True or False

1. The sun's apparent magnitude is less (more negative) than its absolute magnitude because the sun is closer than 10 parsecs.
   True; since the absolute magnitude is defined as the magnitude of an object at 10 parsecs, any object closer than 10 parsecs is brighter than its absolute magnitude. “Brighter” is more negative in the magnitude scale.

2. Stars which emit more light than the sun are hotter than the sun.
   False, as in not always true. Red giants such as Betelgeuse emit more light because they are larger, not because they’re hotter. It is true that the luminosity scaling law, to the 4th power, is a stronger power than the 2nd power scaling law from the radius, but size still matters.

3. Sunspots, on the average, last for approximately eleven years.
   False, sunspots last on the order of weeks. The sunspot (half) cycle is roughly eleven years, yes, but individual sunspots do NOT last nearly that long.

4. The absolute magnitude of a star is defined as the magnitude that a star would have if it were placed at a standard distance of 1 pc.
   False; the standard distance is 10 pc.

5. An atom will radiate energy if an electron migrates from a lower to higher orbit.
   False: An electron must FALL from a higher orbit to a lower orbit to emit energy. It must ABSORB energy to migrate from a lower to higher orbit.

Multiple Choice Select the BEST answer

6. What is the frequency of light with a wavelength of 656.3 nm? (This is the alpha line for the Balmer series in hydrogen)
   a. $6.56 \times 10^9$ Hz (cycles per second)
   b. $4.6 \times 10^{14}$ Hz (cycles per second)
   c. $6.56 \times 10^{11}$ Hz (cycles per second)
   d. $4.6 \times 10^6$ Hz (cycles per second)
   e. None of the above.

7. Which star’s spectrum will likely be broadened (blurred) the least?
   a. A star with a surface temperature of 1,000 K and a rotational period of 60 days.
   b. A star with a surface temperature of 5,000 K and a rotational period of 30 days.
   c. A star with a surface temperature of 20,000 K and a rotational period of 10 days.
   d. A star with a surface temperature of 30,000 K and a rotational period of 3 days.
   e. Could be either “c” or “d”; not enough information is given.
   “A” is correct. Hotter temperatures broaden spectroscopic lines more than cooler temperatures. Slower motion due to rotation will cause less line broadening, though “likely” is an important word here as a star with a larger radii but the same rate of rotation will have faster motion due to rotation (but you were told that these stars have the same radii).
Hopefully you read the question right and didn’t look for the star with the most rotational broadening, but that would have been answer “E” as you do not have enough information to determine whether the temperature or rotational period has the greatest effect.

8. Which type of radiation travels the fastest in a vacuum?
   a. Infrared.
   b. Visible light.
   c. X-rays.
   d. Ultraviolet.
   e. All of the above travel at the same velocity.

   “E”, all EM radiation travels at the same speed in a vacuum. It is important to say “in a vacuum” because light travels more slowly in more dense media, with longer wavelength radiation slowed down less.

9. Below are five statements about particles, and all but one are considered true. Which is incorrect?
   a. The number of protons determine which element an atom is, and the number of protons plus neutrons determines the relative mass of different isotopes of that element.
   b. Neutrinos are lighter than electrons, and most neutrinos pass through the earth.
   c. Uncharged particles such as electrons and neutrons produce all electromagnetic radiation.
   d. Photons are particles of light. (Light can be considered as both a wave and a particle.)
   e. A gamma-ray photon has more energy than a radio photon. (Also, a blue photon has more energy than a red photon.)

   “C” is doubly false: Charged, not uncharged particles, produce all electromagnetic radiation. Also, since neutrons are not charged they do not produce much radiation like protons do.

10. Given that a parsec is roughly $3 \times 10^{13}$ km, how long does it take light at $3 \times 10^5$ km/sec to travel one parsec? (Remember there are 365 days per year, 24 hours per day, 60 minutes per hour, and 60 seconds per minute.)
   a. 3.3 days (Hint: This is between 500 and 600 A.U.)
   b. 1/3 year (Hint: This is between 20,000 and 25,000 A.U.)
   c. 1 year (Hint: This is between 60,000 and 65,000 A.U.)
   d. 3.3 years (Hint: This is a little more than 200,000 A.U.)
   e. $1 \times 10^8$ years (Hint: This is roughly $6 \times 10^{12}$ A.U.)

   “D” A parsec is 3.3 light years. $3 \times 10^{13}$ km/$3 \times 10^5$ km/sec roughly equals $10^8$ seconds. A year is $365 \times 24 \times 60 \times 60$ equals roughly a little more than $3 \times 10^7$ sec, and $10^8 \text{sec}/(3 \times 10^7 \text{sec/yr})$ is roughly 3.3 yrs.

11. We cannot tell how far the Radiative Zone extends from the center of the Sun, true or false?
   a. True, because we cannot see past the Corona.
   Incorrect: We can see through the Corona; we see to the photosphere.
   b. False, because atoms in the Radiative Zone keep their electrons bound as atoms.
   Incorrect: atoms in the Radiative Zone are ionized (do not keep their electrons bound).
   c. False, because waves traveling through the sun can be studied in a manner similar to waves going through the earth.
   Correct: by observing the pressure waves going through the sun, helio-seismology, we can study the interior of the sun.
   d. False, because we can see the Radiative Zone by looking through sunspots.
Incorrect; sunspots are not “holes” that can be seen through, but are cooler areas that aren’t quite as bright as the rest of the photosphere.
e. False, because we can measure the Sun’s magnetic field in a manner similar to how we measure the earth’s magnetic field using “helio-seismology”.
Incorrect: Helio-seismology is NOT studying the sun with magnetic fields. Still, since helioseismology is what is used to study the sun’s interior, this answer could have been seen as correct if you were rushing through too fast, so you were told this was incorrect. But now you know helio-seismology is NOT studying the sun with magnetic fields.

12. Which temperatures are correct for the sun? (Hint: To make this easier, both answers are true or both answers are false.)
   a. The Core is approximately 100,000 K and the Photosphere is approximately 3000 K.
   b. The Radiative Zone is approximately 100,000,000 K and the Chromosphere is approximately 2,000 K.
   c. The Photosphere is approximately 1,000 K and the Corona is approximately 1,000,000,000 K.
   d. The Core is approximately 15,000,000 K and the Photosphere is approximately 6000 K.
   e. None of the above. But the Corona is cooler than the Photosphere because it is further out.

13. Variations in the sun’s luminosity, (or what was called the “solar constant”), can affect the earth’s climate, true or false?
   a. False; the sun’s energy output was called the “solar constant” because it does not change. Incorrect: Astronomers made an incorrect assumption when they coined the term “solar constant.” They didn’t know better, but we now know the sun does slightly vary in luminosity, by 1/1000, over a solar cycle.
   b. Likely true, even though the change in the sun’s output is only 1/1000, which appears too small to change the climate.
   c. True, as an increase in solar output of 1/1000 would be easily enough to have caused the global warming of the last decade.
   d. False. While it is now known that the sun’s energy output is not exactly constant, most of the change occurs due to sunspots coming in and out of view.
   e. True, because an increase in solar activity can cause bad space weather, which causes significant heating of the earth’s lower atmosphere.
Incorrect: these changes occur on timescales of hours or days and are not suspected to cause climate change. (Who knows, though, maybe this “enhances” the luminosity change effect. That is why you were told to circle the best answer.)
           e. True, because an increase in solar activity can cause bad space weather, which causes significant heating of the earth’s lower atmosphere.
Incorrect, because while bad space weather can affect satellites and electrical grids, space weather is only a minor source of heating of the earth.

14. Which of the following regions of the sun is the hottest that can be viewed in visible light from the earth? (Hint: Do not answer any regions that are not directly visible from the earth.)
   a. The Photosphere.
   b. The Radiative Zone.
While this zone is the hottest listed, it is NOT directly visible from the earth.

c. The Convective Zone.
d. The Transition Zone.

Incorrect; the transition zone is cooler than the photosphere.
e. The Corona.

Correct; the corona’s temperature mysteriously rises to 1,000,000 K. Or maybe this mystery has been solved. We can see the corona during eclipses and using “coronagraphs” to create artificial eclipses.

15. Which particle coming from the sun gives the best evidence that the sun is powered by fusion?

   a. Protons.
   b. Neutrons.
   c. Electrons.
   d. Photons.
   e. Neutrinos.

“E”, most neutrinos pass through the sun without being absorbed and re-emitted like electromagnetic radiation is.

16. Which layer of the sun transfers energy the most slowly?

   a. The Core.
   b. The Radiative Zone.
   c. The Convective Zone

In this zone, heat is passed through convection, which is like carrying the heat instead of radiating it.
   d. The Photosphere.
   e. The Corona.

17. What do thermal line broadening and rotational broadening have in common?

   a. Both are caused by Doppler Shifts.
   b. Both result from the thermal motion of atoms, ions, and molecules.
   c. Both come from all parts of a star’s disk.
   d. Both affect absorption lines more strongly than emission lines.
   e. Neither affects the line profiles from all elements.

Both affect lines from all elements.

18. For a thermal source of radiation, the luminosity $L$ is

   a. proportional to the inverse squared of the temperature.
   b. proportional to the inverse of the temperature.
   c. proportional to the temperature.
   d. proportional to the temperature squared.
   e. proportional to the temperature to the $4^{th}$ power.

“E”, Stefan’s law, which is on the table of equations.
19. For a thermal source of radiation, the wavelength $\lambda$ is
   a. proportional to the inverse squared of the temperature.
   b. proportional to the inverse of the temperature.
   c. proportional to the temperature.
   d. proportional to the temperature squared.
   e. proportional to the temperature to the 4th power.

   “B”, Wein’s law, which is on the table of equations.

20. Understanding which of the following is of special importance to understanding the Sun.
   a. The Sun’s electric field
   Not the best answer. The Sun’s electric field affects it most scientists would agree not as strongly as it’s magnetic field, which we studied.
   b. The Sun’s magnetic field
   c. The Sun’s albedo
   d. The Sun’s kharma
   e. Spots on the sun that emit no radiation.

   Sunspots do emit radiation.

21. What solar activity provides direct evidence for the presence of the convective zone? *(Hint: Faculae are also called plage, and are the bright spots on the sun. This is being told to you because you were told in class you would not have to remember the names faculae or plage, but you still should know there are bright areas.)*
   a. Faculae (bright spots on the sun, also called plage)
   b. Sunspots
   c. Granules
   d. Coronal Mass Ejections.
   e. Prominences

   Granules are the tops of convective plumes and last only 5 to 10 minutes. They give the photosphere a “boiling” appearance (your hint).

22. Jupiter’s brightness is going from magnitude –2.6 in January 2001 to –2.1 in March 2001. In January, Jupiter was near Aldebaran, magnitude 0.9, which is one top of a “V” shaped grouping of stars in Taurus. In this “V”, the next four stars in brightness are close to the magnitude of $\varepsilon$ Tauri, the other top star of the “V”.  $\varepsilon$ Tauri is magnitude 3.5. Which of the following is correct?
   a. Jupiter is getting brighter and remains less than 100 times as bright as $\varepsilon$ Tauri.
   b. Jupiter is getting brighter and remains roughly 100 times as bright as $\varepsilon$ Tauri.
   c. Jupiter is getting brighter and remains more than 100 times as bright as $\varepsilon$ Tauri.
   d. Jupiter is getting dimmer and remains less than 100 times as bright as $\varepsilon$ Tauri.
   e. Jupiter is getting dimmer and remains roughly 100 times as bright as $\varepsilon$ Tauri.

   Jupiter is going to up in magnitude, meaning it is getting dimmer (“D” or “E”). Jupiter goes from (3.5)–(–2.6) = 3.5+2.6=6.1 magnitudes brighter to (3.5)–(–2.1) = 3.5+2.1=5.6 magnitudes brighter, so it remains a little more than 100 times as bright as $\varepsilon$ Tauri, “C”. Teacher does not get an “A” on test and must eat crow and beg for forgiveness for not doing his subtraction right. Teacher will ask class if “Everyone gets credit for this problem” is an acceptable solution.
23. Venus is at magnitude –4.5 (as of 31 January 2001). The faintest stars that the unaided eye can see are at about magnitude 6. Venus is currently how much brighter than the faintest stars that the eye can see?

   a. Roughly 100 times.
   b. Roughly 1,000 times.
   c. Roughly 10,000 times.

Taking \((6) - (-4.5) = 6 + 4.5 = 10.5\) which is roughly \(2 \times 5 = 10\) magnitudes, so the Venus is roughly \(100^2 = 10,000\) times as bright as the faintest stars that can be seen by the unaided eye. This is why we use a logarithmic (exponential) scale for magnitude!

   d. Roughly 100,000 times.
   e. Roughly a million times.

24. What would be the least appropriate description or name for the Hertzsprung-Russel diagram?

   a. The color-luminosity diagram.
   b. The magnitude-luminosity diagram.

Magnitude is the measurement for luminosity, so they both can be used for the vertical axis leaving nothing to plot against. A magnitude-luminosity diagram would be as useless as a temperature-Celsius diagram or a speed-miles/hour diagram.

   c. The diagram on which most stars evolve along the main sequence, which can be used for a rough estimate of distance.
   d. The diagram which shows stars’ classifications and intrinsic brightnesses.
   e. The temperature-luminosity diagram.

25. Given that Sirius exhibits 0.37 arc seconds parallax, its distance is?

   a. 2.7 parsecs
   b. 12 parsecs
   c. 2.7 light years
   d. 12 astronomical units (12 AU)
   e. 10 parsecs

\[
\frac{1}{0.37} = 2.7 \text{ pc}
\]

26. Aldebaran has a magnitude of +.86 and Sirius has a magnitude of –1.46. Sirius’ apparent brightness is therefore \(100^{((0.86) - (-1.46))/5} = 8.5\) times as Aldebaran. But Aldebaran is almost 6 times as far away. Sirius’ luminosity is roughly how many times as bright as Aldebaran?

   a. \((8.5/6^2),\) or roughly one fourth as bright as Aldebaran.
   b. \((8.5/6),\) or slightly brighter than Aldebaran.
   c. \((8.5^2/6),\) or on the order of 10 times as bright as Aldebaran.
   d. \((8.5^4/6),\) on the order of 1000 times as bright as Aldebaran.
   e. Not enough information is given.

“A” This is simply the inverse squared law.
27. A “B” star, such as Rigel, has a temperature around 20,000 K. A “K” star, such as Aldebaran, has a
temperature around 4,000 K. If a “B” star is the same size as a “K” star (and if both are at the same
distance), how much brighter would the “B” star, such as Rigel be than the “K” star, such as
Aldebaran?

a. Many hundreds to a thousand times as bright.
b. Roughly a hundred times as bright.
c. 25 times as bright.
d. Five times as bright.
e. Either could be brighter than the other.

Luminosity is proportional to the temperature to the 4th power, so the “B” star is \((20,000 \text{ K}/4,000 \text{ K})^4 = 5^4 = 625\) times as bright, so “A” is correct.

28. If a “B” star, such as Rigel, is actually about 500 times as luminous as the “K” star, such as
Aldebaran, then how many times larger is the “B” star than the “K” star? (A much more exact answer
would require information from the previous question.)

a. Aldebaran is probably larger than Rigel.
b. The “B” star has roughly 1000 times the volume of the “K” star.
c. The “B” star has roughly 10 times the radius of the “K” star.
d. The “B” star has roughly twice the diameter of the “K” star.
e. The stars’ sizes are close enough that either could be larger than the other.

“E” as 500/625 (with the 625 coming from question 27) is a little less than one (hence “A” is incorrect).
Since “a little less than equal” is not a given choice and in the accuracy of many astronomical
measurements, 500/625 could be equal given better measurements, “E” is the best choice. This question
would have been better to have indicated a low level of accuracy, but low accuracy is often not made clear
in actual research measurements. Note that “B” and “C” are the same; this was done to help you quickly
eliminate these choices.
29. Given the following data for measured wavelength of the hydrogen alpha line of a star, made at the same time each day, what can we conclude? Assume the astronomer measures a hydrogen alpha line of 656.30 in her laboratory.

<table>
<thead>
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<th>Date</th>
<th>Wavelength (nm)</th>
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<tbody>
<tr>
<td>27 Jan</td>
<td>656.23</td>
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<tr>
<td>28 Jan</td>
<td>656.30</td>
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<td>29 Jan</td>
<td>656.37</td>
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<td>30 Jan</td>
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<td>31 Jan</td>
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<td>04 Feb</td>
<td>656.23</td>
</tr>
<tr>
<td>05 Feb</td>
<td>656.30</td>
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</tbody>
</table>

a. The star likely rotates with a period of 4 days. Incorrect; the rotation might broaden the wavelength, but would not shift the centroid (ask what “centroid” means).

30. Identify the correct diagram (on the transparency) of the area around the Orion in the current evening sky. (Hint: At 9 pm, which constellation is at the zenith (directly overhead):

Please note: There are more than one reason why each incorrect choice is wrong so that you wouldn’t have to know all of this information to get the right answer.

“A” Incorrect: Saturn and Jupiter, and Sirius and Procyon, and Rigel and Betelguese are interchanged are the biggest giveaways. More subtle are that Rigel and Betelguese are on the wrong east/west side of Orion. I had also mentioned seeing Orion at the zenith in South Africa, something that never happens in Atlanta.

“B” Incorrect: Betelguese is red and Rigel is blue, not vice versa. More subtle are that Rigel and Betelguese are on the wrong east/west side of Orion, and that all the stars are too close to the ground. Canis Major, which includes Sirius, is far too south to be near the zenith.

“C” Incorrect: Jupiter and Saturn are interchanged, and Procyon is not red. Also, Alpha Centauri is not a constellation and much of the constellation Centaurus cannot even be seen as far north as Atlanta.

“D” Correct: This is also the only diagram to show Aldebaran as red, which is part of Laboratory 22. A previous question on this test says that Aldebaran is a K star. More subtle: All of the other diagrams are somewhat warped. Also, the curved ground is more accurate for a sky map. Auriga can be high in the sky.

“E” Eridanus is always too far south to be at the zenith.

31. (Bonus; difficult) The sun’s absolute magnitude is 4.8. What the magnitude of a star 2 times as hot with a radius 25 times as large be if it were in the Andromeda Galaxy (M 31), which we will take as being 1,000,000 pc away? (Latest estimates suggest M 31 is really 900,000 pc, or 2,900,000 ly away.)

a. Roughly -25th magnitude  
b. Roughly +10th magnitude  
c. Roughly +15th magnitude  
d. Roughly +20th magnitude  
e. Roughly +30th magnitude (As faint as the Hubble Telescope can see.)
32. (Bonus; from article) CMEs come from which part of the sun and take how long to reach the earth after erupting? (Hint: M stands for Mass, E for Ejection).

a. The chromosphere, taking slightly over 8 minutes to reach the earth.
b. The chromosphere, taking hours to reach the earth.
c. The corona, taking slightly over 8 minutes to reach the earth.
d. The corona, usually taking 1 or 2 hours to reach the earth.
e. The corona, usually taking 3 or 4 days to reach the earth.

“E” CME stands for “Coronal Mass Ejection”, and the particles as described in the particle are not so highly energetic that they reach the earth at a substantial fraction of the speed of light as “C” or even “D” would require. The article described SOHO as giving the earth an hour or so warning. While not in earth orbit, SOHO is still in the earth’s “neighborhood”, not the half or less of the earth’s distance to the sun for “D” to be correct.