Stellar Astrophysics Homework 4 Solutions

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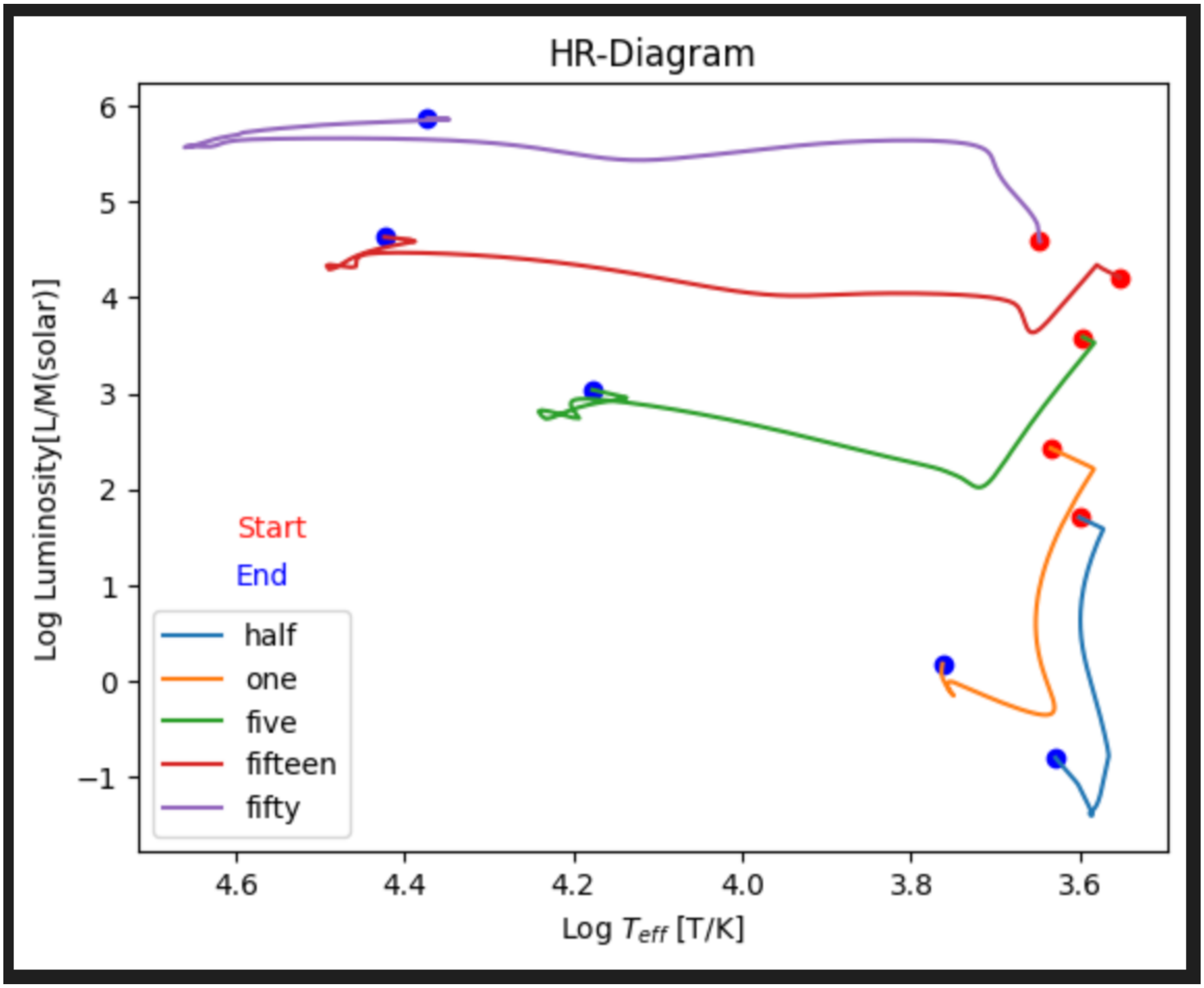
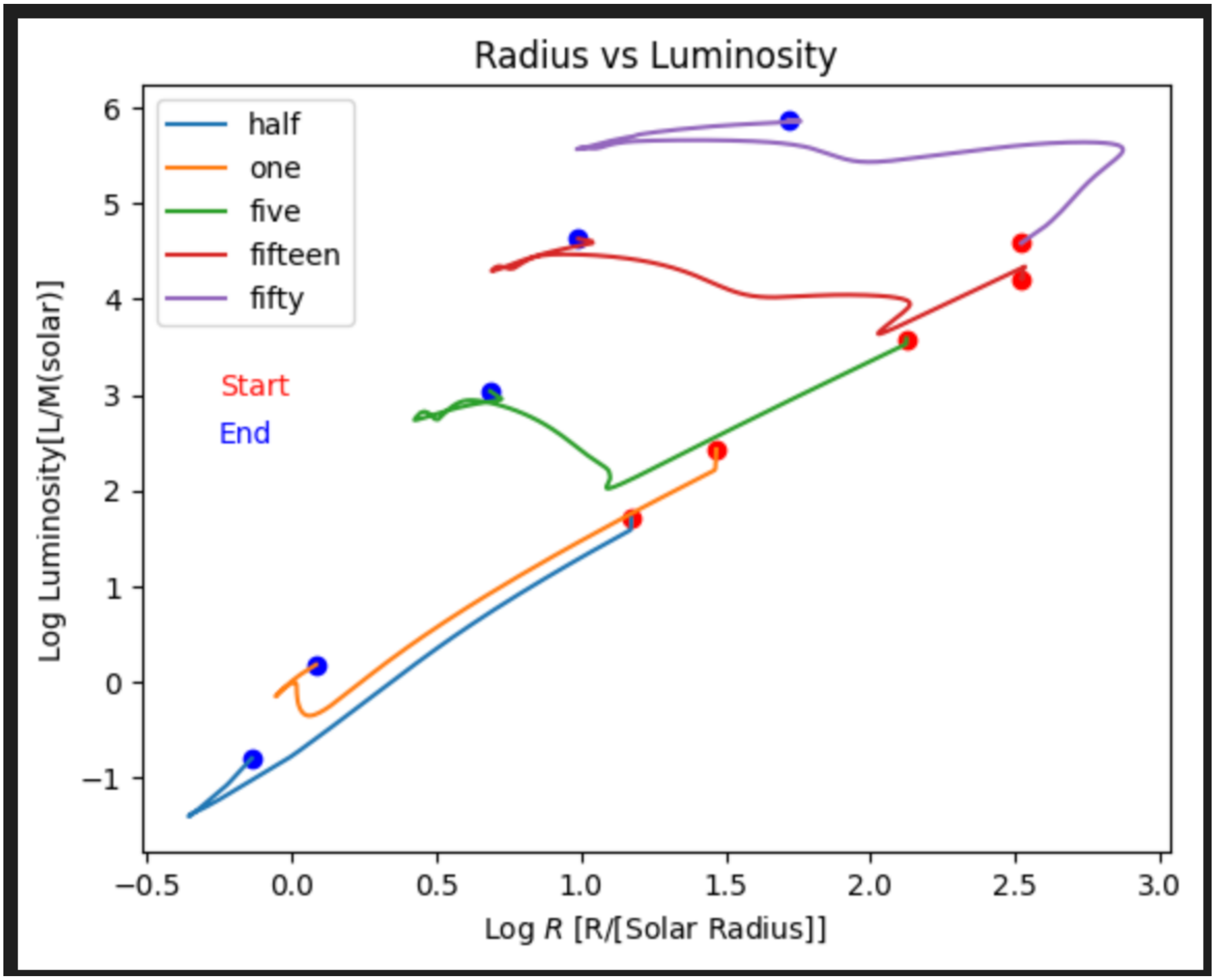
Question 1:





b.

Each star on their track experiences the same general stages during the contraction period. For each track, the star stars its collapse with a free fall, this can be observed in each track except for the 50M track. The free fall is characterized by a sharp decrease in radius corresponding to a decrease in temperature and luminosity and ends when the radius begins to increase again and a small increase in luminosity occurs. I mentioned that the 60M track does not show a free fall time and this is due to the fact that we are looking at the cloud after it already experienced its free fall, and we are seeing it at a point where it begins to burn deuterium starting fusion. After the free fall stage, the middle of the cloud has enough energy to begin fusion, this causes a slight increase in the radius as the thermal pressure begins pushing the cloud back out. The radius will then begin to decrease again while keeping the luminosity roughly constant (excluding the 2 lowest mass stars) and the temperature will increase. This is the stage where convection is practically non-existent, and the energy transfer is purely radiative. The end of this stage is when convection begins again, and hydrogen is fused into helium through pp chains which is when the cloud is officially a protostar. The contraction period is not yet over as the star is not officially on the main sequence until it is fully at an equilibrium point. This can be seen clearly on the red and green tracks as the stars position on the HR-diagram kind of 'wobbles' and only when this wobbling stops the star is officially on the main sequence.

There are a couple of important features seen on the plots here. The first I discussed briefly is that the purple track does not have a free fall stage, and the final point does not show signs of wobbling to find its equilibrium point. This is most likely due to the fact that it is just not finished forming to the main sequence yet and still needs more time to finish forming. The orange and green tracks are comparatively low mass stars. They find their equilibrium points quickly which is because the fusion in the core is much less energetic than the higher mass stars. Even more interesting is that the blue track would be a cloud that forms into an M-type star, and it never really passes the point where convection stops in the center. This makes sense as M-type stars are fully convective throughout the star.

c.

The evolutionary stages for each track can be broken down into 3 major steps. The first is the free fall time, the second is when convection stops in the interior of the cloud and the final is when hydrogen is fused into helium signifying the change into a protostar. The span of time spent forming a protostar for each track, in order from most massive to least massive, is: 3.86e6, 1.07e7, 8.29e7, 8.6e9, and 1.18e11 years. It is plain to see that the more massive the initial cloud is the less time it takes to form. We can examine the time periods for each of the stages for each track and see how long each track takes to get through each evolutionary stage.

	Free Fall	No Convection	PP Chain
50M	N/A	1.9e6 years	1.9e6 years
15M	4.7e3 years	1.2e6 years	9.8e6 years
5M	2.3e5 years	4.3e7 years	3.9e7 years
1M	2.7e6 years	2.4e7 years	8.6e9 years
0.5M	3.2e8 years	N/A	1.1e11 years

The lower mass stars take a longer period to form, and in fact spend most of their time forming in the free fall stage, because the free fall time is proportional to the inverse square of the cloud's mass density.

One last thing to note is that the 0.5M star does not have a period during its contraction where convection stops in the core. These stars remain convective throughout their forming and into their main sequence life time.