Reach For the Stars
SSSS 2020 Answer Key

Team Name and Number:____

Team Members:____

Score:_________

You will have 50 minutes to complete this test.

Do not open this test before instructed to do so.

There are 3 parts to this test.

- Part 1: General Knowledge
- Part 2: ID Questions
- Part 3: Calculation Questions

Partial credit will be given in Parts 2 and 3 at the graders' discretion, but **NOT** in Part 1.

Good Luck! :)

Part 1: General Knowledge

Multiple Choice

1. B
2. C
3. A
4. C
5. D
6. A, C, D
7. A, C
8. D
9. A
10. B
11. A
12. B
13. C
14. B
15. A
16. B
17. B
18. D
19. A, B, C
20. B

Free Response

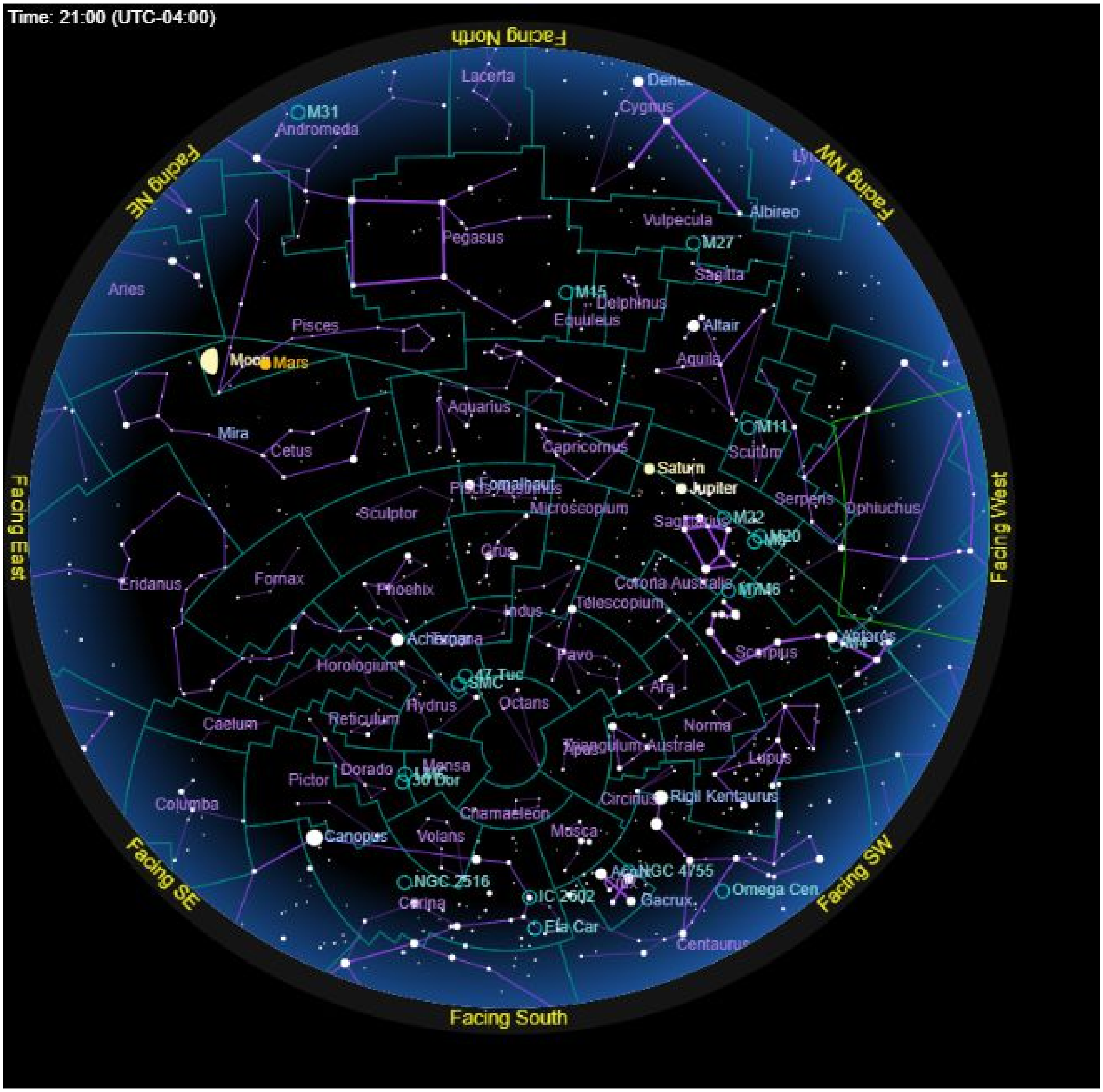
1. Type I supernovae have no hydrogen emission lines, while Type II supernovae do. *(2 points)*
2.
    a. Betelgeuse
    b. Sirius
    c. Aldebaran
    d. Spica
3. Electron Degeneracy Pressure *(or Pauli Exclusion Principle)*
4. Neutron Degeneracy Pressure *(or Pauli Exclusion Principle)*
5.
    a. *One of the following*: observing cold clouds of gas, observing quasars, observing supernova remnants, observing AGNs, observing pulsars, interferometry.
    b. *One of the following*: Observing extremely hot objects, observing x-ray binaries, observing black holes, observing AGNs.
    c. *One of the following*: Piercing through clouds and dust, observing centers of galaxies, observing newly forming stars.

6.
    a. Sb *(0.5 points if "Spiral" is written)*
    b. SBb *(0.5 points if "Barred Spiral" is written)*
    c. S0 *(0.5 points if "Lenticular" is written)*
    d. Sc (*0.5 points if "Spiral" is written)*
7. Proton-Proton Chain
8. CNO Cycle

Part 2: ID Questions

1. The DSO pictured on the cover of this test is M101/Pinwheel Galaxy. *(1 point)* Images P, K, and G are of the same DSO. *(1 point)* Image P is in the X-ray, Image K is in the infrared, and Image G is in the ultraviolet. *(1 point if they get all 3 correct, ½ point if they get 2 of the 3 correct, otherwise give no points)* The X-ray image can be identified by the high energy stars and regions near the core of the galaxy. The infrared image can be identified by the dust spread throughout the galaxy. The ultraviolet image can be identified by the young stars and nebula in the spiral arms of the galaxy. *(2 points if they get all 3 correct, 1 point if they get 2 of the 3 correct, otherwise give no points)*
2. Image B is NGC 5128/Centaurus A/Cen A. *(1 point)* The "spokes" coming out of the galaxy are relativistic jets. *(1 point, if they do not say relativistic give ½ point)* A supermassive black hole at the center of the galaxy causes the jets to form. *(1 point)*
3. Images M, J, N, D, and H are of H II regions. *(2 points for all, 1 point for 3 or 4, ½ point for 2, otherwise give no points)* An H II region is a region of ionized hydrogen. *(1 point)* H II regions are commonly found in nebulae. *(1 point)*
4. The Trapezium is depicted in Image J. *(1 point)* It is a part of M 42/NGC 1976/Orion Nebula. *(1 point)* Image N shows the same DSO. *(1 point)*
5. The Lobster Nebula/NGC 6357 and the Cat's Paw Nebula/NGC 6334, respectively. *(1 point, ½ point if they are switched)* The blue circles around the stars are optical illusions that occur due to the reflections going on inside a telescope. *(2 points)* The DSO on the left (the Lobster Nebula) is often associated with open clusters. *(1 point)*
6. Because Image E is the farthest galaxy we know of, it has to be the oldest we know of because it takes light time to travel. Because it takes light time to travel, we are seeing this galaxy in the past, because it is the farthest, we are seeing it at an earlier point of time than any other galaxy. Therefore, it is the oldest galaxy because we know it existed before any other known galaxy. *(2 points, explanations do not have to be this in depth, just enough to show that they have a clear understanding of this topic)* Additionally, because it is the oldest galaxy that we know and because the universe is expanding, one can conclude that it is the fasting moving galaxy. This is because it has been accelerating for a longer period of time than any other galaxy. Hence, it is the most redshifted because it is moving away from us the fastest. *(2 points, explanations do not have to be this in depth, just enough to show that they have a clear understanding of this topic)* Its distance is possible because the universe is expanding. *(2 points)* Image E is GN-z11. *(1 point)*
7. Images Q and F are stars. *(1 point)* The arc is a bow shock, it forms when a star at high speeds goes through an area with a lot of dust. *(1 point)* The image of Zeta Ophiuchi is in the infrared. *(1 point)* A T Tauri star would be found on the Hayashi Track. *(1 point)* T Tauri stars get their energy through gravity when they contract. *(1 point)* One can identify a T Tauri star by its spectra because a T Tauri star will either have lithium spectral lines or very evident hydrogen lines. *(1 point, they do not have to say lithium and hydrogen only one of the two)* Spectral identification works for T Tauri stars because the temperature at their cores are too low to burn lithium or fuse hydrogen. *(1 point, they do not have to say lithium and hydrogen only one of the two)*

8. NGC 4038/NGC 4039 or the Antennae Galaxies are found in Image C. *(1 point)* The two galaxies are colliding. *(1 point)* The dark matter in these galaxies is moving differently compared to the baryonic (regular) matter. *(2 points)* This tells us that dark matter exists and can interact with itself. *(2 points)*
9. Image T is the Baby Boom Galaxy. *(1 point)* Image T is in Image S. *(1 point)* Image T is a starburst galaxy based on star formation. *(1 point)* This galaxy can not be studied in optical light because there is a lot of dust obstructing our view of it. It can be studied in infrared light because infrared light can penetrate this dust. *(2 points, must write about optical and infrared to receive both points)*
10. Sagittarius A/Sag A is depicted in Image V. *(1 point)* The arrow in Image V is pointing to Sagittarius A*/Sag A*. *(1 point)* Image V is in Image U. *(1 point)* The 3 parts to this object are Sagittarius A*/Sag A*: the supermassive blackhole at the center of the Milky Way Galaxy, Sagittarius A East: a supernova remnant, and Sagittarius A West: a spiral structure. *(2 points, 1 point if there are no explanations/only 2 are named and explained/no names, otherwise give no points)* This object is significant because it is the radio wave producing center of the Milky Way Galaxy. *(1 point)*
11. 1 points to Sagittarius. *(1 point)* Image U on Image Sheet 1 is of the same constellation. *(1 point)* Images V and H are of DSOs in 1. *(1 point)* Image V is of Sag A*; Image H is of the Lagoon Nebula/M8. *(1 point)*
12. 2 points to Crux. *(1 point)* Image I on Image Sheet 1 is of the same constellation. *(1 point)* Image D is of the DSO in 2. *(1 point)* Image D is of the Dragonfish Nebula.
13. 3 points to Tucana. *(1 point)* The Small Magellanic Cloud/SMC is in this constellation. *(1 point)* Image R depicts this DSO. *(1 point)*
14. 4 points to Andromeda. *(1 point)* Image A is of a DSO in 4. *(1 point)* The image was taken in the infrared. *(1 point)* As a result of the collision this galaxy will turn into an elliptical galaxy. *(1 point)*
15. 5 points to Cygnus. *(1 point)* c points to Deneb. *(1 point)* This star would be a part of the Supergiants part of the HR Diagram. *(1 point)* The name of the asterism is the Summer Triangle. *(1 point)* The other 2 stars in the asterism are Altair and Vega. *(1 point)*
16. 6 points to Dorado. *(1 point)* The Large Magellanic Cloud is a Magellanic spiral galaxy. *(1 point, give ½ for just spiral galaxy)* The Large Magellanic Cloud's structure got warped through tidal interactions from other galaxies. *(2 points)*
17. 7 points to Aquila. *(1 point)* b points to Altair. *(1 point)* This star is not spherical because it spins so fast that it bulges at its equator. *(1 point)* This star will supernova and turn into a neutron star when it dies. *(1 point)*
18. 8 points to Scorpius. *(1 point)* a points to Antares. *(1 point)* This star's Yerkes luminosity class is 1ab/1b. *(1 point, accept either or both)* This star will produce a type 2 supernova. *(1 point)*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Facing North
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Lacerta
Cygnus
M31
Andromeda
Albireo
Vulpecula
M27
Pegasus
Sagitta
M15
Delphinus
Equuleus
Aries
Pisces
Altair
Moon
Mars
Aquila
Aquarius
M11
Mira
Cetus
Capricornus
Scutum
Saturn
Jupiter
Fomalhaut
Microscopium
Serpens
Ophiuchus
Sculptor
Sagittarius
M22
M20
Grus
Eridanus
Fornax
Phoenix
Corona Australis
Telescopium
Indus
Scorpius
Pavo
Horologium
47 Tuc
SMC
Ara
Hydrus
Octans
Reticulum
Caelum
Norma
Triangulum Australe
Lupus
Mensa
Dorado
Pictor
30 Dor
Circinus
Rigil Kentaurus
Columba
Chamaeleon
Musca
Canopus
Volans
NGC 4755
NGC 2516
IC 2602
Gacrux
Omega Cen
Carina
Eta Car

Part 3: Calculations

Explanations here are written for clarity and reference. Student answers do not need these precise explanations, and “work” is essentially jotting down equations for calculation purposes. Correct answers are underlined.

1.

According to the Stefan-Boltzmann relation, $L \sim r^2 * T^4$. The base case can assume each of these values as 1. $L = 1^2 * 1^4$. Increasing the radius and temperature by scale factors of 3 and 10 respectively gives $L = 3^2 * 10^4$. Evaluating L gives our answer, a scale factor of <u>90000</u>. *(4 points, + 2 points for showing work)*

2.

We first let x denote the ratio of luminosity between Star B and Star A. The formula to convert the difference of bolometric magnitude of two stars into their ratio of luminosity is: $M_1 - M_2 = -2.512\log(L_1/L_2)$. We substitute L_1/L_2 for x, giving: $M_1 - M_2 = -2.512\log(x)$. We plug the magnitudes of the two stars into the equation, giving -0.43 - 1.45 = -2.512log(x). Solving for x, we obtain the value of ~5.6. Therefore, Star B is approximately <u>5.6 times more luminous</u> than Star A. *(6 points, + 4 points for showing work)*

3.

We first solve for Star C’s distance from Earth using its parallax of 475 milliarcseconds. The formula to convert distance to parallax is d = 1/p, where p is parallax in arcseconds and d is distance in parsecs. We keep the variable d and plug 475 milliarcseconds (0.475 arcseconds) into this equation to obtain d = 1/0.475, so d = ~2.105 parsecs.

Next, we solve for Star C’s absolute bolometric magnitude using its luminosity and the zero-point luminosity. We define x to be Star C’s absolute magnitude. Plugging x, the zero-point luminosity, and Star C’s luminosity of $4 * 10^{28}$ Watts into the equation $M_1 - M_2 = -2.512\log(L_1/L_2)$ gives us $x - 0 = -2.512\log(4 * 10^{28}/3.0128 * 10^{28})$. Solving for x gives the value of approximately -0.31, so Star C’s absolute magnitude is -0.31.

Now, we use the distance modulus equation of m - M = 5log(d) - 5 to solve for Star C’s apparent magnitude. Isolating m, the apparent magnitude, gives m = 5log(d) - 5 + M. Substituting both our obtained distance and our obtained absolute magnitude into this equation gives m = 5log(2.105) - 5.31. Solving for m gives our final answer of <u>-3.69</u>. *(6 points, + 4 points for showing work)*

4.

We can compare the luminosities of these two stars by figuring out their respective temperatures.

First, we find the surface temperature of Star M using its peak wavelength. Wien’s Law states that $t = b/\lambda max$, where t is surface temperature, b is 2898, and λmax is the peak wavelength of the star in microns. Plugging in Star M’s peak wavelength (0.145 microns) into this equation gives t = 2898/0.145, so t = 19986.2˚K.

Vega’s surface temperature is 9602˚K. The Stefan-Boltzmann Law states that a star’s luminosity is directly proportional to the fourth power of its temperature. The full equation is as follows: $L = 4\pi r^2 * \sigma * T^4$. σ is Boltzmann’s Constant, T is surface temperature, r is stellar radius, and L is luminosity.
We are looking for the ratio of luminosity between Star M and Vega, L_1/L_2. Using Star M’s temperature, $L_1 = 4\pi r^2 * \sigma * 19986.2^4$. Using Vega’s temperature, $L_2 = 4\pi r^2 * \sigma * 9602^4$. Dividing the first equation by the second equation gives: $L_1/L_2 = 19986.2^4/9602^4$, so L_1/L_2 = ~18.77. Star M is therefore approximately <u>18.77 times more luminous</u> than Vega. *(6 points, + 4 points for showing work)*

5.

To solve this problem, we recognize that all Type Ia supernovae have similar absolute magnitudes. They are known as standard candles (this is general knowledge).

The distance modulus equation for KSN 2011b is: $m_1 + 19.5 = 5\log(3 * 10^8) - 5$.
The distance modulus equation for the hypothetical supernova is: $m_2 + 19.5 = 5\log(1.3 * 10^8) - 5$.

We can disregard the first equation. We need to solve for m_2. The equation isolating m_2 is: $m_2 = 5\log(1.3 * 10^8) + 14.5$. Evaluating this gives m_2 as <u>+55.07</u>. *(6 points, + 4 points for showing work)*