Physics 2210 (Schroeder) Name ____________________
spring 2008

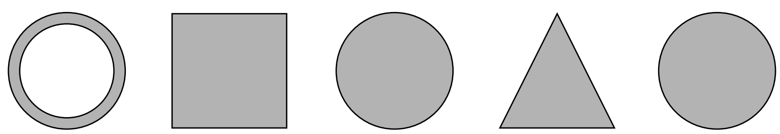
Problem Set 9

(due Tuesday, March 4)

1. A phonograph turntable rotating at $33\frac{1}{3}$ rpm slows down and stops in 30 s after the motor is turned off. (a) What is its average angular acceleration in rev/min^2? What is it in rad/s^2? (b) How many revolutions did it make in this time?

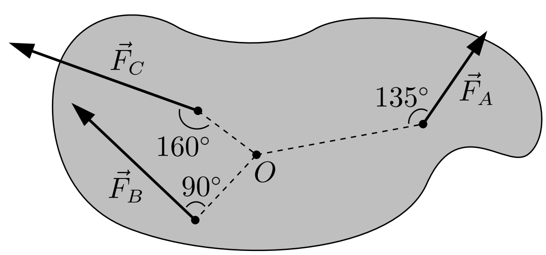
2. A wheel of radius 0.25 m rolls without slipping on horizontal ground. Its initial speed is 42 m/s and it slows down uniformly, coming to a stop after rolling 225 m. (a) What is the (linear) acceleration of the center point on the wheel? (b) What is the wheel's angular acceleration, with respect to the axis through its center? (Hint: If you move along with the wheel's center, what is the acceleration of the ground with respect to you?)

3. Five solids with identical masses are shown in cross section below. The cross sections have equal widths at the widest parts and equal heights (but not necessarily equal thicknesses). (a) Which one has the greatest moment of inertia about an axis through its center, perpendicular to the page? (b) Which has the smallest moment of inertia about such an axis?



4. The length of a bicycle pedal crank is 0.152 m. A foot applies a vertical, downward force of 111 N on the pedal. What is the magnitude of the torque about the axle when the crank makes an angle with the vertical of (a) 30°, (b) 90°, (c) 180°?

5. The object shown below is anchored at point O. Three forces act on the object as shown; their magnitudes are $|\vec{F}_A| = 10$ N, $|\vec{F}_B| = 16$ N, and $|\vec{F}_C| = 19$ N, and the points where they act are 8.0 m, 4.0 m, and 3.0 m from O, respectively. What is the net torque about O?



6. The massive shield door at the neutron test facility at Lawrence Livermore National Laboratory has a mass of 44,000 kg and a width of 2.4 m. (a) From this information, make a rough estimate of the door's moment of inertia about the hinges (located at one edge as usual). (b) The actual moment of inertia is 8.7×10^4 kg·m^2. Neglecting friction, what steady force, applied at the outer edge of the door, is needed to move the door from rest through an angle of 90° in 30 seconds? (c) What force would be required to accomplish the same motion, if it were applied at the middle of the door?

7. Imagine a dumbbell consisting of two 1-kg point masses connected by a massless rod .4 m long. This dumbbell is then twirled about an axis through the middle of the rod and perpendicular

to it, at a rate of 3 revolutions per second. (a) Calculate the moment of inertia of the dumbbell about this axis. (b) Calculate the kinetic energy of the dumbbell using the formula $\frac{1}{2}I\omega^2$. (c) What is the speed of each end of the dumbbell? (d) Calculate the kinetic energy again, using the formula $\frac{1}{2}m|\vec{v}|^2$.

8. A small solid marble, radius r, rolls down an inclined track and then around a "loop-de-loop" (radius $R \gg r$) at the bottom of the hill. If the marble starts at rest from height h, what is the minimum value of h (in terms of R) for the marble to remain in contact with the track all the way around the loop? conservation laws worksheet.)

9. You are driving north on Harrison Blvd. at a speed of 40 mph. The mass of your car is 1200 kg. What is your car's angular momentum with respect to an origin located at the intersection of Harrison and 36th Street? What is your car's angular momentum with respect to an origin located at 25th and Washington (1.2 miles west of Harrison)? What is your car's angular momentum with respect to an origin located at the center of our classroom (.6 miles east of Harrison)? Explain why none of your answers depend on your current location along Harrison Blvd. (unless you're way north or south, where the road bends).

10. After the sun runs out of nuclear fuel (about five billion years from now), it is predicted to collapse to a "white dwarf star", with a diameter roughly equal to that of the earth. Given that the sun currently rotates with a period of about 25 days, estimate its rotation period after the collapse. (Hint: For lack of a better assumption, take the sun to be a sphere of uniform density both before and after the collapse. You may wish to use the conservation laws worksheet.)

11. In a playground, there is a small merry-go-round with a mass of 180 kg and a radius of 1.2 m. For the purpose of determining its moment of intertia, you can pretend that all its mass is located 91 cm from the axis of rotation. (This is a special sort of weighted average radius, known technically as the "radius of gyration.") A child of mass 44 kg runs at a speed of 3.0 m/s along a path tangent to the rim of the initially stationary merry-go-round, then jumps on. (a) Calculate the moment of inertia of the merry-go-round. (b) Calculate the child's angular momentum, while running, with respect to the merry-go-round's axis of rotation. (c) Calculate the angular speed of the merry-go-round after the child has jumped on. (Hint: Use the conservation laws worksheet.)

Table of Analogies

Linear Motion	Rotational Motion
t	t
x	θ
$v_x = \frac{dx}{dt}$	$\omega = \frac{d\theta}{dt}$
$a_x = \frac{dv_x}{dt}$	$\alpha = \frac{d\omega}{dt}$
if a_x is constant,	*if* α is constant,
$v_x(t) = v_x(0) + a_x t$	$\omega(t) = \omega(0) + \alpha t$
$x(t) = x(0) + v_x(0) \cdot t + \frac{1}{2} a_x t^2$	$\theta(t) = \theta(0) + \omega(0) \cdot t + \frac{1}{2} \alpha t^2$
m	I
F_x	τ
$\sum F_x = m a_x$	$\sum \tau = I\alpha$
$K = \frac{1}{2} m v_x^2$	$K = \frac{1}{2} I \omega^2$
$p_x = m v_x$	$L = I\omega$
if no external forces,	*if* no external torques,
$\sum p_x$ doesn't change	$\sum L$ doesn't change

Relations between linear and rotational quantities:

$$\omega = \frac{v_t}{r} \qquad \alpha = \frac{a_t}{r} \qquad I = \sum_i m_i r_i^2 \qquad \tau = r|\vec{F}| \sin\phi \qquad L = \sum_i r_i m_i |\vec{v}_i| \sin\phi_i$$