Cornerstone Electronics Technology and Robotics Week 23
Wheels and Differential Drive

- Administration:
    - Prayer
    - Turn in quiz
    - Review voltage regulator circuit to convert +9 V to +5 V.
- Building Robots for Beginners, Chapter 19, **Wheels**
    - Types of wheels used in robotics:
        - **Sealed pneumatic:**

Figure 2 Sealed Pneumatic Wheel

- Air acts as a shock absorber
- Air filled tires provide the maximum contact for traction

- **Semi-pneumatic:**

Figure 3 Semi-pneumatic Wheel

See:
http://custobots.com/store/index.php?main_page=product_info&cPath=81&products_id=444

- **Solid:**

Figure 4 Solid Rubber O-ring Used as a Tire for a Wheel

- **Omni-directional wheel:**

Figure 5 Omni-directional Wheel
See: http://www.acroname.com/robotics/parts/R76-4CM-ROLLER.html

Figure 6 Omni-directional Wheel
See: http://www.kornylak.com/wheels/transwheel-4000.html

- Specialty Wheels:
  - Wheels to fit servo motors:

Figure 7 Wheel to Fit Futaba Servo

See: http://www.pololu.com/catalog/category/46 or http://www.acroname.com/robotics/parts/R171-BLACK-BLACK-WHEEL.html

  - Plastic and steel ball casters:

Figure 8 Ball Caster

See: http://www.pololu.com/catalog/category/45

- For instructions to make aluminum or servo mounted robotic wheels, see: http://cornerstonerobotics.org/wheel_making.php

- Distance traveled in one revolution:
  - Formula:

$$D = \Pi\, d$$

Where: D = Distance traveled in one revolution in inches (in)
$\Pi = 3.14159\ldots$
d = Diameter of the wheel in inches (in)

Illustration: If you rollout a wheel for one revolution, the distance traveled will be equal to the circumference of the wheel.

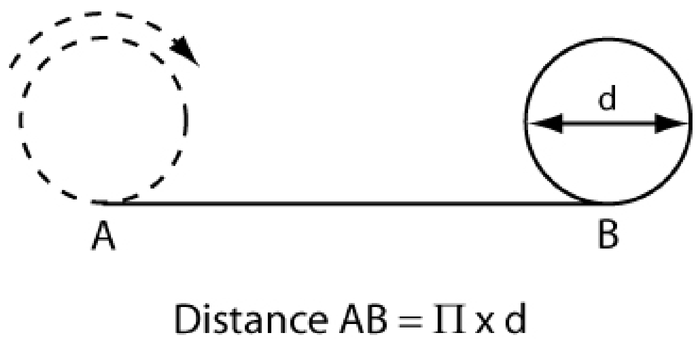

Figure 9 Distance Traveled for a Wheel in One Revolution

- RPM, revolutions per minute:
  - Use an rpm meter to measure the rpm of a motor by friction, and reflectivity.
  - Use PIC chip to measure the rpm of a motor (encoder1.pbp).
- Calculating linear speed:

Linear Speed = Rotational Speed x Tire Circumference

Where: Linear Speed is in inches/minute (in/min)
Rotational Speed is in revolutions per minute (rpm)
Tire Circumference is in inches (in)

Examples:

1. Calculate the linear speed for a Lego 49.6 x 28 tire (Pitsco # 970111) connected to a 9 volt Lego motor at a no load condition. The diameter of a Lego 49.6 x 28 tire is 1.94 in and the rotational speed is 337 rpm.

   Linear Speed = rpm x Π x diameter
   Linear Speed = 337 rev/min x 3.14 x 1.94 in
   Linear Speed = 2053 in/min = 34.2 in/sec = 171 ft/min = 1.94 mph

2. Calculate the linear speed for a Lego Power Technic tire connected to a 9 volt Lego motor. The diameter of a Lego Power Technic tire is 4.24 in and the rotational speed is 332 rpm.

   Linear Speed = rpm x Π x diameter
   Linear Speed = 332 rev/min x 3.14 x 4.24 in
   Linear Speed = 4420 in/min = 73.7 in/sec = 368 ft/min = 4.18 mph

- o Selecting tires for your robot: Consider the following design properties.
  - ▪ Tire diameter: Tire diameter affects speed and torque.
    - Increasing the diameter of the tire will increase the speed proportionally.
    - Increasing the diameter of the tire will decrease the torque proportionally. Therefore, tire diameter is proportional to the speed and inversely proportional to the torque. Larger tires require motors with higher torque to drive them.
    - For center output shaft motors, the tire radius must be larger than the radius of the motor plus whatever clearance is needed. See the illustration below.

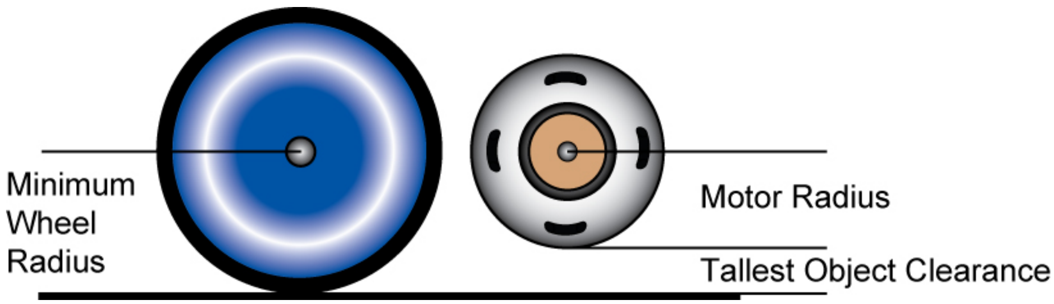

Figure 10 Minimum Tire Radius

    - If the output shaft of the motor is not centered, be careful how you mount the motor to the robot body. See the illustrations below.

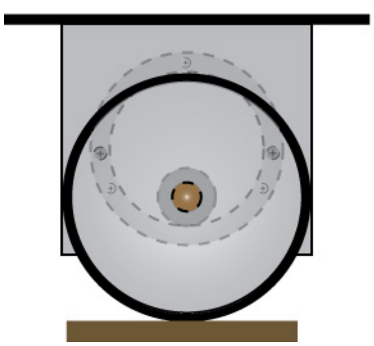

Figure 11
Front View of Proper Motor Mounting

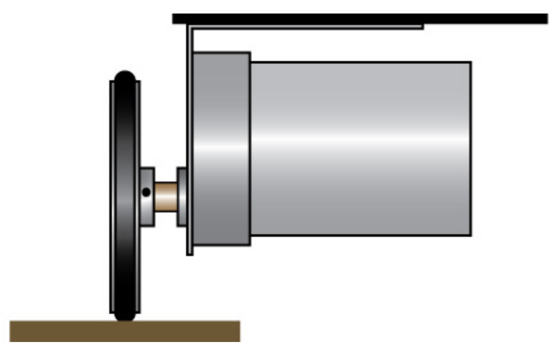

Figure 12
Side View of Proper Motor Mounting

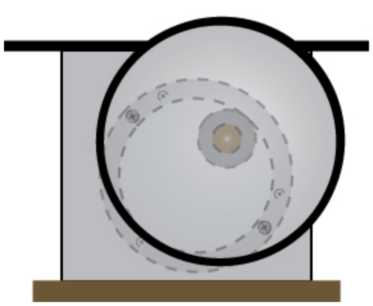

Figure 13
Front View of Improper Motor Mounting

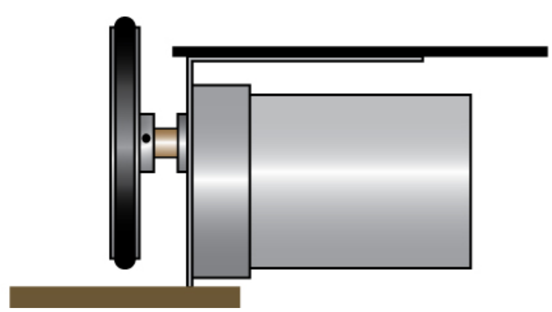

Figure 14
Side View of Improper Motor Mounting

- In simple robot systems, a tire is capable of rolling over an object that is about one-third its diameter. See the illustration below.

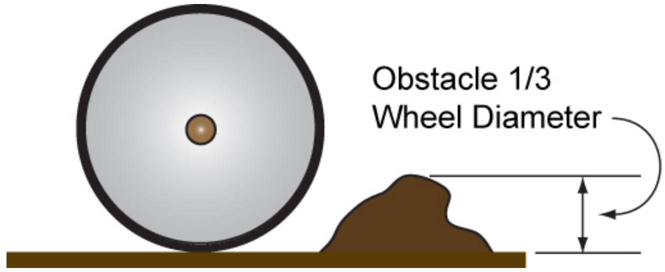

Figure 15 Typical Maximum Obstacle Height

- It is prudent to select the robot tires and drive motors at the same time since the tire diameter and the motor rpm will establish the top speed of the robot.
- In outdoor applications, a tire with a diameter of less than 10 inches (25.4 cm) should be avoided.

▪ Texture and Material:
- If your tire is too smooth then it will not have enough traction. This is a serious issue with omni-wheels. Overly smooth robot tires would likely skid while accelerating and braking. However, a tire that is really rough, such as a foam tire, has higher friction with the ground requiring more powerful motors to move.
- Tires are the most important factor for traction. Even if the robot motors output high torque, it would be wasted if the tires had insufficient traction and simply spun without moving the robot.
- As a rule, use a harder tire on smooth surfaces and a softer tire on more yielding surfaces such as the terrain outdoors.
- Experiment to determine the best tire texture and material for your application.

▪ Width:
- A wider tire will follow a straight line better than a narrow tire.
- A wider tire may hinder the robot’s ability to turn.
- A wide tire increases the resistance when rotating the tire on a surface.

▪ Mounting:
- Consider how the wheel assembly will be attached to the drive motor shaft.

- **Differential Drive:** A differential drive wheel system has two independently powered wheels positioned on either side of the robot and a passive contact point (slider) or a caster that serves as a stability point.
    - o The term 'differential' means that robot turning motion is determined by the difference in the velocity between the wheels.
    - o The differential drive wheel system is the most common wheeled mobile robot configuration. It is the easiest to build and to .0control.
    - o We will examine the three cases of motion for a differential drive robot.
        - Case 1: Velocity and direction of left wheel = Velocity and direction of right wheel: When the velocity and direction of both wheels are the same, the robot base is either going straight forward or reverse (assuming that both motors run at the same rpm). See Figure 8.

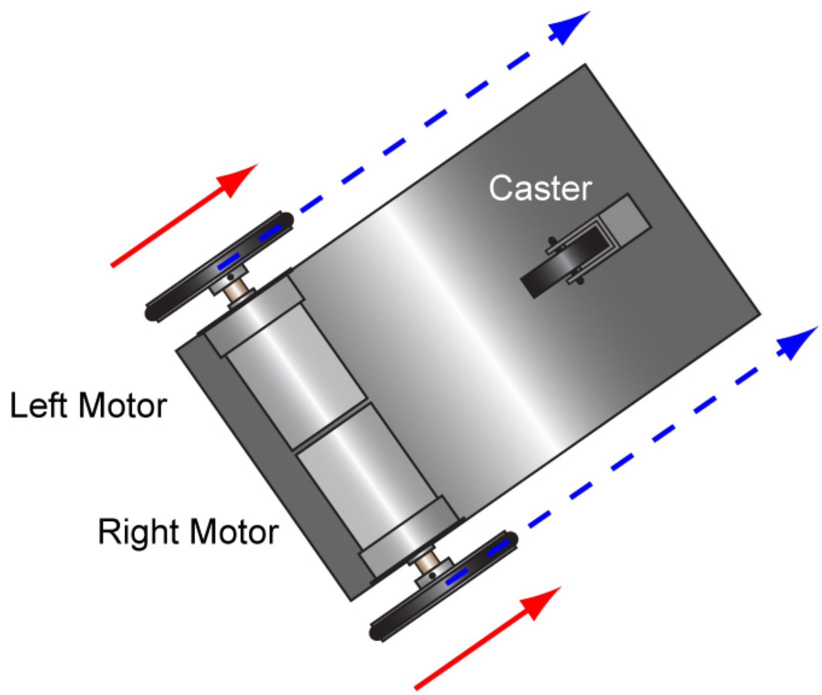

Figure 16 Straight Forward or Reverse Motion

- Note: In outdoor differential drive applications, it is best to place the drive motors in front of the robot and the caster in the rear. It is better to pull the caster over an obstacle than to push it over.

- Case 2: Velocity of left wheel = **-** (Velocity of right wheel): When one passive caster is used, the driving wheels cannot be positioned in the center of the robot base due to stability issues. The center of rotation is not positioned over the center of the robot. See Figure 9.

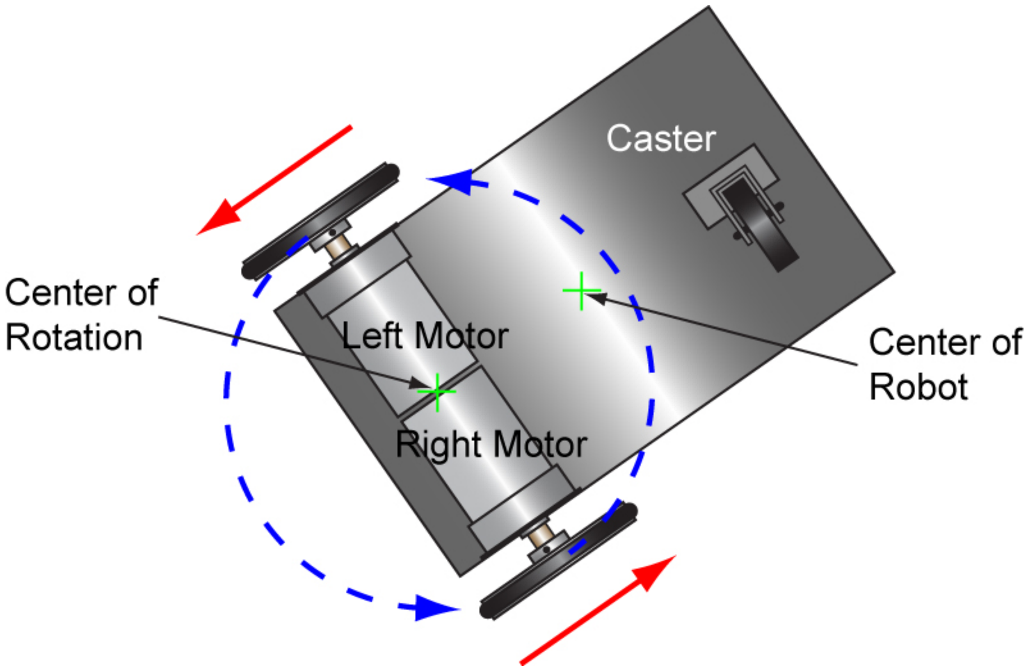

Figure 17 Turning on the Spot with One Caster

- A second passive caster may be added allowing the motors to be placed in the center of the robot base. The center of rotation is now the located at the center of the robot.

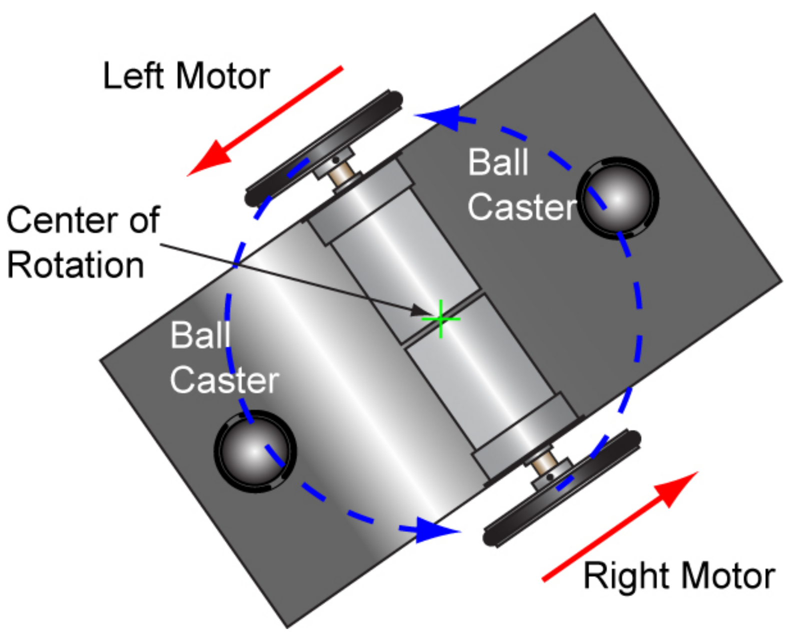

Figure 18 Turning on the Spot with Two Casters

- Case 3: The left motor runs faster than the right motor. The motion follows along the path of a circle.

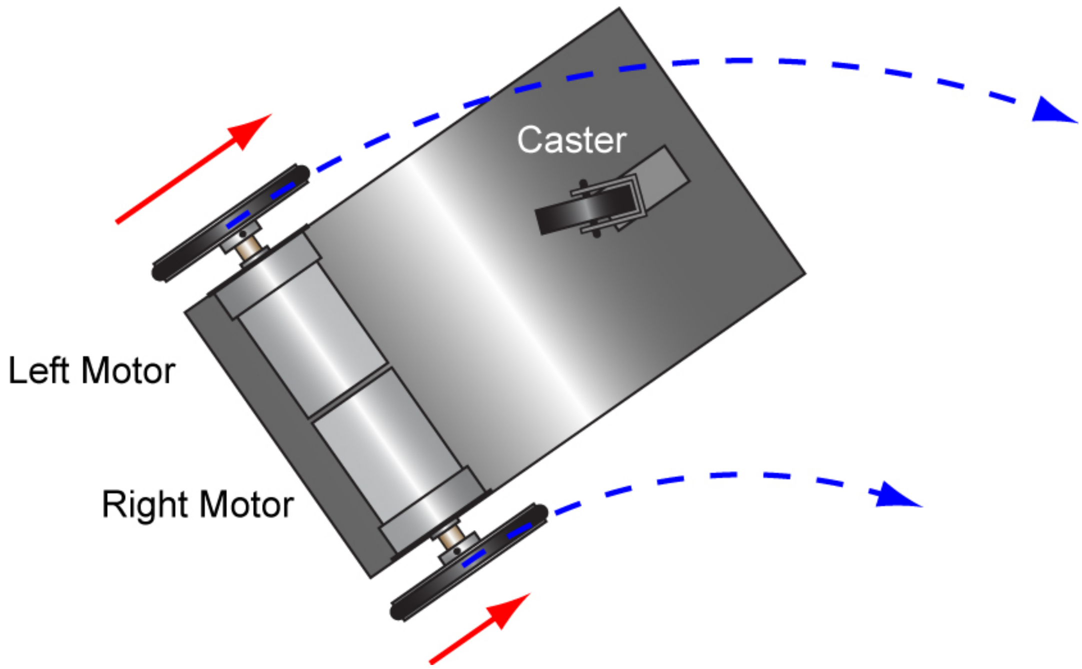

Figure 19 Arc Motion When Left Wheel Turns Faster Than the Right Wheel

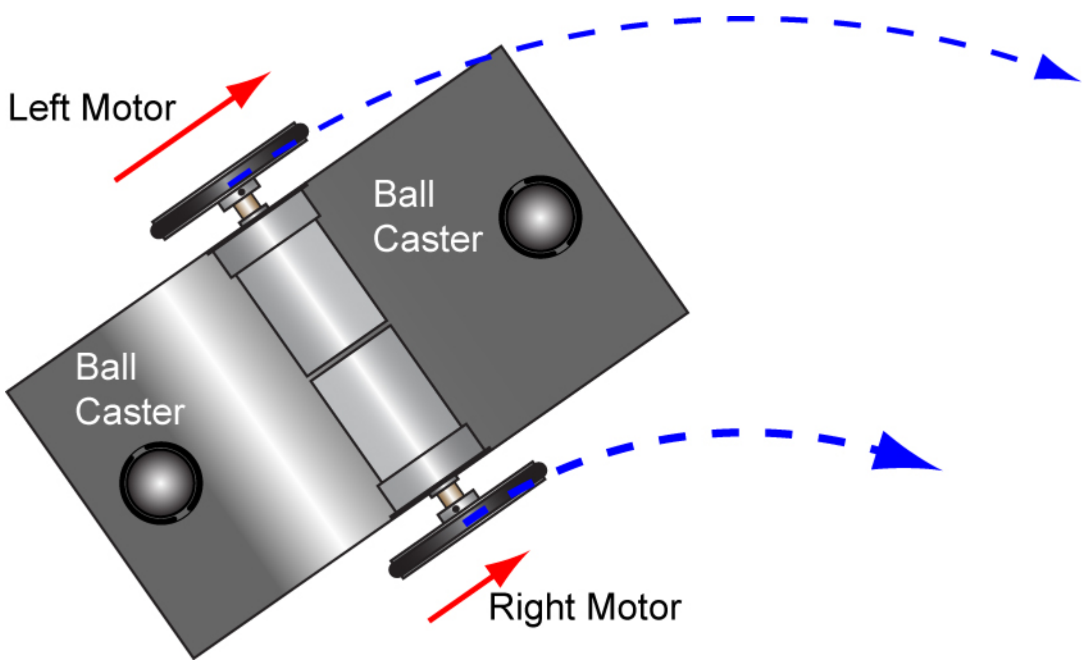

Figure 20 Arc Motion When Left Wheel Turns Faster Than the Right Wheel

One special instance of arc motion is when one wheel breaks and the other rotates. See Figure

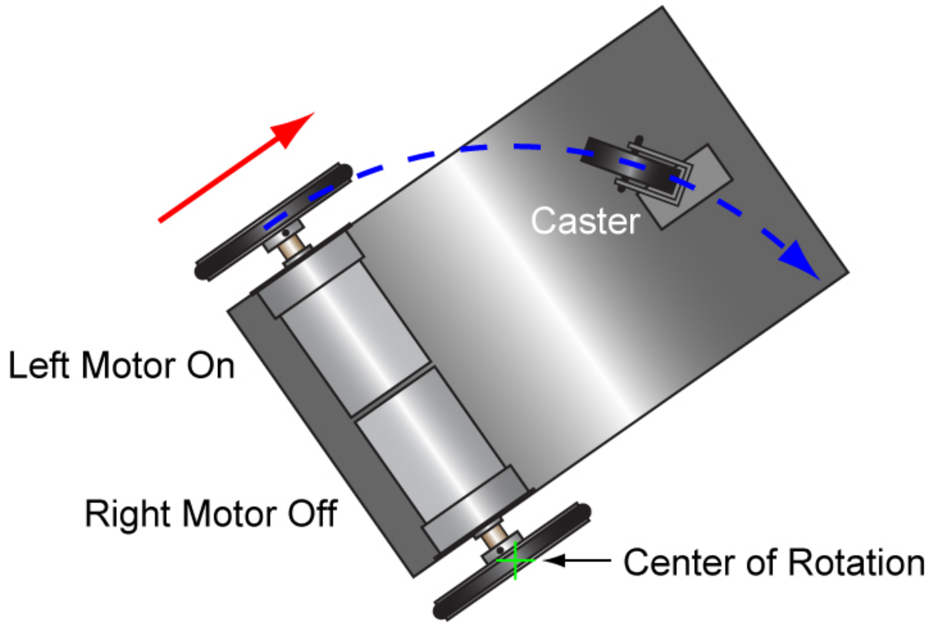

Figure 21 Arc Motion When Left Wheel Turns and the Right Wheel Is Stopped

- Related differential drive websites:
  - http://www.societyofrobots.com/programming_differentialdrive.shtml
  - http://rossum.sourceforge.net/papers/DiffSteer/
  - http://cognitoware.com/tutorials/DifferentialDrive.htm

- **Sandwich:** Continue soldering the Sandwich parts to the Printed Circuit Board (PCB).