1. (25%) In this atomic energy level diagram (like fig 3.12 in the text), which atomic transition
A. would give an emission line which has the longest wavelength?

   e. The atom must lose energy to emit a photon, so it is either (a) or (e). The largest wavelength is the smallest energy difference (energy = h × c / wavelength), so it is (e)

B. would give an absorption line for a photon of the greatest energy?

   b. The atom must gain energy to absorb a photon, so it is either (b), (c), or (d). It's not (c) since any photon with greater than the ionization energy is absorbed, and you don't get a specific line (partial credit for c, since this wasn't worded as well as I would have liked). (b) is the largest energy difference corresponding to an absorption line.

C. represents ionization?

c.

2. (25%) What is a neutrino, and why are astronomers so interested in detecting neutrinos coming from the Sun?

   - A neutrino is a massless (or maybe very low mass), chargeless subatomic particle that interacts only very rarely with other matter
   - They are of interest to astronomers because 1) they are supposed to be created in the same fusion reactions that theory says are responsible for the long life of the sun, and 2) should be directly observable because they can escape from the core of the sun.

3. (15%) (Sample exam question). The order of the layers or parts of the Sun, as radius increases, is

   A. interior, convection zone, photosphere, chromosphere, corona
   B. corona, chromosphere, convection zone, photosphere, interior
   C. interior, convection zone, chromosphere, photosphere, corona
   D. interior, convection zone, corona, chromosphere, photosphere
4. (35%) Log in to the following URL, which we will use as a simulation of a stellar spectrum:
http://www.astro.lsa.umich.edu/users/hughes/Kirchoff/Kirchoff.html
For the source of continuous radiation (left box), select "Blackbody radiation" (this will be the photosphere). For the gas through which the radiation passes (middle box), select "Hydrogen" (this will be the atmosphere). You may leave the right hand box (the observer's filter) at none, so you can see the whole spectrum. By manipulating the temperature of the blackbody, and the Doppler shift (the radial velocity divided by the speed of light) answer the following questions:

A. (10 %) For a photosphere temperature of 5000 and 6000 K, what is the wavelength of maximum intensity? What is the wavelength of Hydrogen-Alpha (does it change?)

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Continuum Maximum</th>
<th>H alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>5000 K</td>
<td>590 nm</td>
<td>656 nm</td>
</tr>
<tr>
<td>6000 K</td>
<td>480 nm</td>
<td>656 nm</td>
</tr>
</tbody>
</table>

The Hydrogen-Alpha wavelength does not change

B. (15 %) About how much Doppler shift produces the same effect on the continuum as the above temperature change? How fast is this in km/sec (stars within our Galaxy move less than a few hundred km/sec).

Doppler shift of +0.2 produces same continuum shift as going from 6000 to 5000 K.

\[ v = 0.2 \times 300,000 \text{ km/sec} = 60,000 \text{ km/sec} \]

It takes a velocity much larger than that seen within our Galaxy to mimic a modest temperature change

C. (10%) Recalling that the Doppler shift of the photosphere and the atmosphere are the same, how can one tell the difference between Doppler shift and temperature changes from the spectrum?

A temperature change moves the continuum but not the lines. A Doppler shift (applied to both) changes the positions of both continuum and lines. So only a Doppler shift will move the lines.