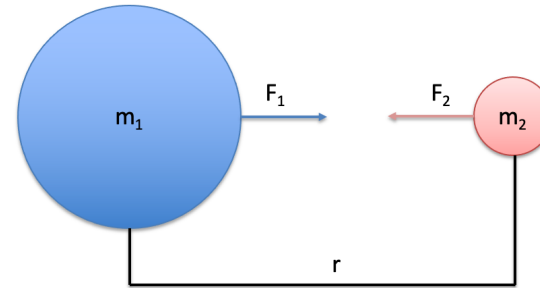
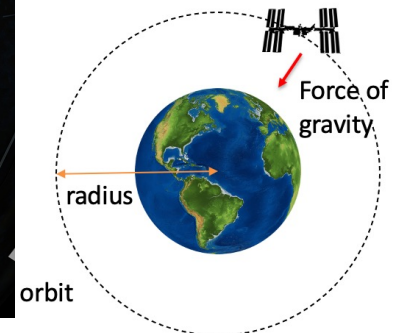


Universal Gravitation

- Gravity
- Law of Universal Gravitation
- Inverse-Square Law
- Extraterrestrial Gravity
- Objects in Circular Orbit
- Geosynchronous Orbits
- Our Bodies in Microgravity
- Interplanetary Travel



$$\vec{F}_G = \frac{Gm_1m_2}{r^2}$$



Preview File

Please enjoy this preview of your Student Version of the presentation. Please note within this sample file:

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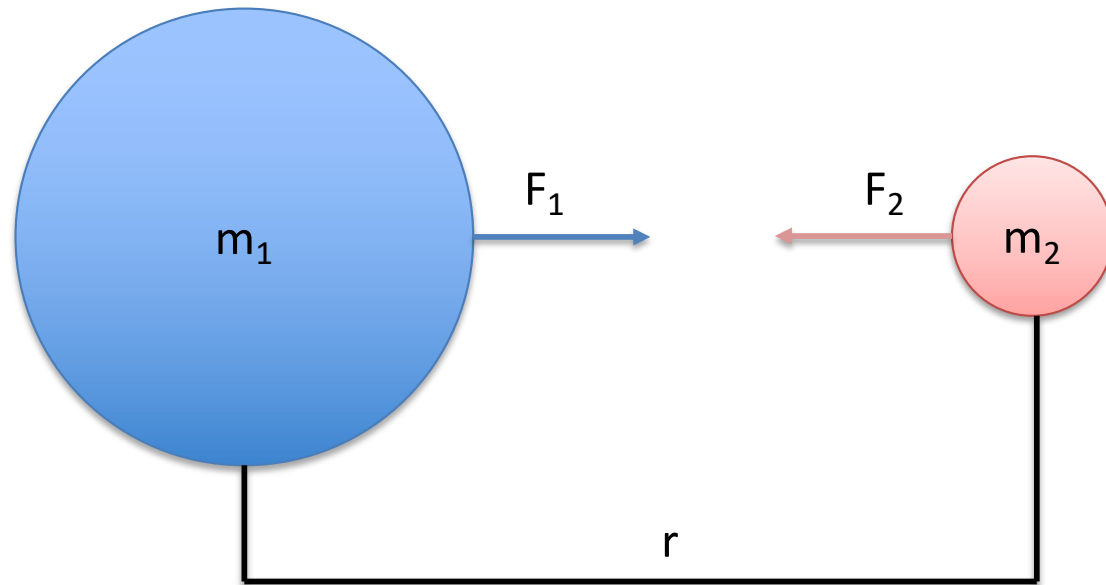


Gravity is everywhere

- Gravity is present wherever there is matter
- Thus, all material things are exerting a force on all other material things

$$\vec{F}_G = \frac{Gm_1m_2}{r^2}$$

Law of Universal Gravitation



F = Force of gravity between the two objects

G = Universal gravitational constant = $6.67 \times 10^{-11} \text{ Nm}^2\text{kg}^{-2}$

m_1 and m_2 are the masses of the objects in kg

r = distance separating the two objects (center to center)

Inverse Square Law

- _____
- Gravity can be calculated $\rightarrow 1/r^2$ where r is the center-to-center distance between two objects
- Increasing the separation distance (r), significantly impacts the force of gravity acting between the objects



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The Power of G

- Extraterrestrial Gravity is gravitational acceleration on other planets
- It can be calculated using this law, as long as the mass of the planet is known

$$\vec{F}_G = \frac{Gm_1m_2}{r^2}$$



Extraterrestrial Gravity

Planet	Radius (m)	Mass (kg)	g (m/s ²)
Mercury	2.43×10^6	3.2×10^{23}	3.61
Venus	6.073×10^6	4.88×10^{24}	8.83
Mars	3.38×10^6	6.42×10^{23}	3.75
Jupiter	6.98×10^7	1.901×10^{27}	26.0
Saturn	5.82×10^7	5.68×10^{26}	11.2
Uranus	2.35×10^7	8.68×10^{25}	10.5
Neptune	2.27×10^7	1.03×10^{26}	13.3
Pluto	1.15×10^6	1.2×10^{22}	0.61

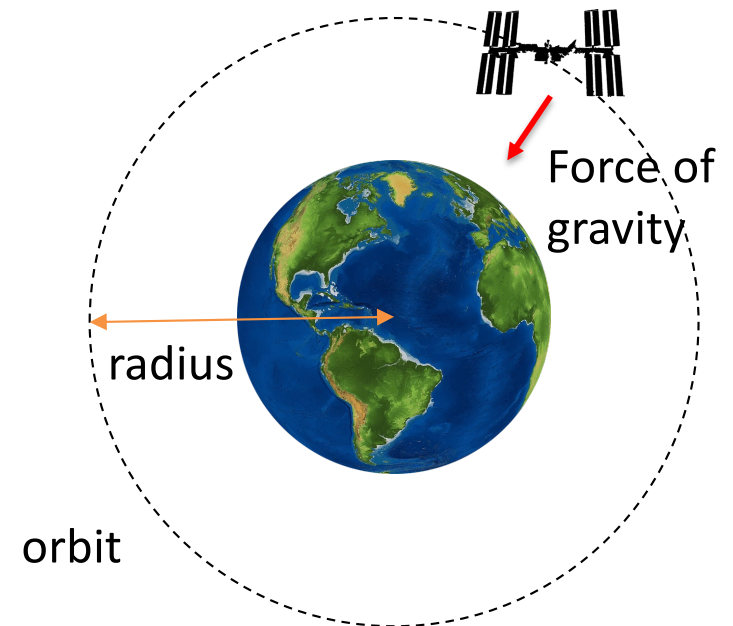
Check Your Understanding

Earth's gravitational pull on a spacecraft some distance away is $1.2 \times 10^2 \text{ N}$ in magnitude. What will the magnitude of the force of gravity be on a second spacecraft with 1.5 times the mass of the first spacecraft, at a distance from Earth's centre that is 0.45 times as great?

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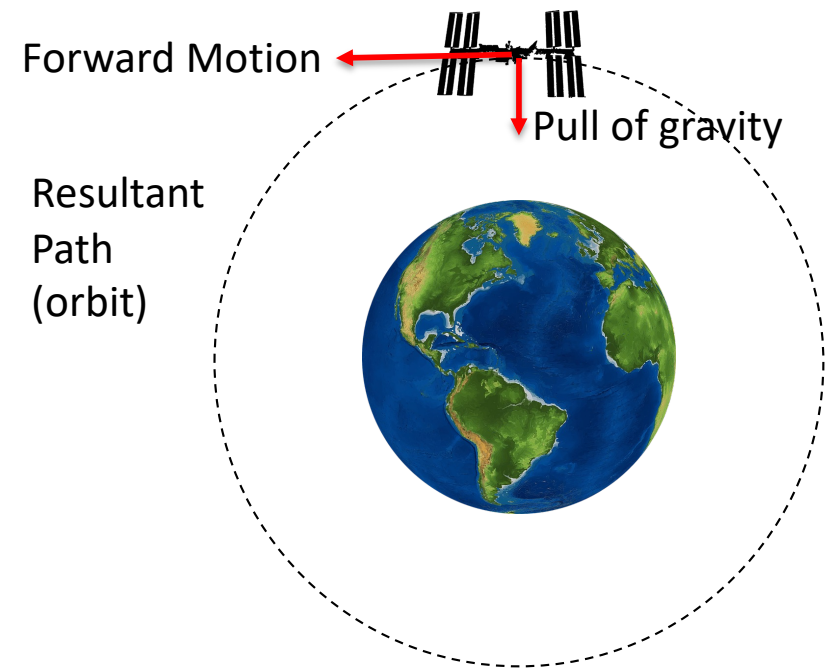
Objects in Circular Orbit

- _____
- Then why isn't an object that is orbiting another in space (i.e., a TV satellite in outer space) simply get pulled down to the surface?



Objects in Circular Orbit

- An object in circular orbit (like a satellite) has forward motion but is constantly being pulled by the force of gravity towards Earth



- _____

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Objects in Circular Orbit

- To analyze the motion of objects in circular orbit, we combine Newton's law of universal gravitation with the equation for centripetal acceleration involving speed

$$\sum F = \frac{Gm_S m_E}{r^2} = \frac{m_S v^2}{r} \quad \longrightarrow \quad v = \sqrt{\frac{Gm_E}{r}}$$

- We can also use our equations for frequency and orbital period

$$\sum F = \frac{4\pi^2 m r}{T^2} = 4\pi^2 m r f^2$$

Check Your Understanding

The Hubble Space Telescope (HST) follows an essentially circular orbit, at an average altitude of 598 km above the surface of Earth.

$$G = 6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2 \quad m_E = 5.98 \times 10^{24} \text{ kg}$$

$$\text{Distance from Earth's core to the surface} = 6.38 \times 10^6 \text{ m}$$

Determine the speed needed by the HST to maintain its orbit. Express the speed both in metres per second and in kilometers per hour.

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Our Bodies in Microgravity

Life without gravity



Our Bodies in Microgravity

The absence of forces against the muscles (caused by microgravity) has significant long-term health consequences

- _____
- _____
- _____

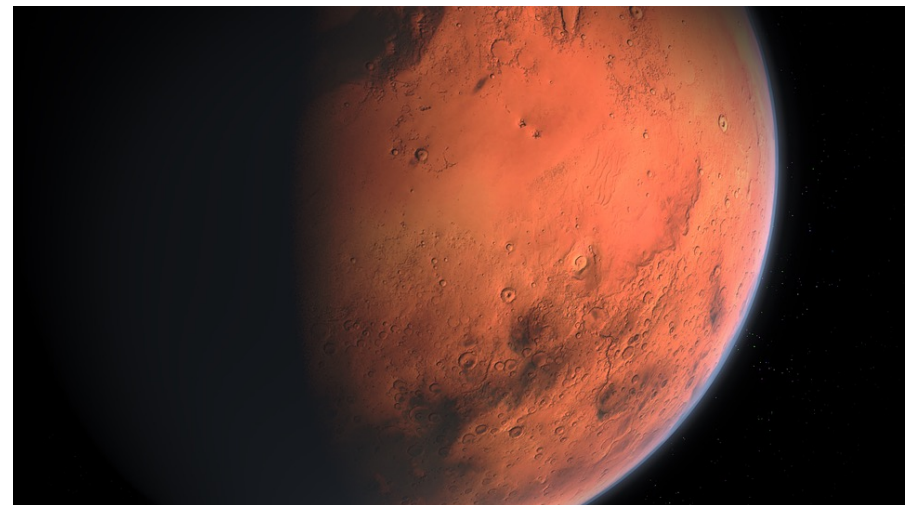


The ISS does not have artificial gravity

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Long-term Solutions

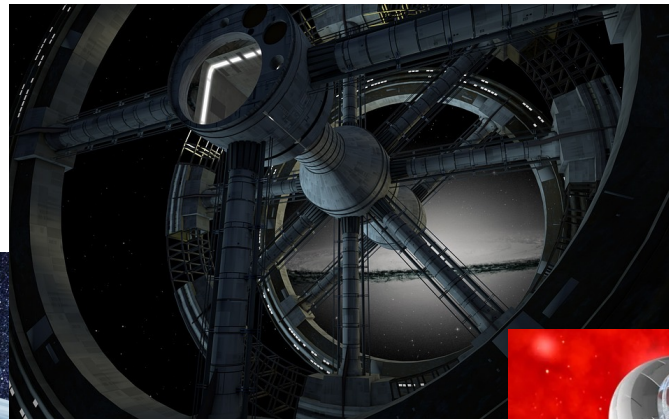
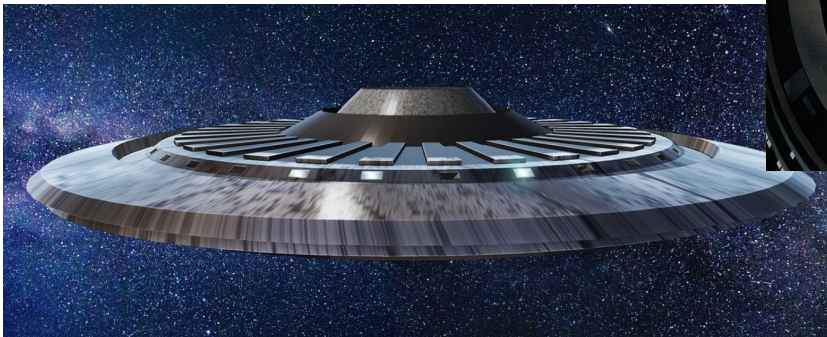
- Any interplanetary mission (to Mars or beyond) or permanent space colony must simulate gravity for the health of participating astronauts/scientists
- Can be done using the principles of circular motion



Rotating Space Stations

- A rotating space station can simulate gravity by creating an external 'floor' which the astronauts would walk on

- _____



Check Your Understanding

A cylindrical space craft travelling to Mars