NYU TANDON SCHOOL OF ENGINEERING

NSF

Promoting robotic design and entrepreneurship experiences among students and teachers

Lesson 3: Basic Concepts of Physics Study of Robot Chassis And Construction

Innovative Technology Experiences for Students and Teachers (ITEST), Professional Development Program, July 2017-19

Mechatronics, Controls, and Robotics Laboratory, Department of Mechanical and Aerospace Engineering, NYU Tandon School of Engineering

CONTENTS

- Basic concepts of physics required for robots
- Structural design concepts
- Design tradeoffs

- **TASK/ACTIVITY**: Assembly and construction of VEX EDR robot chassis

FORCE

- The **push** or **pull** of an object is called force

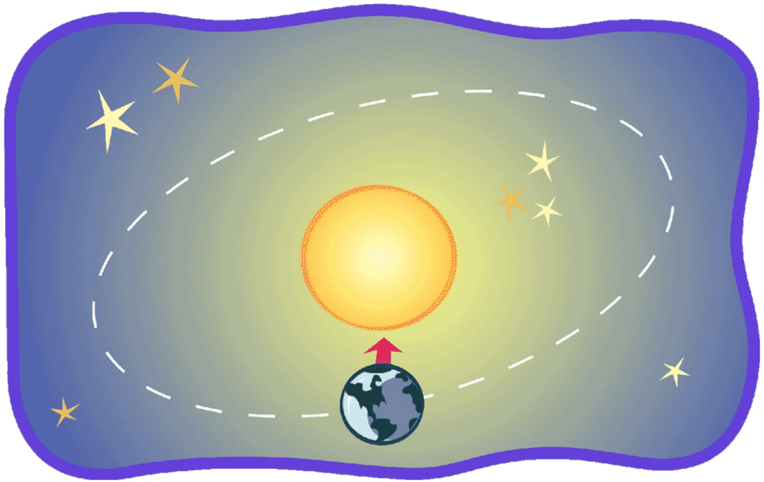
Examples:

Pushing a Car

Pulling a truck

GRAVITY

- Gravity is a **natural force** by which all objects are **attracted** to one another
- On **Earth**: It is the **force** that pulls all the objects towards its **center**



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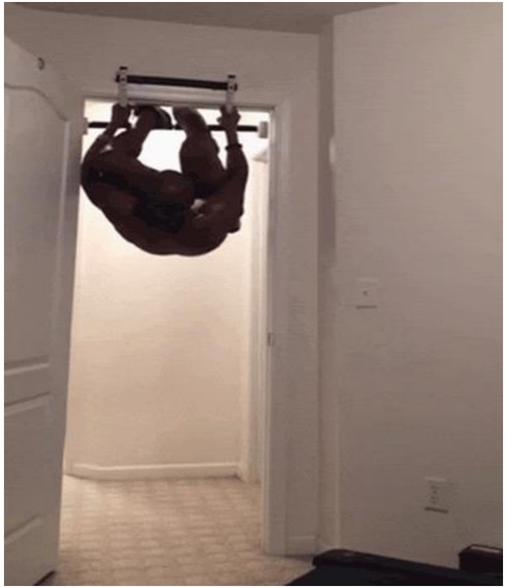

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LAWS OF MOTION

First law of motion

Every object in a **state of rest or uniform motion** tends to remain in that state unless an **external force** is applied to it

When air is blown, the ball changes from rest to motion and continues in its motion

The ball continues to be in motion until stopped

Source

LAWS OF MOTION

Second law of motion

The **sum of the forces** on an object is equal to the **mass** of that object multiplied by the **acceleration** of the object, i.e., $\Sigma F = ma$

Source

- The lighter objects tend to move faster than the heavier objects in response to the same amount of force

LAWS OF MOTION

Third law of motion

For every **action**, there is an equal and opposite **reaction**

Source

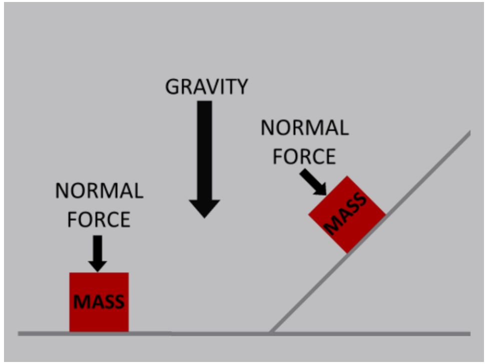
Recoiling of a Cannon

FORCES ACTING ON ROBOTS

Important forces for robotics:

- Weight
- Frictional force
- Momentum
- Centripetal force
- Normal reaction

Robot carrying payload



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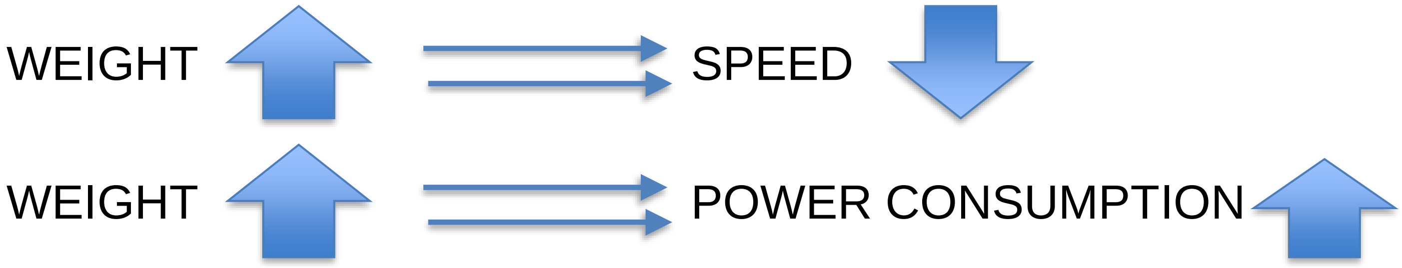
WEIGHT

The weight of an object is related to the amount of force acting on the object due to gravity, i.e., W=mg



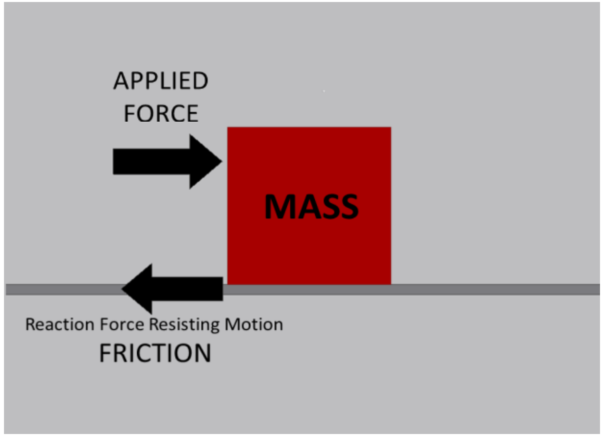
As the weight of the robot increases, the slower it will move (under same input condition)

or

The power consumption will be more (it will draw more current)

FRICTION

- Friction is a force that happens when two things rub together, like wheels and the floor
- It opposes the motion and makes things slow down



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ACTIVITY - 1

- Is it an advantage to have friction or not?
- Why is it advantageous?
- Why is it not advantageous?

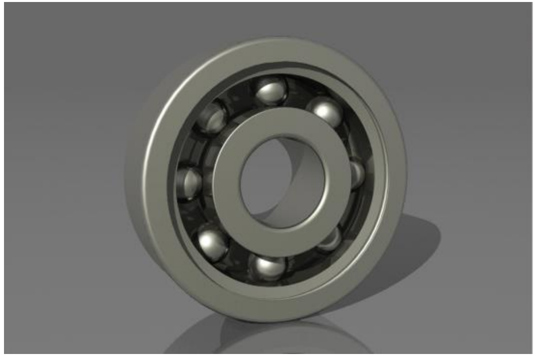
ACTIVITY - 1

- List down where friction could be an advantage

ACTIVITY – 1 SOLUTION

- Is it an advantage to have friction or not?
- List down where friction could be an advantage?

Brake System

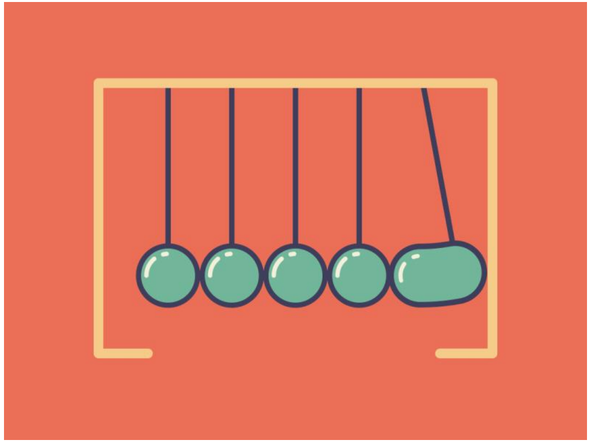


Ball Bearing

Tires and roads

MOMENTUM

Momentum is a measure of inertia in motion, alternatively, it is also the rate of change of force that an object experiences while in motion, i.e., P = mv



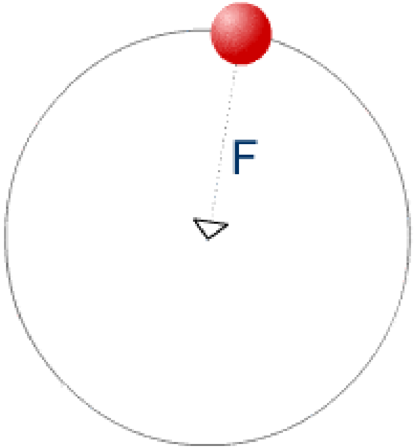
[Newton's cradle](#)

[Collision](#)

If something has a lot of mass — like an elephant — it is hard to get it moving, but once it moves, it is even harder to slow it down, or steer

CENTRIPETAL FORCE

Centripetal force is the force that acts on a body moving in a circular path and is directed toward the center around which the body is moving



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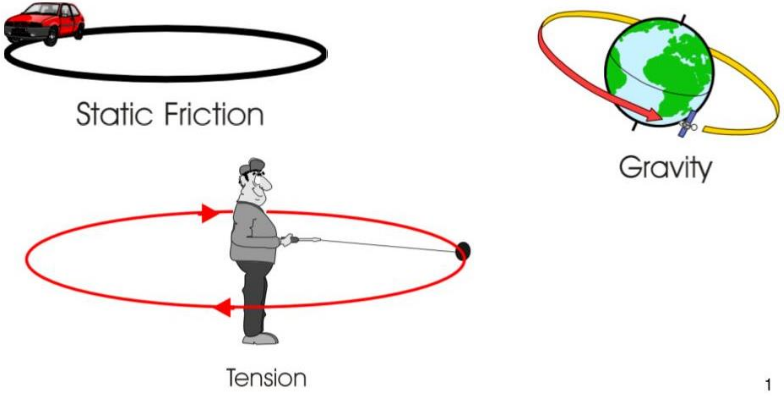

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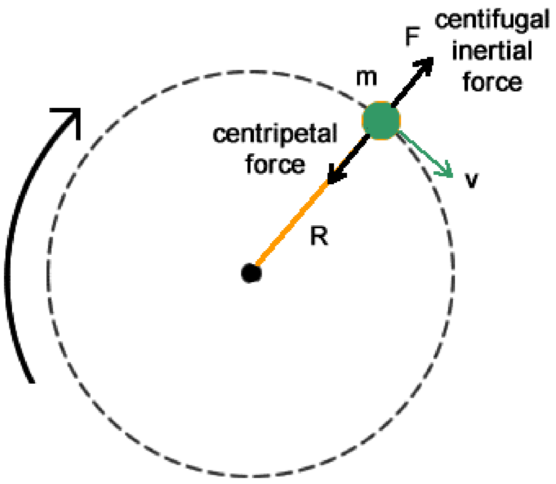
CENTRIFUGAL FORCE

The apparent force that is felt by an object moving in a curved path that acts outwardly away from the center of rotation



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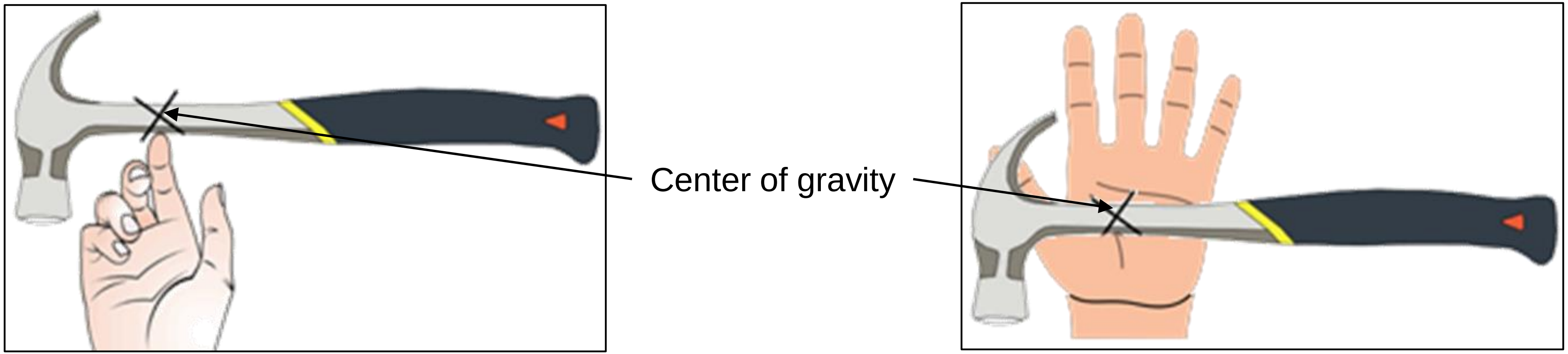
CENTER OF GRAVITY

- The center of gravity is the average location of the weight of an object



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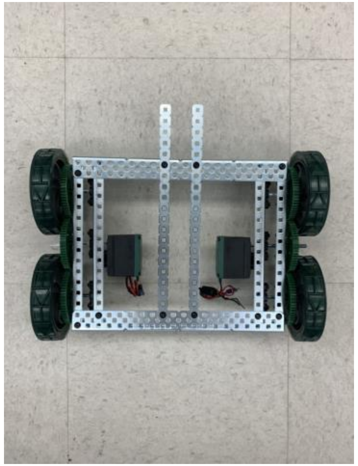
- The larger the contact surface area, the more stable the object

ACTIVITY - 2

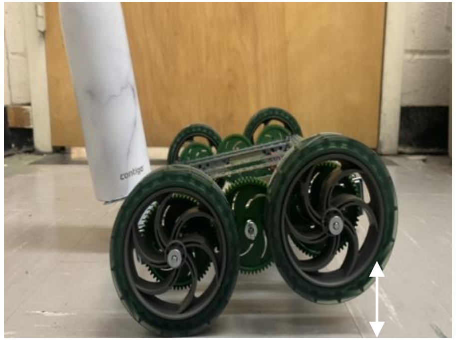
- Balance robot by placing mass at different positions



Robot Chassis

Stable

Stable

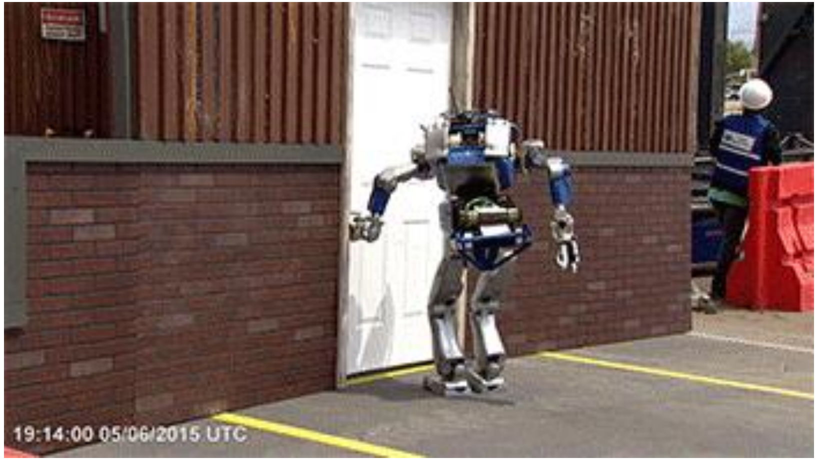


Unstable

As the center of gravity shifts outside the frame of balance, the robot becomes unstable

STABILITY

The state of being firm and secure



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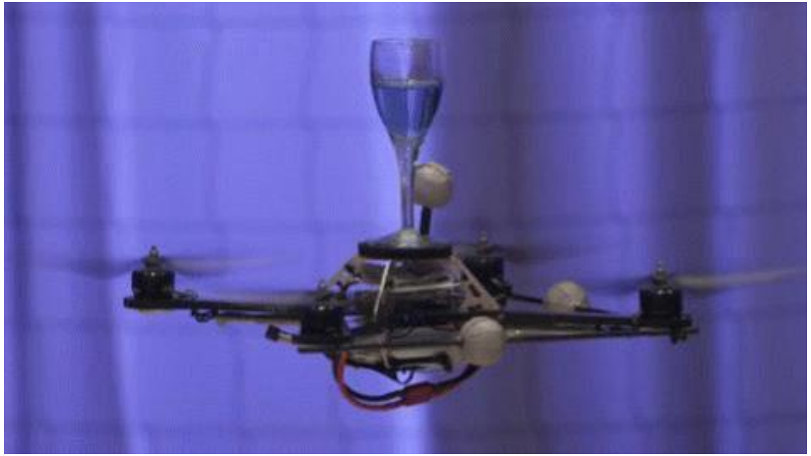
STABILITY

The state of being firm and secure



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STABILITY

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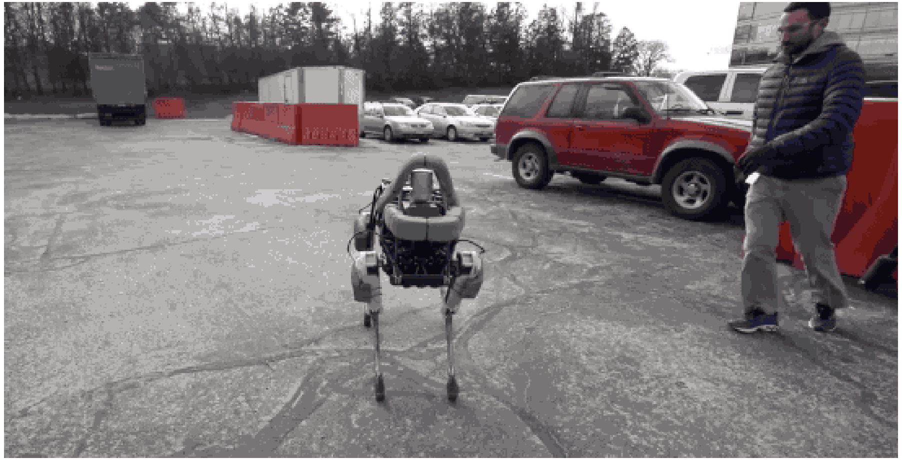

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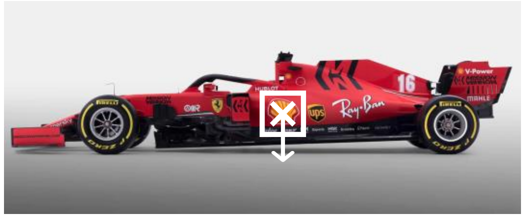
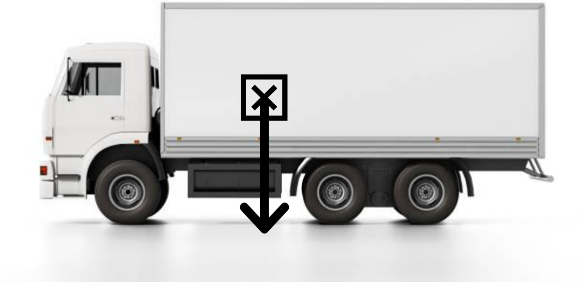
STABILITY AND CENTER OF GRAVITY

The **lower** the center of gravity (CG) the **more stable** it will be



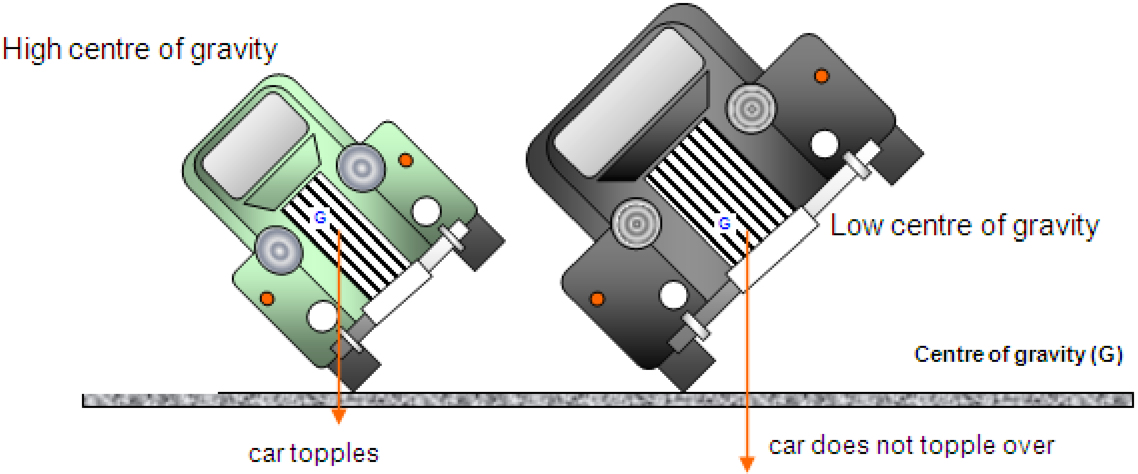
Lower CG - High Stability



Higher CG - Low Stability

STABILITY AND CENTER OF GRAVITY

The **lower** the center of gravity (CG) the **more stable** it will be



Car A

Car B

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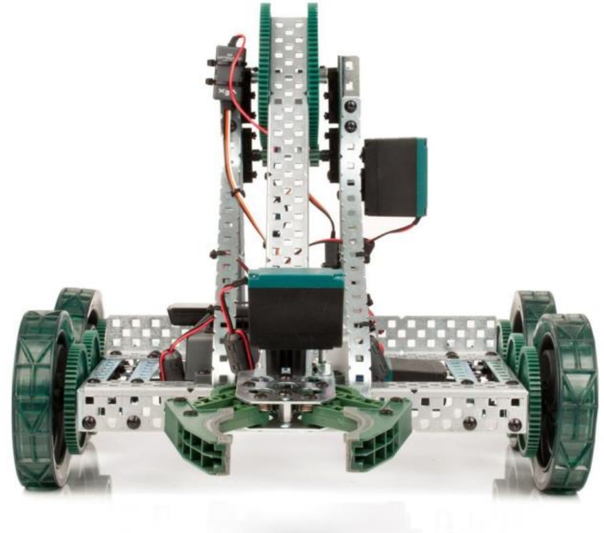
STABILITY AND CENTER OF GRAVITY

The LARGER the area of the **base of support,** the MORE STABLE it will be

F-1 Car



A wide **base of support**, makes this Robot stable.

STABILITY IN CAR

Rigid bodies with a wide base and low center of gravity is more stable and less likely to tip over.

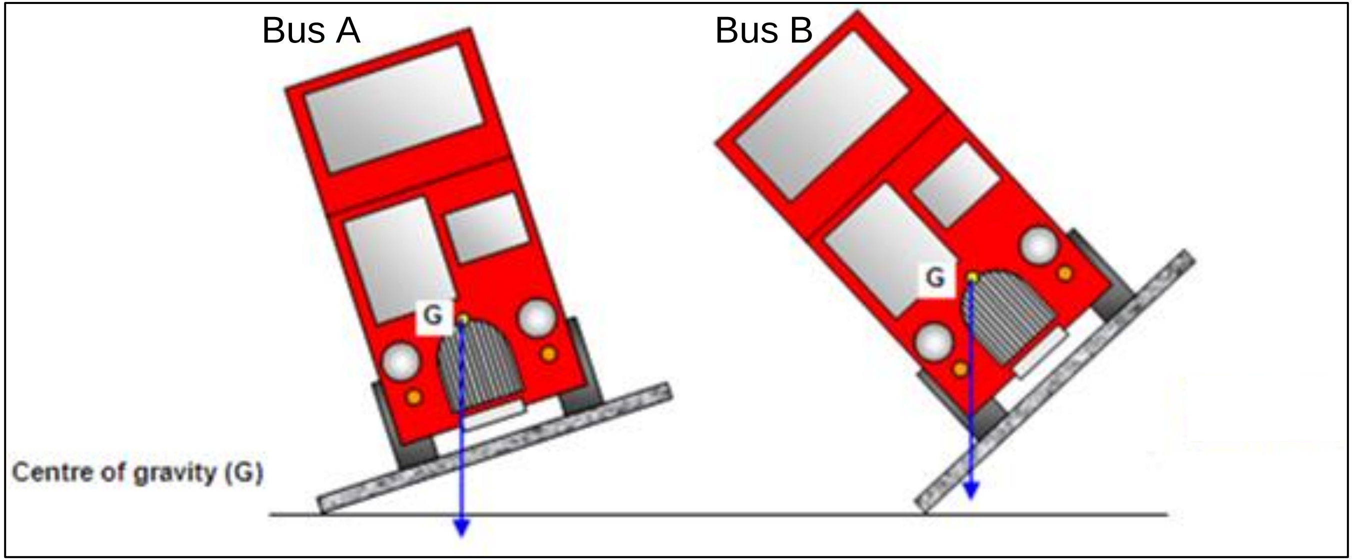
Example: a high-speed racing car

Roll test of a car

Source

ACTIVITY - 3

In which case the bus topples over? And why?



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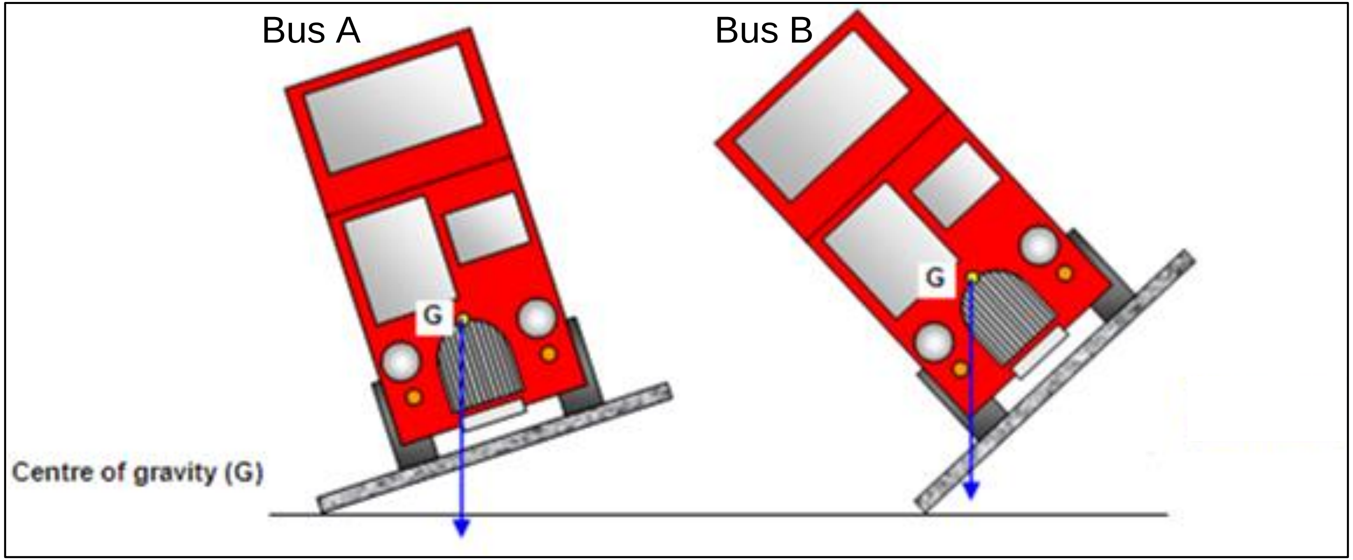
ACTIVITY - 3 SOLUTION

In which case the bus topples over? And why?



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The **closer** your center of gravity is to the center of your base of support, the **more stable** you are

MOBILE ROBOTS

Main feature

The mobile base allows the robot to move freely in the environment

Types

- Wheeled mobile robots

Entertainment Robot

4 Wheeled Robot

- Legged mobile robots

Asimo

Octopod

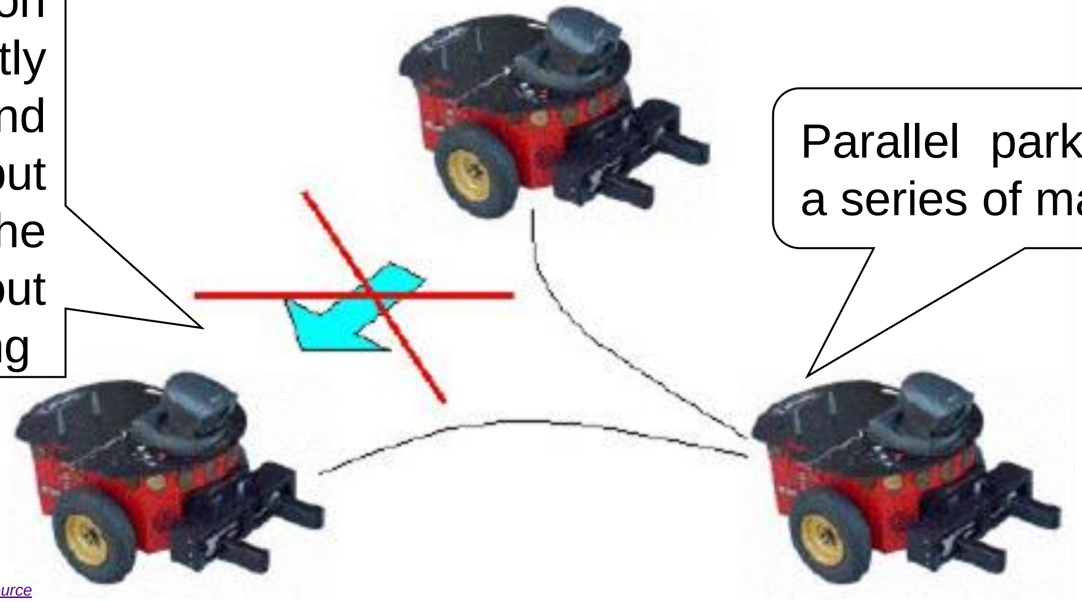
WHEELED MOBILE ROBOTS

- **Locomotion:** The process of causing a robot to **move**
- **Dynamics:** Study of motion in which the **forces** are modeled
- **Kinematics:** Study of mathematics of motion **without considering the forces** that affect the motion

WHEELED MOBILE ROBOTS

Major constraints

The most common robots can instantly move forward and backward but cannot move to the right or left without the wheels slipping



Parallel parking requires a series of maneuvers

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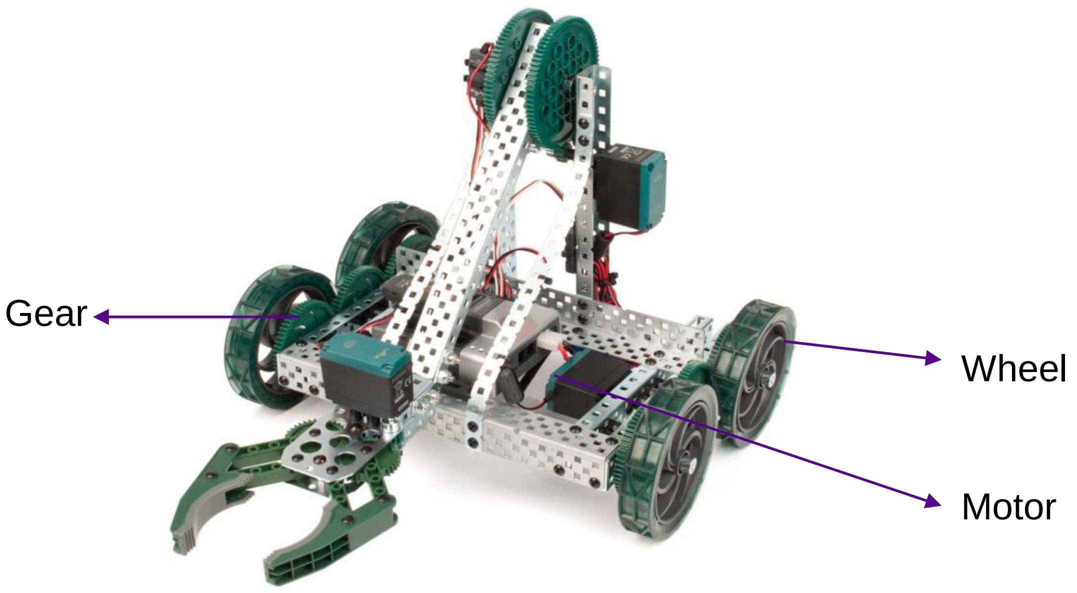
BASE OF ROBOT

- Chassis
  - Structure
  - Geometry
  - Material

- Drivetrain
  - Motors
  - Gears
  - Wheels



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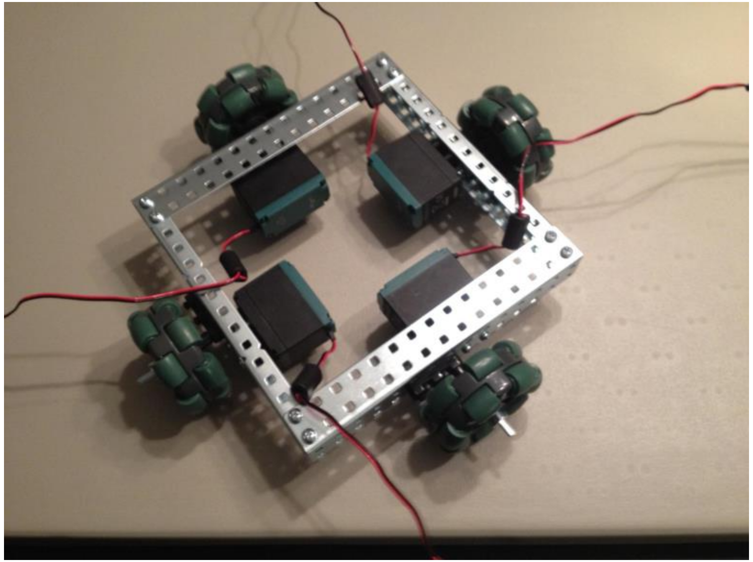
BUILDING A CHASSIS

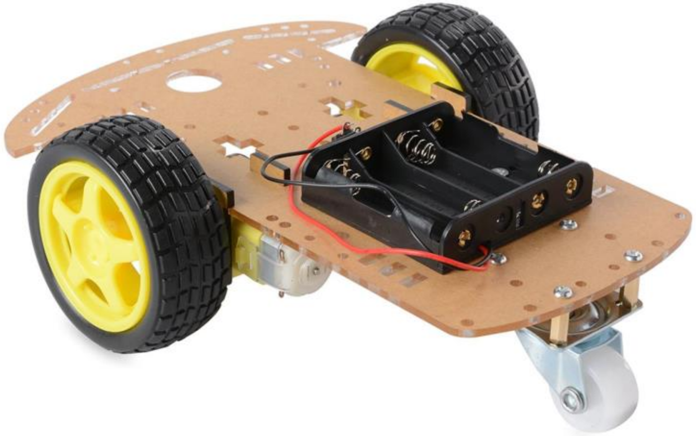
<u>Design tradeoffs</u>

- Stable vs. maneuverable
- Accessible vs. compact
- Strong and rigid vs. light
- Affordable vs. expensive



BUILDING A CHASSIS

The most common robot chassis are 3-wheeled and 4-wheeled as shown



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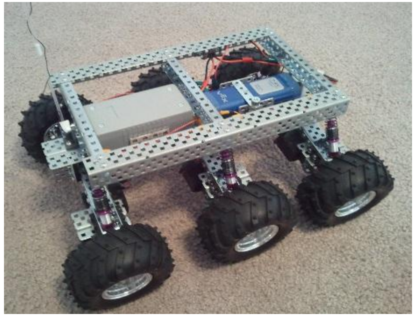
BUILDING A CHASSIS

- **Short and wide robots** turn easily and have lots of control but will tend to **not drive straight**
- **Long and narrow robots** will not turn easily and will have poor turning control but will tend to **drive very straight**
- Depending on the **task**, one should balance the two



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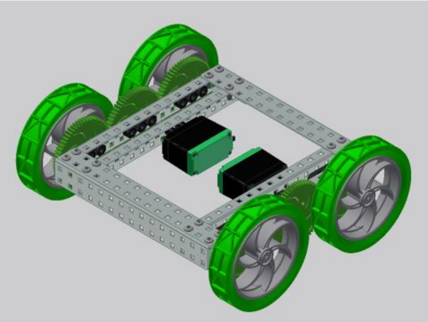

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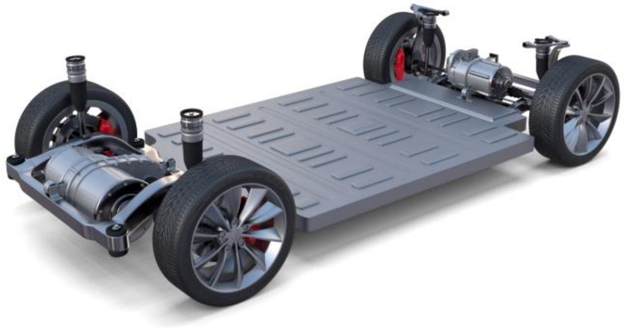
CHASSIS FUNCTION

- Provide a platform for everything
  - Strong
  - Stable
  - Well laid out and accessible
  - Light
- Resist and defend against shock



Chassis of Tesla-S

SUMMARY

- Thus, we must **design the chassis** keeping in mind the purpose of the robot
- The **greater the weight** of the robot, the **slower it will move**, or the **power consumption** will be **more**
- The **greater the weight**, the **more current** it will draw
- The **greater the weight**, the **more difficult** it will be to **maneuver**
- Again, if the chassis is made **light**, it may break easily
- If the chassis is light, the **manipulator** and other **components** will also need to be light

Task / Activity:
Assembly and construction of VEX EDR Robot chassis

Document

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Thank You!

Questions and Feedback?