Astronomy 100 Homework 3: Solutions Dr. Warner

1. Kepler's third law states that: **$P^2 = a^3$** for objects orbiting the Sun, where **P** is the period in years and **a** is the semi-major axis in astronomical units (A.U.). (See sections 4.5 and 4.6 of *Freedman and Kaufmann* for details.)

a) The semi-major axis is the average distance from the Sun, and so for Sedna this is

$$a = \tfrac{1}{2}(850 + 76)\ \text{A.U.} \approx 463\ \text{A.U.}$$

Hence the period (in years) is given by

$$P^2 = (463)^3 \approx 9.925 \times 10^7$$

$$\Rightarrow \quad P \approx 9.96 \times 10^3\ \text{years} \approx 10{,}000\ \text{years}$$

b) If P is 27 years then

$$a^3 = P^2 = (27)^2 = 729 \quad \Rightarrow \quad a = 9\ \text{A.U.}$$

Let d be the distance at aphelion, and we are given the distance at perihelion to be 0.5 A.U., and so

$$a = \tfrac{1}{2}(d + 0.5)\ \text{A.U.} = 9\ \text{A.U.} \quad \Rightarrow \quad d = 17.5\ \text{A.U.}$$

Recall that the semi-major axis of Uranus's orbit is about 19 A.U. while that of Neptune's orbit is 30 A.U. and so this result is Illustrates the fact that such short period comets do not even quite make it out to the Edgeworth-Kuiper belt.

2. This question basically asks for a summary of parts of sections 18.5 to 18.7 of *Freedman and Kaufmann*. The key features are:

Photosphere:

- thin layer (about 300-500km thick)
- The optical surface, i.e. the surface from which the visible light escapes.
- Temperature: 5800K on average, but varies, dropping to 4400K near the top.
- Continuous spectrum emission, but with some absorption near the upper layers.
- Photosphere surface is granulated, with granules about 1000 km across. These granules are convection cells.
- Photosphere surface also exhibits periodic sunspot activity.

Chromosphere:

- red/pink colored layer immediately above the photosphere.
- thin layer, but several times thicker than photosphere (about 2000 km thick)
- Temperature varies but is about that of photosphere, ranging from 4500K to 25,000K (very approximately) as one moves out through the chromosphere
- Very low density: hot thin gas. The red color is due to very strong H_α emission line spectrum. (Compare with the pink of HII regions ofemission nebulae.)
- Exhibits spicules - short lived (typically 10 minute) spikes or jets of gas shooting up a few thousand kilometers.

Corona:

- Very diffuse and very large, outermost layer of the Sun.
- Starts at about 3,000 to 10,000km above photosphere (at outer edge of the **transition zone**).
- Several solar radii in size, irregular shape determined to some extent by the solar magnetic field.
- Temperature: extremely high - a few million degrees K.
- Source of most of the Sun’s U.V. and X-ray emission.
- Probably heated by the magnetic field trapping energy and transporting energy from the solar core.
- There are sporadic holes in the Corona, and these are believed to act as corridors for the solar wind.

3. Remember Wien's Law, which states that the wavelength at which black body radiation has its maximum intensity is given by:

$$\lambda_{\max} \approx \frac{0.0029}{\mathrm{T}} \text{ meters}$$

where T is the temperature in Kelvin.

a) Photosphere:

$$\mathrm{T} = 5{,}800\mathrm{K} \quad \Rightarrow \lambda_{\max} \approx \frac{0.0029}{5800} \text{ meters} = 5 \times 10^{-7} \text{ m} \;= 500 \text{ nm}$$

b) Chromosphere:

$$\mathrm{T} = 50{,}000\mathrm{K} \quad \Rightarrow \lambda_{\max} \approx \frac{0.0029}{20{,}000} \text{ meters} = 1.45 \times 10^{-7} \text{ m} \;= 145 \text{ nm}$$

Note: The temperature given here for the chromosphere is slightly different from the temperature given in question 2. The reason for this discrepancy is that the boundary of the chromosphere and transition zone is rather murky, and the temperature goes up very, very fast in the transition region.

c) Corona:

$$\mathrm{T} = 1.6 \times 10^{6} \text{ K} \quad \Rightarrow \lambda_{\max} \approx \frac{0.0029}{1.6 \times 10^{6}} \text{ meters}$$

$$= 1.81 \times 10^{-9} \text{ m} \;= 1.81 \text{ nm}$$

Now look at figure 5.7 in *Freedman and Kaufmann:* These frequencies lie in a) the visible, b) the ultra-violet and c) the X-ray spectrum.

From figure 6.27 in *Freedman and Kaufmann* one sees that all the optical light passes through the atmosphere (this you know from everyday experience) but only some of the U.V. light and none of the X-rays penetrate the atmosphere. Thus the photosphere, and to some extent the chromosphere can be studied from Earth, but one would get a more complete view of the chromosphere from space. The corona requires space-based observation to see the vast majority of the radiation that it emits.

4.

The solar cycle:

- Begins with the Sun having no, or almost no, sunspots (the sunspot minimum)

- Sunspots then begin to form, but at first only at the mid-latitudes on the solar surface

- As the solar cycle progresses, the number of sunspots increases

- As the solar cycle progresses, the sunspots tend to form nearer and nearer the solar equator - this is called equatorial migration

- At the solar maximum, one has the most sunspots on average, and they are primarily near the equator

- The sunspot count then returns to nearly zero (the sunspot minimum) again This cycle repeats once every 11 years.

- The foregoing cycle is accompanied by a reversal of the Sun's magnetic field. Every 11 years it reverses, and only returns to its original polarity every 22 years.

- The sunspot minima roughly coincide with the time at which the magnetic field almost disappears for a short time during the reversal (... I could not find this given in the book .. so you will not be penalized if you don't get this one .. but you should know it ...)

5. You can find the answer to part of this on p. 406 of Freedman and Kaufmann. The average temperature of the photosphere is 5800K, and so if the umbra of a sunspot is 1600K cooler than the surrounding photosphere, then it has an average temperature of 4200K.

Now recall the Stefan-Boltzmann law:

$$\text{Energy Flux} \propto T^4$$

and that this is the same as the intensity of the radiation. Therefore, for the penumbra:

$$\frac{\text{Energy Flux from umbra}}{\text{Energy Flux from surrounding photosphere}} \approx \left(\frac{4200}{5800}\right)^4 \approx 0.275$$

hence the <u>energy flux from the umbra of the sunspot is only **27.5%** of that from the surrounding photosphere</u>. Therefore while a sunspot is very hot and thus very bright (compared to terrestrial light sources) it is dim in comparison to the surrounding photosphere.

6. The solar neutrino problem is name given to the discrepancy between theoretical predictions of the Sun's neutrino output and the actual measured value.

As we discussed in class, nuclear fusion produces fragments. One of the most common fragments is a neutrino, which is almost massless and very weakly interacting, and so very hard to detect. Neutrinos also come in three different species, and different fusion reactions in the Sun generally yield only one species of neutrino, but at a variety of different energies. The higher energy neutrinos of this one particular species are most easily detected, and the rates have been monitored since the early 1960's. The measured rate was about **one third** of that predicted by theoretical models of nuclear fusion in the Sun's core.

There were two possible ways to resolve this. Freedman and Kaufmann are a little conservative in how they describe this, and indeed there have been relatively recent results from the Sudbury Neutrino Observatory since publication of the text. I will state what I believe is the current view.

The first possibility is that the solar models might not be quite correct, and somehow the temperature in the Sun's core must be lower than the solar models suggest. Particle physicists liked this, and solar modelers did not.... With the developments of detailed helioseismology data it became more probable that the solar models were in fact correct, and the particle physicists needed to rethink their theories.

The second explanation is that we do not (or at least did not) understand neutrinos as well as we should. Several experiments have been done recently to detect and monitor low energy neutrinos, and neutrinos of other species. The evidence is now fairly conclusive and shows that solar neutrinos change species while in flight between Earth and the Sun: this is called neutrino oscillation. The missing neutrinos do indeed appear to be there, but many of them (about 60%) change into a species that is not detectable in the early neutrino detectors. Such neutrinos can however be detected by the more modern detectors like the one in Sudbury.

This whole story is a beautiful example of how astronomy can have a major impact on other areas of science, and can make us re-think some of our most basic ideas. In this instance, it caused a major change in our understanding of the weak nuclear interaction in particle physics.

7. a) Hydrogen burning in the Sun is **thermonuclear fusion** in which the nuclei of hydrogen are combined together (via a complex reaction) to make atoms of helium, along with lots of energy in the form of photons, neutrinos and the motion of other atoms and fragments. The kind of burning that takes place in a log in a fireplace is chemical burning in which combinations of atoms (molecules) recombine into different combinations of the same atoms (other molecules) thereby releasing energy into photons and motion of atoms and molecules. In chemical burning, the atoms themselves are unchanged, and one atom is not converted into another type of atom. Therefore, in chemical burning, the total number of each type of atom does not change in the burning process - the atoms are merely reshuffled into different combinations with one another. Thermonuclear fusion actually transmutes one kind of atom into another.

b) Thermonuclear reactions require the nuclei of atoms to get very close to one another before fusion can take place. Since nuclei repel each other very strongly because of their electric charge, the atoms must be moving very fast if they are to overcome the strong repulsion and get close. This means that one must have very high temperatures.

In order to get enough nuclei to come together and get an appreciable rate of reaction, there must be a lot of atoms in a small volume, and so one needs high densities. The necessity of high density and extremely high temperature means that one must apply extremely high pressure. Sufficiently high temperatures, pressures and densities only occur in the core of the Sun, as opposed to the outer parts of the Sun, or any terrestrial bottle of hydrogen gas.

c) As mentioned above, to get fusion to “go” atomic nuclei have to be forced together against their mutual electrostatic repulsion. To get hydrogen to fuse requires temperatures of a few million K. A hydrogen nucleus has only one proton, but a helium nucleus has two. The repulsion between two helium nuclei is thus four times that of two hydrogen nuclei (you get a factor of two for the charge on each helium nucleus). Thus it requires the atoms to move a lot faster if the collisions are to get them near enough for the nuclei to fuse. It turns out that one needs temperatures of about 100 million K for Helium to fuse at an appreciable rate.

Comments: (i) In discussing massive stars, we encountered shell burning: fusion can take place outside the core of a star if the star is big enough so as to make the pressure, temperature and density of hydrogen large enough away from the core as well. (ii) Fusion reactions have been generated on earth a) in thermonuclear weapons and b) for extremely brief instants in plasma fusion rings. In all instances, to accomplish this matter was compressed and heated to extremely high temperatures, mimicking the conditions near the core of the Sun.

8. Simply put, iron is the most stable element because it takes energy to convert it to a heavier element by fusion and it also takes energy to break it up into lighter elements (fission).

Imagine starting with separated building blocks (nucleons) of an atomic nucleus: protons and neutrons, and then assembling them into an atomic nucleus (this is very, very hard in practice, but imagine doing it anyway). Once the nucleus is assembled, its mass is generally less than the sum of the masses of the parts. This is the mass deficit, and this deficit is directly proportional to the net energy released in the process ($E= mc^2$). If one assembles an iron atom them the mass deficit (per nucleon) and hence the energy released (per nucleon) is maximized. If you make something heavier, or something lighter, you get less energy output (per nucleon). Turning this logic around, to disassemble iron into its component parts takes the highest amount of energy (per nucleon) of all atoms. So in fission, and fusion processes the tendency is to form iron for exactly the same reason that water tends to run to the lowest point: Iron is the lowest energy state, and its formation yields the most energy. Conversely, it takes energy to break it up, or make it heavier. This is what it means to be the most stable element.

9. Put simply, since proper motion is a measurement of angle over time and object A is five times further away (and moving with the same transverse speed), its angular or proper motion must be five times smaller.

In more detail: Proper motion, μ, of a star is the **true** angular motion of a star across the sky per unit time. (The word "true" in this definition is meant to remind you that a star can exhibit apparent cyclic motion in the sky throughout the year due to parallax. This parallax effect must be subtracted from the observed motion in order to get the proper motion.) Proper motion is usually measured in arcseconds per year. Tangential (or transverse) speed, v_t, is the (linear) speed, usually measured in km/s, across the line of sight. Since speed is a measure of distance over time, and proper motion is a measure of angle over time, the tangential (or transverse) speed, v_t , is related to the proper motion, μ, in exactly the same way as physical size is related to angular size: it all depends upon the distance.

If the star is at a distance, **d**, from the observer, then the tangential speed is proportional to both the distance and the proper motion:

$$\mathrm{v_t} \approx \mu\,\mathrm{d} \qquad \text{or} \qquad \mu \approx \frac{\mathrm{v_t}}{d}$$

If stars A and B have the same v_t, but different distances, then:

$$\frac{\mu_A}{\mu_B} \approx \frac{\left(\frac{\mathrm{v_t}}{d}\right)_A}{\left(\frac{\mathrm{v_t}}{d}\right)_B} = \left(\frac{(\mathrm{v_t})_A}{(\mathrm{v_t})_B}\right)\left(\frac{\mathrm{d}_B}{d_A}\right) = \frac{1}{1} \times \frac{1}{5} = \frac{1}{5}$$

Hence: $$\mu_A \approx \frac{\mu_B}{5}$$

Thus, if two stars have the same tangential speed, but one is five times further away than the other, then the proper motion of the more distant star is five times smaller.

10. Brightness, **b**, depends upon luminosity, **L**, and distance, **d**, according to the inverse square law: (**Remember this!**)

$$b \propto \frac{\mathrm{L}}{d^2}$$

and so if two stars are at the same distance from Earth then the brightness is determined by the luminosity. The total luminosity is proportional to the energy flux and the surface area:

$$L \propto \text{(Energy Flux)} \times \text{(Surface Area)}$$

Since the stars have the same size, the relative luminosity is determined by the stars' respective energy flux, which is in turn, determined from the Stefan-Boltzmann law:

$$\text{(Energy Flux)} \propto \mathrm{T}^4$$

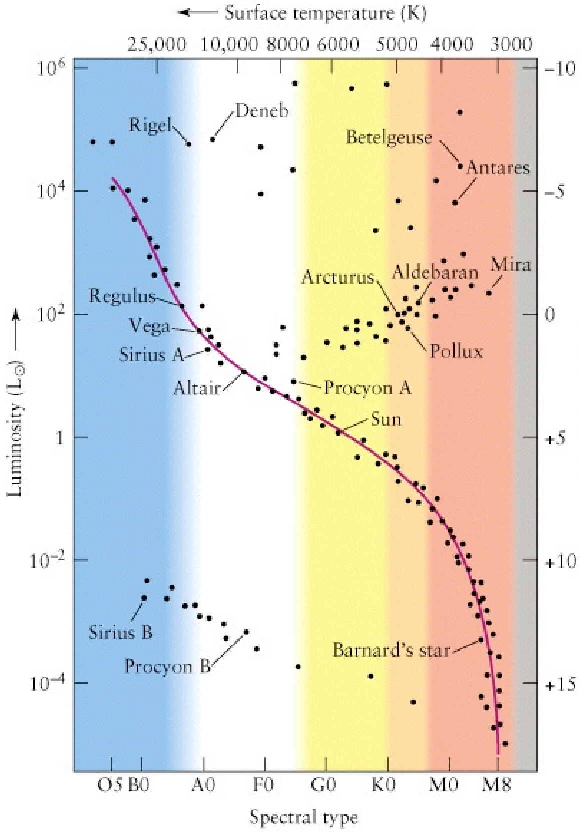
Thus, in the circumstances described in this problem, the brighter star will be the <u>hotter</u> one and a blue star is hotter than a red one. Hence the blue star will be brighter in the night sky.

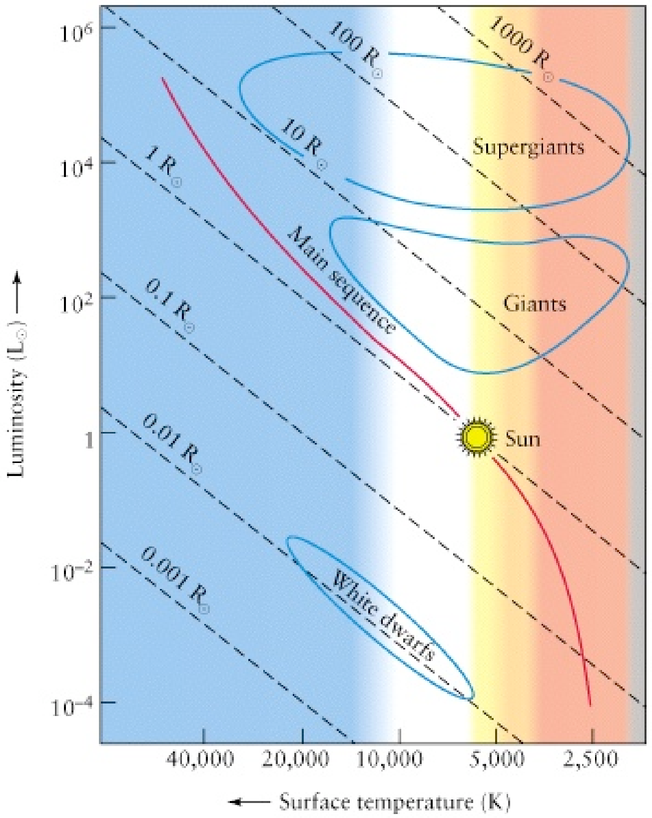
11. This problem is meant to remind you that you should know the basic idea behind the spectral class of a star, and that you should at least have read table 19-2 and look at figure 19.11 in *Freedman and Kaufmann* This table and the surrounding text contains the following basic information.

Spectral Class	Color	Temperature	Spectral Lines
O	Blue-violet	30,000 K	Faint hydrogen lines Strong helium lines Multiply ionized iron lines
A	White	10,000 K	Strong hydrogen lines Faint helium lines Some ionized metals
G	Yellow	6,000 K	Some hydrogen lines No helium lines Well developed lines from metals like calcium and iron
M	Red	3,000 K	Strong metal lines; strong titanium dioxide lines

Comment: For exams, I will not expect you to memorize what kind of star has what kind of line, I merely want you to appreciate the idea of spectral class and how it works.

12. a) For the relevant Hertzsprung-Russell diagrams see section 19.7 and figures 19-14 and 19-15 of *Freedman and Kaufmann.* Reproduced here:





b) The total luminosity of a star proportional to the energy flux (the energy radiated per unit area) and the surface area:

$$L \propto (\text{Energy Flux}) \times (\text{Surface Area})$$

The position on the Hertzsprung-Russell diagram gives one the luminosity, L, and the temperature, T, of the star. From the temperature one can use the Stefan-Boltzmann law to get the energy flux, and using the equation above, one can thus determine the surface area of the star. The surface area of a star is proportional to the square of its radius.

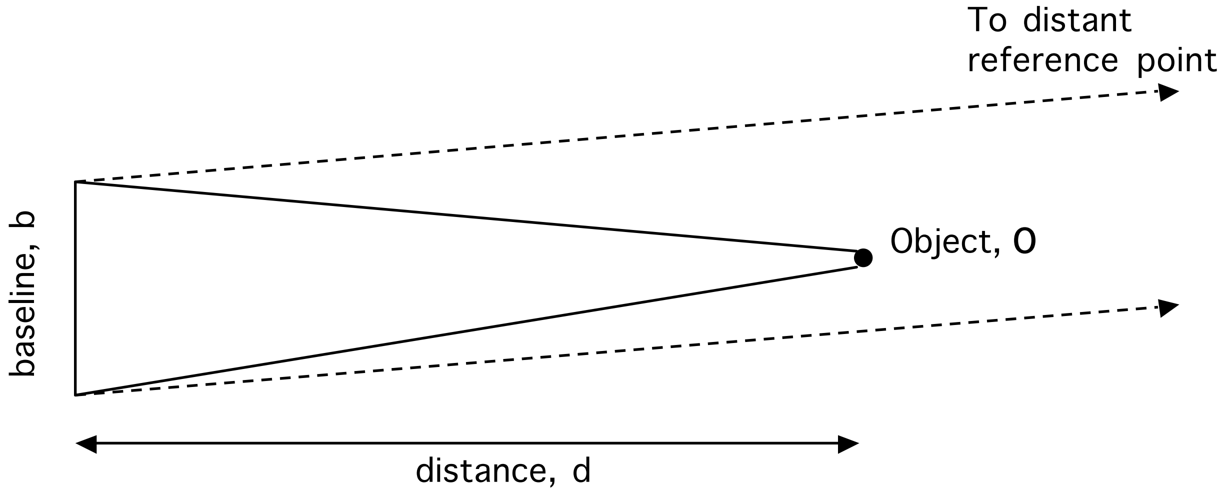
More mathematically:

$$(\text{Energy Flux}) \propto T^4 \quad \text{and} \quad \text{Surface Area} = 4\pi R^2$$

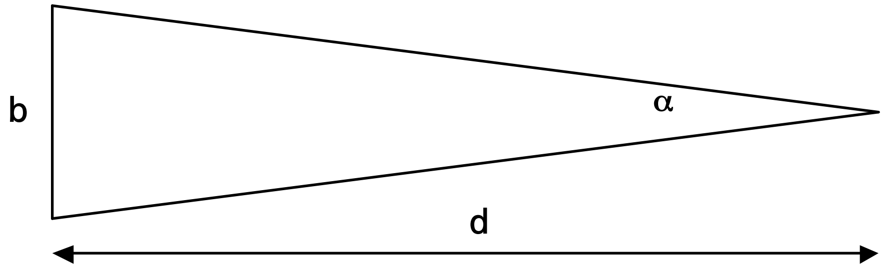
Hence:

$$L \propto T^4 \times R^2 \quad \text{or} \quad R \propto \sqrt{\frac{L}{T^4}}$$

13. a) To measure distance an object, O, by parallax one uses the properties of triangles. That is one measures, or knows, the length of the base (or baseline) of the triangle, and then, from each end of the baseline one measures, from some reference direction or point, the angle to the object in question. One can then use trigonometry or graphical drawing to figure out the distance.



For nearby stars the baseline that we use is the diameter of the Earth's orbit around the Sun (2 A.U. in length). Even so, the triangle is extremely long and thin. This means that one can use the small angle formula:



$$b \approx \frac{\alpha\, d}{57.3} \quad \text{or} \quad b \approx \frac{\alpha\, d}{206{,}265}$$

where **b** is the baseline length, **d** is the distance to the stars and α is the angle in the top of the triangle. The angle α can be figured out from the angles measured at the end of the baseline. If one measures α in degrees then one uses the first formula and if one measures α in arcseconds then one uses the second formula.

13 (continued).

The more distant the star the smaller the value of the angle α. Indeed, for stars, the angle α is extremely small, and the practical limit to the accuracy to which we are presently able to measure α (from Earth's surface) is about 0.005 arcseconds. This means that if a star is so far away that α is less than this limit we cannot use parallax to measure its distance. In practice, parallax cannot be used to measure distances of more than 200pc.

b) Another way to measure distance in general is to use the relationship between brightness and luminosity:

$$b \propto \frac{L}{d^2}$$

One can figure out the distance, d, if one knows the luminosity, L, and measures the brightness, b. In spectroscopic parallax one first determines the temperature of a star by using its spectrum to determine its spectral class (OBAFGKMLT). One then uses the Hertzsprung-Russell diagram to figure out the luminosity from the temperature. (One also uses more details of the spectrum to get a star's luminosity class, and hence determine in what feature of the HR diagram the star lies: e.g. the main sequence.) So the key to spectroscopic parallax is the use of the spectrum and the HR diagram to determine a star's luminosity. The term "spectroscopic parallax" is horrible because the technique makes no use of parallax whatsoever.

This technique is limited by our ability to see the spectrum of an individual star, and thus classify it. In practice we can use spectroscopic parallax out to about 10,000 pc.

c) The dust and gas between us and a star tend to scatter the blue light to the side and preferentially let the red light through. This is called interstellar reddening. It is the same basic reason why the Sun looks red at sunrise and sunset: At sunrise and sunset the light comes to us through much more of the Earth's atmosphere. The amount of gas and dust between us and a star can be determined by comparing the observed color of a star to its true color or, more precisely, the observed mix of colors of a star to the true mix of colors emitted by the star. The former is done by measuring the received color mix, and the latter is determined by the star's spectral type. That is, the spectral type determines the temperature of the star's photosphere, and the true color mix emitted by the star is then precisely the blackbody (Planck) spectrum for that temperature.

14. a) Brightness, **b**, depends upon luminosity, **L**, and distance, **d**, according to the inverse square law:

$$b \propto \frac{L}{d^2}$$

We are given that the stars have the same apparent magnitude, and this means that they have the same brightness. As a result

$$\frac{L_A}{d_A^{\,2}} = \frac{L_B}{d_B^{\,2}} \Rightarrow L_B = \frac{d_B^{\,2}}{d_A^{\,2}} L_A$$

We are also told that $d_B = 10\, d_A$, and hence $L_B = 10^2 L_A = 100\, L_A$. In other words, if B is ten times further away then to have the same apparent magnitude, it must be 100 times more luminous to compensate for the distance.

b) The absolute magnitudes are the apparent magnitudes if the stars were moved to the same fixed distance of 10 pc. Since B is 100 times more luminous than A, then if A and B were located at the same fixed distance, B would be 100 times brighter than A. Now recall that a factor of 100 in brightness, by definition, corresponds to 5 steps on the magnitude scale, and dimmer stars have larger magnitudes than brighter ones. Hence star B has an absolute magnitude, M_B, equal to the absolute magnitude, M_A, of star A minus 5, *i.e.* $M_B = M_A - 5$.

c) If star B had twice the surface temperature of star A: $T_B = 2\, T_A$, then

$$\frac{\text{Energy Flux from Star B}}{\text{Energy Flux from Star A}} = \left(\frac{T_B}{T_A}\right)^4 = 16$$

d) The luminosity of a star is equal to (Energy flux) x (Surface area). From part a) we have $L_B = 100\, L_A$, while from part c) we have: **Energy Flux from B = 16 x (Energy Flux from B).** Putting it all together one gets

$$\text{Surface Area of Star B} = \frac{\text{Luminosity of Star B}}{\text{Energy Flux of Star B}} = \frac{100 \times \text{Luminosity of Star A}}{16 \times \text{Energy Flux of Star A}}$$

$$= \frac{100}{16} \times \text{Surface Area of Star B}$$

14. continued

Finally, the surface area of a star is proportional to the square of the radius (Area = 4 π R^2), and so one has

$$\frac{R_B^{\,2}}{R_A^{\,2}} = \frac{100}{16} \Rightarrow R_B = \sqrt{\frac{100}{16}}\,R_A = \frac{5}{2}\,R_A = 2.5\,R_A$$

In words: B is 100 times more luminous than A. The temperature of B will account for a factor of 16 in the luminosity. The remaining factor of 100/16 = 6.25 must be due to surface area. To increase the surface area by this factor one must increase the radius by a factor of 2.5.

15. a) When a star is part of a binary system one can use Newton's laws to calculate the total mass of both stars in the binary. Recall:

$$M_{total} = \frac{a^3}{P^2}$$

where the semi-major axis, **a**, is measured in A.U., and the period, **P**, is measured in years. One thus needs to observe the system and measure **a** and **P** for all the stars in the system.

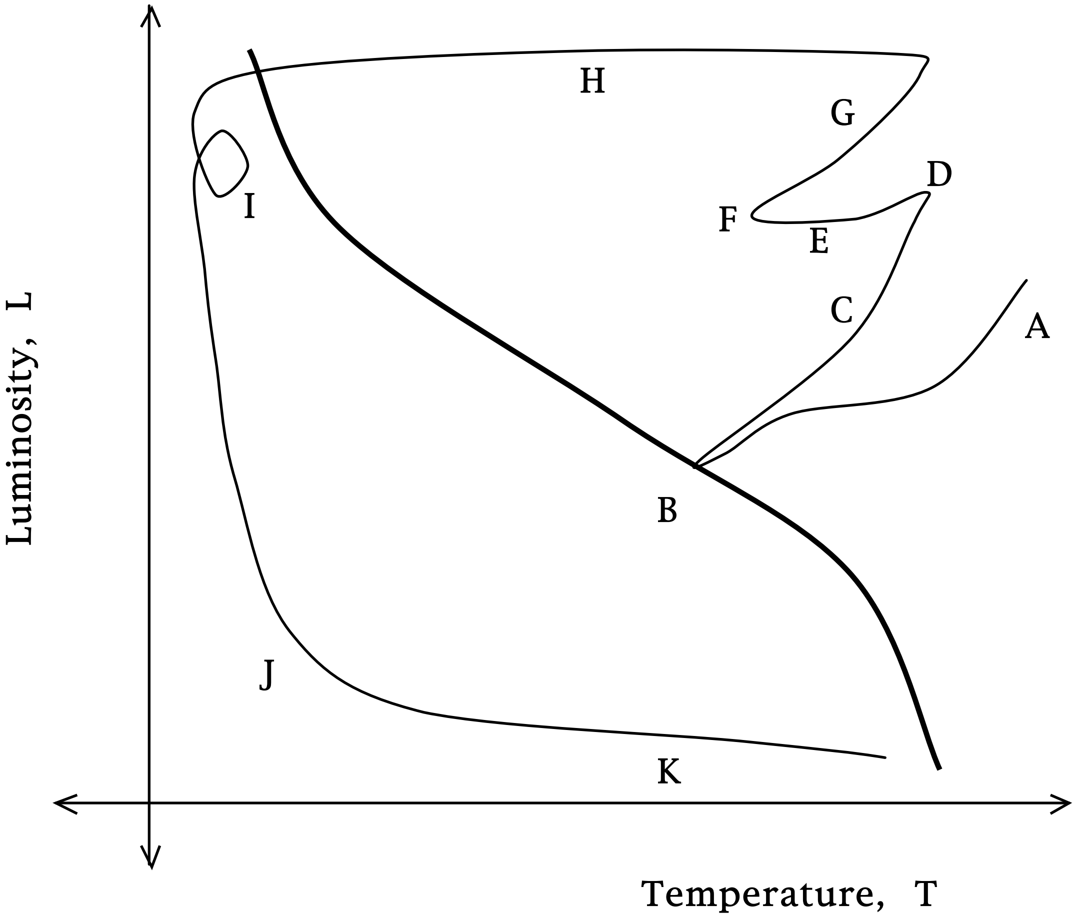
b) When the star is **not** part of a binary system (and even when it is part of a binary system) one can use the mass-luminosity relation *provided that the star is a main-sequence star*. See figure 19.22 in *Freedman and Kaufmann.* The whole point is that for such stars there is a precisely known mathematical relation between luminosity and mass. Therefore, if one finds the luminosity one knows the mass of the star.

Comments:

(i) The mass-luminosity relation was obtained by careful observations of many binary systems to determine the masses of stars. Having discovered the relation, one can reverse one's perspective and use it as a tool to determine stellar masses - hence the answer to part b).

(ii) . To extract individual masses for all the stars in a binary system one needs to locate the common center of the orbits: the center of mass. The two stars orbit around this common center that lies between the two stars: the distance from the stars to the center of mass has a ratio that is the inverse of the ratio of the stars' masses. In other words the common center is nearer the more massive star, and the precise measure of this distance depends upon the ratio of the masses of the two stars. Thus one gets the ratio of masses, and then from this and the total mass, one gets the individual masses.

16.



- At point **A** the Sun first enters the diagram as a proto-star. It is more luminous, and much redder than the Sun is at present. Its source of energy is heat from the collapse of matter, and not from fusion.

- As the protostar collapses it becomes hotter, but less luminous because it is getting a tot smaller. When it reaches point **B** (on the main sequence) it is a ZAMS (Zero Age Main Sequence) star, and starts thermonuclear fusion of hydrogen in its core. It spends about 90% of its life at the point **B.**

- Core hydrogen fusion ceases and hydrogen shell burning starts, expanding the Sun to a red giant (along **C**).

- The helium flash happens (point **B**): The explosive onset of helium core burning. The star descends a little along the horizontal branch (**E**)

- Helium depletes in the core and there helium shell burning starts (point **F**) and causes the star to expand dramatically (along **G**). The section along **G** is called the asymptotic giant branch of the H-R diagram.

- Helium shell burning is devastatingly unstable, and it blows off the outer layers of the star to expose the extremely hot core regions (along H).

- Helium shell burning activity can pulsate causing large variations in the luminosity of the star, represented here by a loop I. These pulsations do not necessarily happen, and they can also happen several times. Our Sun is relatively low mass, and so there will probably be no, or few pulsations.

- Along J the planetary nebula is blown off, to expose the white-hot core of the star. This is a white dwarf star.

- Over billions of years the white dwarf slowly cools (along K) to a black dwarf star.....

So after the red giant phase the outer layers (hydrogen and helium) will be blown off into space as an expanding cloud of hot, but cooling gas. This is called a planetary nebula and it will take several tens of thousands of years to cool, spread out and dissipate into the interstellar medium. The residual core, consisting mainly of carbon and oxygen, but with some hydrogen and helium will be exposed. Its surface temperature will start out at about a few hundred thousand Kelvin, and its radius will be about 10,000 km. (It is extremely dense.) This residual “star” is called a white dwarf, but there will no fusion going on ..... A white dwarf’s glow is solely because of its residual heat. This then slowly cools to become a “black dwarf.”

17. A type II supernova is also known as a core collapse supernova, while a type Ia supernova is also known as a carbon detonation supernova. These alternative names give a better indication of the processes involved:

- A core collapse supernova generally occurs in a very high mass star when iron has formed in the core. Iron cannot provide energy via fusion, and so iron is the truly "dead ash" of all fusion processes. Once it forms in a stellar core, the core collapses and this implosion accelerates inward and the "bounces" off an incredibly highly compressed core, and then returns at very high speed through all the outer layers of the star. These layers consist of all the other elements in the star, mainly hydrogen and helium, but also carbon, oxygen, neon, magnesium, silicon..... . These layers are blown out into space. The important point is that a type II supernova has to go through a lot of matter in the outer part of the star, and as a result, the explosion can be damped (partially smothered), and the appearance of the explosion is usually very complex, and often asymmetrical.

- A type Ia supernova occurs when a white-dwarf star (almost entirely carbon and oxygen) undergoes runaway carbon fusion. This can happen as a result of the white dwarf consuming material from a nearby star, or as the result of the collision, or merger of two white dwarfs. When carbon fusion starts it is catastrophic: The star simply explodes. This is because the white dwarf no longer has outer layers to provide the weight to hold the star together.

- The type Ia, or carbon detonation supernova is thus very "clean." It occurs in a star of pretty well known size and composition, and even more important, there are no outer layers to suppress and mess up the explosion. The relative simplicity of a type Ia supernova means that we know exactly how the luminosity of the star will behave during the explosion. It thus provides a phenomenally useful standard candle, visible over vast distances. It is therefore extremely useful as a distance measuring tool.