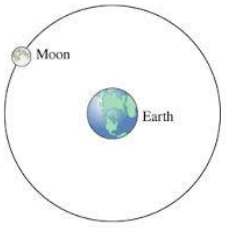
Orbital Motion and Tides

Mutual Gravitation

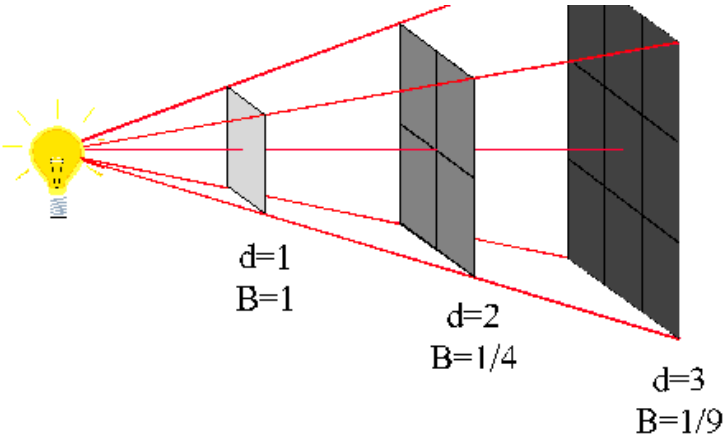
- Once _____figured out his laws, he was able to better understand _____
  - 1st and 2nd law – bodies _____ downward because some force must be pulling _____ on them
    - Ex: the Moon orbiting the Earth
      - It has to be pulled by something and motion along a curved path is *accelerated motion* which is required by a force causing it to follow that curved path
- Newton anticipated that the same _____ holding the Moon in orbit was the same as _____ here on Earth, but that it might get weaker as it reached outer space

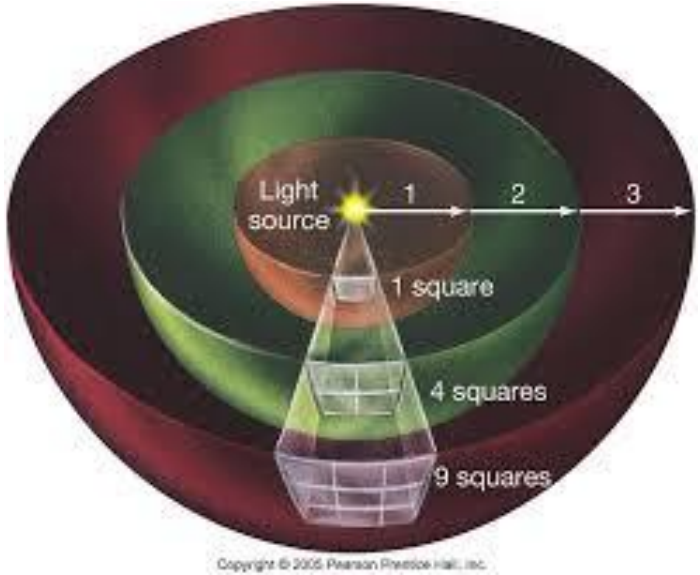


Orbital Motion and Tides

Mutual Gravitation

- Inverse Square Law – strength of a _____ will _____ as the square of the _____ increases
  - Saw this with light
    - A screen set up 1 meter away from a candle flame received a certain amount of light and then that light covered 4 sq. meters when the screen was 2 meters away
    - The light intensity was inversely proportional to the square distance of the screen





Orbital Motion and Tides

Mutual Gravitation

- Earth's gravity follows the inverse _____ law according to Newton
  - This includes the distance from the Earth's _____ and not surface
  - Ex: the Moon is 60 Earth radii away

    gravity is 60^2 (or 360)x less than at the Earth's surface

    acceleration at Earth's surface is 9.8 m/s^2

    this estimates out to be . _____ m/s^2

    To keep the Moon in orbit, acceleration = . _____ m/s^2

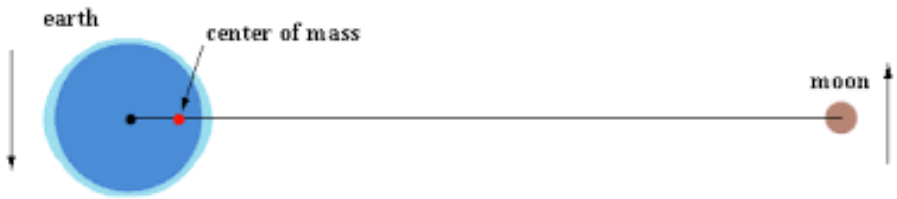


Figure 2. Moon's gravitational pull plus 2-body rotation

Orbital Motion and Tides

Mutual Gravitation

- Gravity depends on _____, and with Earth's mass being so substantial, it's strong enough to hold the _____ in orbit

$$F = -\frac{Gm_1m_2}{r^2}$$

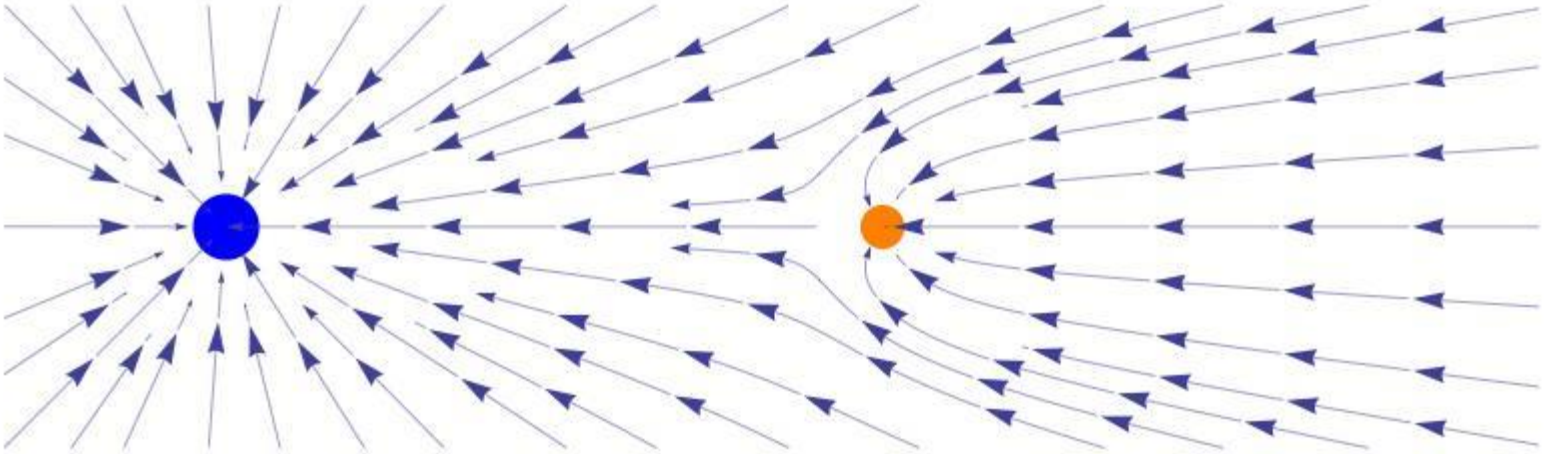
  - F – _____
  - G – gravitational constant
  - *r* – _____between the masses
  - m_1 – mass of the object 1
  - m_2 – mass of object 2

- The force of gravitational attraction between two masses (m_1 and m_2) is proportional to the product of the masses and inversely proportional to the square of the distance between them

Orbital Motion and Tides

Mutual Gravitation

- Field – When two objects exert _____ onto each other without physically _____
  - Ex: Earth and the Moon
  - Used to describe gravity that follows the inverse _____ law



Orbital Motion and Tides

Orbits

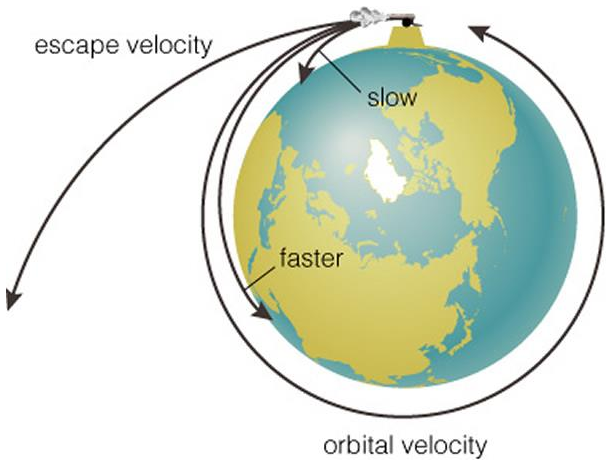
- Orbital motion is how gravity pulls on an _____ object
  - Tidal motion is how gravity pulls on _____ of an object
- _____ was the first to figure out that objects which are orbiting are technically “falling”

Orbital Motion and Tides

Orbits

- Orbiting Earth:

1. An object orbiting Earth is actually falling towards Earth's _____
   - It misses each time because of orbital velocity
   - Circular Velocity – the velocity needed to stay in a _____ orbit
   - Just above Earth's atmosphere, circular velocity is about 7780 m/s (17,400 mph) with an orbital period of about 90 minutes

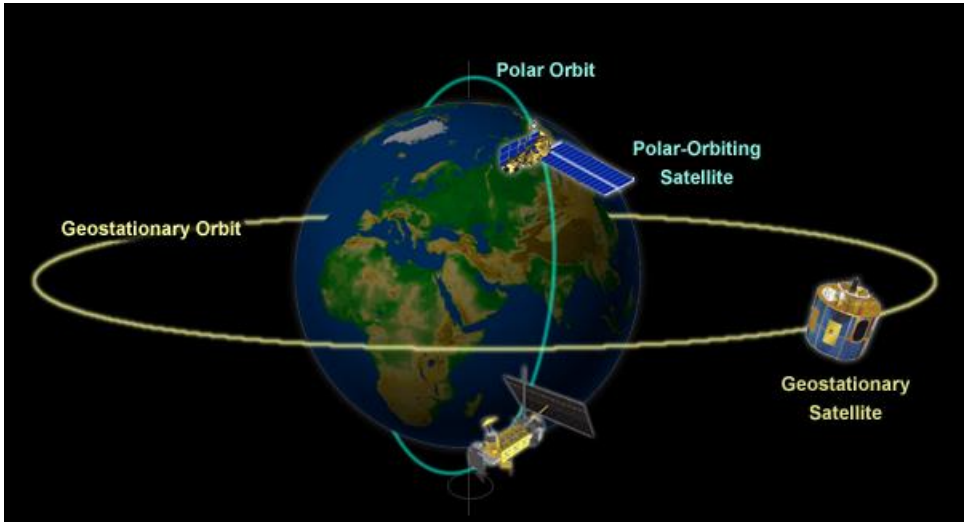


Orbital Motion and Tides

Orbits

- Orbiting Earth:

1. An object orbiting Earth is actually falling towards Earth's center
   - Geosynchronous Satellites – satellites that orbit _____ with the rotation of Earth and remain above a fixed _____
     - About 42,230 km (26,240 mi) from Earth's center
     - Orbits in 24 hours



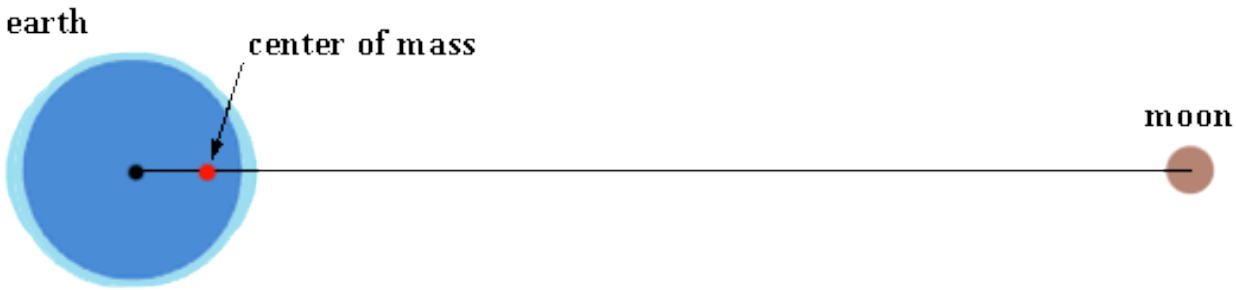
Orbital Motion and Tides

Orbits

- Orbiting Earth:

  2. Objects that are orbiting each other actually revolve around their mutual center of mass

  - An object doesn't orbit Earth, but rather, they orbit each _____
    - Remember, gravity is mutual
  - Center of Mass – the _____ point of the gravitational system (or two objects)
  - Because of Earth's enormous mass, "they" orbit _____ to Earth



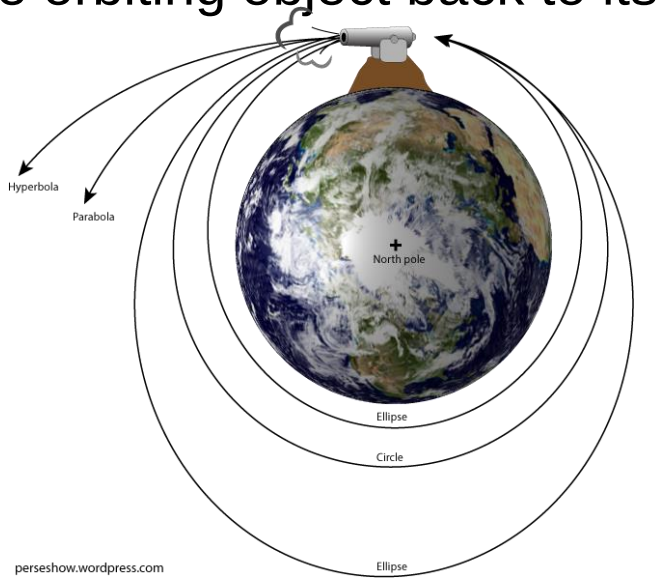
Orbital Motion and Tides

Orbits

- Orbiting Earth:

  3. There are closed and open orbits. A certain *escape* _____ is needed to leave Earth

  - Closed Orbit – _____the orbiting object to its original starting point
  - Escape Velocity – (V_e) the velocity needed to _____ a body
  - Open Orbit – does not _____ the orbiting object back to its original starting point



Orbital Motion and Tides

Orbital Velocity

- Circular Velocity – velocity an object must have in a _____ direction to remain in a _____ orbit

$$V_c = \sqrt{\frac{GM}{r}}$$

- G = gravitational constant (6.673×10^{-11} m^3/s^2kg)
- M = mass of the _____ body
  - Usually Earth (5.97×10^{24} kg)
- r = radius of the _____ in meters
  - Can also be distance if the information is provided as so

Orbital Motion and Tides

Orbital Velocity

$$V_c = \sqrt{\frac{GM}{r}}$$

- Ex: Moon's orbital velocity
  - G = _____ m^3/s^2kg
  - M = Earth (_____ kg)
  - r = distance from the Moon to the center of Earth (_____)

$$V_c = \sqrt{\frac{6.67 \times 10^{-11} \times 5.97 \times 10^{24}}{3.84 \times 10^8}} = \sqrt{\frac{39.8 \times 10^{13}}{3.84 \times 10^8}}$$

$$= \sqrt{1.04 \times 10^6} = 1020 \text{ m/s} = 1.02 \text{ km/s}$$

Orbital Motion and Tides

Orbital Velocity

- Because of the velocity needed to put the _____ in orbit, large _____ are used to get them above the atmosphere and moving at a speed that sets them in that _____ orbit
- Remember, even outside of Earth's atmosphere there is still _____
  - It may be weak or pulling from another object, but it is there

Orbital Motion and Tides

Escape Velocity

- Escape Velocity – (V_e) the _____ required to escape from the surface of an astronomical body

$$V_e = \sqrt{\frac{2GM}{r}}$$

- Exactly like the _____ velocity formula in regards to variables
- It is just _____ times the circular velocity

Orbital Motion and Tides

Escape Velocity

- Ex: Escaping Earth's atmosphere

$$V_e = \sqrt{\frac{2GM}{r}}$$

  - G = _____ m^3/s^2kg
  - M = Earth (_____ kg)
  - r = Earth's atmosphere average radius (_____ m)

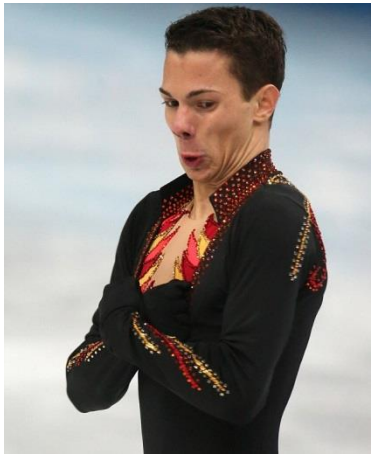
$$V_c = \sqrt{\frac{2 \times 6.67 \times 10^{-11} \times 5.97 \times 10^{24}}{6.37 \times 10^6}} = \sqrt{\frac{7.96 \times 10^{14}}{6.37 \times 10^6}}$$

$$= \sqrt{1.25 \times 10^8} = 11{,}200 \text{ m/s} = 11.2 \text{ km/s}$$

Orbital Motion and Tides

Kepler's Laws Reexamined

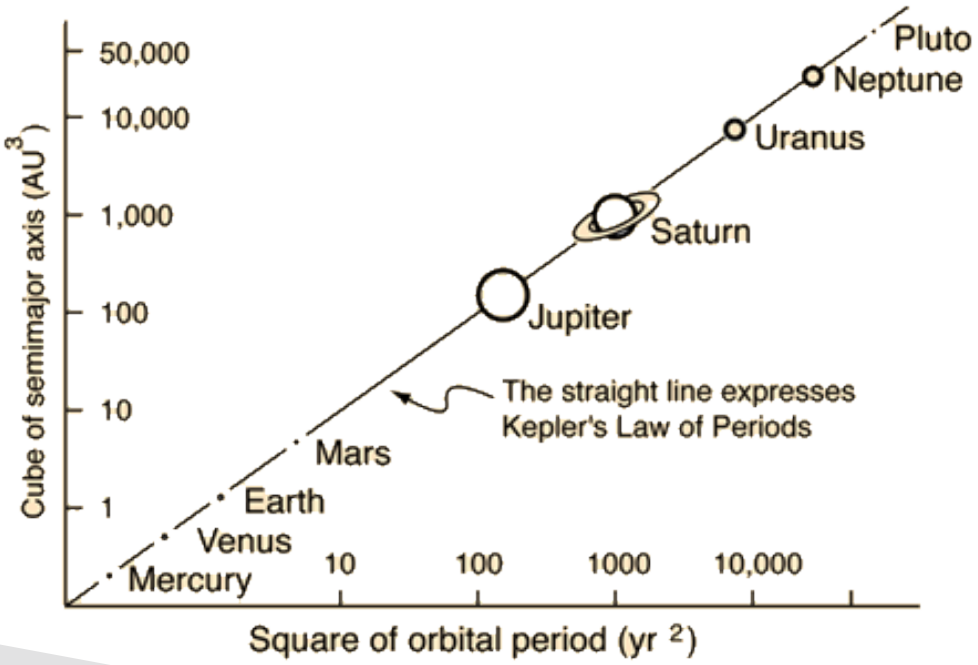
- 1st law – orbits of the planets are _____ with the Sun at one focus
- 2nd law – a planet moves _____ when it is closest to the Sun and slower when it is farther away
  - Angular momentum – a measure of the _____ of the body about some point
    - This remains constant for planets orbiting the sun and moons that orbit planets as long as nothing speeds them up or slows them down



Orbital Motion and Tides

Kepler's Laws Reexamined

- 3rd law – planet's orbital period depends on its _____ from the Sun
  - Relies on energy and the _____ of motion depends on how fast the planet moves
  - The gravitational attraction _____ depends on the size of orbit

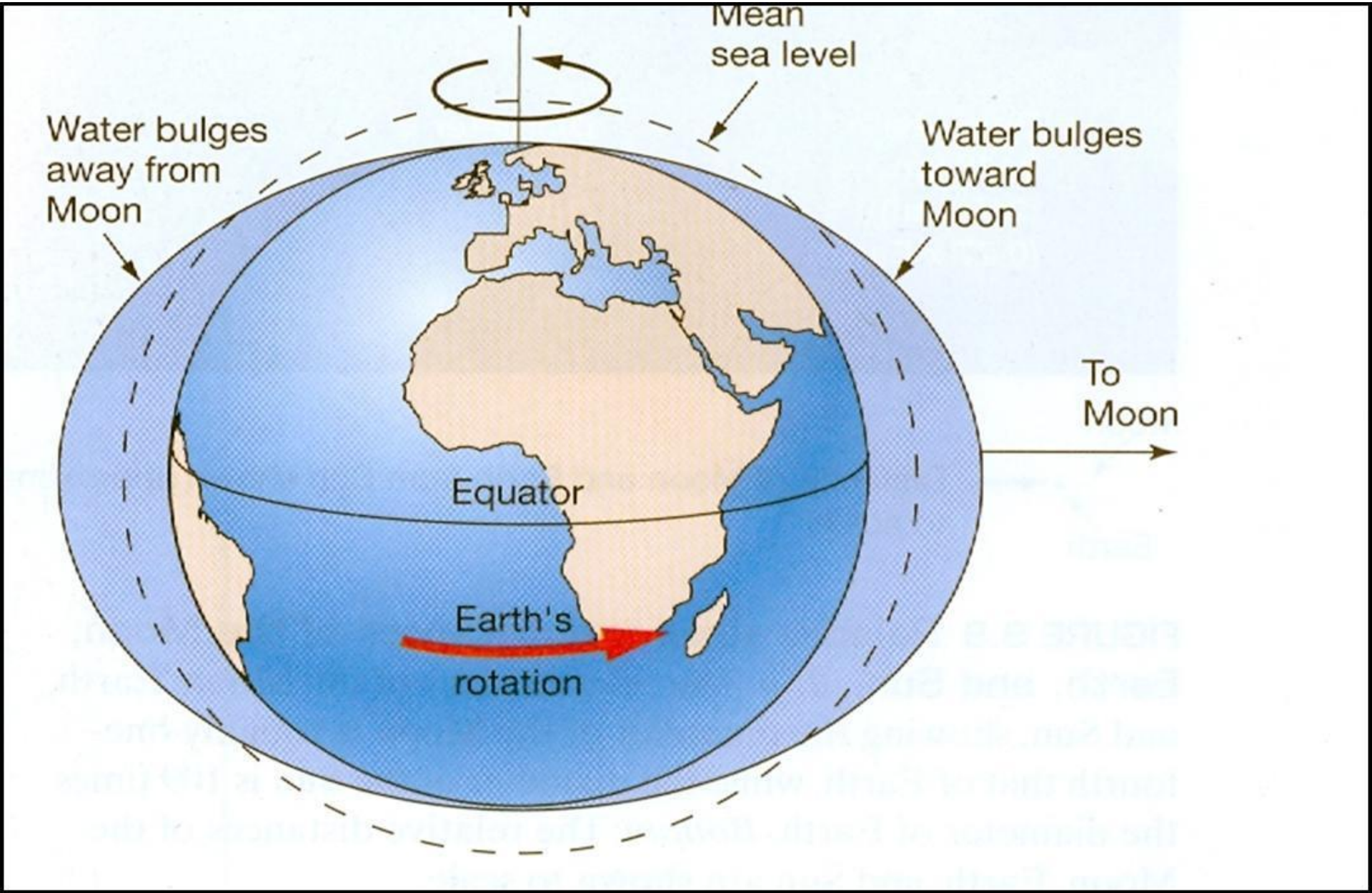


Orbital Motion and Tides

Tides and Tidal Forces

- Because gravity is _____ between the Earth and the Moon, the Moon's gravity can explain the ocean _____
- Tides are caused by small differences in gravitational forces
  - The pull on the side of the _____ facing the Moon causing the water to flow and bulge
  - The opposite happens on the other side of Earth at that time because it has the least _____

Orbital Motion and Tides



Orbital Motion and Tides

Tides and Tidal Forces

- Spring Tides – tides that are _____ high and exceptionally low due to a _____ Moon/new Moon and combination with the Sun's pull
  - Yes, the Sun pulls, too, it's just not as dramatic being that it's really far away
  - "Spring" isn't season related but rather the rapid _____ in the water
- Neap Tides – tides that are less _____ during _____ quarter Moons because of the 90 degree angle between the Sun and Moon
  - Sun cancels out some of the Moon's pull

Orbital Motion and Tides