Minds•On Physics Activity

AT•16

Graphing Rotational Motion

Purpose and Expected Outcome

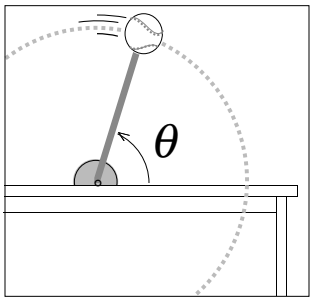
This series of activities will study rotational motion in analogy with linear motion. In this activity, you will become familiar with some rotational motion quantities, such as *angular position*, *angular velocity*, and *angular acceleration*. You will discover that you already have learned some rotational motion ideas, though perhaps without realizing it. You will learn that rotational quantities are *analogous* to linear quantities, such as position, velocity, and acceleration. Also, you will see that many properties of rotational ideas are similar to their linear counterparts.

Prior Experience / Knowledge Needed

You should understand linear motion ideas, such as *position*, *velocity*, and *acceleration*. You should know how to sketch graphs of position, velocity, and acceleration vs. time, and you should know the relationships among position, velocity, and acceleration. You should know that there are 360° or 2π radians in a circle.

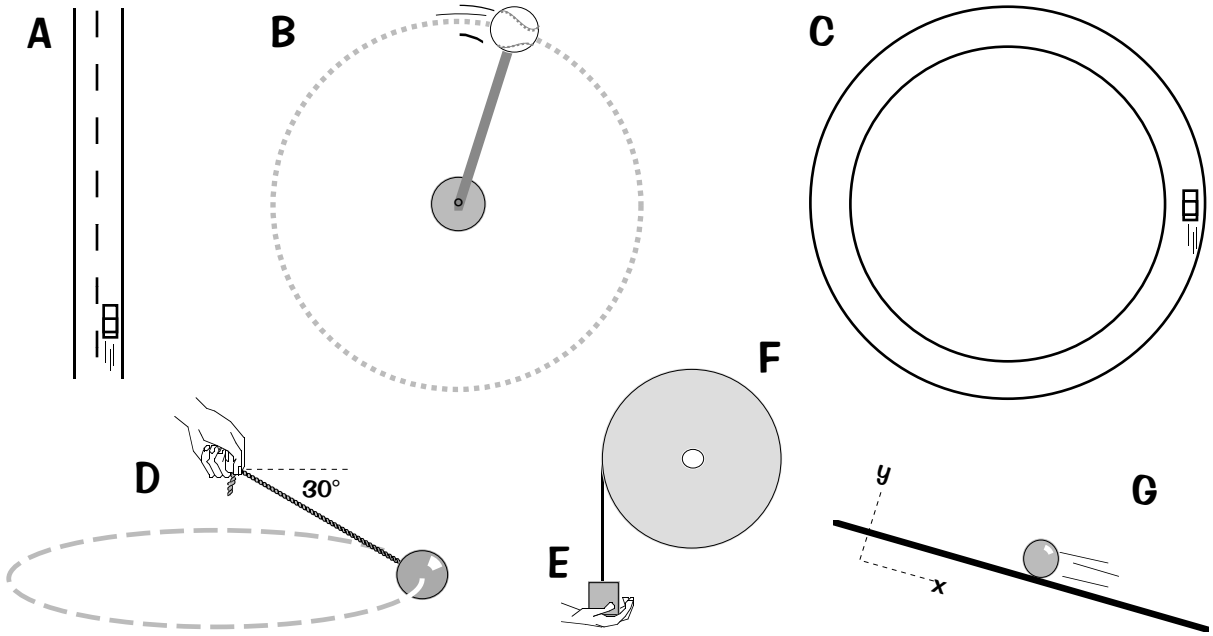
ROTATIONAL MOTION QUANTITIES

Each linear motion quantity has a corresponding rotational motion counterpart. *Angular position* is the angle θ made by an object or arrangement relative to some chosen reference, such as the vertical or horizontal. In the diagram at right, the angle θ ("theta") is measured counterclockwise from the table top, and at the instant shown, $\theta = 72°$. *Angular velocity* is the rate ω ("omega") at which the angle θ is changing. In the example, ω is negative, because θ is positive and getting smaller. *Angular acceleration* is the rate α ("alpha") at which the angular velocity ω is changing. (In the example, we have no information about how the angular velocity is changing.)



Explanation of Activity

Identify the object(s) that correspond to the given graph. Use the following seven objects throughout this part. They are described below.



Object A: a **car** drives down a long, straight highway at constant speed.

Object B: a **baseball** is attached to a light rod, which spins at a constant rate using a motor attached to the pivot.

Object C: a **car** drives around a circular track at constant speed.

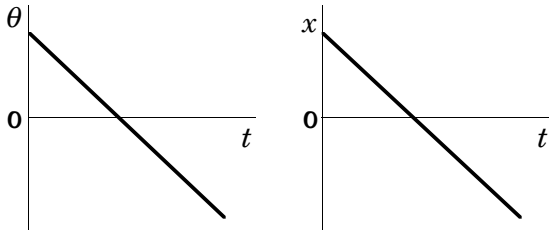
Object D: a **ball** swings in a horizontal circle.

Objects E & F: a **block** is attached to a string wound around a solid **wheel** and released from rest. The wheel spins around a fixed axle.

Object G: a **marble** rolls up a shallow incline.

A1. (a) Which of the objects above might have the angular position (θ) vs. time plot to the right? Explain.

(b) Which of the objects above might have the position (x) vs. time plot to the right? Explain.

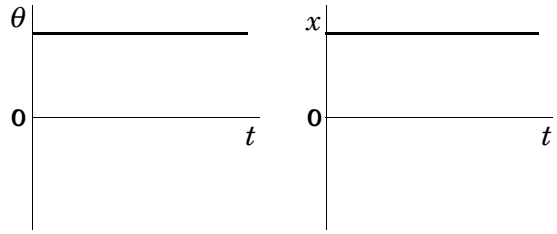


(a) (b)

continued

A2. (a) Which of the objects might have the angular position (θ) vs. time plot to the right? Explain.

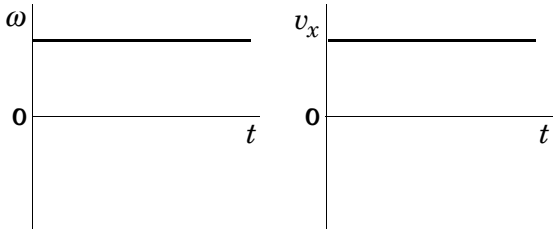
(b) Which of the objects might have the position (x) vs. time plot to the right? Explain.



(a) (b)

A3. (a) Which of the objects might have the angular velocity (ω) vs. time plot to the right? Explain.

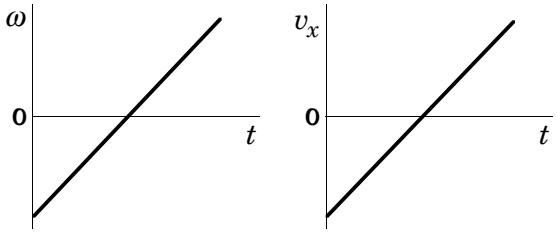
(b) Which of the objects might have the velocity (v_x) vs. time plot to the right? Explain.



(a) (b)

A4. (a) Which of the objects might have the angular velocity (ω) vs. time plot to the right? Explain.

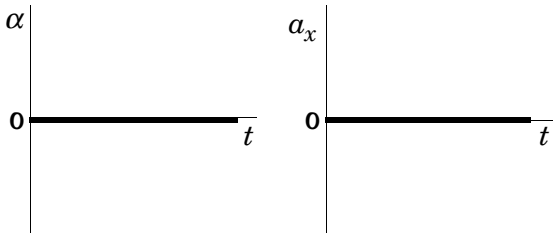
(b) Which of the objects might have the velocity (v_x) vs. time plot to the right? Explain.



(a) (b)

A5. (a) Which of the objects might have the angular acceleration (α) vs. time plot to the right? Explain.

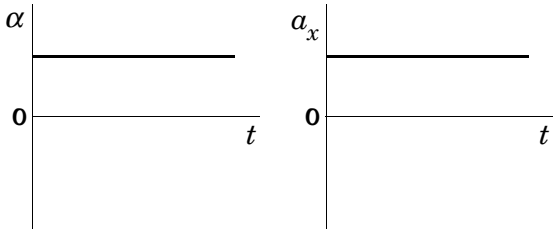
(b) Which of the objects might have the acceleration (a_x) vs. time plot to the right? Explain.



(a) (b)

A6. (a) Which of the objects might have the angular acceleration (α) vs. time plot to the right? Explain.

(b) Which of the objects might have the acceleration (a_x) vs. time plot to the right? Explain.



(a) (b)

Reflection

R1. Reconsider situation B, in which a baseball is attached to a light rod that rotates at a constant rate due to a motor attached to the pivot. The arrangement completes one revolution every 5 seconds.

(a) Make a strobe diagram showing the position of the ball every second for 10 seconds.

(b) Plot the angular position θ vs. time t for 10 seconds.

(c) Can the angular position be negative? Explain.

(d) Can the angular position be larger than 360°? Explain.

(e) Plot the angular velocity ω vs. time t for 10 seconds.

(f) What is the slope of your angular position vs. time graph?

R2. (a) What motion quantity corresponds to the slope of angular position vs. time? Explain.

(b) What motion quantity corresponds to the slope of angular velocity vs. time? Explain.

(c) What motion quantity corresponds to the area below angular velocity vs. time? Explain.

R3. (a) For how many of the twelve graphs was there no object that matched the graph?

(b) Which graphs did not correspond to any of the seven objects given?

(c) For each of these graphs, create, draw, and describe a situation that matches the graph.