PH 1110 **Term C00**

STUDY GUIDE 4: Equilibrium, Angular Kinematics, and Dynamics

Objectives

25. Define torque. Solve problems involving objects in static equilibrium.

26. Define angular displacement, angular velocity and angular acceleration. Given the graph or the functional form of one of the quantities versus time, determine the graphs of the other two.

27. Define moment of inertia, and solve problems involving rotational motion of rigid bodies subject to a net torque.

28. Calculate the angular momentum, relative to a specified axis, of a point mass traveling in a straight line.

29. Calculate the angular momentum of a rigid body whose angular velocity is specified.

30. Solve problems using the law of conservation of angular momentum.

Suggested Study Procedure for Chapter 11.

Study Secs. 10-2 and 11-1 through 11-4.
Answer Discussion Questions 4, 12, 15, 17.
Study particularly Examples 1, 2, 3, 4, 5.
Do Exercises 5, 9, 13, 15, 17.
Do Problems 42, 50, 51, 61, 67.

A. So far we've ignored ONE LITTLE DETAIL about motion: that objects can ROTATE as well as TRANSLATE. We'll TURN to that little detail in this last section of the course. Perhaps you will be happy to hear that we don't really need any new theory for this. We just need to recast all of the old familiar ideas into angular terms. That's one of the things we'll be illustrating and emphasizing a lot in lecture and conference meetings.

B. We think that it is preferable to consider STATIC EQUILIBRIUM first before letting objects rotate, so we're going to deviate just a bit from the order of topics in the text. Because of the timing of Lab Experiment #4, the material of Sec. 10-2 on TORQUE should already be familiar to you, and that's all you need as background to Chapt. 11. Note that the ONE Problem-Solving Strategy on p. 333 applies to ALL of the work covered in Secs. 11-1 through 11.4. About all that changes from one problem to the next is the geometry of the situation! This is what takes some practice.

Suggested Study Procedure for Chapter 9.

Study Secs. 9-1 through 9-5.
Answer Discussion Questions 3, 4, 11, 12.
Study particularly Examples 1 through 9.
Do Exercises 1, 2, 5, 9, 11, 17, 35, 43.
Do Problems 65, 71, 73, 77.

A. As you study Secs. 9-1 through 9-5, keep in mind that ALL of the equations for rotational motion with constant angular acceleration are identical in form to those of one dimensional motion with constant linear acceleration. Table 9-1 is intended to help you learn the new set of angular symbols. The three examples in Sec. 9-4 are also helpful in this regard.

B. MOMENT OF INERTIA plays a role in rotational motion similar to that of MASS in translational motion. We will emphasize the use of moment of inertia in rotational motion rather than the calculation of moment of inertia for different bodies. On the other hand, we will expect you to know the expression for the moment of inertia for our standard objects: the hoop, the uniform disk, the stick, and the point particle at distance R from the rotation axis.

C. Prior to this time we have ignored or neglected the effects of pulleys in problems other than their role in changing the direction of a force. Examples 9-8 and 9-9 show how a real pulley (with mass!) can affect a system.

<u>Suggested Study Procedure for Chapter 10.</u>

Study Secs. 10-1 through 10-7.
Answer Discussion Questions 1, 7, 16, 20.
Study particularly Examples 2, 3, 4, 12, 13, 14, 15, 16.
Do Exercises 11, 28, 30, 31, 35, 39.
Do Problems 47, 57, 73, 74.

A. Study Sec. 10-3 and Examples 10-2 through 10-4 very carefully. These examples show how to apply Newton's laws to problems involving rotation. Notice that the Free-Body Diagram is still an indispensable part of our problem-solving strategy!

B. ANGULAR MOMENTUM deserves more time than we can assign to it! Not only is it important in understanding all sorts of everyday situations but also in the study of phenomena from the sub-atomic way up through the astronomical. For now, however, we have to content ourselves with Secs. 10-5, 10-6, and 10-7, and Examples 10-12 through 10-16, paying particular attention to the definition of angular momentum of a point particle (Eqn. 10-27), the definition of angular momentum of a rigid body (Eqn. 10-31), and the principle of ANGULAR MOMENTUM CONSERVATION (as shown in Examples 10-13 through 10-16). Fortunately, this will be enough coverage to help you understand the inner workings of many everyday angular motion situations that previously puzzled you.

HOMEWORK ASSIGNMENTS FOR STUDY GUIDE 4.

<u>Homework Assignment #13 - due in lecture Monday, Feb 21.</u>

HW 13-1: Ex. 11-12.

HW 13-2: Ex. 11-14.

HW 13-3: Prob. 11-48.

<u>Homework Assignment #14 - due in lecture Wednesday, Feb 23.</u>

HW 14-1: Prob. 11-68, **except** change the coefficient of kinetic friction to 0.300.

HW 14-2: A flywheel subject to constant angular acceleration rotates through 210 rad in a 3.00-s interval, at the end of which it has an angular speed of 80.0 rad/s. **Determine** (a) the angular speed at the beginning of this 3-s interval, **and** (b) the magnitude of the angular acceleration. The flywheel now begins to coast to a stop, again with an angular acceleration of constant value. Given that the angular speed drops to zero during the next 16.0 s, **determine** (c) the magnitude of the angular acceleration during this portion of the motion, **and** (d) the angle through which the flywheel turns (expressed both in terms of radians and of revolutions) during this final 16 s.

HW 14-3: Ex. 9-62; **ALSO,** by way of comparison **repeat** all the calculations for t = 0, the moment that the car begins accelerating from rest, and on this basis **comment** about what will happen to the net force acting on the car for times **greater** than t = 8 s. What will eventually happen to the car as elapsed time becomes ever greater?

<u>Homework Assignment #15 - due in lecture Friday, Feb 25.</u>

HW 15-1: Ex. 9-38.

HW 15-2: Similar to the situation in Prob. 9-70, except m = 5.00 kg and R = 0.400 m.
(a) **Calculate** the angular speed of the system for the exact situation described in Prob. 9-70.
(b) Now imagine releasing the system, again with the point mass on a horizontal radius, but this time with an initial angular speed of 6.00 rad/s. **Show** that this is sufficient angular speed to enable the point mass to coast over the top of its circular path, and **calculate** the angular speed of the system when the point mass is exactly at the top of its circular path.

HW 15-3: A 15.0-kg disk with radius R = 0.200 m is mounted on a fixed, horizontal, frictionless axle. A 3.00-kg mass hangs from a very light string wrapped many times around the circumference of the disk.
(a) Given that the system is initially at rest, use energy techniques to **determine** the speed of the 3-kg mass after it has unwound through a vertical distance of 2.50 m. For the same situation, also **calculate** (b) the angular speed of the disk, (c) the kinetic energy of the disk, (d) the kinetic energy of the 3-kg mass, and (e) the angular acceleration of the disk as the string unwound through 2.5 m.

<u>Homework Assignment #16 - due in lecture Monday, Feb 28.</u>

HW 16-1: Prob. 10-48; Also, do this problem a second time, given now that all the numbers in the problem statement are still correct **but** that there is **additionally** a constant frictional torque in the axle of 12 N·m opposing the motion.

HW 16-2: Same situation as described in Ex. 10-40, but do the following instead:
a) **Calculate** the kinetic energy of the system when the man is at the center of the turntable.
b) **Calculate** the angular speed and kinetic energy the turntable would have if the man moves to a point on the rim of the turntable, 4.00 m from the center. **Calculate** also the man's kinetic energy when he is standing stationary at this point on the turntable.
c) The man now hops radially outward from the rim of the turntable, landing on the ground. **Calculate** the angular speed and kinetic energy the turntable has after the hop.
d) Another 80.0-kg man who has been patiently hanging from a tree branch just above a point 3.00 m from the rotation axis now drops down onto the turntable and stands motionless at that point. **Calculate** the angular speed and kinetic energy the turntable has after this new event.
e) This second man now walks to the center of the turntable. **Calculate** the angular speed and kinetic energy the turntable has once the man reaches the center.

HW 16-3: Ex. 10-38; Also, **calculate** the initial kinetic energy of the bullet, the final kinetic energy of the bullet, and the final kinetic energy of the disk.