### Chapter 13.1 - 13.4 Homework

**Due: 9:00am on Thursday, October 8, 2009**

**Note:** To understand how points are awarded, read your instructor's Grading Policy.

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### Conceptual Question 13.2

The gravitational force of a star on orbiting planet 1 is \( F_1 \). Planet 2, which is twice as massive as planet 1 and orbits at twice the distance from the star, experiences gravitational force \( F_2 \).

#### Part A

What is the ratio \( \frac{F_1}{F_2} \)?

**ANSWER:**

\[
\frac{F_1}{F_2} = 2 \quad \text{Correct}
\]

### Weight on a Neutron Star

Neutron stars, such as the one at the center of the Crab Nebula, have about the same mass as our sun but a much smaller diameter.

#### Part A

If you weigh 685 N on the earth, what would be your weight on the surface of a neutron star that has the same mass as our sun and a diameter of 16.0 km?

Take the mass of the sun to be \( m_{\odot} = 1.99 \times 10^{30} \) kg, the gravitational constant to be \( G = 6.67 \times 10^{-11} \) N \( \cdot \) m\(^2\)/kg\(^2\), and the acceleration due to gravity at the earth's surface to be \( g = 9.810 \) m/s\(^2\).

**Hint A.1** How to approach the problem

**Hint A.2** Law of universal gravitation

The gravitational force exerted on a mass \( m_1 \) by a second mass \( m_2 \) is

\[
F = \frac{G m_1 m_2}{r^2}
\]

where \( r \) is the distance between the two masses, and \( 6.67 \times 10^{-11} \) N \( \cdot \) m\(^2\)/kg\(^2\) is the universal gravitational constant.

**Hint A.3** Calculate your mass

Calculate your mass \( m \) if you weigh 685 N on earth.

Express your answer in kilograms.

**ANSWER:**

\[
m = 69.8 \quad \text{Correct}
\]

**Hint A.4** Calculate the distance between you and the star

Calculate your distance \( r \) from the center of the star if you are standing on its surface.

Express your answer in meters.

**ANSWER:**

\[
r = 8000 \quad \text{Correct}
\]

Express your weight \( w_{\text{star}} \) in newtons.

**ANSWER:**

\[
w_{\text{star}} = 1.45 \times 10^{14} \quad \text{Correct}
\]

This is over \( 10^{13} \) times your weight on earth! You probably shouldn't venture there....

### At the Galaxy's Core

Astronomers have observed a small, massive object at the center of our Milky Way galaxy. A ring of material orbits this massive object; the ring has a diameter of about 15 light years and an orbital speed of about 200 km/s.

#### Part A

Determine the mass \( M \) of the massive object at the center of the Milky Way galaxy.

Take the distance of one light year to be \( 9.461 \times 10^{15} \) m.

**Hint A.1** How to approach the problem

**Hint A.2** Find an equation for the velocity of an orbiting satellite

Express your answer in kilograms.
Part B
Express your answer in solar masses instead of kilograms, where one solar mass is equal to the mass of the sun, which is \(1.99 \times 10^{30}\) kg.

ANSWER:
\[
M = 2.14 \times 10^{7} \text{ solar masses}
\]
Correct

Part C
Observations of stars, as well as theories of the structure of stars, suggest that it is impossible for a single star to have a mass of more than about 50 solar masses. Can this massive object be a single, ordinary star?

ANSWER:
- yes
- no

Correct

Part D
Many astronomers believe that the massive object at the center of the Milky Way galaxy is a black hole. If so, what is its Schwarzschild radius \(R_b\)?

Hint D.1 Equation for the Schwarzschild radius
Einstein's theory of relativity gives
\[
R_b = \frac{2GM}{c^2}
\]
as the Schwarzschild radius, where \(G\) is the gravitational constant, \(M\) is the mass of the object, and \(c\) is the speed of light.

Express your answer in meters.

ANSWER:
\[
R_b = 6.31 \times 10^{10} \text{ m}
\]
Correct

The Schwarzschild radius of an object is the distance within which nothing, not even light, can escape its gravitational attraction. The sphere surrounding a black hole whose radius is the Schwarzschild radius is also called the event horizon.

Part E
Would a black hole of this size fit inside the earth's orbit around the sun? The mean distance from the sun to the earth is \(1.5 \times 10^{11}\) m.

ANSWER:
- yes
- no

Correct

In other words, it would be possible for the earth to orbit the black hole at the same distance that it is from the sun without falling into the event horizon. However, since the black hole is much more massive than the sun, the speed of the earth's orbit would be incredibly high. In fact, if our sun were replaced by the black hole, it would make one earth year (the time to make one complete orbit) equal to just a few hours!

Problem 13.17
The asteroid belt circles the sun between the orbits of Mars and Jupiter. One asteroid has a period of 5.0 earth years.

Part A
What is the asteroid's orbital radius?

ANSWER:
\[
4.37 \times 10^{11} \text{ m}
\]
Correct

Part B
What is the asteroid's orbital speed?

ANSWER:
\[
1.74 \times 10^{4} \text{ m/s}
\]
Correct

Score Summary:
Your score on this assignment is 100%.
You received 25.01 out of a possible total of 25 points.