Artemis II Gravity Assist Problem

Physics 11

Scenario

The Artemis II spacecraft, Integrity, is approaching the Moon and plans to use a **gravity assist (slingshot maneuver)** to change its velocity without using extra fuel.

- Mass of Integrity: 1.8×10^4 kg
- Mass of Moon: 7.35×10^{22} kg
- Radius of Moon: 1.74×10^6 m
- Gravitational constant: $G = 6.67 \times 10^{-11}$ N·m^2/kg^2

(a) Force of Gravity

The spacecraft is 50,000 km from the Moon's center.

1. Calculate the gravitational force acting on Integrity using:

$$F = \frac{GMm}{r^2}$$

2. Draw a free body diagram showing the force acting on Integrity.
3. Explain why this force is the **net force** acting on the spacecraft.

(b) Acceleration

1. Calculate the acceleration of Integrity.
2. Compare this acceleration to 9.8 m/s^2. What do you notice?

(c) Closest Approach

Integrity passes 2.00×10^6 m above the Moon's surface.

1. Determine the distance from the center of the Moon.
2. Calculate the gravitational force at this distance.
3. Explain how changing distance affects gravitational force.

(d) Direction Change

1. Explain how the spacecraft's velocity changes direction as it passes the Moon.

2. Explain why the path is curved using net force and acceleration.

(e) Lunar Flyby (Gravity Assist): Slingshot Maneuver

A **lunar flyby**, or **gravity assist**, is a technique used by spacecraft like the *Integrity* to change their speed and direction by passing close to the Moon.

As the spacecraft approaches the Moon, the Moon's gravity pulls on it, causing the spacecraft to accelerate and follow a curved path. This gravitational force acts as the **net force**, changing the spacecraft's velocity without the need for engines.

During the flyby, the spacecraft effectively "borrows" a small amount of momentum from the Moon. As a result, it leaves the Moon with a different velocity, allowing it to be redirected back toward Earth.

This method saves fuel and relies on the same principles as **Newton's Law of Universal Gravitation** and **Newton's Second Law**, where a force causes a change in motion.

Assume gravitational force provides centripetal force.

1. Use:
$$\frac{GMm}{r^2} = \frac{mv^2}{r}$$
to solve for velocity.

2. Explain how this velocity relates to the slingshot maneuver.