

Physics 306, Honors Astronomy, Final Exam

NAME _____

You are graded on your work, with partial credit where it is deserved.

1. Clearly describe how you (as an astronomer) would measure each of the following:

(a) (2) Which elements are in the atmosphere of a star:

(b) (2) How fast a star is moving away from us (or toward us):

(c) (2) The distance to a Cepheid variable star:

(d) (2) The surface temperature of a star:

(e) (2) The mass of a heavy star which has a substantially lighter star as a companion in a binary system, if the distance between the stars can be determined with, e.g., parallax. (Actually, this basic method works for both stars in any binary system, but for simplicity let us suppose that you can just think of the lighter star as revolving around the heavier one.)

2. Below, in Parts (a) – (d), arrange the following cosmological eras in chronological order, **with the earliest first and the latest last**:

era of atoms (with universe relatively transparent to light)

GUT era and era of inflation

era of nucleosynthesis

Planck era

Then briefly give some substantial information about each era. This information should include a very crude indication of the time and temperature, as well as the fundamental significance of each era.

(a) (3)

(b) (3)

(c) (3)

(d) (3)

3. List the “4 pillars of the Big Bang theory” and briefly indicate how each one of them involves a comparison between theory and observation.

(a) (2)

(b) (2)

(c) (2)

(d) (2)

4. (a) (3) List 6 quantities that must be conserved in a nuclear reaction.

(i)

(ii)

(iii)

(iv)

(v)

(vi)

(b) (7) State whether each of the following reactions is possible. I.e., say whether it satisfies all the conservation laws, and if not say which conservation law is violated.

Here n^0 is a neutron, p^+ a proton, e^- an electron, e^+ a positron, γ a photon, ν a neutrino, and $\bar{\nu}$ an antineutrino.

(i) $n^0 \rightarrow p^+ + e^- + \gamma$

(ii) $n^0 \rightarrow p^+ + e^- + \bar{\nu}$

(iii) $n^0 \rightarrow p^+ + e^- + \nu$

(iv) $p^+ \rightarrow e^+ + \nu$

(v) $p^+ + p^+ \rightarrow p^+ + n^0 + e^+ + \gamma$

(vi) $p^+ + p^+ \rightarrow p^+ + n^0 + e^+ + \nu$

Now, one of the reactions above represents beta decay, and one represents a fusion reaction within our Sun.

Mark these 2 reactions with “beta decay” and “fusion” respectively, with the relevant phrase to the right of the reaction.

5. (a) (5) Once again (just as in class, and even on a previous exam) recall that a mass m , moving with velocity v , must be subjected to a centripetal force

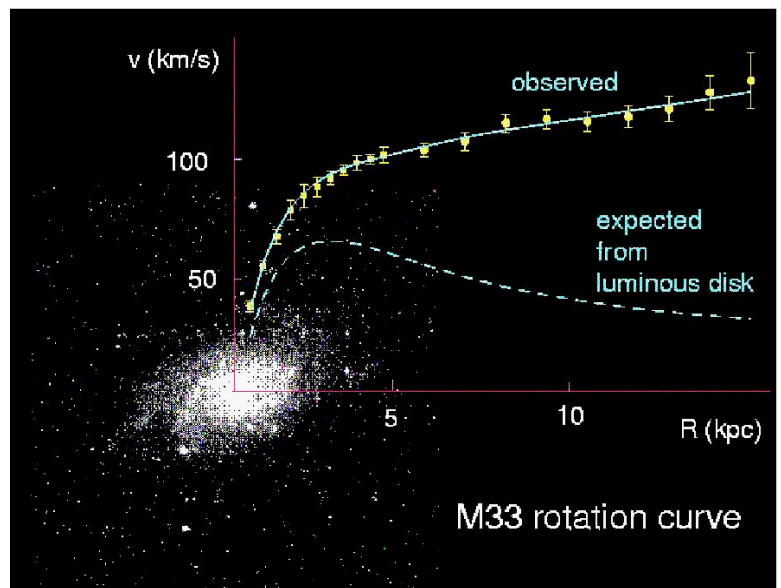
$$F = m \frac{v^2}{r}$$

if it is to be kept in a circular orbit of radius r . If this force is due to the gravitational attraction of a much larger mass M , then we also have

$$F = G \frac{mM}{r^2} \quad \text{where} \quad G = 6.67 \times 10^{-11} \text{ m}^3/\text{kg s}^2.$$

Combine these equations to find the expression for M in terms of m , v , and r .

(b) (5) Hydrogen atoms revolving around a galaxy are typically found to have larger velocities than can be accounted for with only luminous matter, and this is one of the strong arguments for the presence of dark matter. Use the graph below to approximately calculate the mass contained within 10 kpc of the center of the galaxy M33.



From <http://www.pppa.group.shef.ac.uk/dm/images/rotationCurve.jpg>

$$1 \text{ km} = 1 \text{ kilometer} = 10^3 \text{ m}$$

$$1 \text{ kpc} = 1 \text{ kiloparsec} = 3.26 \times 10^3 \text{ light years}$$

$$1 \text{ light year} = 9.46 \times 10^{15} \text{ m}$$

6. (a) (5) A planet discovered around the star 51 Pegasi has an orbital period of 4.23 days.

Calculate the distance of the planet from its star (or more precisely, the semimajor axis a of the planet's elliptical orbit). Since 51 Pegasi has about the same mass as our Sun, you can use the simple form of Kepler's third law

$$p^2 = a^3$$

where the period p is measured in years and a is measured in AU (astronomical units).

1 AU $\approx 1.50 \times 10^8$ km and 1 year ≈ 365 days

(b) (5) Describe 3 major methods used to detect extrasolar planets, saying briefly what each method tells you about the planet.

(i)

(ii)

(iii)

7. A planet is found to block 1% of the light from its star when it is making a transit. The star has a radius of 500,000 km.

(a) (4) Calculate the radius of the planet.

(b) (4) The mass of the planet is found to be 4.0×10^{26} kg. Calculate the mass density in g/cm^3 .

(c) (2) Is this planet more like Earth or more like Jupiter? Explain.

8. List and clearly describe the 3 different processes that can lead to internal heat and volcanic activity in a planet or large moon, making reference to the example that is provided in each case.

(a) (2) Early Earth:

(b) (4) Present-day Earth:

(c) (4) Io:

9. Starting with the Sun, then moving outward (**with the object nearest the Sun first**) list 10 of your favorite objects in the Solar System, including the 8 that are still officially classified as planets.

In each case, clearly describe one substantial and nontrivial feature about each object that you find interesting.

(a) (2)

(b) (2)

(c) (2)

(d) (2)

(e) (2)

(f) (2)

(g) (2)

(h) (2)

(i) (2)

(j) (2)

10. (5 points extra credit) Briefly describe the significance of each of the following experiments:

(a) Wilson and Penzias, 1964:

(b) COBE (Cosmic Background Explorer), early 1990s:

(c) WMAP (Wilkinson Microwave Anisotropy Probe), early 2000s:

11. (5 points extra credit) Qualitatively describe the particles in the Standard Model of particle physics, including the 3 generations of quarks and leptons and the various force-carrying particles.

List all 4 members of the first generation of quarks and leptons.

What is the quark content of a proton and of a neutron?

What are the charges of these quarks?

Happy Holidays, and have a Merry Christmas!