tps

Q: If the Earth were located at 0.5 AU instead of 1 AU, how would the Sun's gravitational force on Earth change?

A. It would be one-fourth as strong.
B. It would be one-half as strong.
C. It would be twice as strong.
D. It would be four times as strong.

Newton & Gravity

- Objectives
  - Why do the planets go around the Sun/Moons go around planets?
  - Newton’s laws of motion
  - Newton’s law of gravity
  - Earth-Moon tides

Isaac Newton

- Kepler and others' work took observations and built models to fit those observations

- Newton developed Laws of Motion (3 of them) that apply to all objects, and then showed that Kepler's laws were a direct consequence of these laws.

- These laws are truly universal- they don't just apply to planets and orbital motion, but motion here on Earth or anywhere else in the universe.

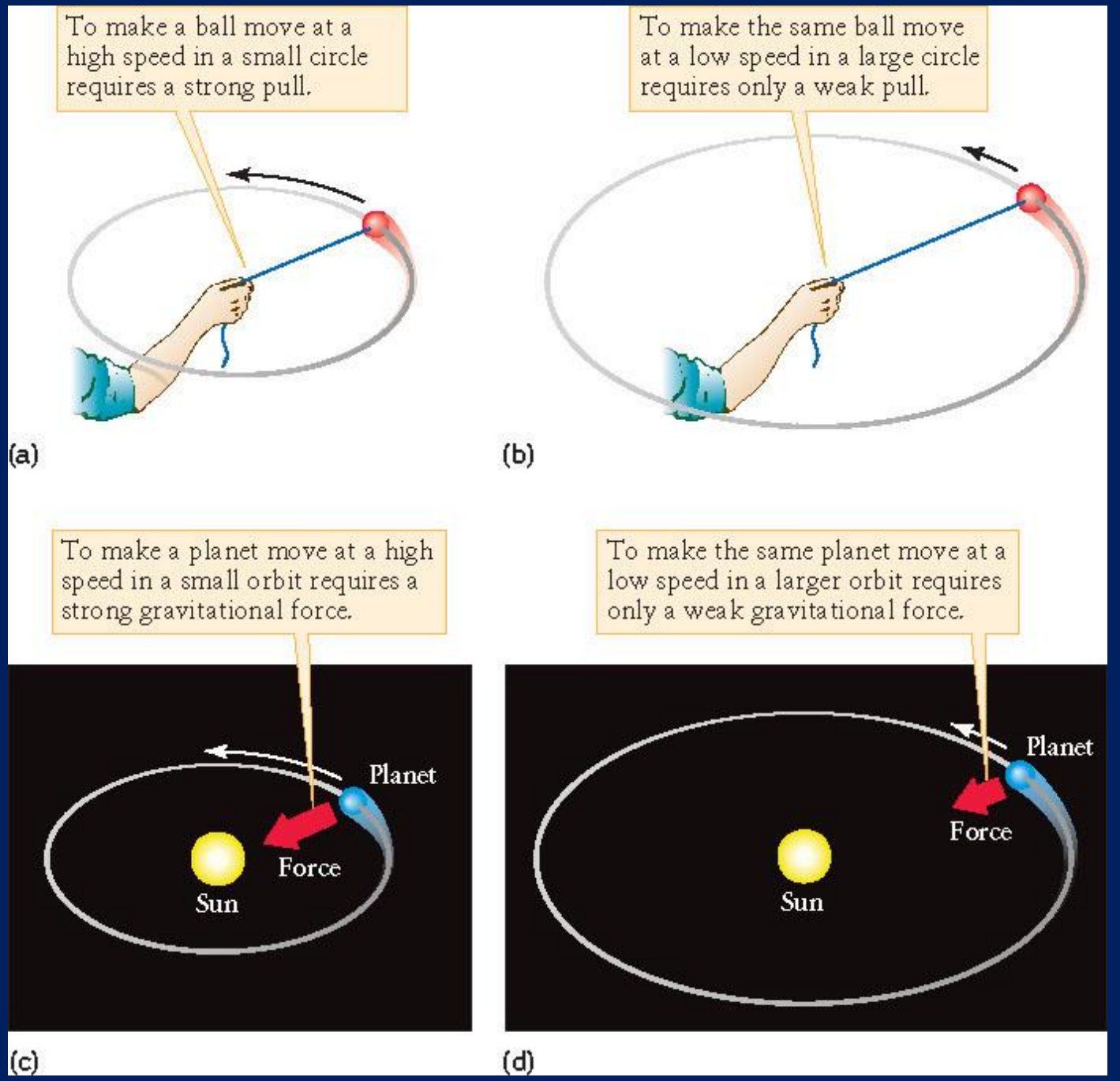
1st Law: Inertia

- An object that is at rest will remain at rest; and an object in motion will remain in motion, ***unless acted on by a net outside force***.

- Why Don't the Planets Fly Off Into Space???

Demo

- Why Don't the Planets Fly Off Into Space???
- A Force is acting on the planets
- This is what Newton deduced



2nd Law

- The (net) force acting on an object is equal to object's mass times its acceleration.

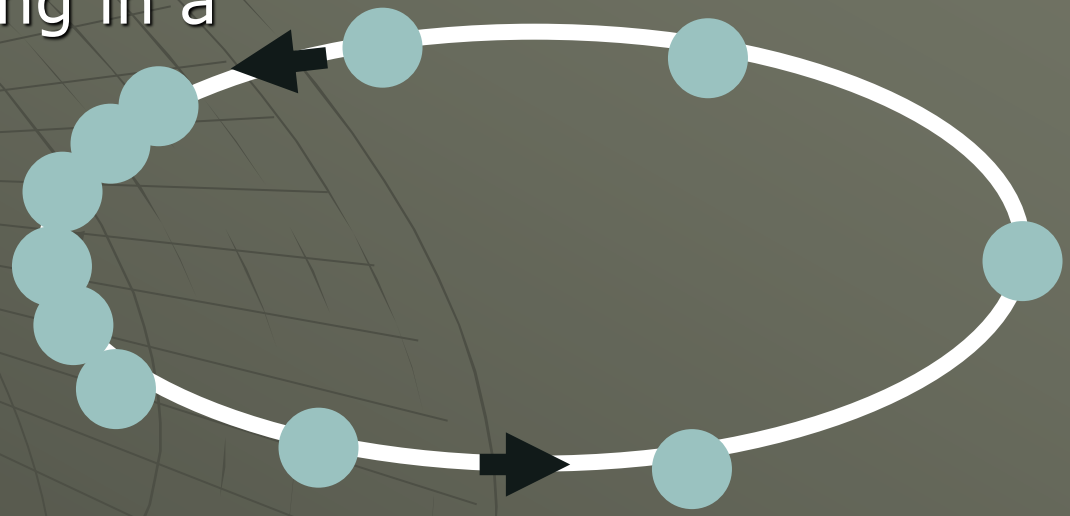
$$F = ma$$

- ***a=acceleration (units m/s²):*** *change in an object's speed or direction*
  - *On Earth a=9.8 m/s²*
- ***m=Mass (units kg):*** is a measure of an object's **inertia**.
- **F=Force (units Newton)**
- **Weight:** Measure of force acting on a mass

- As force on object goes up, acceleration increases
- The more massive an object, the more difficult to accelerate object

Be careful…

- Object speeding up **or** slowing down is *accelerating*.
- Object moving at constant speed, but **changing direction** is *accelerating*.
  - Example: planet in an elliptical or circular orbit
  - Force **required** to keep planet moving in a circle
  - Remember: ball on a string demo



Units

- What is the unit of a Newton???
- $a = m/s^2$
- $m = kg$
- $F=ma$; units = $kg*m/s^2$
- $N = kg*m/s^2$

Unit Analysis

Q: A 200 kg car changes it's speed by 10 m/s in 10 seconds. How many Newtons of force acted on the car?

A. 20 N
B. 100 N
C. 200 N
D. 2000 N

A: $N = kg*m/s^2$
200 (kg) * 10 (m/s) / 10 (s) = 200 * 1 = 200 N

tps

Q: A person has a mass of 50 kg. What is their weight on Earth?

A) 490 N (or 110 lbs)

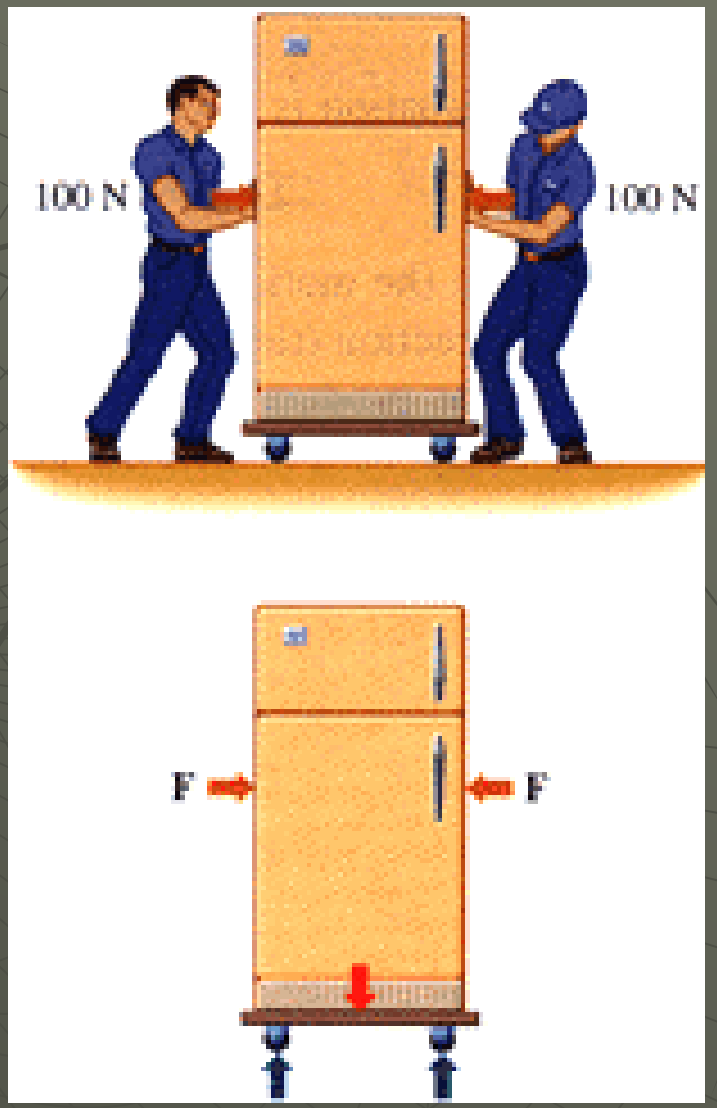
B) 300 N (or 67 lbs)

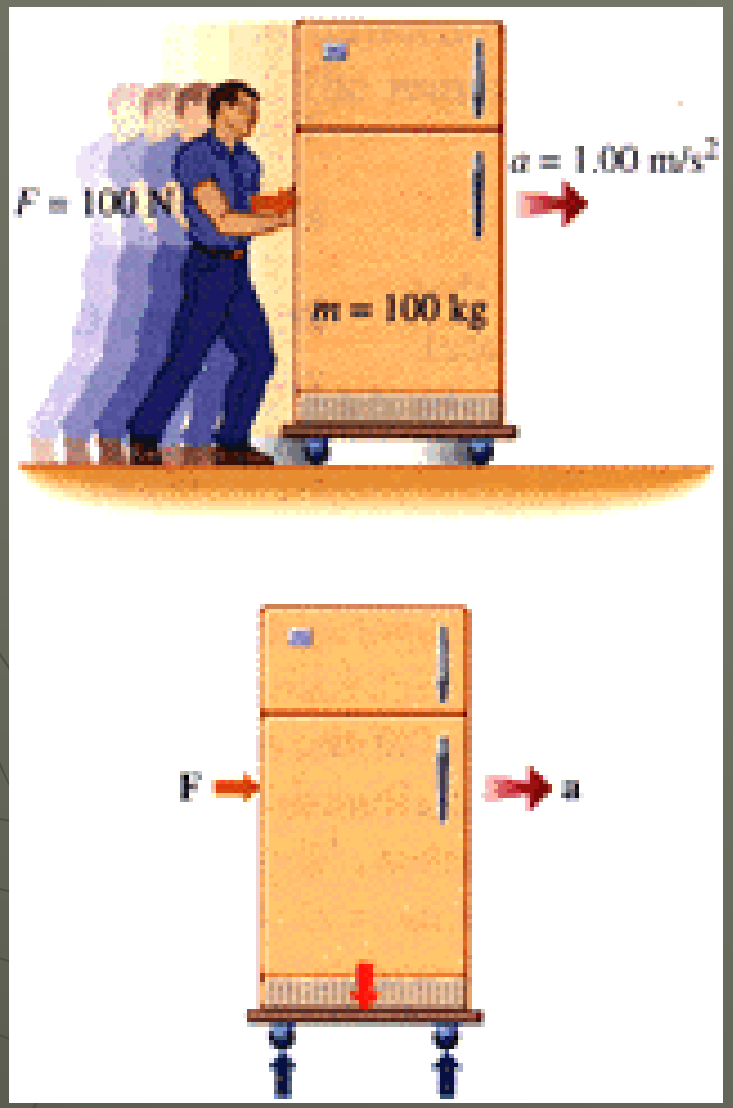
C) 50 kg (or 50 lbs)

D) 8000 N (or 1,797 lbs)

Net Force

- Net = Summation of all forces (add up all forces)





Q: Which of the following cars does NOT experience an acceleration?

A. A car driving due north at a speed of 60 mph
B. A car coming to a stop at a red light
C. A car driving around a curve at a constant speed of 30 mph
D. A car entering a highway and matching its speed to the faster-moving cars

Q: In which of the following cases is a net outside force acting upon an object?

A. A box sits at rest on the floor.
B. A car drives due north at a speed of 60 miles per hour.
C. A hockey puck glides across the ice.
D. A block of wood, after being pushed across a table, eventually stops.

Newton's Third Law of Motion

- Whenever one object exerts a force on a second object, the second object exerts an equal and opposite force on the first object (action-reaction)

- Earth pulls on moon with the same force that moon pulls on earth!
- You are exerting a gravitational force on me, the building, your book, etc!

Example: If you weight 120 lbs, when you sit in a chair you exert a force of 120 lbs on the chair. The chair reacts and pushes against you with a force of 120 lbs.

- Hint: Are you moving? Why aren't you falling?

Newton's Laws & Heliocentricity

- With this simple formalism, Newton's laws explain WHY the heliocentric model is true

- 3rd law says that if the Sun exerts a force on the planets, the planets exert the same force on the Sun

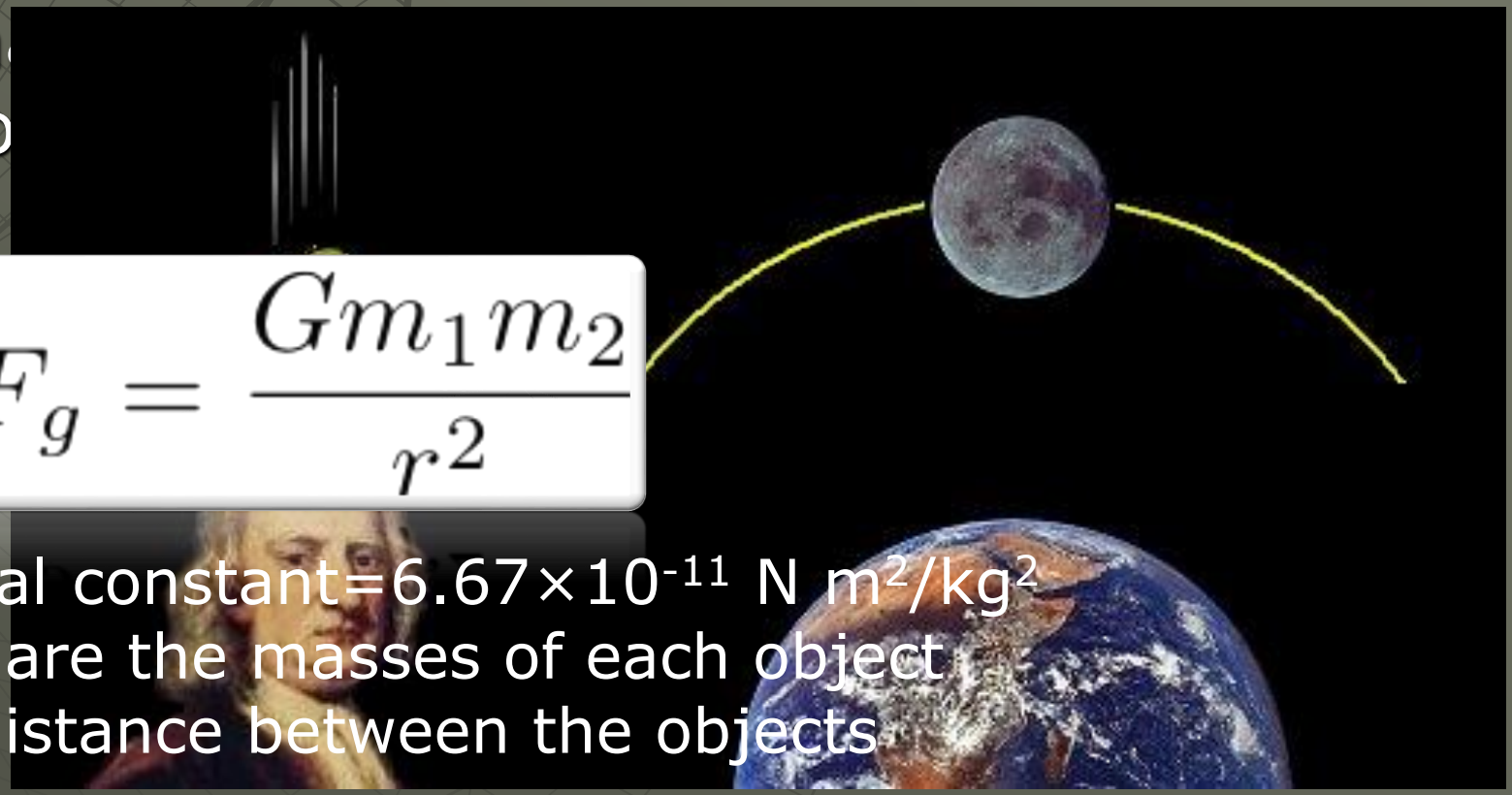
- The 2nd law says that since the Sun is much more massive than the planets, the same force yields a much smaller acceleration for the Sun

- Thus, it is the planets that move (accelerate) and orbit!

Newton's Law of Gravitation

- Newton's First law shows that the planets are acted upon by a force which Newton called gravity
- Same force that "pulls" an apple from a tree
- Two objects attract each other with a force that is directly proportion
  inversely proportio
  between them

$$F_g = \frac{Gm_1m_2}{r^2}$$



G=gravitational constant=6.67×10^{-11} N m^2/kg^2
m_1 and m_2 are the masses of each object
r is the distance between the objects

Why does a feather and a rock hit the ground together?

- Objects fall according to Newton's 2nd law:
  - F=ma
- Gravity is the force responsible for falling:
  - $F=GMm/r^2$ (M=mass of Earth, m=mass of object)

$$\frac{GM\cancel{m}}{r^2} = \cancel{m}a$$

$$a = \frac{GM}{r^2}$$

- *a* in independent of mass of the object!!!

tps

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D. It would be four times as strong.

Q: On which of the following objects would a person have the least mass?

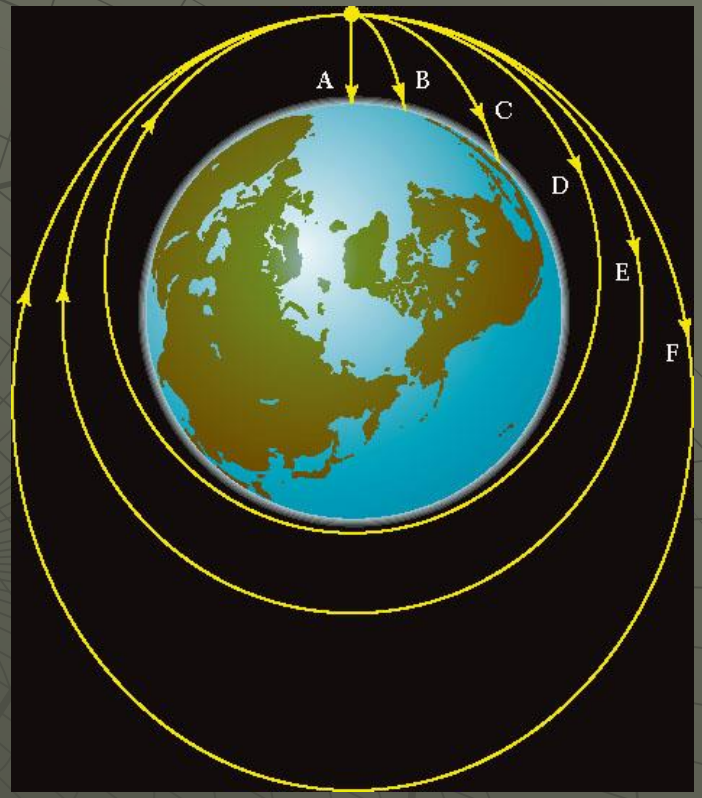
A. Earth
B. Jupiter
C. The Moon
D. A person’s mass would be the same on all three.

LT

- Newton’s Laws and Gravity
  - pg. 29

Gravity and Orbits

- So if all objects attract each other, why don't the planets just all fall into the sun?



Animation

Orbiting objects are always falling; they're just falling *around* the Earth! (or whatever they're orbiting)

Gravity and Orbits

• Newton also generalized Kepler's third law ($P^2=a^3$) to any bodies in orbit around each other (Kepler's law only applies to things orbiting the Sun)

$$P^2 = \left(\frac{4\pi^2}{G(m_1 + m_2)} \right) a^3$$

•M (sun) = 2×10^{30} kg!!!
•M (earth) = 6×10^{24} kg
•m1 + m2 = 2.000006×10^{30} kg

Newtonian Mechanics

- Can mathematically explain and predict all the orbits of the planets, satellites, and most things in the universe

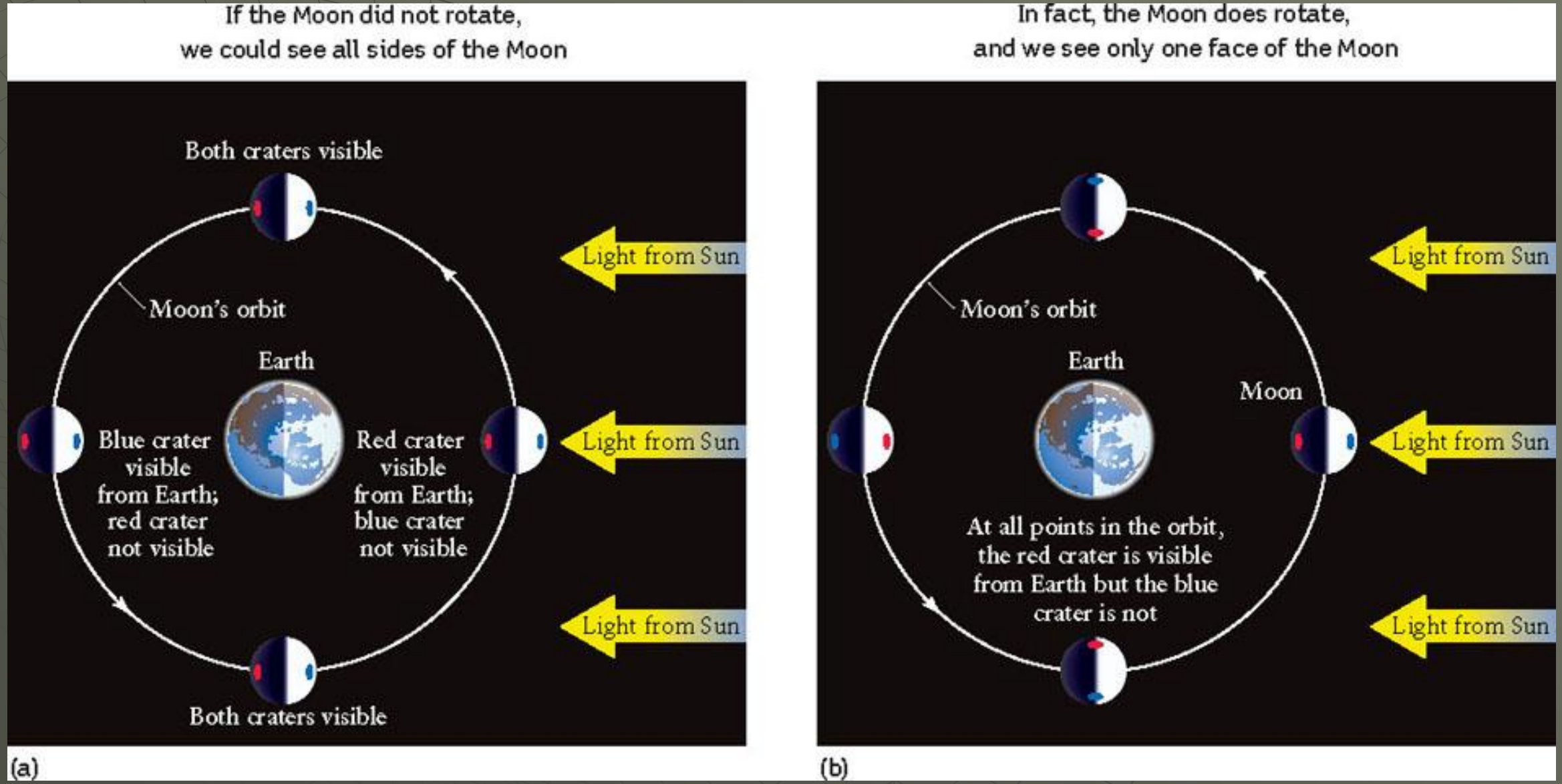
- Was used to predict the existence of Neptune, before it was ever seen

- Still used in many situations today, but not all...Einstein

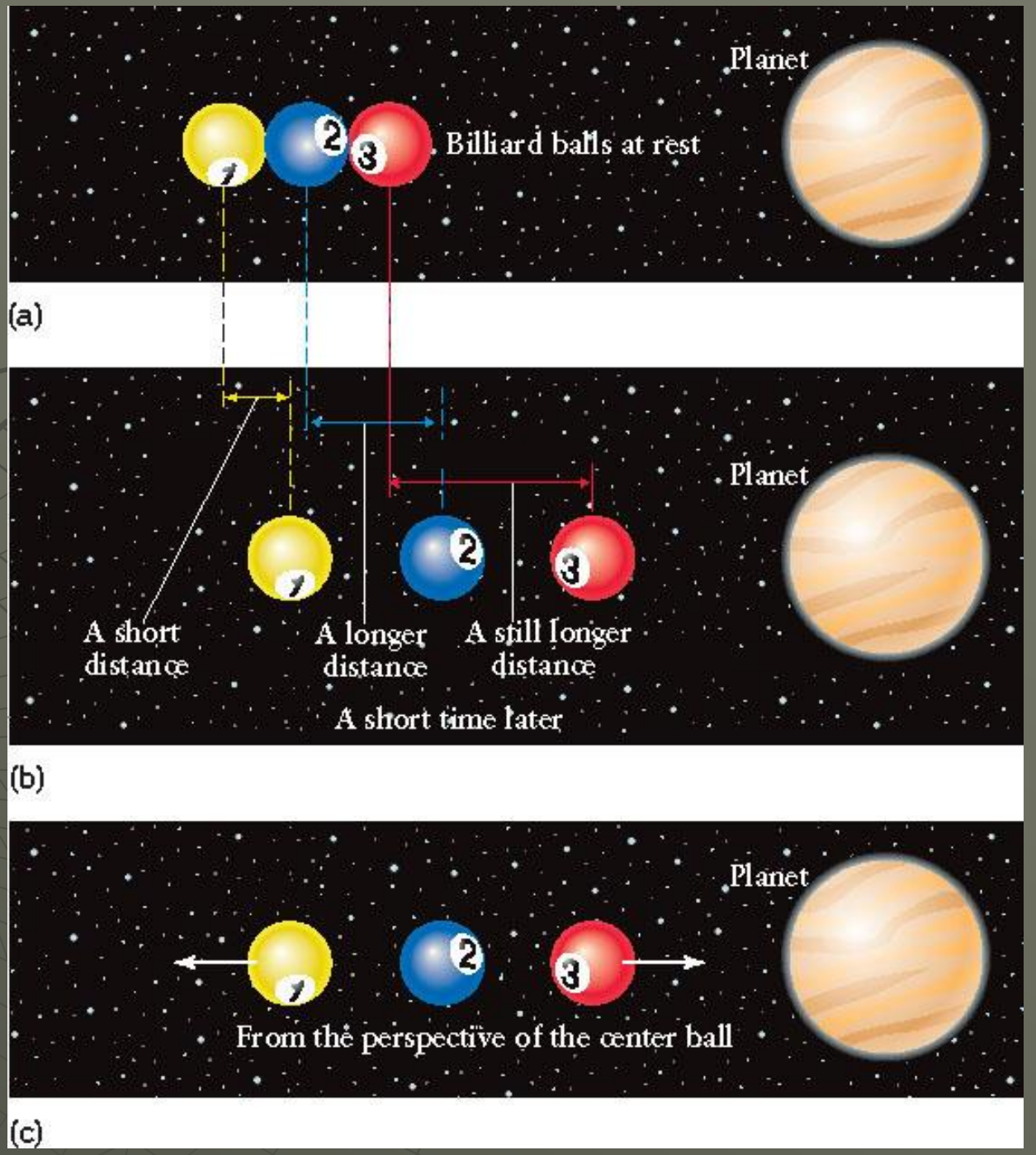
Tidally Locked

- Same face no matter what phase!!!
- The far side of the Moon was not seen in its entirety until 1959, when photographs were transmitted from the Soviet spacecraft Luna 3.
- Does the moon rotate???

Moon's Rotation???

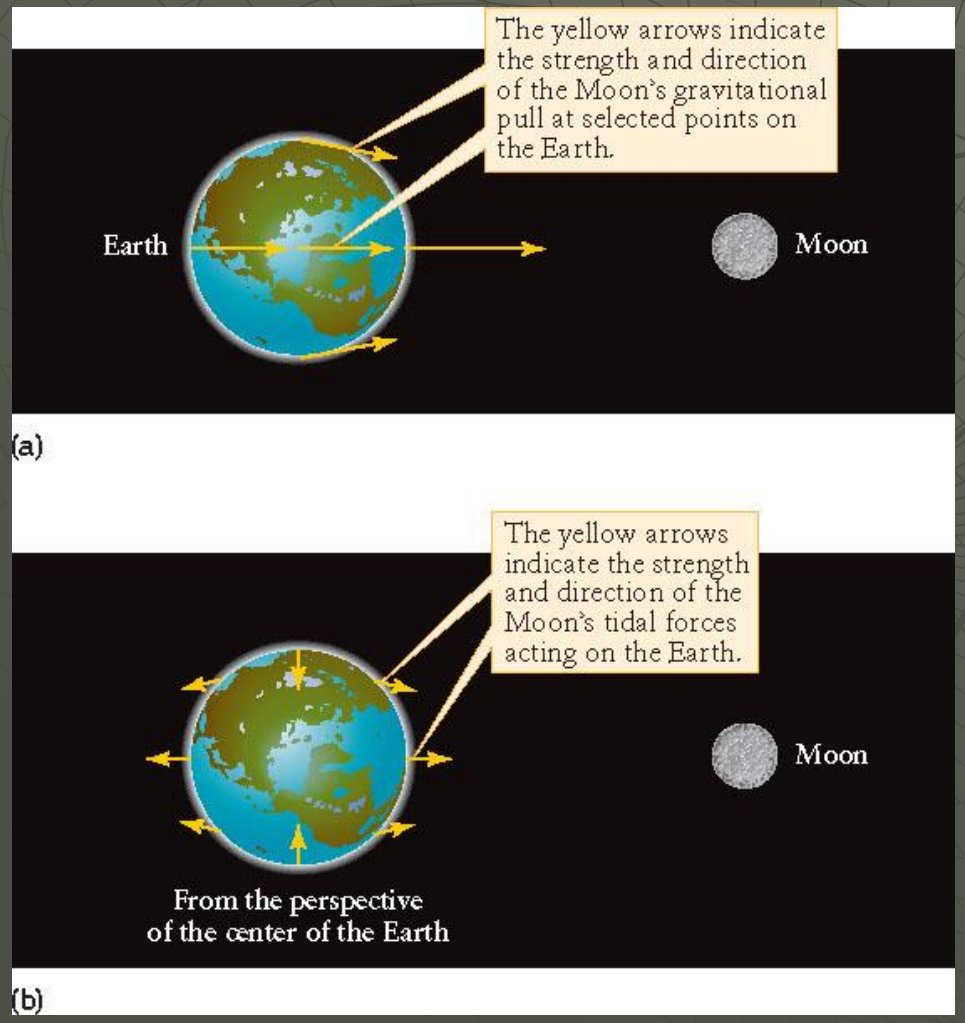


Tidal Forces???

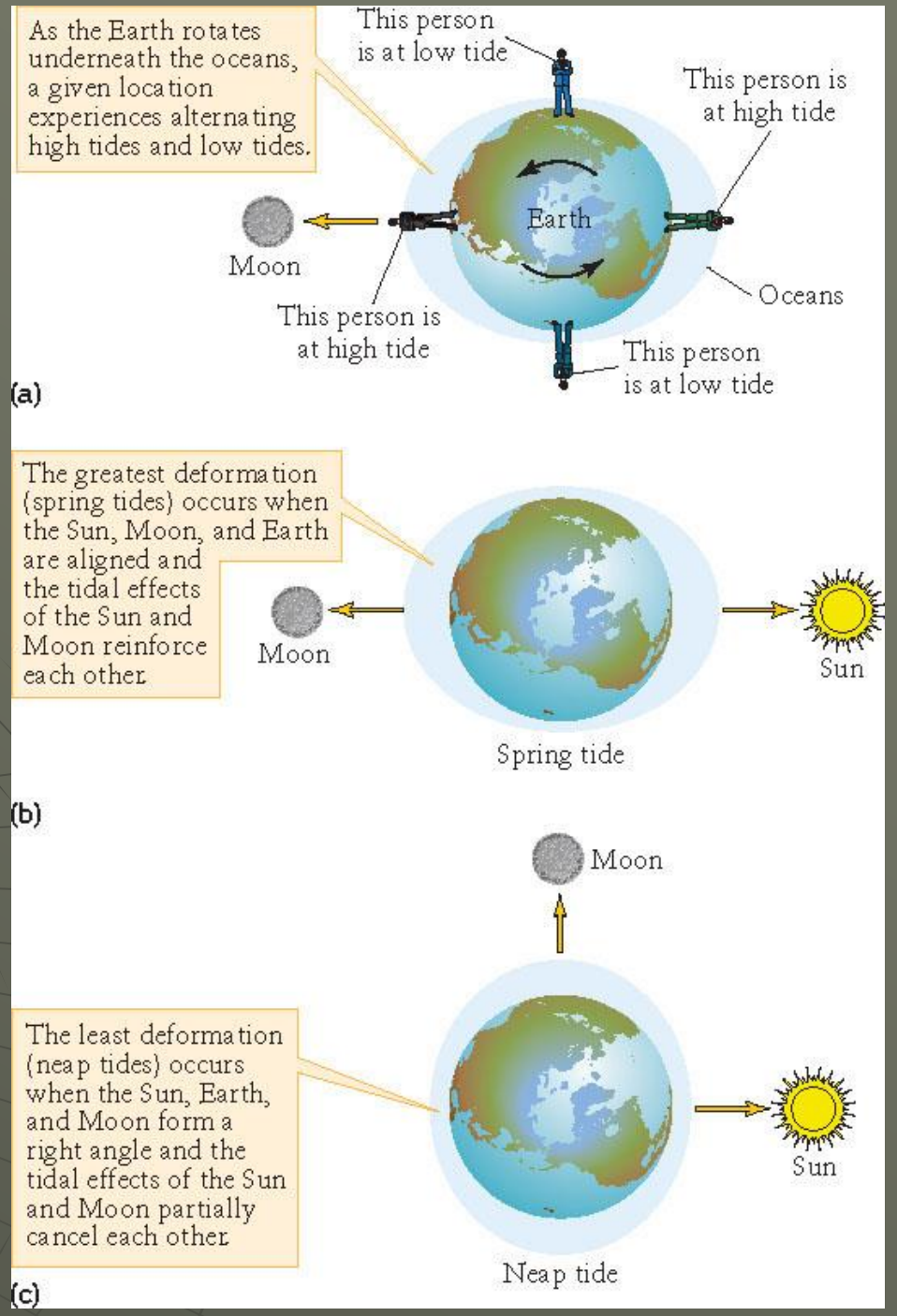


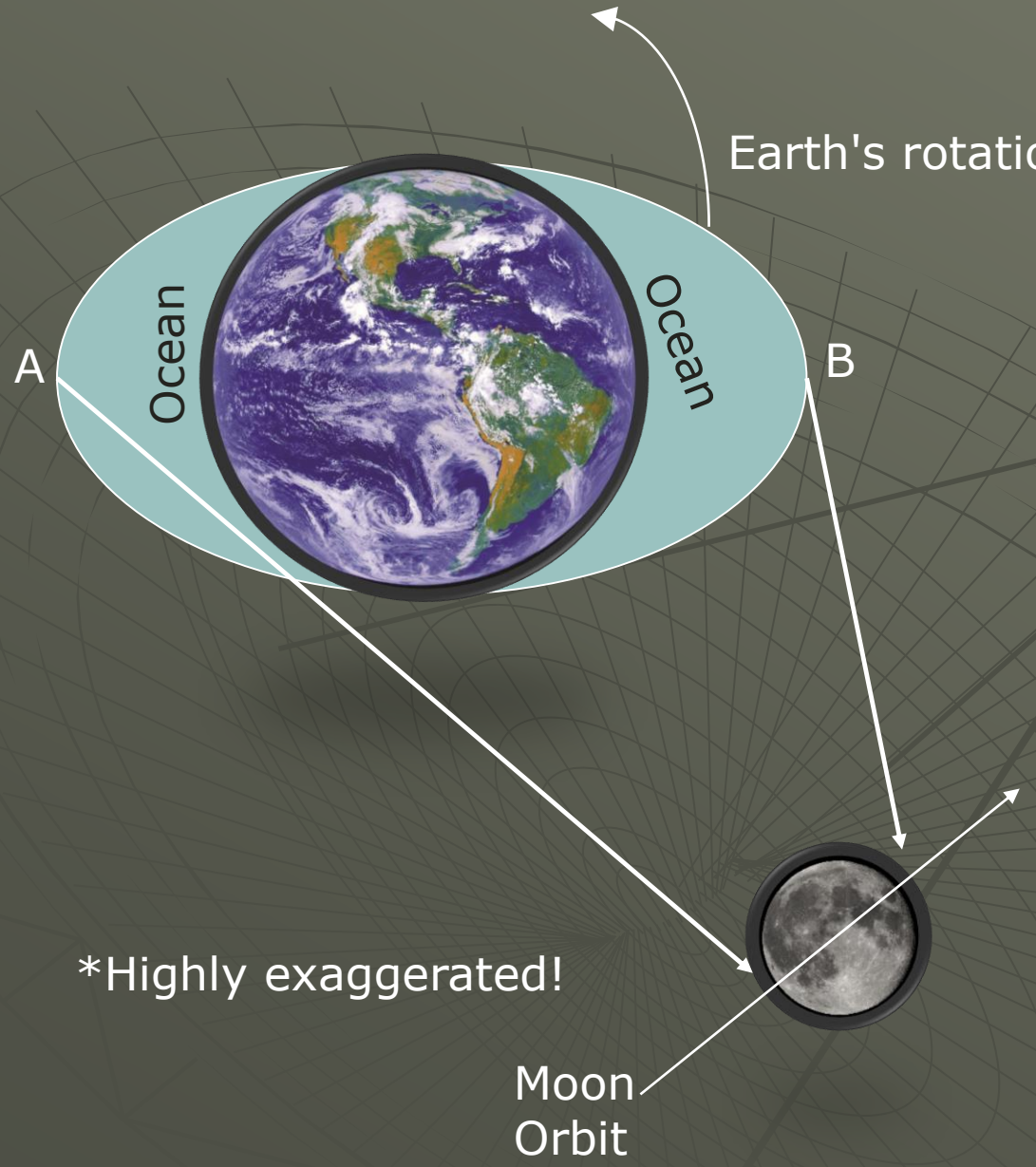
Tides

- Pull from the Moon and Sun cause the water on Earth to bulge



Mostly Due to the Moon





- The Moon causes bulges in the Earth’s oceans
- The Earth rotates faster than the moon’s orbit (gets ahead of the moon)

- Point B pulls on leading edge of the moon
- Point A pulls on the trailing edge of the moon

- Angular momentum
- The Moon is slowly moving away from us by ~3cm/year!!!

- A consequence of the moon-earth tidally locked system, the moon:

A. Doesn’t rotate
B. Rotates at the same rate as it orbits the earth
C. Rotates once a day
D. Rotates so fast, that cheese bits fly off of its surface!