**Phys 135A College Physics I**

**Activity 11: Rotational Motion**



Suppose you are on a merry-go-round, how would you describe your motion as a function of time? Since you are rotating around a fixed point, that is, the center of the merry-go-round, the best way to describe your position is to give the angle you make from some reference line. In other words, instead of a translational position x, you would give the angle (theta). Similarly, instead of talking about a translational velocity , one would talk about an angular velocity (omega), and instead of a translational acceleration , we would have an angular acceleration (alpha).

**Angular Quantities**

To describe rotational motion, we make use of angular quantities such as angular velocity and angular acceleration. They are defined in analogy with the corresponding quantities in linear motion.

|  |  |
| --- | --- |
|  |  |

In rotational motion, we will be dealing with the evolution of the rotation angle and angular velocity (also called angular frequency) with time.

|  |  |
| --- | --- |
| **Translational Motion** | **Rotational Motion** |
| Linear displacement | Angular displacement |
| Linear velocity | Angular velocity |
| Linear acceleration | Angular acceleration |
|  |  |

Note that in general a point of a rotating body can have at any moment a linear acceleration that has two orthogonal components and

|  |  |
| --- | --- |
|  | **For uniform circular motion**: . |

**Example**:

(a) What is the linear speed of a child seated 1.2 m from the center of a steadily rotating merry-

go-round that makes one complete revolution in 4 s?

(b) What is her acceleration?

**Kinematics Equations For Uniformly Accelerated Rotational Motion**

We still did not answer the question of how to describe the motion of rotation. Well, we are already familiar with the translational case of kinematics. All we need to do is to make the correct analogies and come up with the rotational kinematics formulae. As in the translational case, we will limit ourselves to the uniform (angular) acceleration case, as can be appreciated, the angle at a later time depends on how fast the machine is rotating and whether it is rotating at a constant angular velocity or with an angular acceleration.

|  |
| --- |
| Analogies with the linear kinematics physical quantities |
|  |
| 🡺 |
| 🡺 |
| 🡺 |

|  |  |
| --- | --- |
| Linear Kinematics ( | Angular Kinematics () |
|  |  |
|  |  |
|  |  |

**Example**:

A rotor is accelerated from rest to 20,000 rpm in 5 minutes.

(a) What is its average angular acceleration?

(b) Through how many revolutions has the centrifuge rotor turned during its acceleration period?

**Rolling Motion**

This refers to rolling without slipping. Familiar in everyday life: a ball, wheels of a car or a bicycle.

Rolling motion involves both rotation and translation. The linear speed of the center in a rolling motion is the same as the speed of a point at the rim.



**Example**: A bicycle slows down uniformly from 8.4 m/s to rest over a distance of 115 m. If the radius of the wheels of this bicycle is 34 cm, determine

(a) The angular velocity of the wheels at the initial instant.

(b) The total number of revolutions each wheel rotates in coming to a rest.

(c) The angular acceleration of the wheels.

(d) The time it took to come to a stop.

**Torque (Rotational Force)**

The answer to the question of why objects rotate, i.e., what causes rotation, is, as you might imagine, a rotational force called torque. Just like linear force, rotational force, i.e., torque, is a vector. It can be + (counterclockwise rotation) or – (clockwise rotation). Its symbol , the Greek letter “tau.”



If a given force F is applied to a point a distance r from a pivot point, it generates a torque, which is given by

The unit of torque is N.m.

If there is more than one force simultaneously exerted then the net torque is the vector sum of the individual torques of the applied forces.

**Example**: A person exerts a force of 45 N on the end of a door 84-cm wide. Determine the resulting torque if the force is exerted (a) perpendicular to the door, (b) at a angle to the face of the door, and (c) angle?

**Example**: A solid cylinder is pivoted about a frictionless axle, about which it can rotate freely. In addition to its outer body, the cylinder also has a smaller radius protrusion. Two ropes are wrapped around the cylinder at both diameters, and tow tension forces are applied as shown.



(a) What is the net torque, symbolically, acting on the cylinder about the z-axis through the center?

(b) If , , , , what is the magnitude and rotational direction of the net torque?