Motor Mastery Problem Set

Torque

1. A robot weighs 100 lbs (~45.36 kg) and is hanging from a winch. What is the torque needed to keep the 2-inch diameter (0.0508 m) winch stationary?

$$\tau = Fr$$
$$\tau = (45.36\ \mathrm{kg} * 9.8\ \mathrm{m}/s^2)\left(\frac{0.0508\ \mathrm{m}}{2}\right) = 11.29\ \mathrm{Nm}$$

2. The winch is attached to a gearbox. The motor can output a torque of 2 Nm. What is the reduction needed?

$$r = \frac{\tau_{out}}{\tau_{in}}$$
$$r = \frac{11.29\ \mathrm{Nm}}{2\ \mathrm{Nm}} = 5.65{:}\,1$$

Inertia

3. A 25.5” (0.6477 m) long polycarbonate roller has an OD of 2.5” (0.0635 m) and an ID of 2.25” (0.0572 m). Polycarbonate has a density of 1200 kg/m^3. What is the roller’s moment of inertia? Hint, inertia of a thick hoop: $I = \frac{1}{2}M(a^2 + b^2)$.

$$I = \frac{1}{2}M(a^2 + b^2)$$
$$M = D * V$$
$$V = l * (\pi a^2 - \pi b^2)$$
$$I = \frac{1}{2}\big(D * l * \pi(a^2 - b^2)\big)(a^2 + b^2)$$
$$I = \frac{1}{2}\left(1200\frac{\mathrm{kg}}{\mathrm{m}^3} * 0.6477\ \mathrm{m} * \pi\left(\left(\frac{0.0635\ \mathrm{m}}{2}\right)^2 - \left(\frac{0.0572\ \mathrm{m}}{2}\right)^2\right)\right)\left(\left(\frac{0.0635\ \mathrm{m}}{2}\right)^2 + \left(\frac{0.0572\ \mathrm{m}}{2}\right)^2\right)$$
$$I = 4.24 * 10^{-4}\ \mathrm{kg} * \mathrm{m}^2$$

4. An intake uses 3 of those polycarbonate rollers. What is the total moment of inertia of that system? Hint: perpendicular axis theorem.

$$I_{total} = 3 * I_{roller}$$
$$I_{total} = 3 * 4.24 * 10^{-4}\ \mathrm{kg} * \mathrm{m}^2 = 0.00127\ \mathrm{kg} * \mathrm{m}^2$$

5. The intake is spun by a motor through a reduction of 2:1. What is the apparent moment of inertia (i.e. the moment of inertia seen at the motor)?

$$I_{in} = I_{out} * \mathrm{reduction}^{-2}$$
$$I_{in} = (0.00127\ \mathrm{kg} * \mathrm{m}^2) * (2)^{-2} = 3.18 * 10^{-4}\ \mathrm{kg} * \mathrm{m}^2$$

6. Assume a motor is outputting a torque of 2 Nm. What is the acceleration of the motor?

$$\tau = I\alpha$$
$$\alpha = \frac{\tau}{I}$$
$$\alpha = \frac{2\ \mathrm{Nm}}{3.18 * 10^{-4}\ \mathrm{kg} * \mathrm{m}^2} = 6289\ \mathrm{rad/s}^2$$

7. What is the acceleration of the roller?

$$\tau = I\alpha$$
$$\alpha = \frac{\tau}{I}$$
$$\tau_{out} = \tau_{in} * \mathrm{reduction}$$
$$\tau_{out} = 2\ \mathrm{Nm} * 2 = 4\ \mathrm{Nm}$$
$$\alpha = \frac{4\ \mathrm{Nm}}{0.00127\ \mathrm{kg} * \mathrm{m}^2} = 3150\ \mathrm{rad/s}^2$$

OR

$$\alpha_{out} = \alpha_{in} * \mathrm{reduction}^{-1}$$
$$\alpha_{out} = 6289\frac{\mathrm{rad}}{\mathrm{s}^2} * 2^{-1} = 3150\ \mathrm{rad/s}^2$$

Motor Optimization

8. An intake powered by 1 NEO motor is drawing 10 A of current while spinning freely at a steady 12 V state. What is the apparent torque on the motor caused by resistance?

   Go to Vex's motor curve 12 V csv sheet for NEOs.

   See the torque value at the current value closest to 10 A is **0.16405 Nm**.

9. What is the lowest voltage that can be supplied to the motor yet still be able to spin the intake (assuming resistance is constant across speeds).

   Use Vex's data to plot the stall torques against voltage

   Fit a regression curve (typically, linear, logarithmic, or quadratic)

   Use the regression curve to find what voltage corresponds to 0.16405 Nm (**1.3 V**).

10. A shooter powered by 2 Falcon 500 motors is drawing 52 A of current per motor while spinning freely at a steady 12 V state. What is the apparent torque on one motor caused by resistance?

    Go to Vex's motor curve 12 V csv sheet for Falcon 500s.

    See the torque value at the current value closest to 52 A is **0.9376 Nm**.

11. The current reduction on the shooter is 1:1. What reduction would be used if we wanted to sacrifice speed to keep current draw per motor below 40 A?

    Use Torque Design Calculator (Torque to Reduction Tab) to get **1.33:1**.

    Load torque is calculated by multiplying the apparent torque by the number of motors and the old reduction.

12. If we want the shooter to spin at 300 rad/s, what is the maximum load torque at a 30 A limit and what reduction is used to get that?

    Use Torque Design Calculator (Speed to Reduction Tab) to get **2.07 Nm at a reduction of 1.98:1.**