ASTR100

Introduction to Astronomy

Final Exam Review Sheet

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Final Exam Notes:

Final Exam Review Session:	Wednesday, May 12th, 2010	– 7pm-9pm	– PHYS1412
Final Exam:	Friday, May 14th, 2010	– 8am-10am	– PHYS1412

- **Exam Components:** 50 multiple choice questions (2 pts each – 100 pts total)
  8-10 short answer questions (100 pts total)
- **Exam Topics:** Exam is cumulative! It covers chapter 1-15 in the text, but material since the second midterm is more heavily weighted.

- **Exam is closed book, closed notes, and no calculator is allowed.**
- **Bring a #2 Pencil and your Student ID.**

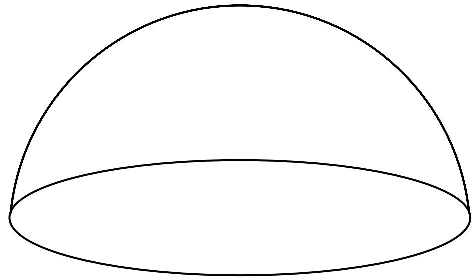
Study Guide Notes:

- **CAVEAT!** This study guide was written as a general study guide for ASTR100. It is by no means a perfect study guide for any particular semester's class of ASTR100. This study guide may not cover all of the requisite topics, and may cover material that is irrelevant. Use this only as a secondary study method, behind studying your lecture notes, and reviewing old homeworks. Feel free to email your TA with questions about this guide.

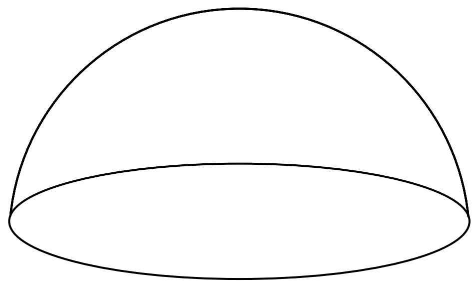
- Some mathematical problems presented here are too hard to complete by hand and require a calculator (unlike all possible mathematical exam problems). Each math based problem indicates if it is a calculator problem or not.

1) **Celestial Sphere.** Draw a diagram of the celestial sphere include the following items: North & South Celestial Pole; Zenith; Horizon; Meridian; Star Trails (of various sorts) and circumpolar stars (when possible) for the following locations on Earth. Don't forget to indicate compass directions!

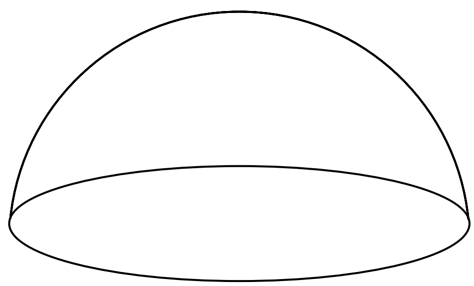
a. **College Park, MD**



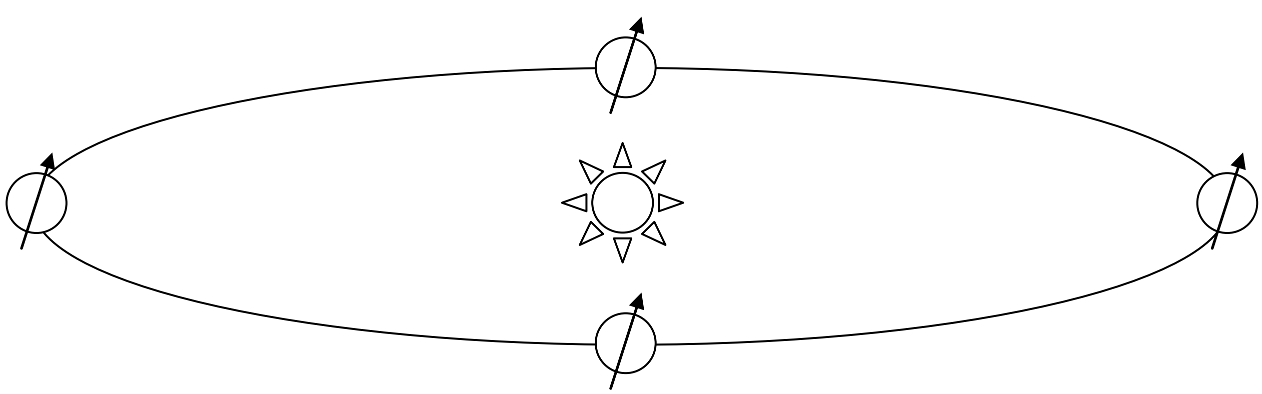
b. **The North Pole**



c. **The Equator**



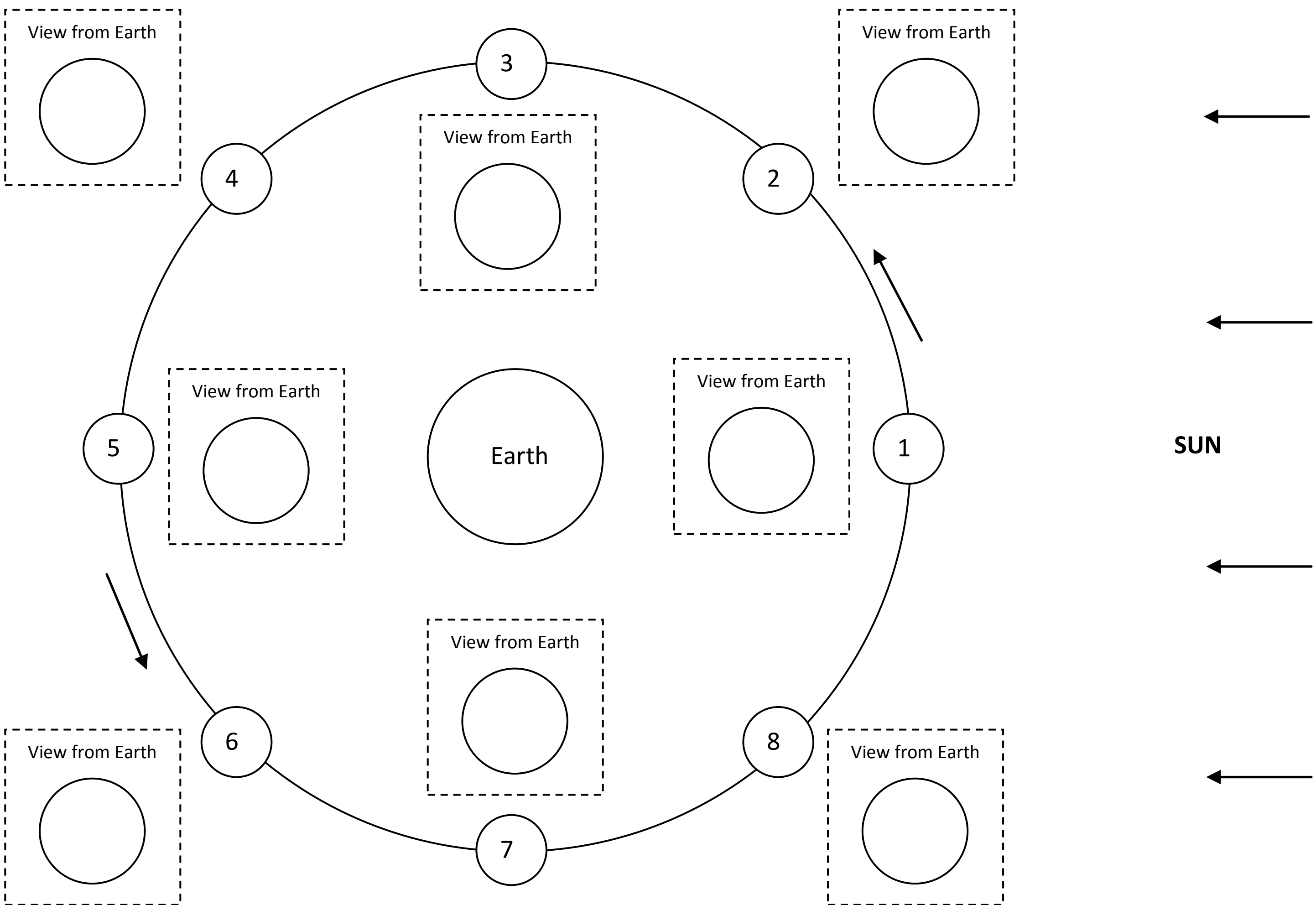
2) **The Seasons.** Label the drawing below with the following items: Autumnal & Vernal Equinoxes; Summer and Winter Solstices. In the space after, define Equinox, Solstice, and explain why we have seasons here on Earth.



3) **Precession.** Precession is:

- **a.** The slow change in the direction of the Earth's rotation axis.
- **b.** The slow change in the angle of the tilt of Earth's axis.
- **c.** The slow change of the Earth's orbital inclination (how tipped an orbit is).
- **d.** The slow change of the Earth's orbital eccentricity (how elliptical an orbit is).

4) **Lunar Phases.** Fill in the diagram below, by shading the Moon's and drawing the appropriate phase for each drawn position.



a. Label the names of each numbered moon position: Also indicate what time that that phase rises, is at maximum height in the night sky, and sets:

i. ______________________________ **rise:** ________ **max.:** ________ **set.:** ________
ii. ______________________________ **rise:** ________ **max.:** ________ **set.:** ________
iii. ______________________________ **rise:** ________ **max.:** ________ **set.:** ________
iv. ______________________________ **rise:** ________ **max.:** ________ **set.:** ________
v. ______________________________ **rise:** ________ **max.:** ________ **set.:** ________
vi. ______________________________ **rise:** ________ **max.:** ________ **set.:** ________
vii. ______________________________ **rise:** ________ **max.:** ________ **set.:** ________
viii. ______________________________ **rise:** ________ **max.:** ________ **set.:** ________

5) **Eclipses.** Draw two diagrams below illustrating how solar and lunar eclipses occur.

   a. **Solar Eclipse:**

   What phase does the moon have to be to create a Solar Eclipse? ________________________

   b. **Lunar Eclipse:**

   What phase does the moon have to be to create a Lunar Eclipse? ________________________

6) **Eclipse Potpourri.** Define the following terms. You're encouraged to draw pictures to help explain.

   a. **Umbra:**

   b. **Penumbra:**

   c. **Total Lunar Eclipse:**

   d. **Partial Lunar Eclipse:**

   e. **Penumbral Lunar Eclipse:**

   f. **Total Solar Eclipse:**

   g. **Partial Solar Eclipse:**

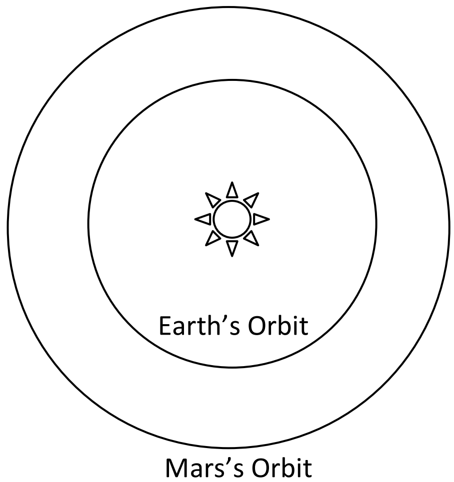
   h. **Annular Solar Eclipse:**

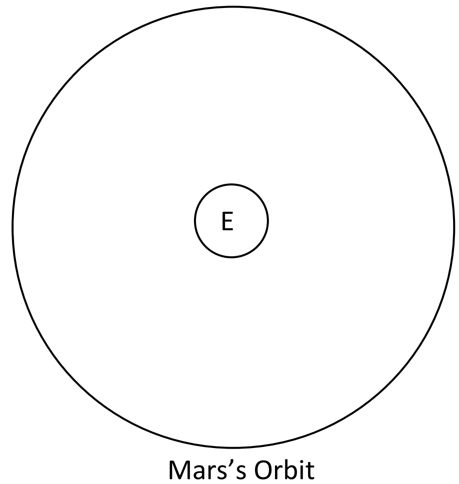
   i. **Saros Cycle:**

7) **Eclipse Commonality.** Which type of eclipse happens the most frequently? [Solar or Lunar]

8) **Not Always Eclipses.** Why don't eclipses happen every time we have a full or new moon?

9) **Retrograde Motion.** Retrograde motion is the apparent backwards motion that some planets (like Mars) do occasionally in the night sky. Given the mock up orbits for both a geocentric and heliocentric universe below, explain how you can get retrograde motion in both.





<u>Heliocentric Model</u>:

<u>Geocentric Model</u>:

10) **Parallax.** Draw a diagram showing the trigonometric relationships when one is measuring parallax.

11) **Latitude from North Star.** The North celestial pole is 35 degrees above your northern horizon (as indicated by looking for the 'north star'). This means…

   a. **You're at a latitude of 35 degrees North**
   b. **You're at a longitude of 35 degrees East**
   c. **You're at a latitude of 45 degrees South**
   d. **You're at a latitude of 45 degrees North**

12) **Polaris.** In spring, Earth's axis is pointed towards the star Polaris. This means that in Fall, Earth's axis will be pointing at:

   a. **Vega**
   b. **The South Celestial Pole Star**
   c. **The Sun**
   d. **Polaris**

13) **Week's Worth of Lunar Phases.** Last week the Moon was in the Waxing Crescent phase.

   a. What phase will it be at tonight? ____

   b. What time will the Moon be highest in the sky? ______________________________

14) **The Sun's Diameter.** The Sun has an angular size of 0.5 degrees. Using this, and the fact that the Earth is at a distance of about 150 million kilometers from the Sun, find the approximate diameter of the Sun. (Compare to the actual diameter of 1,390,000 km)

15) **Sun's Altitude.** Answer the following questions that pertain to the apparent path of the Sun on our sky… Some may have multiple answers.

   a. On what day(s) does the sun attain its highest altitude in the sky?
   [Winter Solstice] [Vernal Equinox] [Summer Solstice] [Autumnal Equinox]

   b. On what day(s) does the sun attain its lowest altitude in the sky?
   [Winter Solstice] [Vernal Equinox] [Summer Solstice] [Autumnal Equinox]

   c. On what day(s) does the sun rise and set directly in the East and West?
   [Winter Solstice] [Vernal Equinox] [Summer Solstice] [Autumnal Equinox]

   d. On what day(s) does the sun rise furthest South?
   [Winter Solstice] [Vernal Equinox] [Summer Solstice] [Autumnal Equinox]

   e. On what day(s) does the sun rise furthest North?
   [Winter Solstice] [Vernal Equinox] [Summer Solstice] [Autumnal Equinox]

16) **Zodiac.** What is the Zodiac?

   a. The constellations around which the planets appear to orbit.
   b. The constellations through which the Moon appears to move through over the course of a month.
   c. The constellations through which the Sun appears to move through over the course of a year.
   d. The constellations that lie on the North-South meridian.
   e. The constellations that all rotate around the North Star, and are visible every night.

17) **Eratosthenes.** In about 240 BC, Eratosthenes made the first accurate measurement of the Earth's circumference. He realized that on the Summer Solstice, the Sun was directly at zenith in Syene, Egypt. 5000 Stadia north in Alexandria, the Sun only came within 7 degrees of zenith. This meant that Syene and Alexandria were 7 degrees of latitude apart.

   a. Using this data, calculate the circumference of the Earth in Stadia.

   b. Convert your answer to kilometers, by assuming 1 stadia = $1/6^{th}$ of a kilometer.

   c. From your measurement of the circumference, find the Earth's approximate radius, and compare it to the actual value of 6378 km. Circumference = $2\pi R$.

18) Tests of Geocentric/Heliocentric Model. Below, describe each of the following tests that one can use to determine if we live in a geocentric or heliocentric universe. Describe what each system expected to see, and why. If necessary, draw a picture explaining each.

Test	Geocentric Model	Heliocentric Model
a. Parallax		
b. Retrograde Motion		
c. Phases of Venus		

19) Kepler's Laws. What are Kepler's three laws?

a. **Kepler's 1^{st} Law:**

b. **Kepler's 2^{nd} Law:**

c. **Kepler's 3^{rd} Law:**

20) Orbits. Draw a typical elliptical orbit below, and label the following items: <u>semimajor axis</u>, <u>aphelion</u>, <u>perihelion</u>, <u>foci (x2)</u>, <u>The Sun</u>.

21) Galileo's Telescope. List at least three big discoveries that Galileo made when he looked at the night sky with his telescope.

   a.

   b.

   c.

22) Scientific Method Terms. Define the following terms. Note: some of these terms really mean different things then in everyday vernacular!

   a. Fact:

   b. Principle:

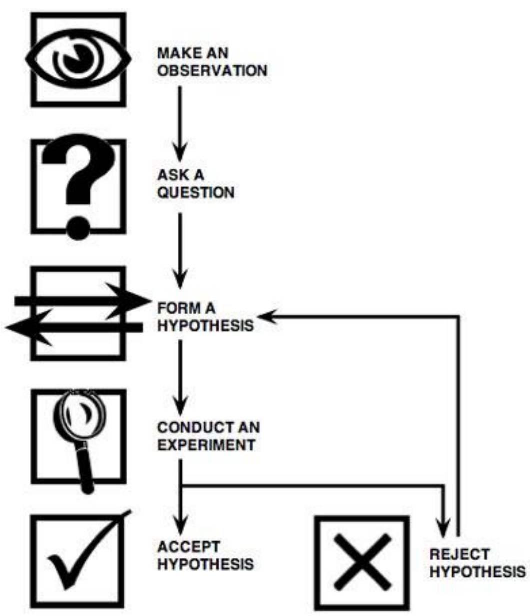
   c. Natural Law:

   d. Hypothesis:

   e. Theory:

   f. Paradigm:

23) Scientific Method. Pick an astronomical example and describe the process by which it went through the scientific method shown below. Describe what happened at each step for your particular example. (Some examples are: Geocentric/Heliocentric Model; What is Dark Matter?; "The Great Debate", etc.)



24) Theories. Which of the following is not true about scientific theories:

   a. A theory must explain a wide range of observations or experiments
   b. Even the strongest theories can never be proved beyond all doubt
   c. A theory is essentially an educated guess.

25) **Einstein v. Newton.** When Einstein's theory of gravity (general relativity) gained acceptance, it demonstrated that Newton's theory of gravity had been:

a. **Wrong**
b. **Incomplete**
c. **Really only a Guess**

26) **Kepler's Third Law.** Using Kepler's Third Law ($P^2 = a^3$), answer the following questions. *(No Calculator)*

a. **Asteroid.** We've discovered an asteroid that orbits at a semimajor axis of 2 AU.
   i. What is this asteroid's orbital period?

   ii. At a distance of 2 AU, what group of objects does this asteroid likely belong to?
      1. The Kuiper Belt
      2. The Oort Cloud
      3. The Trojans
      4. The Asteroid Belt

b. **Comet.** We've discovered a new comet with an orbital period of 1000 years, and an eccentricity of 0.98.
   i. What is this comet's orbital period?

   ii. How many times as this comet orbited the Sun since the Great Pyramid of Giza was built in the year 2560 BCE?

   iii. Where does this comet spend most of its time? [aphelion] or [perihelion]

c. **Vulan.** We've discovered a new dwarf planet with a semimajor axis of 1/4 AU, and an orbital inclination of 5 degrees.
   i. What is this dwarf planet's orbital period?

   ii. Using the flux equation, shown below, calculate how much more light Vulcan receives from the Sun, compared to us here at the Earth:

$$F = \frac{L}{4\pi D^2}$$

27) Accelerations. Place a check mark next to each case that *is* an acceleration:

- **a.** My car going at a constant 25 miles per hour, while turning. _____
- **b.** My car going at a constant 25 miles per hour, while driving straight. _____
- **c.** My car increasing its speed from 25 miles per hour to 30 miles per hour. _____
- **d.** My car decreasing its speed from 25 miles per hour to 10 miles per hour. _____
- **e.** My car falling off a cliff (oh no!). _____
- **f.** Me standing still, watching my car fall off a cliff. _____

28) Weight vs. Mass. Answer the following questions:

- **a.** The amount of matter in an object: [weight] [mass]
- **b.** The force of an object, down onto the ground: [weight] [mass]
- **c.** Changes, depending on which planet you're on: [weight] [mass]

29) Newton's Laws of Motion. Describe each of Newton's Laws of motion.

- **a. Newton's First Law:**
- **b. Newton's Second Law:**
- **c. Newton's Third Law:**

30) Newton's Law's Examples. Write a #1, #2, or #3 next to each case – matching the given example to the Newton's Law that most accurately explains it.

- **a.** A rocket is propelled upwards by the shooting of hot gas out the back: _____
- **b.** A spaceship needs no fuel to keep moving straight in deep space: _____
- **c.** I will weigh less if I stand on the surface of the Moon: _____
- **d.** Getting hit by a more massive baseball will hurt more than a smaller mass baseball: _____

31) Orbit. Why do astronauts in earth orbit (such as on the International Space Station) experience weightlessness?

- **a.** There is no gravity in space.
- **b.** They are far enough away from Earth, so that they don't feel much gravity.
- **c.** They are actually in free-fall.
- **d.** They are accelerating fast enough, such that they feel like they're in weightlessness.

32) Conservation of Angular Momentum. Compare the angular momentum of the Earth when it is closest to the Sun (perihelion) and furthest away from the Sun (aphelion).

- **a.** Angular momentum is greater at perihelion than aphelion.
- **b.** Angular momentum is greater at aphelion than perihelion.
- **c.** Angular momentum is the same at aphelion and perihelion.
- **d.** Angular momentum depends on the Moon's apogee and perigee – not the Earth's aphelion and perihelion.

33) Newton's Versions of Kepler's Third Law. With his discovery of gravity, and development of calculus, Newton was able to derive Kepler's Third Law. Below are three variants of the law that are equally valid:

a. Kepler's Original Third Law: $p^2 = a^3$

i. What units do you use for **P** and **a**?

ii. When is this equation applicable?

b. Intermediate Kepler's Third Law: $p^2 = \left(\frac{1}{M_{total}}\right) * a^3$

i. What units do you use for **P** and **a**?

ii. When is this equation applicable?

c. Newton's Version of Kepler's Third Law: $\left(\frac{p}{2\pi}\right)^2 = \frac{a^3}{G(M+m)}$

i. What units do you use for **P** and **a**?

ii. When is this equation applicable?

34) Examples with Kepler's Third Law. Use the appropriate version(s) of Kepler's Third Law from the previous problem to solve the following problems: *(No calculator)*

a. Stellar Remnant. Let's say we've detected a White Dwarf orbiting an unseen companion (something dark) with a period of 1 year, at a distance of 5 AU.

i. Find out the mass of the unseen companion.

ii. What could this unseen companion be?

b. Hot Jupiter. Let's say we've detected a 2 M_{sun} star, and have noticed that it is wobbling with a period of 3 months, and that we hypothesize that this means that the star has a planet orbiting it once every 3 months.

i. Find out the semimajor axis of our unseen planet.

35) Tides. Draw a schematic diagram of how the Moon (or Sun) generates tides.

36) Tides Recurrence. Based upon your drawing above, how often can a particular position on Earth experience a high tide?

a. Once a day

b. Twice a day

c. Once every lunar phase cycle

d. Only on full moons

37) Electromagnetic Spectrum. Below is a mock-electromagnetic (EM) spectrum. Fill in the missing portions of the EM spectrum. In the columns labeled "wavelength", "frequency" and "energy", draw arrows indicating the direction that that given quantity is increasing.

Spectrum	**Wavelength**	**Frequency**	**Energy**
Radio			
______________________			
______________________			
Optical / Visible			
______________________			
______________________			
______________________			

38) Speed of Light. Which of the following bandwidths of the EM spectrum move the fastest.

a. **Radio**
b. **Optical**
c. **Gamma Rays**
d. **None – they all move at the same speed.**
e. **None – it depends on the source of the light, not the light itself.**

39) Atoms and Such. Fill out the following chart, describing subatomic particles and atoms

Particle:	Is this Particle in the Nucleus of Atoms?	What is the Charge of This Particle?
a. **Proton**	[yes] or [no]	[negative] or [neutral] or [positive]
b. **Neutron**	[yes] or [no]	[negative] or [neutral] or [positive]
c. **Neutrino**	[yes] or [no]	[negative] or [neutral] or [positive]
d. **Electron**	[yes] or [no]	[negative] or [neutral] or [positive]
e. **Photon**	[yes] or [no]	[negative] or [neutral] or [positive]
f. **Positron**	[yes] or [no]	[negative] or [neutral] or [positive]
g. **Anti-Proton**	[yes] or [no]	[negative] or [neutral] or [positive]

40) Atomic Nucleus. Compared to an atom as a whole, an atomic nucleus…

a. Is very tiny, and has most of the mass.
b. Is very large, and has most of the mass.
c. Is very tiny, and has very little mass.
d. Is very large, and has very little mass.

41) Atomic Terminology. Define the following terms:

a. **Atomic Number:**

b. **Atomic Mass:**

c. **Isotopes:**

d. **Ions:**

e. **Molecules:**

42) Frequency/Wavelength. Below is the equation governing light and its frequency and wavelength. Use it to answer the following questions.

$$\lambda * \upsilon = c$$

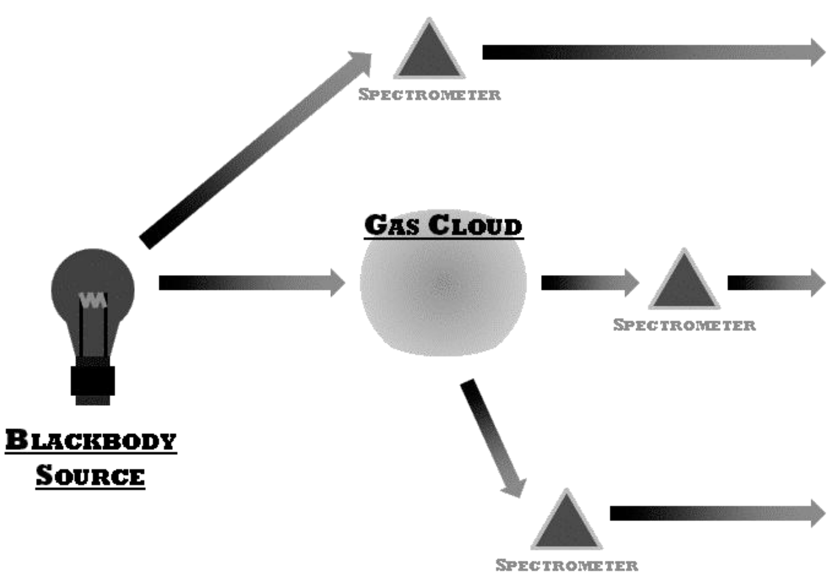
a. What does each term in the above equation mean, and what are their units?

b. What is the wavelength of light with a frequency of 300 Terahertz? (1 Terahertz = 10^{-12} Hertz)?

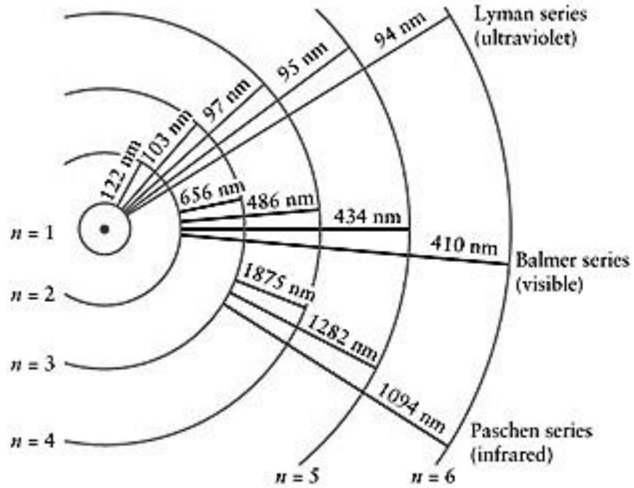
c. What is the frequency of light with a wavelength of 1 nanometer (1 nanometer = 10^{-9} meter)?

d. What is the speed of light with a wavelength of 3 meters?

43) Spectral Types. For the diagram below we see a hot dense source (the light bulb) shining through a low density cloud. Draw a spectrum of what an observer would see from each perspective, and label what type of spectrum that is (Contiuum, Emission, or Absorption).



44) Energy Levels. Below is a diagram showing the energy levels of hydrogen. Explain how these discrete energy levels give us absorption and emission spectra, and also allow us to identify different chemicals in space.



45) Black Body Spectrum. Hot, dense objects tend to emit continuum spectra – which depend solely on the temperature of the object. The wavelength at which such a spectra peaks at is governed by Wien's Law, show below:

$$\lambda_{max}[nm] = \frac{3{,}000{,}000\ [nm]}{T\ [kelvin]}$$

a. For the following stars, Use Wien's law to calculate the wavelength at which they emit most of their light: *(No calculator)*

i. **Star A**: Temperature = 3,000 K

ii. **Star B:** Temperature = 6,000 K (like our Sun)

iii. **Star C:** Temperature = 10,000 K

b. Draw three blackbody curves for the above stars on the plot below. Be sure to label the axes, and to accurately place the peak wavelength derived in part a) above.

46) Stefan Boltzmann's Law. Stefan Boltzmann's law is shown below. It relates the luminosity of a star to the power (σT^4) and the surface area ($4\pi R^2$) for the star. Use it to answer the following examples. *(No calculator)*

$$L = 4\pi R^2 \sigma T^4$$

a. Star A is the same temperature as Star B, but Star B is twice the radius of Star A. Which star is more luminous and by how much?

b. Star C is the same luminosity as Star D, but star D is 3 times as hot. Which star is bigger, and by how much?

c. Star E rapidly expands and becomes 1000 times larger, and drops in temperature by a factor of 2. What is its new luminosity, in terms of its original luminosity?

47) Doppler Shift. Imagine that we are observing a star that may or may not be moving. For each of the following cases, determine whether we see the light from the star redshifted, blueshifted, or unchanged.

a. The star is moving away from us. [redshifted] [blueshifted] [unchanged]
b. The star is moving across our line of sight. [redshifted] [blueshifted] [unchanged]
c. The star is moving towards us. [redshifted] [blueshifted] [unchanged]
d. Neither us, nor the star are moving. [redshifted] [blueshifted] [unchanged]
e. We are moving rapidly away from the star. [redshifted] [blueshifted] [unchanged]
f. We are moving rapidly towards the star. [redshifted] [blueshifted] [unchanged]

48) Doppler Shift Equation. Below is the equation for the Doppler Shift. Use it to answer the following questions: *(No Calculator)*

$$\frac{V_{rad}}{c} = \frac{\lambda_{shift} - \lambda_{rest}}{\lambda_{rest}}$$

a. We're observing a star and see a spectral line at a wavelength of 101 nm, rather than its rest wavelength of 100 nm. What is the velocity of this star, and is it moving towards or away from us?

b. We're observing a galaxy and see a spectral line at a wavelength of 20 nm rather than its rest wavelength of 25 nm. What is the velocity of this galaxy, and is it moving towards or away from us?

49) Refracting / Reflecting Telescopes. Refracting telescopes use ___________________ to collect light, whereas a reflecting telescope uses ___________________ to collect light. Currently, most astronomical telescopes are ___________________ telescopes.

50) **Two Key Properties of Telescopes.** Explain the two key properties of telescopes listed below, and why we would want to build big telescopes to achieve both.

   a. **Light Collecting Area:**

   b. **Angular Resolution:**

51) **Atmosphere and Telescopes.** Below are three obstacles for making astronomical observations. Explain why each is a problem, and how astronomers get around them.

   a. **Light Pollution:**

   b. **Atmospheric Turbulence:**

   c. **Atmospheric Absorption:**

52) **Sunflowers.** Why are sunflowers yellow?

   a. They emit yellow light.
   b. They absorb yellow light.
   c. They reflect yellow light.

53) **Collecting Area.** How much greater is the light collecting area of a 6-meter telescope than a 3-meter telescope?

   a. Two times.
   b. Three Times.
   c. Four Times.
   d. Six Times.

54) **Hubble.** The Hubble Space Telescope obtains higher-resolution images than most ground-based telescopes because:

   a. It is larger.
   b. It is closer to the Stars.
   c. It is further from the Sun.
   d. It is above the Earth's Atmosphere.

55) **Adaptive Optics.** Adaptive optics allows astronomers to…

   a. See in wavelengths that the atmosphere usually absorbs.
   b. Remove the distorting effect of the atmosphere.
   c. Link together far away telescopes to effectively make larger telescopes.

56) Solar Nebula Hypothesis. Below is a list of the steps involved in the Solar Nebula hypothesis. For each step draw a diagram of what the system would look like, and explain what is happening.

Initial Solar Nebula:

Contraction of the Solar Nebula:

Condensation of Solid Particles:
(Focus on the impact of the Ice/Frost Line!)

Accretion of Planetesimals:

Clearing of the Nebula:

57) Solar Nebula. The composition of the solar nebula was:

- **a.** 98% rocks and metals
- **b.** 98% hydrogen compounds (ices)
- **c.** 98% hydrogen and helium

58) Origin of the Moon. Which of the following is the leading theory for the origin of the Moon?

- **a.** It formed in the solar nebula along with the Earth.
- **b.** It formed out of material ejected in a giant impact.
- **c.** It split out of the rapidly rotating early Earth.
- **d.** It was a captured planet from the outer solar system.

59) Extrasolar Planets. Most extrasolar planets so far detected are large, Jupiter mass (or bigger) planets that orbit really close to their host stars, in very eccentric orbits. Does this agree with the solar nebulae hypothesis? Explain your answer.

60) Ice/Frost Line. Where in the solar nebula could the following materials condense (and thus form planetesimals)?

- **a. Metals:**
- **b. Ices:**
- **c. Hydrogen/Helium:**

61) Terrestrial vs. Jovian Planets. Explain the differences in the formation of terrestrial and jovian planets. Be sure to address the following questions: Why are terrestrial planets smaller? Why do Jovian planets have a lot of hydrogen and helium?

<u>**Terrestrial Planets**</u>	<u>**Jovian Planets**</u>

62) Extrasolar Planets. Fill in the chart below, explaining the difference between the two primary methods of extrasolar planet detection:

	<u>**Transit Method**</u>	<u>**Doppler Method**</u>
<u>**How it Works:**</u>		
<u>**Detection Biases?**</u>		

63) Extrasolar Planets. Which detection method has detected the most planets so far?

- **a. Transit Method**
- **b. Doppler Method**

64) Size Comparisons. Earth's radius is about $1/10^{th}$ that of Jupiter. Jupiter's radius is about $1/10^{th}$ that of the Sun. Using the equation for volume, $V = (4/3)\ \pi R^3$…

- **a.** How many Earth's would fit inside of Jupiter?
- **b.** How many Jupiters would fit inside of the Sun?
- **c.** How many Earths would fit inside of the Sun?

65) Monster Ice Balls. The ice-rich planetesimals that formed the cores of the Jovian planets were about 10 times more massive than the Earth. Assuming such an ice ball has a density of 2 g/cm^3. Knowing that the density of the Earth is about 5 g/cm^3, how big would these ice balls be in comparison to the Earth?

Recall: **(density) = (mass)/(volume)**, and that $\mathbf{V = (4/3)\ \pi R^3}$

66) Internal Activity. For terrestrial planets, which of the following planetary properties is the best indicator of the amount of geologic activity?

- **a.** Distance from the Sun.
- **b.** Radius.
- **c.** Atmospheric Pressure.

67) Resurfacing. Below are the four main geologic processes that work to resurface a terrestrial planet. Explain how each helps resurface a planet.

- **a. Impact Cratering**
- **b. Volcanism**
- **c. Tectonics**
- **d. Erosion**

68) Cratering Rates. Draw a plot of the amount of meteorite impacts as a function of time (ranging from the formation of the solar system to current). Explain how we can thus use the number of impact craters as a way to determine the approximate age of a surface.

69) Earth's Internal Heat. Which of the following is the predominant source of Earth's current internal heat?

- **a.** Accretion
- **b.** Radioactive Decay
- **c.** Sunlight
- **d.** Nuclear Fusion
- **e.** Gravitational Collapse

70) Geologically Dead Planets. Which planets are geologically dead? Explain why these worlds are now dead.

71) Greenhouse Gas. Which of the following is a strong greenhouse gas?

- **a.** Nitrogen
- **b.** Water Vapor
- **c.** Oxygen
- **d.** Ozone

72) Surface Area / Volume Ratios. The ratio of surface area to volume is a good indicator of how fast a planet cooled off. High surface area to volume ratios indicate rapid cooling, whereas low surface area to volume ratios indicate slow cooling. Using this, and the fact that surface area = $4\pi R^2$, and volume = $(4/3)\pi R^3$, investigate this ratio for the following cases: *(No calculator)*

- **a.** The Earth's radius is about 3 times that of the Moon. Find the surface area to volume ratio, and determine how much more rapidly the Moon cooled off than the Earth.
- **b.** Mars has a radius about twice that of the Moon. Find the surface area to volume ratio, and determine how much more rapidly the Moon cooled off than Mars. Compare this to your Earth value above as well.

73) Size verse Mass. Draw a plot of the radius of a planet as a function of mass. Explain why this means that even though Saturn is much less massive than Jupiter, it is about the same size. Also explain why planets much more massive than Jupiter are actually smaller than Jupiter.

74) Jupiter v. Neptune. Why does Neptune appear blue, and Jupiter appears Red?

- **a.** Neptune is hotter, giving it bluer thermal emission.
- **b.** Methane in Neptune's atmosphere absorbs red light.
- **c.** Neptune's air molecules scatter blue light, much like Earth's atmosphere.
- **d.** Jupiter is hotter, giving it a redder thermal emission specrum.

75) Jovian Internal Heat. Some Jovian planets give off more energy than they receive from the Sun because…

- **a.** Fusion is taking place in their cores.
- **b.** They are heated from tidal interactions with their moons.
- **c.** They are heated by accretion of ring particles.
- **d.** They are still contracting from formation.
- **e.** They are heated by radioactive decay.

76) Io. Why is Io more geologically active than our Moon – even though they are the same size?

77) Triton. What is unusual about Triton?

- **a.** It orbits backwards.
- **b.** It does not keep the same face towards its host planet.
- **c.** It has a thick nitrogen atmosphere, and possible lakes of hydrocarbons.

78) Saturn's Rings. Saturn's rings…

- **a.** Have remained basically unchanged since they formed with Saturn, about five billion years ago.
- **b.** Were created long ago when tidal forces tore apart a large moon.
- **c.** Are continually supplied with material from impacts of small moons.
- **d.** Are a solid disk of ices, rocks, and metals.

79) Disappearing Io. Io is currently ejecting about 1000 kilograms of sulfur dioxide and other materials each second into Jupiter's magnetosphere. Io has a mass of 9×10^{22} kilograms. Suppose sulfur dioxide currently makes up 1% of Io's mass. When will it run out material at its current rate? Compare this with the age of the Solar system.

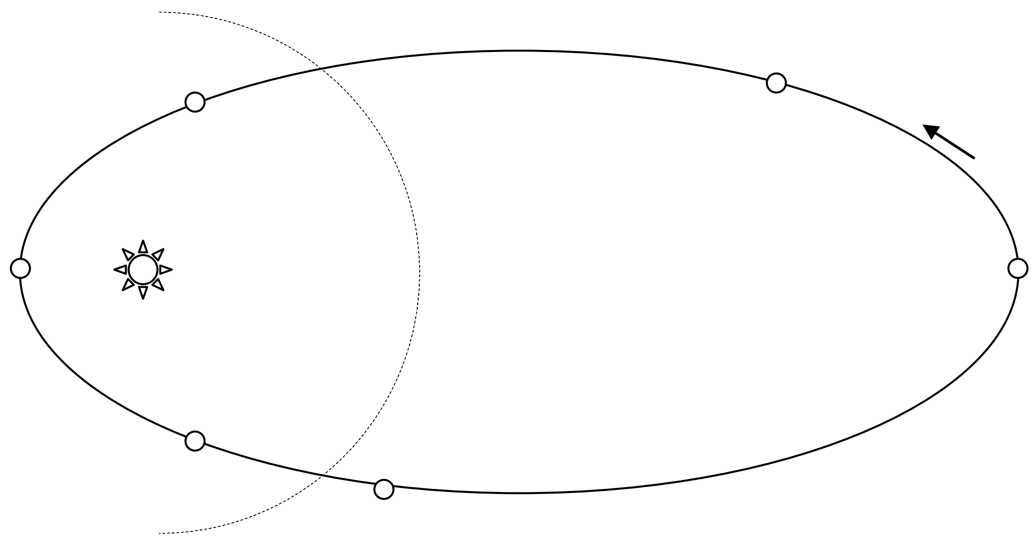
80) Resonances. Explain what resonances are, and how they affect the following systems:

   a. **Saturn's Rings:**

   b. **Io and Europa's internal Heat:**

   c. **Kirkwood Gaps in the Asteroid Belt:**

81) Orbit of a Comet. Below is the orbit of a typical comet. Draw a diagram of what the comet looks like at each of the marked positions (where a nucleus is already drawn). The dashed line represents the location of the ice line.



(Don't forget to include the comet's coma, and two different tails!)

82) Meteorites. Match the following terms (left) to their definitions (right)

<u>Terms:</u>	<u>Definitions:</u>
Meteor	A piece of rock, still in space.
Meteorite	A piece of rock as it enters our atmosphere, creating a shooting star.
Meteroid	A piece of rock that has impacted the Earth's surface.

83) Proto-Asteroid Belt. Did a large terrestrial planet ever form in the region that is currently occupied by the asteroid belt?

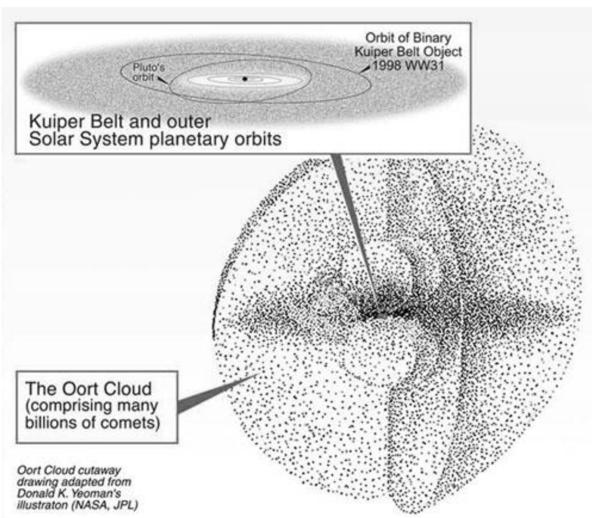
   a. **Yes** – but it was shattered by a giant impact.
   b. **Yes** – but it was destroyed by tidal effects from the Sun and Jupiter.
   c. **No** – because there was never enough mass to form a planet.
   d. **No** – because Jupiter prevented one from accreting.

84) **Pluto.** What type of object does Pluto most closely resemble?

- **a.** A terrestrial planet
- **b.** An asteroid
- **c.** A jovian planet
- **d.** A comet

85) **Pluto is not a Planet.** What is the current IAU definition of a planet, and why is Pluto no longer a planet?

86) **Oort Cloud vs. Kuiper Belt.** Below is a diagram showing the Oort Cloud and the Kuiper Belt. Describe the origin of both groups of objects, and how they are similar and different.



87) **Asteroid Belt Volume.** It is estimated that there are a million asteroids 1 kilometer across or larger. If they were all combined into one object, how large would it be in comparison to the Earth, which has a diameter of about 10,000 km (roughly). *(No calculator)* Recall: volume, $V = (4/3)\,\pi R^3$

88) **Dinosaur Killer.** Explain what the "Iridium Spike" is, and why it is a major line of evidence for the idea that an asteroid killed off the dinosaurs 65 million years ago.

89) Hydrostatic Equilibrium. What is hydrostatic equilibrium?

90) Solar Structure. Draw two diagrams below – one of the Sun's internal structure and one of the Sun's atmosphere. Include the terms listed below.

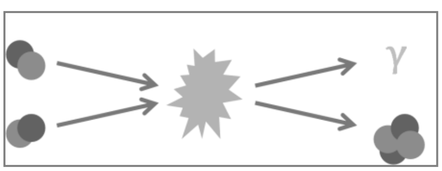
Internal Structure

Include: core, convective zone, radiative zone, photosphere.

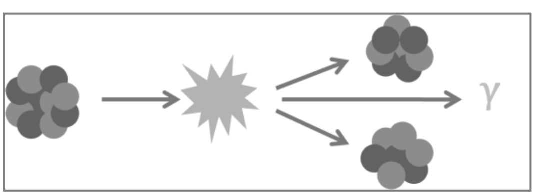
Atmosphere

Include: photosphere, sunspots, chromosphere, flares filaments, corona, solar wind.

91) Nuclear Fusion/Fission. Below are two sample nuclear reactions. Identify which is nuclear fusion, and which is nuclear fission.



This is a [fission] [fusion] reaction.



This is a [fission] [fusion] reaction.

92) The Proton Proton Chain. Write down the individual steps of the Proton-Proton chain – which is the main way the Sun (and other stars) generate power.

93) Nuclear Fusion Temperatures. Why does nuclear fusion only occur in the cores of stars, at high temperatures? (Hint: Relate to the Strong Force and Electromagnetic Forces.)

94) Temperatures…

- **a.** Which of these layers of the Sun is the <u>coolest</u>?
  - i. Photosphere
  - ii. Chromosphere
  - iii. Corona
- **b.** Which of these layers of the Sun is the <u>coolest</u>?
  - i. Core
  - ii. Radiation Zone
  - iii. Convective Zone

95) Sunspots. Why are Sunspots darker than their surroundings?

96) Neutrinos. How does the number of neutrinos passing through your body at night compare with the number passing through your body during daytime?

- **a.** It's zero.
- **b.** It's about the same.
- **c.** It's much smaller.
- **d.** It's much larger.

97) Solar Wind. Which of these things pose the greatest hazard for orbiting satellites?

- **a.** High Energy Photons
- **b.** High Energy Particles
- **c.** High Energy Magnetic Fields

98) Helioseismology. What is helioseismology, and how is it helpful for astronomers?

99) Solar Cycle. Explain what the solar cycle is, and what it means for us here on Earth.

100) Binary Stars. Explain the difference between the following types of binary stars:

a. **Visual Binaries**

b. **Eclipsing Binaries**

c. **Spectroscopic Binaries**

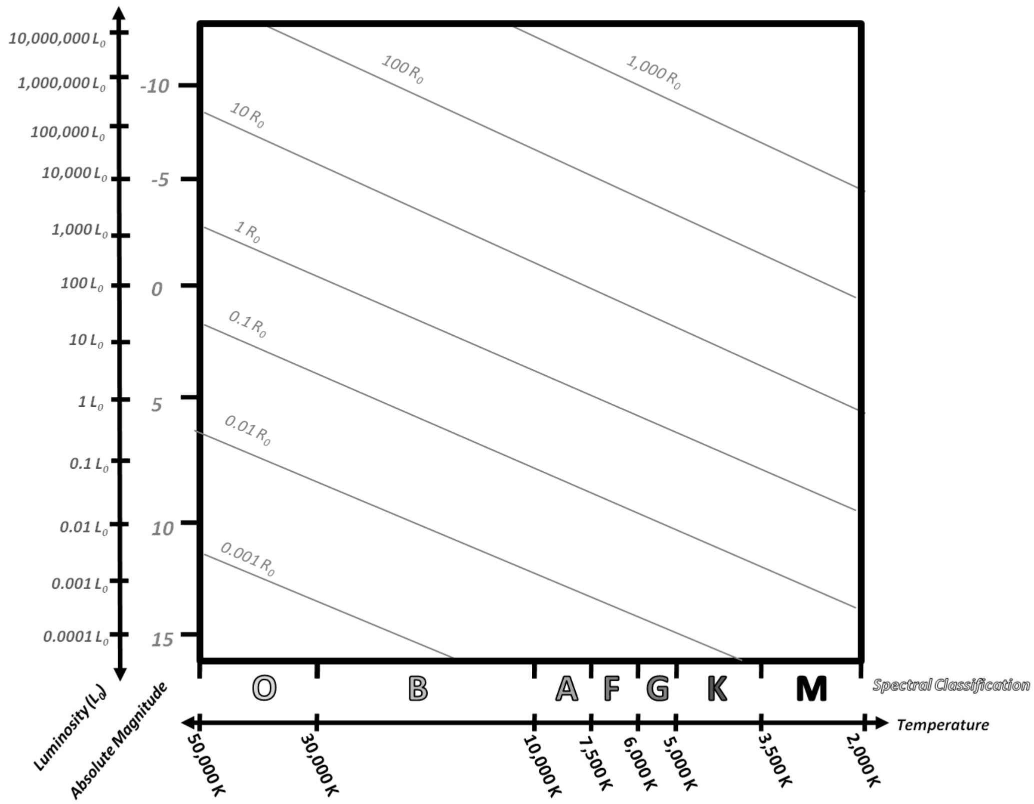
101) Hertzsprung-Russel (HR) Diagram. The HR diagram is perhaps the most key tool used for understanding the properties of stars.

i. **Axes and Scaling.** Indicate the general trends : in which direction does luminosity, radius, temperature, etc. increase? Also label the spectral classifications: OBAFGKM.

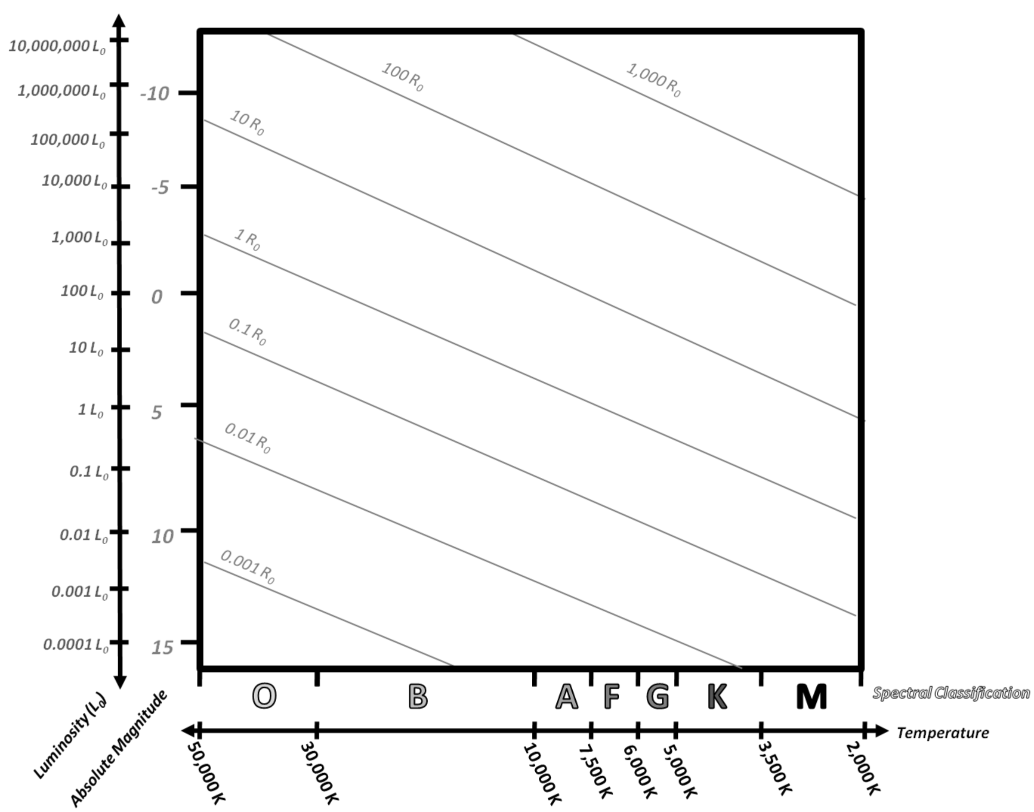
For the Spectral Classifications Below, indicate a general trend by drawing an arrow in the direction quantities increase:

Classification	Temperature	Size	Lifetime
O			
B			
A			
F			
G			
K			
M			

b. Major Groupings. Put the following groupings of stars: the main sequence, the giants, the super giants, the white dwarfs, etc, and the Sun.



c. Stellar Evolution. Draw the evolution track of both a low mass (sun like) star, and a high mass star on the diagram below:



102) Brown Dwarfs. What are brown dwarfs, and how are they supported from collapse?

- **a.** An object not quite massive enough to be a star – supported by hydrogen fusion.
- **b.** An object not quite massive enough to be a star – supported by degeneracy pressure.
- **c.** A white dwarf that has cooled off – supported by degeneracy pressure.
- **d.** A white dwarf that has cooled off – supported by electromagnetic repulsion.
- **e.** A star less massive than Jupiter – supported by hydrogen fusion.
- **f.** A star less massive than Jupiter – supported by degeneracy pressure.

103) Cores of Stars. Which of these stars has the hottest core?

- **a.** A blue main sequence star.
- **b.** A red supergiant star.
- **c.** A red main sequence star.

104) Hydrostatic Equilibrium. When the core runs out of hydrogen to fuse, what happens to both the core and the star?

- **a.** The core expands; the star expands.
- **b.** The core collapses; the star expands.
- **c.** The core expands; the star collapses.
- **d.** The core collapses; the star collapses.

105) Nucleosynthesis. Draw a plot showing the energy released during fusion for different elements (defined by their atomic number).

- **a.** Using your chart above, explain why stars do not fuse elements above iron.
- **b.** Using your chart above, explain why nuclear fusion generates more energy than nuclear fission.
- **c.** **Origin of Elements:** Where does each of the following groups of elements come from:
  - i. Hydrogen – Helium: ______________________________
  - ii. Helium – Iron: ______________________________
  - iii. Iron – Uranium: ______________________________
  - iv. Uranium – and beyond: ______________________________

106) Mass is Destiny. Describe the statement: “Mass is Destiny” – and how it pertains to stellar evolution.

107) Stellar Remnants. Fill out the chart below, with information about stellar remnants:

	White Dwarfs	**Neutron Stars**	**Black Holes**
Mass Range of Progenitor Star:			
Mass Range of Resulting Remnant:			
Remnant Size Comparison:			
What's Supporting the Remnant from Collapse?			Nothing!

108) Remnant Sizes. Rank the following objects from largest to smallest in terms of size (1 – 7).

a. 1.3 solar mass white dwarf ____
b. 1 solar mass star ____
c. 1 solar mass white dwarf ____
d. 2.5 solar mass neutron star ____
e. 5 solar mass star ____
f. 2 solar mass neutron star ____
g. 4 solar mass black hole. ____

109) White Dwarves in Binaries. White dwarfs can occasionally be in binary pairs, and can accrete mass from their binary companion. There are two possible outcomes of such an event. Describe both:

a. Novae:

b. White Dwarf Supernovae:

110) Pulsars. Neutron stars spin rapidly when they are born, and their strong magnetic fields can sweep beams of radiation out much like a lighthouse. Answer the following questions about pulsars and neutron stars:

a. All pulsars are neutron stars, but not all neutron stars are pulsars: **[true]** or **[false]** Explain your answer:

b. Why do neutron stars rotate so fast?

111) Sun → Black Hole. What would happen to the Earth's orbit if the Sun were suddenly replaced by a 1 solar mass black hole?

- **a.** Earth would gradually spiral into the black hole.
- **b.** Earth would be quickly sucked into the black hole.
- **c.** Earth would spiral outwards.
- **d.** Earth's orbit would remain unchanged.

112) X-Ray Binaries. What are X-Ray binaries? What's their parallel with White Dwarfs?

113) Unknown Binary. Which of these binary systems likely contains a black hole?

- **a.** An X-Ray binary containing an O star and another object of equal mass.
- **b.** A binary with an X-Ray burster.
- **c.** An X-Ray binary containing a G star and another object of equal mass.

114) Spaghetiffication. When falling into a black hole, tidal forces are the true killer. Why is it said that it'd be better to fall into a supermassive black hole, than a low mass black hole?

115) Schwarzschild Radius. Answer the following questions about the Schwarzschild Radius: $R_s = 2GM/c^2$

- **a.** The Schwarzschild radius is the distance from the singularity of a black hole to the event horizon. What is the event horizon?

- **b.** Notice how the Schwarzschild radius scales linearly with radius. Show that by combining the $2G/c^2$ factor and the mass of the Sun (2.0×10^{30} kg = M_{sun}), that the equation above reduces to: $R_s = (3\ \text{km}/M_{sun})$

- **c.** Find the Schwarzschild Radius for a black hole with …
  - i. Mass = 1 M_{sun}
  - ii. Mass = 100 M_{sun}
  - iii. Mass = 1,000,000 M_{sun}

    Compare this Schwarzschild to the size of 1 AU (1 AU = 150,000,000 km)

116) Milky Way Structure. Draw two sketches of the Milky Way: one looking at the disk edge on, and another looking at the disk face on. Give an approximate size scale, and label the following structures: disk, bulge, halo, bar, spiral arms, and globular clusters.

117) Star Orbits. Describe the orbits of the following groups of stars in the Milky Way (or any spiral):

a. **Stars in the Central Bulge:**

b. **Stars in the Disk:**

c. **Stars in the Halo:**

118) Star Populations. Describe the following "populations" of stars. What makes each class distinctive? Where would we find the given populations? How old are typical stars in each population?

a. **Population I (Disk Population):**

b. **Population II (Spheroidal Population):**

c. **Population III:**

119) Metallicity of the Interstellar Medium. As a galaxy evolves, and stars are born and die, how does the metallicity (amount of elements heavier than hydrogen) of the Milky Way's interstellar medium (ISM) change?

- **a. It Decreases**
- **b. It Remains Constant**
- **c. It Increases**

120) The Star-Gas-Cycle. In galaxies, gas is recycled between stars and the surrounding interstellar medium. Fill in the star-gas-cycle diagram shown below. For each step, write a one sentence description on what's happening.

1. ______________________________

6. ______________________________ 2. ______________________________

5. ______________________________ 3. ______________________________

4. ______________________________

121) Star Formation. Place a check mark next to each place where star formation would be <u>very likely</u> to occur:

- **a. Galactic Bulge** ____
- **b. Spiral Arms** ____
- **c. Galactic Halo** ____
- **d. Globular Clusters** ____
- **e. Ionization/Emission Nebulae** ____

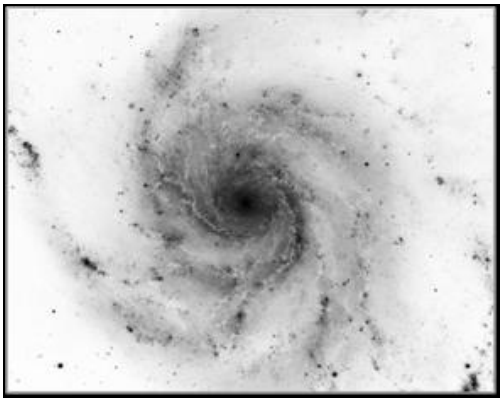
122) Early Planet Formation. Planets like earth probably could form around the first stars ever produced (Population III stars). (Explain your answer)

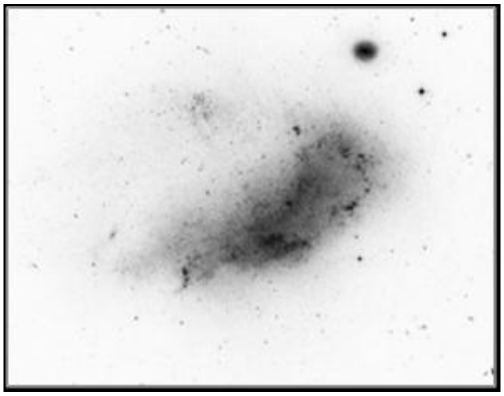
- **a. True**
- **b. False**

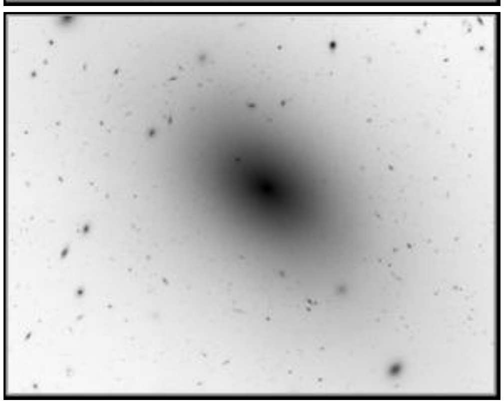
123) Picture of the Milky Way. We did not understand what the Milky Way looked like until NASA launched satellites in the 1980's into the galactic halo, letting us see the Milky Way from the outside. (Explain your answer)

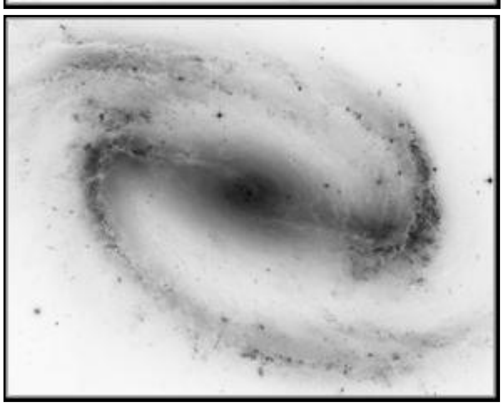
- **a. True**
- **b. False**

124) Galaxy Types. Identify the following galaxy types, and give a two-three sentence description of each.









125) Galaxy Populations. Which type of galaxy is the most common <u>in open space</u>?

a. **Spirals**
b. **Ellipticals**
c. **Irregulars**

126) Galaxy Clusters. Which type of galaxy is most common <u>in galaxy clusters</u>?

a. **Spirals**
b. **Ellipticals**
c. **Irregulars**

127) Super Massive Black Holes. How do we know that there is a super massive black hole at the center of the Milky Way?

a. We observe stars near the galactic center vanish – telling us that they've been sucked into the black hole.
b. We observe an accretion disk and powerful jets in the galactic center – caused by the feeding black hole.
c. We observe the flat rotation curve of stars out in the disk of the galaxy – caused by the black hole's gravity.
d. We observe the rapid motion of stars near the galactic center – telling us that there's a lot of mass there.
e. We observe a lot of high energy radiation from the galactic center – no doubt emitted by the black hole.

128) Hydrogen Content of Stars. How much hydrogen are in sun like stars currently in the Milky Way, and how will that percentage of hydrogen change with time as the galaxy evolves?

a. **90**% hydrogen currently – and **decreasing** with each generation of stars.
b. **90**% hydrogen currently – and **increasing** with each generation of stars.
c. **90**% hydrogen currently – and remaining **constant** with each generation of stars.
d. **75**% hydrogen currently – and **decreasing** with each generation of stars.
e. **75**% hydrogen currently – and **increasing** with each generation of stars.
f. **75**% hydrogen currently – and remaining **constant** with each generation of stars.
g. **50**% hydrogen currently – and **decreasing** with each generation of stars.
h. **50**% hydrogen currently – and **increasing** with each generation of stars.
i. **50**% hydrogen currently – and remaining **constant** with each generation of stars.

129) High Velocity Stars. Most stars move at about 20 km/s relative to the sun (their velocity relative (towards/away) to the sun – *not* their orbital velocities around the galaxy). Suppose we discover a star in the solar neighborhood traveling much faster, say 200 km/s. What kind of orbit does this star probably have around the Milky Way? In what part of the galaxy does it spend most of its time? Explain.

130) The Distance Ladder. Fill out the chart below, showing how we measure the distances to astronomical objects.

| **(The Most Distant Galaxies)** --

Method:

Relevant Equation: $v = H_0 d$

Description:

| **(Distant Galaxies)** --

Method: Supernovae (Standard Candles)

Relevant Equation:

Description:

| **(Nearby Galaxies)** --

Method:

Relevant Equation: $F = L/4\pi R^2$

Description:

| **(Milky Way)** --

Method:

Relevant Equation: $F = L/4\pi R^2$

Description: We use a well known cluster of stars to calibrate for the apparent brightness of its main sequence stars – and use that (and the flux equation above), to find the distance to other similar clusters.

| **(Nearby Stars)** --

Method: Parallax

Relevant Equation:

Description:

| **(The Solar System)** --

Method:

Relevant Equation: $d = c * t$

Description:

| **(Earth)** --

(On earth, we can directly measure distances)

131) Mass of the Milky Way's Halo. The Large Magellanic Cloud (LMC) is a small galaxy that orbits the Milky Way. It is currently orbiting at a distance of 160,000 lightyears from the galactic center at a velocity of 300 km/s. Use these values and the orbital velocity law to estimate the mass of the Milky Way within the LMC's orbit. Give your answer in both kilograms and solar masses (1 solar mass = 2 x 10^{30} kg). *(Calculator Problem)*

$$M = \frac{r * v^2}{G}$$

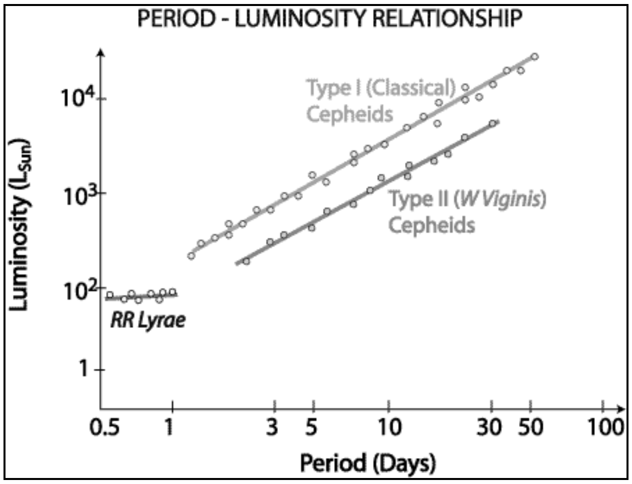
132) Mass of a Globular Cluster. Stars in a typical globular cluster orbit at speeds of 10 km/s in a circular orbit at a distance of about 50 lightyears (at the outskirts). Use these facts and the orbital velocity law above to calculate the mass of a typical globular cluster. *(Calculator Problem)*

133) Mass of Saturn and Earth in Ratio. Earth's Moon's orbit has about the same semimajor axis as Saturn's moon Dione (r = 380,000 km for both). The Moon's orbital velocity is about 1 km/s, whereas Dione's orbital velocity is about 10 km/s. Using the orbital velocity law above, and a ratio, find the approximate mass of Saturn in terms of Earth masses. **(You *could* directly solve for their masses, but try to use a ratio!)** *(No Calculator!)*

134) Cepheid Galaxies in M100. Using the Hubble Space Telescope, we have observed Cepheids in the galaxy of M100. Below are three such Cepheids. Use the data below to answer the following questions:

Cepheid A:brightness: 9.3×10^{-19} watts/m^2 period: 25 days
Cepheid B:brightness: 3.8×10^{-19} watts/m^2 period: 7 days
Cepheid C:brightness: 8.7×10^{-19} watts/m^2 period: 11 days

a. **Period-Luminosity Relationship:** Estimate the luminosity of each Cepheid from its period using the provided period-luminosity relationship plot below. (Note: we are observing Type I (Classical) Cepheids.) Give your answer in both Solar Luminosities (L_{sun}), and watts (1 L_{sun} = 3.4×10^{26} watts). *(Calculator problem)*



Cepheid A Luminosity: ____________________ L_{sun} and ___________________________ watts
Cepheid B Luminosity: ____________________ L_{sun} and ___________________________ watts
Cepheid C Luminosity: ____________________ L_{sun} and ___________________________ watts

b. **Flux Equation.** Using the flux equation (shown below), calculate the distance to each Cepheid. Give your answer in both meters and lightyears. *(Calculator Problem)*

$$F = \frac{L}{4\pi D^2}$$

Cepheid A Distance: ____________________ m and ___________________________ lightyears
Cepheid B Distance: ____________________ m and ___________________________ lightyears
Cepheid C Distance: ____________________ m and ___________________________ lightyears

c. **Accuracy?** Do all your distance measures agree? Estimate the true distance and an uncertainty in that measurement (ex., 10 lightyears ± 2 lightyears):

135) Cepheids. Cepheids make good standard candles because they all have the exact same luminosity.

- **a. True**
- **b. False**

136) Long Range Distance Measures. Which of the following type of standard candle is the best for measuring distances to extremely distant galaxies? (Explain your answer)

- **a. White Dwarfs**
- **b. Cepheid Variable Stars**
- **c. White Dwarf Supernovae**

137) Radar Distance Measurements: Apophis. To directly measure the distance to a near-Earth asteroid 99942 Apophis, we send out a pulse of radio waves and wait for the reflection signal. Let's say the return signal is detected 20 minutes after we sent it. How far away is Apophis from Earth right now? Give your answer in light-minutes, meters, and AU.

$$distance = speed * time$$

c = speed of light = 3.0×10^8 m/s
1 AU = 1.5×10^{11} m

138) Radar Distance Measurements: Alpha Centauri. If we wanted to use the radar-ranging technique we use in the solar system to directly determine the distance to the nearest star, Alpha Centauri, how long would we have to wait for the signal to return? (Alpha Centauri is 4 lightyears away.) Asides from this time delay, what is at least one other problem with this method?

139) White Dwarf Supernovae. Let's say we've observed the following white dwarf supernovae. Given their apparent brightness, rank them in order of increasing distance (1 = closest; 4 = furthest).

- **a. SN #1:** Luminosity = 1000 L_{sun} Rank: _____
- **b. SN #2:** Luminosity = 10 L_{sun} Rank: _____
- **c. SN #3:** Luminosity = 0.01 L_{sun} Rank: _____
- **d. SN #4:** Luminosity = 100 L_{sun} Rank: _____

140) Supernovae Distance Measures. Why are White Dwarf Supernovae (Type I) better distance measures for distance then typical high mass star Supernovae (Type II)?

- **a.** Type I supernovae occur only in far away galaxies; Type II can occur anywhere.
- **b.** Type I supernovae are all exactly the same brightness; Type II can be any range of brightnesses.
- **c.** Type I supernovae are always brighter then Type II supernovae.
- **d.** Type II supernovae are extremely rare compared to Type I supernovae.
- **e.** Type II supernovae can repeat periodically, and thus give false readings.

141) Parallax. The general equation for parallax is:

$$Distance\,[parsecs] = \frac{1\ AU}{Parallax\ Angle\,[arcseconds]}$$

Using this equation, answer the following questions:

- **a.** Rank the following stars in order of increasing distance (1 = closest; 6 = farthest). You do not need to actually calculate the distance.
    - i. **Star A**: parallax angle = 1 arcsecond ____
    - ii. **Star B**: parallax angle = 0.5 arcseconds ____
    - iii. **Star C**: parallax angle = 1 arcminutes ____
    - iv. **Star D**: parallax angle = 0.5 arcminutes ____
    - v. **Star E**: parallax angle = 1 degrees ____
    - vi. **Star F**: parallax angle = 0.5 degrees ____
- **b.** **Star G** has a parallax angle of 0.1 arcseconds. Calculate out its distance. *(No calculator)*

142) Hipparcos – Parallax. The Hipparcos satellite's mission was to accurately measure distances via the parallax technique. Hipparcos could detect parallax angles as small as 0.002 arcseconds.

- **a.** **Hipparcos at Earth**. Given the above angular resolution, determine the maximum distance Hipparcos could accurately measure via parallax. Give your answer in parsecs. *(No calculator)*

- **b.** **Hipparcos at Saturn.** Imagine that we could have put Hipparcos at Saturn's orbit, rather than Earth. This effectively increases the baseline of the parallax measurement. Determine the *new* maximum distance that Hipparcos can measure. Is the distance smaller or greater than when measured from Earth? (Saturn orbits at a distance of 10 AU) *(No calculator)*

143) Scaling with the Flux Law. Use either ratios or scaling to answer the following questions that are based off of the flux equation:

$$F = \frac{L}{4\pi D^2}$$

a. Star A and Star B have the same luminosity, but Star B is 5 times further away than Star A. How many times brighter is Star A than Star B?

b. Star C and Star D are the same distance away, but Star D has a flux that is 9 times larger than Star C. How does the luminosity of Star D compare to star C?

c. Star E is flying away from the Sun at 10 AU/year. Its luminosity is constant with time. If we observe Star E 10 years from now, how much dimmer will it be?

144) Hubble's Law. What discovery did Edwin Hubble make in the 1920's that resulted in Hubble's Law, and what did this mean?

145) Hubble's Law Examples. Using Hubble's Law, find the approximate distance to the following galaxies:

$$v = H_0 * d$$

(Where v is velocity [km/s], d is distance [Mpc = megaparsec], and H_0 is Hubble's Constant: 70 km/s/Mpc) *(No Calculator)*

a. **Galaxy A:** Speed away from us: 14,000 km/s d = ___________ Mpc

b. **Galaxy B:** Speed away from us: 21,000 km/s d = ___________ Mpc

c. **Galaxy C:** Speed away from us: 28,000 km/s d = ___________ Mpc

146) Hubble's Law Limitations. Why doesn't Hubble's Law work for nearby galaxies?

a. Nearby galaxies are not affected by the expansion of the universe – as this only affects galaxies in the early/distant universe.

b. The velocities of nearby galaxies are predominantly due to interactions with other galaxies – and not primarily universal expansion.

c. The high amounts of dark matter in the nearby universe negate the universal expansion – thus, invalidating Hubble's Law.

147) Galaxy Formation: Spirals vs. Ellipticals. When the first galaxies were forming, proto-galaxy spin and density are both important factors in determining whether that proto-galaxy will become a spiral or an elliptical galaxy. Circle which type of galaxy you get in the following cases, and briefly explain why.

- **a. Low Spin / Angular Momentum:** Spiral Elliptical
- **b. High Spin / Angular Momentum:** Spiral Elliptical
- **c. Low Density:** Spiral Elliptical
- **d. High Density:** Spiral Elliptical

148) Starburst Galaxies. Define what a starburst galaxy is, and how it comes to be:

149) Quasars. Where are most quasars located?

- **a.** Most quasars are located nearby --- implying they are a late stage in galactic evolution
- **b.** Most quasars are located far away --- implying they are an early stage in galactic formation
- **c.** Quasars are spread out across the universe --- implying they are an ongoing process in galaxy evolution

150) Size of Active Galactic Nuclei (AGN). AGN have the ability to vary on the timescale of light hours, meaning that they must be no larger than a few light hours across. Which of the following objects is around the size of AGN?

- **a.** The Sun
- **b.** The Solar System
- **c.** A Star Cluster
- **d.** The Milky Way

151) Power Source of AGN. What is the power source of Active Galactic Nuclei? Explain your reasoning.

- **a.** Antimatter-Matter Reactions
- **b.** Nuclear Fusion Energy
- **c.** Nuclear Fission Energy
- **d.** Chemical Energy
- **e.** Release of Potential Energy

152) Look-Back Time. Which of the following galaxies is likely the oldest? Explain Why.

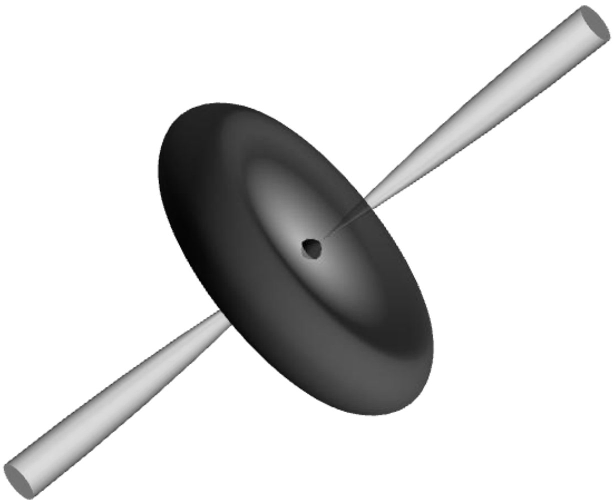
- **a.** A galaxy within the Local Group
- **b.** A galaxy observed at a distance of 5 billion lightyears
- **c.** A galaxy observed at a distance of 10 billion lightyears

153) Hubble's Constant. Hubble's constant is: 70 km/s/Mpc. Recall that 1 Mpc ~ 3×10^{19} km.

- **a.** Reduce the units of Hubble's constant to base SI units, and show that it has the units of 1/s.

- **b.** In a simple universe that is neither accelerating or decelerating, an estimate of the age of the Universe can be found by taking the inverse of Hubble's constant: $t = 1/H$. By using this method, how old is the Universe?

154) Standard Model of AGN. Below is a diagram of an AGN. According to the standard model, the type of AGN we see just depends on what angle we're looking at the AGN at. On the diagram, draw the different viewpoints and what type of galaxy you'd be 'observing.'



155) Galaxy Rotation. How do we know how fast stars orbit in galaxies?

- **a.** Direct Detection – we can directly watch the stars orbit when observed on long time scales.
- **b.** Spiral Arm Counts – we can infer the speed based on the number and structure of spiral arms.
- **c.** Doppler Method – we

156) Rotation Curves. Draw rotation curves for the following situations:

- **a.** **Solid Body Rotation** – the rotation curve for a solid object, like a rotating compact disk.
- **b.** **Keplerian Rotation** – the rotation curve for solar system (or other point mass system).
- **c.** **Uniform Density Rotation Curve** – a galaxy of uniform density, that truncates at some point.
- **d.** **Flat Rotation Curves** – the actual types of rotation curves we see in galaxies, due to <u>dark matter!</u>

157) Flat Rotation Curves. The flat rotation curve tells us that stars in the outskirts of the Milky Way orbit…

- **a.** Orbit just as fast as stars closer in to the center.
- **b.** Rotate more rapidly on their axes.
- **c.** Travel in straight lines, rather than elliptical orbits.

158) Dark Matter Evidence. Strong evidence for the existence of dark matter comes from observations of…

- **a.** Our solar system.
- **b.** Black hole and neutron stars.
- **c.** The center of the Milky Way.
- **d.** Clusters of Galaxies.

159) Dark Matter in Clusters. Explain the following three methods for measuring the mass of galaxy clusters (and thus methods to probe for dark matter).

- **a. Observing the orbits of individual galaxies in clusters:**

- **b. Observing the hot intergalactic gas in a cluster:**

- **c. Gravitational Lensing:**

160) MOND. How could modifying gravity (i.e., changing Newton's Laws of Gravity slightly) fix the dark matter problem? Why isn't this a popular solution?

161) Dark Matter Composition. Below are two different ideas of what could make up Dark Matter. Explain what each type is, and how they differ.

- **a. MACHOS**(Massive Compact Halo Objects):

- **b. WIMPS** (Weakly Interacting Massive Particles):

162) The Fate of the Universe. For each of the following cases, draw a schematic showing what will happen to the Universe – based upon the density of dark matter (ρ_{DM}), density of baryonic matter (ρ_{BM}), and amount of dark energy (ρ_{DE}) in comparison to the critical density ($\rho_{Critical}$). Also indicate the geometry of the associated universe.

a. Re-collapsing Universe:

$\rho_{DM} + \rho_{BM} > \rho_{Critical}$

$\rho_{DE} = 0$

Geometry: ________________

```
          size
           |
           |
           |
-------------------------------------------------------------------------------> time
           |
           |
           |
```

b. Critical Universe:

$\rho_{DM} + \rho_{BM} = \rho_{Critical}$

$\rho_{DE} = 0$

Geometry: ________________

```
          size
           |
           |
           |
-------------------------------------------------------------------------------> time
           |
           |
           |
```

c. Coasting Universe:

$\rho_{DM} + \rho_{BM} < \rho_{Critical}$

$\rho_{DE} = 0$

Geometry: ________________

```
          size
           |
           |
           |
-------------------------------------------------------------------------------> time
           |
           |
           |
```

d. Accelerating Universe:

$\rho_{DM} + \rho_{BM} < \rho_{DE}$

Geometry: ________________

```
          size
           |
           |
           |
-------------------------------------------------------------------------------> time
           |
           |
           |
```

e. Which of these model universes do we think we live in? ____

163) Dark Energy. Dark energy has been inferred to exist because…

- **a.** Observations suggesting that the expansion of the universe is expanding.
- **b.** The high orbital speeds of stars far from the center of our galaxy.
- **c.** The giant voids between large-scale structures in the universe.

164) Big Bang. Which of the following is <u>the most basic</u> premise of the Big Bang Theory?

- **a.** The Universe exploded from nothingness 14 billion years ago.
- **b.** The Universe was once much more hot and dense than it is now.
- **c.** The four fundamental forces used to be combined into one super force.
- **d.** The Universe is composed of about 75% Dark Energy, and 25% Matter.

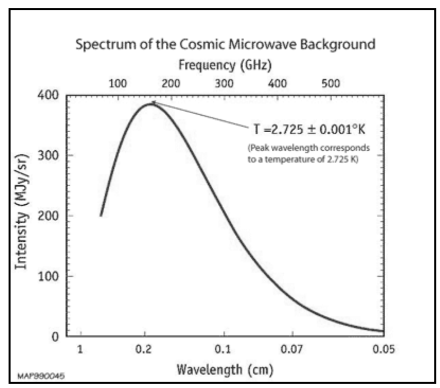
165) Fundamental Forces. Write a brief description of each of the following fundamental forces:

- **a. Gravity:**
- **b. Electromagnetic:**
- **c. Strong Force:**
- **d. Weak Force:**

166) Early Forces. Circle which forces were combined to form the following 'unified' forces – which only form at extremely high temperatures:

- **a. GUT (Grand Unified Theories):** Gravity, Electromagnetic, Strong Force, Weak Force
- **b. Electroweak:** Gravity, Electromagnetic, Strong Force, Weak Force

167) Cosmic Microwave Background (CMB).



- **a. Spectrum.** To the right is an image of the spectrum of the Cosmic Microwave Background. Thinking back, what type of spectrum is this?
  - i. **Emission Spectrum**
  - ii. **Absorption Spectrum**
  - iii. **Blackbody Spectrum**
  - iv. **Radio Spectrum**

- **b. Wien's Law.** Using Wien's Law (shown below), calculate the temperature of the Cosmic Microwave Background, knowing that it peak emits at 1.0 x 10^6 nm. *(No Calculator)*

$$\lambda_{max}[nm] = \frac{2{,}900{,}000\ [nm]}{T\ [kelvin]}$$

- **c. Origin.** Describe, <u>in detail</u>, what the origin is of the CMB. The CMB is by far the most important piece of evidence for the Big Bang model!

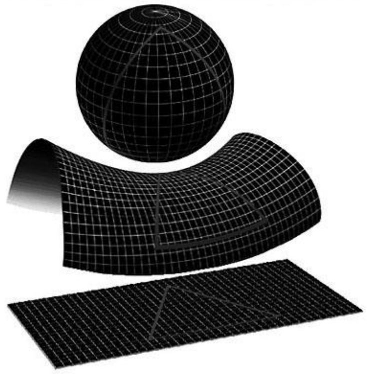
168) Timeline of the Early Universe. Fill out the chart below, discussing the different eras of the early universe.

Time	Era	Description	Temperature
	Planck Era		
10^{-43} Seconds			10^{32} K
	GUT Era		
10^{-38} Seconds			10^{29} K
	Electroweak Era		
10^{-10} Seconds			10^{15} K
	Particle Era		
10^{-3} Seconds			10^{12} K
	Nucleosynthesis Era		
5 minutes			10^{9} K
	Era of Nuclei		
380,000 yrs			3000 K
	Era of Atoms/Galaxies		
Now			3 K

169) Element Abundances.

- **a.** What was the original abundance of light elements, just after Big Bang Nucleosynthesis?
  - **i.** Hydrogen: ____
  - **ii.** Helium: ____
  - **iii.** Metals: ____
- **b.** Why didn't all of the elements form during Big Bang Nucleosynthesis?
  - **i.** There wasn't enough hydrogen and helium around to fuse heavier elements.
  - **ii.** The Universe cooled off too quickly for bigger reactions to move forward.
  - **iii.** All of the extra material that didn't form hydrogen and helium got annihilated by antimatter.
  - **iv.** At the time, all other atoms (carbon, iron, etc.) were unstable and would radioactively decay.

170) Universe Geometry. Looking at the figure below, identify what type of Universe geometry is represented, and answer the following questions about such universes.



a. **Flat Geometry: [A / B / C]**
   i. Parallel lines [**DO** / **DO NOT**] cross.
   ii. Angles in a triangle sum up to [**LESS THAN** / **EQUAL** / **MORE THAN**] 180 Degrees.

b. **Open Geometry: [A / B / C]**
   i. Parallel lines [**DO** / **DO NOT**] cross.
   ii. Angles in a triangle sum up to [**LESS THAN** / **EQUAL** / **MORE THAN**] 180 Degrees.

c. **Closed Geometry: [A / B / C]**
   i. Parallel lines [**DO** / **DO NOT**] cross.
   ii. Angles in a triangle sum up to [**LESS THAN** / **EQUAL** / **MORE THAN**] 180 Degrees.

171) Neutron Decay. The prime reason we have the ratio of hydrogen to helium that we do is because in the early universe, free neutrons decay (with a half-life of about 15 minutes). If the neutron decay rate were longer (or it never decayed), how would this affect the ratio of hydrogen to helium? Explain.

172) Cosmic Microwave Background Formation.

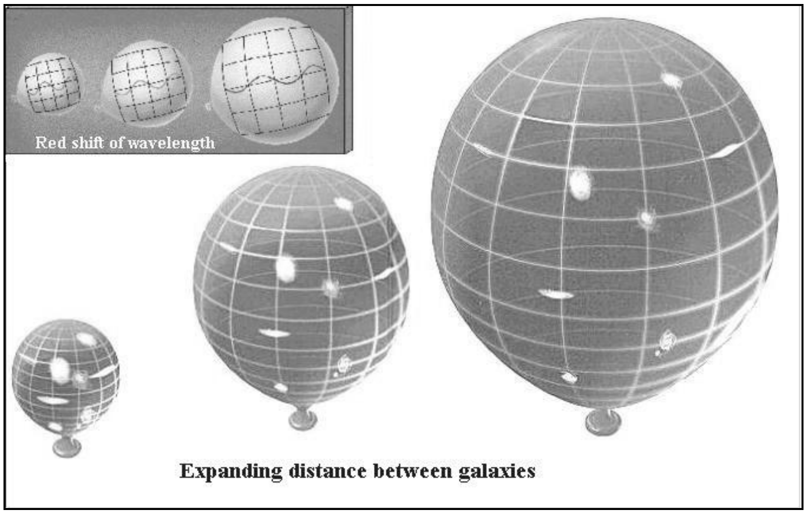
a. The CMB formed at the time that the Universe became optically thin (transparent) to photons, about 380,000 years after the Big Bang. The temperature of the universe at that time was 3000 Kelvin. Using Wien's Law, calculate out the wavelength of the CMB at the time of its formation: *(No Calculator)*

$$\lambda_{max}[nm] = \frac{3{,}000{,}000\ [nm]}{T\ [kelvin]}$$

b. Where does this peak lie in the electromagnetic spectrum? ____

c. What would the night sky have looked like if you were around right after the CMB's formation?

173) Expansion of the Universe. Below is a typical balloon-analogy diagram showing the expansion of the Universe. Explain why light from the early Universe gets redshifted over time.



174) Inflation. Inflation is a period in the early Universe where the Universe rapidly expanded (expanding by a factor of 10^{30} in as little as 10^{-36} seconds). Explain why Inflation is necessary for the following facets of the Big Bang Theory:

- **a. Why do we have structure in the Universe?**
- **b. Why the temperature of the CMB is is nearly homogeneous?**
- **c. Why the Universe appears to be flat?**

175) Olbers Paradox. Simply stated, Olber's paradox is "why is the sky dark"? Explain why each of the following models of the universe can yield "dark" skies.

- **a. The Universe is Finite in Size.**
- **b. The Universe is Finite in Age.**

176) Antimatter. Early in the universe, it is thought that there was an equal amount of matter and antimatter. However, today, all we see is regular matter in the Universe. What happened to that antimatter?

- **a.** The antimatter fused with the matter, forming atoms.
- **b.** The antimatter chemically reacted with the matter, forming molecules.
- **c.** The antimatter annihilated with most of the matter, forming gamma-rays.
- **d.** The antimatter is still out there, just obscured by dark matter.

177) Big Bang Test. Which of the following is not a good test of the Big Bang model:

- **a.** Observations of the Cosmic Microwave Background.
- **b.** Observations of the amount of Hydrogen in the Universe.
- **c.** Observations of the ratio of Helium to Hydrogen in the Universe.

178) Observations of the Big Bang. What is the earliest time in the Universe that we can theoretically directly observe?

- **a.** We can directly observe the Big Bang
- **b.** A few minutes after the Big Bang
- **c.** A few hundred thousand years after the Big Bang
- **d.** A few hundred million years after the Big Bang

179) Uniformity of the Cosmic Microwave Background. The Cosmic microwave background differs by only a few parts in 100,000 over the entire sky. Compare this to the surface of a table that is 1 meter in size. How large would the biggest bumps on the table be if it were level to one part in 100,000? Would you be able to see these bumps? *(No calculator)*

180) Antimatter Bomb. In the book/movie "Angels and Demons", terrorists steal half a gram of antimatter, and threaten to use it as a bomb. Using Einstein's famous " $E = mc^2$ ", find out how much energy would be released if that .5 grams of antimatter met up with .5 grams of regular matter. Compare this with the energy yield of a small nuclear bomb, which puts out 100 trillion joules. *(No calculator)*

181) Drake Equation. Use the Drake equation to make your own estimate of the number of alien civilizations in our galaxy that we could possibly communicate with right now:

$$N = R^* * f_p * n_e * f_l * f_i * f_c * L$$

R^* = average rate of star formation in our galaxy
f_p = fraction of those stars that have planets
n_e = fraction of those planets that can potentially support life
f_l = fraction of those that actually develop life
f_i = fraction of that life that becomes intelligent
f_c = fraction of those civilizations that send out detectable signals
L = the length of time such civilization sends out detectable signals

Which of the above numbers can we observationally measure right now?

Which of the above numbers are close to observationally measuring right now?

182) Intergalactic Cruiser. Suppose we have a spaceship about the size of a typical ocean cruiser today (mass = 100 million kilograms), and it is capable of reaching speeds of 10% the speed of light.

a. **Energy to 10% the Speed of Light.** How much energy would be required to get the ship to 10% the speed of light? You can find this out by determining the ship's kinetic energy at cruising speed: *(No Calculator)*

$$Kinetic\ Energy = \frac{1}{2}mv^2$$

b. **Antimatter Fuel.** Let's say the ship's engines are powered by antimatter/matter reactions (possibly regulated by dilithium crystals). How much matter and antimatter would be required to reach cruising velocity?

$$E = mc^2$$

c. **Cost of the Energy.** The typical cost of energy today is about 5 cents per 1 million joules. Using this price, how much would it cost to generate the energy needed by your space ship.

d. **Acceleration.** Let's say we want to comfortably accelerate at a rate of 1 x Earth's Gravity (9.81 m/s^2). How long would it take for the ship to reach its cruising speed of 10% the speed of light at this acceleration?

$$Acceleration\left[\frac{m}{s^2}\right] * time[s] = velocity\left[\frac{m}{s}\right]$$

e. **Reaching Alpha Centauri.** Neglecting the time spent on accelerating/decelerating, how long would it take to reach our nearest star: Alpha Centauri (distance = 4 lightyears) at our cruising speed of 10% the speed of light?