NAME

Astronomy 321
Test 1
February 5, 2014

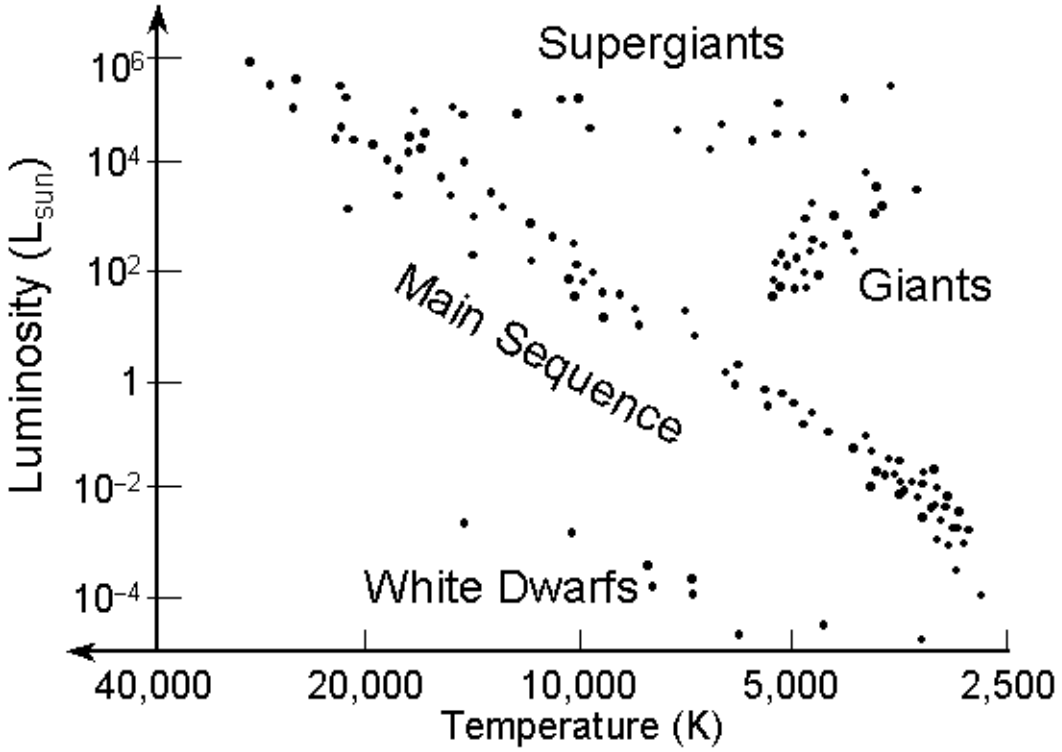
Answer all of the following questions. Each question carries equal weight.

Constants

Electron charge (e)	$1.60 \times 10^{-19}\,\mathrm{C}$
Electron Volt (eV)	$1.60 \times 10^{-19}\,\mathrm{J}$
Electron rest mass (m_e)	$9.11 \times 10^{-31}\,\mathrm{kg}$ ($0.511\,\mathrm{MeV/c^2}$)
Proton rest mass (m_p)	$1.673 \times 10^{-27}\,\mathrm{kg}$ ($938\,\mathrm{MeV/c^2}$)
Neutron rest mass (m_n)	$1.675 \times 10^{-27}\,\mathrm{kg}$ ($940\,\mathrm{MeV/c^2}$)
Atomic mass unit (AMU)	$1.7 \times 10^{-27}\,\mathrm{kg}$
Atomic weight of a hydrogen atom	1 AMU
Atomic weight of a nitrogen atom	14 AMU
Atomic weight of an oxygen atom	16 AMU
Planck's constant (h)	$6.63 \times 10^{-34}\,\mathrm{J{\cdot}s}$
Speed of light in vacuum (c)	$3.00 \times 10^{8}\,\mathrm{m/s}$
Boltzmann's constant (k_B)	$1.38 \times 10^{-23}\,\mathrm{J/K}$
Stefan-Boltzmann constant (σ)	$5.67 \times 10^{-8}\,\mathrm{W/m^2/K^4}$
Gravitational constant (G)	$6.67 \times 10^{-11}\mathrm{N{\cdot}m^2/kg^2}$
Permeability of free space ($\mu_\circ$)	$4\pi \times 10^{-7}\,\mathrm{H/m}$
Permittivity of free space ($\epsilon_\circ$)	$8.85 \times 10^{-12}\,\mathrm{F/m}$
Mass of sun ($M_\odot$)	$1.99 \times 10^{30}\,\mathrm{kg}$
Radius of sun ($R_\odot$)	$6.96 \times 10^{8}\,\mathrm{m}$
Luminosity of sun ($L_\odot$)	$3.84 \times 10^{26}\,\mathrm{W}$
1 atmosphere	1.01×10^{5} Pa

Question 1

On the schematic Hertzsprung-Russell (H-R) diagram below



a. the bulk of the observable stars are found along the Main Sequence. Roughly, what fraction of observable stars is found along the Main Sequence and what is the significance of this result in terms of stellar evolution?

b. Using stars on the H-R diagram, compare the radii of a K2 V star, and a K2 I star. A star of spectral class K2 has surface temperature $\sim$ 5,000 Kelvin.

c. Compare the radii of a 5,000 Kelvin I star and a 20,000 Kelvin V star who have the same luminosity.

Question 2

Main Sequence stars are in equilibrium, mechanical equilibrium (hydrostatic equilibrium) and thermal equilibrium.

a. Explain why we know that Main Sequence stars are roughly in hydrostatic and thermal equilibrium.

b. If hydrostatic equilibrium is violated, a star would rapidly collapse if only gravity is taken into acccount. Using a dimensional argument, show that the collapse time is proportional to $1/\sqrt{G\rho}$ where G is the gravitational constant and ρ is the average stellar density.

c. Estimate the collapse time for the Sun. The mass of the Sun is 2.0×10^{30} kg and the radius of the Sun is 7.0×10^{8} meters. Estimate the collapse time for a typical red Supergiant. Use a mass of 20 $M_{\odot}$ and radius of 1.5×10^{12} meters for the Supergiant.

Question 3

Write the equations of stellar structure. Define terms and quantities which appear in the equations.

Using dimensional arguments:

a. show that the luminosity of a Main Sequence star dominated by radiation transport scales with its mass, when the opacity is dominated by electron scattering $\kappa \sim 0.34$ cm^2/g, as $L \propto M_*^3$.

b. Repeat the derivation in part (a) to show that $L \propto M_*^{5.5}/R_*^{0.5}$ when the opacity is dominated by bound-free and free-free transitions. Use Kramer's opacity law $\kappa \sim \rho/T^{3.5}$ cm^2/g.

*. Continue the derivation from part (b) by eliminating R_* from the relationship.