Mr. Wright's Math Extravaganza

Physical Sciences

(Chemistry, Physics, Physical Science)

Force

Units 02 Newton's Laws, 03 Uniform Circular Motion, 04 Momentum

Average Level for All Three Units

Level 2.0: 70% on test, Level 3.0: 80% on test, Level 4.0: level 3.0 and success on bumper lab

Score	I Can Statements
4.0	☐ I can design a device that minimizes force on an object during a collision and justify its design.
3.5	In addition to score 3.0 performance, partial success at score 4.0 content.
3.0	**02 Newton's Laws** ☐ I can use Newton's second law of motion to describe the mathematical relationships between net force, acceleration, and mass. **03 Uniform Circular Motion** ☐ I can explain how unbalanced forces applied to a system can cause a change in its rotational motion. **04 Momentum** ☐ I can explain how to minimize force on an object during a collision. ☐ I can explain why the total momentum of a system of objects is conserved when there is no net force on the system.
2.5	No major errors or omissions regarding score 2.0 content, and partial success at score 3.0 content.
2.0	**02 Newton's Laws** ☐ I can explain why force and acceleration are often represented with vectors. ☐ I can defend Newton's first law of motion by explaining what a balanced net force of zero means when related to objects in motion and at rest. ☐ I can explain the difference between mass and weight and their common measurement units. ☐ I can recall the equation for Newton's second law of motion. ☐ I can explain Newton's third law of motion. **03 Uniform Circular Motion** ☐ I can calculate torque on a rotating object. ☐ I can calculate how changes in the moment of inertia cause changes to its rotational velocity. **04 Momentum** ☐ I can use Newton's second law of motion and the equation for acceleration to find the relationship between impulse and momentum change. ☐ I can explain the inverse relationship between force and time using the equations for impulse and momentum change. ☐ I can explain why objects colliding for the same amount of time experience equal impulse in opposite directions, and therefore equal and opposite changes in momentum. ☐ I can recall the law of conservation of momentum. ☐ I can compare the initial and final momenta of objects in a collision.

	☐ I can determine the degree to which a collision is elastic or inelastic by determining whether kinetic energy is conserved. ☐ I can assess the force, momentum, impulse, and velocity associated with real-world examples of the rebound effect and elastic and inelastic collisions.
1.5	Partial success at score 2.0 content, and major errors or omissions regarding score 3.0 content.
1.0	With help, partial success at score 2.0 content and score 3.0 content.
0.5	With help, partial success at score 2.0 content but not at score 3.0 content.
0.0	Even with help, no success.

Physics 03-01 Rotation Angle and Centripetal Acceleration **Name: __________________________**

Uniform Circular Motion

Motion in ___________ with constant ___________

Rotation Angle ($\Delta\theta$)

___________ through which an object ___________

Arc Length (Δs)

- ___________ around part of a ___________

$$\Delta\theta = \frac{\Delta s}{r}$$

Angle Units

- 1 Circle = 1 revolution
- 1 Circle = 360°
- 1 Circle = 2π radians

Arc length must be in ___________

Convert 60° to radians

Convert 2 revolutions to radians

Angular Velocity (ω)

How fast an object ___________

$$\omega = \frac{\Delta\theta}{\Delta t}$$

Unit: rad/s CCW___________ CW___________

$$v = r\omega$$

A CD rotates 320 times in 2.4 s. What is its angular velocity in rad/s? What is the linear velocity of a point 5 cm from the center?

Centripetal Acceleration

$$a_c = \frac{v^2}{r} = r\omega^2$$

At any given moment

v is pointing ___________ to the circle

a_c is pointing towards the ___________ of the circle

If the object suddenly broke from circular motion would travel in ___________ ___________ to circle

Two identical cars are going around two corners at 30 m/s. Each car can handle up to 1 g. The radius of the first curve is 50m and the radius of the second is 100 m. Do either of the cars make the curve? (Hint: find the a_c)

Physics 03-01 Rotation Angle and Centripetal Acceleration **Name: ___________________________**

Practice Work

1. The speedometer of your car shows you are traveling at a constant speed of 35 m/s. Is it possible that your car is accelerating? If so, explain how this could happen.
2. The equations of kinematics describe the motion of an object that has a constant acceleration. These equations cannot be applied to uniform circular motion. Why not?
3. Is it possible for an object to have an acceleration when the velocity of the object is constant? When the speed of the object is constant? In each case, give your reasoning.
4. There is an analogy between rotational and linear physical quantities. What rotational quantities are analogous to distance and velocity?
5. Can centripetal acceleration change the speed of circular motion? Explain.
6. Microwave ovens rotate at a rate of about 6 rev/min. (a) What is this in revolutions per second? (b) What is the angular velocity in radians per second? (OpenStax 6.2) **0.1 rev/s, 0.63 rad/s**
7. (a) What is the period of rotation of Earth in seconds? (b) What is the angular velocity of Earth? (c) Given that Earth has a radius of 6.4×10^6 m at its equator, what is the linear velocity at Earth's surface? (OpenStax 6.4) **86400 s, $\mathbf{7.3 \times 10^{-5}}$ rad/s, 470 m/s**
8. A baseball pitcher brings his arm forward during a pitch, rotating the forearm about the elbow. If the velocity of the ball in the pitcher's hand is 35.0 m/s and the ball is 0.300 m from the elbow joint, what is the angular velocity of the forearm? (OpenStax 6.5) **117 rad/s**
9. In lacrosse, a ball is thrown from a net on the end of a stick by rotating the stick and forearm about the elbow. If the angular velocity of the ball about the elbow joint is 30.0 rad/s and the ball is 1.30 m from the elbow joint, what is the velocity of the ball? (OpenStax 6.6) **39.0 m/s**
10. A car travels at a constant speed around a circular track whose radius is 2.6 km. The car goes once around the track in 360 s. What is the magnitude of the centripetal acceleration of the car? (Cutnell 5.2) **0.79 m/s^2**
11. Computer-controlled display screens provide drivers in the Indianapolis 500 with a variety of information about how their cars are performing. For instance, as a car is going through a turn, a speed of 221 mi/h (98.8 m/s) and a centripetal acceleration of 3.00g (three times the acceleration due to gravity) are displayed. Determine the radius of the turn (in meters). (Cutnell 5.5) **332 m**
12. There is a clever kitchen gadget for drying lettuce leaves after you wash them. It consists of a cylindrical container mounted so that it can be rotated about its axis by turning a hand crank. The outer wall of the cylinder is perforated with small holes. You put the wet leaves in the container and turn the crank to spin off the water. The radius of the container is 12 cm. When the cylinder is rotating at 2.0 rev/s, what is the magnitude of the centripetal acceleration at the outer wall. (Cutnell 5.6) **19 m/s^2**
13. Each of the space shuttle's main engines is fed liquid hydrogen by a high-pressure pump. Turbine blades inside the pump rotate at 617 rev/s. A point on one of the blades traces out a circle with a radius of 0.020 m as the blade rotates. (a) What is the magnitude of the centripetal acceleration that the blade must sustain at this point? (b) Express this acceleration as a multiple of g. (Cutnell 5.8) **$\mathbf{3.0 \times 10^5}$ m/s^2, $\mathbf{3.1 \times 10^4}$ g**
14. A fairground ride spins its occupants inside a flying saucer-shaped container. If the horizontal circular path the riders follow has an 8.00 m radius, at how many revolutions per minute will the riders be subjected to a centripetal acceleration 1.50 times that due to gravity? (OpenStax 6.10) **12.9 rev/min**
15. The propeller of a World War II fighter plane is 2.30 m in diameter. (a) What is its angular velocity in radians per second if it spins at 1200 rev/min? (b) What is the linear speed of its tip at this angular velocity if the plane is stationary on the tarmac? (c) What is the centripetal acceleration of the propeller tip under these conditions? Calculate it in meters per second squared and convert to multiples of g. (OpenStax 6.13) **126 rad/s, 145 m/s, $\mathbf{1.82 \times 10^4}$ m/s, $\mathbf{1.85 \times 10^3}$ g**
16. Olympic ice skaters are able to spin at about 5 rev/s. (a) What is their angular velocity in radians per second? (b) What is the centripetal acceleration of the skater's nose if it is 0.120 m from the axis of rotation? (c) An exceptional skater named Dick Button was able to spin much faster in the 1950s than anyone since—at about 9 rev/s. What was the centripetal acceleration of the tip of his nose, assuming it is at 0.120 m radius? (d) Comment on the magnitudes of the accelerations found. It is reputed that Button ruptured small blood vessels during his spins. (OpenStax 6.16) **31.4 rad/s, 118 m/s^2, 384 m/s^2**
17. A rotating space station is said to create "artificial gravity"—a loosely-defined term used for an acceleration that would be crudely similar to gravity. The outer wall of the rotating space station would become a floor for the astronauts, and centripetal acceleration supplied by the floor would allow astronauts to exercise and maintain muscle and bone strength more naturally than in non-rotating space environments. If the space station is 200 m in diameter, what angular velocity would produce an "artificial gravity" of 9.80m/s^2 at the rim? (OpenStax 6.19) **0.313 rad/s**

Centripetal Force

Newton's Second Law

$$F = ma$$

$$F_C = \frac{mv^2}{r} = mr\omega^2$$

Some other ___________ creates ___________ force

- Swinging something from a string →___________
- Satellite in orbit →___________
- Car going around curve →___________

A 1.25-kg toy airplane is attached to a string and swung in a circle with radius = 0.50 m. What was the centripetal force for a speed of 20 m/s? What provides the F_C?

What affects F_C more: a change in mass, a change in radius, or a change in speed?

Why do objects seem to fly away from circular motion?

How does the spin cycle in a washing machine work?

Practice Work

1. A bug lands on a windshield wiper. Explain why the bug is more likely to be dislodged when the wipers are turned on at the high rather than the low setting.
2. A penny is placed on a rotating turntable. Where on the turntable does the penny require the largest centripetal force to remain in place? Explain.
3. Define centripetal force. Can any type of force (for example, tension, gravitational force, friction, and so on) be a centripetal force? Can any combination of forces be a centripetal force?
4. If centripetal force is directed toward the center, why do you feel that you are 'thrown' away from the center as a car goes around a curve? Explain.

5. A 0.015-kg ball is shot from the plunger of a pinball machine. Because of a centripetal force of 0.028 N, the ball follows a circular arc whose radius is 0.25 m. What is the speed of the ball? (Cutnell 5.11) **0.68 m/s**
6. In a skating stunt known as "crack-the-whip," a number of skaters hold hands and form a straight line. They try to skate so that the line rotates about the skater at one end, who acts as the pivot. The skater farthest out has a mass of 80.0 kg and is 6.10 m from the pivot. He is skating at a speed of 6.80 m/s. Determine the magnitude of the centripetal force that acts on him. (Cutnell 5.12) **606 N**
7. At an amusement park there is a ride in which cylindrically shaped chambers spin around a central axis. People sit in seats facing the axis, their backs against the outer wall. At one instant the outer wall moves at a speed of 3.2 m/s, and an 83-kg person feels a 560-N force pressing against his back. what is the radius of a chamber? (Cutnell 5.14) **1.5 m**
8. (a) A 22.0 kg child is riding a playground merry-go-round that is rotating at 40.0 rev/min. What centripetal force must she exert to stay on if she is 1.25 m from its center? (b) What centripetal force does she need to stay on an amusement park merry-go-round that rotates at 3.00 rev/min if she is 8.00 m from its center? (OpenStax 6.23) **483 N, 17.4 N**
9. Calculate the centripetal force on the end of a 100 m (radius) wind turbine blade that is rotating at 0.5 rev/s. Assume the mass is 4 kg. (OpenStax 6.24) $\mathbf{4 \times 10^3}$ **N**
10. The Earth with mass 5.98×10^{24} kg orbits the sun in an approximately circular orbit with radius 147 billion meters. (a) What provides the centripetal force? (b) What is the centripetal force required to keep the Earth in its orbit? (Hint: find the angular velocity in rad/s first. It takes 1 year for the Earth to orbit the sun.) (RW) **(b)** $\mathbf{3.48\times10^{22}}$ **N**
11. A baseball pitcher throws a ball at 90 mph (40.2 m/s). Right before the ball is thrown, it is traveling in a circular arc by the pitcher's arm. If the mass of the baseball is 0.145 kg and the pitcher's arm is 63.5 cm, what centripetal force on the baseball? (RW) **369 N**
12. A Chevy Corvette Z06 will slide on a corner if the centripetal force is greater than 2.00×10^4 N (1.19 g). If the mass of the car is 1710 kg and is traveling at 1.00×10^2 m/s, what is the smallest radius of an unbanked corner it can go around without slipping? (RW) **855 m**

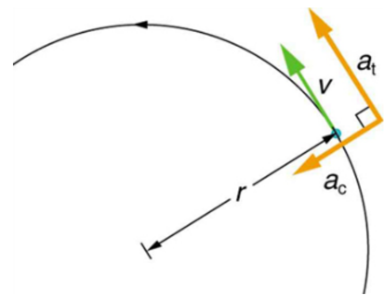
Physics 03-03 Kinematics of Rotational Motion | *Name: ________________*

Rotational motion

Describes ______________ motion

- θ is like ______________
  - $x = r\theta \rightarrow$ ______________
- ω is like ______________
  - $\omega = \frac{\Delta\theta}{\Delta t}$
  - $v = r\omega \rightarrow$ ______________
- α is like ______________
  - $\alpha = \frac{\Delta\omega}{\Delta t}$
  - $a_t = r\alpha \rightarrow$ ______________

Two ______________ to acceleration



- ______________
  - Toward ______________
  - Changes ______________ only since ______________ to v
  - $a_c = \frac{v^2}{r}$
- ______________ (linear)
  - ______________ to circle
  - Changes ______________ only since ______________ to v
  - ______________

Equations of kinematics for rotational motion are same as for linear motion

$$\theta = \overline{\omega}t$$
$$\omega = at + \omega_0$$
$$\theta = \frac{1}{2}\alpha t^2 + \omega_0 t$$
$$\omega^2 = \omega_0^2 + 2\alpha\theta$$

Reasoning Strategy

1. ______________ the situation to determine if ______________ motion involved
2. Identify the ______________ (a ______________ can be useful)
3. Identify the ______________
4. Pick the appropriate ______________ based on the knowns/unknowns
5. ______________ the values into the ______________ and ______________
6. ______________ to see if your answer is ______________

A figure skater is spinning at 0.5 rev/s and then pulls her arms in and increases her speed to 10 rev/s in 1.5 s. What was her angular acceleration?

A ceiling fan has 4 evenly spaced blades of negligible width. As you are putting on your shirt, you raise your hand. It brushes a blade and then is hit by the next blade. If the blades were rotating at 4 rev/s and stops in 0.01 s as it hits your hand, what angular displacement did the fan move after it hit your hand?

Practice Work

1. Explain why centripetal acceleration changes the direction of velocity in circular motion but not its magnitude.
2. In circular motion, a tangential acceleration can change the magnitude of the velocity but not its direction. Explain.
3. Suppose a piece of food is on the edge of a rotating microwave oven plate. Does it experience nonzero tangential acceleration, centripetal acceleration, or both when: (a) The plate starts to spin? (b) The plate rotates at constant angular velocity? (c) The plate slows to a halt?
4. At its peak, a tornado is 60.0 m in diameter and carries 500 km/h winds. What is its angular velocity in revolutions per second? (OpenStax 10.1) **0.737 rev/s**
5. An ultracentrifuge accelerates from rest to 100,000 rpm in 2.00 min. (a) What is its angular acceleration in rad/s^2? (b) What is the tangential acceleration of a point 9.50 cm from the axis of rotation? (c) What is the radial acceleration in m/s^2 and multiples of g of this point at full rpm? (OpenStax 10.2) **87.3 rad/s^2, 8.29 m/s^2, $\mathbf{1.04 \times 10^7}$ m/s^2, $\mathbf{1.06 \times 10^6}$ *g***
6. With the aid of a string, a gyroscope is accelerated from rest to 32 rad/s in 0.40 s. (a) What is its angular acceleration in rad/s^2? (b) How many revolutions does it go through in the process? (OpenStax 10.5) **80 rad/s^2, 1.0 rev**
7. Suppose a piece of dust finds itself on a CD. If the spin rate of the CD is 500 rpm, and the piece of dust is 4.3 cm from the center, what is the total distance traveled by the dust in 3 minutes? (Ignore accelerations due to getting the CD rotating.) (OpenStax 10.6) **405 m**
8. A gyroscope slows from an initial rate of 32.0 rad/s at a rate of 0.700 rad/s^2. (a) How long does it take to come to rest? (b) How many revolutions does it make before stopping? (OpenStax 10.7) **45.7 s, 116 rev**
9. During a very quick stop, a car decelerates at 7.00 m/s^2. (a) What is the angular acceleration of its 0.280-m-radius tires, assuming they do not slip on the pavement? (b) How many revolutions do the tires make before coming to rest, given their initial angular velocity is 95.0 rad/s? (c) How long does the car take to stop completely? (d) What distance does the car travel in this time? (e) What was the car's initial velocity? (f) Do the values obtained seem reasonable, considering that this stop happens very quickly? (OpenStax 10.8) **−25.0 rad/s^2, 28.7 rev, 3.80 s, 50.5 m, 26.6 m/s, reasonable**

Physics 03-04 Torque	Name: _______________________
First Condition of Equilibrium	

- Equilibrium means no _____________

First condition of equilibrium

- $net\ F = 0$
- _____________ and _____________
- They can still _____________, so…

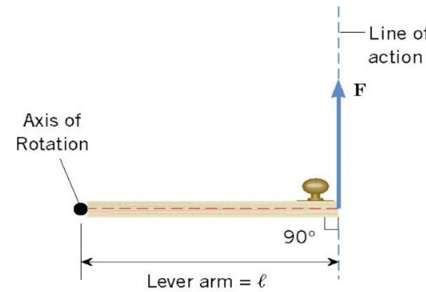
Torque

$$\tau = F \times r$$

This means we use the component of the _____________ that is _______________ to the _____________ arm

$$\tau = F_{\perp} r$$
$$\tau = Fr\sin\theta$$

- Where θ is the angle between the _____________ and the _____________
- Unit: Nm
- CCW: _____________
- CW: _____________

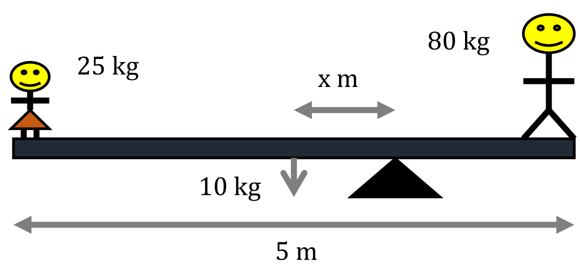


You are meeting the parents of your new "special" friend for the first time. After being at their house for a couple of hours, you walk out to discover the little brother has let all the air out of one of your tires. Not knowing the reason for the flat tire, you decide to change it. You have a 50-cm long lug-wrench attached to a lugnut as shown. If 900 Nm of torque is needed, how much force is needed?

Second condition of equilibrium

- _____________

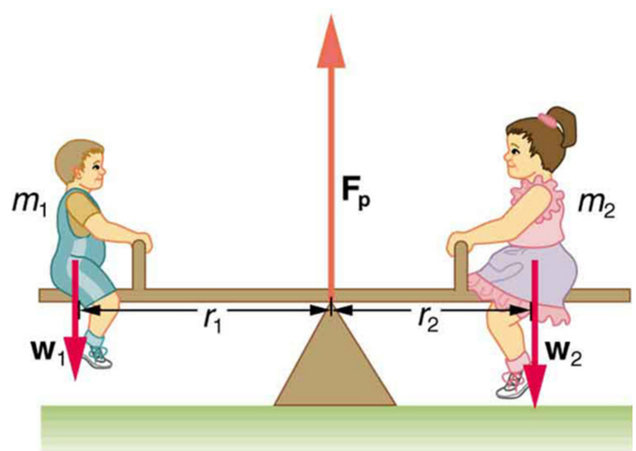
A 5 m, 10 kg seesaw is balanced by a little girl (25 kg) and her father (80 kg) at opposite ends as shown below. How far from the seesaw's center of mass must the fulcrum be placed?



How much force must the fulcrum support?

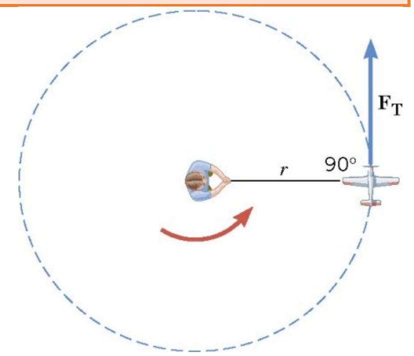
Physics 03-04 Torque	***Name: ________________________***
Practice Work	

1. What can you say about the velocity of a moving body that is in dynamic equilibrium? Draw a sketch of such a body using clearly labeled arrows to represent all external forces on the body.
2. Under what conditions can a rotating body be in equilibrium? Give an example.
3. What three factors affect the torque created by a force relative to a specific pivot point?
4. A wrecking ball is being used to knock down a building. One tall unsupported concrete wall remains standing. If the wrecking ball hits the wall near the top, is the wall more likely to fall over by rotating at its base or by falling straight down? Explain your answer. How is it most likely to fall if it is struck with the same force at its base? Note that this depends on how firmly the wall is attached at its base.
5. Mechanics sometimes put a length of pipe over the handle of a wrench when trying to remove a very tight bolt. How does this help? (It is also hazardous since it can break the bolt.)
6. (a) When opening a door, you push on it perpendicularly with a force of 55.0 N at a distance of 0.850m from the hinges. What torque are you exerting relative to the hinges? (b) Does it matter if you push at the same height as the hinges? (OpenStax 9.1) **46.8 Nm**
7. When tightening a bolt, you push perpendicularly on a wrench with a force of 165 N at a distance of 0.140 m from the center of the bolt. (a) How much torque are you exerting in newton × meters (relative to the center of the bolt)? (b) Convert this torque to footpounds. (OpenStax 9.2) **23.1 Nm, 17.0 ft lb**
8. Two children push on opposite sides of a door during play. Both push horizontally and perpendicular to the door. One child pushes with a force of 17.5 N at a distance of 0.600 m from the hinges, and the second child pushes at a distance of 0.450 m. What force must the second child exert to keep the door from moving? Assume friction is negligible. (OpenStax 9.3) **23.3 Nm**
9. The two children shown in the are balanced on a seesaw of negligible mass. (This assumption is made to keep the example simple—more involved examples will follow.) The first child has a mass of 26.0 kg and sits 1.60 m from the pivot. (a) If the second child has a mass of 32.0 kg, how far is she from the pivot? (b) What is $F_{\perp}$, the supporting force exerted by the pivot using the second condition for equilibrium (net $\tau = 0$), employing any data given or solved for in part (a). (OpenStax 9.4) **1.30 m, 568 N**
10. Repeat the previous problem with the center of mass of the seesaw 0.160 m to the left of the pivot (on the side of the lighter child) and assuming a mass of 12.0 kg for the seesaw. The other data given in the example remain unchanged. (OpenStax 9.5) **1.36 m, 686 N**



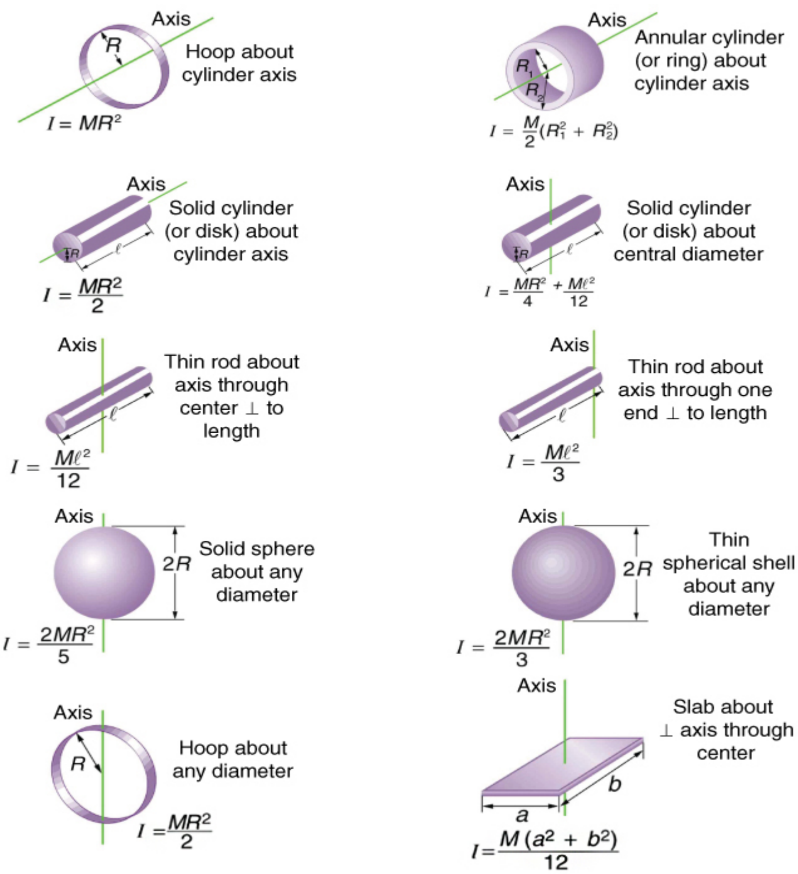
Physics 03-05 Moment of Inertia **_Name: _________________________**

Dynamics of Rotational Motion



Newton's Second Law for Rotation

- ______________
  - α is in ______________
- $I = mr^2$ → Moment of ______________ of a ______________
- Moment of Inertia (I) measures how much an ______________ wants to keep ______________ (or not start ______________)
  - Use ______________ to find $I = \sum mr^2$
  - Unit: ______________



The St. Joseph River Swing Bridge in St. Joseph, Michigan has a mass of 300 tons (2.72×10^5 kg) and is 231 ft (70.4 m) long. If the motor produces 563 kNm of torque and takes 10 s to accelerate the bridge to 0.05 rad/s, what is the bridge's moment of inertia?

A spinning ride at a carnival is accelerating at 4 rad/s^2. If the ride is shaped like a hoop, and the motor is exerting 128000 Nm of torque, what is the radius of the 500 kg ride?

Physics 03-05 Moment of Inertia	*Name: ________________________*
Practice Work	

1. The moment of inertia of a long rod spun around an axis through one end perpendicular to its length is $\frac{ML^2}{3}$. Why is this moment of inertia greater than it would be if you spun a point mass M at the location of the center of mass of the rod (at $\frac{L}{2}$)? (That would be $\frac{ML^2}{4}$.)
2. Why is the moment of inertia of a hoop that has a mass M and a radius R greater than the moment of inertia of a disk that has the same mass and radius? Why is the moment of inertia of a spherical shell that has a mass M and a radius R greater than that of a solid sphere that has the same mass and radius?
3. Give an example in which a small force exerts a large torque. Give another example in which a large force exerts a small torque.
4. While reducing the mass of a racing bike, the greatest benefit is realized from reducing the mass of the tires and wheel rims. Why does this allow a racer to achieve greater accelerations than would an identical reduction in the mass of the bicycle's frame?
5. Calculate the moment of inertia of a skater given the following information. (a) The 60.0-kg skater is approximated as a cylinder that has a 0.110-m radius. (b) The skater with arms extended is approximately a cylinder that is 52.5 kg, has a 0.110-m radius, and has two 0.900-m-long arms which are 3.75 kg each and extend straight out from the cylinder like rods rotated about their ends. (OpenStax 10.11) $\mathbf{0.363\ kg \cdot m^2}$, $\mathbf{2.34\ kg \cdot m^2}$
6. The triceps muscle in the back of the upper arm extends the forearm. This muscle in a professional boxer exerts a force of 2.00×10^3 N with an effective perpendicular lever arm of 3.00 cm, producing an angular acceleration of the forearm of 120 rad/s^2. What is the moment of inertia of the boxer's forearm? (OpenStax 10.12) $\mathbf{0.500\ kg \cdot m^2}$
7. A soccer player extends her lower leg in a kicking motion by exerting a force with the muscle above the knee in the front of her leg. She produces an angular acceleration of 30.00 rad/s^2 and her lower leg has a moment of inertia of 0.750 kg · m^2. What is the force exerted by the muscle if its effective perpendicular lever arm is 1.90 cm? (OpenStax 10.13) $\mathbf{1.18 \times 10^3\ N}$
8. Suppose you exert a force of 180 N tangential to a 0.280-m-radius 75.0-kg grindstone (a solid disk). (a) What torque is exerted? (b) What is the angular acceleration assuming negligible opposing friction? (c) What is the angular acceleration if there is an opposing frictional force of 20.0 N exerted 1.50 cm from the axis? (OpenStax 10.14) $\mathbf{50.4\ N \cdot m}$, $\mathbf{17.1\ rad/s^2}$, $\mathbf{17.0\ rad/s^2}$
9. Consider the 12.0 kg motorcycle wheel shown in Figure 1. Assume it to be approximately an annular ring with an inner radius of 0.280 m and an outer radius of 0.330 m. The motorcycle is on its center stand, so that the wheel can spin freely. (a) If the drive chain exerts a force of 2200 N at a radius of 5.00 cm, what is the angular acceleration of the wheel? (b) What is the tangential acceleration of a point on the outer edge of the tire? (c) How long, starting from rest, does it take to reach an angular velocity of 80.0 rad/s? (OpenStax 10.15) $\mathbf{97.9\ \frac{rad}{s^2}}$, $\mathbf{32.3\ \frac{m}{s^2}}$, $\mathbf{0.817\ s}$
10. A child rolls a full can of cream of mushroom soup by applying a 2.00 N force tangential to the edge of the can. The can's diameter is 8.25 cm and its height is 10.8 cm. Its mass is 298 grams. What is the angular acceleration of the can? (RW) **325 rad/s²**

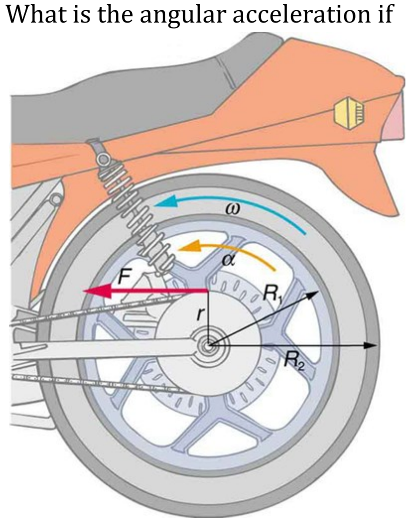


Figure 1

Physics Unit 3: Uniform Circular Motion and Torque Review

1. Know about uniform circular motion, centripetal acceleration, centripetal force, torque, measures of rotational motion (position angle θ, angular velocity ω, angular acceleration α), moment of inertia
2. A car engine idles at 900 rpm. What is this in rad/s?
3. A centrifuge spins test tubes in a circle. The centrifuge has a radius of 2 cm and creates 20 m/s^2 of centripetal acceleration. What is the speed of the test tube as it spins?
4. Clothes in a washing machine are spun in a circle with radius 40 cm. If the mass of the clothes is 5 kg, what is the centripetal force when the clothes are moving at 15 m/s?
5. An 80-kg ice skater goes around a 3-m radius corner. She will slip if the centripetal force exceeds 6000 N. What speed can the skater go around the corner without slipping?
6. A string is tied to the end of a lever that pivots at its other end. The lever is 2 m long and the string makes a 50° angle with the lever. If the string is pulled with a force of 20 N, what is the torque on the lever?
7. A playground seesaw has a fulcrum in the center of the board. The board is 10 m long. If a 30-kg child sits on one end, what mass child should sit 3 m from the other end to balance the board?
8. A CD disc is spinning at 100π rad/s. What angle does it spin through in 1 ms?
9. A 50-kg kid is spinning in a centrifuge-like ride with a radius of 3 m. If the angular speed change from 5 rad/s to 100 rad/s in 20 s, what is the tangential acceleration of the test tube?
10. A 100-cm radius propeller is rotating at 500 rad/s and a 0.001-kg piece of gum is stuck to the edge. What is the linear speed of the stone?
11. A 100-cm radius propeller is rotating at 500 rad/s and a 0.001-kg piece of gum is stuck to the edge. What is the centripetal force required to keep the stone from flying out?
12. How much torque is required to accelerate a hollow spherical shell rotating about its center in 4 seconds is its mass is 2 kg, its diameter is 10 cm, its initial speed was 2π rad/s and its final speed is 5π rad/s?
13. A 50-cm diameter hoop has a mass of 2 kg. A person applies 5 Nm of torque so that the hoop rotates about a diameter. What is the angular acceleration of the hoop?
14. What is the moment of inertia of a 10-kg thin rod rotated about the axis through one end perpendicular to its length if its length is 0.5m?

Physics Unit 3: Uniform Circular Motion and Torque Review

Answers

2. $\frac{900 \text{ rev}}{\text{min}}\left(\frac{2\pi\, rad}{1\, rev}\right)\left(\frac{1 \text{ min}}{60\, s}\right) = \boldsymbol{30\pi\, rad/s}$

3. $a_c = \frac{v^2}{r}$

   $20\frac{m}{s^2} = \frac{v^2}{0.02\, m}$

   $0.4\frac{m^2}{s^2} = v^2$

   $\boldsymbol{0.632\frac{m}{s}} = v$

4. $F_c = \frac{mv^2}{r}$

   $F_c = \frac{(5\, kg)\left(15\frac{m}{s}\right)^2}{0.40\, m}$

   $F_c = \boldsymbol{2810\, N}$

5. $F_c = \frac{mv^2}{r}$

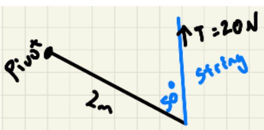
   $6000\, N = \frac{(80\, kg)v^2}{3\, m}$

   $18000\, Nm = (80\, kg)v^2$

   $225\frac{m^2}{s^2} = v^2$

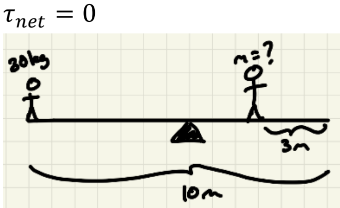
   $\boldsymbol{15\frac{m}{s}} = v$

6. $\tau = Fr\sin\theta$

   $\tau = (20\, N)(2\, m)\sin 50° = \boldsymbol{30.6\, Nm}$

7. $\tau_{net} = 0$

   $(30\, kg)\left(9.8\frac{m}{s^2}\right)(5\, m) - m\left(9.8\frac{m}{s^2}\right)(5\, m - 3\, m) =$
   0

   $1470\, Nm = m\left(19.6\frac{m^2}{s^2}\right)$

   $\boldsymbol{75\, kg} = m$

8. $\omega = \frac{\Delta\theta}{\Delta t}$

   $100\pi\frac{rad}{s} = \frac{\Delta\theta}{1\times10^{-3}\, s}$

   $\boldsymbol{0.1\pi\, rad} = \Delta\theta$

9. $\alpha = \frac{\Delta\omega}{\Delta t}$

   $\alpha = \frac{100 \text{ rad/s} - 5 \text{ rad/s}}{20\, s} = 4.75\, rad/s^2$

   $a_t = r\alpha$

   $a_t = (3\, m)\left(4.75\frac{rad}{s^2}\right)$

   $a_t = \boldsymbol{14.3\frac{m}{s^2}}$

10. $v = r\omega$

    $v = (1\, m)\left(500\frac{rad}{s}\right) = \boldsymbol{500\frac{m}{s}}$

11. $F_c = mr\omega^2$

    $F_c = (0.001\, kg)(1\, m)\left(500\frac{rad}{s}\right)^2 = \boldsymbol{250\, N}$

12. $\tau = I\alpha$

    $I = \frac{2MR^2}{3} = \frac{2(2\, kg)(0.05\, m)^2}{3} = \frac{1}{300}kg\, m^2$

    $\alpha = \frac{\Delta\omega}{\Delta t} = \frac{5\pi \text{ rad/s} - 2\pi \text{ rad/s}}{4s} = \frac{3\pi}{4}\frac{rad}{s^2}$

    $\tau = I\alpha = \left(\frac{1}{300}\, kg\, m^2\right)\left(\frac{3\pi}{4}\frac{rad}{s^2}\right) = \boldsymbol{7.85 \times 10^{-3}\, Nm}$

13. $\tau = I\alpha$

    $I = \frac{MR^2}{2} = \frac{(2\, kg)(0.25\, m)^2}{2} = 0.0625\, kg\, m^2$

    $\tau = I\alpha$

    $5\, Nm = (0.0625\, kg\, m^2)\alpha$

    $\boldsymbol{80\frac{rad}{s^2}} = \alpha$

14. $I = \frac{M\ell^2}{3}$

    $I = \frac{(10\, kg)(0.5\, m)^2}{3} = \boldsymbol{0.833\, kg\, m^2}$