

Review for Final Exam: in 2103 CHAMBERLIN, not our usual classroom

Lecture 1: Thursday 21 December 2:45pm; Lecture 3: Tuesday 19 December 12:25pm

Appendix A: Powers-of-ten notation, significant figures and rounding. Units of measurement: meter, kilometer, kilogram, astronomical unit, light year.

- Ch. 1: Angular distance and size: box 1.2. Celestial sphere, apparent motions of stars. Motion of Sun relative to “fixed stars”, ecliptic plane; Moon motion relative to stars, phases and eclipses; planet motions.
- Ch. 2: Only 2.3 – explaining planet motions in an Earth-centred planet system.
- Ch. 3: Planet motions in Sun-centred system: conjunction, opposition, retrograde motion, phases of Venus. Kepler's laws of planet motion.
- Ch. 4: Galileo: inertia and force, Box 4.1. Newton's 3 laws of motion; Newton’s law of gravity, finding the mass of planets, Box 4.3.
- Ch. 5: Atoms (5.1): protons, neutrons and electrons. Light (5.3): speed, frequency, wavelength, electromagnetic spectrum. Box 5-2: energy of light. Spectral lines (5.2): each atom makes its own lines; Kirchhoff laws.
- Ch. 6: Reflecting and refracting telescopes: why can lenses and mirrors focus light? Light-gathering power. Resolution and “seeing”: the effect of Earth’s atmosphere.
- Ch 7: Only: 7.3–7.5, curved space and the future of the cosmos. The amount of matter determines both the curvature of space, and whether cosmic expansion will continue. In 7.3, *not* Solar system and experimental tests of relativity.
- Ch. 12: The Sun. Luminosity, radius, mass, surface temperature--how do we know? Box 12.1, 12.2. Kelvin scale for temperature; Wien law for λ_{\max} , Stefan-Boltzmann law for power radiated per square meter. Energy production: hydrogen ‘burns’ to He, producing neutrinos that reach Earth. How energy moves within the Sun: radiation, convection. Photosphere, granules and sunspots, magnetic field. Corona, solar wind.
- Ch 13: Other stars as Suns: distances from parallax. Apparent brightness and luminosity (*Not* Box 13.1, the magnitude system.) From color to temperature to radius. O B A F G K M classes: why do some stars have strong hydrogen lines and others do not? HR diagram, main sequence. Masses of stars: visual and spectroscopic binaries. Doppler shift: Box 10.1. Why are there no stars with $0.01 M_{\odot}$? Why no stars of $100 M_{\odot}$?
- Ch. 14: Interstellar gas. What are HII regions and how do we observe them? Neutral gas: 21cm line. Molecules in space. Why are radio telescopes sometimes more useful than optical telescopes? Dust scatters light to make stars look redder and dimmer; reflection nebula. How stars form. (Not 14.5, planets of other stars)
- Ch. 15: Star lives: interpreting the HR diagram. Where do protostars get the energy to shine? What happens in the core as they reach the zero-age main sequence? End of Sun’s life: red giant stage (H burns in shell); helium flash, helium burning, planetary nebula, white dwarf. Lives of massive stars: CNO cycle. Telling the age of a star cluster: how long do stars of different masses stay on the main sequence? [15.8 applies only to single stars!]

- Ch. 16: Dead stars: white dwarfs, neutron stars (pulsars), black holes. Binary stars: mass transfer, nova and Type Ia supernova. Exploding massive stars: Type II supernova. Where are elements heavier than carbon made? Gamma ray bursts: hypernova?? X-ray binaries: gas pours onto disk around black hole or neutron star, heats up to make X-rays. Background only: synchrotron radiation Box 16.1.
- Ch. 17: Milky Way: a typical spiral galaxy. Shape and size. Disk, bulge, halo, globular clusters. Where are young stars now born? Where are the oldest stars? Why do globular-cluster stars contain little iron? What makes the spiral pattern? Milky Way's rotation, mass (Box 17.1); what is the dark matter? How do we measure the mass of the central black hole?
- Ch. 18: Hubble's "law": measuring distances, age from expansion (Box 18.1). Dark matter and dark energy: what slows the expansion? What speeds it up? Other kinds of galaxies: spirals, ellipticals, irregulars. Which still make new stars? How is mass-to-light ratio related to new stars? Groups and clusters of galaxies: masses from galaxy motions. Using Hubble's law to map superclusters and voids, gas between the galaxies. Telescope as a "time machine".
- Ch. 19: Active galactic nuclei, including quasars: see class 21 notes on web. Huge power, tiny volume (19.6); activity powered by gas falling around giant black hole, huge version of X-ray binaries in Ch16. Twin jets of fast electrons (like pulsars: Ch16) produce radio emission. All sizable galaxies have black holes: most not now active. *Not*: details of 19.3, 19.4; gravitational lenses 19.5.
- Ch. 20: Our (almost) homogeneous Universe: microwave background; making helium – why not heavier elements? Deuterium levels tell us amount of normal matter (neutrons, protons); about 1/6 of total mass. "Ripples" in Fig 20.9; WIMPs, making galaxies. Curvature of space from Ch7: why microwave background tells us there is dark energy. *Not*: 20.7–8.

Formulas: these will be given on the exam. You don't need to memorize them, but be sure you understand them.

$$a^3 \text{ (in AU)} = P^2 \text{ (in years)} \text{ for planets circling the Sun; generally } P^2 = a^3 \left[\frac{4\pi^2}{GM} \right] \text{ or } \frac{a^3}{P^2} = \frac{GM}{4\pi^2}$$

If we measure speeds V instead, then for circular orbits, $aV^2 = GM$.

$$c = \lambda f \quad E = hf = hc/\lambda \quad 1 \text{ nanometer (nm)} = 10^{-9} \text{ meters; } 1\text{AU}=150 \text{ million km}$$

$$\lambda_{\text{max}} = \frac{3mm}{T(K)} \quad F \text{ (energy, in Watts per sq meter)} = \sigma T^4$$

$$\text{Perimeter of circle} = 2\pi r; \text{ area} = \pi r^2 \quad \text{Surface area of sphere} = 4\pi r^2; \text{ volume of sphere} = 4\pi r^3/3$$

$$\frac{\Delta \lambda}{\lambda} = \frac{V}{c} : \text{Doppler formula} \quad \text{Apparent brightness } b = \frac{L}{4\pi d^2}$$

$$\text{Parallax: } p(\text{arcsec}) = \frac{1}{d(\text{parsecs})} ; 1 \text{ parsec} = 3.26 \text{ light years}$$

Hubble's "law" $v = H \times d$; H is about 20 km/sec/mega-light-year.

Review questions (look back at 6-week and 12-week reviews too)

- In Wisconsin, a full moon
 - rises at midnight
 - sets at midnight
 - sets at sunrise
 - sets at noon
 - rises at noon
- The rings of Saturn consist of billions of tiny particles. According to Kepler's laws,
 - particles in the innermost ring must have the shortest period
 - particles in the outermost ring must have the shortest period
 - all the ring particles must have the same period, so the rings move like a rigid disk
 - Kepler's laws apply only to planets orbiting the Sun
- Two stars orbit each other with a period of 20 years and a separation of 10 AU; their total mass is
 - 2 solar masses
 - 2.5 solar masses
 - 0.5 solar masses
 - 80 solar masses
- The spectrum produced by a hot opaque object like a tungsten filament in a light bulb is
 - a continuous spectrum
 - a bright line spectrum
 - an absorption line spectrum
 - any of the above, depending on temperature
- Your oven is set to 500 K (450 F). When you open the door, the most intense light streams out at
 - 600 nm
 - 6000 nm
 - 1.5×10^9 nm
 - 1500 nm
 - can't tell without more information.
- A thin, hot gas that is transparent to most wavelengths of light produces
 - a continuous spectrum
 - a bright line spectrum
 - a dark line spectrum
 - no spectrum
- The greater the separation of two atomic energy levels, the smaller is the _____ of the photon given out when an electron jumps down from the higher level to the lower.
 - velocity
 - wavelength
 - frequency
 - energy
- The H α line (rest wavelength 656nm) emitted by a galaxy moving away from us with a speed of 3000 km/s will be observed at a wavelength of about
 - 663nm
 - 657nm
 - 656nm
 - 650nm
- Here are the temperatures and luminosities of four stars. Which star is largest in diameter?
 - T = 10,000 K; L = 100 L_{sun}
 - T = 4,000 K; L = 100 L_{sun}
 - T = 10,000 K; L = 1/100 L_{sun}
 - T = 4,000 K; L = 1/100 L_{sun}
- The elements heavier than helium found in the Sun's atmosphere were made
 - in the Big Bang
 - in galactic gas clouds
 - by stars near the end of their lives
 - by black holes
 - by the ultraviolet radiation of stars
- Stars cannot generate energy by fusing (joining together) atomic nuclei heavier than
 - iron (Fe)
 - carbon (C)
 - potassium (K)
 - hydrogen (H)
 - helium (He)

12. When a star runs out of hydrogen fuel in its core, in the next stage of its life
 - A. its burned-out hydrogen contracts until the protons stick together to form helium nuclei
 - B. its helium core contracts, causing the star to shrink
 - C. its helium core contracts, causing the rest of the star to expand and become a red giant
 - D. the helium flash occurs, expanding the rest of the star and forming a red giant

13. Four main-sequence stars with these spectral types have the same apparent brightness. Which is most distant?

A. A	B. O	C. M	D. G
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14. Compared to a main sequence star of the same surface temperature, red giants

A. are more luminous	C. have larger radii
B. are less dense	D. all of ABC
	E. none of ABC

15. There are few star clusters in the Milky Way whose hottest main sequence stars are O stars because

A. tidal forces in the galaxy disrupt them	C. O stars don't form in most clusters
B. O stars live only a short time	D. A and B

16. Carbon is much more abundant than gold (note the prices of coal and gold per pound) because
 - A. carbon is made by the fusion of hydrogen, which is very common
 - B. carbon is the principal energy source of the stars
 - C. carbon is needed for life, but gold is not
 - D. gold is formed only during supernova explosions of very massive stars, while almost all stars will produce carbon

17. The Schwarzschild radius of a black hole is the distance at which

A. escape velocity equals orbital velocity	C. gas orbiting the black hole gives out X-rays
B. tidal forces disrupt anything that falls in	D. escape velocity equals the speed of light

18. The band of light across the sky that we call the Milky Way suggests that
 - A. the Sun is at the center of the galaxy
 - B. the Milky Way is a flattened disk with the Sun above the disk
 - C. the Milky Way is a flattened disk with the Sun within the disk
 - D. dust between the stars blocks out light coming from directions other than the disk

19. Some quasars vary greatly in brightness within a very short time. This means they must be

A. very far away	C. very small
B. very large	D. very old

20. The energy output of a bright quasar is equivalent to

A. a million bright galaxies	C. 100 stars like the Sun
B. 100 bright galaxies	D. that of the Milky Way Galaxy

21. If we discovered stars that were 50 billion years old, this would
 - A. show that the Universe contained more matter than we thought
 - B. show that the Universe could not be expanding
 - C. show that we can see galaxies at much greater distances than we had thought
 - D. show that the Universe contained more dark energy than we thought

- G1. Why do the spiral arms show up so clearly in spiral galaxies?
- A. stars are spread almost uniformly over the disk, but the brightest stars are only found in the spiral arms, making the arms stand out
 - B. stars are found only in the spiral arms and the bulge, with essentially none between the arms
 - C. The number of stars in the arms is several times larger than the number between the arms
 - D. stars are spread almost uniformly over the disk, but dust hides all except the stars in the arms.
- G2. Cosmic expansion takes place
- A. mainly in the huge voids between clusters of galaxies
 - B. only over distances about the size of a galaxy: our Milky Way expands but the Earth does not
 - C. only between objects separated by a vacuum: our bodies do not expand but the Earth-Moon system does
 - D. between all objects, even the atoms in our bodies.
- G3. An astronomer finds that the spectrum of a galaxy shows only low-mass stars and red giants. What kind of galaxy is the astronomer studying?
- A. a barred spiral
 - B. an irregular galaxy
 - C. a spiral galaxy
 - D. an elliptical galaxy