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) Cepheids and RR Lyrae are examples of
   [ ] main sequence stars.
   [ ] blue giants.
   [ ] blue supergiants.
   [ ] white dwarfs.
   [x] pulsating variables.

2) As the proto–sun contracted to the main sequence, it followed
   [x] the Hayashi track for fully convective stars.
   [ ] the main sequence.
   [ ] the horizontal branch.
   [ ] the AGB.
   [ ] the cooling curve for white dwarfs.

3) The energy generated in the solar core is produced *mostly* by
   [ ] Helium burning.
   [x] the proton–proton chain.
   [ ] the CNO cycle.
   [ ] gravitational contraction.
   [ ] convection.

4*) A K4III star is
   [x] bigger than a K4V star.
   [ ] smaller than a K4V star.
   [ ] bigger than a K4I star.
   [x] smaller than a K4I star.
   [x] more luminous than any white dwarf.

5) This type of star is a variable young star
   [ ] Mira or *o* Ceti.
   [ ] RR Lyrae.
   [ ] δ Cephei.
   [x] T Tauri.
   [ ] α Centauri A (G2V).

6) A star with an inert He core and a H–burning shell around it, is
- [ ] a main sequence star.
- [x] ascending the RGB.
- [ ] sitting on the HB.
- [ ] ascending the AGB.
- [ ] a white dwarf.

7) The envelope of a lightweight star is eventually ejected as a
- [ ] convective envelope.
- [ ] radiative zone.
- [ ] HII region.
- [ ] Herbig–Haro object.
- [x] Planetary Nebula.

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

9) A star whose parallax is 0.1 arc seconds has a distance modulus
- [x] $m - M = 0$.
- [ ] $m - M = 5$.
- [ ] $m - M = 10$.
- [ ] $m - M = 15$.
- [ ] $m - M = 7$.

10) What force is responsible for holding protons and neutrons together?
- [ ] The gravitational attraction.
- [ ] The electromagnetic force.
- [x] The strong force.
- [ ] The frictional force.
- [ ] They can never attract each other.

*11) Gallex, SAGE and Kamiokande
- [x] are experiments measuring the solar ν_e flux.
- [ ] are theories of star formation.
- [ ] are experiments measuring gravitational waves.
- [x] detect less than they should according to the Standard Model.
- [x] can detect what they detect through miles of rock.

12) The mass of 4 atoms of Hydrogen is
- [ ] slightly less than the mass of 1 atom of Helium.
- [ ] the same as the mass of 1 atom of Helium.
- [x] slightly more than the mass of 1 atom of Helium.
- [ ] about half of the mass of 1 atom of Helium.
- [ ] about twice the mass of 1 atom of Helium.

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 $m = 17$. 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 $m - M = 17$. With $m - M = 0$ at 10 pc, $m - M = 15$ would be $10^3 \times 10$ pc $= 10$ kpc.

$m - M = 17$ is two magnitudes fainter so must be $(1.585)^2 = 2.5$ times farther.

So $d = 25$ 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 F0 approximately. The age of the cluster is equal to the Main Sequence lifetime of such a star. From the table this is 3×10^9 yr.

From the fact that the age is a few billion years, that there is no obvious horizontal branch (HB) nor asymptotic red giant branch (AGB), this is an old open/galactic 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 hydrogen is exhausted at the center **up to** the point where the He–flash occurs. **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.

As H is exhausted at the center of the core of a Main Sequence star, an inert (non–burning) inner core of He forms, surrounded by a H–burning shell. Initially the envelope expands and the star moves to the red. This is the brief Subgiant phase. When the core is developed and the envelope is fully convective we have a red giant. More Luminosity is generated by the shell than on the MS. The envelope expands as the core contracts but the mass of inert He continues to increase as the shell burning adds more He to the core. The envelope and photosphere expand as the star ascends the Red Giant Branch (RGB) at more or less constant surface temperature. When the core reaches about 10^8 *K, the triple alpha reaction kicks in and most of the core is converted to C/O is a few minutes. This explosive burning is the He-flash.*

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 40 days. Explain why this star is likely to be a Cepheid and estimate the approximate distance to M100.

From the graph one gets $M = -6$ *approximately for 40 days. So* $m - M = 25 - (-6) = 31$. $m - M = 30$ *would correspond to* 10 *Mpc. Since it appears one magnitude dimmer it must be a factor of* 1.585 *farther. Therefore the distance is* $d = 16$ *Mpc.*