University of California, Santa Barbara
Department of Physics

Astronomy 2 Midterm
Spring 2012

Answer Key

Potentially Useful Values:

Planck's Constant: $h = 6.63 \times 10^{-34}$ J·s

Speed of Light: $c = 3.0 \times 10^{8}$ m/s

Gravitational Constant: $G = 6.67 \times 10^{-11}$ N $(\mathrm{m/kg})^2$

Stefan-Boltzmann Constant: $\sigma = 5.67 \times 10^{-8}$ W/(m^2 K^4)

Mass of an Electron: $m_e = 9.11 \times 10^{-31}$ kg

Mass of a Proton: $m_p = 1.67 \times 10^{-27}$ kg

Mass of the Sun: $M_{sun} = 1.99 \times 10^{30}$ kg

Luminosity of the Sun: $\mathcal{L}_{sun} = 3.84 \times 10^{26}$ W

Potentially Useful Equations:

Eddington Limit: $\mathcal{L}_{Edd} = 30,000 \left(\frac{M}{M_{sun}}\right) \mathcal{L}_{sun}$

Stefan-Boltzmann Law: Surface Irradiance $= \sigma T^4$

Angular Resolution: $R = \frac{\lambda}{D}$

Force Associated with a Circular Orbit: $F = m\frac{v^2}{r}$

Mass-Energy Equivalence: $E = mc^2$

Energy of Photon: $E = h\nu = \frac{hc}{\lambda}$

Gravitational Force Law: $F = G\frac{Mm}{r^2}$

Conversion Between Radians and Arcseconds: 1 radian $= 2.06 \times 10^5$ arcseconds

Section I: True or False (2 points each)

1. We could calculate the mass of the Earth by simply knowing (1) the radius of the Earth (2) the air pressure at sea level and (3) the value of the gravitational constant G. **(False)**

2. We are able to observe the stars very close to the center of the Milky Way, orbiting our Supermassive Black Hole. **(True)**

3. Iron is the heaviest element produced abundantly in stars because it has the greatest mass per nuclear particle. **(False)**

4. We can estimate the approximate age of galaxies by counting the number of turns of the spiral arms. **(False)**

5. The stars very close to the supermassive black hole at the center of the Milky Way obey all of Kepler's Laws, whereas the stars out in the arm tend to not. **(True)**

6. Einstein's Special Theory of Relativity provides an accurate framework with which can understand gravity very well. **(False)**

7. The oldest stars are made of pure hydrogen and helium; no spectral lines are observed from heavier elements. **(False)**

8. The surface brightness of the Sun (flux per square degree on the Celestial Sphere), is the same whether your observe it from Earth or from Pluto. **(True)**

9. Microlensing observations of the stars in the Large Magellanic Cloud (a smaller companion galaxy to our own Milky Way) show that most of our galaxy's dark halo is in the form of brown dwarfs. **(False)**

10. Time passes more quickly on an orbiting Earth satellite compared with time on the surface of the Earth. **(True)**

Section II: Multiple Choice Questions (4 points each)

11. We can estimate the mass of an object by observing the orbits of objects orbiting around it. If a certain object of mass m and velocity v is orbiting a star a distance R from the center of the star, what is the star's mass M:

    A. $M = \frac{vR}{G}$

    B. $M = \frac{vR^2}{G}$

    C. $M = \frac{vR}{4\pi G}$

    D. $M = \frac{v^2R}{G}$

    E. $M = \frac{1}{2}\frac{v^2R}{G}$

12. Historically, it was difficult to find the optical objects corresponding to radio sources because the angular resolution of a single radio telescope was too poor. How did we get around the problem?

    A. Wizardry.

    B. By making the telescope lens square instead of round, the problem was fixed through strange phenomenon in quantum mechanics.

    C. We set up large interferometers with multiple radio telescopes kilometers apart in distance.

    D. New types of detectors were invented which resolved the problem.

    E. We didn't. That is why we primarily observe in the infrared, optical, and ultraviolet regimes.

13. Which of the following is NOT true about the formation of elements in the natural universe?

    A. Primordial nucleosynthesis following the Big Bang led to the production of elements heavier than helium.

    B. In the accretion disks of black holes, conditions can be hot and dense enough for nuclear fusion to occur.

    C. Elements heavier than iron are primarily formed during supernovae, which are the only natural events extreme enough to produce large quantities of heavier elements.

    D. Newly formed stars in the arms of spiral galaxies tend to have a greater abundance of heavier elements.

    E. These are all correct.

14. Electron/position annihilation must be taking place in objects near the Milky Way nucleus. When a positron and an electron meet, they annihilate and their mass gets converted into two photons, each with energy equal to about half of the total energy of the original two particles. Assume that an electron and positron meet, while moving slowly enough that you can estimate each energy as just mc^2. (Positrons are the anti-matter electron, so they have the same mass.) What frequency are the photons produced in this annihilation.

    A. 2.5×10^{20} Hz

    B. 6.2×10^{19} Hz

    C. 2.5×10^{17} Hz

    D. 1.2×10^{20} Hz

    E. 6.2×10^{22} Hz

15. What determines the temperature of a rocky planet, assuming it has no atmosphere, and orbits around a star.

    A. the chemical composition of the outer surface

    B. the radiation absorbed from the star

    C. the radiation emitted from the planet

    D. the heat left over from its formation

    E. both (B) and (C)

16. The principle nuclear reaction in main sequence stars is

    A. fusion of helium into carbon

    B. fusion of carbon into iron

    C. fusion of hydrogen into helium

    D. fission of heavy elements into iron

    E. both (A) and (C)

17. Approximately how big is a neutron star?

    A. the size of the Earth's orbit around the Sun

    B. the size of the Sun

    C. the size of a city

    D. the size of a house

    E. both (A) and (D)

18. Cephied variable stars are very useful for finding distances to other galaxies because they exhibit a strong relation between their pulsation period and their:

    A. age

    B. luminosity

    C. mass

    D. surface temperature

    E. distance from Earth

19. The globular clusters are found mostly on one side of the Celestial Sphere. This suggests:

    A. The other half of the Celestial Sphere is obscured by dust.

    B. The globular clusters are located mostly on one side of the Milky Way.

    C. The globular clusters are made of very old stars.

    D. The globular clusters are low in heavy element abundance.

    E. The globular clusters are centered on the Milky Way and we are offset from the center.

20. The rotation curves of spiral galaxies indicate the presence of dark matter due to:

    A. the shape of the rotation curve in the vicinity of the central black hole.

    B. the shape of the rotation curve for radii similar to that of the Sun.

    C. the fact that the outermost stars in galaxies follow Kepler's laws.

    D. the fact that the outermost stars disobey Kepler's laws.

    E. the fact that most rotation curves look the same.

21. What sets the Eddington limit (the maximum luminosity of any body held together by self-gravity)?

    A. the balance between gravity and outward hydrostatic pressure.

    B. the balance between the luminosity and masses of stars.

    C. the balance between the outward pressure from photons and the gravity.

    D. the maximum luminosity of a white dwarf star.

    E. Eddington sets the Eddington limit.

22. The key axiom of General Relativity is:

    A. The speed of light is the same for any observer in any reference frame.

    B. It is impossible to distinguish if you're in an accelerating windowless spaceship or in a windowless box on the surface of a gravitating body.

    C. Light pressure always balances gravitational force.

    D. Massive stars run out of hydrogen fuel faster than low mass stars.

    E. Lighter elements have more mass per nuclear particle than either hydrogen or helium.

23. The Very Large Array of radio telescopes has 27 dish antennas spread over a distance of 30 km. If you are observing radio waves of wavelength $\lambda = 6$ cm, what is your approximate angular resolution?

    A. 0.1 arcseconds

    B. 0.4 arcseconds

    C. 1.2 arcseconds

    D. 0.4 arcminutes

    E. 0.1 degrees

24. The most powerful quasars have luminosities of around 10^{41} Watts. The Eddington Limit requires that the masses of the quasars have to be at least what value?

    A. $1.7 \times 10^{29} M_{sun}$

    B. $5.5 \times 10^{6} M_{sun}$

    C. $8.7 \times 10^{9} M_{sun}$

    D. $6.2 \times 10^{16} M_{sun}$

    E. $1.1 \times 10^{21} M_{sun}$

25. Which is NOT a good test of spatial curvature?

    A. The mass/luminosity relation on the main sequence, and the periods of Cephied variable stars.

    B. comparing the angular sizes of distant galaxies to that expected from the small angle formula

    C. adding the interior angles of a big triangle to see if they total 180°.

    D. Comparing the fluxes of galaxies as a function of distance to the small angle formula.

    E. All of these are a good test of spatial curvature.