Chapter 10

1

Rotation Of A Rigid Object About A Fixed Axis

1

Lecture 04

2

Torque

2

Torque

3

Torque,τ, is the tendency of a force to rotate an object about some axis.

Torque is a vector, but we will deal with its magnitude here:

$$\tau = |\vec{r}||\vec{F}|sin\varphi$$

F Is the force

Φ is the angle the force makes with the horizontal

r is the distance between the rotation axis and the point of application of $\vec{F}$.

There is no unique value of the torque on an object.

Its value depends on the choice of a rotational axis.

3

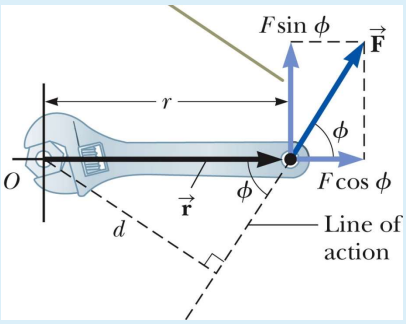
Torque, cont

4

- The moment arm, d, is the *perpendicular* distance from the axis of rotation to a line drawn along the direction of the force.

$$d = rsin\varphi$$

- The horizontal component of the force ($Fcos\varphi$) has no tendency to produce a rotation.



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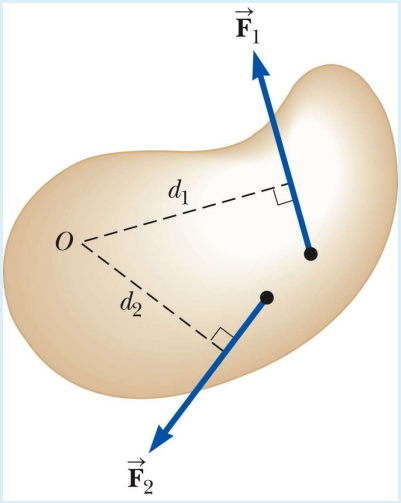
Net Torque

5

- Torque will have direction.
  - If the turning tendency of the force is counterclockwise, the torque will be positive.
  - If the turning tendency is clockwise, the torque will be negative.
- force $\vec{F}_1$ will tend to cause a counterclockwise rotation about O.
- The force $\vec{F}_2$ will tend to cause a clockwise rotation about O.

$$\sum \tau = \tau_1 + \tau_2 = F_1 d_1 - F_2 d_2$$



5

Torque vs. Force

6

- Forces can cause a change in translational motion.
  - Described by Newton's Second Law
- Forces can cause a change in rotational motion.
  - The effectiveness of this change depends on the force and the moment arm.
  - The change in rotational motion depends on the torque.

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Torque Units

- The SI units of torque are $N.m$.
  - Although torque is a force multiplied by a distance, it is very different from work and energy.
  - The units for torque are reported in $N.m$ and not changed to Joules.

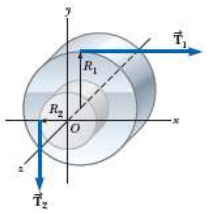
The Net Torque on a Cylinder

Saturday, 30 January, 2021 16:19

Lecturer: Mustafa Al-Zyout, Philadelphia University, Jordan.

- [x] R. A. Serway and J. W. Jewett, Jr., *Physics for Scientists and Engineers*, 9th Ed., CENGAGE Learning, 2014.
- [ ] J. Walker, D. Halliday and R. Resnick, *Fundamentals of Physics*, 10th ed., WILEY,2014.
- [ ] H. D. Young and R. A. Freedman, *University Physics with Modern Physics*, 14th ed., PEARSON, 2016.
- [ ] H. A. Radi and J. O. Rasmussen, *Principles of Physics For Scientists and Engineers*, 1st ed., SPRINGER, 2013.

- What is the net torque acting on the cylinder about the rotation axis (which is the z axis)?
- Suppose $T_1 = 5\,N$, $R_1 = 1\,m$, $T_2 = 15\,N$ and $R_2 = 0.5\,m$. What is the net torque about the rotation axis, and which way does the cylinder rotate starting from rest?



$$\sum \tau = \tau_1 + \tau_2 = R_2T_2 - R_1T_1$$

Substitute the given values: $\sum \tau = (0.50\text{ m})(15\text{ N}) - (1.0\text{ m})(5.0\text{ N}) = 2.5\text{ N}\cdot\text{m}$

Because this net torque is positive, the cylinder begins to rotate in the counterclockwise direction.

The Torque Vector

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A force of $\vec{F} = 2\hat{\imath} + 3\hat{\jmath}$ (N) is applied to an object that is pivoted about a fixed axis aligned along the z coordinate axis. The force is applied at a point located at $\vec{r} = 4\hat{\imath} + 5\hat{\jmath}$ (m). Find the torque applied to the object.

$$\vec{\tau} = \vec{\mathbf{r}} \times \vec{\mathbf{F}} = [(4.00\,\hat{\mathbf{i}} + 5.00\,\hat{\mathbf{j}})\ \mathrm{m}] \times [(2.00\,\hat{\mathbf{i}} + 3.00\,\hat{\mathbf{j}})\ \mathrm{N}]$$

$$\vec{\tau} = [(4.00)(2.00)\,\hat{\mathbf{i}} \times \hat{\mathbf{i}} + (4.00)(3.00)\,\hat{\mathbf{i}} \times \hat{\mathbf{j}} + (5.00)(2.00)\hat{\mathbf{j}} \times \hat{\mathbf{i}} + (5.00)(3.00)\hat{\mathbf{j}} \times \hat{\mathbf{j}}]\,\mathrm{N \cdot m}$$

$$\vec{\tau} = [0 + 12.0\hat{\mathbf{k}} - 10.0\hat{\mathbf{k}} + 0]\,\mathrm{N \cdot m} = 2.0\hat{\mathbf{k}}\,\mathrm{N \cdot m}$$

Torque on a particle due to a force

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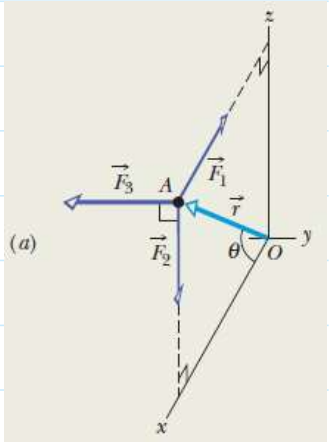
Three forces, each of magnitude $2\,N$, act on a particle, as shown. The particle is in the plane at point A given by position vector $\vec{r}$, where $r = 3\,m$ and $\theta = 30^{\circ}$. What is the torque, about the origin O, due to each force?



$$\tau_1 = rF_1 \sin\phi_1 = (3.0\text{ m})(2.0\text{ N})(\sin 150^\circ) = 3.0\text{ N}\cdot\text{m},$$
$$\tau_2 = rF_2 \sin\phi_2 = (3.0\text{ m})(2.0\text{ N})(\sin 120^\circ) = 5.2\text{ N}\cdot\text{m},$$
$$\text{and}\quad \tau_3 = rF_3 \sin\phi_3 = (3.0\text{ m})(2.0\text{ N})(\sin 90^\circ)$$
$$= 6.0\text{ N}\cdot\text{m}. \qquad \text{(Answer)}$$