ISP 205
Review Questions, Week 11

This is not required homework. It will not be graded. Answers will be supplied on Monday afternoon.

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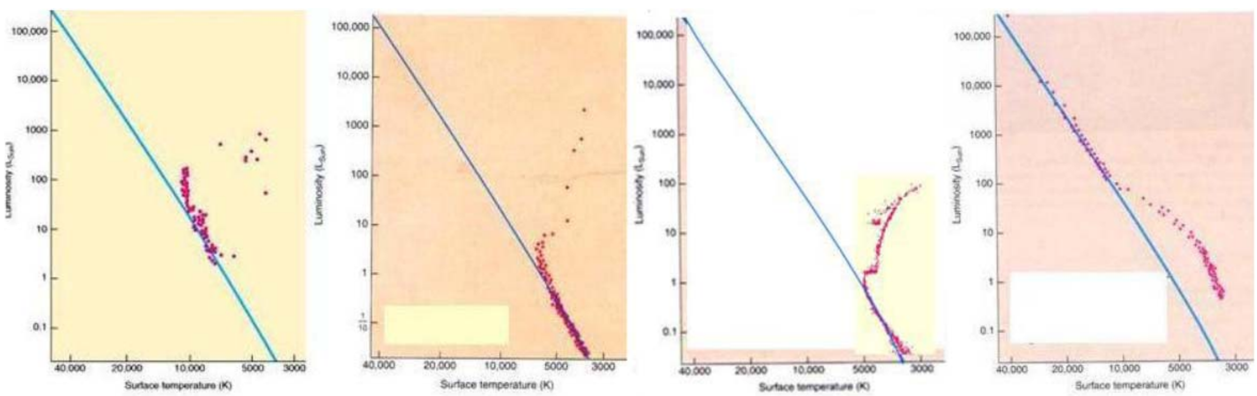
1. The Sun will spend 10 billion years on the main sequence (i.e. converting H into He in its central core). Another star has a mass of 20 solar masses, and a luminosity of 100,000 solar luminosities. How long will it survive on the main sequence? Use the fact that a star's lifetime is proportional to mass/luminosity to make the calculation.

The star has 20 $M_\odot$ of H = 20 times more fuel than the Sun has. But it is burning it up 100,000 times faster. So the star's lifetime = 20/100,000 = 0.0002 times as long as the Sun's lifetime. The Sun will spend about 10,000,000,000 (10 billion) years burning H into He on the main sequence, so the other star will last for only 2,000,000 (2 million) years.

2. The following figure shows the Hertzprung-Russell diagrams of star clusters A, B, C and D. Order the clusters in age, from youngest = 1 to oldest = 4.



Cluster A Cluster B Cluster C Cluster D

The more massive stars have shorter lifetimes. Also, the more mass that a main sequence star has, the higher its surface temperature. Cluster D has main sequence stars with surface temperatures all the way up to 20,000 degrees and more. These are stars that do not live for very long as main sequence stars, so this is a young cluster. At the other extreme, cluster C has no main sequence stars with surface temperatures above 5000 degrees, meaning that all of the stars with higher surface temperatures (= more mass) have already gone through their lifetimes and died. The correct order from youngest to oldest is: DABC.

3. What are the three possible end states for stars? What determines which end befalls a particular star? *White dwarf, neutron star, black hole. The particular end state is determined by the mass of the star at the end of its life.*

4. What is meant by "electron degeneracy"? *The electrons that are in the gas that makes up the star refuse to get pushed any closer together. This creates a form of pressure that can hold up the star against gravitational collapse.*

5. State the Principle of Equivalence. Why is this important? *Two ways to state it: (1) You cannot tell the difference between being in a gravitational field and being accelerated by some other force; and (2) you cannot tell the difference between being in freefall in a gravitational field, and being someplace where there is no gravitational field. This simple idea was Einstien's starting point for working out his General Theory of Relativity.*

6. What is the description of gravity that comes from the General Theory of Relativity? *Gravity is a curvature of space-time, into some other direction beside the 3 space-like and 1 time-like dimensions that we are used to thinking about. In the analogy used in class, a bug lives on a surface that is its universe. There are only two dimensions to that universe, and the bug cannot leave the surface. Yet you can curve the 2D surface off into a 3rd direction (as on the surface of a sphere). So we are bugs living in a 3D universe, that can curve off in some 4th direction, and gravity is the thing that makes it curve.*

7. Name three "proofs" (= experimental verifications) that General Relativity gives a better description of the effects of gravity than is given by Newton's Law of Gravity.

At no extra charge, here are 4 such test cases:

(1) The path of light is bent as it passes through a gravitational field (as shown by the solar eclipse experiment).
(2) The precession of the direction of the long axis of Mercury's orbit.
(3) The gravitational redshift of light emitted from the surface of a white dwarf (time dilation).
(4) Clocks run at different speeds when they are closer to or farther from the Earth's center, including clocks in GPS satellites (time dilation).

8. A simple way to calculate the size of a black hole is to say that it is the point where the escape velocity becomes larger than the speed of light. What does this mean for light that is emitted from inside the black hole, if we are looking from the outside? *The light is not moving fast enough to escape from the gravitational field, so it must fall back into the black hole. That is of course not really a correct description – light always moves at the speed of light, so it is really a case of the light following a path that curves back on itself. But the escape velocity argument gives the correct answer, in a far simpler fashion than having to work out the solution to the general relativity problem of calculating the curvature of space.*