Exam 2.5 – Score Statistics

Letter Grade	Score Range	No. of Students
A	53 – 60	26
A⁻	50 – 52	12
B⁺	48 – 49	11
B	45 – 47	23
B⁻	42 – 44	12
C⁺	39 – 41	13
C	36 – 38	14
C⁻	33 – 35	8
D	30 – 32	7
F	< 30	10

Total # Exams: 136
Mean = 43.5/60 = 72.5%

Breakdown by letters:

A : B : C : D : F

38 : 46 : 35: 7: 10

28%: 34%: 26%: 6%: 7%

FMQ: Frequently Missed Questions

- *"What is a positron?"* This particle is produced during the first step of the p-p chain. In this step, two protons fuse to form a deuterium (D, heavy hydrogen) nucleus containing one proton and one neutron, while giving off a low-energy neutrino and a positron – the anti-particle of an electron, which has a positive charge. On Exam 1, one of the questions asked about which items were not produced during the p-p reaction.
- *"Total power emitted over the entire surface of a thermal emitter.* The power emitted by a thermal emitter depends on ***both temperature and surface area***: L = surface area x energy per unit surface area. Many people said that it depended on the temperature but *not* the surface area; that was the correct answer to ***a different question***, the one asked on Exam 1. Word to the wise: don't just memorize answers to old exams!!

FMQ: Frequently Missed Questions

- *"What does the Kepler satellite actually see, to show that an exoplanet may be present?"* Just saying "transits," would have made this question a matter of mere memorizing. Instead, the question described in plain words what actually happens when there is a transit by an exoplanet, namely a dip in the level (brightness) of the star's light curve, as shown in animations and graphs – e.g. slides 17 & 18 from 10/11. Kepler does not magnify a distant star to the point of seeing a bright disk with a dot in front it – the ***only*** time we actually see a dot crossing a disk is when Mercury or Venus transits our own Sun!
- *"What was surprising about 51 Peg b?"* There was a (different) question about this object on Exam 2, also a question about "hot Jupiters." 51 Peg b was the first "hot Jupiter," a massive planet close in. It does ***not*** orbit a pulsar!

FMQ: Frequently Missed Questions

- *"What was seen at the center of the Crab Nebula?"* We have previously had questions about the importance of SN 1987A, specifically the detection of neutrinos emitted when the core collapsed and a neutron star formed. The Crab Nebula is the remnant of a supernova that happened about a thousand years ago, so obviously no neutrinos were seen at that time! The significant thing seen in the Crab Nebula was the discovery of a pulsar there. See the Index Card of 10/30 for clarification of what is significant in each of these supernovae.
- *"Which are sources of energy for some stars?"* Some people missed that adding He nuclei to elements such as Ne, Mg, etc. can generate energy; these are the later fusion stages of high-mass stars (see slides from 10/25 and Nov. 1 Index Card).

Exam 2.5 Essay Questions

1. Why do most pulsars slow down with time? What do a few of them speed up?

- Pulsars slow down with time because they are losing energy; their rotational energy is being converted to the radio pulses that give them their name (synchrotron radiation, produced with the help of the magnetic field). See slides from Nov. 1.
- Under special circumstances, certain pulses can be "sped up" again. The main method for this is when mass is transferred from a binary companion. This mass has angular momentum due to the orbital motion of the two stars, and it acts like a hand "spinning up" a bicycle wheel. Some pulsars are sped up so much that they end up with periods measured in milliseconds! Another event that can speed up a pulsar, but just a little bit, is when it experiences a "starquake" and its crust shifts.

To See or Not to See … (a Pulsar)

Pulsars are spinning neutron stars, formed by the core-collapse of a high-mass star going supernova.

What conditions must be met, in order for us to actually see pulses from a pulsar?
- It must be emitting in our direction at least some of the time (its beam must "cross" our direction)
– The spin axis must be different from the magnetic axis (that's true for the Earth!)
- It must not (yet) have lost most of its initial rotational and magnetic energy

The Slowing & Fading of Pulsars

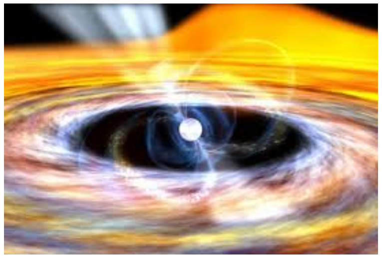
Kaler, p. 165: "A pulsar's energy is derived from its magnetic field and ultimately from its spin."

- A pulsar is "born" from a core-collapse supernova, spinning rapidly (P = 10^{-2} to 10^{-3} seconds).
- It starts with a huge amount of rotational energy; its rapid spin induces a strong magnetic field via a "dynamo" effect.
- The magnetic field causes synchrotron emission, which carries energy away (an energy "drain").
- As the star spins more slowly, the magnetic field weakens.

Kaler, p. 165: "As a neutron star slows, it loses its ability to radiate… By the time the period is up to 4 seconds or so, it is too old and weak to radiate much, and it disappears from view."

Pulsar "Spin-ups"

For a neutron star/pulsar in a binary system, if matter with angular momentum is transferred to the accretion disk, it can dramatically speed up the neutron star's rotation.



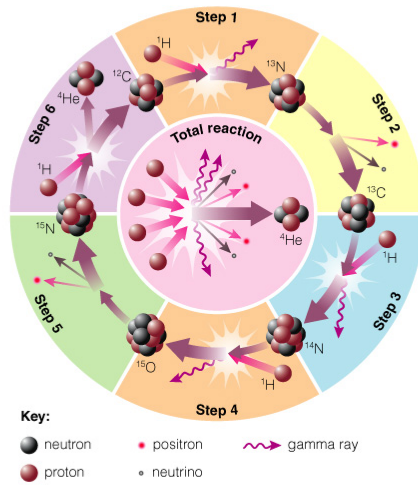
This is thought to be the origin of the "millisecond" pulsars, P = .001 sec, some of which are seen in very old star clusters (globular clusters), so they cannot be recently formed NS.

Exam 2.5 Essays, cont'd.

2. What is the CNO cycle, what is needed and what produced?

- The CNO cycle is an alternative method of H fusion, besides the p-p chain. Like most fusion, it requires high temperature and density. (It requires higher T than p-p, because C has 6+ charges.) The inputs are H and C; at the end of the set of reactions, the products are He and C. (C acts as a catalyst.).

Alternate H-fusion method: CNO Cycle



10/23/12

- Main Sequence stars of more than 1.5 $M_{\odot}$ fuse H into He using carbon as a *catalyst*, instead of through the familiar p-p reaction that happens in the Sun
- Higher core temperature enables nuclei to overcome the electric repulsion between the nuclei

Exam 2.5 Essays, cont'd.

3. What exoplanet search method(s) give you an idea of the planet's mass? When can you get the actual planet mass?

- The Doppler wobble method gives the planet's mass, or at least a minimum mass: if the orbit is tilted, we see only part of the velocity and the planet's mass will be underestimated.
- If transits are also seen, then we must be viewing the orbit nearly edge-on, so the Doppler mass is the true mass.

Reminder: Quiz 5 Feedback

1. What properties of an exoplanet can you determine if the from transit measurements? from Doppler measurements?

Transit measurements give you *radius* or physical size of the planet, as well as the orbital period. Doppler measurements give you the orbital period and an indication of the planet's *mass*; if you do not know the orbital tilt, this is only a minimum possible mass.

If you have both, then you know the approximate orbital tilt (nearly edge-on), therefore the actual planet mass. And the mass and radius of the planet together tell you the average density, hence some ideas of the possible composition (rocky, gaseous, etc.).

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Exam 2.5 Essay Questions

4. Compare white dwarfs and neutron stars.

- ***mass***: white dwarfs are limited to less than 1.4 $M_{\odot}$, while neutron stars can have up to 2 - 3 $M_{\odot}$.
- Neutron stars have much smaller ***radii*** than white dwarfs: a WD is about the size of the Earth, a NS of a city (10-12 km)
- White dwarfs are usually mostly composed of C and O, neutron stars are composed of neutrons!
- Both are supported by degeneracy ***pressure***, the WD by electron degeneracy, the NS by neutron degeneracy pressure
- WD are the end-state of the cores of lower mass stars (up to 8 $M_{\odot}$), NS are the leftover cores of high mass stars
- Once they are out in the open (the outer layers have flown off) both WD and NS will stay at fixed radius, dimming and cooling like a baked potato, unless something comes along to rejuvenate them (like mass transferred from a companion star)

Exam 2.5 Essays, cont'd.

5. Summarize the post-Main Sequence life of a lower mass star.

- This is a pretty straightforward matter to stepping through the major stages in a star's life. The last part asks you to specify when a star has the largest/smallest luminosity, temperature, and radius – the "extremes" along its track in the HR Diagram:
- It is largest in radius and luminosity, and coolest in surface temperature, on the AGB.
- It has the smallest radius and luminosity, and the hottest surface temperature, when it is a white dwarf, but by then it has lost some of its mass; before then, it has the most compact structure (smallest radius) and lowest luminosity, ironically, as a Main Sequence star!

Life Stages of a Low-Mass Star