

AST 301
Test #3
Friday Nov. 12

Name: _____

1. a) The Sun is in hydrostatic equilibrium. What does this mean? What is the definition of hydrostatic equilibrium as we apply it to the Sun?

Pressure inside the star pushing it apart balances gravity pulling it together.

So it doesn't change its size.

1. a) The Sun is in thermal equilibrium. What does this mean? What is the definition of thermal equilibrium as we apply it to the Sun?

Energy generation by nuclear fusion inside the star balances energy radiated from the surface of the star. So it doesn't change its temperature.

b) Give an example of an equilibrium (not necessarily an astronomical example) different from hydrostatic and thermal equilibrium.

Water flowing into a bucket balances water flowing out through a hole.

When supply and demand are equal the price is stable.

The floor pushes me up to balance gravity pulling me down.

2. If I want to use the Doppler technique to search for a planet orbiting around a star, what measurements or observations do I have to make?

I would measure the Doppler shift in the spectrum of the star caused by the pull of the planet's gravity on the star.

2. If I want to use the transit (or eclipse) technique to search for a planet orbiting around a star, what measurements or observations do I have to make?

I would observe the dimming of the star's light when the planet passes in front of the star.

If I find evidence of a planet this way, describe some information my measurements give me about the planet. (Do I know its mass? size? composition? orbit?) Explain briefly how the observations gave this information.

Doppler technique tells me the orbital period of the planet from the period of variation of the Doppler shift and information about the mass of the planet from the motion of the star caused by the planet's gravity.

The transit technique tells me the size of the planet from the fraction of the star's light it blocks. It also tells me the period of the planet's orbit from the time between transits.

3. The diameter of Polaris (the north star) is 100 times the diameter of the Sun.
- a) How does the circumference of Polaris compare to the circumference of the Sun? (Which is larger, and how many times larger?)
 Polaris. 100 times larger. (Both diameter and circumference are distances (1-dimensional quantities) so they scale together.)
- b) How does the surface area of Polaris compare to the surface area of the Sun?
 Polaris is $10,000 = 100^2$ times as big in area. (Area is 2-dimensional.)
- c) How does the volume of Polaris compare to the volume of the Sun?
 Polaris is $1,000,000 = 100^3$ times as big in volume. (Volume is 3-dimensional.)
- d) If the mass of Polaris is 10 solar masses, how does the density of Polaris compare to the density of the Sun?
 Density = Mass / Volume, so Polaris is $10 / 1,000,000 = 1 / 100,000$ times the Sun.
- e) Polaris lies directly above the Sun on the H-R diagram. What does this tell you about Polaris?
 Polaris is more luminous. If it is directly above the Sun, it has the same temperature as the Sun.
- f) How does the luminosity of Polaris compare to the luminosity of the Sun?
 If its temperature is the same as the Sun's, its luminosity scales with its surface area, so it is 10,000 times the Sun's.
4. Each second, 600×10^9 kg of hydrogen is converted to 596×10^9 kg of helium inside of the Sun. How can I use Einstein's equation $E = m c^2$ to calculate the rate of energy generation by the Sun? How is this related to the luminosity of the Sun?
 Each second $600 \times 10^9 - 596 \times 10^9 = 4 \times 10^9$ kg of mass is converted into energy.
 So the energy generated is $4 \times 10^9 \times c^2$ Joules/second. This is the luminosity of the Sun.

5. The luminosity of a 2 solar mass main-sequence star is about 10 solar luminosities.

a) Why is the luminosity of a 2 solar mass star greater than the luminosity of the Sun?

Its greater mass gives it greater gravity, so its interior pressure and density are greater. This makes fusion run faster.

The location on the HR diagram tells us that the 2 solar-mass star has greater luminosity, but it doesn't explain why it does.

The greater size and surface temperature of the 2 solar-mass star are results of the greater rate of energy generation by fusion.

b) How does the main-sequence lifetime of a 2 solar mass star compare to that of the Sun? (Which is greater, and how many times greater is it?)

Like a car, the 2 solar-mass star has twice as much fuel, but it is burning 10 times as much each second, so it only lasts $2/10 = 1/5$ times as long.

6. a) Why does the core of a massive star collapse once fusion has turned the elements in the core into iron?

Fusion of iron absorbs energy instead of generating energy. So it removes energy and pressure from the core of the star, so pressure no longer balances gravity, so the core collapses. If the core mass is less than about 4 solar masses a neutron star is formed.

b) What prevents a white dwarf from collapsing when nuclear fusion stops so energy is no longer being made by nuclear fusion?

Densely packed electrons (degenerate electrons) must move fast even if they are cold. So the pressure doesn't drop when a white dwarf can't generate energy to replace what it loses, so it doesn't collapse.