Chapter 8

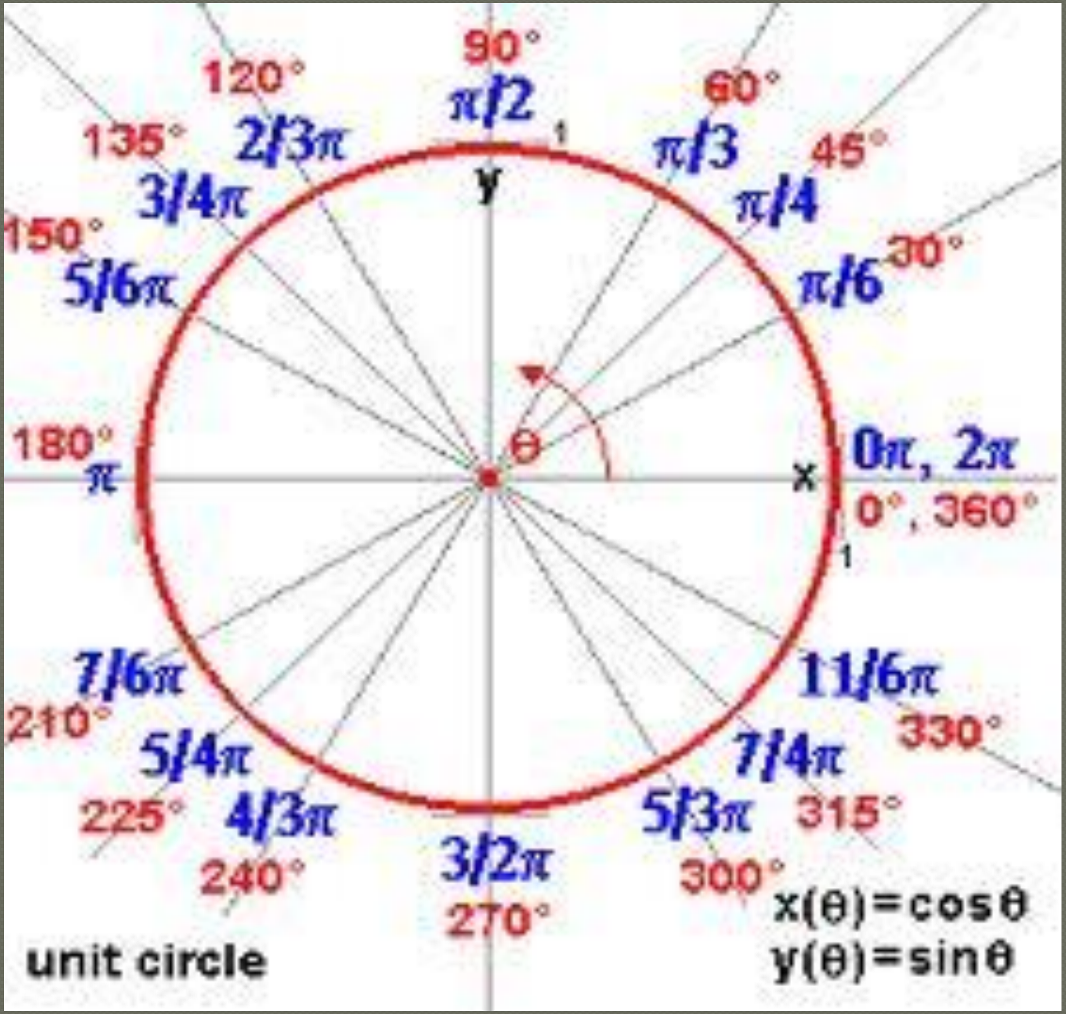
Rotational Motion

8.1
Describing Rotational Motion

Angular Displacement

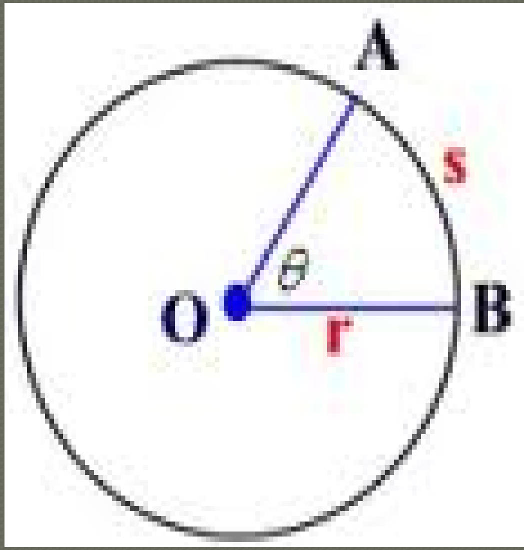
- As an object rotates, the ________________ is called ________________________.
  - Counterclockwise:
  - Clockwise:
- Angle can be measured in ____________ or ________________.
  - 1 Revolution =
  - KNOW HOW TO CONVERT BETWEEN THE THREE
  - EX:

EX: In 6 hours, Earth rotates through 90° or $\pi/2$ radians



Distance a Rotating Object Travels

- For rotation through an _______________, a point at a __________________ from the center moves through a distance of:
  - θ **needs to be in ______________**



Angular Velocity

- Angular velocity, ω, is equal to the ________________________________, divided by the ______________required to make the rotation.
- Units: rad/s
- Sign depends on direction

Angular and Linear Velocity

- In a ________________, all points ___________ at the ____________________.
- However, different points on the body may _________________ different linear distances, but still rotate through the _______________________.
- Meaning: Points on the same object can have the _______________________ but _________________________________.
- Given ω, to find linear velocity:

Angular Acceleration

- Angular acceleration, α, is equal to the ______________________________ divided by the _______________ to make that change.
- Units: rad/s^2
- Given angular acceleration, to find linear acceleration:

EX:

- A record player's needle is 6.5 cm from the center of a 45-rpm record. What is the velocity of the needle?

EX:

- The rotational velocity of a merry-go-round is increased at a constant rate from 1.5 rad/s to 3.5 rad/s in a time of 9.5 s. What is the rotational acceleration of the merry-go-round?

8.2
Rotational Dynamics

Rotation

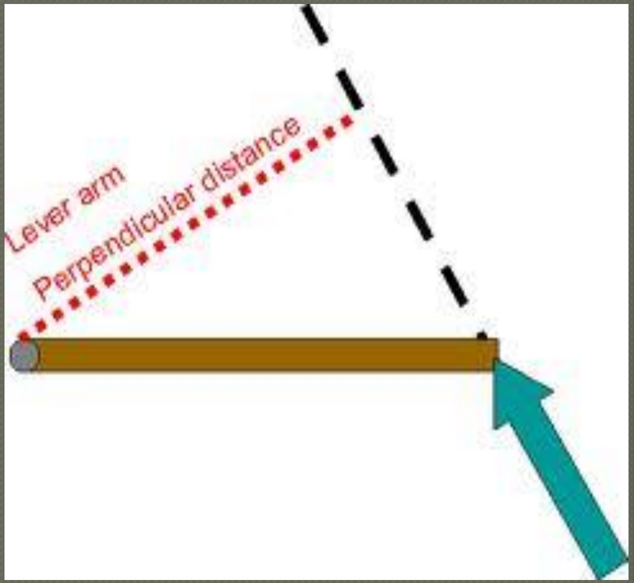
- Rotating an object depends on:
  - The ________________ of the _______________________
  - The _____________________ of the __________________ ____________________
  - The ___________________ of the _____________________
- EX: What is the easiest way to open a door?

Lever Arm

- Lever arm – the ______________________ from the _____________________ to the point where the ______________________.
    - EX: If you push a door at a right angle, the lever arm is the distance from the hinges to where you are pushing.
    - EX: If you rotate a pulley with a string, the lever arm is the radius of the pulley.

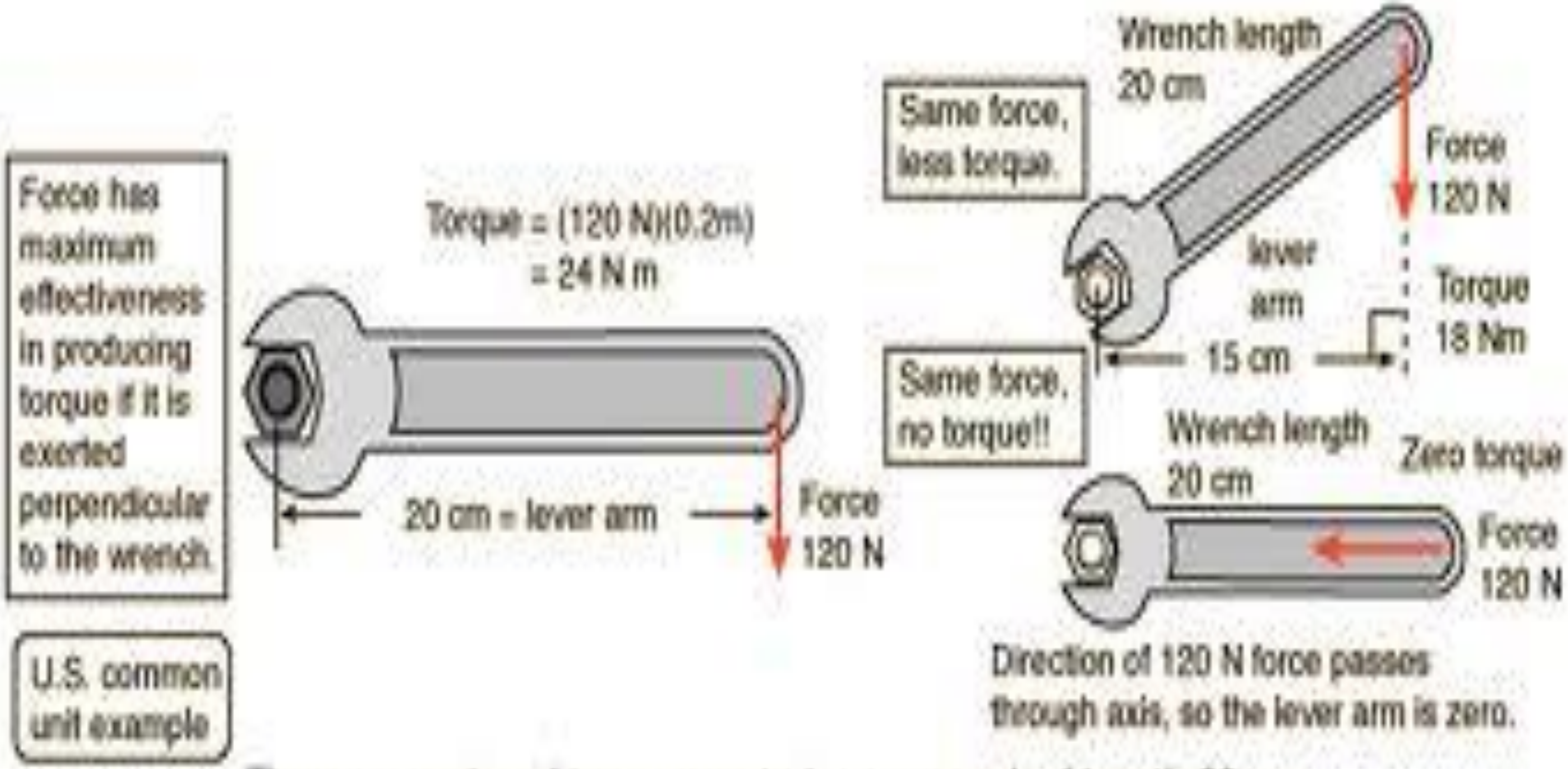
Lever Arm

- To find lever arm:
  - Extend the ____________________ until it forms a _________________ with a line from the center of rotation.
  - This distance is the lever arm.



    - L is the lever arm
    - r is the distance from the axis of rotation
    - θ is the angle between the force and r

Lever Arm



Three examples of torque exerted on a wrench of length 20 cm.

Torque

- Torque (τ) – a _______________ of how effectively a __________________________.
- Torque is the product of the force and the lever arm:

- Units = N·m

EX:

- A bolt on a car engine needs to be tightened with a torque of 35 Nm. You use a 25 cm long wrench and pull on the end of the wrench at an angle of 75° from the perpendicular. How long is the lever arm and how much force do you have to exert?

Net Torque

- Net torque – the ________ of _______________ being applied to an object.
  - Direction of Torque: The way the ____________ ______________________________________
- ____________ torques but _______________ ____________________ = NO rotation
- EX: Seesaw

EX:

- Cara (56 kg) and Ally (52 kg) want to balance on a seesaw. If Cara sits 1 m from the pivot point, where should All sit?

Moment of Inertia

- In order to rotate an object, both the _________ and the __________________________ are important.
- Moment of Inertia – the _______________ to _____________________.
  - For a Point Mass:
- Units: $kg \cdot m^2$

Moment of Inertia

- Objects that have their mass distributed ____________________ from the axis of rotation will have a ____________________ moment of inertia.
  - Meaning __________________________________.
  - EX:

EX:

- A simplified model of a twirling baton is a thin rod with two round objects at each end. The length of the baton is 0.65 m, and the mass of each object is 0.30 kg. Find the moment of inertia of the baton if it is rotated about its midpoint. Then find the moment of inertia if it is rotated around one end. Which is greater? Neglect the mass of the rod.

Newton's 2nd Law for Rotational Motion

- Remember: F=ma
- For Rotational Motion:
- Angular Acceleration is directly proportional to the _________________ and inversely proportional to the ____________________________________.

EX:

- A solid steel wheel has a mass of 15 kg and a diameter of 0.44 m. It starts at rest. You want to make it rotate at 8 rev/s in 15 s.
  - What torque must be applied to the wheel?
  - If you apply the torque by wrapping a strap around the outside of the wheel, how much force should you exert on the strap?

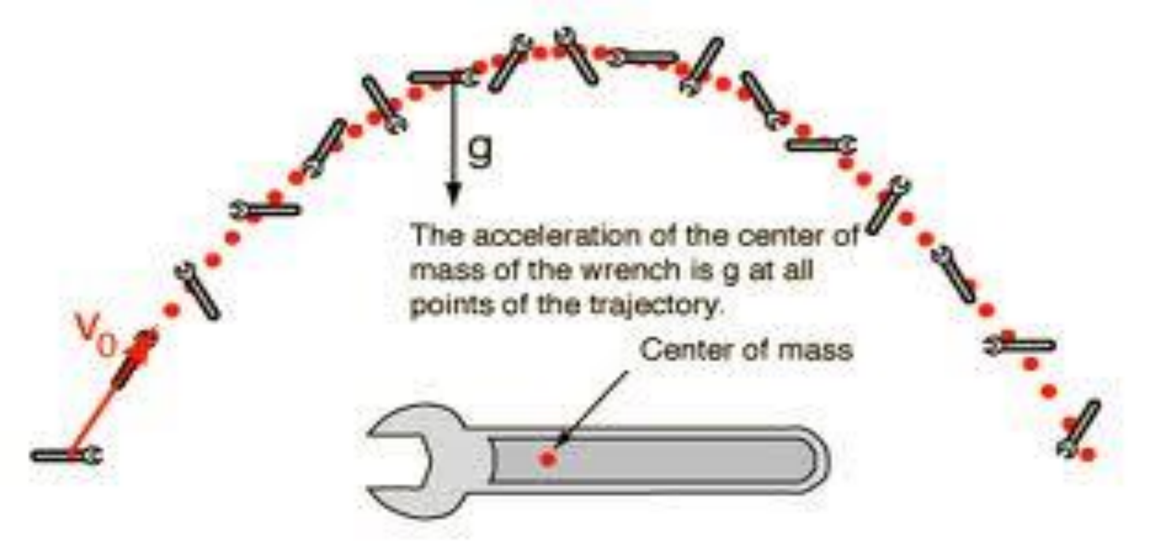
8.3
Equilibrium

Center of Mass

- Center of Mass – the ____________________ that moves in the same way that a ________ __________________ would move.

Center of Mass

- All freely ____________________ will ________ about an axis that goes through their ______________________________.
- http://www.youtube.com/watch?v=ksGsBAWoXMw

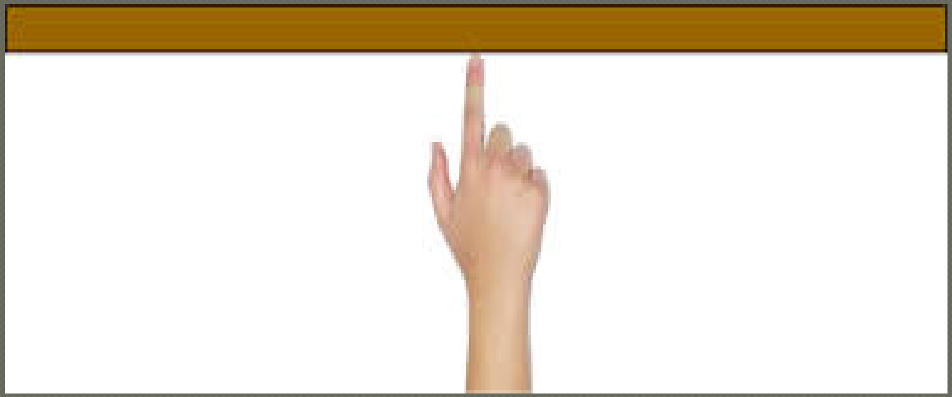


Center of Mass

- The ________________ of an objects acts at its _________________
- When an object is _________________ at its _________________, there is _____________ _____________ acting on it.

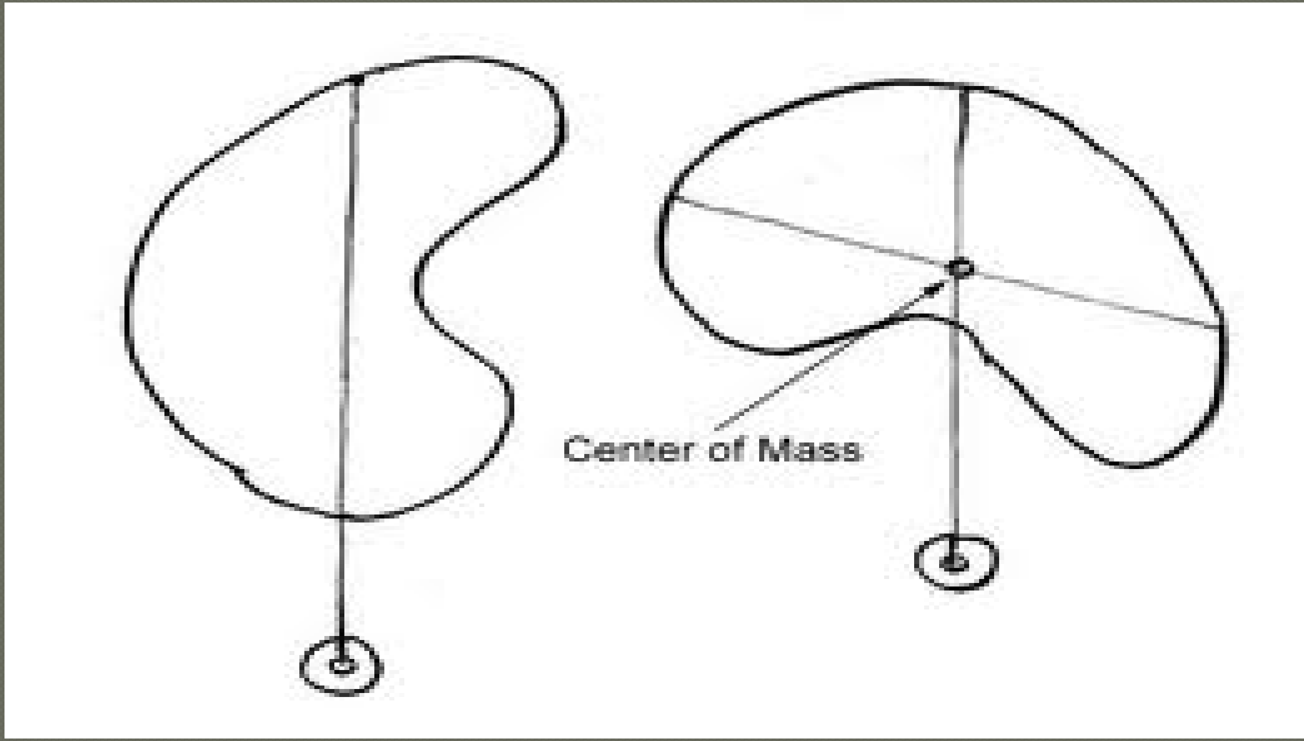
- If the center of mass is ______________________ ______________________, it is the ___________________ ___________________of the object.

- EX: The middle of a meter stick.



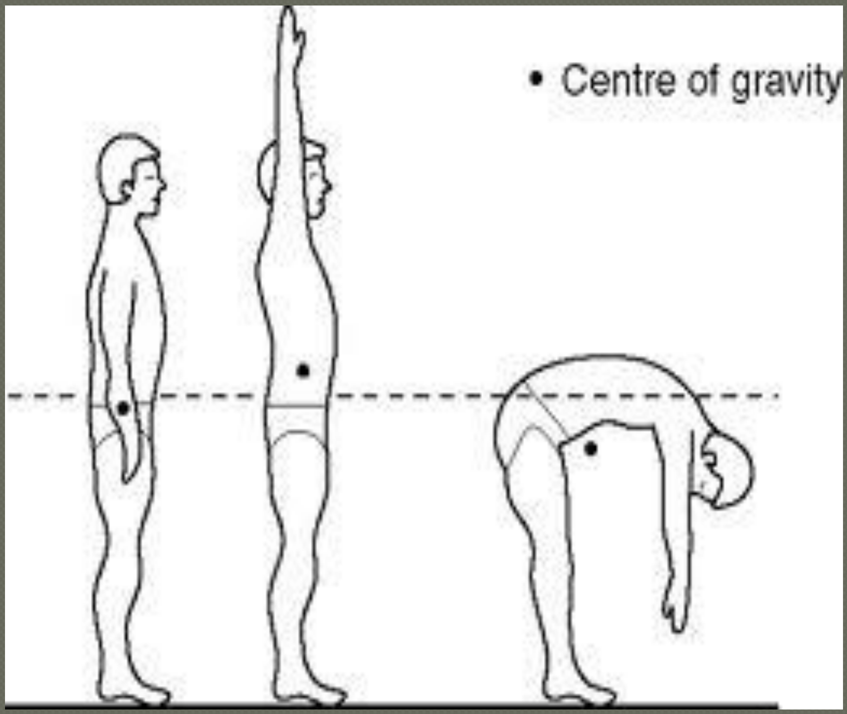
To Find the Center of Mass:

http://www.technologystudent.com/forcmom/cengrav1.html



Center of Mass

- The center of mass for a person standing with arms down is a few centimeters below the naval.
- However, the center of mass of a person is not fixed.



Center of Mass and Stability

- Most objects have a ____________________ due to their ______________________________.
- Meaning:
  - If an object is rotated/tilted through a certain angle the torque due to its weight will bring it back to its natural position without causing it to tip over.
  - In order to ______________ a stable object, the force applied must rotate it so that the object's ____.

- An object is ______________ if an external ___________________ is required to __________.
- Stable objects:
  - Have a ______________________________
  - Have a ______________________________
  - Because:
  - They require a ________________________ for the _______________________ to go _______________ __________________________
  - EX: A racecar is more stable than an SUV

Static Equilibrium

- An object is in static equilibrium if both its ___________________ and ______________ ______________ are ___________________________.
- For this to happen:
  - It must be in **translational equilibrium**:
  - It must be in **rotational equilibrium**:

EX:

- A 5.8 kg ladder, 1.8 m long, rests on two sawhorses. Sawhorse A is 0.6 m from one end of the ladder, and sawhorse B is 0.15 m from the other end of the ladder. What force does each sawhorse exert on the ladder?