07-03

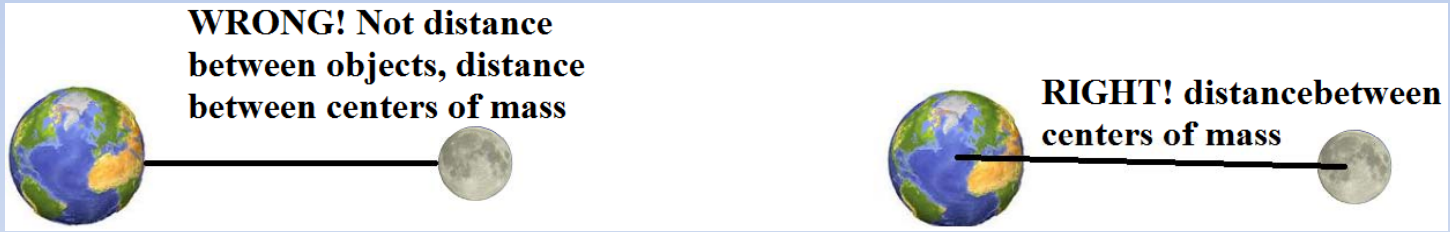
Circular Motion Gravitation, Orbits, Torque

Gravity

- Gravity is a field force
- Gravity: weakest fundamental force; only attractive force, no repulsive gravitational force (unlike magnets)
- Follows inverse square law
- $F_g = \dfrac{G\, m_1\, m_2}{r^2}$
- Other examples of inverse square law: Sound intensity, light intensity, electrical forces, magnetic forces
- Understanding inverse square law is important…practice it!
- I won't have you plug in numbers, but know relationships…examples on next page

Gravity – inverse square law
Looking for changes, not absolute numbers

- $F_g = \dfrac{G\, m_1\, m_2}{r^2}$
- r is distance between center of masses



- r or M: Use comparisons (ratios)
  - You: 4,000 mile from earth's center (r = 4000 mi)
  - Go 8,000 mile into space
  - You: 12,000 mi from earth's surface (3x farther away)
  - 3 x farther = 9x change in force (9x less!)

Gravity – inverse square law - examples

- $F_g = \dfrac{G\, m_1\, m_2}{r^2}$
- If the moon was twice farther away, what force would it feel? (4x less force)
- If the earth were three times more massive, how would that change the earth pulls on the earth with? (9x more force)
- The moon is 240,000 miles from the earth, how would the gravitational force change if its center of mass were only 60,000 miles from earth's? (16x more force)

Gravity – inverse square law - examples

- $F_g = \dfrac{G\, m_1\, m_2}{r^2}$
- The earth is 93,000,000 from the sun. How far from the sun would it have to be to have 100 times more gravitational force? (9,300,000 miles)
- Earth's radius is 4,000 mi. Many satellites are placed 22,000 miles from earth's surface. How much more/less is the gravitational force on this satellite compared to if it were on the surface? (6.5^2x less force, or 42x less force)

Gravity – orbit

- Rotate: circular motion on own axis (“spinning”)
- Revolve: circular motion about another object
- Space station: LEO (low earth orbit, a couple hundred miles from surface), takes 90 minutes per orbit
- Moon: 238,000 miles from earth, takes 27.3 days to orbit once (revolves around earth)
- Period of orbit depends on distance
  - Close satellites have short periods
  - Distant satellites have long periods
  - Special distance 22,300 mi. from earth’s surface
    - period = 24 hrs
    - Rotation of earth = 24 hrs
    - Satellite stays in SAME POINT IN SKY (point your satellite dish there!)
    - Geosynchronous orbit
    - In plane of equator, so always point satellite dishes south

Gravity – Why do astronauts feel weightless?

- Newton's 3rd law: Action-reaction pairs
- You feel normal force because ground STOPS you from accelerating
- Astronauts are in freefall
- No normal force = no weight

Figure 13
When this elevator accelerates, the normal force acting on the person changes. If the elevator were in free fall, the normal force would drop to zero and the person would experience a sensation of apparent weightlessness.

Torque

- Torque: quantity that gets things to rotate
- Door handle location, long wrench, “do not overtighten”
- Given greek symbol “tao”, τ
- $\tau = Fd \sin(\Theta)$
  - d is distance from axis of rotation
  - d sin(Θ) called “lever arm”
  - Lever arm is kind of a “useful distance”
  - Book calls it “perpendicular distance”
  - Example (which gets door moving?):
    - Stand square to a door and push
    - Push nearly parallel to a door
  - Units are Nm (Newtons x meters)
  - Yes, a Nm equals a Joule in work, but not here

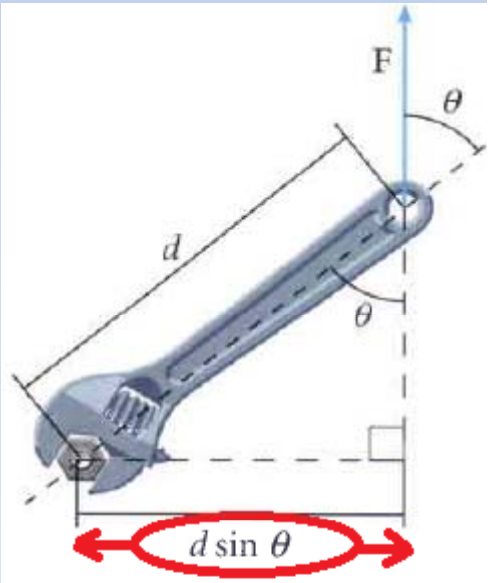


Figure 18
The direction of the lever arm is always perpendicular to the direction of the applied force.

Torque is a vector

- Torque has a direction and magnitude
- Finding direction:
  - Right hand rule:
    - Curl fingers so finger tips align with rotation direction
    - Thumb points to direction of torque
- If an object is not spinning, torques are balanced ($\sum\tau = 0$)
- Meaning: Same Nm trying to make

Object spin CCW as CW

- If $\sum\tau \neq 0$, rate of spin changing