulty: 3

Distance to the Star

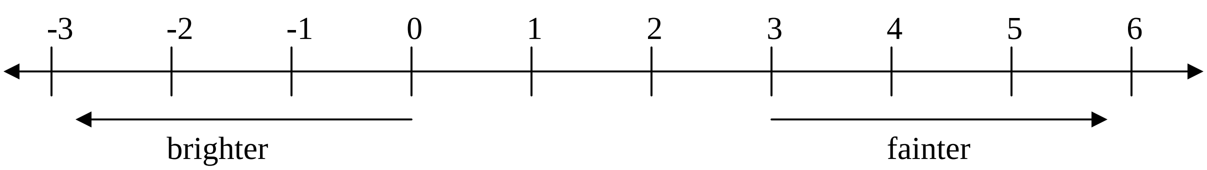


Key Concept: Magnitude System

Secondary Concepts: Apparent magnitude; Absolute magnitude

Description:
A question is presented that provides the absolute and apparent magnitude values for a selected star in the night sky. Students should determine a mostly likely value for the distance to the star from the Earth.

Answer:
The magnitude numbering system is designed as follows:



Apparent magnitude (m) is measure of how bright a star appears to be in the night sky. Absolute magnitude (M) is measure of how bright a star actually is when it is placed a distance of 10 parsecs (pc) from the Earth. If a star happens to be located at an actual distance of 10 pc, its apparent and absolute magnitude will have the same value. If a star is located beyond 10 pc, its absolute magnitude value will be less than its apparent magnitude; and if a star is located closer than 10 pc, its absolute magnitude value will be greater than its apparent magnitude. Also, the amount of the difference between the magnitude values reflects the star's distance from 10 pc. Thus:

Formalhaut (m = 1.2; M = 1.7) would be slightly less than 10 pc.
Wolf 359 (m = 13.4; M = 16.6) would be much less than 10 pc.
Deneb (m = 1.3; M = -7.5) would be much more than 10 pc.

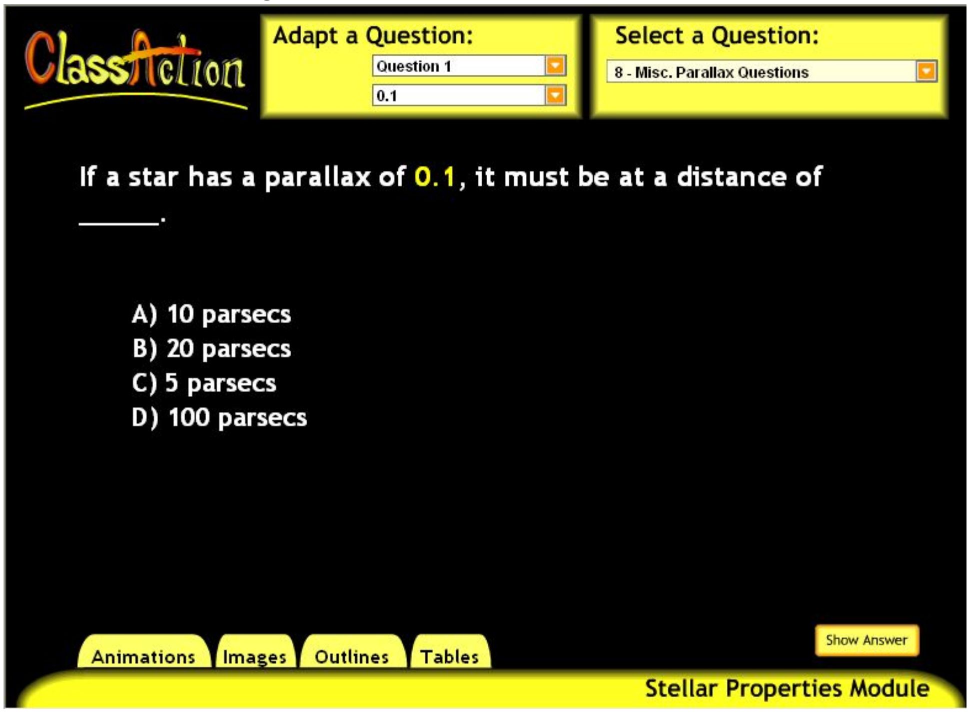
Suggestions:
There are 3 different adaptations to the question, therefore the instructor could talk through and present the solutions to one of the adaptations and use the think-pair-share method with the remaining adaptations.

Recommended animations: Distance Modulus Explorer.

Recommended outlines: Distance Modulus.

Difficulty: 3

Misc. Parallax Questions



Key Concepts: Parallax; Parsec

Description:
Multiple questions are presented that provides either the distance to a star in parsecs or the parallax angle in arcseconds for that star. Students should determine the quantity not provided between these two choices.

Answer:
As long as the parallax angle is provided in arcseconds or the distance provided in parsecs, the relationship between these two quantities is relatively straightforward:

$$d = \frac{1}{p}$$

where d is distance and p the parallax angle.

Suggestions:
There are 12 total different adaptations for the 4 questions provided, therefore the instructor could talk through and present the solutions to one or two adaptations and use the think-pair-share method with the remaining adaptations.

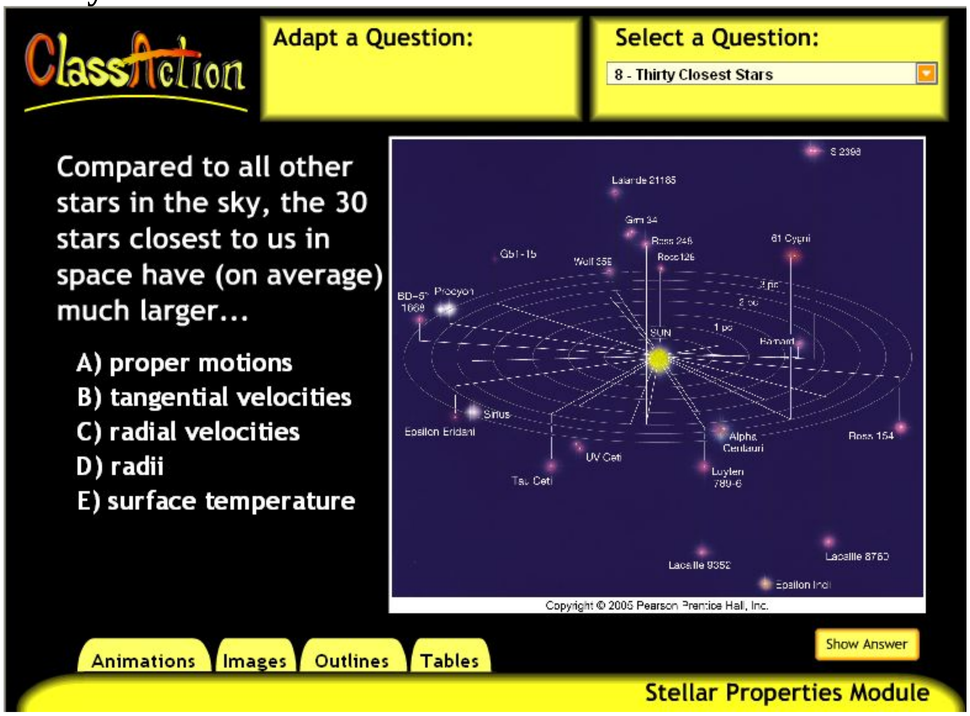
Recommended animations: Parallax Calculator.

Recommended images: Parallax I, II, III, IV.

Recommended outlines: Parallax.

Difficulty: 2

Thirty Closest Stars



Key Concept: Proper Motion

Secondary Concepts: Tangential velocity; Radial velocity

Description:
An image is displayed that shows the 30 closest stars to the Earth. Students should determine which stellar property has on average a larger value for these 30 stars.

Answer:
Proper motion is the angular displacement of a star on the sky due to its motion through space. As distance increases, angular displacements and proper motion will decrease; and as distance decreases, angular displacements and proper motion will increase. Thus:

For the 30 closest stars, distance is relatively small and therefore the proper motion relatively large.

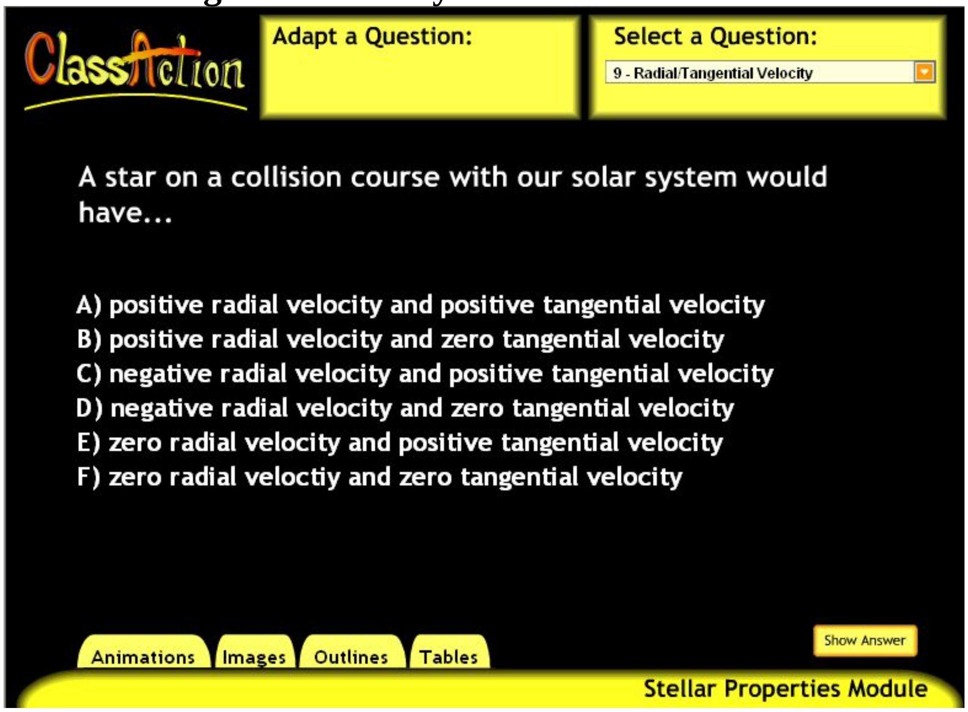
Suggestions:
Recommended animations: Stellar Velocity Calculator.

Recommended images: Space velocity.

Recommended outlines: Stellar velocity.

Difficulty: 2

Radial / Tangential Velocity



Key Concepts: Radial velocity; Tangential velocity

Description:
An incomplete sentence is presented that indicates a star is headed towards the Earth. Students should determine the type of radial and tangential velocity values such a star would have.

Answer:
Radial velocity is the velocity component of a star that is orientated either towards or away from the Earth. For radial velocity, negative values indicate motion towards the Earth and positive values away. Tangential velocity is the velocity component of a star that is orientated tangential to the Earth. Thus:

If a star is headed right for the Earth, there is no tangential velocity and the radial velocity would have to be zero.

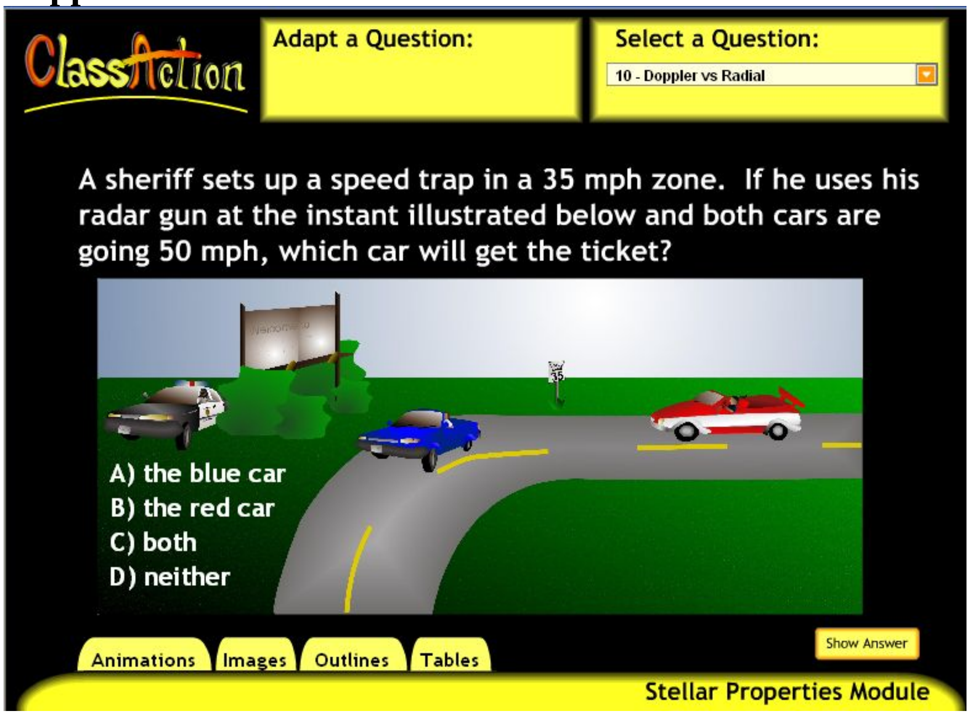
Suggestions:
Recommended animations: Stellar Velocity Calculator.

Recommended images: Space velocity.

Recommended outlines: Stellar velocity.

Difficulty: 2

Doppler vs Radial



Key Concepts: Doppler Effect; Radial velocity

Description:
The image displayed shows a sheriff's police car hiding behind the bushes as a blue begins to move parallel to the police car at 50 mph and the red car moves toward the police car at 50 mph. Students should determine which car(s) will receive a speeding ticket.

Answer:
A policeman's radar gun employs the Doppler effect to determine how fast a car may be traveling. The Doppler effect is only applicable for motions either towards or away from an observer and object, thus:

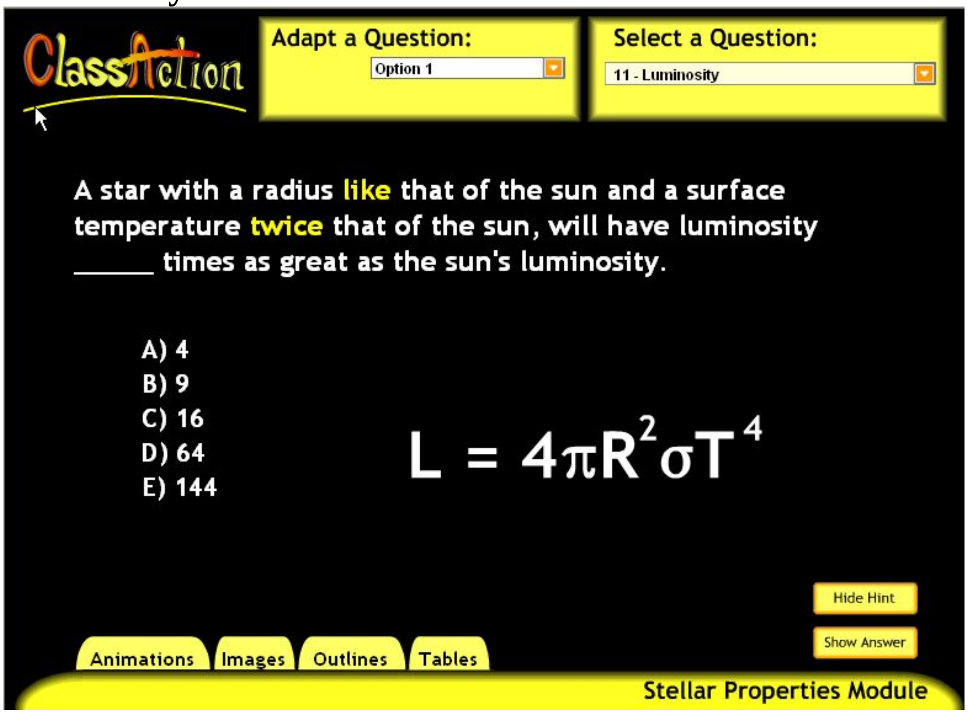
The red car will receive the ticket as it is moving towards the police car.

Suggestions:
Recommended images: Space velocity.

Recommended outlines: Stellar velocity.

Difficulty: 3

Luminosity



Key Concept: Stellar Luminosity

Description:
An incomplete sentence is presented that indicates the size and surface temperature a certain star has relative to the Sun. Students should determine how the stellar luminosity will compare with the Sun. Initially there is no equation displayed.

Answer:
Luminosity of a star is proportional to the square of the star's radius and proportional to the 4th power of its surface temperature. Thus:

For option 1, with a similar radius and twice the surface temperature, the star's luminosity would be 16 times the Sun's luminosity. ($2^4 = 16$)
For option 2, with twice the radius and a similar surface temperature, the star's luminosity would be 4 times the Sun's luminosity. ($2^2 = 4$)
For option 3, with twice the radius and twice the surface temperature, the star's luminosity would be 64 times the Sun's luminosity. ($2^2 * 2^4 = 64$)
For option 4, with three times the radius and a similar surface temperature, the star's luminosity would be 9 times the Sun's luminosity. ($3^2 = 9$)
For option 5, with three times the radius and twice the surface temperature, the star's luminosity would be 144 times the Sun's luminosity. ($3^2 * 2^4 = 144$)

Suggestions:
There are 5 different adaptations, therefore the instructor could talk through and present the solutions to one or two adaptations and use the think-pair-share method with the remaining adaptations.

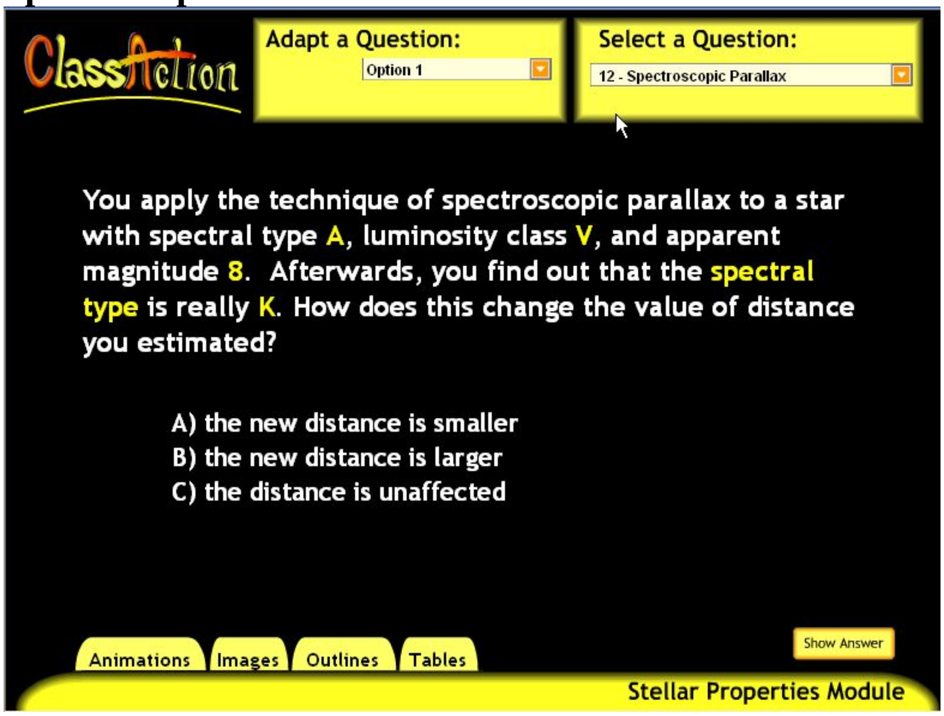
Recommended animations: Stellar Luminosity Calculator.

Recommended outlines: Flux (or Intensity); Luminosity.

Hints:
This question provides a hint by displaying the Stefan-Boltzmann's Law which is the exact relationship between luminosity, radius, and surface temperature.

Difficulty: 3 (with hint: 2)

Spectroscopic Parallax

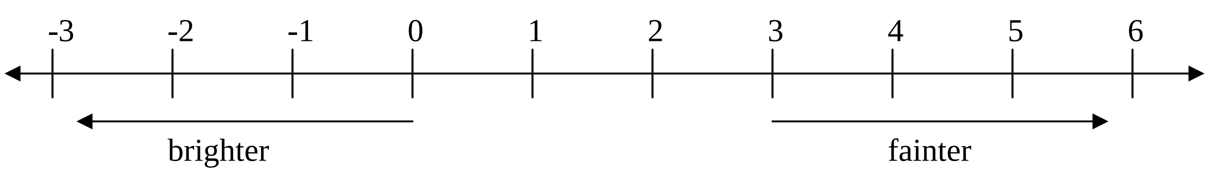


Key Concept: Spectroscopic parallax

Secondary Concepts: Spectral type; Luminosity class; Apparent magnitude; HR diagram

Description:
A question is presented that provides values for various stellar properties, including spectral type, luminosity class, and apparent magnitude. One of the values is incorrect, and the correct value is provided. Students should determine how this correction would affect an estimated distance to the star.

Answer:
Spectral type indicates surface temperature through the convention OBAFGKM, where O type is the hottest and M the coolest. Luminosity class indicates an inherent brightness related to a star's evolutionary stage. There are 5 luminosity classes (I, II, III, IV, V), where in general class V is the least bright and I the most bright between the classes; and for each individual class brightness can increase with an increase in surface temperature. The magnitude numbering system is designed as follows:



Apparent magnitude indicates how bright a star appears to be in the night sky. Luminosity and surface temperature are the ordinate and abscissa of an HR diagram, respectively. Thus:

For option 1: A correction from spectral type A to K means the star is cooler, its inherent brightness will be smaller, the difference between inherent and apparent brightness will be less, and therefore the star will be closer.
For option 2: A correction from spectral type F to B means the star is hotter, its inherent brightness will be larger, the difference between inherent and apparent brightness will be greater, and therefore the star will be farther away.
For option 3: A correction from luminosity class V to III means the star's inherent brightness will be greater, the difference between inherent and apparent brightness will be greater, and therefore the star will be farther away.
For option 4: A correction from luminosity class II to IV means the star's inherent brightness will be smaller, the difference between inherent and apparent brightness will be less, and therefore the star will be closer.
For option 5: A correction from apparent magnitude 8 to 9 means the star's apparent brightness will be smaller, the difference between inherent and apparent brightness will be greater, and therefore the star will be farther away.

Suggestions:
There are 5 different adaptations, therefore the instructor could talk through and present the solutions to one or two adaptations and use the think-pair-share method with the remaining adaptations.

Recommended animations: Spectroscopic Parallax Simulator.

Recommended outlines: Spectroscopic Parallax.

Recommended tables: Measuring the Stars.

Difficulty: 4

Section 3: *Challenge Questions*

This section contains astronomy questions that are designed to be more challenging to the students. These questions are not only designed to test 2 – 4 astronomical concepts, but students must synthesize these concepts in a context that they would not have been generally covered in a lecture and/or textbook.

It is recommended that the think-pair-share method be employed for these questions.

Teaching suggestions, and possibly hints, are provided for every question.

A degree of difficulty (1 – 5; 1 being easy and 5 being difficult) is also provided for every question.

Parsec Size

Key Concept: Definition of the Parsec

Description:
A question is presented that has a "person" from Mars and a "person" from Venus debating each specific planet's length of the parsec. Students should determine which planet's parsec is bigger and by how much. Initially, there is no image of the Sun, Mars, and Venus shown underneath the answer options.

Answer:
As one moves farther and farther away from the Sun and looks back on the solar system, the solar system and everything in it will subtend smaller and smaller angles. When the space from the Sun to a given planet in the solar system subtends exactly 1 arcsecond, that distance from the Sun is that planet's "parsec." For the Earth, this distance is 3.0856 x 10^{16} m (the distance that 1 A.U. would appear to subtend 1 arcsecond). Mars is about twice as far from the Sun as Venus, thus:

The Martian parsec would be about twice as big as the Venusian parsec.

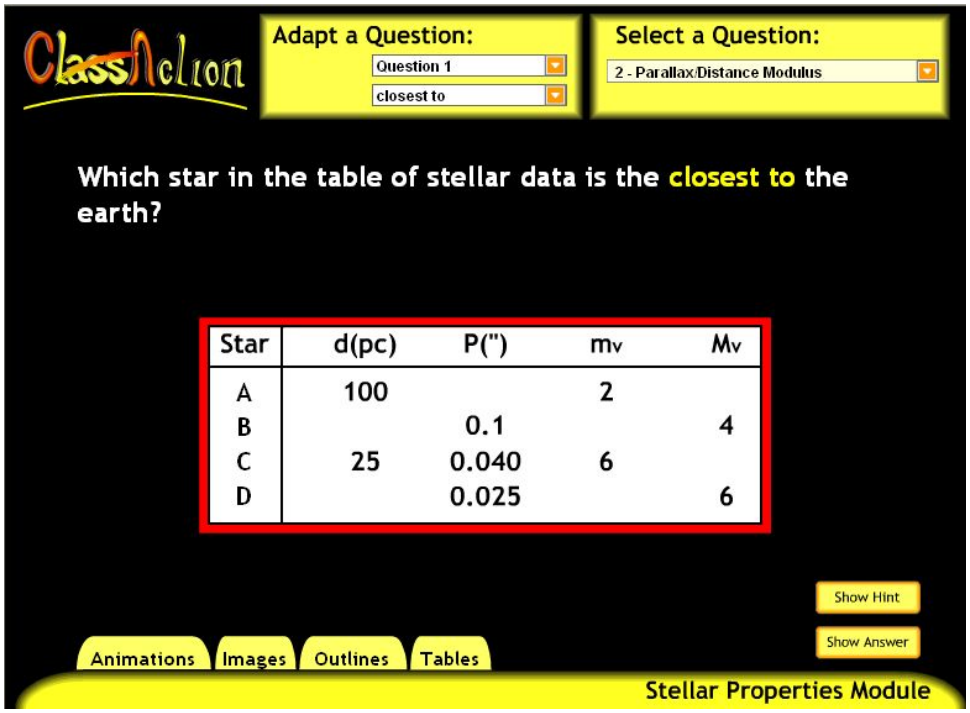
Suggestions:
Recommended images: Stellar Parallax.

Recommended outlines: Parallax.

Hints:
This question provides a hint in the form of an image showing the relative spaces between both Mars and Venus with the Sun, and the graphical distances that those spaces would subtend 1 arcsecond.

Difficulty: 3

Parallax / Distance Modulus



Key Concept: Parallax; Distance Modulus

Secondary Concepts: Apparent magnitude; absolute magnitude; Parsec

Description:
An incomplete table is presented that includes some of the values for distance (in parsecs), parallax angle (in arcseconds), apparent magnitude, and absolute magnitude for 4 stars. Students should determine the missing values for each star and answer the selected question based upon the information in the complete table.

Answer:
As long as the parallax angle is provided in arcseconds or the distance provided in parsecs, the relationship between these two quantities is relatively straightforward:

$$d = \frac{1}{p}$$

where d is distance and p the parallax angle.

The relationship between the distance modulus (the difference of the apparent magnitude and absolute magnitude) and distance in parsecs is also relatively straightforward:

$$m_v - M_v = -5 + 5\log d$$

Based upon these relationships, the smaller the parallax angle, the greater the distance, and the greater the distance, the greater the distance modulus (and vice versa). This relationship is also useful for determining a missing value of the apparent or absolute magnitude given the other and the distance. Thus:

Question 1: Star B is closest to Earth since it is only 10 pc away. Star A is farthest at 100 pc.
Question 2: Star B has the largest parallax since it has the smallest distance, and Star A has the smallest parallax since it has the largest distance.

Question 3: Absolute magnitude is a measure of intrinsic brightness, therefore Star A is the most intrinsically bright, and Star D the least.
Question 4: Apparent magnitude is a measure of how bright a star appears to be, therefore Star A also appears to the brightest and Star D the faintest.

Suggestions:
Recommended animations: Parallax Calculator; Distance Modulus Explorer.

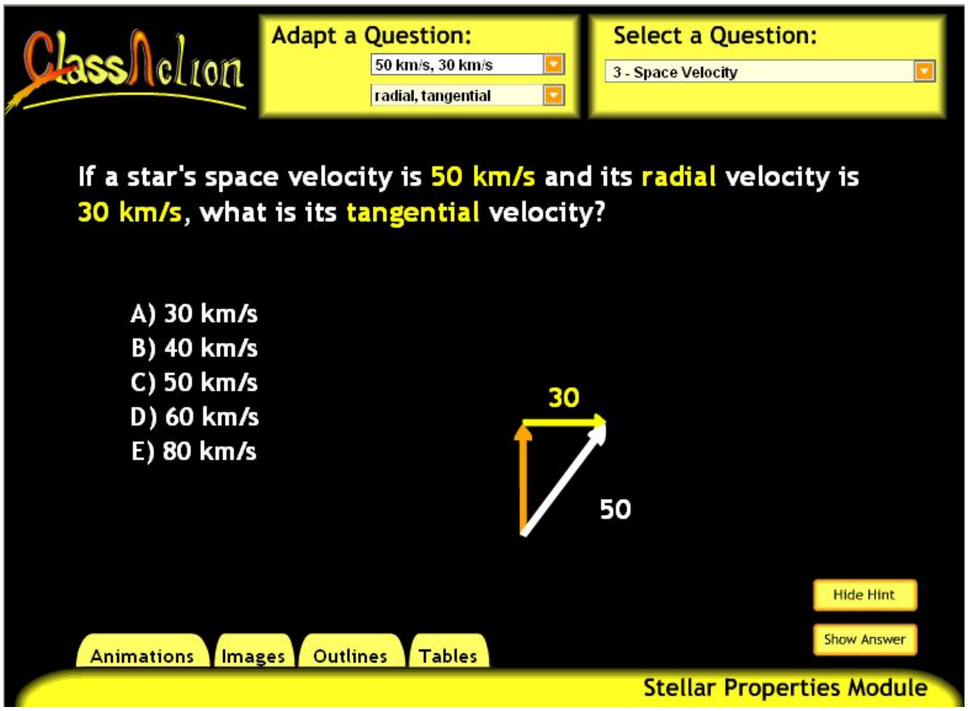
Recommended images: Stellar Parallax.

Recommended outlines: Parallax; Distance Modulus.

Hints:
This question provides a hint by automatically completing the table, eliminating the need for calculation if so desired.

Difficulty: 4 (with hint: 2)

Space Velocity



Key Concepts: Tangential velocity; Radial velocity

Description:
A question is presented that provides values for a star's total space velocity and either its radial or tangential velocity. Students should determine the value of the velocity component not provided. Initially there is no image provided.

Answer:
Radial velocity is the total space velocity component of a star that is orientated either towards or away from the Earth. Tangential velocity is the total space velocity component of a star that is orientated tangential to the Earth. Radial velocity and tangential velocity are perpendicular are always perpendicular to each other. Thus:

When the total space velocity is 50 km/s and the radial / tangential velocity is 30 km/s, the tangential / radial velocity is 40 km/s.
When the total space velocity is 50 km/s and the radial / tangential velocity is 40 km/s, the tangential / radial velocity is 30 km/s.
When the total space velocity is 100 km/s and the radial / tangential velocity is 60 km/s, the tangential / radial velocity is 80 km/s.
When the total space velocity is 100 km/s and the radial / tangential velocity is 80 km/s, the tangential / radial velocity is 60 km/s.

Suggestions:
There are 8 different adaptations, therefore the instructor could talk through and present the solutions to one or two adaptations and use the think-pair-share method with the remaining adaptations.

Recommended animations: Stellar Velocity Calculator.

Recommended images: Space velocity.

Recommended outlines: Stellar velocity.

Hints:
This question provides a hint in the form of an image showing the total space velocity vector (in white), the radial velocity (in yellow), and the tangential velocity (in orange).

Difficulty: 3 (with hint: 1)

Section 4: *Discussion Questions*

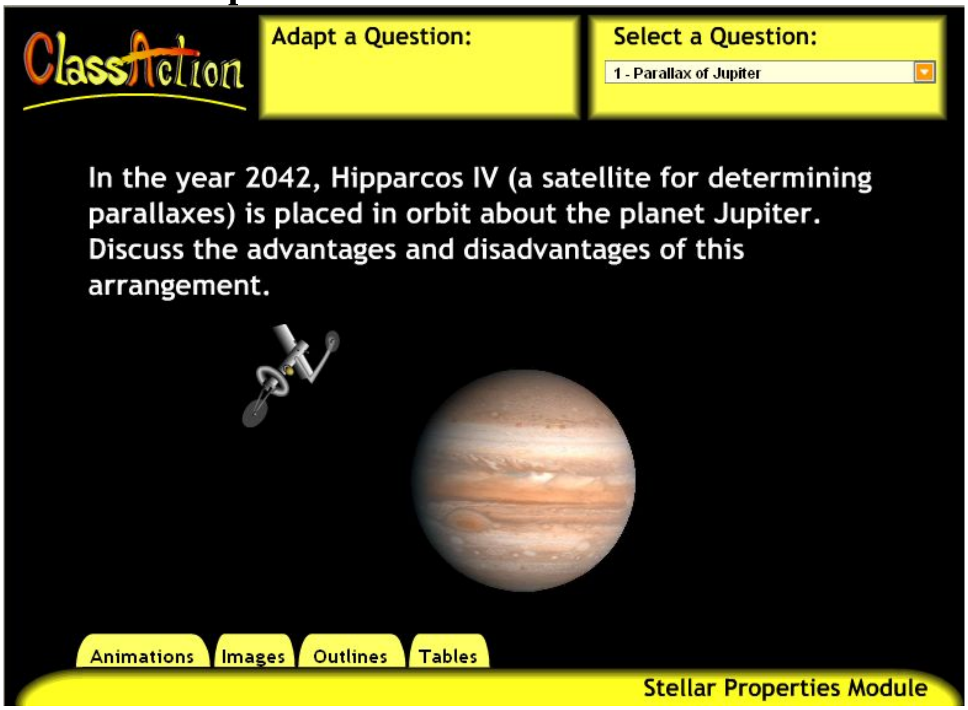
This section contains discussion questions. These questions do not have answer options since they are sufficiently complicated to require a few sentences to a paragraph to answer.

It is recommended that the students discuss these questions in groups and then make oral reports to the class of their conclusions.

Teaching suggestions, and possibly hints, are provided for every question.

A degree of difficulty (1 – 5; 1 being easy and 5 being difficult) is also provided for every question.

Parallax of Jupiter



Key Concept: Parallax

Description:
The image above depicts a satellite in orbit around Jupiter whose main function is to determine parallax angles for stars. Students should discuss the advantages and disadvantages of this arrangement.

Answer:
Currently, parallax angles are determined using a similar satellite in orbit around the Earth, therefore the baseline is Earth's orbital diameter. If there was a satellite placed in orbit around Jupiter, the baseline would become Jupiter's orbit diameter. This is about 6 times larger than the Earth's orbital diameter, which means in theory parallax angles 6 times smaller should be possible, which in turn means determining distances 6 times farther as well. The major disadvantage would be communication with and maintenance for a satellite so far from Earth.

Suggestions:
Recommended animations: Parallax Calculator.

Recommended images: Parallax I, II, III, IV; Stellar Parallax.

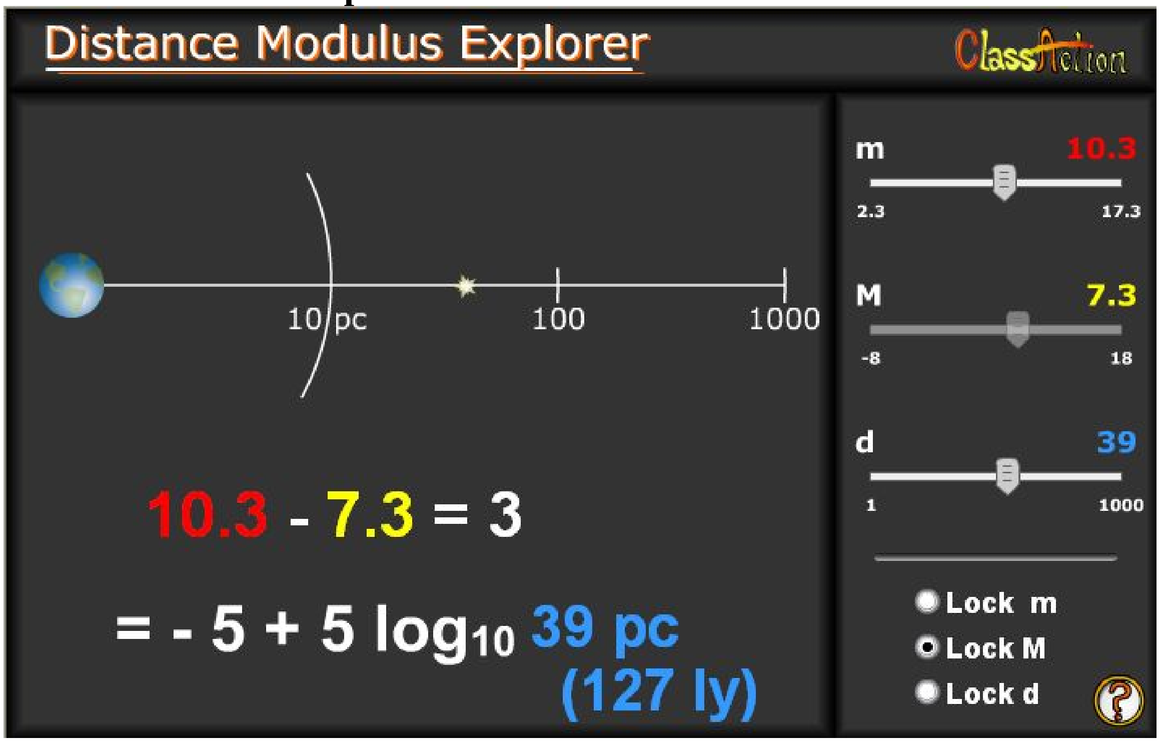
Recommended outlines: Parallax.

Difficulty: 3

Section 5: *Animation Resources*

This section contains a basic primer for each of the animation resources provided for this module. The intent of each animation resource is to supplement and support the discussions generated by the questions presented in this module, which in turn will hopefully lead to a better understanding of the astronomical topics and concepts involved.

Distance Modulus Explorer

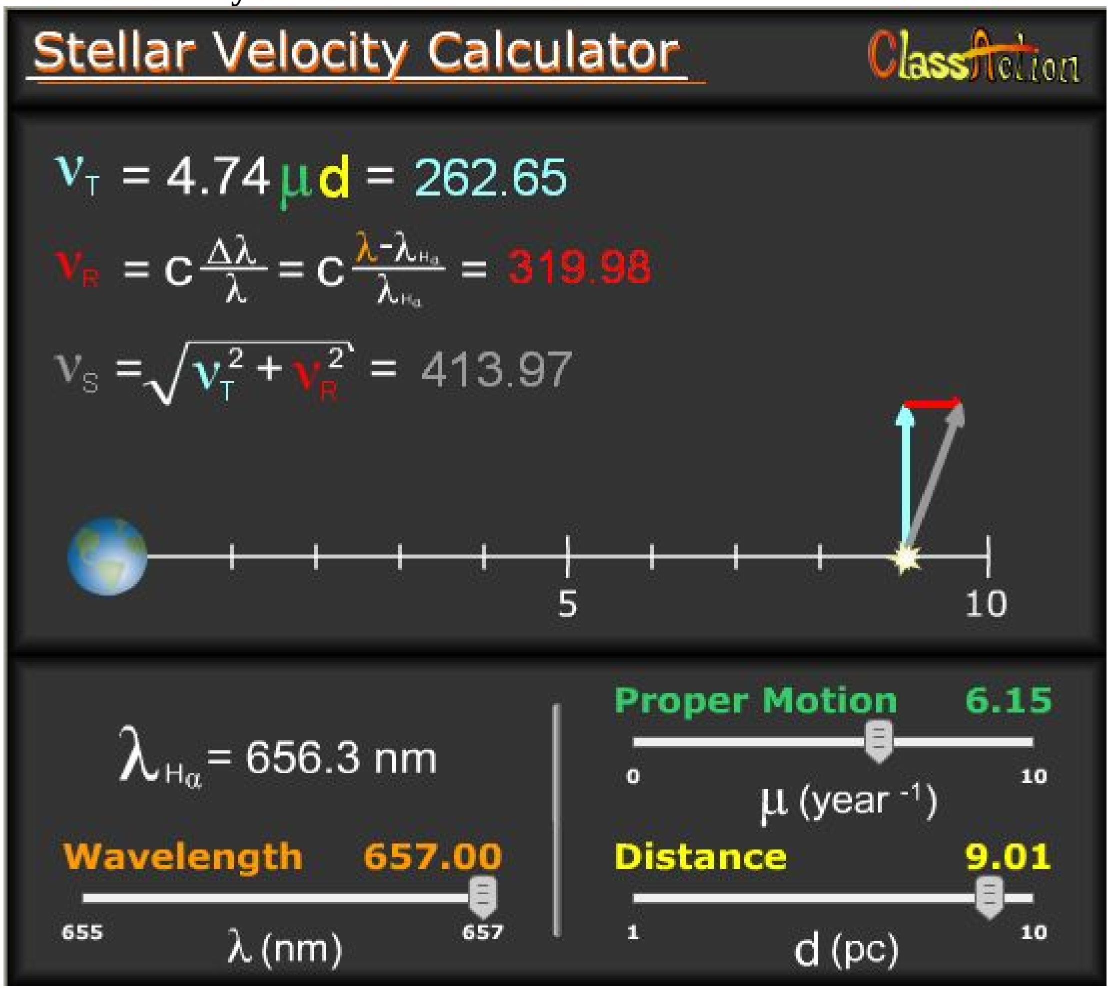


Main Purpose:
This explorer allows the user to investigate the relationship between apparent magnitude, absolute magnitude, and distance. It can also be used to calculate a quantity given the other two.

Images:
The image displays the Earth with a distance reference line in parsecs extending to the right. The 10 pc standard distance for absolute magnitude is emphasizes and a current location of a star is shown. Below the image are the calculations involving the apparent magnitude (m, in red), the absolute magnitude (M, in yellow), and the distance (d, in blue).

Controls:
The user can change the values for m, M, or d using the controls at the right. For a specific exploration, one of the quantities must have a constant value, which must be chosen and "locked" by clicking the appropriate button at the lower right. Once something is locked, changing one of the other quantities changes the values of the third quantity and image accordingly.

Stellar Velocity Calculator

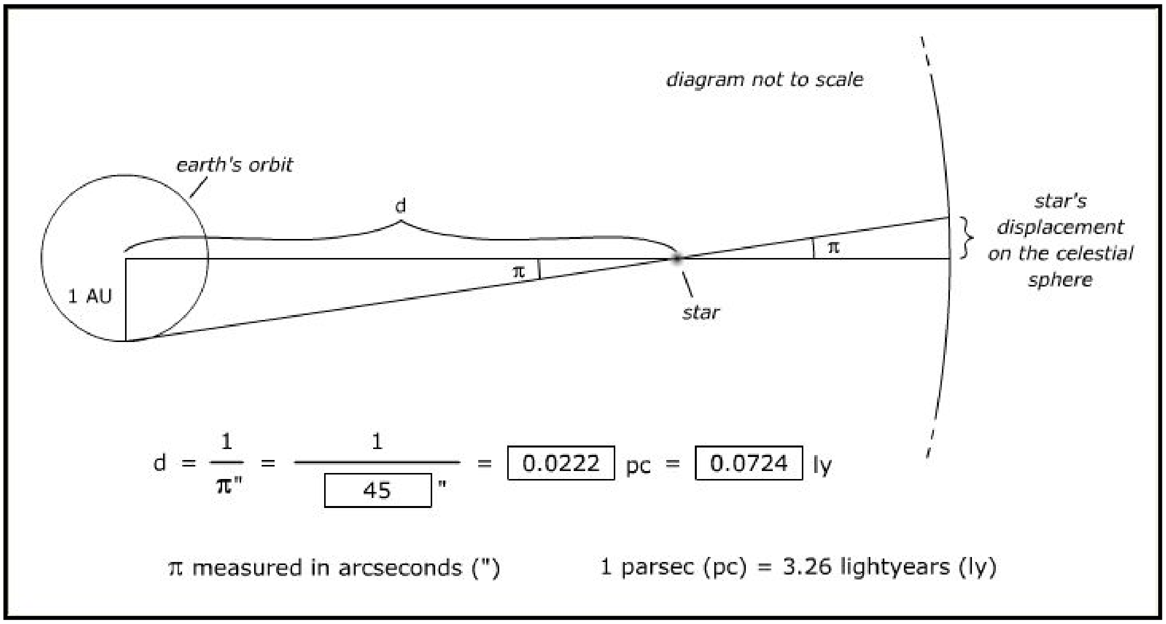


Main Purpose:
This calculator allows the user to investigate the relationships between proper motion (μ), stellar radial velocity (V_R), stellar translational velocity (V_T), total stellar velocity (V_S), wavelength of light (λ) and distance (d). It can also be used to calculate a total stellar velocity given the proper motion, wavelength, and distance of a star.

Images:
The image displays the Earth with a distance reference line in parsecs extending to the right. A current location of a star is shown as well as its calculated radial velocity (red arrow), translational velocity (blue arrow), and total stellar velocity (gray arrow). Above the image are the calculations involving proper motion (in green), radial velocity (in red), translational velocity (in blue), total stellar velocity (in gray), distance (in yellow), and wavelength (in orange).

Controls:
The user can change the values for μ, λ, and d by using the controls at the bottom. Changing one of the quantities changes some of the calculated values and image accordingly.

Parallax Calculator

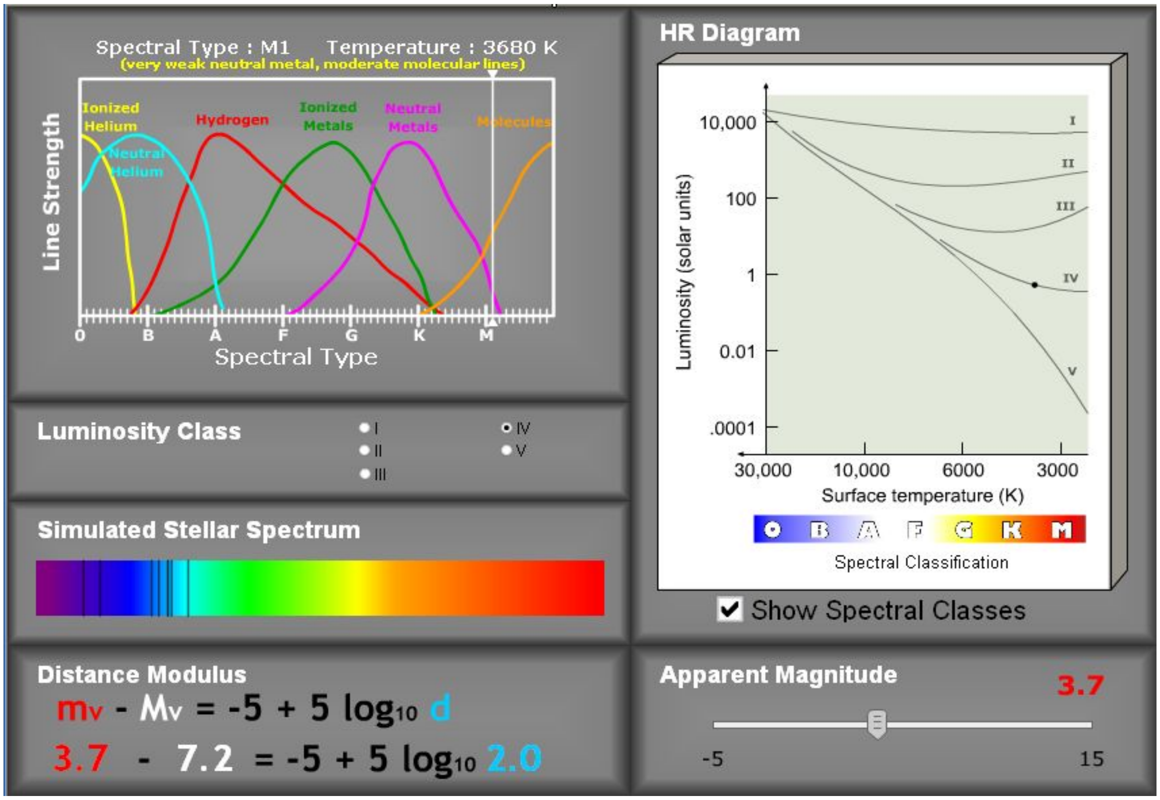


Main Purpose:
This calculator allows the user to investigate the relationships between the distance (d) to a star and that star's parallax angle (π) on the celestial sphere. It can also be used to calculate a quantity given the other.

Images:
The image displays the Earth orbit around the Sun with a distance reference line in parsecs extending to the right. A current location of a star with its current parallax angle included. Below the image are the calculations involving the parallax angle and distance.

Controls:
The user can type in values for the parallax angle or distance. The calculator will automatically calculate the other quantity.

Spectroscopic Parallax Simulator



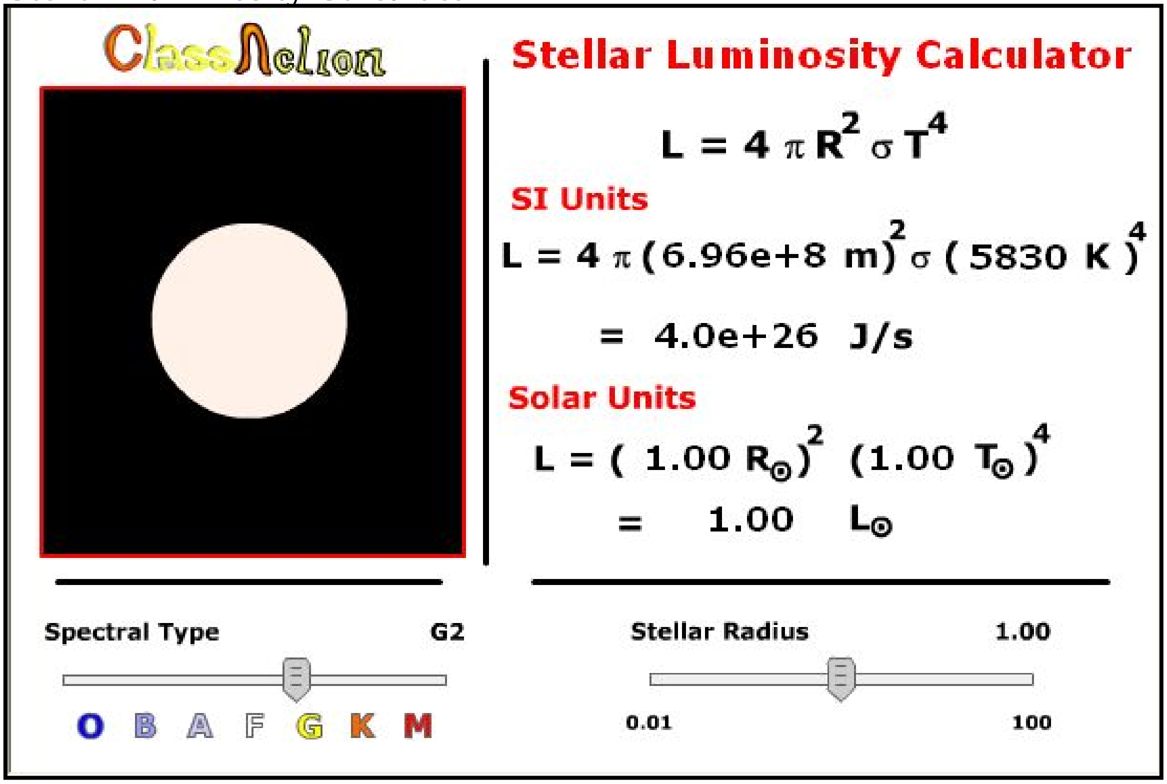
Main Purpose:
This simulator allows the user to investigate the relationships between the distance (d) to a star, the apparent magnitude (m), the absolute magnitude (M), spectral type, stellar spectrum, luminosity classes, and surface temperatures. These relationships encapsulate an understanding of the spectroscopic parallax distance method.

Images:
In the upper left is a graph of line strength versus spectral type with familiar atomic and molecular information provided. The vertical white line denotes the current spectral type. At the lower left is a simulated stellar spectrum that has absorption lines representative of the atomic and molecular information from the graph above. At the upper right is an HR diagram displaying the 5 different luminosity classes and a small black dot indicating the current location on the graph based upon the information selected.

Controls:
The user can select a spectral type by clicking and dragging the vertical white line in the graph at the upper left. The user can select a luminosity class by clicking a class at the middle left. The apparent magnitude can be changed by using the slider at the lower right. As any of these values change, the images and calculations (at the lower left) change accordingly.

The user can also show or not show the spectral classification below the HR diagram by click the "show spectral classes" box.

Stellar Luminosity Calculator

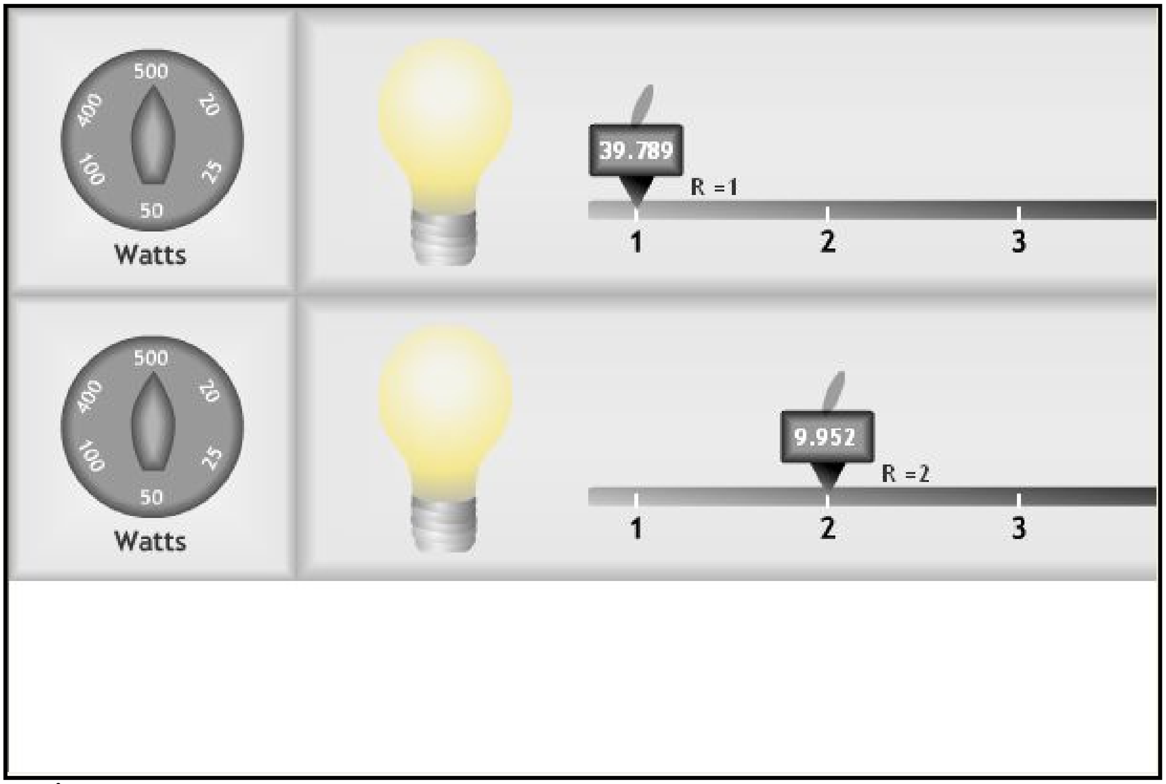


Main Purpose:
This calculator allows the user to investigate the relationships between the stellar luminosity, stellar radius, and surface temperature. It can also be used to calculate the stellar luminosity (in both standard units and solar units) using selected values of stellar radius and surface temperature.

Images:
At the left the image displays a star with a size and color appropriate with the spectral type (temperature) and radius selected. At the right is Stefan-Boltzmann's Law and the calculations for stellar luminosity.

Controls:
The user can change the spectral type (temperature) with the slider at the bottom left and the radius with the slider at the bottom right. The image and the calculations will change accordingly.

Flux Simulator



Main Purpose:
This simulator allows the user to investigate the inverse square law for brightness and flux.

Images:
At the left the image displays two dials that indicate the current wattage of the light bulb immediately to the right of the dial. At the right are light-sensitive flux detectors that indicate a flux value in generic units for a selected distance from the bulbs. There are two identical simulators so values can be compared.

Controls:
The user can change the wattage of the bulbs by clicking and turning a dial. The user can also move the detectors by clicking and dragging them to a different position. The flux detector values will change accordingly.

Section 6: *Image Resources*

This section contains list of the astronomical images included in this module. Included is a brief description of each image. The intent of each image is to supplement and support the discussions generated by the questions presented in this module, which in turn will hopefully lead to a better understanding of the astronomical topics and concepts involved.

Images

Parallax I: An image displaying different parallax angles for nearby and far objects.

Parallax II: An image displaying how to determine the distance to a far away object using a parallax angle and a baseline.

Parallax III: A follow-up image to Parallax II with actual distances and angle measurements denoted.

Parallax IV: An image displaying how a nearby object can appear different with respect to background stars from opposite sides of the Earth.

Stellar Parallax: a) An image of the Earth's precession being compared to the that of a spinning top. b) An image of the north celestial pole's path of precession from 2000 B.C. to 24,000 A.D.

Hipparcos: A photograph of the Hipparcos satellite which currently orbits the Earth and makes parallax angle measurements of stars.

Proper Motion: Two photographs showing the proper motion of a star.

Space Velocity: An image displaying the Alpha Centauri system's motion through space with respect to the solar system, emphasizing the difference between radial velocity, transverse velocity, and true space velocity.

Inverse Square Law: An image of a point light source that emphasizes how light spreads out with distance.

Flux-Luminosity Distance: An image displaying how two stars can produce the same flux for an observer (therefore look to be the same brightness), but can actually have different luminosities (therefore different inherent brightness) due to distance.

Colors of Stars: Two photographs of star fields that emphasize the various colors and surface temperatures of stars.

B & V Filters: A graph of flux versus frequency / wavelength with three blackbody curves of different temperatures displayed. Emphasis is on the differences in the B filter and V filter fluxes for the different blackbody curves – also known as the color index.

Spectral Classification: A images displaying the prominent absorption spectral lines (and which element / molecule they belong to) for each spectral class.

Stellar Radii: An image displaying the radii of various stars, including our Sun, to scale.

Prominent Stars: An HR diagram of Luminosity versus Surface Temperature / Spectral Class with a set of prominent stars denoted.

Nearest Stars: An HR diagram of Luminosity versus Surface Temperature / Spectral Class with a set of the nearest stars denoted.

Brightest Stars: An HR diagram of Luminosity versus Surface Temperature / Spectral Class with a set of the brightest stars denoted.

Hipparcos Stars: An HR diagram of Luminosity versus Surface Temperature / Spectral Class with all of the stars that the Hipparcos satellite has analyzed on the diagram.

Distance Ladder: An image displaying some of the techniques used for determining distance within certain distance ranges.

Luminosity Classes: An HR diagram of Luminosity versus Surface Temperature / Spectral Class with the various luminosity classes denoted.

Section 7: *Table Resources*

This section contains list of the astronomical tables included in this module. Included is a brief description of each table. The intent of each table is to supplement and support the discussions generated by the questions presented in this module, which in turn will hopefully lead to a better understanding of the astronomical topics and concepts involved.

Tables

Distance Modulus: A table of different distance modulus values and the corresponding distance in parses.

Magnitude & Intensity: A table of different apparent magnitude differences the corresponding intensity ratio for the two stars.

Apparent Magnitudes: An apparent magnitude scale with various objects and touchstones labeled.

Luminosity vs. Absolute Magnitude: A luminosity scale in solar units and an absolute magnitude equivalent scale.

Stellar Colors & Temperatures: A table listing various B / V flux values, surface temperatures, colors, and familiar stellar examples.

Stellar Spectral Classes: A table listing spectral classes, surface temperatures, noteworthy absorption lines, and familiar stellar examples.

Stellar Luminosity Classes: A table listing luminosity classes and basic descriptions.

Variations in Stellar Properties: A table listing surface temperatures, luminosities (solar units), radius (solar units), standard object classifications, and familiar stellar examples.

Measuring the Stars: A table listing stellar properties, measurement techniques for a given stellar property, quantities that would be known, quantities that would be measured, and the theories applied.

Key Properties of Main Sequence Stars: A table listing some well-known main sequence stars, spectral types, masses, core temperatures, luminosities, and estimated lifetimes.

Section 8: *Outline Resources*

This section contains list of the astronomical outlines included in this module. Included is a brief description of the contents of each outline. The intent of each outline is to supplement and support the discussions generated by the questions presented in this module, which in turn will hopefully lead to a better understanding of the astronomical topics and concepts involved.

Each outline can be supplied to the student before class in order to prepare for the astronomical topic to be discussed, or can be supplied and/or shown during class to provide a reference for the discussion.

Outlines

Flux (or Intensity): A primer describing how flux and luminosity are related.

Apparent Magnitude: A primer about the basic magnitude scale and an image of an apparent magnitude scale with various objects and touchstones labeled..

Intensity & Magnitude: A primer about to calculate differences in magnitudes and intensities.

Absolute Magnitude: A primer about how absolute magnitude is defined and related to apparent magnitude.

Distance Modulus: A primer about how the difference between absolute magnitude and apparent magnitude (the distance modulus) and distance are related.

Parallax: A primer and an image explaining the relationship between the parallax angle and distance to nearby stars.

Stellar Velocity: A primer that describes how to calculate the radial velocity, tangential velocity, and total space velocity of a star.

Luminosity: A primer that describes how to calculate the total luminosity using the flux and total surface area of a star.

Spectroscopic Parallax: A primer describing the steps involved for employing the spectroscopic parallax method for measuring the distance to far away stars.