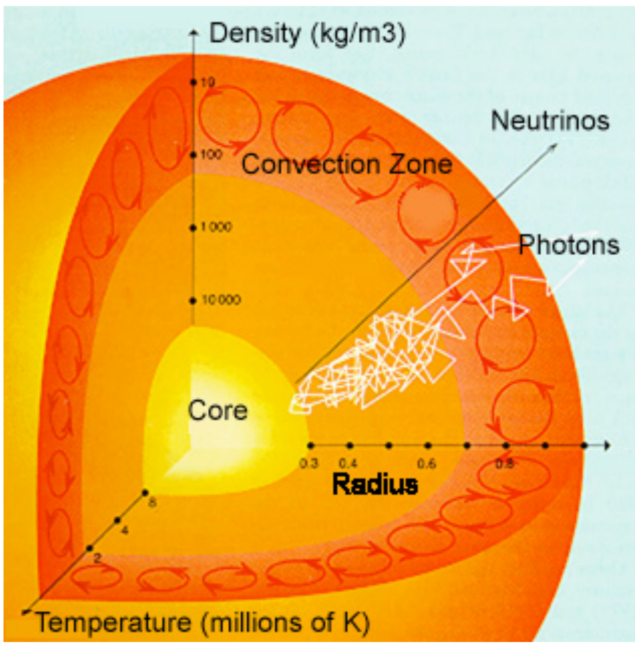
Exam 03: Solution

1. The **solar constant** refers to the
   A) temperature of the photosphere: 5800K.
   B) number of sunspots visible on the solar surface at any given instant.
   C) percent of the sun's mass that is made up of hydrogen.
   D) amount of energy radiated by the sun: 1400 Joules/sec per m^2 reaches the Earth.
   E) luminosity class of a star. All stars like the sun have a solar constant of "G."

2. **Hydrostatic equilibrium** refers to
   A) the balance between land and water on the surface of the sun.
   B) the atmospheric pressure of the sun, which keeps water liquid deep below the surface.
   C) the balance between the inward pull of gravity and outward thermal gas pressure.
   D) the balance between thermal radiation and convection in the transition zone above the solar corona.



3. In the figure above, explain what's happening with the squiggly lines labeled "Photons."
   A) The figure was obviously drawn by a preschooler.
   B) The paths indicate how the radiation zone just outside the core is opaque to visible light, but the convection zone allows visible light to pass through.
   C) Answer B is backwards! The radiation zone is transparent, and the convection zone is opaque to visible light.
   D) The squiggles are indicating that more energy is produced in the radiation zone than is produced in the convection zone.
   E) The radiation zone is less dense than the convection zone, so the photons have more room to move around, which is indicated by more squiggles in the radiation zone.

4. True or **false**: The sun is transparent to visible light, so we can see all the way to the stellar core.

5. Explain **convection** as a mechanism of heat transfer.
   A) Convection occurs when an electron absorbs a photon and jumps to a higher-energy orbit.
   B) Convection transfers heat through a fluid medium by bulk motion: in the sun, hotter gas rises and cooler gas sinks.
   C) Convection is the emission of a low-energy photon that occurs spontaneously when an electron in a hydrogen atom spin-flips to a lower, more stable energy state.
   D) Convection is heat transfer by direct contact, like when you put a frying pan on an electric coil. Unless the coil touches the pan, it doesn't get hot.
   E) Convection occurs only in the core of the sun, when protons are squeezed so close together that the electrostatic repulsion between them becomes so great that there is an actual explosion of energy.

6. Why does convection stop at the photosphere, and radiation again become the mechanism for energy transport?
   A) Density decreases with increasing distance from the core. When the density becomes too low, there is not enough matter to maintain convection cells.
   B) At the transition from the photosphere to the chromosphere, there is a sudden spike in density, which creates an increase in radiation.
   C) The photosphere absorbs visible light, then must re-radiate the energy at a lower, infrared, frequency. This cannot be done via convection.
   D) It doesn't. Convection remains the dominant mechanism for energy transfer through the photosphere, chromosphere, and solar corona as well.

7. If the sun is a yellow star, why does the chromosphere appear very pink?
   A) It doesn't. The chromosphere has no color.
   B) This is an optical illusion caused by the Earth's atmosphere. Viewed from space, the chromosphere would look yellow.
   C) Because the cooler gas of the chromosphere absorbs blue light.
   D) Molecules of iron oxide (literally, rust) form in the chromosphere, and appear reddish.
   E) The pink color is the result of the H-α emission line, which is red.

8. What color does the chromosphere appear?
   A) It doesn't. The chromosphere has no color.
   B) The sun appears yellow because the chromosphere is yellow.
   C) The chromosphere is so hot that it emits only in the ultraviolet.
   D) Molecules of iron oxide (literally, rust) form in the chromosphere, and appear reddish.
   E) The pink color is the result of the H-α emission line, which is red.

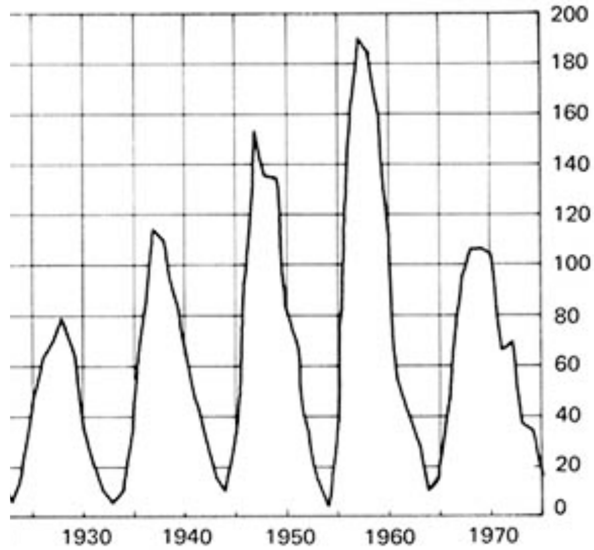
9. Is the solar photosphere hotter than the solar corona?
   A) Yes. The farther you get from the core of the sun, the cooler the temperature. Since the corona is the outermost layer, it is the coolest.
   B) Yes, because convection occurs in the photosphere, but only radiation occurs in the solar corona.
   C) No. The photosphere, chromosphere, and corona all have the same temperature.
   D) The corona is hotter than the photosphere, but only slightly, just a few hundred K.
   E) No. The corona is very, *very*, *very* much hotter than the photosphere.

10. The sun is losing mass as particles are carried away by the solar wind. How much mass?
    A) About 1 million tons every second.
    B) About 1 million tons every day.
    C) About 1 million tons every week.
    D) About 1 million tons every year.
    E) All of these answers are ridiculous. If the sun was losing mass that fast, it would have disappeared a long time ago!

11. Which of the following trends or patterns of solar behavior has ***not*** been observed?
    A) The temperature and pressure of the solar wind has decreased since the mid 1990s.
    B) The sun's magnetic field has weakened by more than 30% since the mid 1990s.
    C) Average sunspot activity has decreased over the last 8-10 years.
    D) The sun has been gaining mass at a rate of about 1 million tons per year, for about the past 10-20 years.
    E) Each of these trends have been observed and verified. They are all true.

12. **True** or false: The Maunder Minimum coincided with a period of unusually cold weather in the Northern Hemisphere.

13. What can you conclude about the absence of sunspot data prior to 1610?
    A) Sunspots did not exist before 1610.
    B) An enormous amount of sunspot data was compiled by the ancient Greeks, but it was lost when the library at Alexandria was accidentally burned up by Caesar in 48BCE.
    C) Until Galileo turned his telescope to the sun in about 1609, no one knew that sunspots existed.
    D) Sunspots were known to exist, and even appear in ancient cave paintings. It's just that nobody thought they were important or significant enough to count.
    E) Sunspot data exists, and is astonishingly complete for dates earlier than 1610, but because the observations were made in China, the West has never acknowledged the accomplishment.



14. The graph above illustrates sunspot counts for the middle of the 20th century. Based on the trend above, when would you predict the next sunspot maximum to occur?
    A) 1975–77
    B) 1980-82
    C) 1985-87

15. The graph above illustrates sunspot counts for most of the 20th century. A maximum is shown at about 1927. Based on the trend above, when would you expect the previous sunspot maximum to have occured?
    A) 1915-16
    B) 1923-24
    C) 1975-77
    D) 1980-82
    E) 1985-87

16. Where are we, in the year 2009, on the sunspot cycle?
    A) 2009 has been a mediocre year for sunspots. Since we are about halfway through the cycle, observations agree with the predictions that a medium (not too high, not too low) number of sunspots are forming.
    B) Sunspot activity is predicted to be maximum in 2009. Current observations agree with the prediction.
    C) Sunspot activity is predicted to be maximum, but actual sunspot counts for 2009 are well below the prediction.
    D) 2009 should be a year of minimal sunspot activity. This prediction is supported by actual sunspot counts.
    E) 2009 should be a year of minimal sunspot activity. However, scientists are alarmed because the actual counts are well above the predicted normal levels.

17. Where are we, in the year 2010, on the sunspot cycle?
    A) 2010 has been a mediocre year for sunspots. Since we are about halfway through the cycle, observations agree with the predictions that a medium (not too high, not too low) number of sunspots are forming.
    B) Sunspot activity is predicted to be maximum in 2010. Current observations agree with the prediction.
    C) Sunspot activity is predicted to be maximum, but actual sunspot counts for 2010 are well below the prediction.
    D) 2010 should be a year of minimal sunspot activity. This prediction is supported by actual sunspot counts.
    E) 2010 should be a year of minimal sunspot activity. However, scientists are alarmed because the actual counts are well above the predicted normal levels.

18. Where are we, in 2011, on the sunspot cycle?
    A) 2011 has been a midway (not maximum, not minimum) year for sunspots. Recent data and observations show larger than numbers of sunspots forming, but the numbers are within the predicted error bars.
    B) Sunspot activity is predicted to be maximum in 2011. Current observations agree with the prediction.
    C) Sunspot activity is predicted to be maximum, but actual sunspot counts for 2011 are well below the prediction.
    D) 2011 should be a year of minimal sunspot activity. This prediction is supported by actual sunspot counts.
    E) 2011 should be a year of minimal sunspot activity. However, scientists are alarmed because the actual counts are well above the predicted normal levels.

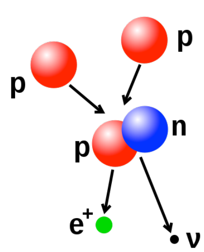
19. Where are we, in the year 2012, on the sunspot cycle?
    A) 2012 should be a year of minimal sunspot activity. This prediction is supported by actual sunspot counts.
    B) 2012 should be a year of minimal sunspot activity. However, scientists are alarmed because the actual counts are well above the predicted normal levels.
    C) 2012 has been a midway (approaching maximum) year for sunspots. Recent data and observations show larger than numbers of sunspots forming, but the numbers are within the predicted error bars.
    D) Sunspot activity is predicted to be maximum in 2012. Current observations agree with the prediction.
    E) Sunspot activity is predicted to be maximum, but actual sunspot counts for 2012 are well below the prediction.

20. Why does a sunspot appear dark?
    A) Because it is made of gas and dust that absorbs visible light.
    B) A dark sunspot is cooler than the surrounding areas on the sun's surface.
    C) Because it is made of iron, a magnetic material.
    D) The spots are openings, or holes, through which the sun's interior can be seen. It's dark in there!
    E) This is another optical illusion caused by viewing the sun through the Earth's atmosphere. Sunspots are not visible from space.

21. Why do sunspots occur in pairs?
    A) They don't. If you see multiple sunspots in a group, however many there are, it is a coincidence. The spots are unrelated.
    B) The sun is a very large place...spots get lonely too, you know.
    C) Because whenever a sunspot forms, it automatically fragments, or splits in two.
    D) Because they are the result of the convection process: one spot is hotter (rising), the other is cooler (sinking).
    E) Sunspot pairs correspond to the N and S poles of a magnet, because they are the result of magnetic field lines breaking through the surface of the photosphere.

22. How is the shape of the solar corona related to the sunspot activity cycle?
    A) When sunspot activity is minimal, the corona appears fairly uniform and symmetric.
    B) Periods of maximum sunspot activity result in a symmetric, uniformly shaped corona.
    C) The corona is always a very symmetric, uniform shape. However, it is only visible when sunspots are very active.
    D) The corona is never symmetric or uniform; its shape is always irregular. However, when sunspot activity decreases, the coronal asymmetry increases.
    E) The shape of the solar corona is unrelated to sunspot activity. There is no correlation.

23. The fundamental forces are **gravity**, **electrostatic**, and the **nuclear strong force**. Which force is actually the strongest?
    A) Gravity, because it is strong enough to keep huge planets circling even huger stars!
    B) The electrostatic force: The repulsion between like charges is so strong that gravity and the strong force pale in comparison.
    C) The strong force is literally the strongest. It has to be, because it keeps like charges (protons) bound together in the nuclei of atoms.
    D) Each of the previous statements is true, which means that all of the forces are equally strong. It is only because they act on different objects that the forces get different names.

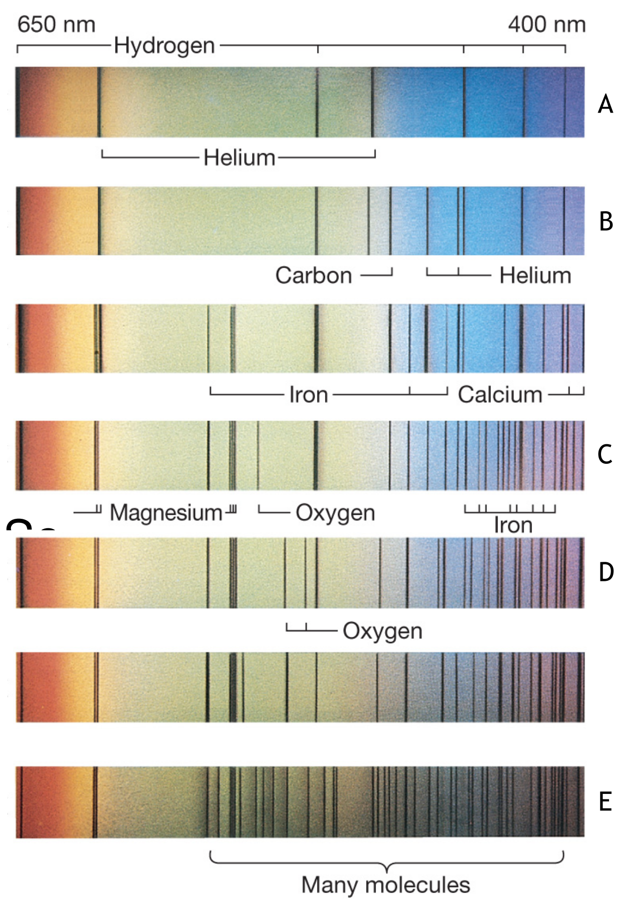


The figure on the left illustrates the first step on the proton-proton chain.

24. Why is a positron (e+) emitted?
    A) Because one proton loses a tiny bit of mass and charge as it converts into a neutron.
    B) Because one proton takes a bit of mass from the other one, causing some (+) charge to be expelled.

25. What is the final result of the proton-proton chain?
    A) You start with two protons, you end with two protons. Hence the name.
    B) Two protons collide, and one becomes a neutron. This nucleus collides with another proton to form an unstable He nucleus. Two of these He nuclei collide, and after two protons are ejected, you are left with a single, stable He nucleus.
    C) After several nuclear reactions, two protons split to become four protons (then those four become eight, and so on).
    D) The name is strictly literal: protons bind to other protons, forming a long chain (like beads on a wire). Each "bead" added causes some energy to be released.
    E) The *final result* is a supernova. Once all of the protons have been "chained" together, the internal pressure at a star's core is so great that the star explodes.

26. True or **false**: Hydrogen fusion occurs everywhere throughout the sun, from the solar corona all the way down to the core.



27. Of the stellar spectra shown above, which represents the hottest star? **A**

28. **True** or false: Star B is significantly hotter than Star C.

29. Which spectrum represents the coolest star? **E**

30. Which spectrum is most likely to represent a sun-like (spectral type G) star? **D**

31. The apparent (or visual) magnitude scale
    A) increases linearly with a star's apparent brightness: a magnitude 2 star appears twice as bright as a magnitude 1.
    B) decreases linearly with a star's apparent brightness: a magnitude 1 star appears twice as bright as a magnitude 2 star.
    C) increases exponentially with a star's apparent brightness: a magnitude 2 star appears 10 times as bright as a magnitude 1 star.
    D) decreases logarithmically as a star's apparent brightness increases: a magnitude 1 star appears 2.5 times brighter than a magnitude 2 star.
    E) varies unpredictably with the apparent brightness of the star: there is no way to compare.

32. **True** or false: The B–V color index of a star is a very reliable way to determine its temperature.

Use the table of star data on the ***back page*** of this exam to answer the following **Questions 21—25**.

33. Rank the stars on the table in **distance** order: from **closest to farthest** from the Earth.
    A) Antares, Spica, Capella, Arcturus, Procyon, Sirius
    B) Sirius, Procyon, Arcturus, Capella, Spica, Antares
    C) Sirius, Arcturus, Antares, Spica, Procyon, Capella
    D) Antares, Spica, Capella, Arcturus, Procyon, Sirius
    E) Spica, Sirius, Procyon, Capella, Arcturus, Antares

34. True or **false**: The star which *appears* the brightest to us is also *intrinsically* the brightest.

35. True or **false**: The star which appears the dimmest to us is also intrinsically the least luminous.

36. Which of the stars on the list is the most massive, and how do you know?
    A) Procyon, because its absolute magnitude is the greatest.
    B) Sirius, because it appears the brightest in our sky.
    C) Antares. The star with the greatest luminosity will also have the largest mass.
    D) Spica. Its spectral class is "B." A B-type star is more massive than anything except an "O," and there are no O-types on the list.
    E) The information on the table cannot be used to determine the mass of any of the stars.

37. Which of the stars is the hottest? That is, which star has the highest surface temperature?
    A) Spica
    B) Sirius
    C) Procyon
    D) Arcturus
    E) Antares

38. Which of the stars is the coolest? That is, which star has the lowest surface temperature?
    A) Spica
    B) Sirius
    C) Procyon
    D) Arcturus
    E) Antares

39. Which of these stars are main sequence stars?
    A) They are all main sequence stars!
    B) Antares, Arcturus, Capella, and Procyon.
    C) Arcturus and Antares only.
    D) Procyon and Capella only.
    E) Sirius and Spica.

40. Of the following main sequence stars, which will have the **shortest** lifespan?
    A) Alpha Centauri (G2 V).
    B) Alpha Eridani (B5 V).
    C) Epsilon Eridani (K2 V).
    D) Phi Orionis (B0 V)
    E) Gamma Virginis (F0 V)

41. Of the following main sequence stars, which will have the **longest** lifespan?
    A) Alpha Centauri (G2 V).
    B) Alpha Eridani (B5 V).
    C) Epsilon Eridani (K2 V).
    D) Phi Orionis (B0 V)
    E) Gamma Virginis (F0 V)

42. Polaris has the same spectral type as the sun (G2), but its luminosity is 10,000$L_\odot$. Therefore,
    A) its radius must be 10,000$R_\odot$.
    B) its radius must be (1/10,000)$R_\odot$.
    C) its radius must be 100$R_\odot$.
    D) its radius must be (1/100)$R_\odot$.
    E) its radius must be 1$R_\odot$, the same as the sun.

43. Place Polaris in the appropriate location on the H-R diagram. **D**

44. Where on the H-R diagram would you find the sun? Use the regions marked on the H-R Diagram on the back page of this exam. **C**

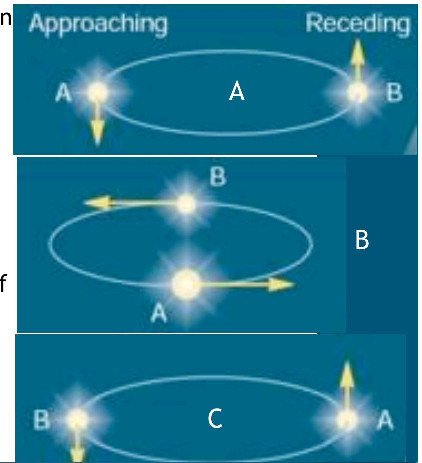
45. True or **false**: All of the stars on the main sequence of the HR diagram fall along the same constant radius diagonal. They are all the same size as the sun.

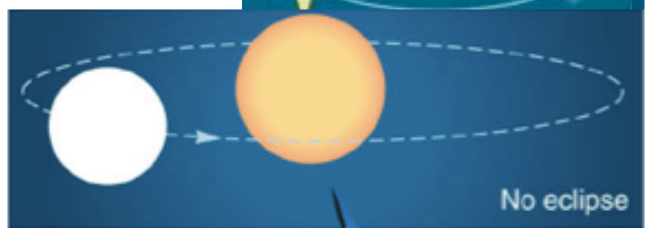
46. What information does the luminosity class of a star provide?
    A) Brightness: Higher luminosity class indicates a higher apparent magnitude, which actually means a dimmer star as viewed from Earth.
    B) Temperature: Stars with a higher luminosity class have a higher temperature.
    C) Mass: The higher the luminosity class, the larger the mass of the star.
    D) Radius: Stars with a larger radius have a higher luminosity class.
    E) Size: Luminosity classes I through IV are giant stars, but lower number indicates larger star. Class V is main sequence.

47. True or **false**: If you count the number of each different type of star, you will find many more O and B type stars than K and M type stars.

48. True or **false**: Every visual binary is also an eclipsing binary.

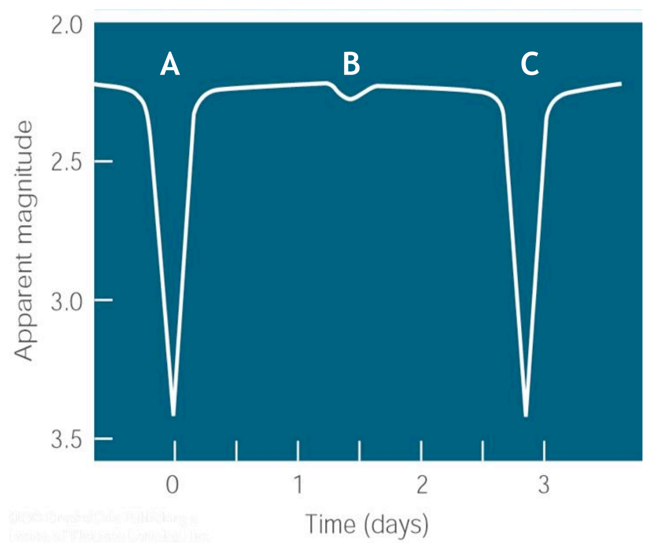
49. In which position will the light from star B be blue-shifted? **C**
    D) Star B will never have a blue-shifted spectrum.
    E) The spectrum of Star B will always appear blue-shifted.





The central star is the cooler star, and the slightly smaller star is a hotter star.

50. As the hotter star eclipses (passes in front of) the cooler star, what happens to the light curve? **B**



    D) Either A or C, since they are the same.
    E) None of the above; the intensity of the light curve does not change just because one star is moving around the other one!

51. In the interstellar medium, how do you distinguish between "gas" and "dust?"
    A) Singular atoms or molecules form a gas, but when molecules begin to clump together, it is considered dust.
    B) Gas is hydrogen. Anything that is not hydrogen is considered dust.
    C) Gas is transparent to all wavelengths of electromagnetic radiation. Dust is opaque to all wavelengths.
    D) Gas is found in regions of starbirth, but dust is only found in regions of old, dying stars.
    E) There is no real difference, it's like saying "the forest" or "the woods." Either way, it's all a bunch of trees.

52. When viewing stars in the Pleiades, a region that is moderately dusty, the starlight you receive
    A) will be more blue than red. Longer wavelength red light will be absorbed by the gas and dust before it reaches the Earth.
    B) will be more red than blue. It is the shorter wavelength blue light that is absorbed and scattered by the molecules of gas and dust.
    C) will be unaffected by the gas and dust. The interstellar medium is transparent to visible light of all wavelengths.
    D) will be exclusively infrared. The gas and dust will absorb all visible frequencies, so nothing will be visible except the infrared wavelengths.
    E) will be very dim. The gas and dust will absorb almost all of the visible light, of every color. No single color will be absorbed or scattered more than any other color.

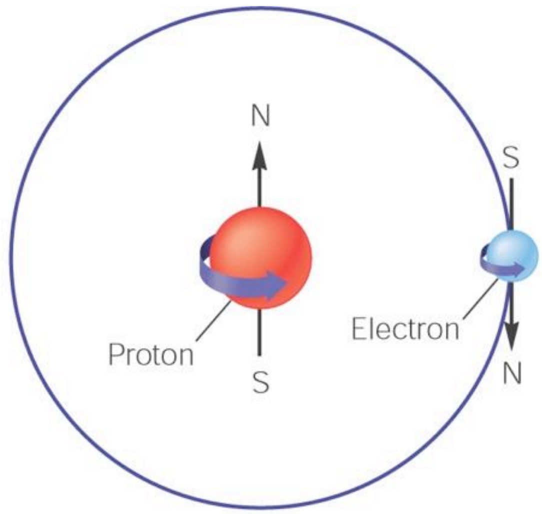
53. The composition of the interstellar medium?
    A) Hydrogen. 100% pure organic hydrogen.
    B) Helium. There is a surprising abundance of helium in interstellar gas clouds.
    C) Water vapor. Just like clouds on Earth, interstellar clouds are made of water vapor, with traces of more complex molecules.
    D) Interstellar clouds have stellar compositions. That is, they are 99% hydrogen and helium, with about 1% everything else.
    E) There is no way to generalize. Every region has a completely unique composition. One cloud might be hydrogen rich, another might have no hydrogen at all. No way to tell.

54. What color does an emission nebula typically appear?
    A) White. A nebula is a cloud, it appears white or maybe grayish, like clouds on Earth.
    B) Black. A emission nebula does not emit visible light, so it appears as a black patch.
    C) Green. Because green is in the middle of the visible spectrum, it's the average wavelength. Nebulae are usually green.
    D) Blue. A cool emission nebula reflects and scatters the blue light that strikes it.
    E) Red. The emission nebula is hot and glows red because of the strong H-α emission line.

55. What color does a reflection nebula typically appear?
    A) White. A nebula is a cloud, it appears white or maybe grayish, like clouds on Earth.
    B) Black. A reflection nebula does not emit visible light, so it appears as a black patch.
    C) Green. Because green is in the middle of the visible spectrum, it's the average wavelength. Nebulae are usually green.
    D) Blue. A cool reflection nebula reflects and scatters the blue light that strikes it.
    E) Red. The emission nebula is hot and glows red because of the strong H-α emission line.

56. **True** or false: The Earth is located near the center of what is called the "Local Bubble," a region of unusually hot low-density gas.

57. **True** or false: A dark dust cloud which does not emit or reflect visible light is typically colder and denser than a bright emission nebula.



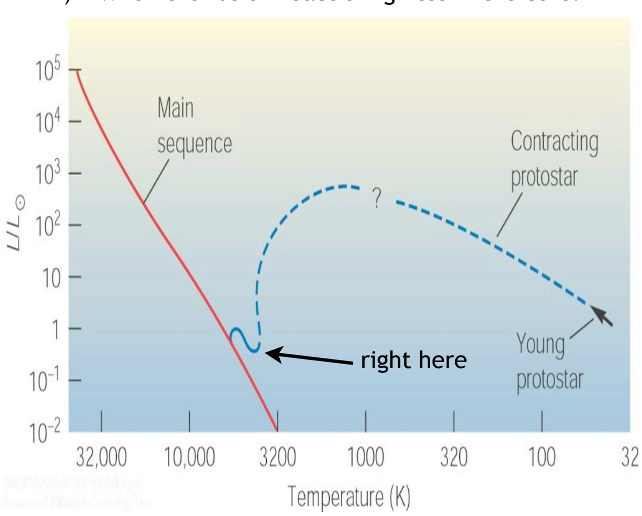
58. A neutral hydrogen atom is illustrated in the figure above. Is the electron shown likely to spin-flip and emit a photon?
    A) Yes. The atom is in an unstable, high-energy state, so the e^- will flip to the opposite spin.
    B) No. The opposing magnetic fields are the stable, low energy state. The e^- has no reason to flip its spin.
    C) You cannot say whether the electron will flip or not. It's totally random.
    D) This is a trick question. The *electron* does not spin-flip. The **proton** in the nucleus will flip its spin.

59. When an electron executes a spin-flip transition in a hydrogen atom, how much energy is released?
    A) It varies. Each transition will be unique, depending on how fast the electron is spinning when it flips.
    B) This is a high-energy transition, and a high frequency X-ray photon is emitted.
    C) The energy emitted will be in the form of a photon having a 650nm wavelength—this is red light!
    D) Very little energy is released. The photon emitted has a 21cm wavelength, making it a radio wave.
    E) None. Energy must be absorbed by the electron, not emitted.

60. In a molecular cloud, you will typically find spectral lines for molecules like ammonia, water vapor, and even formaldehyde. What you won't find is a 21-cm hydrogen line. Why not?
    A) Because there is no hydrogen in a molecular cloud. The missing line proves it!
    B) The 21-cm line will be obscured by the other lines from all the other molecules. It's there, but it's hidden.
    C) There's hydrogen, and it emits that 21-cm line. The other molecules, however, absorb that energy and the line disappears.
    D) All of the hydrogen has been ionized. When the electron is stripped from the hydrogen nucleus, there cannot be a 21-cm line.
    E) The cloud is cool enough that the atomic hydrogen has combined with other atoms (ammonia = NH_3 for example), or with itself to make hydrogen molecules. Either way, no atomic hydrogen is left to form the line.

61. What minimum mass is required for a collapsing cloud fragment to become a true star, with hydrogen fusion at its core?
    A) Minimum M ≈ $1000M_\odot$.
    B) Minimum M ≈ $100M_\odot$.
    C) Minimum M ≈ $10M_\odot$.
    D) Minimum M ≈ $1M_\odot$.
    E) Minimum M ≈ $0.1M_\odot$.

62. When does a collapsing cloud fragment become a protostar?
    A) When the original cloud is disturbed and begins to collapse.
    B) When its size is reduced to about 100 times the size of our solar system.
    C) When it stars to assume a definite spherical shape and a photosphere can be seen.
    D) When it begins bipolar outflow, entering the t-tauri phase.
    E) When the fusion reaction ignites in the core.

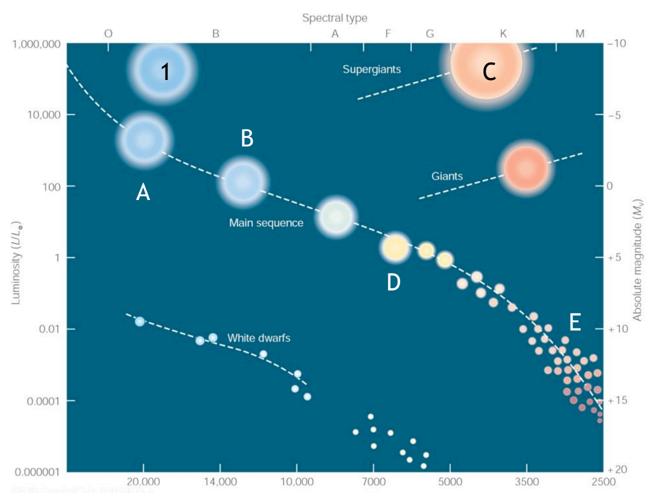


63. On the figure above, what happens at the point labeled "right here?"
    A) The dip represents the point at which fusion ignites at the core of the contracting protostar, making it an actual star.
    B) The dip is the point at which the protostar emerges from the cloud of gas and dust.
    C) That is the point where the protostar starts its t-tauri phase and begins ejecting mass.
    D) That point is where the star begins to glow, not because of fusion, but because of contraction. Fusion only happens when the star hits the main sequence line.
    E) Nothing; it's a joke, right? LIke pointing at one of the spiral arms of the Milky Way and saying "You are here."

64. During a protostar's T-Tauri phase, it
    A) begins a period of reduced activity. It wil become much smaller and dimmer.
    B) expands dramatically, becoming a red giant.
    C) lies on the main sequence. It remains stable for at least 5–10 billion years.
    D) changes its spin direction, which causes it to collapse into a black hole.
    E) may develop very strong winds, resulting in bipolar flow, or mass ejections.

65. **True** or false: The larger the fragment of interstellar cloud, the faster it will collapse into a protostar and ultimately into a star.

66. If a collapsing cloud fragment has about 50 times the mass of Jupiter, it will become
    A) an O-type blue giant star.
    B) a G-type star like the sun.
    C) a terrestrial planet like the Earth.
    D) a brown dwarf.
    E) a round wharf.



67. In the diagram above, what will happen to the star labeled "1" as it evolves over its lifetime? That is, where on the H-R diagram will it end up? **C**

68. **True** or false: The presence of large O- and B-type stars is generally considered to indicate a young star cluster.

69. **True** or false: Globular clusters are populated by large numbers of very old, low-mass stars.

Data for Several Well-Known Stars

Star	Parallax (arcsec)	Apparent Magnitude	Absolute Magnitude	(B — V)	Spectral Type	Luminosity (L/L⊙)
Sirius	0.379	-1.44	+1.5	+0.01	Al V	22
Arcturus	0.089	-0.05	-0.3	+1.23	K2 III	110
Capella	0.077	+0.08	-0.5	+0.80	G III	130
Spica	0.012	+0.98	-3.5	-0.13	B1 V	2,200
Procyon	0.286	+0.40	+2.7	0.40	F5 IV	7.2
Antares	0.005	+1.06	-5.3	+1.87	M1 Ib	11,000

H-R Diagram