Gravity
Student Page

Purpose

To investigate the relationship between a planet's mass and radius and the effect they have on its gravity.

Before you Begin

1. If you were to move to a planet that had the same mass as the Earth, but twice the Earth's radius, how would that planet's gravity be different from the Earth's?

2. If the Sun were to suddenly turn into a black hole without changing its mass, what gravitational effects would there be on the rest of the solar system?

A.J.J.A.R. Programs Required

Jumping
Escape Velocity

Questions

1. What effect does doubling the mass of a planet have on your ability to jump? How much more or less gravity does that planet have compared to the Earth?

2. What effect does doubling the radius of a planet have on your ability to jump?

3. Derive a mathematical relationship allowing you to calculate how high you would jump on a planet based on the planet's mass, the planet's radius, and how high you can jump on the Earth.

4. How fast would you have to travel to escape the Earth's gravity? Convert this number to miles/sec.

5. If you were to travel at this speed, how long would it take to you to get to your school from your home?

Advanced Questions

1. You own a spaceship that consumes 5000 liters of fuel every second and accelerates at a constant rate of 28 m/s^2. Assuming you launch from the Earth's surface, calculate how many liters of fuel you will need to burn in order to reach escape velocity from the Earth.

2. You take your spacecraft to the planet Mars. When you are ready to return, your spacecraft still consumes 5000 liters of fuel every second, but due to the combination of the different Martian gravity and the fact that you're hauling several tons of Mars rocks, your acceleration is now 35 m/s^2. How many liters of fuel will you burn in order to reach escape velocity from Mars?

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Possible Answers to Before you Begin

1. Student preconceptions will run the entire spectrum regarding these two questions. Many students believe that having a planet with twice the radius of the Earth will result in no difference in the amount of gravity. Others will believe the gravity will be lower because of the radius is larger (the correct answer), and still others will think the gravity will increase because the volume of the planet is bigger.

2. Most students will incorrectly conclude that the Sun, as a black hole, will suck all of the planets into it. In reality, there would be no gravitational effects on the rest of the solar system. Since the mass of the Sun would remain the same, its gravity would remain the same.

A.J.J.A.R. Programs Required

Jumping
Escape Velocity

Answers to Questions

1. Doubling the mass of a planet will mean you will only be able to jump half as high as on the Earth. The planet has twice the gravitational pull as the Earth.
2. Doubling the radius of a planet will mean you can jump four times higher as on the Earth.
3. height jumped on planet $= \dfrac{\text{height jumped on Earth} \times \text{radius}^2}{\text{mass}}$, radius and mass are in units of Earth radius and mass.
4. 11.183 km/s
5. Answer will vary, but the formula used to calculate the answer is $\text{time} = \dfrac{\text{distance}}{\text{velocity}}$

Answers to Advanced Questions

1. Average acceleration is defined as the change in velocity of an object divided by the time interval during which this change occurs:

$$\bar{a} = \frac{v_f - v_i}{t_f - t_i}$$

therefore, $t_f = \frac{v_f - v_i}{\bar{a}} + t_i$

$t_i = 0$

$v_i = 0$

so, $t_f = \frac{v_f}{\bar{a}} = \frac{11{,}180 \text{ m/s}}{28 \text{ m/s}^2} = 399 \text{ s}$

399 s × 5000 l/s = **1,995,000**

2. Using the Escape Velocity program, you find that the escape velocity for Mars is 5.015 km/s (mass – 0.107 Earths and radius is 0.532 Earths).

$$t_f = \frac{v_f}{\bar{a}} = \frac{5020 \text{ m/s}}{35 \text{ m/s}^2} = 143 \text{ s}$$

143 s × 5000 l/s = 715,000 l

Additional Internet References

Exploring Gravity
http://www.curtin.edu.au/curtin/dept/phys-sci/gravity/index2.htm