Mid-term test AST121, Feb. 15th, 1 hour

Student Name: **Student Number:**

The test is composed of 20 multiple choice questions. Only one answer is correct. One point each question. Mark your answers on the scantron sheet. Hand in **both** the exam paper and the scantron sheet. The exam paper has 4 pages (double-sided).

A list of physical constants in MKS (or SI) units, kg is kilogram, m is meter, K is Kelvin, s is second, N is Newton, J is Joule, C is coulomb.

elementary charge $e = 1.602 \times 10^{-19}$ C

proton rest mass $m_p = 1.672 \times 10^{-27}$ kg

neutron rest mass $m_n = 1.675 \times 10^{-27}$ kg

hydrogen atom mass $m_H = 1.673 \times 10^{-27}$ kg

electron rest mass $m_e = 9.109 \times 10^{-31}$ kg

mass of the Sun $M_\odot = 1.99 \times 10^{30}$ kg

Planck constant $h = 6.625 \times 10^{-34} J \cdot s$

Speed of light in vacuum $c = 2.998 \times 10^8 ms^{-1}$

Gravitational constant $G = 6.673 \times 10^{-11} m^3 kg^{-1} s^{-2}$

Fine structure constant $\alpha = 1/137.036$

Boltzmann constant $k = 1.380 \times 10^{-23} JK^{-1}$

Electron volt $eV = 1.602 \times 10^{-19} J$

Stefan-Boltzmann constant $\sigma = 5.67 \times 10^{-8} Js^{-1} m^{-2} K^{-4}$

Coulomb constant $k_e = \frac{1}{4\pi\epsilon_0^2} = \frac{c^2\mu_0}{4\pi} = 8.988 \times 10^9 Nm^2 C^{-2}$.

Astronomical Unit 1 AU $= 1.5 \times 10^{11}$ cm

1. **[C]** The Voyager spacecraft has taken 35 yrs to travel 115 AUs. How long would it take, roughly, at this speed, to travel to the nearest star?

   A) 1 billion years. B) 10 million years. C) 10^5 years. D) 1000 years.

2. **[B]** In the Cosmic Calendar where the history of the universe is compressed into a year, which of the following statements is correct?

   A) the Milky Way galaxy was made on January 1st.

   B) the Sun, the Earth and the first life forms were all made in September.

   C) human civilization (counting since ancient Egypt) existed about 1 day.

   D) if aliens come to visit the Earth sometime in December, they would likely discover modern civilization.

3. **[A]** The statement that 'looking out is looking back' means

A) whichever direction we look out the universe, we are seeing the universe as it was younger.

B) looking out on the sky, we can see our own past and that of the Solar System.

C) looking out on the sky, we can see more space into which the universe can expand.

D) we can see the past of the universe when looking in one direction, and the future when looking in another direction.

4. [**A**] The absorption lines we observe in the solar spectrum arise from

   A) electrons on the solar surface jumping to higher energy levels.

   B) electrons on the surface jumping down to lower energy levels.

   C) the surface gas being hotter than the solar interior.

   D) gas in the hotter interior radiating like a blackbody.

5. [**C**] Why are very heavy atoms not stable in nature?

   A) Because too many protons will cause too strong an electro-static repulsion.

   B) Because more quarks are produced when a nucleus is enlarged.

   C) Because the strong force only acts within a very small distance.

   D) Because heavy atoms need heavy quarks. The latter are not common in the universe today.

6. [**B**] Which of the following has your "cosmic address" in the correct order?

   A) you, Earth, solar system, Milky Way, Local Supercluster, Local Group

   B) you, Earth, solar system, Milky Way, Local Group, Local Supercluster

   C) you, Earth, solar system, Local Group, Milky Way, Local Supercluster

   D) you, Earth, Local Group, Local Supercluster, solar system, Milky Way

7. [**D**] Some stars in our Galaxy have redshifted spectral lines, while most galaxies in the universe also appear redshifted. Which of the following is correct?

   A) These two types of redshifts are the same and are both Doppler shifts caused by these objects moving away from us at some speeds.

   B) These two types of redshifts are different. Stars are moving away from us while galaxies are too massive to be going anywhere.

   C) Different. Stars are locked in the Galaxy so can not go anywhere, while galaxies are free to travel in space.

   D) Different. These stars are moving away from us, while the galaxies are carried away from us by the expansion of space.

   E) None of the above.

8. [**D**] Muons produced at the top of the Earth's atmosphere can travel to the surface of the Earth, a journey of 10 kms in length. But the decay half-life of muons is only 2.2×10^{-6} sec (FYI: $2.2 \times 10^{-6}\,\text{sec} \times c = 0.66$ km). Which of the following is a **FALSE** statement?

   A) Muons can at best travel very nearly the speed of light.

   B) Muons' are moving so fast relative to the Earth, their internal clocks are running at a slower rate than that on Earth. They still decay in the above half-life time, measured by their own clocks.

   C) The 10km length is what observers on Earth measure. The physical length, viewed by muons, is shorter, so they can decay in a few microseconds and can still manage to reach the ground

D) Measured by observers on Earth, the 10km path that the muons have to travel have contracted. This allows muons to get to the Earth before they decay.

9. [**B**] We observe two distant galaxies: Galaxy 1 is twice as far away as Galaxy 2. In that case,

   A) we are seeing Galaxy 1 as it looked at a later time in the history of the universe than Galaxy 2

   B) we are seeing Galaxy 1 as it looked at an earlier time in the history of the universe than Galaxy 2

   C) Galaxy 1 must be twice as bright as Galaxy 2

   D) Galaxy 2 must be twice as old as Galaxy 1

10. [**A**] If all the "dark matter" in the Universe were to be, somehow, instantaneously removed, which of the following would NOT happen?

    A) The Solar Sytem would fly apart. B) The Milky Way would fly apart.

    C) Clusters of galaxies would fly apart. D) The Universe would expand forever.

11. [**C**] When one observes a distant galaxy, one finds that a spectral line normally found in the visible part of the spectrum is shifted into the infrared, to a wavelength that is some three times longer. What do you conclude?

    A) The galaxy must be born early in the universe. It is so red because it has old stars.

    B) Due to the presence of dark matter, stars in the galaxy are rotating at a very high speed. This shifts their spectral line due to the Doppler effect.

    C) The distance between us and the galaxy is increasing at a rate that is faster than the speed of light.

    D) Dust in the galaxy obscures visible light but allows infrared light to go through.

12. [**C**] Stars radiate like blackbodies. Sirius A, the brightest star on the sky, is 2 times hotter than the Sun, 2 times bigger in radius compared to the Sun. Sirius A is intrinsically brighter compared to the Sun by a factor of

    A) 4 B) 16 C)64 D)256 E) Don't know. I give up.

13. [**D**] Mars (the planet) has a surface temperature of -55^o C. It looks red to our eyes because

    A)it is too cold to radiate as a blackbody, and we are just seeing the red sun-light it reflects.

    B)its blackbody radiation comes out in very long wavelength due to its low temperature, therefore it looks red.

    C)it contains sand in its atmosphere. These sand blocks out most of the blackbody radiation from Mars, letting only the long wavelength part escape.

    D)our eyes are not sensitive to its blackbody radiation, but only to the red sun-light reflected off its surface.

14. [**A**] If the Sun is to turn into a black hole (of the same mass) at this very moment, which of the following will result?

    A) Nothing. The Earth will keep on orbiting as before.

    B) The Earth will notice the change in space curvature and start to fall toward the black hole immediately.

    C) The Earth will keep orbiting for about 8 minutes, then it will fall toward the black hole.

    D) All the photons in the solar system will be attracted to the black hole.

15. [**A**] An electronic transition causes a spectral feature at $6000\mathring{A}$. If electrons, on the surface of a star, are moving toward us with a speed of 100 metres per second, this spectral feature is

    A) shifted to a shorter wavelength by $0.002\mathring{A}$. B) shifted to a longer wavelength by $0.02\mathring{A}$.

    C) shifted to the infrared wavelengths. D) shifted to the ultra-violet wavelengths.

16. [**F**] Bohr's hydrogen model. Compared to the wavelength of the photon emitted when the electron jumps from the $n = \infty$ (free state) to the $n = 1$ state, how long is the wavelength of the photon emitted when the electron undergoes the $n = 2$ to $n = 1$ transition?

    A) Half. B) Twice. C) Four times. D) A quarter. E) Three-quarters. F) Four-thirds.

17. [**B**] When an electron and a positron annihilate, two similar photons will be radiated. What are the wavelengths of these photons?

    A) $\sim 4.3 \times 10^{-9}$m B) $\sim 2.4 \times 10^{-12}$m C) $\sim 1.2 \times 10^{-17}$m D) $\sim 4.3 \times 10^{-20}$m

18. [**E**] The mass of the Earth can be calculated by

    A)measuring the orbital speed of the Moon going around us.

    B)measuring the orbital period and distance of Earth's orbit around the Sun.

    C)knowing the Sun's mass and measuring the average distance of Earth from the Sun.

    D)knowing the Sun's mass and measuring how Earth's speed changes during its elliptical orbit around the Sun.

    E)measuring the orbital period and distance of the Moon.

19. [**A**] Which of the following is a valid statement for dark matter candidates?

    A) Dark matter candidates cannot travel at exactly the speed of light.

    B) Neutrinos have non-zero momentum. So they have must have mass and can be the missing matter.

    C) Dark matter candidates only need to have no charge so they give no light and are dark.

    D) A dark matter particle needs to be more massive than a proton because dark matter contributes more mass to the galaxy than normal matter.

20. [**B**] A star exerts gravity on its planet as the latter orbits around the star. But why is the planet not falling toward the star?

    A) The planet also exerts gravity on the star. The two forces cancel.

    B) The planet is under-going free-fall in space-time, but the free-fall is not leading to the star.

    C) The planet is falling but the rate is very small.

    D) Expansion of the universe guarantees that the planet will not fall toward the star.

21. [**B**] **BONUS QUESTION. One extra point.** A star orbits the center of a dwarf galaxy in a circle. Its rotation velocity is measured to be 65 km/s and it is at a distance of 4.0×10^{19} metres away from the galactic center. What is the mass (expressed in unit of solar mass) in the galaxy inside the star's orbit? Assume for convinience that the Galaxy is spherical. *(Hint: Be careful with your units. Convert the above numbers first to SI unit.).*

    A) $\sim 10^7 M_\odot$ B) $\sim 10^9 M_\odot$ C) $\sim 10^{11} M_\odot$ D) $\sim 10^{13} M_\odot$