# Giant planets in a cup of water

Throwing the giant planets in a cup of water

# Metadata

## *General Info*

Title
Giant planets in a cup of water

Short description

In this demonstrator we have to recall physics concepts as the density, the upthrust and the Newton's law of universal gravitation, in order to calculate the density of the gas planets in our solar system. Then the students can compare these values of density with the density of water. That is critical to see if the planet would float on the surface of a giant cup of water!

Keywords
solar system, giant planets, water, density, mass, volume, upthrust

## *Educational Context*

Context (Greek curriculum)

- 1st Grade of Junior High school, Physics, Mass - Calculation of density
- 2nd Grade of Junior High school, Physics, a) Gravitational Force, b) Pressure – Upthrust
- 1st Grade of High school, Physics, a) Newton's law of universal gravitation b) Periodic motions - smooth circular motion
- Skills Laboratory

Age: 16-18 and junior high school students with the mass and the volume of the planets given

Prerequisites: density, upthrust, Newton's law of universal gravitation

Duration: 3 hrs

## *Educational Objective*

Cognitive Objectives

- To understand the clear difference between the density and the weight of an object
- To take into account the natural laws for solving a hypothetical scenario which could intrigue the interest of students

Affective

- To look deeper in a hypothetical physics problem

Psychomotor

- To cooperate in order to solve a physics problem

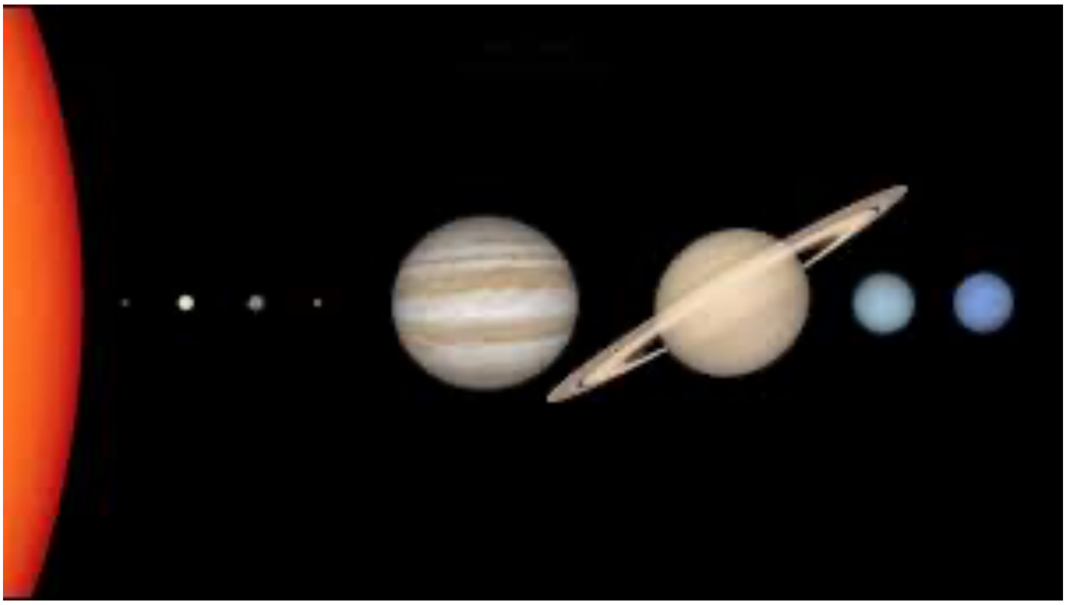
## *Subject Domain*

Big Ideas of Science

The heavier body is not necessarily the denser.
If an object is denser than the liquid in which it is located, it sinks. If both of them have the same density, the object balances being entirely into the liquid. And if the object has a lower density, it floats.

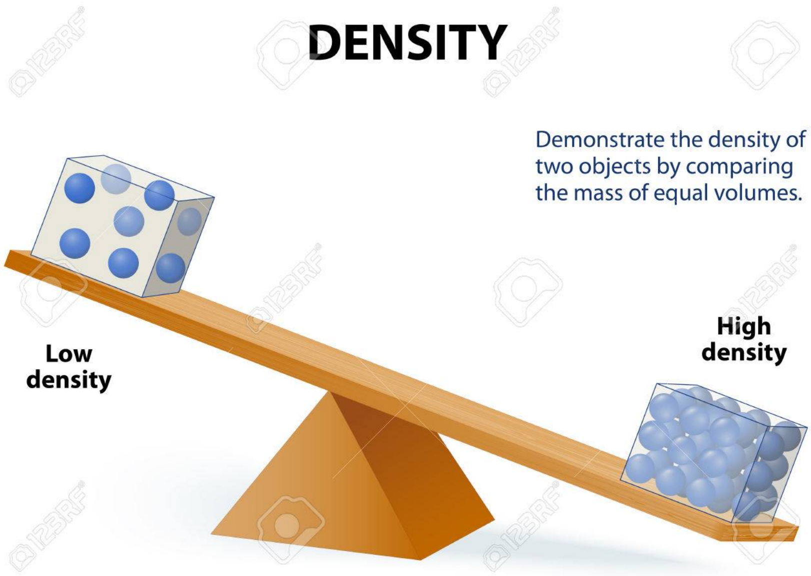
# Orienting & Asking Questions

## *Orienting: Provide Contact with the content and/or provoke curiosity*



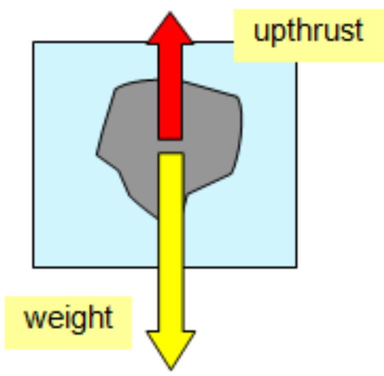
*Credit: NASA (distances not to scale)*

- Above you can see the planets to scale about their sizes and not to scale about their distances.
- The density shows us how dense a body is and to find it, we divide the mass of the body by its volume.




- If you try to lift up a weight in a swimming pool and then try to lift the same weight outside the pool, it feels much lighter in the water. Archimedes said that the water gives an upward force or upthrust in the object in it. More specifically, the Archimedes' principle states that when a body is partly or totally immersed in a fluid, there is an upthrust that is equal to the weight of displaced liquid.

Did that force remind you of the feeling that you have when you swim? If there isn't this force, could you actually swim?




The weight of displaced liquid is the weight of the liquid that has been replaced by the object. The volume of this amount of liquid is equal to the volume of the object itself. The weight of fluid displaced and therefore the upthrust will be bigger if the density of the liquid is large.

### *Define Goals and/or questions from current knowledge*

Why does a tiny stone sink in the water while a huge ship does not, which is much heavier?

Which is heavier? 1 kg of cotton or 1 kg of steel?

# Hypothesis Generation and Design

### *Generation of Hypotheses*

If you could throw a planet, instead of a stone, into a giant interplanetary cup of water, what would happen then?

Would every planet sink?

What does this depend on?

## *Design/Model*

Just as we calculate the density of objects and can judge whether they will be submerged in water, here we will do the same experiment with the gas planets, which have much larger masses than the rocky ones but this fact do not apply to their density.

# Planning and Investigation

## *Plan Investigation*

It would be preferable for you to split into groups of perhaps three people and work together.

Firstly, we'll calculate the masses of the gas giant planets of our solar system. Let's see how you do that.
Let's consider that the orbits of natural satellites of these planets are circular and the speeds are stable. In order to maintain those circular orbits, a force needs to be applied toward the center. This force is called the centripetal force and it is given by the equation

$$F_c = \frac{mv^2}{r}$$

where m is the mass of the object moving in a circle, v is the velocity of the object, and r is the radius of the circle.

Think also that in equal times the object travels equal arcs. So, the speed could be calculated by the equation

$$\mathbf{v} = \frac{2\pi r}{T}$$

where T is the time that the object needs for a full revolution around the central body

Whenever a body such as a moon or satellite is orbiting a planet, the centripetal force is provided by the gravitational attraction between the two bodies ($F_g$) which is equal to

$$F_g = G\frac{M_1 M_2}{r^2}$$

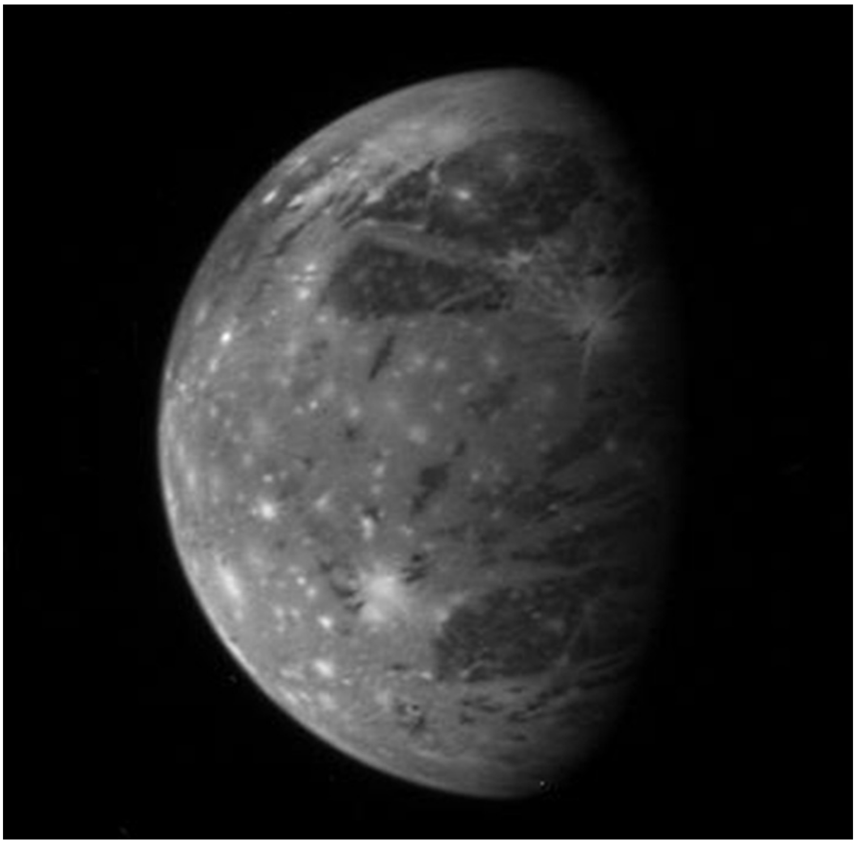
$M_1$ is the mass of the body in the center, $M_2$ the mass of the satellite, r is the distance between them and G is a constant which is equal to $6.674\times10^{-11}$ $m^3\cdot kg^{-1}\cdot s^{-2}$

If you combine all these equations, you'll find **the mass of a planet** by this equation, where r is the distance of a natural satellite from the planet and T is the period of time that the satellite needs for a revolution

$$M_1 = \frac{4\pi^2}{G}\frac{r^3}{T^2}$$

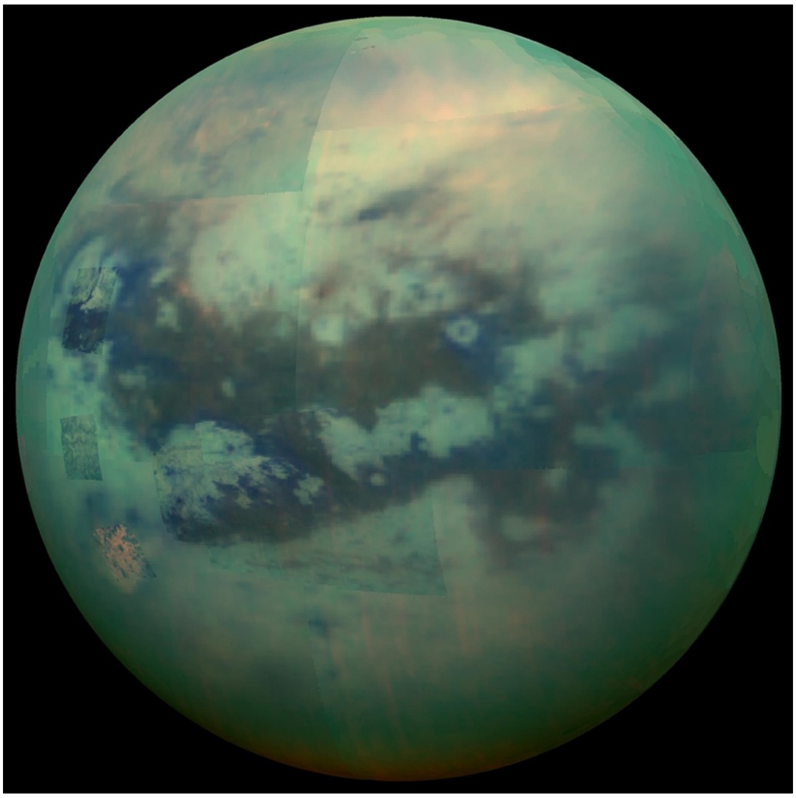
Here you have the distances of the biggest natural satellites from their own planets and their orbital periods.

| Planet | Jupiter | Saturn | Uranus | Neptune |
|---|---|---|---|---|
| **Satellite** | Ganymede | Titan | Titania | Triton |
| **Distance r (km)** | 1,070,400 | 1,221,865 | 435,840 | 354,800 |
| **Orbital period T (hrs)** | 171.72 | 382.68 | 208.94 | 141.12 |



*Ganymede*

*Credit: New Horizons (NASA)*



*Titan*

*Credit: Cassini NASA*

*Titania*
*Credit: Voyager 2 (NASA)*

*Triton*
*Credit: Voyager 2 (NASA)*

Below you have the radii of the giant planets in our solar system. Knowing this parameter and the equation for **the volume** of a sphere ($V = {}^{4}/_{3}\ \pi R^3$ ), find their densities by the formula $\mathbf{d} = \frac{M}{V}$ !!

| **Planet** | Jupiter | Saturn | Uranus | Neptune |
|---|---|---|---|---|
| **Radius (km)** | 71,492 | 60,268 | 25,559 | 24,764 |

# Analysis & Interpretation

The density of water in a temperature of 4 °C is about 1.000 $Kg/m^3$.

Now that you have the densities of these planets, can you compare them with the value of density of water?

Which planet has the smaller density? What will happen when we throw them in a giant cup of water?

A video about the sizes and the distances in our solar system:
https://youtu.be/DMZ5WFRbSTc
A video about the density of planets:
https://www.youtube.com/watch?v=4WuXB2LhMCM

# Conclusion & Evaluation

## *Conclude and communicate result/explanation*

Try to do an experiment using balls of different densities by throwing them into a bowl of water. You can paint them in order to indicate the planets in our solar system. Share the results with your classmates!

The results can be communicated in various ways. One of them is with a poster, which will show the sinking planets into the giant cup of water and those that float.
The graphics of the poster can also be used for the editing of an educational video.

## *<u>Evaluation/Reflection</u>*

About the importance of this project for you, rate from 1 (lowest) to 5 (highest) each topic:

- The interest that this activity provoked to you
- The desire to talk about it to your classmates
- The knowledge acquired/reinforced
- The skills you obtained