1. An old record player turntable is turned on. It is noted that the disk turns 0.75 revolutions as it goes from rest to 33.3 rpm, clockwise. (a) Determine the disk's final angular velocity in radians per second. (b) Determine the disk's angular acceleration. Now suppose the turntable is switched off and the disk takes 2.00 seconds to come to a stop. (c) Determine the angular acceleration. (d) Determine the angular displacement that occurs during the slow down.

2. Fossil records indicate that the day was 22 hours long about 370 million years ago. (a) Use this information to determine the average rate of angular deceleration of the Earth. (b) If the rate of deceleration is constant in how much time will a day last 25 hours?

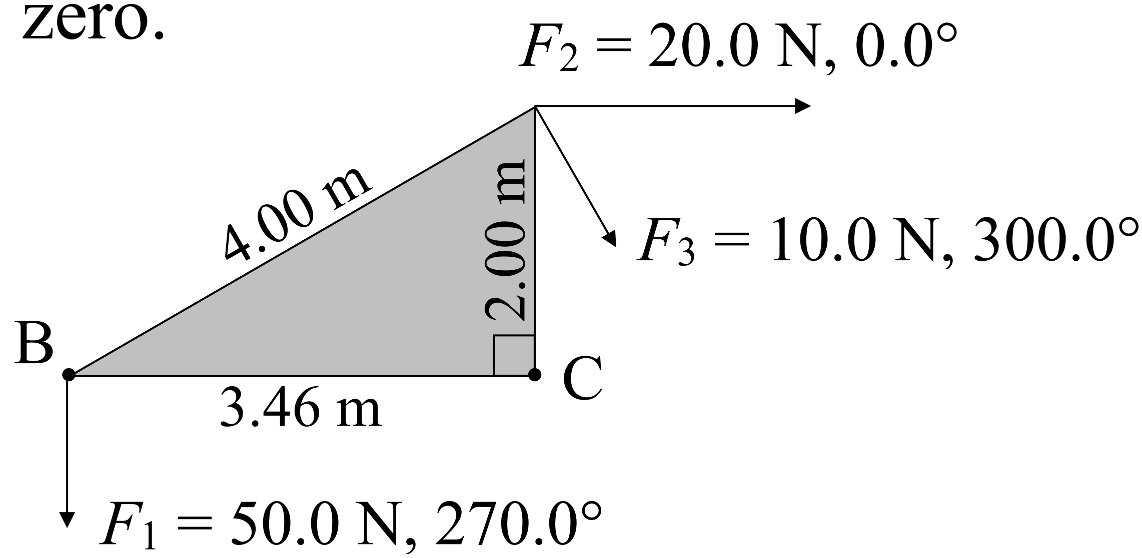
3. Determine the angular velocity and angular acceleration of an object in the classroom. Use these results to determine the velocity and acceleration of a point located on the rotating object.

4. Find the velocity and linear acceleration of a point on the equator of the Earth. Repeat for a point at latitude 36°.

5. The digital “pits” of a CD are designed to pass by the laser of the player’s read head at a constant speed of 1.3 m/s. In order for this to happen the angular speed of the disk must continuously change. (a) Find the angular speed when the laser is at a radius of 2.5 cm (the beginning of the CD). (b) Repeat for a radius of 5.8 cm (the end of the CD). (c) If the CD plays for 74 minutes, what is the angular acceleration? (d) How many revolutions has it made? (e) What is the “pitch” of the spiral track of data (*i.e.* how far apart are the “grooves”)?

6. The tire on a certain car has a diameter of 70.0 cm. Suppose this car accelerates from 0 to 25.0 m/s in 10.0 s. (a) Find the number of rotations the tire will make in this time. (b) Find the final angular speed of the tire. (c) Find the rate of angular acceleration of the tire.

7. Refer to the figure below. (a) Determine the net torque about point C. (b) Determine the net torque about point B. (c) Find the point along line BC about which net torque is zero.



8. Suppose two arbitrary point masses are located at arbitrary points in a vertical plane. Show that gravity's torque about an origin is equal to the cross product of the position of the center of mass and the total weight of the two masses. Would this result work for a larger collection of masses?

9. Suppose a force F acts on a mass m. Show that the torque about an arbitrary origin divided by the angular acceleration equals mr^2. This quantity is called "moment of inertia".

10. Masses of 3.0 kg and 2.0 kg are attached to the ends of a rod of length 0.800 m that has negligible mass. (a) Determine the moment of inertia about the rod's center. (b) Determine the moment of inertia about the 3.0 kg mass. (c) Determine the moment of inertia about the 2.0 kg mass.

11. Find the moment of inertia of a thin rod of mass M and length L about an axis that passes perpendicularly through its center. Repeat for an axis that passes perpendicularly through its end.

12. Find the moment of inertia of a thin ring rotating about an axis that passes perpendicularly through its center.

13. Find the moment of inertia of a thin disk rotating about an axis that passes perpendicularly through its center.

14. Use the previous result to derive the rotational inertia of a uniform solid sphere that rotates about an axis through its center.

15. Find the moment of inertia of a thin disk rotating about an axis that passes along its diameter.

16. Use the parallel axis theorem to determine the moment of inertia of a thin rod rotating about an axis that passes perpendicularly through one end.

17. Use the parallel axis theorem to determine the moment of inertia of a thin rectangular plate rotating about an axis that passes perpendicularly through its center.

18. A certain gyroscope has a solid disk of mass 195 g and radius 3.80 cm which turns with very little friction on an axle of radius 0.10 cm. The gyroscope is set into motion by wrapping 40.0 cm of string around the axle and pulling the end with a constant force of 5.0 N. (a) Determine the rate of angular acceleration. (b) Determine the angular speed that results from this action.

19. Two unequal masses, m_1 and m_2, are attached to a string that passes over a pulley with moment of inertia I and radius R. Determine the acceleration of each mass.

20. A meter stick is free to pivot about one end. The stick is released from a horizontal position and swings like a pendulum.
    (a) Find the initial angular acceleration and linear acceleration of the free end.
    (b) Find the maximum angular speed and maximum linear speed of the free end.

21. A bicycle wheel of mass M and radius R is accelerated by a horizontal force F exerted on its axle. It rolls without slipping. The mass of spokes is negligible. (a) Derive and simplify expressions for the amounts of acceleration and friction. (b) Repeat for a solid cylinder.

22. Repeat the previous problem but now the applied force is at the top of the wheel, acting tangentially in a horizontal direction.

23. Derive an expression for the acceleration of a sphere on a ramp of incline θ, rolling down without slipping. Repeat for the case rolling up the ramp without slipping.

24. An object rolls down a ramp of height h and onto a table of height y and then falls off the end of the table. Find the horizontal distance x that it travels beyond the edge of the table before hitting the floor: (a) if it is a solid sphere, (b) if it is a piece of pipe.

25. A bicycle wheel is spun with initial angular speed ω_0 and released onto the floor with initial speed zero. (a) Find the speed with which the wheel eventually rolls away. (b) Determine the length of the skid mark. Use $I = \frac{3}{4} MR^2$ and $\mu_k = 0.8$.

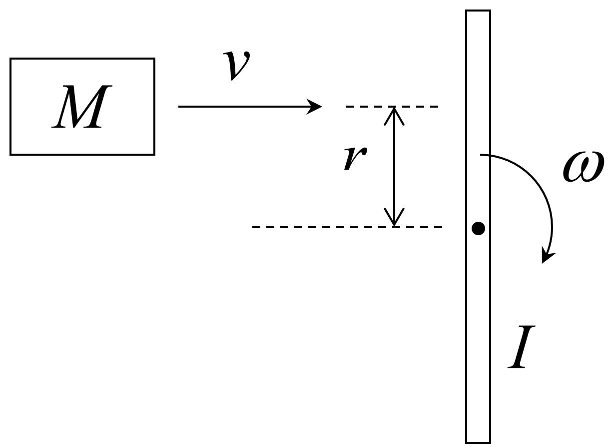
26. Estimate the speed attained by an 80.0 kg cyclist that makes 5 maximal strokes on the pedals. Bicycle specs – ea. wheel: m = 2.2 kg, R = 0.33 m, frame: M = 8.0 kg, crank length L = 0.17 m.

27. Determine the acceleration of a bicycle in terms of the tangential force, F, applied to the pedal, as a function of the following: m = mass of each wheel, M = mass of frame and rider, R = radius of each wheel, r_1 = radius of front sprocket, r_2 = radius of rear sprocket, l = length of pedal's moment arm. Assume bearings are frictionless, rolling resistance is negligible, and that the chain, sprockets, and spokes have negligible mass. Hint: analyze torques and rotation of each wheel and the front chain sprocket and the linear acceleration of the entire system of masses.

28. A ruler of mass 29 grams and length 31 cm is dropped on a spinning horizontal disk of mass 86 grams radius 9.75 cm. After a bit of sliding the two objects spin together with the ruler offset from center by 2.1 cm. Find the percent decrease in kinetic energy.

29. Find the sweet spot for a solid disk. When hit at this spot in the absence of friction it would appear to roll along an invisible surface.

30. A cart of mass M collides with horizontal rod with moment of inertia I. The impact is at a distance r from the rod's axis of rotation. Determine the resulting angular speed of the rod in terms of the cart's change in speed. Ignore friction.



31. Suppose the collision described in the previous problem is perfectly elastic. Determine the value of I that will cause the cart to stop moving.

32. Pluto has speed 3700 m/s at its farthest distance from the Sun, 7.38×10^{12} m. Find the speed of Pluto at its closest distance, 4.44×10^{12} m.

33. Find the speed of Mars at perihelion and at its mean distance from the Sun. (mass of Sun = 1.99×10^{30} kg, mean distance = 2.279×10^{11} m, eccentricity = 0.09346)

34. Due to tidal interaction, the Earth's spin is slowing and the Moon is receding from its current distance of 384.4 Mm, orbiting with period 27.32 days. Eventually the two objects will be tidally locked. Find the eventual separation and period of rotation.
Earth: $m_1 = 5.974 \times 10^{24}$ kg, $R_1 = 6378$ km;
Moon: $m_2 = 7.349 \times 10^{22}$ kg, $R_2 = 1737$ km.

current angular momentum of system:

$$L = I_1\omega_1 + \vec{r}_1 \times \vec{p}_1 + I_2\omega_2 + \vec{r}_2 \times \vec{p}_2$$

(earth: spin + wobble + moon: spin + orbit)

$$L = 5.862 \times 10^{33} + 3.470 \times 10^{33} + 2.361 \times 10^{29} + 2.821 \times 10^{34}$$

$$L = 3.4417 \times 10^{34} \text{ kg m}^2/\text{s}$$

eventual:

$$(L' = 1.273 \times 10^{32} + 4.166 \times 10^{32} + 1.405 \times 10^{29} + 3.387 \times 10^{34})$$