Name: ....

ASTRONOMY 1102 – 1

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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*) Miras, Cepheids and RR Lyrae are
- [ ] found on the main sequence.
- [ ] blue giants.
- [ ] blue supergiants.
- [x] found on the instability strip.
- [x] pulsating variables.

2) As the proto–sun contracted to the main sequence, H fusion began on
- [ ] the Hayashi track for fully convective stars.
- [x] the zero-age main sequence.
- [ ] the horizontal branch.
- [ ] the AGB.
- [ ] the cooling curve for white dwarfs.

3) The energy generated in a 0.5 $M_\odot$ star is produced *mostly* by
- [ ] Helium burning.
- [ ] gravitational contraction.
- [ ] the CNO cycle.
- [x] the proton–proton chain.
- [ ] convection.

4*) A M0I star is
- [x] bigger than a M0V star.
- [ ] smaller than a M0V star.
- [x] bigger than a M0III star.
- [ ] smaller than a M0III star.
- [x] cooler than any main sequence star of types O–K.

5) A long period, somewhat irregular variable star is:
- [x] Mira or o Ceti.
- [ ] RR Lyrae.
- [ ] δ Cephei.
- [ ] T Tauri.
- [ ] α Centauri A (G2V).

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

7) The H-rich gas outside the core of an RGB star is a
[x] convective envelope.
[ ] radiative zone.
[ ] HII region.
[ ] Herbig–Haro object.
[ ] Planetary Nebula.

8) When a solar mass star reaches the top of the AGB
[ ] the He–flash occurs.
[ ] it has become a Horizontal Branch star.
[x] 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) A star whose parallax is 0.01 arc seconds has a distance modulus
[ ] $m - M = 0$.
[x] $m - M = 5$.
[ ] $m - M = 10$.
[ ] $m - M = 15$.
[ ] $m - M = 7$.

10) He–burning requires a higher temperature than H–burning because
[ ] the gravitational attraction is greater.
[x] the electromagnetic repulsion force is larger.
[ ] The strong force is stronger.
[ ] the He nucleus has less mass.
[ ] He nuclei can never attract each other.

*11) Gallex, SAGE and Kamiokande see less ν_e
[x] because the ν_e oscillate into other types of neutrinos.
[x] than they should according to the Standard Model.
[ ] than gravitational waves.
[ ] because the solar models are in error.
[ ] because they are located under miles of rock.

12) The triple alpha reaction
[ ] requires slightly less than the mass of 1 atom of Helium.
[x] turns He into C.
[ ] burns H into He.
[ ] powers main sequence stars.
[ ] starts operating at a temperature of a few million degrees.

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 $m = 14$. 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 $m - M = 14$. With $m - M = 0$ at 10 pc, $m - M = 10$ would be $10^2 \times 10$ pc $= 1$ kpc.

$m - M = 14$ is four magnitudes fainter so must be $(1.585)^4 = 6.35$ farther.

So $d = 6.3$ 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 B0 approximately. The age of the cluster is equal to the Main Sequence lifetime of such a star. From the table this is 10^7 yr.

From the fact that the age is ten million years, that there is no horizontal branch (HB) nor asymptotic red giant branch (AGB), this is a young open/galactic cluster.

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

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

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

Problem 3: Describe the evolution of a star like the sun **from** the time helium is exhausted at the center **up to** the point where the envelope is ejected. **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.

When He is exhausted at the center of a Horizontal Branch star, an inert (non–burning) inner core of C/O forms, surrounded by a He–burning shell, which is in turn aurrounded by a H–burning shell. The subsequent evolution mirrors the evolution away from the main sequence: first the star gets redder and bigger. Then it ascends the Asymptotic Giant Branch and eventually it reaches the biggest size as a star (bigger than at the top of the RGB, just before the He–flash). The burning is unstable, and thermal pulses eject the envelope as a Planetary Nebula. All nuclear burning ceases.

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

From the graph one gets $M = -4$ *approximately for 7.5 days. So* $m - M = 25 - (-4) = 29$. $m - M = 30$ *would correspond to* 10 *Mpc. Since it appears one magnitude brighter it must be a factor of 1.585 closer. Therefore the distance is* $d = 6.3$ *Mpc.*