# DR. ROSENGRANT'S VIRTUAL STEM LABORATORY

VIDEO GAME VIGNETTES

**TOPIC / BRANCH:**

Mechanics:
Gravity

**GAME:**

Outer Worlds

**QUESTION:**

**What is the acceleration due to gravity on each planet? Use this acceleration to find the mass of each planet using Newton's Law of Universal Gravitation. Then using the same law find the force between the two planets.**

**GAMEPLAY FOOTAGE:**

https://usf.box.com/s/h979zeivn5jvq1gdbzd3gebs3dv5wqkn

**LEARNING OBJECTIVES:**

- Understand how to apply Newton's Law of Universal Gravitation.

**GUIDING IDEAS:**

- Planets are considered perfect spheres in most applications.
- Newton's Law of Universal Gravitation follows Newton's second law.

## SOLUTION KEY:

Variables:

Timber Hearth will have the T subscript

The Attlerock will have the A subscript

The Player will have the P subscript

Mass (m)

Diameter (d)

Radius (r)

Time (t)

Acceleration (a)

Velocity (v)

Gravitational Constant (G)

Displacement (x)

Solution:

The acceleration for Timber Hearth can be determined by using kinematics and looking at the third part of the video:

$$x = v_p t + 0.5 a_T t^2$$

Since the player's velocity at the apex of the jump is zero, the equation becomes:

$$x = 0.5 a_T t^2$$

The acceleration can then be calculated:

$$a_T = \frac{2x}{t^2}$$

The displacement must be found using the

Pythagorean theorem:

$$c^2 = b^2 + x^2$$

$c = 26meters$ based on the video and $b = 10meters$

$$x = \sqrt{a^2 - b^2}$$

$$x = \sqrt{26^2 - 10^2}$$

$$x = 24$$

Based on the video, $t$ = 2 seconds.

$$a_T = \frac{2 \times 24}{4}$$

$$a_T = 12 \frac{meters}{second^2}$$

Since the gravity of each planet is related to the gravity of Timber Hearth. As seen in the first two parts of the video, the acceleration due to gravity on Timber Hearth is one times “gravity” and the acceleration due to gravity on the Attlerock is 0.4 to 0.5 times “gravity”. All future calculations will be using 0.5 times “gravity” for the Attlerock. There will be different answers for using the 0.4 times “gravity” for the Attlerock.

$$a_A = \frac{1}{2} a_T$$

Newton's Law of Universal Gravitation: $F = G\frac{m_1 m_2}{r^2}$ says that the force between object 1 and object 2 with a distance r between the two objects,

Using Newton's second law, $F = ma$, the total force equals the mass of an object times the total acceleration that object is experiencing. Since the player is only experiencing the force from the planet they are standing on, the total force equals the force between two objects,

$$m_p a = \frac{G m_p m}{r^2}$$

with the distance between the player and the planet they are on equaling the radius of the planet because the player is standing on the planet's surface. The player's mass cancels out and then the mass of the planet can be solved for,

$$m = \frac{a \times r^2}{G}$$

For the Attlerock:

Based on the first clip, the diameter of the planet is shown with the “Scout” label. d = 2r with d = 153 meters

$$r_A = \frac{d_A}{2}$$

$$r_A = \frac{153 meters}{2} = 76.5 meters$$

The mass of the Attlerock is $m_A = \frac{a_A \times {r_A}^2}{G}$

$$m_A = \frac{0.5 \times 12 \times 76.5^2}{G} = 5.26 \times 10^{14} kilograms$$

For Timber Hearth:

Based on the second clip, the diameter of the planet is shown with the “Scout” label at the bottom of the screen. d = 503 meters

$$r_T = \frac{d_T}{2}$$

$$r_T = \frac{503 meters}{2} = 251.5 meters$$

The mass of Timber Hearth is $m_T = \frac{a_T \times r_T^2}{G}$

$$m_T = \frac{12 \times 251.5^2}{G} = 1.14 \times 10^{16} kilograms$$

The force between both planets is $F_{TA} = \frac{G m_T m_A}{r^2}$

The distance between the two planets can be seen in the fourth clip. r = 574 meters because that is when the “Scout”, on the Attlerock, is above the player, on Timber Hearth.

$$F_{TA} = \frac{G \times 5.26 \times 10^{14} \times 1.14 \times 10^{16}}{574^2} = 1.21 \times 10^{15} Newtons$$