Astronomy C10 / L&S C70U – Fall 2015 – Professor Alex Filippenko

Midterm Exam #1 — 9 October 2015

Print name: Solutions (A) **Sign** name: _____ Student ID #: _____

Print your GSI's Name: _____ Discussion section # (or day, time): _____

Print and sign your name on your SCAN-TRON 882 form. Under "subject," please put your GSI's name and your discussion section number.

CLOSED BOOK, CLOSED NOTES, NO CALCULATORS

Mark all answers on SCAN-TRON form 882. Use a #2 pencil. Completely fill in the appropriate bubble. *Be sure to thoroughly erase all altered answers and stray marks!*

For true/false questions: mark bubble **A** if the statement is *true*, and bubble **B** if *false*. For multiple choice questions: mark the bubble corresponding to the *single best answer.*

All 25 questions carry equal weight. Read each question *carefully* before answering. **There is no penalty for guessing.** If you need extra room for work, use the last (blank) page.

Turn in *both* this multi-page set of questions *and* your SCAN-TRON form.

DO NOT OPEN THIS EXAM UNTIL TOLD TO DO SO!!

Time limit: 45 minutes — **budget your time appropriately. GOOD LUCK!**

Possibly Useful Information

d (pc) $= 1/p$ (arcsec) $\quad d = vt \quad$ density $\rho = M/V \quad c = 3 \times 10^5$ km/s

For a sphere, $V = \frac{4}{3}\pi R^3$, $A_{\rm surface} = 4\pi R^2 \quad$ For a circle, $A = \pi R^2$, $C = 2\pi R \quad \pi \approx 3.14$

There are about 3.2×10^7 seconds per year, and 86,400 (roughly 10^5) seconds per day

Degrees Kelvin = degrees Centigrade + 273; Fahrenheit = (9/5)Cent. + 32 $\quad \theta \approx \lambda/D$

1 AU $= 1.5\times10^8$ km ≈ 8.3 light minutes $\quad$ 1 light year (ly) $\approx 63,000$ AU $\approx 9.5\times10^{12}$ km $\approx 10^{13}$ km

1 pc $= 3.26$ ly $\approx 3 \times 10^{18}$ cm $\approx 3 \times 10^{13}$ km $\quad$ 1 Å $= 10^{-8}$ cm $= 10^{-10}$ m $= 0.1$ nm

$60''$ (arcsec) $= 1'$ (arcmin), $60' = 1°$ (degree), $360°$ = full circle $= 2\pi$ radians = 24 hours

$\lambda_{\rm peak} T \approx 3 \times 10^6$ nm K $= 3 \times 10^7$ Å K $\quad \lambda f = c \quad P = 1/f \quad \mathcal{E} = \sigma T^4 \quad E = hf$

$z = (\lambda - \lambda_0)/\lambda_0 = \Delta\lambda/\lambda_0 \approx v/c$ if $v \lesssim 0.2c \quad z = \sqrt{\frac{1+(v/c)}{1-(v/c)}} - 1$ for all $v \leq c$.

$F = GM_1M_2/d^2 \quad M_1r_1 = M_2r_2 \quad L \propto M^4 \quad R \propto M^{0.75} \quad p + e^- \rightarrow n + \nu$

$R_{\rm S} = 2GM/c^2 \quad R_{\rm photon\ sphere} = 3GM/c^2 \quad M_{\rm Ch} = 1.4\ M_\odot \quad F = ma$

$L_{\rm thermal} = 4\pi R^2 \sigma T^4$ (for a sphere) $\quad b = L/(4\pi d^2) \quad E = mc^2 = m_0c^2[1 - (v^2/c^2)]^{-1/2}$

$v = H_0 d$, where $H_0 \approx 70$ km/s/Mpc $\quad \Omega = \rho/\rho_{\rm crit} \quad \rho_{\rm crit} = 3H_0^2/(8\pi G) \quad M = v^2R/G$

$N = R_* f_s f_p n_e f_l f_i f_c L$, where $R_* \approx N_*/T$ (N_* = # stars in galaxy, T = age of galaxy)

$P^2 = kR^3$ [$k \approx$ constant $\approx 4\pi^2/(GM_1)$ if $M_1 >> M_2$]; in general, $P^2 = (4\pi^2R^3)/[G(M_1 + M_2)]$

For planets, $v \propto 1/\sqrt{R} \quad t_{\rm moving} = (t_{\rm rest})[1 - (v^2/c^2)]^{1/2} \quad L_{\rm moving} = (L_{\rm rest})[1 - (v^2/c^2)]^{1/2}$

Be sure you answer question #1 correctly (6 points off if incorrect)!

(1) The instructor of Astronomy C10 / L&S C70U, Fall 2015 (i.e., this class) is
(a) Alex Filippenko.
(b) Kim Kardashian.
(c) Dr. Spock.
(d) Donald Trump.
(e) Madame Curie.

(2) T or F. The gravitational force pulling an elephant toward Earth is the same strength as the gravitational force pulling Earth toward this elephant.

(3) Rank the parts of the electromagnetic spectrum in correct order from the lowest frequency to the highest frequency.
(a) Gamma rays, X rays, ultraviolet, infrared
(b) Infrared, gamma rays, ultraviolet, X rays
(c) Ultraviolet, infrared, X rays, gamma rays
(d) X rays, ultraviolet, gamma rays, infrared
(e) Infrared, ultraviolet, X rays, gamma rays

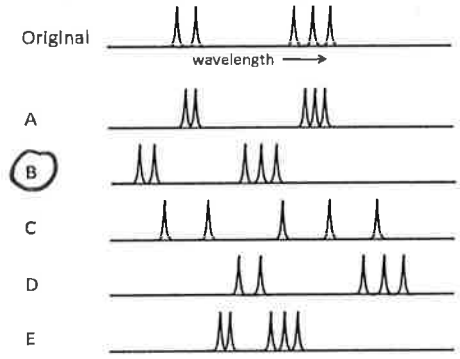
(4) Which one of the following statements about the terrestrial planets is FALSE?
(a) Earth's atmosphere plays a central role in keeping Earth from having freezing cold temperatures over most of its surface.
(b) Venus is the hottest planet in our Solar System, mainly owing to a greatly elevated greenhouse effect.
(c) Long ago, Mars probably had a thicker atmosphere than it does now, with sufficiently high temperatures and pressures to allow large quantities of liquid water to exist on its surface.
(d) Earth's atmosphere allows the Sun's infrared radiation in but doesn't allow much visible light to escape, resulting in the greenhouse effect.
(e) Despite being the closest planet to the Sun, some parts of Mercury have a surface temperature far below the freezing point of water.

(5) Which one of the following statements is TRUE?
(a) Groups of asteroids can only be found in the main asteroid belt between Mars and Jupiter.
(b) The frequency of meteorite impacts on Earth has been roughly the same throughout the history of our Solar System.
(c) The asteroid belt was probably produced when two large, fully formed terrestrial planets collided with and shattered each other.
(d) Comets are like icy asteroids in composition, but they come primarily from regions beyond Neptune's orbit such as the Kuiper belt and the Oort cloud.
(e) Meteor showers are produced when a cluster of stars falls through Earth's atmosphere.

(6) T or F Telescopes in space can use a spherical mirror because only light that has traveled through the atmosphere is affected by spherical aberration.

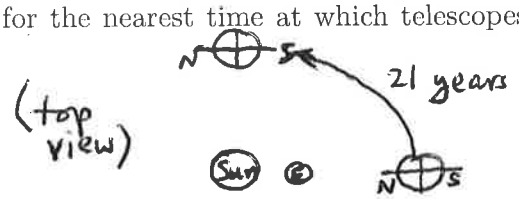
(7) Which one of the following statements about our Solar System is FALSE?
(a) Earth is the only terrestrial planet that now has plate tectonics.
(b) Despite Earth's axial tilt, regions on Earth's equator experience about 12 hours of daylight throughout the year.
(c) The Jovian planets all have a rocky core.
(d) There are more moons than planets in the Solar System.
(e) The main reason Pluto is no longer considered to be a genuine planet is its small mass.

(8) Below is an emission spectrum from a gas consisting of a hypothetical atom called Bearsium. Wavelength increases to the right. The "original" spectrum shows where the emission lines are seen when the gas is at rest. Which one of the following shows what you would see if the gas were moving *toward* you at high speeds?



(9) Uranus has an axial tilt of about 98° and an orbital period of about 84 years. Its *northern* hemisphere experienced one of its summer solstices in June 1944. Which one of the following dates gives the best approximation for the nearest time at which telescopes on Earth could have next seen Uranus's *southern* pole?

(a) December 1944
(b) 1965
(c) 1986
(d) 2028
(e) Because of Uranus's axial tilt, telescopes on Earth can *never* see Uranus's southern pole.



1944 + 21 = 1965

(10) Suppose Planet Wren orbits a star at a distance (semi-major axis) of 2 AU. The star's mass is four times the Sun's mass. What is Wren's orbital period?

(a) $\sqrt{8}$ years
(b) 2 years
(c) $\sqrt{2}$ years
(d) $1/\sqrt{2}$ year
(e) 1/2 year

$P^2 = \frac{4\pi^2}{GM} R^3 \propto \frac{R^3}{M}$

$\left(\frac{P_W}{P_E}\right)^2 = \left(\frac{M_\odot}{M_{*,W}}\right)\left(\frac{R_W}{R_E}\right) = \left(\frac{1}{4}\right)(2)^3 = \frac{8}{4} = 2$, so $P_W = \sqrt{2}\, P_E = \sqrt{2}$ years

(11) T or (F). Six months from now, the time at which a particular star appears overhead will be earlier than it is now by 6 hours.

6 months × 2 hours/month = 12 hours

(12) If you were on the Moon and continued to stand at the same location,

(a) the daytime sky would be blue, and sunset would occur approximately every 24 hours.
(b) the daytime sky would be black, and sunset would occur approximately every 24 hours.
(c) the daytime sky would be blue, and sunset would occur approximately every 30 days.
(d) the daytime sky would be black, and sunset would occur approximately every 30 days.
(e) sunset would never occur because half of the Moon is always bright and the other half is always dark.

Lunar cycle ≈ 30 days. No atmosphere.

(13) (T) or F. The energy of a photon needed to ionize an atom from a bound electron level is greater than the energy needed to get that same electron to any of the higher bound levels.

(14) Which one of the following statements about Ptolemy's model of the Solar System is FALSE?

(a) No matter how many epicycles you add, the model can describe only relatively simple patterns of planetary motions in the sky.

(b) The model explains only the new and crescent phases of Venus, not its other phases.

(c) Planets orbit Earth in the model.

(d) At the time Copernicus's heliocentric model was published, Ptolemy's model was about as consistent with the observed motions of planets as Copernicus's model.

(e) The model successfully accounts for the observed retrograde motion of the planets.

(15) Suppose Planet Nat has two very small moons, Jake and Deepthi. Moon Jake is held together only by electromagnetic forces, and Moon Deepthi is held together only by gravitational forces. If the orbits of both moons were placed inside Planet Nat's Roche limit, what would most likely happen?

(a) Jake would break up, while Deepthi would not.

(b) Both Jake and Deepthi would break up.

(c) Deepthi would break up, while Jake would not.

(d) Neither Jake nor Deepthi would break up.

(e) Either Jake or Deepthi would get ejected from the system.

(16) Suppose two stars that are *actually* 12 light years apart are 3 light years apart in a scale model. What is the radius of a star in this scale model if its actual radius is 16 solar radii?

(a) 1 solar radius

(b) 4 solar radii

(c) 7 solar radii

(d) 8 solar radii

(e) 16 solar radii, since a scale model only affects distances *between* stars, not their radii.

$\frac{12\ ly}{3\ ly} = 4$ All distances are reduced by this factor. So, $\frac{16\ R_\odot}{4} = 4\ R_\odot$

(17) T or F. From Earth, we can see Saturn in its full and nearly full (gibbous) phases, but not in its new or crescent phases.

Sat Nearly full

(18) From Earth, we see lunar phases because

Sun E Sat Full

(a) as the Moon revolves around Earth, different parts of it are in Earth's shadow.

(b) the Moon revolves along an epicycle over the course of its orbit.

(c) the Moon rises above the horizon at a different time in each phase.

(d) the Moon does not rotate on its axis, while Earth does rotate.

(e) the side of the Moon facing us is differently lit over the course of its orbit.

(19) T or F. If Saundra uses a telescope to look at a galaxy whose light has taken 8 billion years to reach her, this galaxy could have already been 8 billion years old when the light Saundra is now seeing left it. $8 + 8 = 16$ billion years, but the Universe is only 14 billion years old.

(20) Which one of the following statements about eclipses is FALSE?

(a) If you were on the Moon during a total lunar eclipse, you would see Earth block the Sun's disk, and Earth would be surrounded by an orange/red ring.

(b) The minimum amount of time between a lunar eclipse and a solar eclipse is about 2 weeks.

(c) The phase of the Moon 3–4 days before a solar eclipse is waning gibbous. (Waning crescent)

(d) A given total solar eclipse is visible only from a narrow path when viewing from Earth's surface.

(e) When it is *totally* eclipsed, the Sun is safe to look at with unprotected (i.e., no filter) eyes, binoculars, or telescopes.

(21) If Star Medford (which can be considered a thermal blackbody) is suddenly observed to have 16 times its previous luminosity but the same radius, then the wavelength at which its spectrum peaks would

(a) remain the same as before.
(b) increase to twice its previous value.
(c) increase to four times its previous value.
(d) reduce to half of its previous value.
(e) reduce to one-quarter of its previous value.

$L \propto R^2 T^4 \propto T^4$ if R = constant.
An increase of a factor of 16 in L corresponds to T increasing by a factor of 2.
Wien's law: $\lambda_{peak} T$ = constant. If T doubles, λ_{peak} becomes $\frac{1}{2}$ of its previous value.

(22) (T)or F. Small moons can often be found next to narrow planetary rings, and they are a major reason these rings remain stable.

(23) Which one of the following statements about comet and meteoroid impacts is TRUE?

(a) A large asteroid colliding with Earth generally produces a crater at least 10 times wider than the asteroid itself, and severely affects an even larger region around it.
(b) Because Comet Shoemaker-Levy 9 was torn apart by tidal forces before it impacted Jupiter, the impact was small and very little total energy was released.
(c) There is still no direct evidence that a comet or meteoroid impact helped cause the Cretaceous-Paleogene (i.e., Cretaceous-Tertiary) extinction during which the dinosaurs were killed because no matching crater has yet been found.
(d) We know that more meteoroids and comets collide with Mercury than with Earth because Mercury's surface is more heavily cratered than Earth's surface.
(e) In principle, nothing can be done to prevent collisions of asteroids with Earth, so we might as well not worry about them too much.

(24) Suppose Superman Kyle shakes a magnet up and down extremely quickly. He periodically moves it up 200 nm and then back down 200 nm, and then back up 200 nm and so on, over and over, consistently and precisely, reaching the top 10^{15} times per second. Which one of the following would he create? (Note that $c = 3 \times 10^{17}$ nm/s.)

(a) Electromagnetic radiation with a wavelength of 100 nm.
(b) Electromagnetic radiation with a wavelength of 200 nm.
(c) Electromagnetic radiation with a wavelength of 300 nm.
(d) Electromagnetic radiation with a wavelength of 600 nm.
(e) Nothing. Electromagnetic radiation cannot be created with a magnet.

$\lambda f = c \rightarrow \lambda = \frac{c}{f} = \frac{3 \times 10^{17} \text{ nm/s}}{10^{15}/\text{s}} = 300 \text{ nm}$

(25) Which one of the following statements about tides and tidal forces is FALSE?

(a) The Moon causes a high tide on the side of Earth nearest the Moon, and a low tide on the side of Earth farthest from the Moon.
(b) In a billion years, the average height difference between the high tide and low tide on Earth will be smaller than it is today.
(c) The main reason for the intense volcanic activity on Jupiter's moon Io is strong variations in the tidal forces experienced by Io.
(d) A given coastal location on Earth generally goes through two high tides and two low tides in a single 24-hour day.
(e) Low and high tides on Earth tend to be most extreme when the Moon is new or full.

End of Examination