Astronomy C10 / L&S C70U – Fall 2016 – Professor Alex Filippenko

Midterm Exam #2 — 7 November 2016

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 $= 1.5{\times}10^8$ km ≈ 8.3 light minutes $\quad$ 1 light year (ly) $\approx 63,000$ AU $\approx 9.5{\times}10^{12}$ 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 $v \leq c$.

$F = GM_1M_2/d^2 \quad M_1 r_1 = M_2 r_2 \quad L \propto M^4 \quad R \propto M^{0.75} \quad p + e^- \rightarrow n + \nu$

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

$L_{\rm thermal} = 4\pi R^2 \sigma T^4$ (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, $v \propto 1/\sqrt{R} \quad t_{\rm moving} = (t_{\rm rest})[1 - (v^2/c^2)]^{1/2} \quad L_{\rm moving} = (L_{\rm rest})[1 - (v^2/c^2)]^{1/2}$

(1) The star nearest to Earth is
(a) Sirius.
(b) the Sun.
(c) 3C 273.
(d) Proxima Centauri.
(e) Supernova 1987A.

(2) The carbon, nitrogen, oxygen, and heavier elements in our bodies
(a) existed from the moment the Universe was born.
(b) were made in giant clouds of interstellar gas undergoing nuclear fusion.
(c) were made on planets from chemical reactions among lighter elements.
(d) were made in stars and supernovae billions of years ago.
(e) were created only about 6000 years ago, along with the rest of Earth.

(3) T or F. Pulsars are rapidly rotating neutron stars that have two oppositely directed beams of particles and radiation moving along their magnetic axis.

(4) If an emission line in the spectrum of an active galaxy is measured to be at a wavelength of 750 nm, and in a laboratory setting (at rest) it is measured to be at a wavelength of 150 nm, what is the galaxy's redshift, z?
(a) 5
(b) 4
(c) 1/4
(d) 1/5
(e) 4/5

$$z = \frac{\Delta\lambda}{\lambda_0} = \frac{\lambda - \lambda_0}{\lambda_0} = \frac{750 - 150}{150} = \frac{600}{150} = 4$$

(5) Which one of the following is an assumption that is made when estimating the age of a cluster of stars?
(a) Stars in a cluster differ significantly in age from one another.
(b) All of the stars in a cluster are on the main sequence.
(c) All stars in the cluster with the same surface temperature have the same mass.
(d) Stars having a wide variety of masses were formed in the cluster.
(e) Stars move "up" along the main sequence before moving off of it.

(6) T or F. The rotation curve of the Milky Way Galaxy tells us that the mass, M, enclosed within a circle of radius R increases exponentially with increasing R.

(7) Which one of the following statements about black holes is TRUE?
(a) The surface of the singularity of a black hole is known as the event horizon.
(b) Being more massive, a supermassive black hole has a greater gravitational pull than a stellar-mass black hole, so if you approach the event horizon of a supermassive black hole, you will be torn apart more easily than if you approach the event horizon of a stellar-mass black hole.
(c) If the Sun were to become a black hole of the same mass, Earth would spiral into the black hole and be eaten.
(d) The "photon sphere" is a region inside a black hole where photons orbit the center, so they cannot escape.
(e) In principle, energy can be extracted from a region outside a rotating black hole.

(8) A main-sequence star with mass of 20 solar masses produces energy primarily from
(a) fusion of hydrogen into helium.
(b) fusion of helium into carbon and oxygen.
(c) fusion of silicon into iron.
(d) gravitational contraction.
(e) chemical reactions that cause the gases to burn.

(9) In class, we learned that the simple relation between redshift and an object's recession velocity is just an approximation that is valid for $v < 0.2c$. If we are studying a spectral feature that has a rest-frame wavelength of 650 nm, then this approximation will not be very accurate if we measure the wavelength of the spectral feature to be greater than about
(a) 78 nm.
(b) 130 nm.
(c) 780 nm.
(d) 3,250 nm.
(e) 7,800 nm.

$\frac{\Delta\lambda}{\lambda_0} \approx \frac{v}{c} \approx 0.2 \rightarrow \Delta\lambda \approx 0.2\lambda_0 = (0.2)(650\text{nm})$
$= 130$ nm.
$\Delta\lambda = \lambda - \lambda_0 \rightarrow \lambda = \lambda_0 + \Delta\lambda$
$\lambda = 650\text{ nm} + 130\text{ nm} = 780$ nm

(10) T or (F) If the Schwarzschild radius of a 10 solar mass nonrotating black hole is 30 km, the event horizon of a 100 solar mass nonrotating black hole would have a radius of 3000 km.
$R_s = 2GM/c^2 \propto M$ $\frac{100}{10} = 10$ times more massive $\rightarrow$ 10 times larger.
$(30\text{ km})(10) = 300$ km.

(11) Which one of the following statements about quasars is FALSE?
(a) All quasars are active galactic nuclei, but not all active galactic nuclei are quasars.
(b) The accretion of material onto a supermassive blackhole gives the best explanation for the huge power output of quasars.
(c) The emitting volume of a quasar is very small relative to the size of the galaxy in which it's located.
(d) We can observe quasars only if their jet of material is pointed toward Earth.
(e) The reason we find quasars only very far from us is that they faded over time.

(12) If you measure a red giant's parallax and apparent brightness, knowing which one of the following quantities would allow you to determine its radius?
(a) Mass
(b) Doppler shift
(c) Wavelength at which its spectrum peaks
(d) Chemical composition
(e) Luminosity

parallax gives distance.
$b = \frac{L}{4\pi d^2} \rightarrow L = 4\pi d^2 b$,
so you know L.
$L = 4\pi R^2 \sigma T^4 \propto R^2 T^4$. Get T from Wien's law, $\lambda_{peak} T = \text{constant}$. Know $L, T \rightarrow$ get R.

(13) T or (F) In taking the measurements that would later appear on the Hubble diagram, Edwin Hubble used the parallax method to measure the galaxy distances he needed. (Galaxies too distant for parallax method.) Cepheids.

(14) Which one of the following statements about galaxies is TRUE?
(a) Most of the stars in the bulge and halo of a spiral galaxy are old.
(b) The spiral arms of our Milky Way Galaxy consist mostly of old stars.
(c) Elliptical galaxies consist mostly of young stars.
(d) Our Solar System is at the center of the Milky Way Galaxy.
(e) We will underestimate the distance of a distant star in the plane of our Galaxy unless we take into account the dust that absorbs and scatters its light.
(overestimate!)

$\left(b = \frac{L}{4\pi d^2}\right)$

(15) Suppose you observe two stars, Elan and Rachel, that have the same apparent brightness. Which one of the following statements is necessarily TRUE? (not Luminosity L)

(a) They must be equal in size (radius).
(b) If you know their radii are equal, they must have the same surface temperature.
(c) If you increase the luminosity of Star Elan by a factor of 3, Star Rachel will then appear 1/3 as bright as Star Elan.
(d) If you increase the luminosity of Star Elan by a factor of 2, Star Rachel will then have half the luminosity of Star Elan.
(e) The stars must be the same distance from the Earth.

If Elan has 3 times the previous luminosity, then 3 times the previous brightness. But Rachel stays the same, so $\frac{1}{3}$ as bright as Elan.

(16) Which one of the following statements about the detection (or potential detection) of black holes is FALSE?

(a) Black holes cannot be detected because they emit no light and are therefore impossible to directly observe.
(b) A binary pair of black holes was detected in the past year through measurements of the gravitational waves emitted when they merged to form a single black hole.
(c) The presence of supermassive black holes in the centers of galaxies has been inferred from the motions of stars and gas near them.
(d) Evidence for black holes can be found if material in the surrounding accretion disk goes through the event horizon and fades from view, rather than releasing energy as it hits a hard stellar surface.
(e) Candidate black holes are sometimes found in binary systems that suddenly brighten at X-ray wavelengths.

(17) T or F. If we can see more sunspots, it is likely there will be more auroral activity on Earth.

(18) Which one of the following statements about white dwarf stars is TRUE?

(a) White dwarfs shine because of ongoing nuclear reactions.
(b) The mass of most white dwarfs is close to the Chandrasekhar limit.
(c) White dwarfs consist mostly of iron.
(d) A typical white dwarf's diameter is approximately the size of Berkeley.
(e) White dwarfs are supported against gravity by electron degeneracy pressure.

(19) T or F. According to Hubble's law, if Galaxy Ben is currently twice as distant from us as Galaxy Ned, then Galaxy Ben's recession speed from us is twice that of Galaxy Ned.

$V = H_0 d$ Twice as distant → moves twice as fast.

Be sure you answer question #20 correctly (6 points off if incorrect)!

(20) Jake Duncan, the Head GSI for this class (Astronomy C10 / L&S C70U, Fall 2016),

(a) is a graduate student at UC Berkeley.
(b) lives on a moon orbiting Saturn.
(c) is actually a punk rock star in disguise.
(d) can't possibly be human, because he's made of pure niobium and plutonium.
(e) was brought to Earth from the Moon during the Apollo landings in the early 1970s.

(21) Which one of the following statements about stars is FALSE?

(a) The main-sequence stage is by far the longest phase in a star's active lifetime.

(b) A brown dwarf never undergoes any fusion reactions.

(c) Enormous temperatures in the core of a star are needed for the nuclei to overcome their mutual electrical repulsion.

(d) The Sun's main-sequence lifetime is approximately 10 billion years.

(e) If a gas cloud is dense enough, its own gravity will cause it to contract and form stars.

(22) T or F. By studying many distant galaxies, we have been able to determine how galaxies formed and evolved, and predict the likely future of our own Milky Way Galaxy.

(23) Suppose you measure the parallax of a Star Sammie to be 0.1 arcsecond. If Earth is then hit by a huge asteroid and settles into a new orbit twice as far from the Sun, the new measured parallax of Star Sammie will be

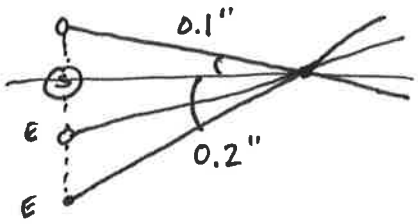
(a) 0.025 arcsecond.

(b) 0.05 arcsecond.

(c) 0.1 arcsecond.

(d) 0.2 arcsecond.

(e) 0.4 arcsecond.



(24) An "emission nebula" glows primarily because

(a) it scatters light from young stars in all directions, and blue wavelengths are scattered more easily than red wavelengths.

(b) it scatters light from a dying star in all directions.

(c) it produces thermal radiation.

(d) it is undergoing nuclear fusion.

(e) gas is ionized by ultraviolet light and then recombines, or electrons excite atoms and ions by colliding with them.

(25) Which one of the following statements about the Sun's future evolution is FALSE?

(a) As the Sun expands to form a red giant, its surface temperature decreases but its core temperature increases.

(b) As the Sun expands to form a red giant, both its radius and luminosity increase.

(c) During its red giant stage, the Sun will first have a helium core with a hydrogen-burning shell, and then a carbon-oxygen core with helium-burning and hydrogen-burning shells.

(d) After the red giant stage, the Sun will evolve into a planetary nebula.

(e) The Sun will ends its life as a white dwarf, but occasionally it will brighten suddenly to form a nova.

End of Examination