Physics 4A
Chapter 8: Dynamics II – Motion in a Plane

"*Keep in mind that neither success nor failure is ever final*." – Roger Ward Babson

"Our greatest glory is not in never failing, but in rising up every time we fail."
Ralph Waldo Emerson

"If you continue to do what you've always done, you'll continue to get what you've always got."
Yogi Berra

"Defeat is not defeat unless accepted as a reality in your own mind." – Bruce Lee

Reading: pages 182 – 196

Outline:

⇒ Uniform Circular Motion
⇒ Circular Orbits
⇒ Nonuniform Circular Motion

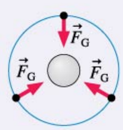
APPLICATIONS

Orbits

An object acted on only by gravity has a circular orbit of radius r if its speed is

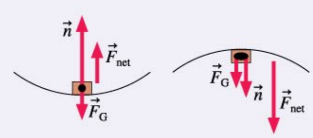
$$v = \sqrt{rg}$$

The object is in free fall.



Circular motion on surfaces

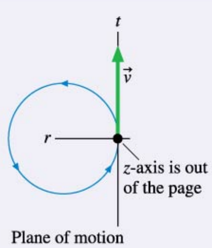
Circular motion requires a net force pointing to the center. n must be > 0 for the object to be in contact with a surface.



IMPORTANT CONCEPTS

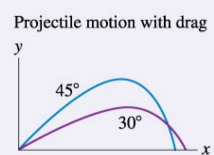
rtz-coordinates

- The r-axis points toward the center of the circle.
- The t-axis is tangent, pointing counterclockwise.



Projectile motion

- With no drag, the x- and y-components of acceleration are independent. The trajectory is a parabola.
- With drag, the trajectory is not a parabola. Maximum range is achieved for an angle less than 45°.



GENERAL PRINCIPLES

Newton's Second Law

Expressed in x- and y-component form:

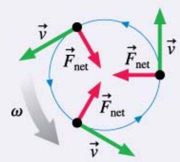
$$(F_{\text{net}})_x = \sum F_x = ma_x$$
$$(F_{\text{net}})_y = \sum F_y = ma_y$$

Expressed in rtz-component form:

$$(F_{\text{net}})_r = \sum F_r = ma_r = \frac{mv_t^2}{r} = m\omega^2 r$$
$$(F_{\text{net}})_t = \sum F_t = \begin{cases} 0 & \text{uniform circular motion} \\ ma_t & \text{nonuniform circular motion} \end{cases}$$
$$(F_{\text{net}})_z = \sum F_z = 0$$

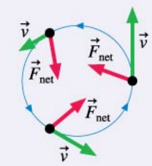
Uniform Circular Motion

- Speed is constant.
- $\vec{F}_{\text{net}}$ points toward the center of the circle.
- The **centripetal acceleration** $\vec{a}$ points toward the center of the circle. It changes the particle's direction but not its speed.



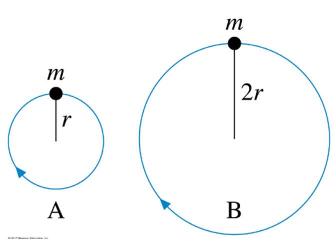
Nonuniform Circular Motion

- Speed changes.
- $\vec{F}_{\text{net}}$ and $\vec{a}$ have both radial and tangential components.
- The radial component changes the particle's direction.
- The tangential component changes the particle's speed.



Conceptual Questions and Example Problems from Chapter 8

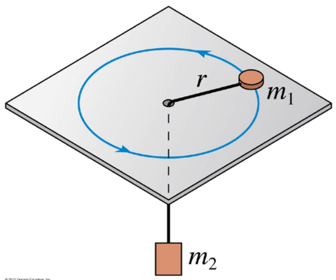
Conceptual Question 8.5
The figure below shows two balls of equal mass moving in vertical circles. Is the tension in string A greater than, less than, or equal to the tension in string B if the balls travel over the top of the circle with equal speed?



Conceptual Question 8.6
Ramon and Sally are observing a toy car speed up as it goes around a circular track. Ramon says, "The car's speeding up, so there must be a net force parallel to the track." "I don't think so," replies Sally. "It's moving in a circle, and that requires centripetal acceleration. The net force has to point to the center of the circle." Do you agree with Ramon, Sally, or neither? Explain.

Problem 8.7
A 200 g block on a 50-cm-long string swings in a circle on a horizontal, frictionless table at 75 rpm. (a) What is the speed of the block? (b) What is the tension in the string?

Problem 8.13
Mass m_1 on the frictionless table of the figure to the right is connected by a string through a hole in the table to a hanging mass m_2. With what speed must m_1 rotate in a circle of radius r if m_2 is to remain hanging at rest?



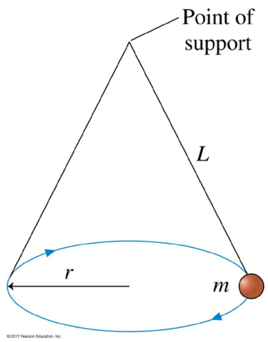
Problem 8.20
A roller coaster car crosses the top of a circular loop-the-loop at twice the critical speed. What is the ratio of the normal force to the gravitational force?

Problem 8.24
A 500 g ball swings in a vertical circle at the end of a 1.5-m-long string. When the ball is at the bottom of the circle, the tension in the string is 15 N. What is the speed of the ball at that point?

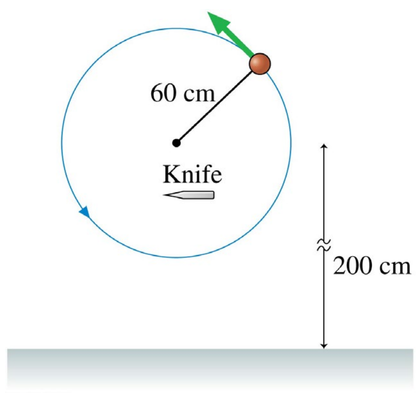
Problem 8.29
An 85,000 kg stunt plane performs a loop-the-loop, flying in a 260-m-diamter vertical circle. At the point where the plane is flying straight down, its speed is 55 m/s and it is speeding up at a rate of 12 m/s per second. **(a)** What is the magnitude of the net force on the plane? You can neglect air resistance. **(b)** What angle does the net force make with the horizontal? Let an angle above the horizontal be positive and an angle below the horizontal be negative.

Problem 8.40
A concrete highway curve of radius 70 m is banked at a 15° angle. What is the maximum speed with which a 1500 kg rubber-tired car can take this curve without sliding? ($\mu_s = 1.0$)

Problem 8.47
A conical pendulum is formed by attaching a ball of mass *m* to a string of length L, then allowing the ball to move in a horizontal circle of radius *r*. The figure below shows that the string traces out the surface of a cone, hence the name. Find an expression for the tension T in the string.



Problem 8.56
A 100 g ball on a 60-cm-long string is swung in a vertical circle about a point 200 cm above the floor. The tension in the string when the ball is at the very bottom of the circle is 5.0 N. A very sharp knife is suddenly inserted, as shown in the figure below, to cut the string directly below the point of support. How far to the right of where the string was cut does the ball hit the floor?



Problem 8.59
A 100 g ball on a 60-cm-long string is swung in a vertical circle about a point 200 cm above the floor. The string suddenly breaks when it is parallel to the ground and the ball is moving upward. The ball reaches a height of 600 cm above the floor. What was the tension in the string an instant before it broke?