Note: numbers used in solution steps can be different from the question part. You can practice the methods in
the solution and verify with the numbers and answers given in the question part. Or you should practice the
methods in the solution and verify your calculation with numbers in your webassign.

Problem 1, A torque of 0.97 N·m is applied to a bicycle wheel of radius 35 cm and mass 0.75 kg. Treating the
wheel as a hoop, find its angular acceleration. \[ \text{rad/s}^2 \]

7. Picture the Problem: The torque applied to the bicycle wheel causes it to rotate with constant angular acceleration.

Strategy: Calculate the moment of inertia of the wheel using \( I = mR^2 \) (table 10-1) and then use Newton’s Second Law
for rotation (equation 11-4) to determine the angular acceleration.

Solution: Solve equation 11-4 for \( \alpha \) :

\[ \alpha = \frac{r}{I} = \frac{r}{mr^2} = \frac{0.97 \text{ N·m}}{(0.75 \text{ kg})(0.35 \text{ m})} = 1 \text{ rad/s}^2 \]

Insight: To exert a 0.97 N·m torque on a 0.35-m wheel you need only apply a tangential force of 2.8 N or 10 ounces.

For a hoop all mass are distributed at distance “R” away from the center. So rotating along the center axis
perpendicular to the hoop, \( I = mR^2 \), regardless of the thickness, because mass distribution along the axis doesn’t
change I, as long as mass are not distributed closer or further from the rotation axis.

Problem 2, A fish takes the bait and pulls on the line with a force of 2.1 N. The fishing reel, which rotates
without friction, is a cylinder of radius 0.055 m and mass 0.84 kg.

(a) What is the angular acceleration of the fishing reel? \[ \text{rad/s}^2 \]
(b) How much line does the fish pull from the reel in 0.25 s? \[ \text{m} \]

14. Picture the Problem: The fish exerts a torque on the fishing reel and it rotates with constant angular acceleration.

Strategy: Use table 10-1 to determine the moment of inertia of the fishing reel assuming it is a uniform cylinder
(\( \frac{1}{2} mR^2 \)). Find the torque the fish exerts on the reel by using equation 11-1. Then apply Newton’s Second Law for
rotation (equation 11-4) to find the angular acceleration and equations 10-2 and 10-10 to find the amount of line pulled
from the reel.

Solution: 1. (a) Use table 10-1 to find \( I \):

\[ I = \frac{1}{2} mR^2 = \frac{1}{2}(0.84 \text{ kg})(0.055 \text{ m})^2 = 0.00127 \text{ kg·m}^2 \]

2. Apply equation 11-1 directly to find \( \tau \):

\[ \tau = rF = (0.055 \text{ m})(2.1 \text{ N}) = 0.12 \text{ N·m} \]

3. Solve equation 11-14 for \( \alpha \):

\[ \alpha = \frac{\tau}{I} = \frac{0.12 \text{ N·m}}{0.00127 \text{ kg·m}^2} = 92 \text{ rad/s}^2 \]

4. (b) Apply equations 10-2 and 10-10:

\[ s = r\theta = r\left(\frac{1}{2}\alpha t^2\right) = (0.055 \text{ m})\left(\frac{1}{2}(92 \text{ rad/s}^2)(0.25 \text{ s})^2\right) = 0.16 \text{ m} \]

Insight: This must be a small fish because it is not pulling very hard; 2.1 N is about 0.47 lb or 7.6 ounces of force. Or
maybe the fish is tired?

For a cylinder most mass are distributed closer to the center than R, respect to its center axis,
\( I = \frac{1}{2} mR^2 \), regardless of thickness. This result is from integration. You do not need to memorize it but you
need to know that rotational inertia I for cylinders is less than that for hoops with same mass and same radius.

Problem 3, A wheel on a game show is given an initial angular speed of 1.22 rad/s. It comes to rest after
rotating through 3/4 of a turn.

(a) Find the average torque exerted on the wheel given that it is a disk of radius 0.71 m and mass 6.4 kg.
(b) If the mass of the wheel is doubled and its radius is halved, will the angle through which it rotates before
coming to rest increase, decrease, or stay the same?
Be very careful about the square dependence on R. \( I = \frac{1}{2} mR^2 \)
On the other hand, if the mass of the wheel is halved and its radius is doubled, the new \( I \) will be a factor of 4twice of the old \( I \). In that case, the moment of inertia doubles.

With the same torque, the angular acceleration will decrease by a factor of 1/2. So, the wheel is spinning for longer before reducing its angular velocity to zero, and the angle traveled increases.

**Problem 4**, A 2 kg mass and a 5 kg mass are attached to either end of a 3 m long massless rod.

a.) Find the center of mass of the system.

Find the rotational inertia (I) of the system when rotated about:

b.) the end with the 2 kg mass.

c.) the end with the 5 kg mass.

d.) the center of the rod.

e.) the center of mass of the system.

f.) If the system is rotated about the center of mass by a force of 8 N acting on the 5 kg mass, (perpendicular to the rod), what will the size of the angular acceleration of the system be?

**Solution.** (a) We will calculate the x-coordinate of the CM, with \( x = 0 \) at the position of the smaller mass, as shown.

\[
X_{CM} = \frac{1}{m_1 + m_2} (m_1 x_1 + m_2 x_2) = \frac{1}{7 \text{ kg}} ((2 \text{ kg})(0) + (5 \text{ kg})(3 \text{ m})) = 2.143 \text{ m}
\]

It makes sense that CM is closer to the larger mass.

(b) To find the rotational inertia (the moment of inertia \( I \)) about various points, we will use the simple expression for point masses, Here we do not consider the size and radius of the masses. The question was asking as if the masses are mass points.

\[
I = m_1 r_1^2 + m_2 r_2^2
\]

Rotating around to the left end, \( r_1=0 \), \( I = m_1 L^2 = (5 \text{ kg})(3 \text{ m})^2 = 45 \text{ kg-m}^2 \)

(c) Now Rotating around to the right end, \( r_2=0 \):
\[ I = m_1 L^2 = (2 \text{ kg})(3 \text{ m})^2 = 18 \text{ kg-m}^2 \]

\textbf{(d)} Now about the point \( x = L/2 \):

\[ I = m_1 \left( \frac{L}{2} \right)^2 + m_2 \left( \frac{L}{2} \right)^2 = (2 \text{ kg})(1.5 \text{ m})^2 + (5 \text{ kg})(1.5 \text{ m})^2 = 15.75 \text{ kg-m}^2 \]

\textbf{(e)} About \( x = 2.143 \text{ m} \):

\[ I = m_1 (2.143 \text{ m})^2 + m_2 (L - 2.143 \text{ m})^2 = (2 \text{ kg})(2.143 \text{ m})^2 + (5 \text{ kg})(0.857 \text{ m})^2 = 12.86 \text{ kg-m}^2 \]

It is interesting to notice that the minimum moment of inertia is always about the CM. As we discussed in the class. CM is a special point where all mass points are distributed not too far away from it. CM minimizes its distance to all mass points. As a result, when the system rotates around any other axis, the masses are distributed further from the axis than to the CM, hence the moment of inertia respect to any other axis will be more than that respect to the CM.

\textbf{(f)} The torque about the CM from this force would be equal to the force times the distance from where it acts to the CM:

\[ \tau = Fd = (8 \text{ N})(0.857 \text{ m}) = 6.856 \text{ N-m} \]

This gives an angular acceleration of

\[ \alpha = \frac{\tau}{I} = \frac{6.856 \text{ N-m}}{12.86 \text{ kg-m}^2} = 0.533 \text{ rad/s}^2 \]