ASTRONOMY 1102 – 1

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Study Guide for Second Test – Friday March 12, 1999

This test will be based on material we have covered in class, supported by the material in chapters 24, 25, 26 and 27 of ASTRONOMY: From the Earth to the Universe, 5th Edition. Please note that certain **basic concepts: em radiation, Doppler effect, radiation laws: Stefan-Boltzmann, inverse-square law, and geometric parallax** that were covered and tested in the first test **will be included** in this and all subsequent tests. The test will consist of two parts: multiple choice questions (60 %) and problems (40 %). I give below an example of what the test will look like and a couple of examples of questions and problems.

Review class notes: do not memorize first, understand first, and then commit to memory only a few basic definitions and laws. Review homework.

Chapter 24: Stellar Distances and Motions

§24.4 The Hertzsprung–Russell Diagram or HR diagram. Luminosity classes. Supergiants (I), Giants (III) and MS dwarfs (V). Need complete spectral type including luminosity class to use Spectroscopic Parallaxes (§24.5) for distance determinations. Distance modulus $m - M$ and its uses. See corresponding HW problems. You must be able to use this for distance estimates: $m - M = 0$ means $d = 10$ pc by definition of Absolute Magnitude. $m - M = 5$ means a flux 100 times weaker than expected and therefore a distance 10 times greater than the base distance of 10 pc, so $d = 100$ pc. $m - M = 1$ means flux $\sqrt[5]{100} = 2.512$ times weaker, hence distance $\sqrt[10]{100} = 1.585$ times farther.

Chapter 25: Doubles, Variables, and Clusters

§25.2-3 Stellar Masses and Radii. The Mass–Luminosity and Mass–Radius relationship for MS stars: $L \propto M^3$ and $R \propto M$. Comparison of the simple approximate expression $L \propto M^3$ and the observed relation shown on Fig. 25-7.

§25.4 Variable Stars. Their names (box 25.1). Mira variables, Cepheids, and RR Lyrae. The instability strip and the "kappa–mechanism": opacity increases with temperature. Leavitt and the Period–Luminosity (or Period–Absolute Magnitude) relation for Cepheids. Importance of the Magellanic Clouds: all Cepheids in the same cloud are approximately at the same distance. The use of Cepheids and RR Lyrae as distance estimators. See HW 4.

§25.5 Clusters and Stellar Populations. Open or galactic and globular clusters. HR diagrams of Clusters. Their uses: Main Sequence Fitting (distance) and Ages (MS turnoff). See HW 5.

Chapter 26: The Birth, Youth and Middle Age of Stars

§26.1: Star Formation. Example evolution of a 1 $M_\odot$ protostar. The Hayashi track is the near vertical portion of the evolutionary path toward the Main Sequence (MS) in Fig. 26-3. Young stellar objects: T Tauri stars. Disks and bipolar ejections: bipolar nebulae. Narrow collimated ejections: jets and Herbig Haro Objects.

§26.2-4 The origin of the stellar luminosity: gravitational contraction is too short to explain the age of the sun/earth. Nuclear fusion of Hydrogen into Helium. Two possible pathways: the proton-proton chain and the CNO cycle. In the CNO cycle the Carbon required at the beginning is returned at the end, and the Nitrogen and Oxygen are generated and destroyed at the same rate. So the C is like a *catalyst*. In both p-p chain and CNO cycle the *net result* is the fusion of 4H $\rightarrow$ He with the conversion of 0.7% of the mass into energy. The p-p chain dominates in stars like the sun and less massive ones. The CNO cycle Main Sequence life of a star: the *relatively long and uneventful* time a star burns (fuses) H into He. Massive stars have more H to burn, but do so much faster (recall the Luminosity–Mass Relationship $L \propto M^3$) that their MS lifetimes are shorter. Stars less massive than the sun live on the MS for much longer than 10^{10} yr.

§26.5 Strong and electromagnetic forces. The onset of nuclear fusion for H and He. Fusing He requires a much higher temperature to overcome the electromagnetic repulsion of He nuclei.

§26.6 The solar neutrino experiments: why try to detect neutrinos? Because they are the only messengers from the core that can reach us. The experiments all show less neutrinos than expected. Probable cause: neutrino oscillations: change of electron neutrinos ν_e into other types of neutrinos (ν_μ and ν_τ) which are not detected by current experiments. So "New physics" beyond the Standard Model seems necessary.

Chapter 27: The Death of Stars like the Sun

A balancing act: Gravity versus Pressure. The Main Sequence life of a star ends when H is exhausted at the center (completely fused to He). All *lightweight* stars with $M \lesssim 8 M_\odot$, die as **white dwarfs**.

§27.1 Red Giants: after 10^{10} yr, a star like the sun will exhaust H at the center of the core and H–burning stops there. The H–burning continues in a **shell** surrounding the inert (hot but non-burning) core of He. Core material contracts and heats while the envelope expands. The star goes relatively rapidly through a **subgiant** phase and reaches the bottom of the red giant branch (RGB). The H-burning shell continues fusing H to He, the core mass grows and gets hotter. The envelope expands to accomodate the higher rate of burning and the star's luminosity increases as the star "ascends the RGB". At the top of the RGB the core reaches a temperature of 10^8 K and the triple–alpha (3α) reaction kicks in, producing a lot of energy suddenly (few minutes) in the **helium flash**. The star now settles on the **horizontal branch** (HB) and burns steadily He into C in its core while shell H–burning continues. The position of the star in the HR diagram essentially "jumps" from the top of the RGB down (less luminous) and to the left (hotter) to $L \lesssim 100 L_\odot$.

§27.2: When He is exhausted at the center (completely fused to C), a He–burning shell forms, surrounded still by the H–burning shell, and the star expands again becoming a red giant for the second time following the asymptotic giant branch (AGB). Instabilities produce thermal pulses which eject the envelope, subsequent eruptions are faster and the material piles up in a **planetary nebula** (PN). Ionization and emission line nebulae. The gas forming the PN is **chemically enriched**: it contains more "metals" than it did before the star formed. Ages of PN: trace back to ejection point. PN are relatively young: they disperse after 50,000–100,000 yr.

§27.3: The remnant after the ejection of the PN is a hot core which eventually (in a few million yr) becomes a **white dwarf** (WD). No nuclear burning going on, the WD just cools at more or less constant radius. Properties of WDs: radius $\lesssim R_E$, but $\sim 300,000$ times more mass, so over a million times denser than water! Degenerate matter. Chandrasekhar limit: no WD can have a mass of more than 1.4 $M_\odot$. Pressure of **electron degeneracy**.

§27.4 and 27.5: Observing WDs: the wobble of Sirius, Procyon and 40 Eridani. Hot stars: EUVE; faint blue stars in GC: HST. Surface temperatures: 4,000 K$\lesssim T \lesssim$ 200,000 K. WD in binaries: Novae. Accretion and Nova explosions.

SAMPLE:

Part I – Multiple Choice questions (5 pts/question; total = 60 pts)
Identify the correct answers by placing a check between the brackets [ ]. Check **ALL** correct answers in the questions identified by a *.

1) The energy generated in the core of the sun is produced by
   - [ ] mostly the p-p chain but some by the CNO cycle.
   - [ ] convection in the convection zone.
   - [ ] the p-p chain alone.
   - [ ] the CNO cycle alone.
   - [ ] by the solar wind.

2) A star (it's surface temperature T) of spectral type G3I is
   - [ ] cooler than a G3V star .
   - [ ] hotter than a G3V star.
   - [ ] smaller but the same T as a G3V star.
   - [ ] bigger but the same T as a G3V star.
   - [ ] smaller but the same T as a G3III star.

3) Horizontal Branch stars
   - [ ] burn H in the core.
   - [ ] burn He in the core and H in a shell.
   - [ ] do not burn H anywhere.
   - [ ] burn He in a shell and H in another shell surrounding the first.
   - [ ] do not burn He anywhere.

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Part II – Problems (10 pts/problem; total = 40 pts)
Problem 1: The position of WDs in the HR diagram indicates that they are typically 10 magnitudes fainter than a MS star of the same surface temperature. What can you say about their radii: Are they smaller/bigger than MS stars and by what factor approximately?

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Problem 2: All HB stars have roughly the same luminosity of about $100 L_\odot$ and RR Lyrae are HB stars in the instability strip. Approximately what will be the absolute magnitude of HB and RR Lyrae stars?