Physics 04-05 Dynamics of Rotational Motion　　　　Name: ____________________

Dynamics of Rotational Motion

Newton's Second Law for Rotation

- ____________
    - α is in ____________
- $I = mr^2 \rightarrow$ 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: ____________

Work for rotation

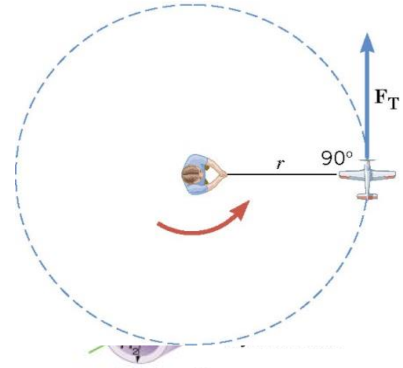
- ____________

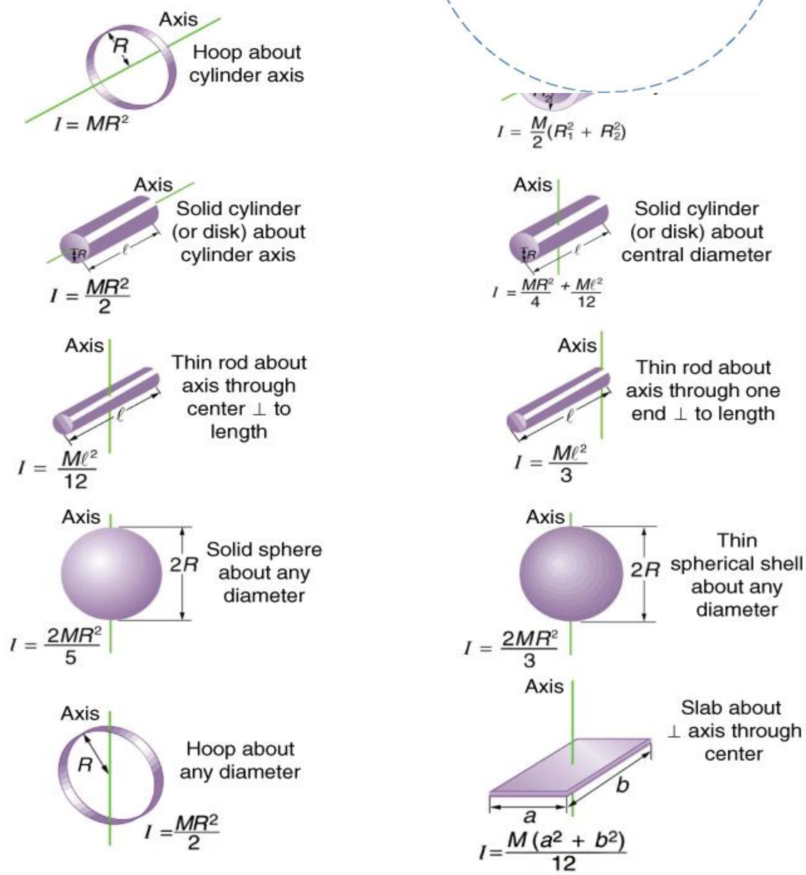
Kinetic Energy

- ____________

Conservation of Mechanical Energy

- $PE_i + KE_i = PE_f + KE_f$
- Remember that the _________ can include both ______________ and ____________.





Zorch, an archenemy of Superman, decides to slow Earth's rotation to once per 28.0 h by exerting an opposing force at and parallel to the equator. Superman is not immediately concerned, because he knows Zorch can only exert a force of 4.00×107 N (a little greater than a Saturn V rocket's thrust). How long must Zorch push with this force to accomplish his goal? (This period gives Superman time to devote to other villains.)

A solid sphere (m = 2 kg and r = 0.25 m) and a thin spherical shell (m = 2 kg and r = 0.25 m) roll down a ramp that is 0.5 m high. What is the velocity of each sphere as it reaches the bottom of the ramp?

Homework

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. Describe the energy transformations involved when a yo-yo is thrown downward and then climbs back up its string to be caught in the user's hand.
6. 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) $\mathbf{0.363\ kg \cdot m^2}$, $\mathbf{2.34\ kg \cdot m^2}$
7. 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) $\mathbf{0.500\ kg \cdot m^2}$
8. 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) $\mathbf{1.18 \times 10^3\ N}$
9. 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) $\mathbf{50.4\ N \cdot m}$, $\mathbf{17.1\ rad/s^2}$, $\mathbf{17.0\ rad/s^2}$
10. 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) $\mathbf{97.9\ rad/s^2}$, $\mathbf{32.3\ m/s}$, $\mathbf{0.817\ s}$
11. What is the final velocity of a hoop that rolls without slipping down a 5.00-m-high hill, starting from rest? (OpenStax 10.22) $\mathbf{7.00\ m/s}$
12. (a) Calculate the rotational kinetic energy of Earth on its axis. (b) What is the rotational kinetic energy of Earth in its orbit around the Sun? (OpenStax 10.23) $\mathbf{2.57 \times 10^{29}\ J}$, $\mathbf{2.65 \times 10^{33}\ J}$
13. Calculate the rotational kinetic energy in the motorcycle wheel (Figure 1) if its angular velocity is 120 rad/s. Assume M = 12.0 kg, R1 = 0.280 m, and R2 = 0.330 m. (OpenStax 10.24) $\mathbf{8.09 \times 10^3\ J}$

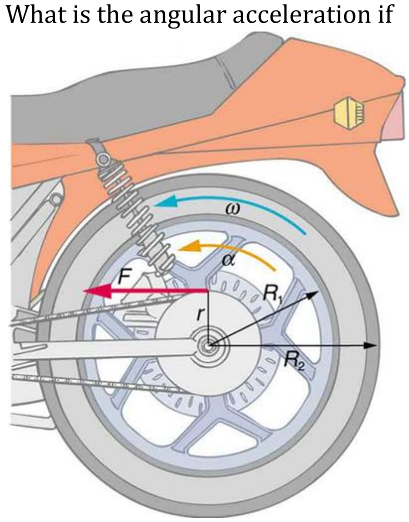


Figure 1

14. A baseball pitcher throws the ball in a motion where there is rotation of the forearm about the elbow joint as well as other movements. If the linear velocity of the ball relative to the elbow joint is 20.0 m/s at a distance of 0.480 m from the joint and the moment of inertia of the forearm is 0.500 kg · m^2, what is the rotational kinetic energy of the forearm? (OpenStax 10.25) $\mathbf{434\ J}$
15. While punting a football, a kicker rotates his leg about the hip joint. The moment of inertia of the leg is 3.75 kg·m^2 and its rotational kinetic energy is 175 J. (a) What is the angular velocity of the leg? (b) What is the velocity of tip of the punter's shoe if it is 1.05 m from the hip joint? (c) Explain how the football can be given a velocity greater than the tip of the shoe (necessary for a decent kick distance). (OpenStax 10.26) $\mathbf{9.66\ rad/s}$, $\mathbf{10.1\ \frac{m}{s}}$