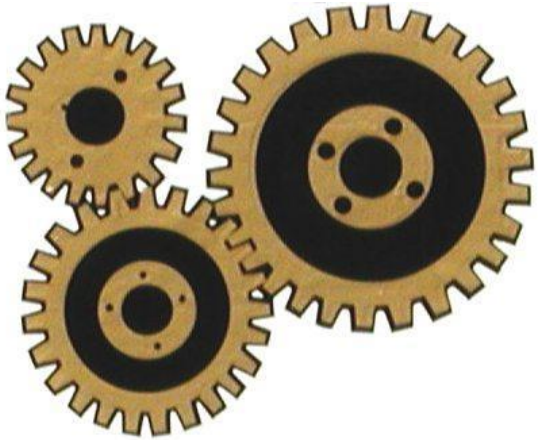
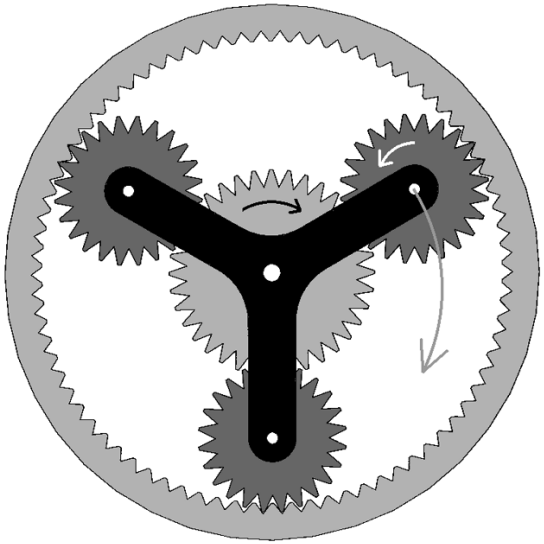
ADAMBOTS
Team 245

Application of Gearing



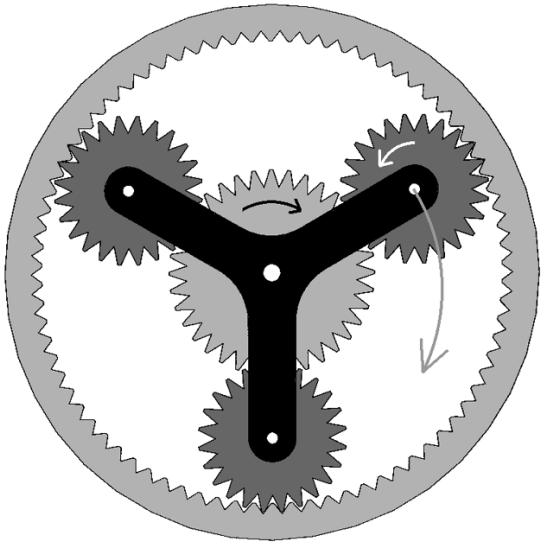


Gears

Why do we need Gears??

- Provide speed reduction
  - Motors deliver needed power at speeds much higher than speed where the power can be applied
- Change axis of rotation
  - Motors often cannot fit in the location where the rotation needs to be applied and gears are used to translate the axis of rotation
  - Can shift to another parallel axis or can change axis by 90°

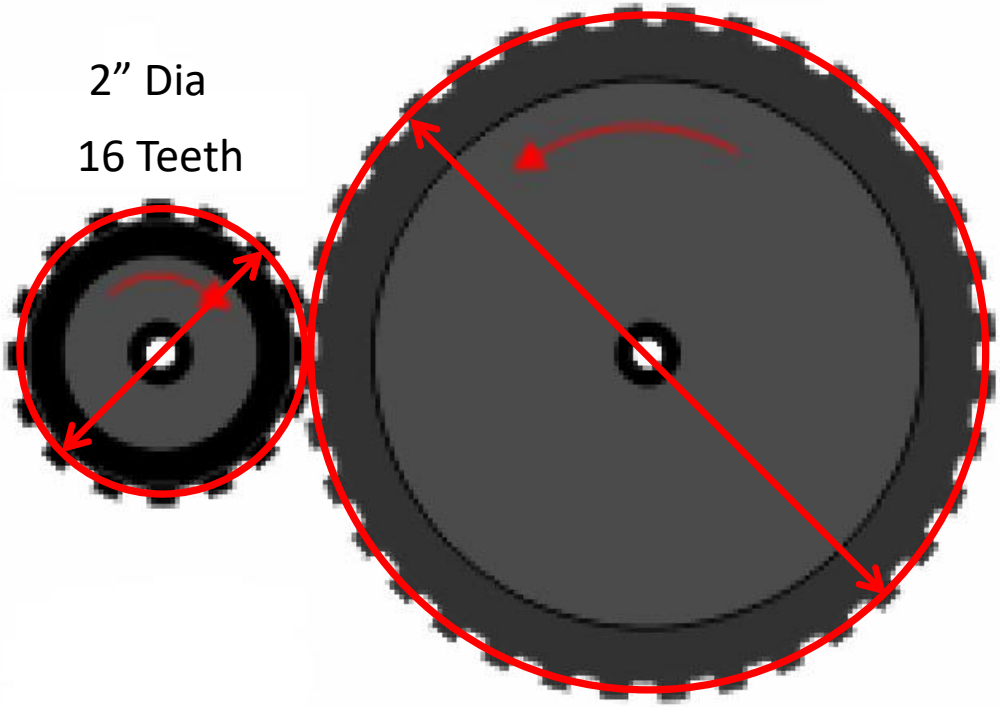
Planetary Gears



Worm Gear

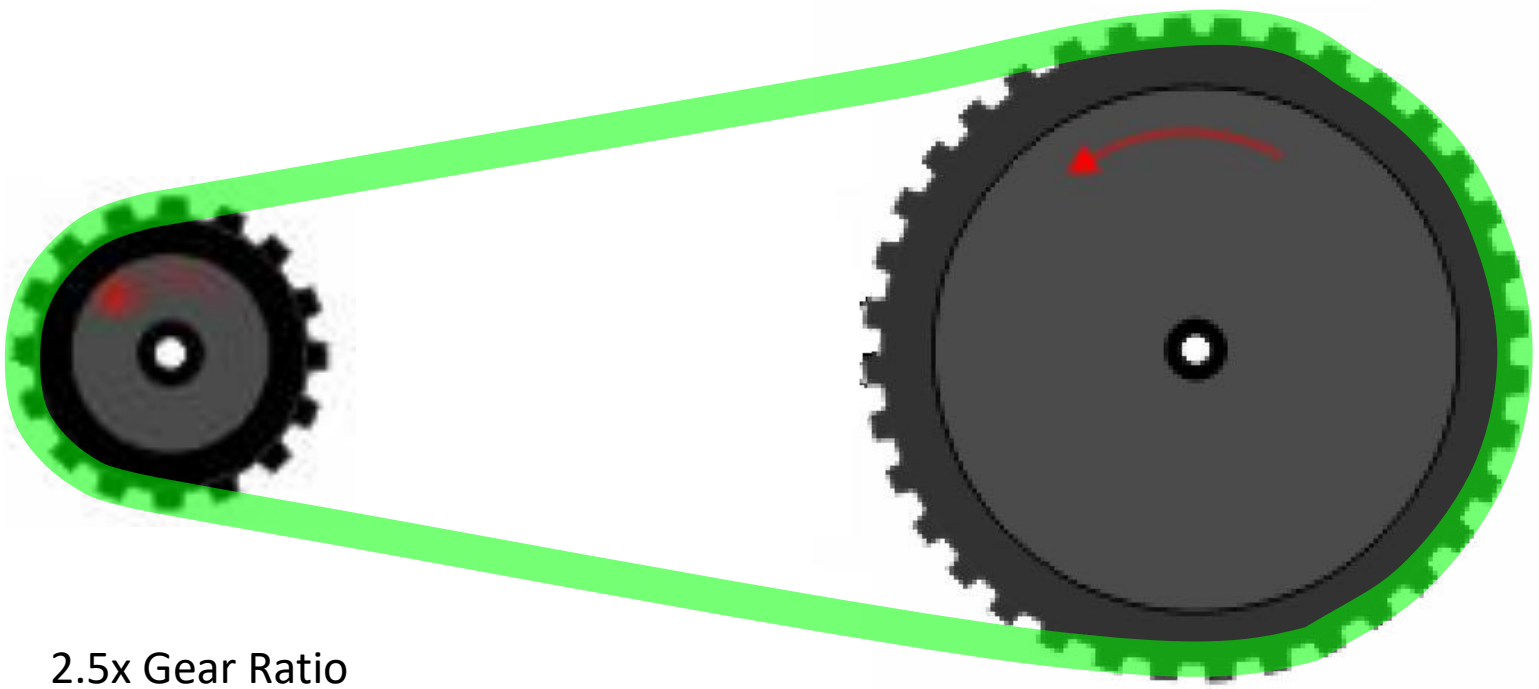
Speed Reduction

- **Speed Reduction is Driven by Diameter Ratio or by Ratio of Number of Teeth**



Speed Reduction

- **Speed Reduction Can Be Achieved Using a Belt or Chain Drive In Combination with Sprockets**



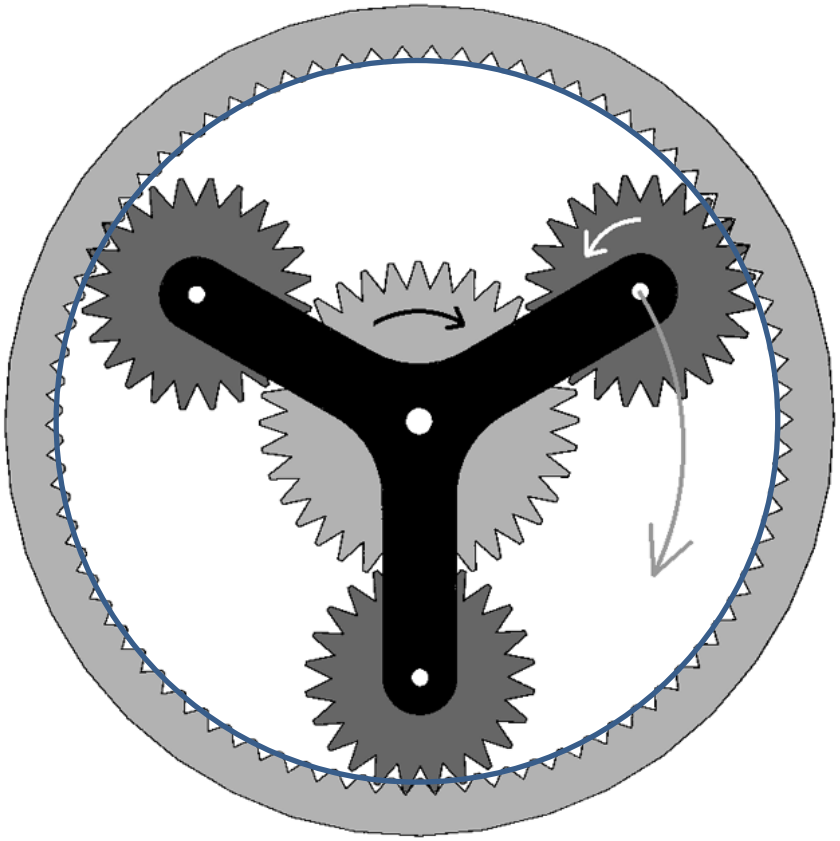
2.5x Gear Ratio
Large Offset of Axis
Same Rotation Direction of Axle

Speed Reduction

- **Combination of Planetary Gear Stages Allows Higher Gear Ratio along the same axis**

3.5x Gear Ratio for 1 Stage

3 Stages gives 39:1 Ratio along the Same Axis



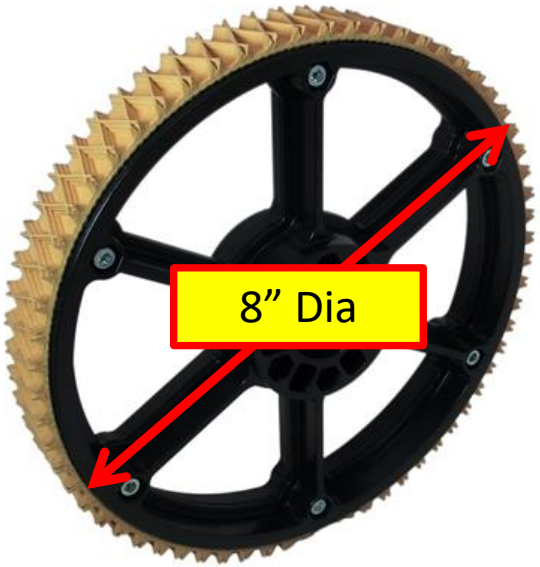
Example: Apply Maximum Power at the Drive Wheels

- Want to apply maximum power to drive wheels at forward speed of 4 Feet/Second
- What gear ratio would be needed to match 4 Feet/Second with the Maximum power point of the motor for 12V operation?

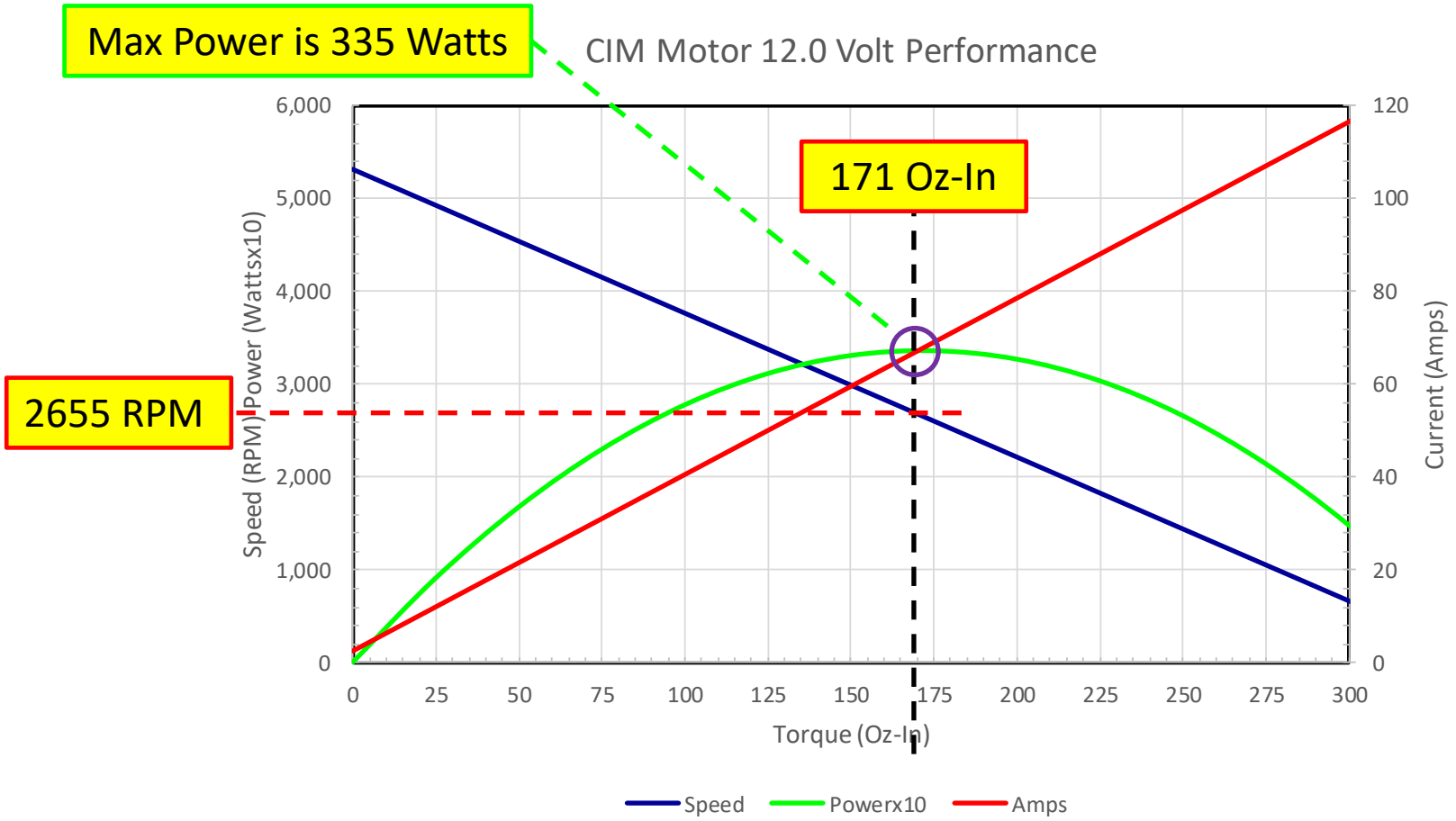
- Break this problem into small steps to gain full understanding of the process

Find Wheel Speed for 4 Feet/Second Forward Speed

- **Start with wheel diameter of 8”**
  - Circumference is π x Diameter
    - 3.14159 x 8 = 25.13 Inches
  - 1 Revolution covers 25.13 Inches or 2.09 Feet
  - 4 Feet requires: 4 / 2.09 = 1.91 Rev’s
  - 1.91 Revolutions needed in 1 Second
  - Transfer to RPM by x 60
  - 1.91 x 60 = 114.8 Rev/Min or RPM
  - Need to provide Max power at 114.8 RPM at the wheels



What is Max Power Point of the Motor



- **Maximum Power Point of Motor at 12V**

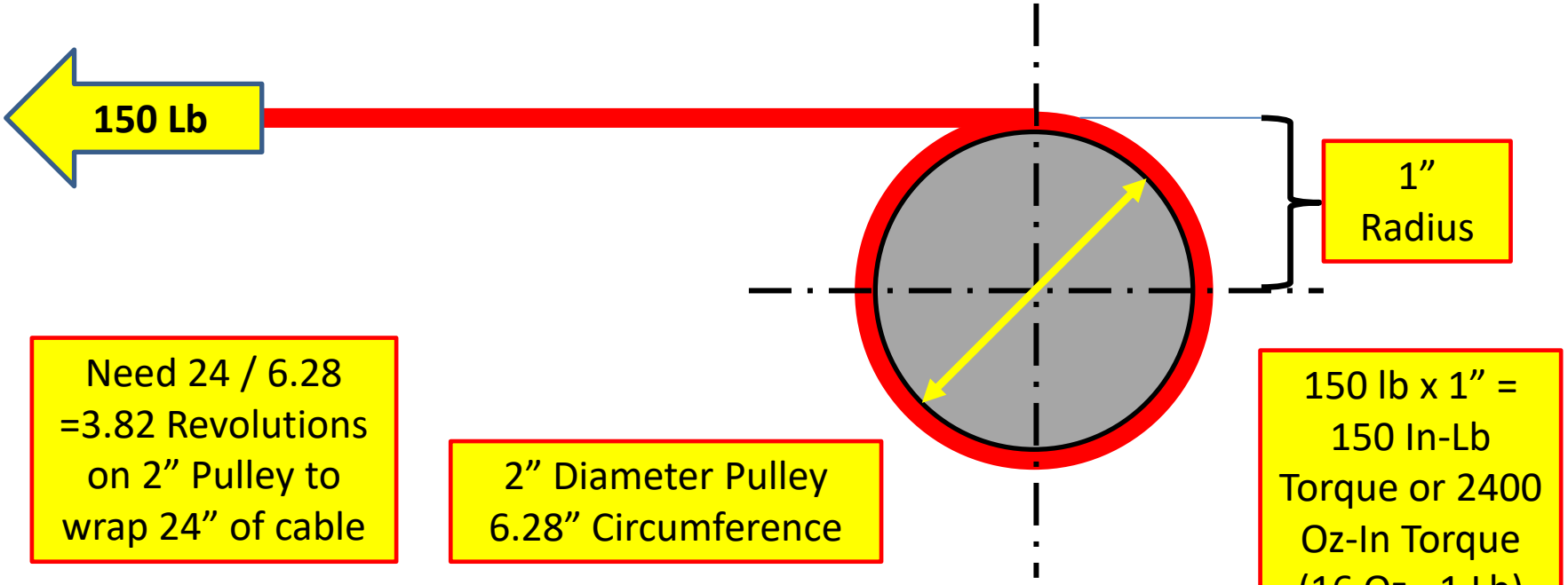
What Gear Ratio is Needed to Match Max Power at 4 Ft/Sec Forward Speed?

Find Gear Ratio

- Motor speed at Max Power is 2655 RPM
- Wheel speed at 4 Ft/Sec = 114.8 RPM
- Need 2655/114 Reduction ratio = 23.2:1 to match motor operating at Max power point at 4 Ft/Sec
- Torque available at the wheel at 114.8 RPM found by multiplying by the gear reduction ratio
  - 171 Oz-In at motor x 23.2 = 3962 Oz In
  - Assuming no power losses in the gear transmission

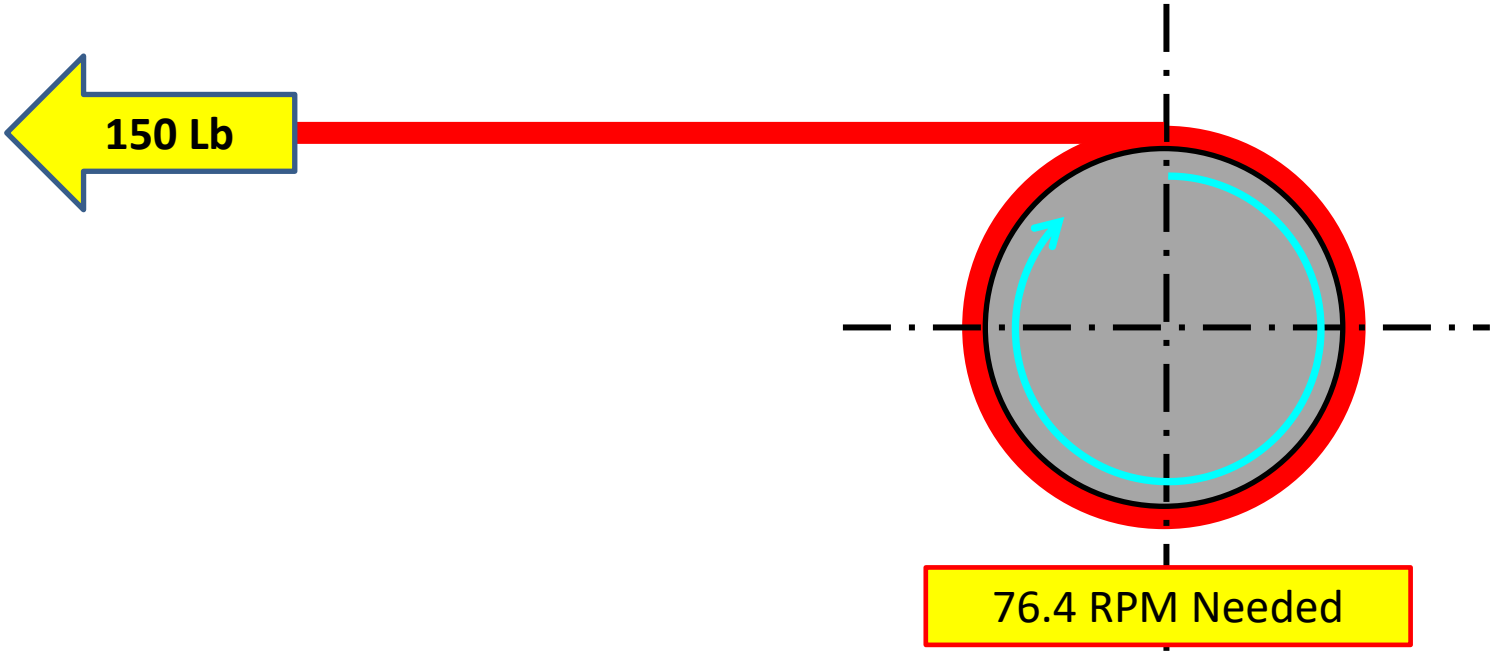
Robot Climbing Example

- **Need to lift a 150 Pound robot 24 Inches in 3 Seconds**
  - Use a cable wrapped around a 2” Diameter pulley
  - Pulley is long enough to hold 24” of cable along outer edge without overlapping



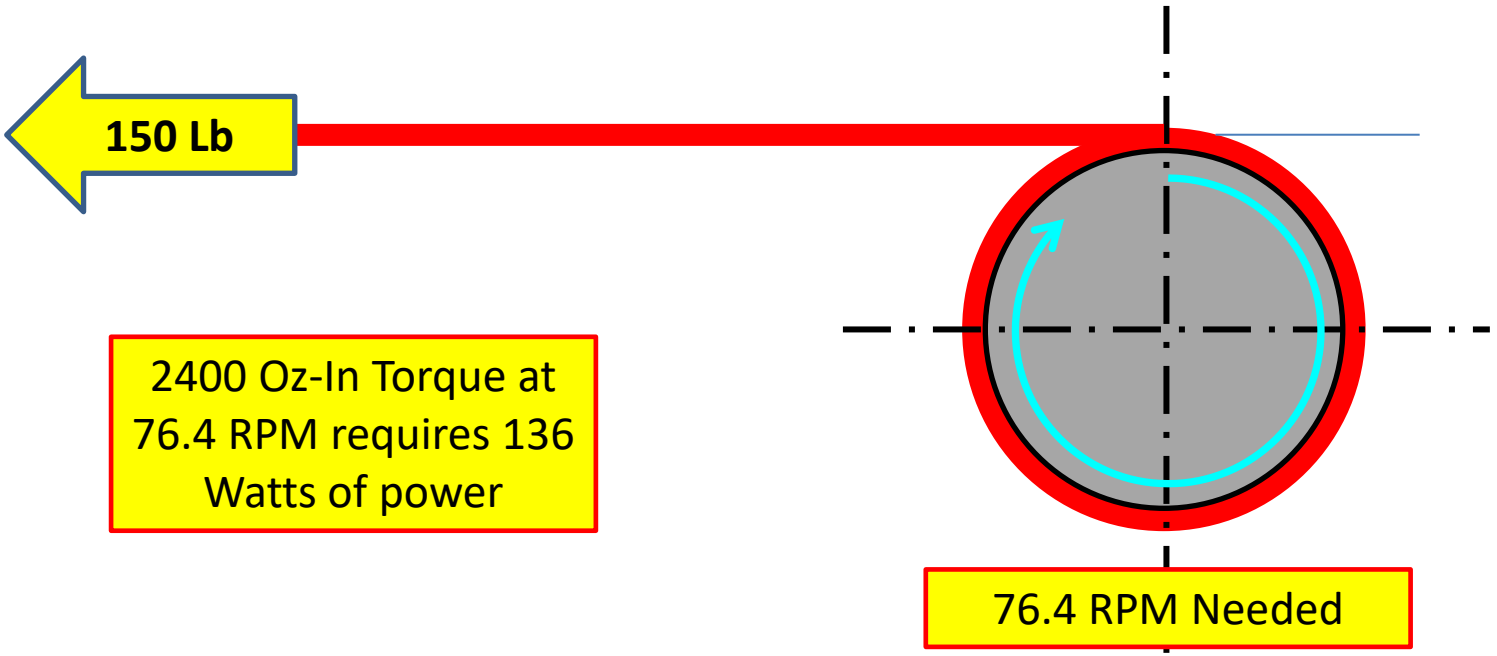
Robot Climbing Example

- **How fast does pulley need to turn to pull 24” in 3 Seconds?**
  - 3.82 Revolutions needed for 24”
  - 24” or 3.82 Revolutions needed in 3 Seconds
  - 3.82 Rev in 3 Seconds = 1.27 Rev/Sec or 76.4 RPM

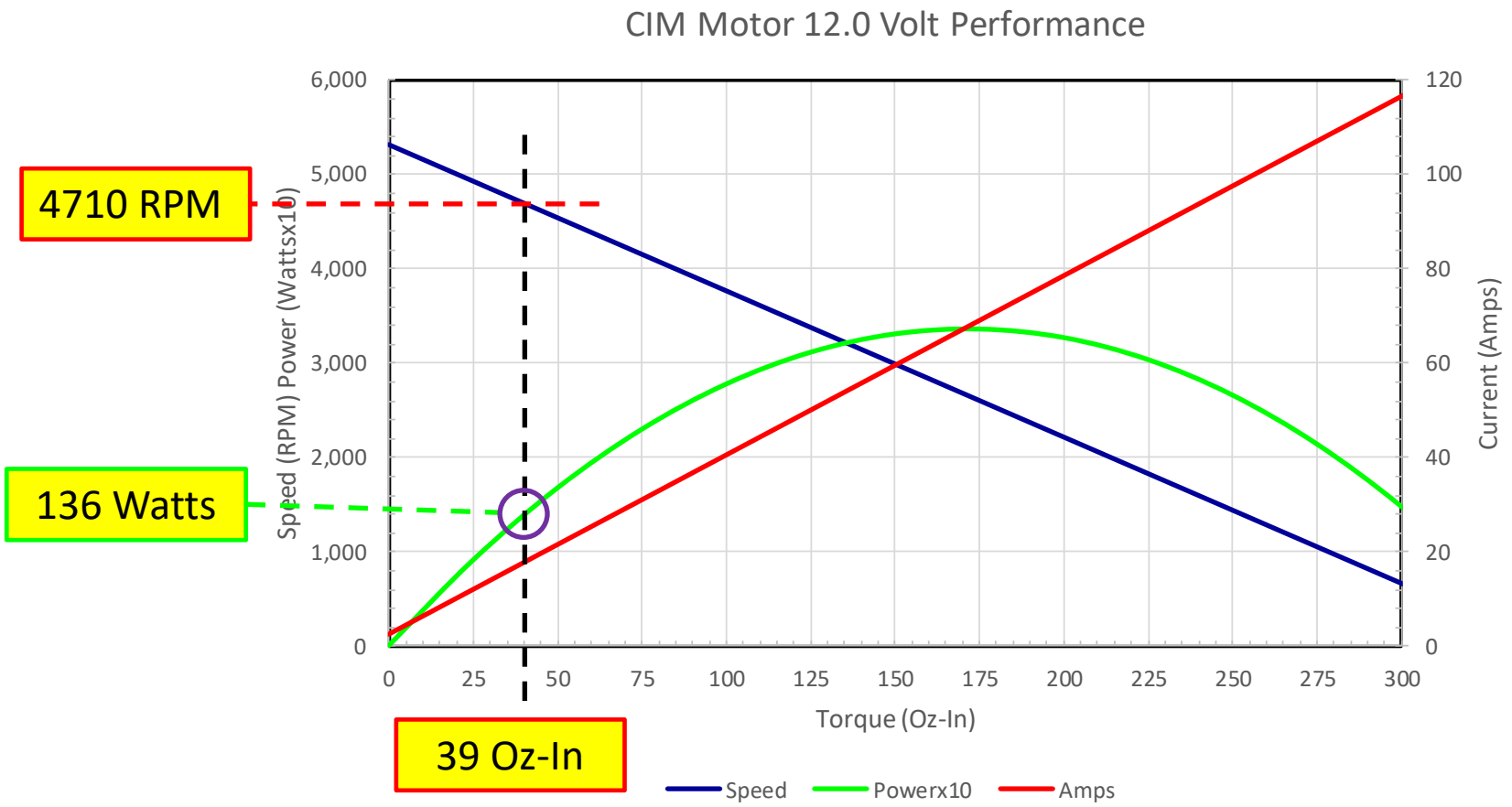


Robot Climbing Example

- **How much Power is needed to lift 150 Pounds 24” in 3 Seconds??**
  - 2400 Oz-Inches at 76.4 RPM gives 136 Watts



Where is 136 Watt Operating Point @12V?



Gear Ratio Calculation:

What is Needed Gear Ratio to Match Power?

- Need 76.4 RPM at Pulley and 136 Watts
- 136 Watts output on motor at 12 Volts needs 4710 RPM
- Need speed reduction of 4710 / 76.4 RPM = 61.6
- Need 62:1 gear ratio to match

Application to Robot

Limitations for Application

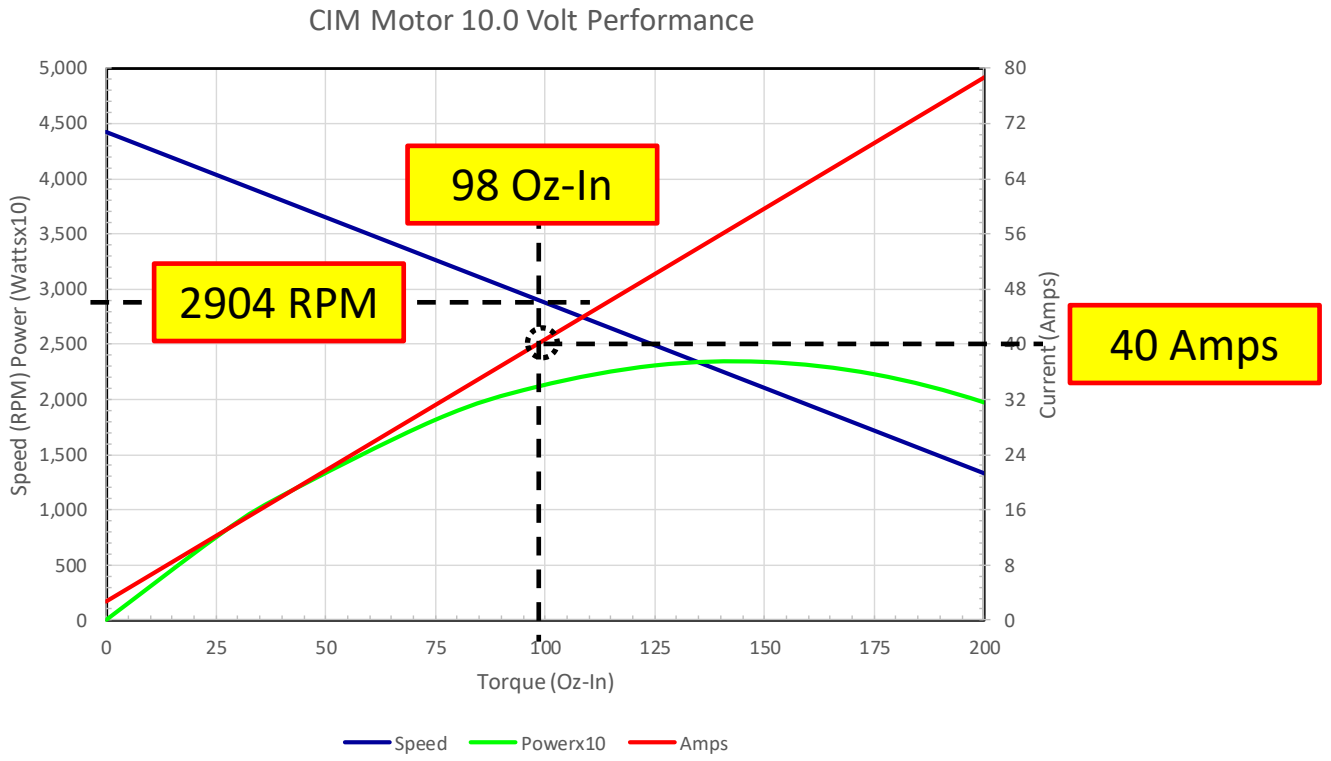
- Voltage to motor will not be 12V
  - Battery voltage may be dropping at end of match
  - Will loose Voltage through wire resistance at high current draw operation
- Need to keep within maximum 40 Amp current limit per circuit on the robot

➔ These limitations impact application of motor to the robot

- Do calculations assuming we have 10 Volts at the motor

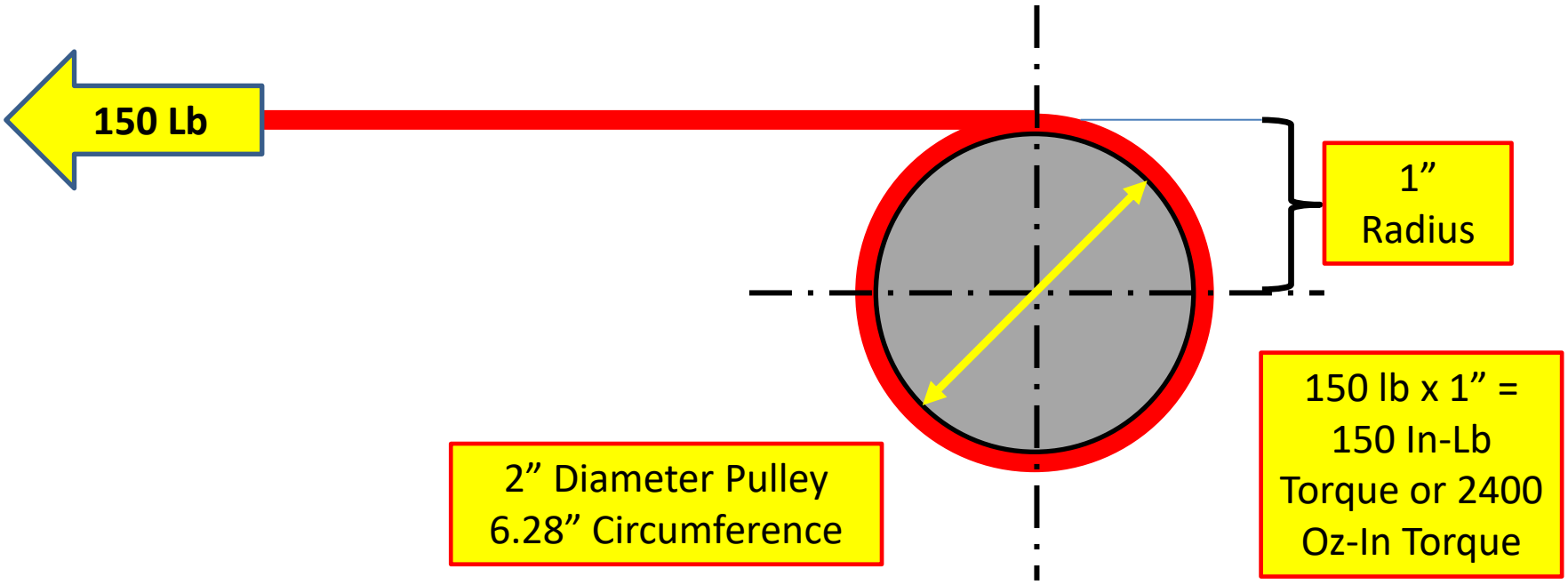
Repeat Climbing Example: 150 Pound Robot 24” Climb

- Determine climbing speed keeping within 40 Amp Limit and 10V at motor
- Start with 10V Motor Curve



Repeat: Robot Climbing Example

- **Need to lift a 150 Pound robot**
  - Use a cable wrapped around a 2” Diameter pulley
  - Need 2400 Oz-In Torque



Use Needed Torque to Choose Speed Ratio

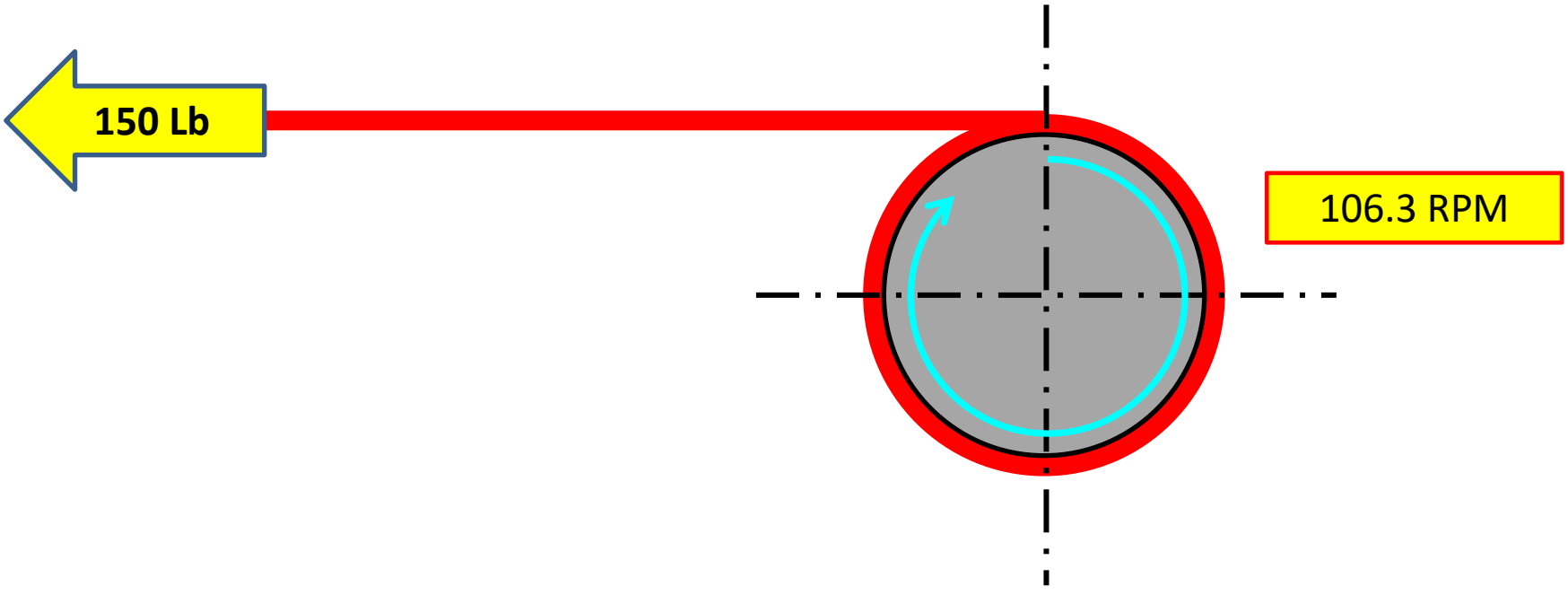
Need 2400 Oz-In Torque to lift Robot

- 40 Amp Torque limit for the motor is 98 Oz-Inches
- Need 2400 Oz-In Torque
- Assume 90% Power Transfer efficiency
  - 98 Oz-In Torque at Motor is reduced to 88 Oz-In
- Calculate speed ratio based on Torque ratio:
  - 2400 / 88 = 27.3
  - Need 27.3:1 Ratio or Higher to climb robot keeping within the 40 Amp per motor limitation
- Speed at pulley is 2904 / 27.3 = 106 RPM

Robot Climbing Example

How fast will pulley wrap 24” of cable?

- 3.82 Revolutions needed for 24”
- Pulley speed is 106.3 RPM
- 106.3 RPM is 1.77 Rev/Sec
- 3.82 Rev / 1.77 Rev/Sec = 2.15 Seconds



Importance of Proper Speed Ratio Sizing

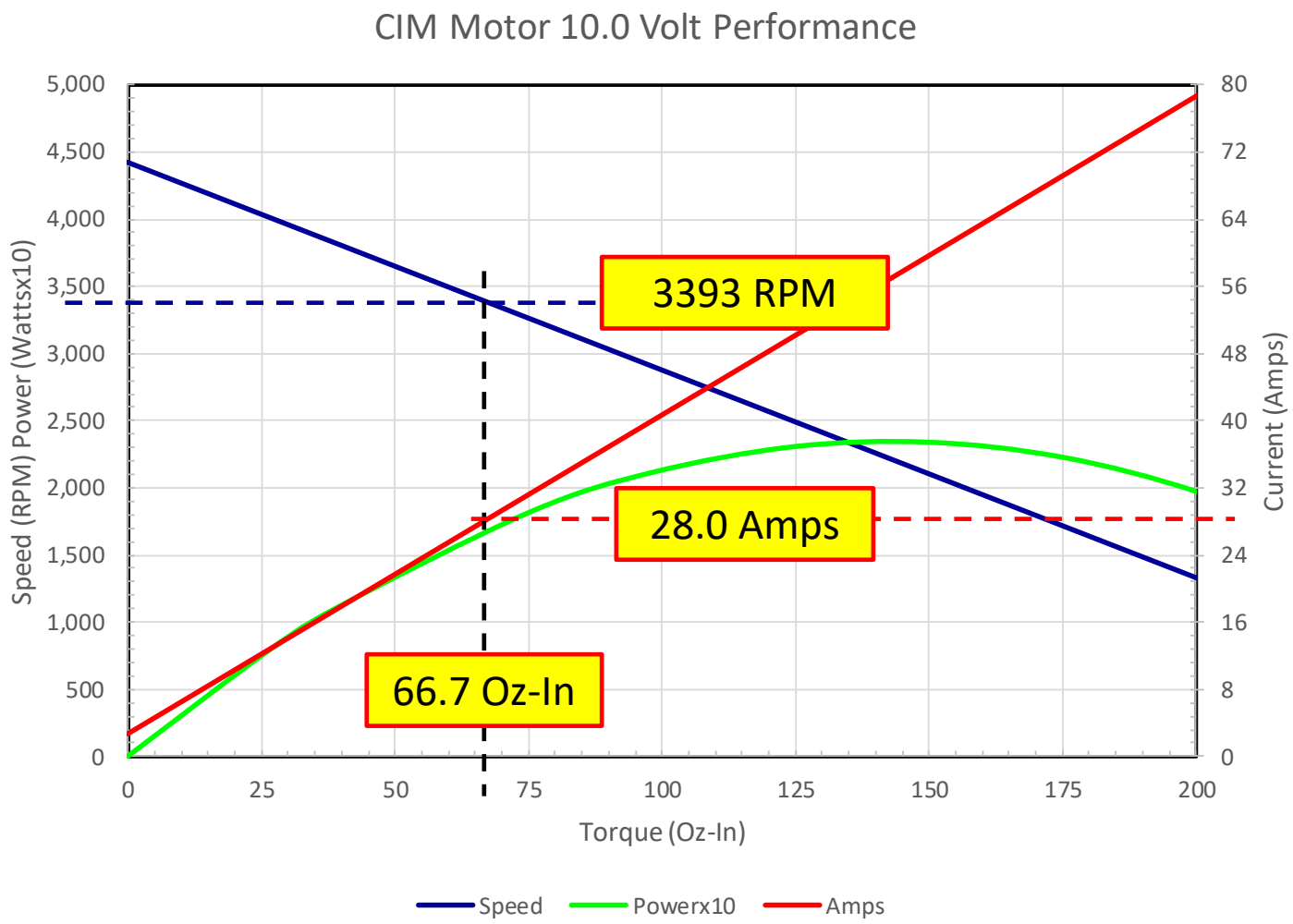
- **Previous Example identified a 27.3:1 Speed Ratio**
  - This matched climbing the robot at the 40 Amp limit of the motor circuit
  - Ratio lower than 27.3:1 will require more than 40 Amps
  - Ratio higher than 27.3:1 will climb faster and will use less current
- **What would be motor operating point if a 40:1 Speed ratio was used:**

Revisit Climbing with a 40:1 Speed Ratio

Use 40:1 Speed ratio

- 2400 Oz-In needed torque at spool is reduced to 60 Oz at the motor with 40:1 ratio
- Apply 90% Power transfer efficiency increases torque to 66.7 Oz-In
- Find 66.7 Oz-In point on 10V motor curve
- Find current at 66.7 Oz-In
- Find speed at 66.7 Oz-In and determine speed for pulley
- Then determine how many seconds is needed to turn pulley 3.82 Revolutions

Find Motor Operation at 66.7 Oz-In



Find Climbing Speed Based on 3393 Motor Speed

- **Use 40:1 Speed ratio**
  - 3393 RPM at motor is 3393 / 40 = 84.8 RPM at the Pulley
  - Need 3.82 Revolutions
  - 84.8 RPM is 84.8 / 60 = 1.41 Rev/Sec
  - 3.82 Revolutions will take 3.82 / 1.41 = 2.70 Sec
  - Will require 28 Amps
- **Comparison:**
  - 40:1 Ratio = 28 Amps and 2.70 Seconds
  - 27:1 Ratio = 40 Amps and 2.15 Seconds
  - Lower than 27:1 will not climb due to 40 Amp limit