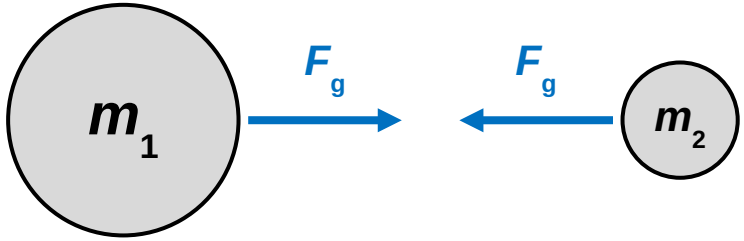
Universal Gravitation

Essential Question

How strongly do two masses pull on each other?

Gravity Is Universal

- Any two masses attract
- Each pulls on the other equally
- More mass, more force



same size pull on each

Newton's Law of Gravitation

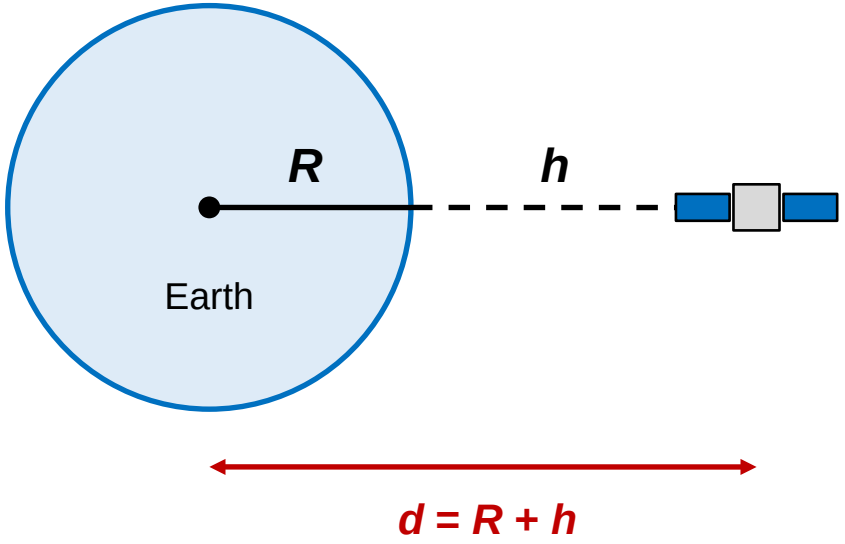
$$F_g = G m_1 m_2 / d^2$$

F_g	G	m_1, m_2	d
gravitational force (N)	6.67×10^{-11} $N \cdot m^2/kg^2$	masses (kg)	center-to-center distance (m)

G is the universal gravitational constant

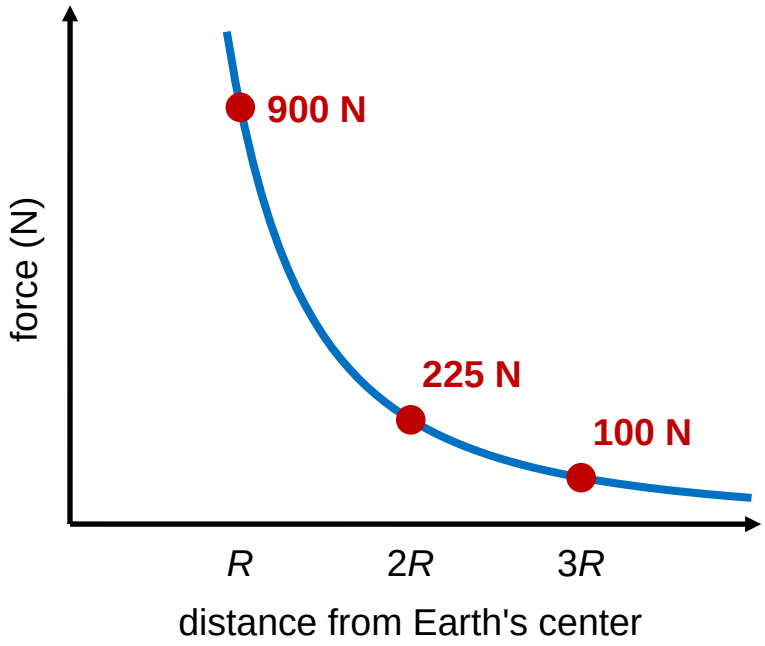
Center to Center

- Measure *d* center to center
- Above a planet: $d = R + h$
- Not surface to surface



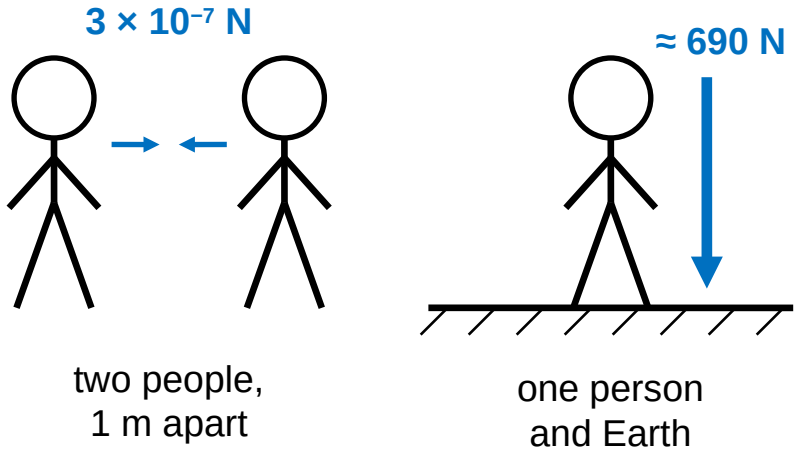
Inverse Square Law

- Double *d*: ¼ the force
- Triple *d*: 1/9 the force
- Weaker, but never zero



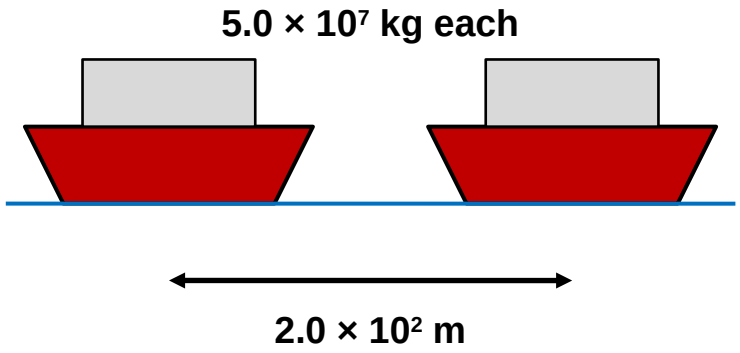
Why Is Gravity So Weak?

- *G* is tiny
- Everyday objects: tiny pull
- Only huge masses pull hard



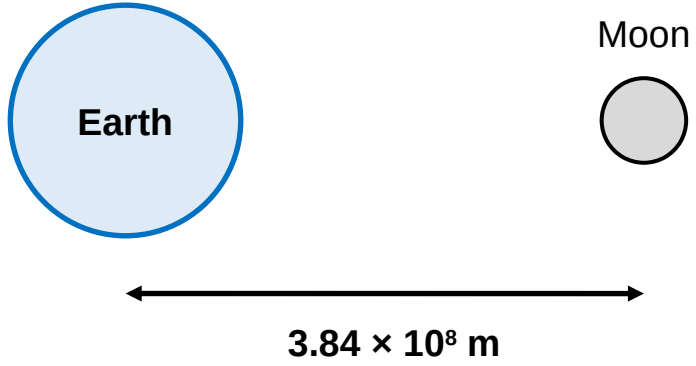
Example: Two Cargo Ships

Two cargo ships, each with a mass of 5.0×10^7 kg, are 2.0×10^2 m apart (center to center). What is the gravitational force between them?



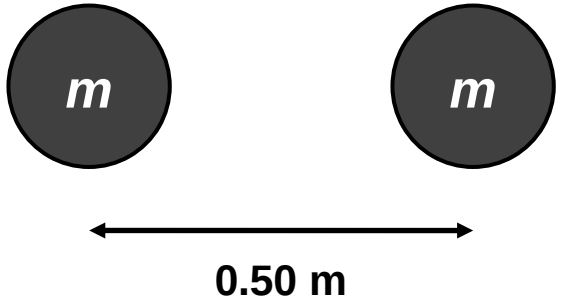
Example: Earth and the Moon

Earth has a mass of 5.97×10^{24} kg and the Moon has a mass of 7.35×10^{22} kg. Their centers are 3.84×10^{8} m apart. What is the gravitational force between them?



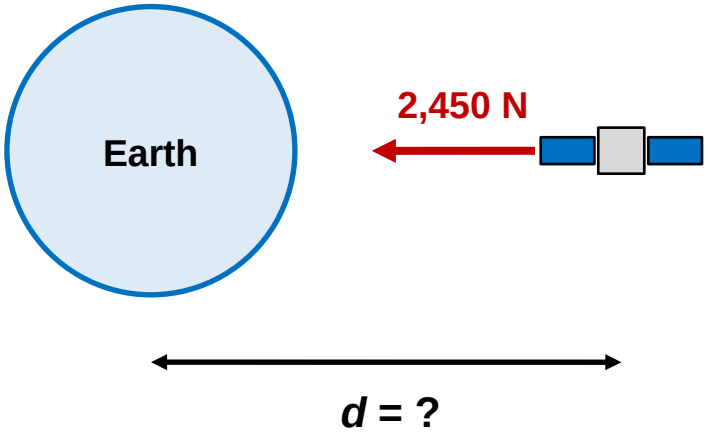
Example: Two Bowling Balls

Two identical bowling balls are 0.50 m apart, center to center. They attract each other with a force of 1.5×10^{-8} N. What is the mass of each ball?



Example: Finding the Distance

Earth (5.97×10^{24} kg) pulls on a 1.00×10^{3} kg satellite with a force of 2,450 N. How far is the satellite from Earth's center?



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Big Ideas

- Every two masses attract
- $F_g = Gm_1m_2/d^2$, $G = 6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2$
- d is measured center to center
- Inverse square: 2× distance, ¼ force