

Astronomy 18, UCSC
Planets and Planetary Systems
Generic Mid-Term Exam (A combination of exams from the past several times this class was taught)

This exam consists of two parts:

Part 1: Multiple Choice Questions

Part 2: Short-Answer Questions.

Equations you may want to refer to:

$$K. E. = (1/2) m v^2$$

$$p^2 = a^3 \text{ (Kepler's 3rd Law) Units: Earth years, AU}$$

$$p^2 = \frac{4\pi^2}{G(M_1 + M_2)} a^3 \text{ (Newton's version of Kepler's 3rd Law) Units: sec, m, kg}$$

$$G = 6.67 \times 10^{-11} \frac{m^3}{kg \text{ sec}^2}$$

$$E = hf = hc / \lambda, \quad h = 6.63 \times 10^{-34} \text{ joule sec}$$

$$\text{Flux} = \sigma T^4 \text{ Watts}/m^2, \quad \sigma = 5.7 \times 10^{-8} \text{ Watts}/(m^2 K^4)$$

Speed of light: $c = 300,000 \text{ km/sec}$

$$1 \text{ nm} = 10^{-9} \text{ m}$$

$$\text{Doppler shift: } \frac{v}{c} = \frac{\Delta\lambda}{\lambda_0}$$

$$\text{Diffraction limit (arc sec)} = 2.5 \times 10^5 \left(\frac{\lambda}{D} \right) \text{ where } \lambda \text{ and } D \text{ are in the same units}$$

Part 1: Multiple Choice Questions

- 1) Why did Carl Sagan say that we are “star stuff”?
 - a) The composition of most stars is about the same as the composition of our bodies
 - b) Nearly every atom from which we are made was once inside of a star
 - c) Nearly every atom from which we are made was once inside the Sun

- 2) What is an Astronomical Unit?
 - a) The average speed of the Earth around the Sun
 - b) The length of time it takes the Earth to go around the Sun in its orbit
 - c) The average distance from the Earth to the Sun

- 3) Which object has the most kinetic energy?
 - a) A 4,000 kg truck moving at 50 km/hr
 - b) A 3,000 kg truck moving at 70 km/hr
 - c) A 2,000 kg truck moving at 90 km/hr
 - d) A 1,000 kg truck moving at 110 km/hr

(this space left blank for scratch calculations)

- 4) How large is the *acceleration of gravity* at the surface of the Earth?
 - a) 9.8 meters / sec downward
 - b) 9.8 meters / sec² downward
 - c) 9.8 m² / sec downward

- 5) If you drop a rock from a great height, about how fast will it be falling after 5 seconds, neglecting air resistance?
 - a) 10 meters / sec
 - b) 50 meters / sec
 - c) It depends how heavy the rock is

- 6) Momentum is defined as
 - a) mass times velocity
 - b) mass times acceleration
 - c) force time velocity
 - d) force times acceleration

- 7) Circle all that apply: Kepler's third law, $p^2 = a^3$, means that
- a) A planet's period does not depend on the eccentricity of its orbit
 - b) All orbits with the same semi-major axis have the same period
 - c) The period of a planet does not depend on its mass
 - d) Planets that are farther from the Sun move at slower average speeds than nearer planets
 - e) All of the above
- 8) Circle all that apply: The *frequency* of a wave is
- a) the number of peaks passing by any point each second
 - b) measured in cycles per second
 - c) equal to the speed of the wave divided by the wavelength of the wave
 - d) all of the above
- 9) When white light passes through a cool cloud of gas, we see
- a) thermal radiation
 - b) an absorption line spectrum
 - c) an emission line spectrum
- 10) What do we mean by the *diffraction limit* of a telescope?
- a) It is the maximum size to which a telescope lens or mirror can be built
 - b) It describes the farthest distance to which a telescope can see
 - c) It describes the maximum exposure time for images captured with a telescope
 - d) It is the best angular resolution the telescope could achieve, if its optical quality were perfect and if there were no distortions due to the atmosphere
- 11) What is the primary purpose of *adaptive optics*?
- a) To improve the magnification of space telescopes
 - b) To eliminate the distorting effects of atmospheric turbulence for telescopes on the ground
 - c) To increase the collecting area of telescopes on the ground
 - d) To allow several small telescopes to work together with the effective angular resolution of a single larger telescope
- 12) What percentage of the mass of the early solar nebula consisted of the elements hydrogen and helium?
- a) 0.5 percent
 - b) 5 percent
 - c) 50 percent
 - d) 98 percent

- 13) What was the first *frost line* of the Solar System?
- a) The distance from the Sun where temperatures were low enough for metals to condense. Roughly between the Sun and the present-day orbit of Mercury.
 - b) The distance from the Sun where temperatures were low enough for rocks to condense. Roughly between the present-day orbits of Mercury and Venus.
 - c) The distance from the Sun where temperatures were low enough for hydrogen compounds to condense into ices. Roughly between the present-day orbits of Mars and Jupiter.
 - d) The distance from the Sun where temperatures were low enough for hydrogen and helium to condense. Roughly between the present-day orbits of Saturn and Uranus.
- 14) Why are the inner planets made of denser materials than the outer planets?
- a) Denser materials were heavier and sank to the center of the solar nebula.
 - b) In the inner part of the nebula, only metals and rocks were able to condense because of the high temperatures there.
 - c) Early in the life of the solar nebula when the protoplanetary disk was spinning faster, centrifugal forces flung the lighter materials toward the outer part of the nebula.
- 15) According to the nebular hypothesis for Solar System formation, what are the asteroids and comets?
- a) They are shattered remains of collisions between planets
 - b) They are shattered remains of collisions between moons
 - c) They are leftover planetesimals that never accreted into planets
 - d) They are chunks of rock or ice that condensed long after the planets had formed
- 16) The age of our Solar System is approximately
- a) 10,000 years
 - b) 4.6 million years
 - c) 4.6 billion years
 - d) 13 billion years
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Part 2: Short-Answer Questions

Be sure to explain each step of your reasoning in words as well as in symbols, and be sure to clearly state what units you are using. That way we can give you partial credit even if your answer isn't complete.

1) How far is a light-year? Show your work clearly in the space below, and indicate what units you are using. *Hint:* refer to speed of light in the list of equations.

2) The Moon orbits the Earth in an average of 27.3 days at an average distance of 384,000 km. Using Newton's version of Kepler's third law (see equation section), calculate the mass of the Earth. You may neglect the mass of the Moon compared with the mass of the Earth. Be sure to use consistent units (e.g. kg, meters, sec), and describe your reasoning below:

3) Suppose that when the Sun was very young, its surface temperature was 18,000K (rather than the 6,000K that it is today). How much more thermal radiation flux would the young Sun be emitting? Be sure to state what units you are using.

4) In a hydrogen atom, the transition from level 2 to level 1 has a rest wavelength of 121.6 nm. (1 nm = 10^{-9} meter.) Suppose you observe spectra of two stars and find that this line is at a wavelength of 121.4 nm in Star A, and at 121.7 nm in Star B.

a) Describe whether each star is moving towards us or away from us. Which star is moving fastest relative to us? *Hint*: you will not need a calculator to answer the questions in part a).

b) Calculate the speeds of Stars A and B. Be sure to state your units, and whether each star is moving towards or away from us.

5) The diffraction-limited angular resolution of a 10-m diameter telescope is about 0.02 arc sec for *infrared light* whose wavelength is 1 micron (1 micron = 10^{-6} meters). Let's say that you wanted to build a *radio telescope* that would detect radio waves at a wavelength of 10^{-2} m = 1 cm. What would the diameter of the radio telescope have to be in order to achieve an angular resolution of 0.02 arc sec? How big is this in km? Is this practical? How else might you achieve this angular resolution?

7) In the entire early Solar System, assume that the density of material forming solid planetesimals was $3 \times 10^3 \text{ kg m}^{-3}$. How many planetesimals of 100-km diameter would it take to form a body with the mass of the Earth, which has a mass of $6 \times 10^{24} \text{ kg}$? *Hint:* It is a reasonable approximation to treat these planetesimals as spheres. The volume V of a sphere of radius R is given by $V = (4/3) \pi R^3$.