The following should give you a bit of a sampling of the types of test questions I may ask and serve as a review for the topics we've discussed so far this semester. On the test I will supply you with any tables of data, equations, or constants that you could need to complete the questions. For the sake of this review, I'm assuming you can use your book to look these types of things up.

1. What kind of objects lie in the halo of our galaxy?
   A. Open clusters
   B. O and B stars
   C. Globular clusters
   D. Gas and dust
   E. All of the above

2. What kind of objects lie in the disk of our galaxy?
   A. Open clusters
   B. O and B stars
   C. Old K and M stars
   D. Gas and dust
   E. All of the above

3. How can we see through the interstellar medium (dust)?
   A. By observing at wavelengths (like X-ray) that are not absorbed by interstellar dust
   B. By observing only the brightest stars in the sky
   C. By observing with only the biggest telescope
   D. By observing with telescopes above the Earth's atmosphere, such as the Hubble Space Telescope
   E. We can not see through the interstellar medium

4. Compare the motions and orbits of stars in the disk to stars in the halo.

   Solution: Stars in the disk follow mostly circular orbits in the same direction as they orbit in the plane of the disk. Halo stars orbit in elliptical paths in all directions about the center of the Milky Way.

5. Why do we believe that most of the mass of the Milky Way is in the form of dark matter?
   A. The orbital speeds of stars far from the galactic center are surprisingly high, suggesting that these stars are feeling gravitational effects from unseen matter in the halo.
   B. Although dark matter emits no visible light, it can be seen with radio wavelengths, and such observations confirm that the halo is full of this material.
   C. Theoretical models of galaxy formation suggest that a galaxy cannot form unless it has at least 10 times as much matter as we see in the Milky Way disk, suggesting that the halo is full of dark matter
   D. Our view of distant galaxies is sometimes obscured by dark blotches in the sky, and we believe these blotches are dark matter located in the halo.

6. What produces the 21-cm radio line that we can use to map the Milky Way?
   A. Atomic hydrogen
   B. Ionized hydrogen
   C. Molecular hydrogen
   D. Carbon Monoxide
   E. Helium

7. Where does most star formation in the Milky Way occur?
   A. In the halo
   B. In the bulge
   C. In the spiral arms
   D. In the galactic center
   E. Uniformly throughout the galaxy

8. The galactic center lies in the direction of what constellation?
   A. Orion
   B. The Big Dipper
   C. Sagittarius
   D. Taurus

9. Compared to our Sun, most stars in the halo are:
   A. young, red, dim, and have fewer heavy elements.
   B. young, blue, bright and have many more heavy elements.
   C. old, red, dim and have fewer heavy elements.
   D. old, red, dim and have many more heavy elements.
   E. old, red, bright and have fewer heavy elements.

10. True or False? The Sun is located near the very edge of our galaxy, approximately 100,000 light-years from the galactic center.

    Solution: False! Only about 2/3 to 3/4 of the way out. Not in the middle, but not on the edge either.

11. Explain why stars that formed early in the history of the galaxy contain a smaller proportion of heavy elements than stars that formed more recently.

    Solution: Each time a star goes through its lifetime, it releases heavier elements back into the galaxy as it lives and dies. These elements cool and then are included as part of future stars. So each generation of stars is slowly increasing the amount of heavier elements in the new stars throughout the galaxy.

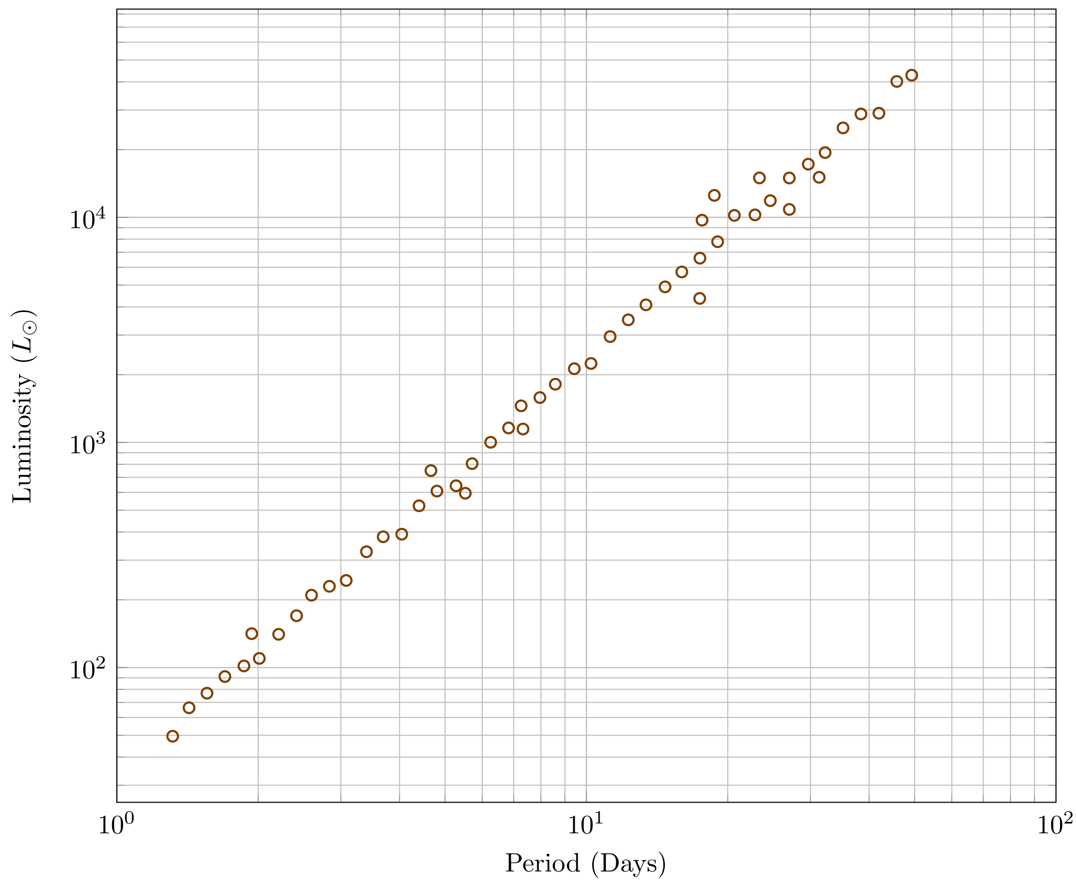
12. Explain why spiral arms tend to have a blue color.

Solution: Spiral arms are where new stars are formed. Blue stars tend to be very bright but very short lived, and thus show up mainly in the area where they are formed. Thus the light from the spiral arms is dominated by blue stars. And we don't see than same blue light elsewhere because the blue stars die out too fast.

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 only massive stars that have progressed to the red-giant stage
    - C. They contain no hot, young blue stars
    - D. A and B
    - **E. A and C**

14. Why are Cepheid variables important?
    - A. Cepheid variables are stars that vary in brightness because they harbor a black hole. Therefore, they provide direct evidence for black holes.
    - **B. Cepheid variables are pulsating stars whose pulsation periods are directly related to their true luminosities. Therefore they can be used as distance indicators.**
    - 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 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.

15. A Cepheid variable is measured with a period of 4 days. The star has an apparent magnitude of 3. The apparent brightness of Vega is $2.276 \times 10^{-8}\ \mathrm{W/m^2}$. Use the below plot and your distance and magnitude equations to determine the distance to the star. (*This is decidedly a lot more involved than anything that will appear on the final. PARTS of this problem could appear individually though.*)



Solution: From the plot, we can read off that a star with a period of 4 days has a luminosity of 4×10^2 times the luminosity of the Sun. (Recall that $10^0 = 1$ if you are trying to find where 4 days is.) We can then use our inverse brightness equation to determine how the brightness of our star compares to the brightness of Vega:

$$\frac{B}{B_{vega}} = 10^{0.4(m_{vega}-m)} = 10^{0.4(0-3)} = 0.063$$

Thus, if I just want to find the brightness of our star:

$$B = 0.063 B_{vega} = 0.063 \times \left(2.276 \times 10^{-8}\ \mathrm{W/m^2}\right) = 1.436 \times 10^{-9}\ \mathrm{W/m^2}$$

Now we can apply our known luminosity and brightness equation:

$$B = \frac{L}{4\pi d^2}$$

Rearranging, we get:

$$\begin{aligned}
d^2 &= \frac{L}{4\pi B} \\
&= \frac{(4 \times 10^2)(4 \times 10^{26}\,\mathrm{W})}{4\pi(1.436 \times 10^{-9}\,\mathrm{W/m^2})} \\
&= 8.866 \times 10^{36}\,\mathrm{m}^2 \\
\Rightarrow d &= 2.9776 \times 10^{18}\,\mathrm{m} \\
&\approx 314.7\,\mathrm{lyrs}
\end{aligned}$$

16. What two quantities did Edwin Hubble compare for a sample of galaxies to discover the expansion of the universe?
    A. Velocity and distance
    B. Luminosity and distance
    C. Velocity and temperature
    D. Luminosity and temperature
    E. Age and distance

17. What makes white-dwarf supernova (Type I) very good standard candles for distance measurements?
    A. They are very bright, so they can be sued to determine the distances to galaxies billions of light years away.
    B. They should all have approximately the same luminosity.
    C. They occur so frequently that we can sue them to measure the distances to virtually all galaxies.
    D. We have had several occur close to us in the Milky Way, so we have been able to determine their luminosities very accurately.
    E. Both A and B

18. Dr. X believes that the Hubble constant is $H = 50\,\mathrm{km/s/Mpc}$ whereas Dr. Y believes that the Hubble constant is $H = 70\,\mathrm{km/s/Mpc}$. Which state below automatically follows?
    A. Dr. X believes that the universe in expanding, but Dr. Y does not.
    B. Dr. X believes that the Andromeda Galaxy (a member of our Local Group) is moving away from us at a slower speed than Dr. Y believes.
    C. Dr. X believes that the universe is older than Dr. Y believes.
    D. Dr. X believes that the universe will someday stop expanding, while Dr. Y believes it will expand forever.
    E. Dr. X believes that the universe has a much higher density than Dr. Y believes.

19. A distance galaxy is observed to be moving away from us at $2000\,\mathrm{km/s}$. How far away is it from us, assuming the modern accepted value of the Hubble constant?

    Solution: About $27.7\,\mathrm{Mpc}$ from us.

20. Why are galaxy-galaxy interactions more common than star-star interactions?

    Solution: Compared to their size, galaxies are much closer to one another than stars are. Thus they are much more likely to collide and interact.

21. Evidence that the cosmic background radiation is the remnant of a Big Bang comes from predicting characterstics of the remnant radiation from the Big Bang and then comparing these predictions with observations. Four of the five statements below are real. Which one is ficticious?
    A. The cosmic background radiation is expected to have a temperature just a few degrees above absolute zero, and its actual temperature turns out to be 2.73 K.
    B. The cosmic background radiation is expected to have a perfect thermal spectrum, and observations from the COBE spacecraft verify this prediction.

C. The cosmic background radiation is expected to contain redshifted emission lines from hydrogen and helium, and it does.

D. The cosmic background radiation is expected to look essentially the same in all directions, and it does.

E. The cosmic background radiation is expected to have tiny temperature fluctuations at the level of about 1 part in 100,000. Such fluctuations were found in the COBE satellite data.

22. Explain why it is impossible for us to optically look past the cosmic microwave background.

> **Solution:** The cosmic microwave background represents the era in time when ionized atoms cooled enough to become neutral. This recombination allowed light to freely pass between them, and made the universe largely transparent. Prior to this, the universe resembled the inside of a star, which is not transparent and thus can not be "looked though"!

23. The initial mass density of the universe determines two properties about the universe. What are they?

> **Solution:** The shape of the universe and whether its expansion is increasing or decreasing (the eventual fate of the universe).

24. What is responsible for the increasing acceleration of the universe?

A. Visible matter

B. Dark matter

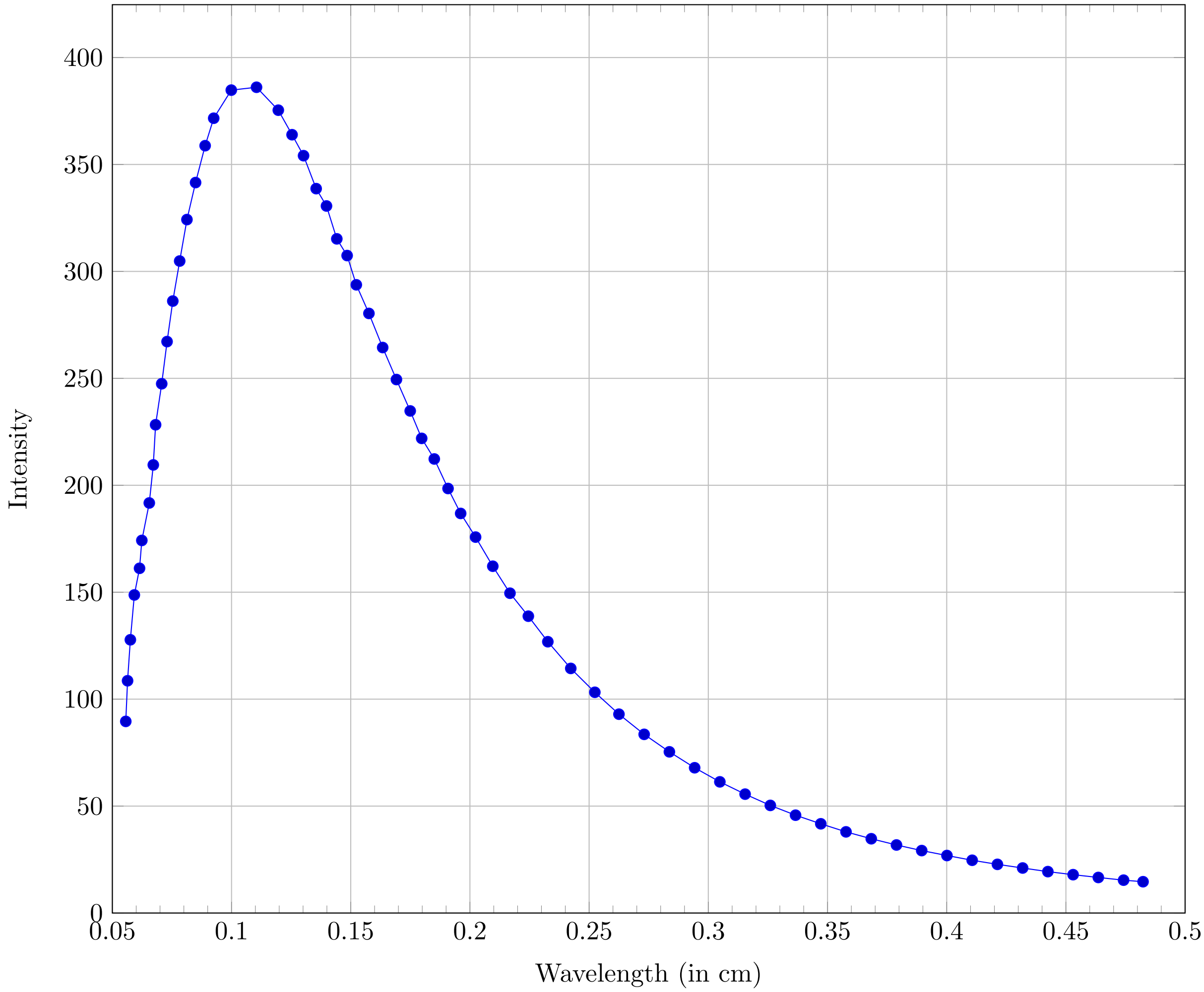
C. Dark energy

D. Neutrinos

25. How much of the universe seems to be made of visible matter? What percentage is comprised of dark matter? What percentage is comprised of dark energy?

> **Solution:** According to current models, the best fit seems to give that the universe is about 3% visible matter, 27% dark matter, and 70% dark energy!

26. The CMB was predicted and observed to be a perfect black-body. Given the plot below of the CMB spectrum, use Wien's Law to calculate the temperature of the CMB. (Don't forget that Wien's law does things in nanometers, so you'll need to convert.)



Solution: Wien's law states that:

$$\lambda \text{ (in nm)} = \frac{2900000}{T}$$

Rearranging that, we get that

$$T = \frac{2{,}900{,}000}{\lambda} = \frac{2{,}900{,}000}{0.11 \times 10^{-2} \times 1 \times 10^{9}} = 2.63\,\mathrm{K}$$

27. How does the theory of inflation explain the near-uniformity of the cosmic microwave background?
   A. The expanding universe would have cooled.
   B. Matter expanded into regions of space that had no matter, and thus ended up at the same temperature.
   C. Matter was near the critical-density for a universal collapse, which smoothed out the differences in temperatures.

D. **Prior to rapid inflation, all regions of space were close enough to bounce radiation back-and-forth and reach the same temperature**

28. Explain how Hubble's discovery of the relationship between galactic distance and redshift led to the idea of the Big Bang.

> **Solution:** Once it had been determined that the universe was expanding, it was natural to think it reverse. If it is now expanding and of some size, in the past it must have been much smaller. Following that to its logical conclusion is what first seeded the idea of a Big Bang.

29. Explain where our current models predict the initial lumpiness of the universe originated from. This initial lumpiness is needed so that gravity can start to bring dense regions together to form stars and galaxies.

> **Solution:** The current idea is that inflation blew up tiny quantum fluctuations to galactic scales. These quantum fluctuations are always present, due to quantum uncertainties, but the inflation stage of the Big Bang essentially expanded them to a huge scale across the universe. Similar to having a tiny dot on a balloon and then, upon blowing the balloon up, having a larger fuzzy patch.