NAME:______________________________

Astronomy 350 **Fall 2012**

HOUR EXAM 1

September 28, 2012

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1. DO NOT OPEN THIS EXAM UNTIL INSTRUCTED TO DO SO.
2. Write you name and all answers in your test booklet. Turn in your booklet and this sheet.
3. Show all of your work in the test booklet, and indicate clearly your final answer! A correct final answer may not receive credit if no work is shown.
4. Budget your time! Don't get stalled on any one question.
5. Short answer questions can be answered in 1-2 sentences, unless indicated otherwise. If you are writing paragraphs, you may have misread or misunderstood the question.
6. For your reference there are constants listed below.
7. The total number of points on the exam is 100, and there are 5 additional bonus points available.

Possibly Useful Information

Note that a symbol may take different meanings in different equations.

$d = vt$

$a_{\rm AU}^3 = P_{\rm yr}^2$

$F = ma$

$KE = \frac{1}{2}mv^2$

$T = 3000\ {\rm K}\ \times\ (10^{-6}\ {\rm m}/\lambda_{\rm peak})$

$F = L/4\pi R^2$

$G = 6.7 \times 10^{11}\ {\rm m}^3/{\rm kg\ s}^2$

$1\ {\rm AU} = 1.5 \times 10^{11}\ {\rm m}$

$1\ {\rm kpc} = 10^3\ {\rm pc} = {\rm c} \times (3300\ {\rm yr})$

$M_\odot = 2.0 \times 10^{30}\ {\rm kg}$

$L_\odot = 3.8 \times 10^{26}\ {\rm Watts}$

$\Delta v = a \times \Delta t$

$a^3 = GMP^2/4\pi^2$

$F = Gm_1m_2/R^2$

$v/c = \Delta\lambda/\lambda_{\rm em} = (\lambda_{\rm obs} - \lambda_{\rm em})/\lambda_{\rm em}$

$d = 1\ {\rm pc}/p_{\rm arcsec}$

$c = 3.0 \times 10^8\ {\rm m/s}$

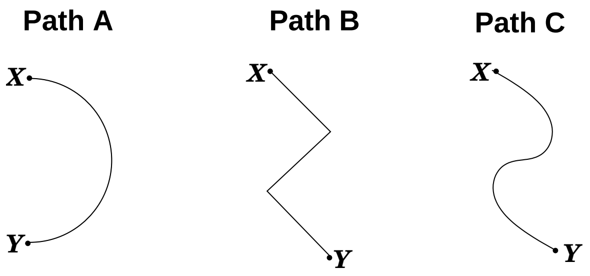
$1\ {\rm pc} = 3.1 \times 10^{16}\ {\rm m} = 3.3\ {\rm lyr}$

$M_{\rm Earth} = 6.0 \times 10^{24}\ {\rm kg}$

Multiple Choice: 5 points each

Circle the single *best* answer for each question. Be sure only one final answer is given.

1 . A particle moves from point X to point Y. Possible paths from X to Y are shown at right. Which of these paths *must* have nonzero acceleration somewhere along the path?



(a) A only
(b) B only
(c) C only
(d) A and C only
(e) **A, B, and C**

Acceleration is a change in velocity *which is to say a change in* either *speed or* direction *of motion. Note that none of the paths are straight lines, so all of them must involve a change in direction of motion, so all of them must involve acceleration at some point, even if speed is held constant.*

2 . A star is observed one night with the mighty U of Illinois telescope at the campus Observatory. Which of these properties of the star can be known *without* knowing the star's distance?
I. flux   II. luminosity   III. surface composition

(a) I only
(b) II only
(c) III only
(d) **I and III only**
(e) I, II, and III

Flux is by definition the apparent brightness measured by the telescope, and thus is by definition the directly measured brightness. Because it is directly measured, it does not require knowledge of distance to measure! Surface composition comes from the appearance of atomic emission or absorption lines it he spectrum, and these too do not require distance to measure. Luminosity, on the other hand, has $L = 4\pi d^2 F$ *and thus requires not only flux but also distance.*

3 . NASA's *Voyager* spacecraft has flown away from the Solar System, and is moving very fast (much faster than the Earth's speed around the Sun). *Voyager* send signals to us with a radio emitting at wavelength 10 cm. On Earth, the signals are received with wavelength

(a) **greater than 10 cm**
(b) less than 10 cm
(c) equal to 10 cm

The light from an object moving away will undergo a redshift, so that observed wavelength is longer than the emitted wavelength.

4 . Star IR has a spectrum that peaks in infrared at $\lambda_{\rm peak,IR} = 10^{-6}$ meters. Star UV has a spectrum that peaks in ultraviolet $\lambda_{\rm peak,UV} = 10^{-7}$ meters. Based only on this information, we conclude that

(a) star IR is hotter than star UV
(b) **star IR is cooler than star UV**
(c) star IR has a larger radius than star UV
(d) star IR has a smaller radius than star UV

Peak wavelength is a measure of color, which in turn is a measure of temperature (Wein's law: $T \propto 1/\lambda_{\rm max}$*). Objects with shorter (bluer) wavelengths are hotter than those with longer (redder) wavelengths. Thus the UV star is hotter than the IR star.*

5 . An asteroid orbits the Sun with period $P = 8$ years. The asteroid has a semi-major axis of
(a) 2 AU
(b) **4 AU**
(c) 8 AU
(d) 16 AU
(e) none of the above

Objects orbiting the Sun obey $P^2 = a^3$*, with* P *in years and* a *in AU. Here was have* $P = 8 = 2^3$*. Thus we have* $a = P^{2/3} = (2^3)^{2/3} = 2^{2\cdot 3/3} = 2^2 = 4$ *AU.*

6 . In the geocentric cosmology, the Sun goes around the Earth with what period?
(a) **1 day**
(b) 1 month
(c) 1 year
(d) in the geocentric cosmology, the Sun is still and the Earth moves

The Sun circles the sky once a day, and so in the Geocentric cosmology this is the period of the Sun's orbit around the Earth.

Short Answer

Answer briefly but completely. Your responses should not require more than 1-2 sentences.

1. *Alternate Universes: Strong Gravity.* Imagine that the strength of the gravitational force is increased, by somehow increasing the value of the constant G in the gravitational force law; the contents and properties of the universe (masses, compositions) are otherwise unchanged.

   (a) **[5 points]** Consider the effect on you, living on Earth's surface. Imagine Earth keeps the same size. Would your weight be larger than it is now, smaller, or the same? Briefly explain.

   The weight of an object is the force of gravity on the object. The gravitational force of the earth on a body of mass m *is* $F = GM_{\rm earth}m/R^2_{\rm earth}$*. Thus* $F \propto G$ *and so in a universe with larger* G *one's wieght is higher.*
   Another way to see this: larger G *means stronger gravity, and stronger gravity means larger weight.*

   (b) **[10 points]** Now consider the effect on the Earth. Imagine the Earth keeps the same distance from the Sun as it does now, and that its orbit is circular. Would the Earth's orbit period be longer, shorter, or the same as it is now? Briefly explain why.

   If gravity is stronger, but the distance is kept the same, then the force is stronger and thus acceleration larger. For a fixed orbital radius, more acceleration means larger circular speed, and thus less time is required to make one orbit: the period is smaller.
   Mathematically: from the equation sheet we have $a^3 = GMP^2/4\pi^2$*, or* $P^2 = 4\pi^2 a^3/GM$*. Thus* $P \propto 1/\sqrt{G}$*: larger* G *means smaller period.*

2. *Rotation Curves and Dark Matter.*

   (a) **[10 points]** Sketch the rotation curve observed for our Galaxy. Be sure to:

      i. label both axes
      ii. label the curve "observed"
      iii. indicate the center of the Galaxy
      iv. indicate the Sun's location
      v. indicate the visible edge of the Galaxy

   (b) **[5 points]** On the same plot as part (a), or in a new plot with the same labels, sketch the rotation curve our Galaxy **would** have if all of the matter were in the form of stars. label this curve "stars only."

   (c) **[10 points]** Explain why the observed rotation curve of our Galaxy gives evidence for dark matter.

   The observed curve shows that the measured speeds are larger than those in the stars-only case. In particular, the observed rotation curve remains constant ("flat") at large distances at which no stars at all are found. This behavior implies that there is a large amount of unseen matter beyond the visible edge of the Galaxy.

   (d) **[10 points]** Suppose that dark matter is proven not to exist. In this case, explain what is implied by the observed Galactic rotation curve.

   The observed rotation curve remains as it is, and so contradicts the predictions of Newtonian gravity. Thus we must conclude that Newtonian gravity is incomplete/wrong.

3. **[10 points]** *The Night Sky in an Elliptical Galaxy.* Imagine our Sun were in elliptical galaxy Gaga, at a position neither at the center nor at the edge of the luminous portion. What pattern would we see in the night sky due to the other stars in our galaxy Gaga? Briefly explain why this pattern would or would not be different from the usual appearance of the Milky Way on the celestial sphere.

   An elliptical galaxy is a large, roughly spherical distribution of stars, with essentially no gas and dust. Thus, from such a typical viewing point inside an elliptical galaxy, we would see stars in all directions in the sky–and more stars than in our sky, due to the lack of dust obscuration. Because of the off-center viewpoint, the distribution of stars would not be uniform: there would be the most stars in the direction of the center, and the fewest towards the anitcenter.

4. *Testing a Dark Matter Candidate.* World-famous cosmologist Prof. Bieber announces his theory that dark matter is made of of exotic particles called "biebons," and that a biebon particle

   - has the same mass as a hydrogen atom,
   - never emits electromagnetic radiation of any form, and
   - always absorbs all electromagnetic radiation that hits it.

   Prof. Bieber buys a tuxedo, anticipating the Nobel Prize for his bold new theory.

(a) **[10 points]** Explain why biebons meet the two requirements for dark matter candidates.

Dark matter must gravitate and thus have mass; biebons meet this criterion. Dark matter must also emit little or no light (electromagnetic radiation); biebons also fill the bill on ths score.

(b) **[5 bonus points]** Thanks to ASTR 350, you realize that biebons cannot be the dark matter.

Imagine that huge swarms of biebons make up the dark matter of the Milky Way and all other galaxies. What astronomical (i.e., telescope) observation(s) that you have seen in class show that such particle cannot be the dark matter? Explain very briefly.

The light from objects outside of our Galaxy–such as that of other galaxies–must pass through the dark halo of our own Galaxy. If dark matter were made of biebons, the light from other galaxies would be absorbed by the biebons. Indeed, due to the cosmological principle, we would expect biebons in the halos of other galaxies to absorb their light as it leaves. Thus we would expect that we would be unable to see light from any other galaxies. Yet in class we have seen images of many other galaxies, which contradicts this prediction and thus rules out biebons as dark matter.