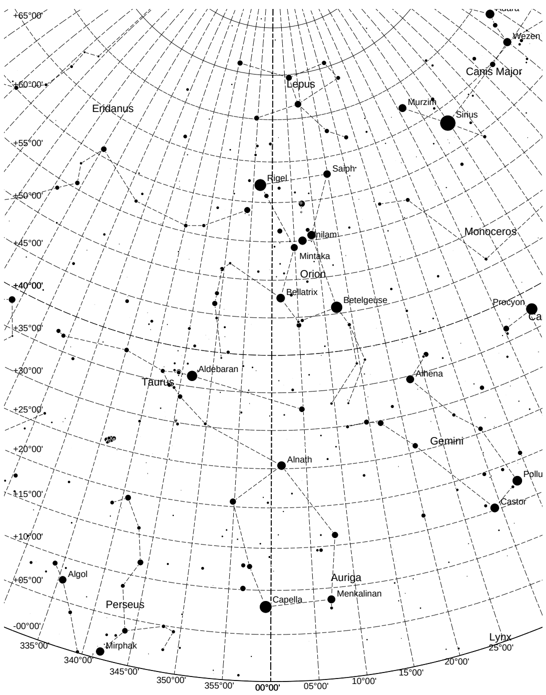
Name: ______________________________

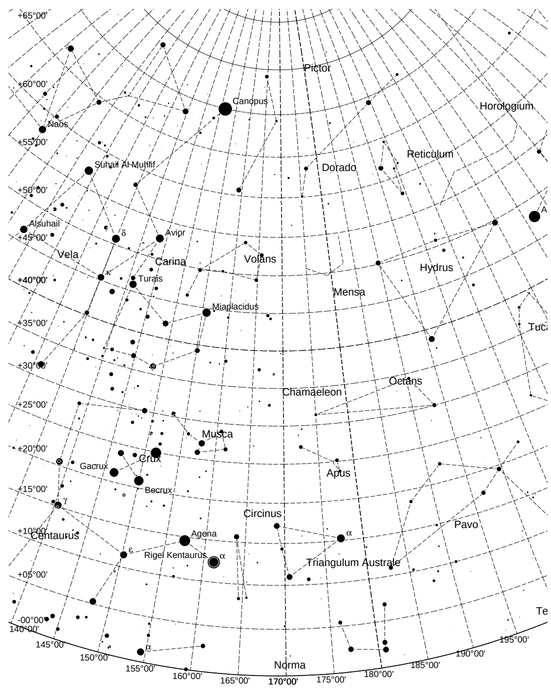
> Please answer the following questions to the best of your ability. In the case of multiple choice questions, please circle your answer clearly. **Show all your work or explain your thinking, even on multiple choice problems, for a chance at partial credit!** Good luck!

(1) 1. Given the two views below, what is the latitude of your observing location?

Looking North



Looking South



A. 25 °S

B. 25 °N

C. 35 °S

D. 62 °N

(1) 2. Which of the following models best explains why our galaxy has spiral arms?

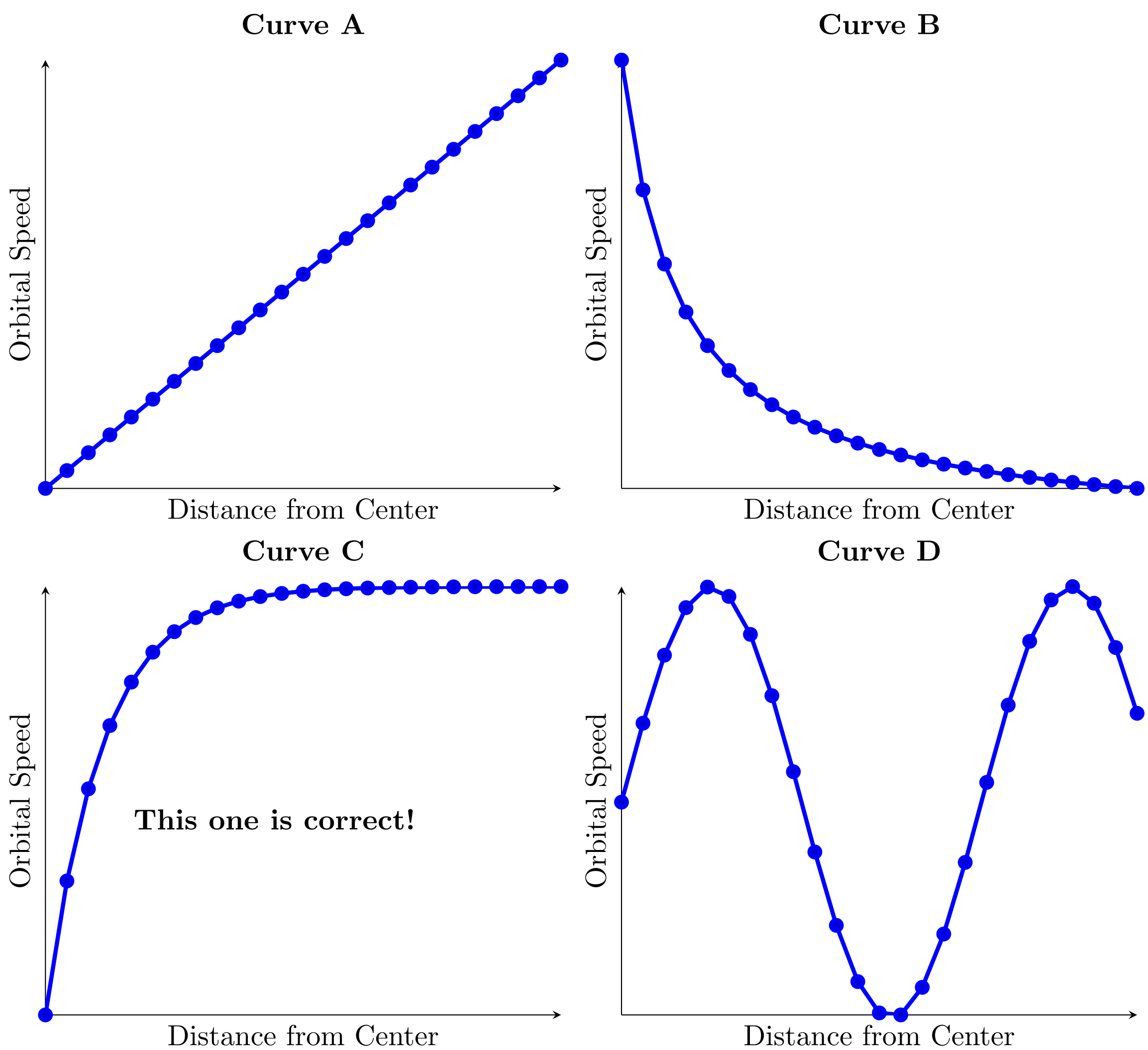
A. The spiral arms were imprinted on the galaxy at its birth. Ever since, like a coiling rope, the spiral arms have been wound tighter with each galactic rotation.

B. The spiral arms are composed of groups of stars that are bound together by gravity and therefore always stay together as the galaxy rotates.

C. The spiral arms are a wave of star formation caused by wave of density propagating outward through the disk of the galaxy.

D. No model can explain the existence of the arms, which rotate with the galaxy like the fins of a giant pinwheel toy.

(1) 3. Which of the below rotation curves best depicts that of the Milky Way, and thus serves as the primary motivation for the existence of dark matter?

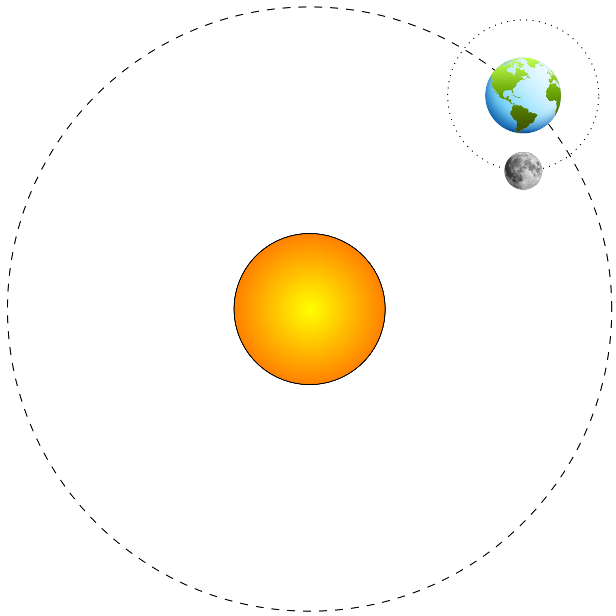


(2) 4. Summarize each of Kepler's 3 Laws. You'll only be scored on two.

Solution:

- Planets move in ellipses with the Sun at a foci
- Planets move faster near the Sun and slower further way
- $p^2 \propto a^3$

(2) 5. The image below shows the relative positions of the Earth, Moon and Sun at a particular time of year. Keeping in mind that the Moon orbits counter-clockwise in this view, describe as much as you can about the phase of the Moon as viewed from Earth. (eg. Is it waxing? Waning? Quarter phase? Full? Crescent? Gibbous? When could you see it in the sky?)



Solution: Would be a waxing crescent moon, up in the late afternoon to early evening

(1) 6. In the picture above, if the moon continued onwards and the orbital planes were oriented correctly, which would occur first:

A. A solar eclipse

B. A lunar eclipse

C. An Iridium Flare

D. A Blue Moon

(1) 7. Suppose I drew a circle that was 1 meter in diameter on the board in the front of the room. The back of the classroom is 9 meters away. What angular size would they observe the circle to have?

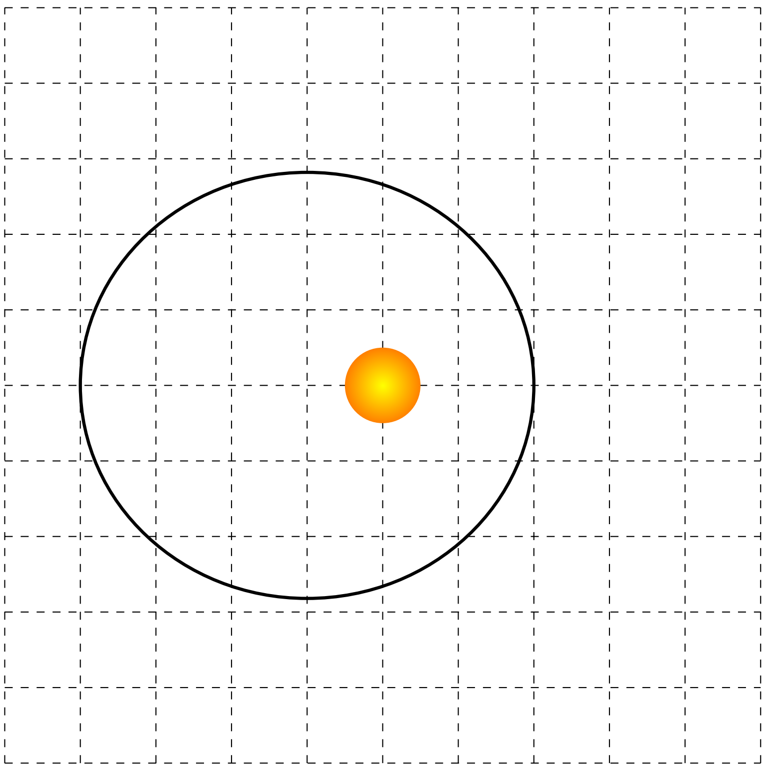
A. $0.1°$

B. $6°$

C. $9°$

D. $40°$

(4) 8. In the diagram below has gridlines 1 AU in size and depicts the location of the Sun. If a planet is 2 AU from the Sun at its closest approach and 4 AU from the Sun at its most distant, sketch in a possible orbit for the planet. Show your work for full points!



(1) 9. The Cosmic Microwave Background shows us an image from what era of the Big Bang?

A. Inflation

B. Recombination

C. When stars and galaxies first began to form

D. When protons and neutrons first formed from quarks

(1) 10. Visible, luminous matter (such as stars within galaxies) amounts to what percentage of the total mass density of the universe?

A. less than 2%

B. 6%

C. 30%

D. 70%

(3) 11. Name three distinct properties of a light *source* that you can determine from analyzing the light it gives off.

Solution: Temperature, Composition, Radial Velocity

(3) 12. Dr. Alpha makes a measurement of a distance galaxy and finds that a strong hydrogen line is located at 695.9 nm, but here on Earth the hydrogen line is usually located at 680 nm. Taking the Hubble Constant to be 72 km/s/Mpc, how far away is the galaxy in Mpc?

Solution: Hubble's law tells us that

$$v = Hd$$

So we need to know v to find d. We can get it from the doppler shift:

$$\frac{\lambda_{moving} - \lambda_{rest}}{\lambda_{rest}} = \frac{v}{c}$$

$$\frac{695.9 - 680}{680}(3 \times 10^8) = 7.0147 \times 10^6 \text{ m/s}$$

Dividing that by the Hubble constant gives the distance. Realize that the Hubble constant is in units of km/s, so the velocity needs to be in that same unit!

$$d = \frac{v}{H} = \frac{7.0147 \times 10^3}{72} = 97.4 \text{ Mpc}$$

(1) 13. Why do elliptical galaxies appear yellow or red?

A. They have very little dust or cold gas, and thus have little ongoing star formation

B. They contain few or zero hot, young blue stars

C. They contain only massive stars that have progressed to the red-giant stage

D. A and B

E. A and C

(1) 14. An accreting white dwarf will explode into a Type I supernova if it accretes enough mass to reach a particular limit. Who was this limit named after?

A. Abraham Lincoln

B. Wolfgang Pauli

C. Karl Schwarzschild

D. Subrahmanyan Chandrasekhar

(1) 15. Dark matter can best be described as:

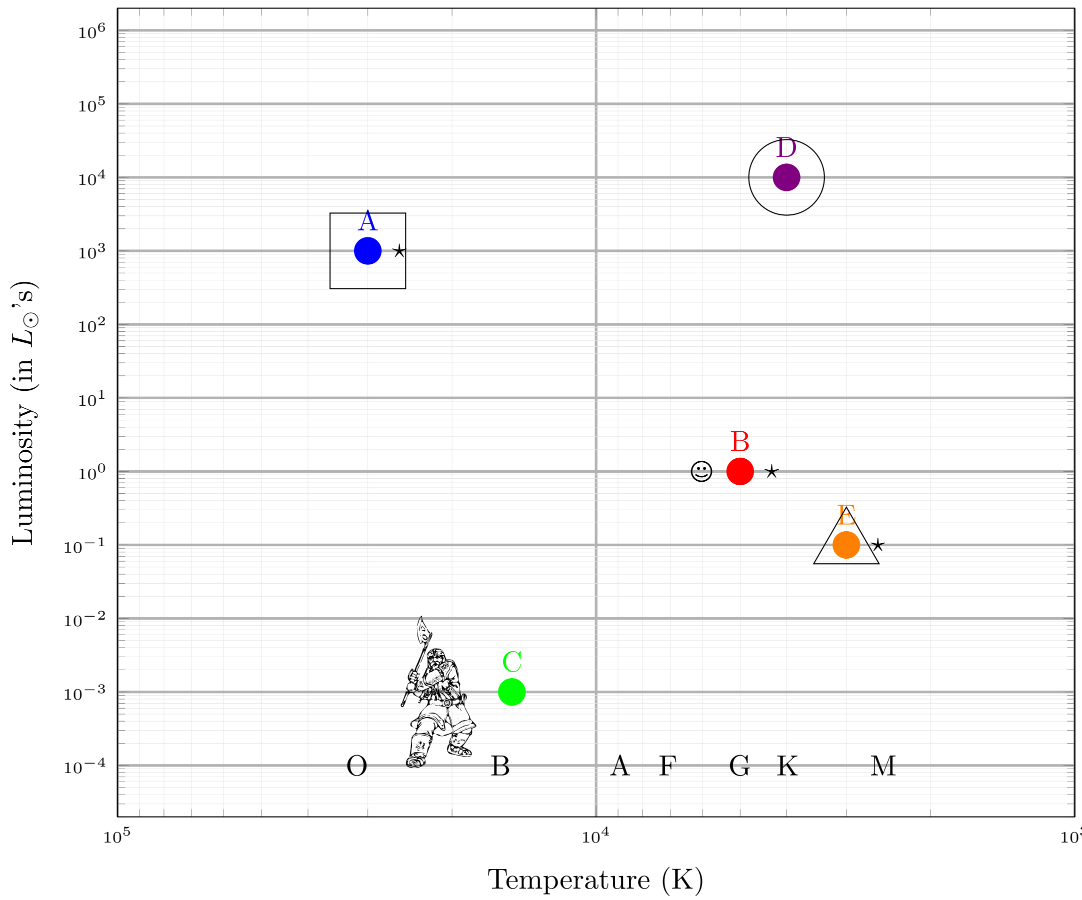
A. material responsible for the period of inflation happening soon after the Big Bang

B. material responsible for the increasing rate of expansion of the universe

C. material responsible for explaining the rotation curves we see in large scale structures like galaxies

D. material which does not give off light but has significant mass, such as black holes

16. Use the below Hertzsprung-Russell Diagram to answer the following questions.



(1) (a) Put a star next to all the main sequence stars.

(1) (b) Circle the largest star.

(1) (c) Draw a triangle around the coldest star.

(1) (d) Draw a square around the main sequence star with the shortest lifetime.

(1) (e) Draw a smiley face next to the star that most closely approximates our Sun.

(1) (f) Draw a dwarf near any stars that are white dwarfs.

(1) 17. Suppose the cosmic microwave background had been discovered instead at a much longer wavelength, say large radio waves. This could have implied any of the following *except*:

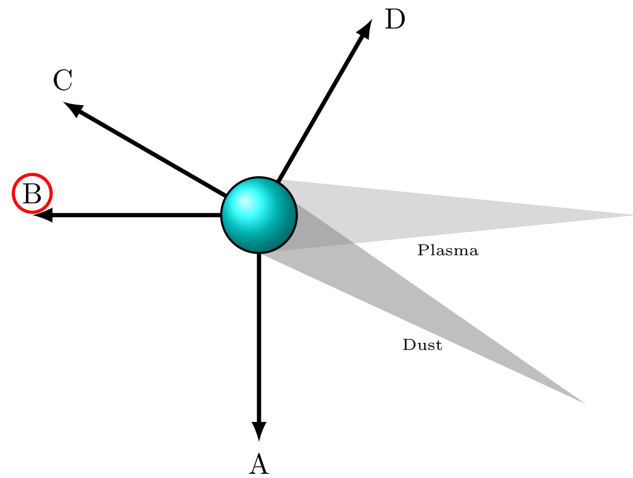
A. The universe is smoother than we thought

B. Our universe is older than we thought

C. Recombination happened earlier in the universe's timeline than we thought

D. The early universe was not as hot as we thought

(1) 18. The comet below has grown tails as it nears the Sun. Based on the position of the tails, which arrow indicates the direction towards the Sun?



(1) 19. Why are Cepheid variables important?

A. Cepheid variables are supermassive stars that are on the verge of becoming supernova. Therefore they allow us to choose candidates to watch if we hope to observe a supernova.

B. Cepheid variables are stars that vary in brightness because they harbor a black hole. Therefore, they provide direct evidence for black holes.

C. Cepheid variables are a type of irregular galaxy, much more common in the early universe. Therefore they help us understand how galaxies are formed.

D. Cepheid variables are pulsating stars whose pulsation periods are directly related to their true luminosities. Therefore they can be used as distance indicators.

(1) 20. Suppose that the initial density of the universe was measured to have a value of $\Omega = 1.78$. This would imply that the universe is:

A. Curved with positive curvature (like a sphere)

B. Flat

C. Curved with negative curvature (like a saddle)

D. Supported on the back of an immense, cosmic turtle

(1) 21. The spectra below could have come from what type of light source?

A. A pure excited (hot) gas

B. The Sun

C. A star shining behind a cloud of colder gas

D. An incandescent light bulb

(1) 22. Planetary orbits in our Solar System are generally:

A. Mostly circular but in all directions

B. Spinning in alternating directions

C. Highly elliptical and in the same plane

D. Mostly circular and in the same plane

(1) 23. What causes the high winds of Jupiter?

A. The short length of Jupiter's day

B. The many gravitational pulls from asteroids in the asteroid belt

C. The Great Red Spot propagates storms outwards

D. The distance of Jupiter from the Sun

(1) 24. Transit measurements of a planet passing in front of a star can give you all of the following information about the exoplanet orbiting that star except for what?

A. The distance of the planet from the star

B. The size of the planet

C. The period of the planet's orbit

D. The mass of the planet

(1) 25. What happens when a star like the Sun exhausts its core hydrogen supply?

A. Its core expands, but its outer layers contract and the star becomes smaller and brighter

B. It contracts, becoming hotter and brighter

C. Its core contracts, but its outer layers expand and the star becomes bigger and brighter

D. It expands, becoming bigger but dimmer

(1) 26. How does the Sun primarily produce energy?

A. Nuclear fusion through a proton-proton chain

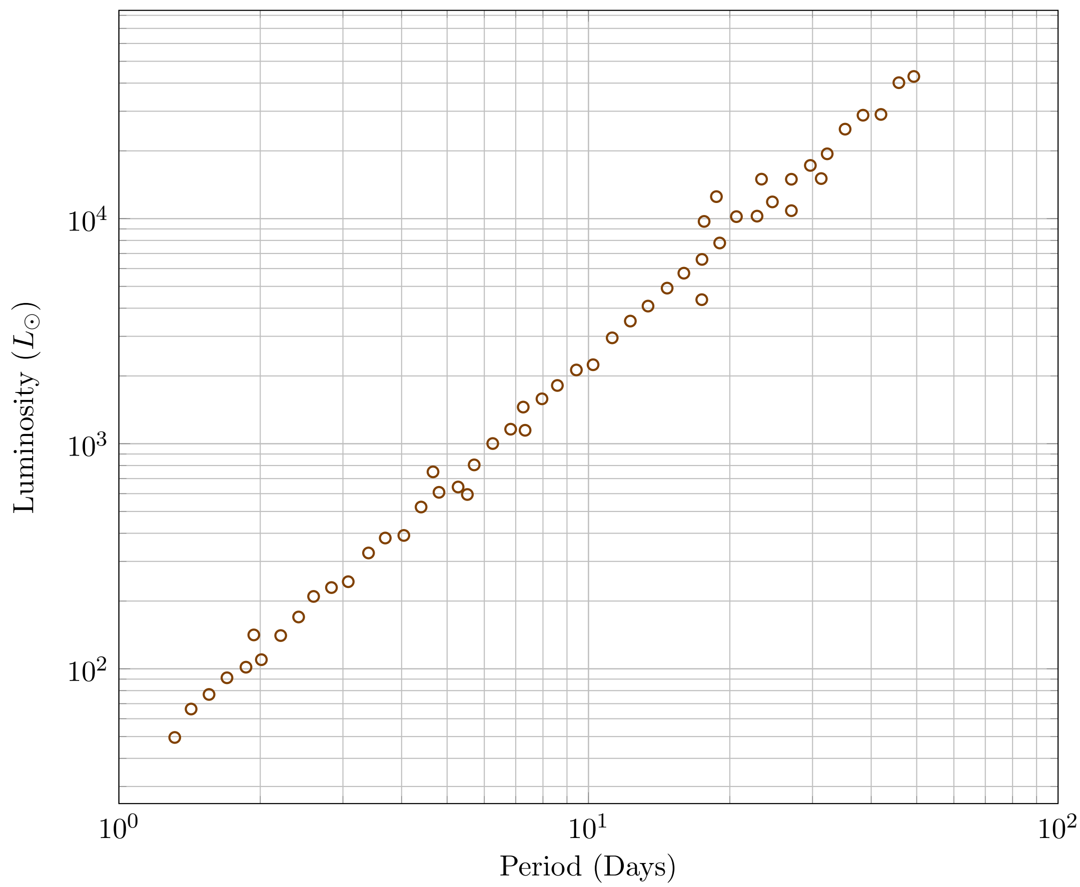
B. Nuclear fission

C. The burning of highly flammable hydrogen

D. Nuclear fusion through the CNO cycle

27. A Cepheid variable is measured with a period of 40 days. The star has a measured brightness of 3.5×10^{-17} W/m.

Relationship between Period and Luminosity for Type 1 Cepheid Variables



(3) (a) Using the above plot to help, what is the distance to the star in meters?

Solution: Based on the plot, a variable with a period of 40 days should have a luminosity of $3 \times 10^4 L_\odot$, or 1.2×10^{31} W. Then we know:

$$
\begin{aligned}
L &= 4\pi d^2 B \\
\Rightarrow d^2 &= \frac{L}{4\pi B} \\
\Rightarrow d &= \sqrt{\frac{L}{4\pi B}} \\
&= \sqrt{\frac{1.2 \times 10^{31}}{4\pi \cdot 3.5 \times 10^{-17}}} \\
&= 1.652 \times 10^{23}\text{ m}
\end{aligned}
$$

(3 (bonus)) (b) Convert your above answer to megaparsecs.

Solution: We are going to need to know the number of meters in a light-year. To do so, we'll take the speed of light and multiply it by the number of seconds in a year:

$$(3 \times 10^8\,\mathrm{m/s}) \times \frac{60\,\mathrm{s}}{1\,\mathrm{min}} \times \frac{60\,\mathrm{min}}{1\,\mathrm{h}} \times \frac{24\,\mathrm{h}}{1\,\mathrm{d}} \times \frac{365.25\,\mathrm{d}}{1\,\mathrm{year}} = 9.467 \times 10^{15}\,\mathrm{m}$$

Then we can convert our meters to the desired Mpc:

$$(1.652 \times 10^{23}\,\mathrm{m}) \times \frac{1\,\mathrm{lyr}}{9.467 \times 10^{15}\,\mathrm{m}} \times \frac{1\,\mathrm{pc}}{3.26\,\mathrm{lyr}} \times \frac{1\,\mathrm{Mpc}}{10^6\mathrm{pc}} = 5.352\,\mathrm{Mpc}$$

28. Polaris has an apparent magnitude of 1.99 whereas Rigel has an apparent magnitude of 0.12.

(1) (a) Which star appears brighter?

A. Rigel

B. Polaris

C. They are equally bright

D. It depends on their distances

(2) (b) What is the ratio between their apparent brightnesses? (Eg. what is $\frac{B_{Polaris}}{B_{Rigel}}$?)

Solution:

$$\frac{B_{Pol}}{B_{Rig}} = 10^{0.4(m_{Rig} - m_{Pol}} = 10^{0.4(0.12-1.99)} = 0.1786$$

(1) (c) Which star has a greater luminosity?

A. Polaris

B. Rigel

C. It depends on their distance away

D. They are equally bright

(3) 29. List 3 major methods by which we can determine the distances to stars or galaxies.

Parallax **Cepheids** **Hubbles Law**

(1) 30. What halts the collapse of a star's core during a supernova and keeps it from becoming a black hole (so that it ends up a neutron star)?

A. Gas pressure

B. Electron degeneracy

C. Neutron degeneracy

D. A supportive neighbor star

(1) 31. Which of the following are NOT observed to lie in the disk of the Milky Way?

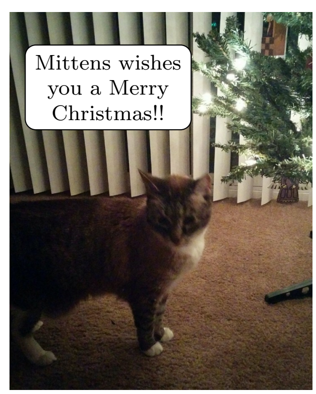
A. Open clusters

B. Old K and M stars

C. Globular clusters

D. Gas and dust

(1 (bonus)) 32. Draw me a picture of your favorite topic from this semester!



Thank you all for the great semester! I hope you found it enjoyable as well as educational, and I hope you'll stop by my office to say hi or wave when I see you about campus! Have a terrific winter break and enjoy the holiday season!! And remember to look up at the sky every once in a while!!

The Equation Page

Constants

$G = 6.67 \times 10^{-11}\,\mathrm{Nm^2/kg^2}$
$\sigma = 5.67 \times 10^{-8}\,\mathrm{W/m^2/K^4}$
$c = 3 \times 10^{8}\,\mathrm{m/s}$
$H = 72\,\mathrm{km/(s\,Mpc)}$

$\odot =$ Pertaining to Sun
$M_\odot = 1.99 \times 10^{30}\,\mathrm{kg}$
$\mathcal{L}_\odot = 4 \times 10^{26}\,\mathrm{W}$
$R_\odot = 695{,}700\,\mathrm{km}$

$1\,\mathrm{pc} = 3.26\,\mathrm{lyrs}$
$\oplus =$ Pertaining to Earth
$M_\oplus = 5.97 \times 10^{24}\,\mathrm{kg}$
$R_\oplus = 6.37 \times 10^{6}\,\mathrm{m}$

Math Equations

$$A_c = \pi r^2$$
$$A_e = \pi ab$$
$$C = 2\pi r$$
$$f = \sqrt{a^2 - b^2}$$
$$\varepsilon = \sqrt{1 - \frac{b^2}{a^2}}$$

Math Descriptions

$A_c =$ area of circle
$A_e =$ area of ellipse
$a =$ semi-major axis
$b =$ semi-minor axis
$r =$ radius of circle
$C =$ circumference of circle
$f =$ foci of ellipse
$\varepsilon =$ eccentricity of ellipse

Physics Equations

$$\lambda_{peak}(\mathrm{nm}) = \frac{2900000}{T}$$
$$\frac{a_r^3(\mathrm{AU})}{p^2(\mathrm{yrs})} = (M_1 + M_2)_\odot$$
$$F = Ma$$
$$F_g = G\frac{M_1 M_2}{a_r^2}$$
$$L = Mvr$$
$$\frac{v}{c} = \frac{\lambda_{obs} - \lambda_{rest}}{\lambda_{rest}}$$
$$\frac{\theta}{360} = \frac{r}{2\pi d}$$
$$\lambda f = c$$
$$f_{lost} = \frac{r_p^2}{r_s^2}$$
$$v = \frac{C}{p}$$
$$d(\mathrm{pc}) = \frac{1}{\phi('')}$$
$$\mathcal{L} = 4\pi r^2 \sigma T^4$$
$$\mathcal{L} = 4\pi d^2 B$$
$$m = -2.5 \log\left(\frac{B}{B_{Vega}}\right)$$
$$\frac{B_1}{B_2} = 10^{0.4(m_2 - m_1)}$$
$$R_s = \frac{2GM}{c^2}$$
$$E = Mc^2$$
$$v = Hd$$

Physics Descriptions

$T =$ temperature
$\lambda =$ wavelength
$p =$ period
$a_r =$ avg distance between or semi-major axis
$F =$ force
$M =$ mass
$a =$ acceleration
$v =$ velocity
$L =$ angular momentum
$r =$ radius
$\theta =$ angular radius
$d =$ distance to object
$f =$ frequency
$f_{lost} =$ fraction light lost
$r_{p/s} =$ radius of planet/sun
$\phi =$ parallax angle
$\mathcal{L} =$ luminosity
$C =$ circumference
$m =$ magnitude
$B =$ brightness
$R_s =$ Schwarzchild Radius
$E =$ Energy

SI Prefixes

pico	nano	micro	milli	centi	Base	kilo	mega	giga	tera	peta
10^{-12}	10^{-9}	10^{-6}	10^{-3}	10^{-2}	1	10^{3}	10^{6}	10^{9}	10^{12}	10^{15}