Chapter 15: The Density of Stellar Remnants

Student Worksheet

Objective:

Learn more about the wild physical nature of stellar remnants via density and escape velocity calculations.

Engage:

Think of some of the densest things on this planet. What could they be? Where are they found? What about some of the least dense?

Introduction:

In this activity, you will use the typical mass and radius data in Table 1 below to calculate the densities and escape velocities of the three main types of stellar remnants: white dwarfs, neutron stars, and black holes. These dense and amazing objects are an important part of our universe, and doing this activity will give you an opportunity to understand them better!

- The density of an object is its mass divided by its volume, $\rho = \frac{m}{V}$
- The escape velocity of an object comes from Newton's laws, $v_{escape} = \sqrt{\frac{2Gm}{r}}$
- The volume of a sphere is $V = \frac{4}{3}\pi r^3$
- M is for mass and r is for radius. G has a value of 6.67×10^{-11}
- ⊙ stands for Sun, ⊕ stands for Earth

Table 1 Typical Mass and Radius Values

Celestial Object	Mass, M	Radius, R
Earth	5.97×10^{24} kg, 1 M⊕	6,378,000 m, 1R⊕
Sun	1.989×10^{30} kg, 1M☉	6.96×10^{8} m, 1R☉
White Dwarf	1 M☉	1 R⊕
Neutron Star	2 M☉	10,000 m
Stellar Black Hole	20 M☉	60,000 m

Problems to solve:

1. Using the data in Table 1 above, calculate the average density of the Earth. Before solving this problem, convert kilograms to grams and meters to centimeters so your answer's units are in g/cm^3 rather than kg/m^3. A cubic centimeter is about the size of a sugar cube. For reference, the density of water is 1 g/cm^3.

2. Would you guess the density of the Sun to be greater or less than the density of the Earth? Why? Calculate the average density of the Sun. Again, use g/cm^3.

3. Now that you are familiar with density calculation, calculate the densities of a white dwarf, a neutron star, and a black hole. Show your work below. Copy your answer into the appropriate column in Table 2 below.

4. The musical group, The Flaming Lips, have a popular song entitled: “A Spoonful Weighs a Ton”. A typical spoonful is about 2.5 cm^3. A metric ton is 1,000 kg, (1,000,000 g). What is the mass of a spoonful of each of the stellar remnants? Show your work below. Copy your answer into the appropriate column in Table 2 below.

5. The escape velocity of Earth is about 11 km/s. The escape velocity of the Sun is 617 km/s. What are the escape velocities for each type of stellar remnant? Show your work below. Copy your answer into the appropriate column in Table 2 below.

Table 2 Stellar Remnant Values

	Density (g/cm^3)	**Mass of a Spoonful (Metric tons)**	**Escape Velocity (km/s)**
White Dwarf			
Neutron Star			
Black Hole			

Conclusion questions:

1. What is the single property of a star that determines which stellar remnant it will become?

2. When the Sun comes toward the end of its life, which type of stellar remnant will it leave behind?

3. A white dwarf no longer fuses atoms. What will happen over time? What would be a good name for a white dwarf in the far distant future?

4. Looking at the values for black holes and neutron stars in table 2, which property is more defining of the stellar remnant, *density* or *escape velocity*?

5. Think about the escape velocity of a celestial object. On what does it depend? What sort of celestial object would have a very small escape velocity?

Extend:

- There are a few varieties of each of the three stellar remnants. Study the various forms of black holes, neutron stars, and white dwarfs. How do they differ?

- In order to reach such great densities, neutron stars and black holes do not allow for the immense empty space in normal atoms. In these stellar remnants the electrons have merged into the nucleus making the empty space that composes atoms vanish. If you could turn the Earth into an object with the same density as a neutron star, how big would it be?