Andover Robotics Team Training Series

II. Physics and Robotics

Robot Physics: Part 1

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Team 115

(some of the following slides are from their original presentation)

Topics:

- Velocity
- Acceleration
- Force
- Friction/Traction
- Work
- Power
- Torque
- Center of Gravity
- Potential and Kinetic Energy
- Mechanical Advantage
- Sports and Physics

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Velocity

- Velocity is how fast an object is moving (in a certain direction)
  - Speed is just how fast an object is moving
- **Average Velocity = $\frac{\Delta \text{ Distance}}{\text{Time}}$**

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Acceleration

- Acceleration is the change in velocity over time (in a certain direction)
- **Average Acceleration = $\frac{\Delta \text{ Velocity}}{\text{Time}}$**
  - Gravitational Acceleration = 32.19ft/s^2
  - If at 12:00PM you are traveling North in a car at 50mph and at 12:01PM you are still traveling North, but this time at 70mph then what is your acceleration?

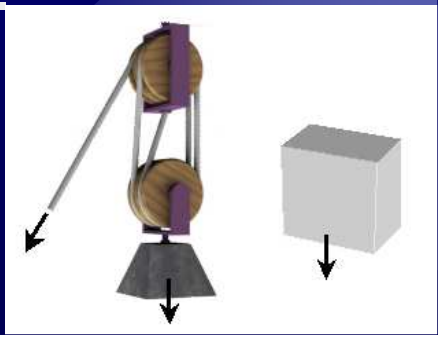
$$\text{Average acceleration} = \frac{V_{final} - V_{initial}}{\text{Time}} = \frac{70\text{m/h} - 50\text{m/h}}{1/60\text{ h}}$$

$$\text{Average acceleration} = 1200\text{mile/h}^2$$

*Note: The reason hours is in the denominator and not minutes is keep the **units consistent**. In maintaining consistency of unit, minutes **must be converted to hours**

Force

- A force is a push or a pull on an object that can cause it to move, bend or break. It has both magnitude and direction.
- Examples of forces are weight, friction, impact and centrifugal forces.
- The unit of force is Newton (N) and pound (lbf)
- Discuss the concept of point forces.
  - Force = Mass x Acceleration



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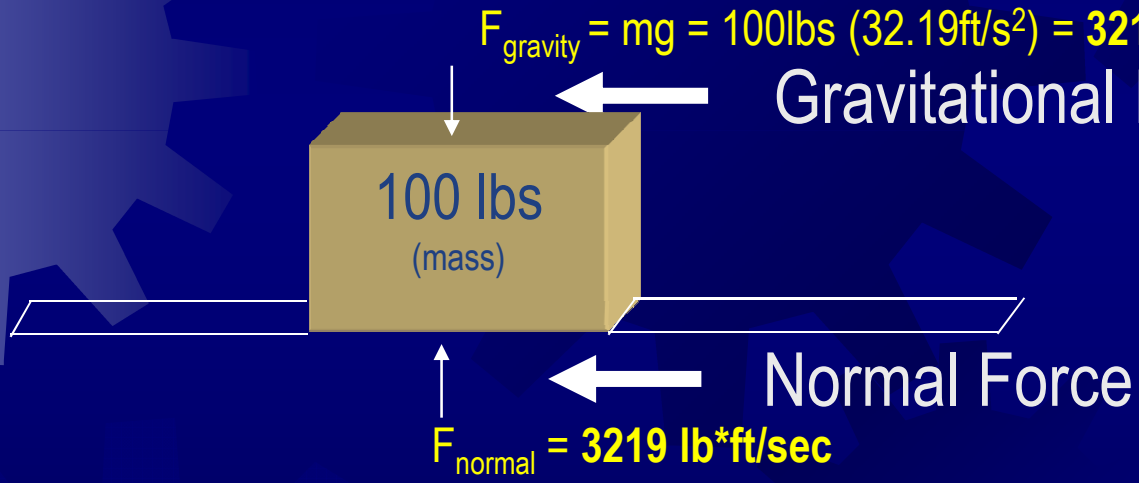
Types of Forces

Normal Force: a force exerted by one object on another in a direction perpendicular to the surface of contact .



Gravitational Force: a force exerted by the earth on an object, which is equal to mass times gravitational acceleration.

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Friction Force and Traction

- Traction is the amount of force an object can transmit to a surface, the force before the wheels slip.
- **Friction Force = μ X Normal Force**
- Normal Force (F_n): weight of object (unless on a sloped surface)
- Coefficient of Friction (μ): how much 2 surfaces resist sliding. (μ is pronounced *mu*)

Types of Forces

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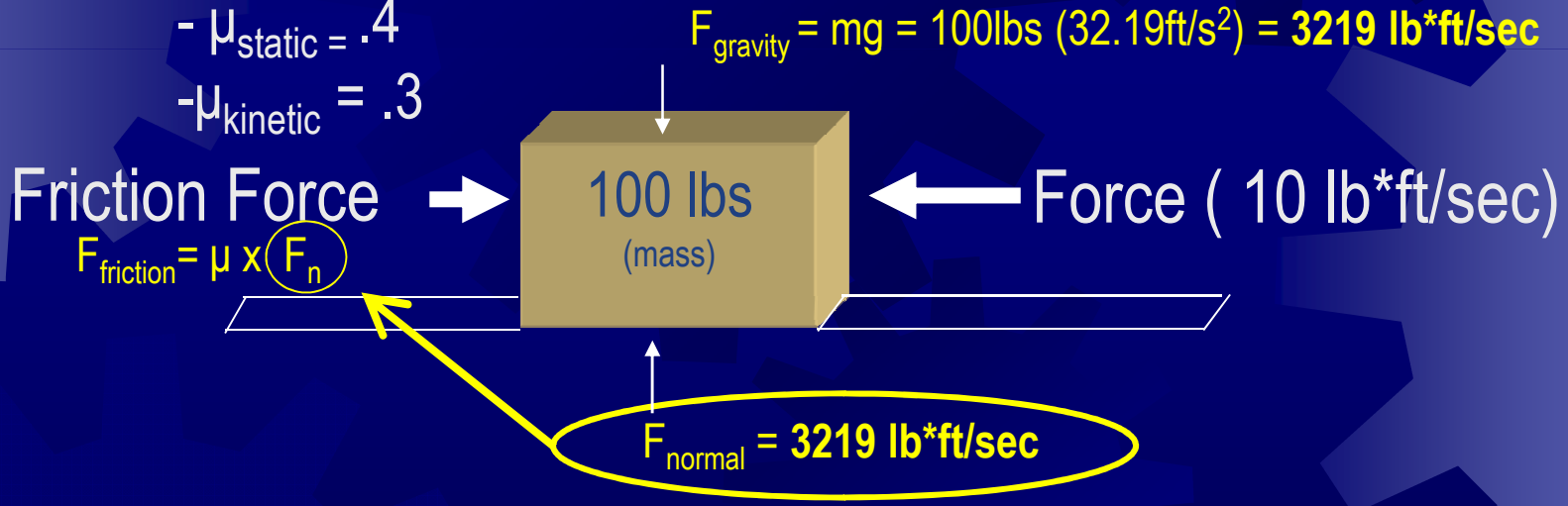
Frictional Force: a resistive force that opposes the relative motion of two contacting surfaces (that are either moving past each other, or at rest with respect to each other)

-Friction Force = Friction Coefficient x Normal Force

$F = \mu \times F_N$

- $\mu_{static} = .4$
- $\mu_{kinetic} = .3$



***Note: Friction force is independent of the amount of surface area.**

- it depends on Coefficient of Friction (μ) and Normal Force

- Simplifies to: → it depends on the type of Surface and Mass of object

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Friction Example

- You push a box across a carpet floor. If the box weighs 20 kg and the force required to push is 10 N, what is the friction coefficient?

$$\text{Force} = \mu \times \text{weight}$$

$$10\ \text{N} = \mu \times 20\ \text{kg}$$

$$\mu = .5$$

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Work

- Work = Force X Distance
- Example:

  A box weighs 130 lbs and must be moved 10 ft. The coefficient of friction between the floor and the box is .5 .

  How much work must be done??

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Work

Force = μ X weight = .5*130

Force = 65 lbs

so…

Work = Force * Distance

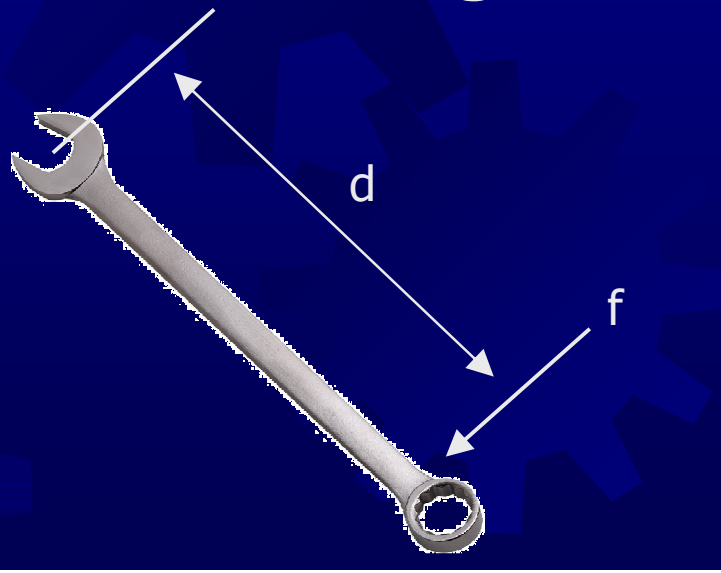
Work = 65 * 10 = 650 ft lbs

Power

- Power is the rate at which work is done
- **Mechanical Power = Speed X Force**
  - Power = Work / Time
    = Force x Distance / Time
    = Force x Velocity

Torque

- **Torque is a measure of rotational force on an object. It can be thought of as a twist. The magnitude of a torque is defined as the product of a force “f” and the length of the lever arm “d”.**



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Torque vs. Speed

- **Power = Torque X Angular Velocity**
- Torque is a force (rotational force)
- Angular Velocity is rotational speed
- There is only a certain amount of power available.
- This means:
  - If there is lots of Torque (strong), it has lower velocity (slow)
  - If it has high velocity(really fast), it has less Torque (weak)
  - Try and have a good balance of speed and torque

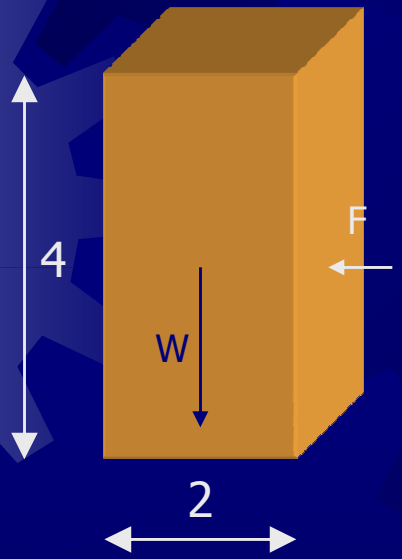
Center of Gravity

- **The center of gravity of a system of particles is a specific point at which the system's mass behaves as if it were concentrated at that point.**
- **It is the point in any object about which it is in perfect balance.**
  - Example 1: high jumper using the Fosbury flop to clear the bar without the c.g. clearing it.

Center of Gravity

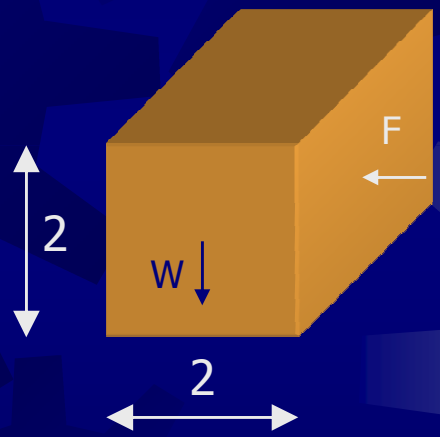
- Example 2: Which object is more stable?

Weight = 100 lb



$W \times d_1 = F \times d_2$
$100 \times 1 = F \times 2$
$F = 50$ lb

Weight = 100 lb

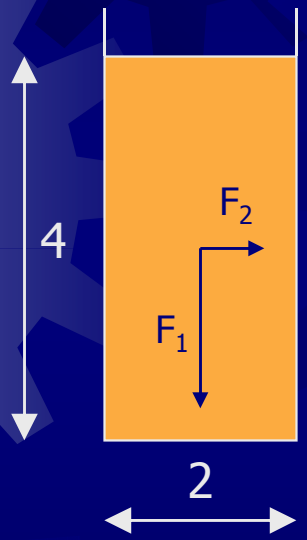


$100 \times 1 = F \times 1$
$F = 100$ lb

Center of Gravity

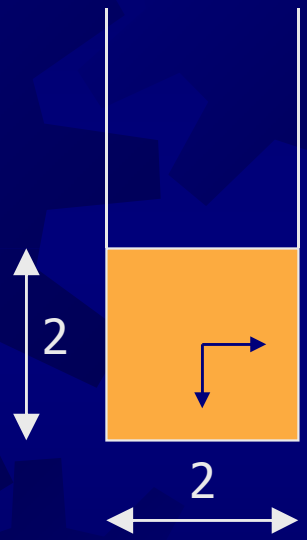
- Example 3: How easy does a cup tip over?

Mass = 10



$F_1 \times d_1 = F_2 \times d_2$
$10g \times 1 = 10a \times 2$
$a = 0.5g$

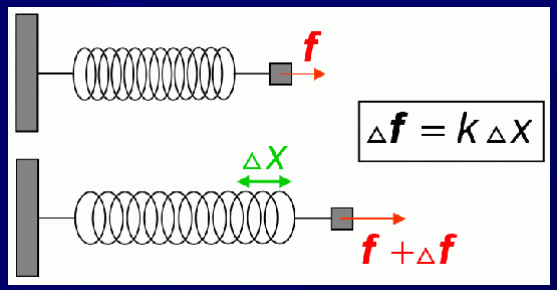
Mass = 5



$5g \times 1 = 5a \times 1$
$a = 1g$

Potential Energy

- **Potential energy can be thought of as energy stored within a physical system. It is called potential energy because it has the potential to be converted into other forms of energy, such as kinetic energy, and to do work in the process.**
  - Example: stretch a spring, lift an object.



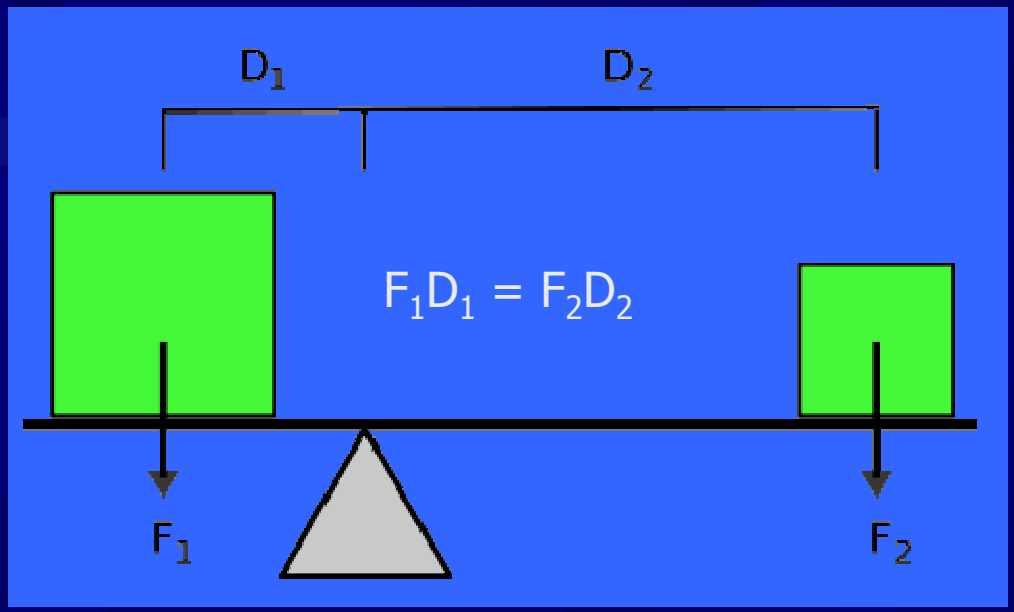
Kinetic Energy

- **The kinetic energy of an object is the extra energy which it possesses due to its motion.**
  - It is calculated using the formula $E_k = \frac{1}{2}mv^2$

where m is mass, v is velocity

Mechanical Advantage

- A lever is one of the six classical simple machines.



Power = Force x Velocity

Sports and Physics

- Body Motions
  - Throwing
  - Kicking
  - Pushing
  - Pulling