Name: ....

ASTRONOMY 1102 – 1

Instructor: Juhan Frank

Second Test – Friday March 12, 1999

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) Population II cluster variables found on the HB are
   [ ] Cepheids.
   [ ] blue giants.
   [ ] blue supergiants.
   [ ] Mira variables.
   [x] RR Lyrae.

2) Soon after the He-flash the sun will be found on the HR diagram on
   [ ] the Hayashi track for fully convective stars.
   [ ] the zero-age main sequence.
   [x] the horizontal branch.
   [ ] the AGB.
   [ ] the cooling curve for white dwarfs.

3) The energy generated in a 10 $M_\odot$ star is produced *mostly* by
   [ ] Helium burning.
   [ ] gravitational contraction.
   [x] the CNO cycle.
   [ ] the proton–proton chain.
   [ ] convection.

4*) A F3V star is
   [ ] bigger than a F3I star.
   [x] smaller than a F3I star.
   [ ] bigger than a F3III star.
   [x] smaller than a F3III star.
   [ ] hotter than any white dwarf.

5) This kind of star is often in the company of Herbig–Haro Objects:
   [ ] Mira or o Ceti.
   [ ] RR Lyrae.
   [ ] δ Cephei.
   [x] T Tauri.
   [ ] α Centauri A (G2V).

6) A "star" made almost entirely of C/O and no nuclear burning anywhere is
- [ ] a main sequence star.
- [ ] ascending the RGB.
- [ ] sitting on the HB.
- [ ] ascending the AGB.
- [x] a white dwarf.

7) A jet from a young stellar object may end in a
- [ ] convective envelope.
- [ ] radiative zone.
- [ ] HII region.
- [x] Herbig–Haro object.
- [ ] Planetary Nebula.

8) When a solar mass star is burning He steadily,
- [ ] the He–flash occurs.
- [x] it has become a Horizontal Branch star.
- [ ] it has expanded to the largest size it will ever attain as a star.
- [ ] it has become a white dwarf.
- [ ] it is destroyed without trace.

9) An F0V star whose apparent magnitude is +3, must be
- [ ] 0.1 pc distant.
- [ ] 1.0 pc distant.
- [x] 10 pc distant.
- [ ] 100 pc distant.
- [ ] 1 kpc distant.

10) The Period–Luminosity relation for Cepheids was discovered
- [x] by Henrietta Leavitt studying the Magellanic Clouds.
- [ ] by Harlow Shapley when studying globular clusters.
- [ ] by studying periodic variables in distant galaxies.
- [ ] by Hertzsprung and Russell when studying clusters.
- [ ] by Edwin Hubble studying variables in the Andromeda Galaxy.

11) Gallex, SAGE and Kamiokande are located in deep mines
- [ ] because the ν_e oscillate into other types of neutrinos.
- [ ] because they should according to the Standard Model.
- [x] to avoid false signals caused by cosmic rays.
- [ ] therefore they see less ν_e than predicted by the Standard Model.
- [ ] since physicists prefer to work in isolation.

12*) In the CNO cycle
- [x] Carbon is a helper nucleus or catalyst which is not burnt.
- [ ] turns He into C.
- [ject to interpretation] burns C into N and O.
- [ ] powers low–mass main sequence stars.
- [x] H is fused to He.

Part II – Problems (10 pts/problem; total = 40 pts) **NO CALCULATORS!**

Problem 1: Several RR Lyrae stars ($L \approx 10^2 L_\odot$) are observed in a globular cluster at a magnitude $m = 16$. Estimate the distance to this cluster.

$1L_\odot$ corresponds to $M = +5$ (the sun, G2V, from table).

$10^2 L_\odot$ is 5 magnitudes brighter, so it corresponds to $M = 0$.

Therefore $m - M = 16$. With $m - M = 0$ at 10 pc, $m - M = 15$ would be $10^3 \times 10$ pc $= 10$ kpc.

$m - M = 17$ is one magnitude fainter so must be 1.585 times farther.

So $d = 16$ kpc.

Problem 2: Estimate the age of the cluster whose HR diagram is shown below. What kind of cluster it this?

From the graph one finds the Main Sequence Turnoff occurs at spectral class G0 approximately. The age of the cluster is equal to the Main Sequence lifetime of such a star. From the table this is 10^{10} yr.

From the fact that the age is about ten billion years, that there is an obvious horizontal branch (HB), some blue stragglers, and an asymptotic red giant branch (AGB), this is an old globular cluster.

$\lambda = cT \quad \lambda f = c \quad \frac{\Delta\lambda}{\lambda_{\rm emi}} = \frac{\lambda_{\rm obs} - \lambda_{\rm emi}}{\lambda_{\rm emi}} = \frac{v}{c} \quad \lambda_{\rm obs} = \lambda_{\rm emi} + \Delta\lambda$

1 pc = 3.26 LY $\quad d(\text{pc}) = 1/p(\text{arcsec}) \quad \lambda_{\max} \propto 1/T \quad E \propto T^4 \quad Flux \propto 1/d^2$

$L \propto R^2 T^4 \quad \sqrt[5]{10} = 1.585 \quad \sqrt[5]{100} = 2.512$ On the MS: $L \propto M^3$, $R \propto M$

Problem 3: Describe the evolution of a star like the sun **from** the time a planetary nebula is ejected **up to** the formation of a cool white dwarf. **Please do NOT include any earlier or later phases.** Sketch the corresponding path on the HR diagram provided. Sketch the internal structure of the star identifying what kind of - if any - nuclear burning is taking place and and where.

Once the envelope of an AGB star is ejected as a Planetary Nebula, all nuclear burning ceases and eventually the almost bare core of C and O is exposed. As the remaining envelope is evaporated the star reapidly moves to the blue reaching temperatures of hundred thousand or more Kelvin and finally turns down and cools along the white dwarf track. This is a constant radius line on the HR diagram. *Problem 4:* The Hubble Space Telescope has discovered in the Galaxy M100 a pulsating variable with a median magnitude of 25 and a regular period of about 70 days. Explain why this star is likely to be a Cepheid and estimate the approximate distance to M100.

From the graph one gets $M = -7$ *approximately for 70 days. So* $m - M = 25 - (-7) = 32$. $m - M = 30$ *would correspond to* 10 *Mpc. Since it appears two magnitudes dimmer it must be a factor of* $1.585^2 = 2.5$ *farther. Therefore the distance is* $d = 25$ *Mpc.*