Astro 205. Fall 2003
Final Exam Study Questions

The final exam will be on Sunday, January 18, at 1 pm, 145 Peyton Hall, the auditorium in which we have our lectures. The exam will be drawn **entirely** from the following questions and will be **three hours** long. The exam will have two parts: the first quantitative, calculational problems, and the second a series of definitions. The list of questions in the exam itself will of course be much shorter than the list here. You may work together in preparation for the exam, but not during the exam itself. The exam will be closed book; calculators will be needed for the exam. We'll supply all necessary physical and astronomical constants with the exam, plus all necessary formulae except the most basic. In the meantime, you can find necessary constants and formulae in the course notes and on the course web site.

We will hold review sessions on **January 7 2004 and Jan 12 2004** from 7 - 10 pm in 145 Peyton Hall, the classroom for the course. You will be encouraged to work together during these sessions and we will be available for guidance. Also don't hesitate to contact any of us, any time, with questions.

Part 1: Quantitative Questions

1. Write down the Drake equation for the current number of civilizations in the Galaxy with the technology to communicate over interstellar distances. Write a short paragraph describing the meaning of each term in the equation, giving your best estimate of the value of that term, and a justification for it. With these values, evaluate the Drake Equation. **This question will be on the exam.** Needless to say, there is no one correct answer for this problem, but your values should be well justified.

2. The Earth is at a distance of 1.5 $\times 10^{13}$ cm (1 astronomical unit, AU) from the Sun and takes one year to make one complete orbit. From the Earth's distance, the Sun's angular diameter is about $30'$, 30 minutes of arc. What is the mean density of the Sun? Express your result in units of grams per cubic centimeter. **Calculate this from the information given in the question and your knowledge of physics and physical constants. Don't look up the radius and mass of the Sun.**

3. Suppose we decided to use **all** the Sun's light to support our civilization, and did this by pulverizing the Earth and surrounding the Sun with a thick spherical shell at our distance, 1 A.U. Assume that this shell radiates like a black body. The Sun would of course not be visible directly from the outside.
(a). As seen from another star at a distance of 5 parsecs, what would the effective temperature, spectrum, and luminosity of this system be?
(b). Would an astronomer 5 parsecs away be able to infer that this system was made by a technological civilization, or is it indistinguishable from an ordinary star or planet? That is, are there stars or planets of this surface temperature with this radius?

4. Consider a planet in circular orbit around a star of luminosity 10^3 $L_\odot$. Calculate the range of distances between the planet and the star in which water would be in liquid form. Express your result in AU. State your assumptions!

5. (a). Calculate the amplitude (in cm) of the the Sun's reflex motion due to Jupiter's orbit. You can ignore the effect of all other planets.
(b). Suppose the Galaxy is full of solar-mass stars with a single planet the mass of Jupiter orbiting at 5 AU. NASA Administrator Sean O'Keefe tells you to build an interferometer to detect the change in position of these stars due to the orbits of their planets. You have to do so for stars on the other side of the Galaxy (10 kiloparsecs away). Your interferometer operates at visible light, with a wavelength of 5000 Å$= 5 \times 10^{-5}$ cm. How long does the baseline of your interferometer have to be? Express the answer in meters.

6. An earth-like planet orbiting a solar-mass star has an orbital semi-major axis of 1 AU and an eccentricity of 0.5.
(a) What is the period of its orbit? Express the answer in years.
(b) What are its least and greatest distances from the star? Express the answer in AU.
(c) Estimate the range of temperatures encountered by the planet during its "year".

7. What diameter telescope would be required to distinguish North America (width: 5000 km) when observing from Alpha Centauri (distance: 4.4 light years) using visible light (wavelength: 5000 Å$= 5 \times 10^{-5}$ cm). Express the answer in meters.

8. For the sake of argument, assume that every star has exactly one planet with the same mass and composition as the Earth, and that the planet's distance from the star is equally likely to have any value between 0.01 and 100 AU. Define the inner and outer radii of the habitable zone as the freezing and boiling points of water. Star A has twice the Sun's mass, and star B has half the Sun's mass.
(a). Which star is more likely to have a habitable planet, A or B ? Why?
(b). Now consider a star with 20 times the mass of the Sun. Is this star likely to have a planet which can support intelligent life?

9. According to legend, famous physicist, practical joker, and Princeton graduate Richard Feynman once tried to get out of a traffic ticket for running a red light (wavelength 8000Å) by claiming that he was driving so fast that the light looked green (wavelength 5000Å) because of the Doppler effect. Unfortunately for Feynman, the traffic judge, who had taken some physics courses as an undergraduate, pretended to believe this story and fined him \$1 for every mile per hour in excess of the posted speed limit. Estimate the fine Feynman paid.

10. In a last-ditch attempt to preserve earthlings from Weapons of Mass Destruction, the U.S. decides to send spacecraft to other stars, with DNA sequence data and robotic labs to clone citizens from chemicals available at the destination. Each is a cylinder 10m long by 1 m in radius, has the approximate density of water, travels between stars at the orbital velocity of the Earth, and costs $\$10^5$ per kilogram.

(a) Assuming that sun-like stars are about 6 light-years apart and that one in a thousand has a habitable planet, how long will it take to reach the nearest safe haven? Express your answer in years.
(b) Since we don't know which sun-like stars have habitable planets, so that spacecraft must be sent to one thousand stars to have a reasonable chance that one will have a habitable planet, can earthlings be saved without doubling the U.S. national debt (currently seven trillion dollars)?
(c) Upon arrival, the spacecraft discovers a planet with an atmosphere and surface temperature similar to that of Earth a billion years after it formed. Could the planet support humans? If not, propose a long-term strategy for the propagation of DNA-based life, if not human life, on the planet.

11. Observations indicate that most sun-like stars are born with gas disks having about one percent of a solar mass and lasting a few million years. For a star with metallicity of 2% by mass (i.e., the same as the Sun) , what is the maximum number of earth-mass planets each star could form?

12. (a) The gravitational acceleration g on the surface of a planet of radius R and mass M is GM/R^2. Calculate the ratio of the gravitational acceleration on the surface of the Earth to that on the surface of a neutron star (radius 10 km, mass 1.4 solar masses).
(b) Close to the surface, g is constant and an object dropped from a height H will impact the surface with a speed $\sqrt{2gH}$. Calculate the kinetic energy released when a marshmallow (mass 5 gm) dropped from a height of 1 meter impacts the surface of the earth, and when it impacts the surface of a neutron star. Express your answers in ergs.
(c) Calculate the energy in ergs released in the explosion of a 1 kilogram hydrogen fusion bomb; remember that 0.7% of the rest-mass energy of hydrogen is released when it fuses to helium. How many marshmallows would have to be dropped onto a neutron star and onto the Earth to equal the energy released by the bomb?

13. (a) You have an instrument capable of measuring the position of a star to a precision of one microarcsecond (one millionth of an arc second). How close to us would a sun-like star have to be for us to be able to detect the motion of the star on the sky due to an Earth mass planet at 1 AU from that star? A Jupiter mass planet at 5.2 AU from that star? Express your answer in parsecs.
(b) What measurement precision (in meters per second) would be required to detect (i) a one earth mass planet orbiting a solar mass star at a distance of 1 AU and (ii) a 1 Jupiter mass planet orbiting a solar-mass star at a distance of 5.2 AU?

14. (a) A planet of radius R_{pl} is in a circular orbit at a distance D from a star of radius $R_\star$. Derive a formula giving the range of the orbital inclination (in radians) to the line of sight that will cause a transit (eclipse) that can be seen by a distant observer (i.e., one much further away than D). Include the effect of the size of the planet; that is, assume that even a partial eclipse can be detected. You can assume that the inclination angle is small and thus use the small-angle approximation.
(b) You can assume that inclination angles vary uniformly from 0 to $\pi/2$ radians (or 90

degrees), i.e. from exactly aligned with the line of sight to perpendicular to the line of sight, what is the probability of observing a transit for this star-planet system?
(c) Calculate this probability of observing a transit for a Jupiter-sized planet orbiting a sun-like star at a distance of 0.05 AU.

15. A technical civilization sets up a beacon to broadcast a signal. The largest radio telescope in the world, the Arecibo 305 m, can detect signals with a received flux of 7×10^{-23} ergs/sec/cm^2. What is the luminosity of a beacon powerful enough to be detected by Arecibo at a distance of 10 kiloparsecs (i.e., the other side of the Galaxy? Express your answer in erg/sec. What fraction of the Sun's luminosity is this? How does it compare with the total amount of sunlight received by the Earth?

16. (a) What is the land area of the Earth? The Earth's radius is 6400 km and 70% of the surface is covered by oceans. Express your answer in square meters.
(b) Assume that the Earth's human population grows at 1% per year. This implies that the world population, N will obey

$$N(t) = N_o \exp(t/100\,\mathrm{yrs})$$

where N_o is the population when $t = 0$. The world population in 2000 was 6 billion. If growth continues at this rate what would the population be in year 2100? in year 3000?
(c) What would the population density (number of people per square meter) be 100 and 1000 years from now?

17. Consider the impact between an iron meteoroid (density $\rho = 7$ g/cm^3, diameter 300 meters) and the Earth. Calculate the meteroid's kinetic energy in ergs if it hits the Earth at a velocity of 12 km/s. Compare the energy released in this impact with that of the A-bomb which destroyed Hiroshima in WWII - the equivalent of 15,000 tons of TNT. (The explosion of 1 ton of TNT releases 4.2×10^{16} ergs).

18. The Voyager I spacecraft detected nine active volcanoes on Jupiter's moon Io. Io's radius is 1800 kilometers. On average, there are nine volcanoes active on Io at any given time. Each volcano emits 50 km^3 of lava per year. Calculate how deep the layer of lava will be on Io's surface after one year. Express your answer in centimeters.

19. The effective temperature of a object is calculated from its luminosity and radius assuming that it is radiating as a black body:

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

Jupiter is at a distance of 5.2 AU from the Sun and has an albedo of 0.5. What would be its equilibrium temperature due to the heating of the Sun (assuming no greenhouse effect)? But Jupiter's effective temperature is observed to be 125 K. What is the explanation for the discrepancy? *Hint: it is not due to the greenhouse effect.*

20. The first extrasolar planets discovered were Jupiter mass planets closer to the star than 1 AU.

(a) Why are these planets easiest to detect? Your answer should include any relevant formulae that express the relationship between the planet's mass and orbital distance from the star, and the quantity which is measured to establish the existence of the planet.
(b) Why were astronomers surprised to find massive planets so close to the Sun?
(c) We know that at least one of these massive planets has a hydrogen atmosphere. How do we know this?

Part 2: Definitions

Define each term listed below and give its major significance, in the context of the material covered in AST 205, in two or three sentences. Stick to the most important points rather than attempting to say all that you might know about the topic. For example, if the term were "amino acids", a reasonable answer would look something like this:

Amino acids are a class of organic compounds in which a carbon atom is bound to an amino (NH_2) and a carboxy (COOH) group and which typically contain a total of one or two dozen atoms. The amino and carboxy portions of any two amino acids may join (or "plug") together to form a peptide bond. Proteins consist of long chains of 20 specific amino acids held together by peptide bonds in an order which is encoded by nucleic acids.

Kepler's Laws
Angular momentum
Black body radiation
The main sequence
Doppler shift
The radial velocity or Doppler wobble technique
Brown dwarfs
Gravitational lens
Microlensing light curve
Planetary transit
Inclination
Telescope resolving power
Pupil coronagraph
Interferometry
Big Bang
Cosmic Microwave Background
Protostellar disks
Planetary migration
Greenhouse effect
Snowball Earth
Pulsars
Pulsar timing
Proteins
Nucleic acids
Codons

Eukaryotes
Urey-Miller Experiment
Tree of Life
Mars
Europa
Hydrothermal vents
Three domains of life
Adenosine triphosphate (ATP)
Darwinian evolution
Metazoans
Time statistics
Plate tectonics
Galactic time units
Biomarkers
The red edge
Earthshine
SETI
Bussard interstellar ramjet
Fermi paradox
Panspermia
Terrestrial Planet Finder (TPF)