Chapter 7 Circular Motion Lecture Notes

Chapter 7 — Circular Motion and Gravitation

Table of Contents

Chapter menu Resources

Chapter 7 — Section 1 Circular Motion

Tangential Speed

- The **tangential speed** (v_t) of an object in circular motion is the object's speed along an imaginary line drawn tangent to the circular path.
- Tangential speed depends on the **distance** from the object to the center of the circular path.
- When the tangential speed is constant, the motion is described as **uniform circular motion.**

Chapter menu Resources

Chapter 7 — Section 1 Circular Motion

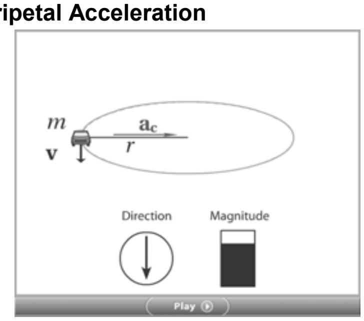
Objectives

- **Solve** problems involving centripetal acceleration.
- **Solve** problems involving centripetal force.
- **Explain** how the apparent existence of an outward force in circular motion can be explained as inertia resisting the centripetal force.

Chapter menu Resources

Chapter 7 — Section 1 Circular Motion

Centripetal Acceleration



Chapter menu Resources

Centripetal Acceleration

- The acceleration of an object moving in a circular path and at constant speed is due to a **change in direction.**
- An acceleration of this nature is called a **centripetal acceleration.**

Chapter menu Resources

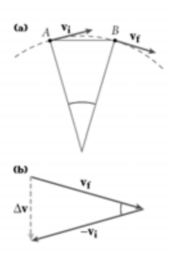
Centripetal Acceleration, *continued*

- You have seen that **centripetal acceleration** results from a **change in direction.**
- In circular motion, an acceleration due to a **change in speed** is called **tangential acceleration.**
- To understand the difference between centripetal and tangential acceleration, consider a car traveling in a circular track.
  - Because the car is moving in a circle, the car has a **centripetal** component of acceleration.
  - If the car's speed changes, the car also has a **tangential** component of acceleration.

Chapter menu Resources

Centripetal Acceleration, *continued*

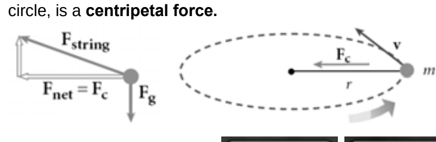
- **(a)** As the particle moves from *A* to *B*, the direction of the particle's velocity vector changes.
- **(b)** For short time intervals, $\Delta\mathbf{v}$ is directed toward the center of the circle.
- **Centripetal acceleration is always directed toward the center of a circle.**



Chapter menu Resources

Centripetal Force

- Consider a ball of **mass *m*** that is being whirled in a horizontal circular path of **radius *r*** with constant speed.
- The force exerted by the string has horizontal and vertical components. The **vertical** component is equal and opposite to the **gravitational force**. Thus, the **horizontal component** is the **net force.**
- This net force, which is is directed toward the center of the circle, is a **centripetal force.**



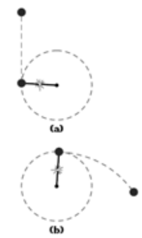
Chapter menu Resources

Centripetal Force, *continued*

Newton's second law can be combined with the equation for centripetal acceleration to derive an equation for centripetal force:

Centripetal Force, *continued*

- If the centripetal force vanishes, the object stops moving in a circular path.
- A ball that is on the end of a string is whirled in a vertical circular path.
  - *If the string breaks at the position shown in* ***(a),*** *the ball will move vertically upward in free fall.*
  - *If the string breaks at the top of the ball's path, as in* ***(b),*** *the ball will move along a parabolic path.*



Centripetal Force, *continued*

- **Centripetal force** is simply the name given to the **net force** on an object in uniform circular motion.
- **Any type of force or combination of forces can provide this net force.**
  - For example, **friction** between a race car's tires and a circular track is a centripetal force that keeps the car in a circular path.
  - As another example, **gravitational force** is a centripetal force that keeps the moon in its orbit.

Describing a Rotating System

- To better understand the motion of a rotating system, consider a car traveling at high speed and approaching an exit ramp that curves to the left.
- As the driver makes the sharp left turn, the passenger slides to the right and hits the door.
- What causes the passenger to move toward the door?

Describing a Rotating System, *continued*

- As the car enters the ramp and travels along a curved path, the passenger, because of inertia, tends to move along the original straight path.
- If a sufficiently large centripetal force acts on the passenger, the person will move along the same curved path that the car does. The origin of the centripetal force is the force of friction between the passenger and the car seat.
- If this frictional force is not sufficient, the passenger slides across the seat as the car turns underneath.

So what's centrifugal force?

- It's an imposter!
- The term is used when objects moving in a circular path do not experience the centripetal force..
  - Example..a car making a sharp turn throws its passengers to the outside door..why

Because the passenger wants to go in a straight line!

End

Classifying Acceleration

- The force that causes the acceleration resulting in circular motion is called the *centripetal force*
- Centripetal means "center seeking"..named because the acceleration points towards the center of the circle

Practice Problem

- A ball is swung in a circular path on a string that is 1.5 m long and completes one revolution every 0.5 seconds.
  - Find the tangential velocity of the ball
  - Find the tension force exerted by the string in the ball

End

Multiple Choice

1. An object moves in a circle at a constant speed. Which of the following is *not* true of the object?

A. Its centripetal acceleration is constant.
B. Its tangential speed is constant.
C. Its velocity is constant.
D. A centripetal force acts on the object.

End Of Slide
Chapter menu Resources

Multiple Choice, *continued*

Use the passage below to answer questions 2–3.

A car traveling at 15 m/s on a flat surface turns in a circle with a radius of 25 m.

3. What is the most direct cause of the car's centripetal acceleration?

End Of Slide
Chapter menu Resources

Multiple Choice, *continued*

Use the passage below to answer questions 2–3.

A car traveling at 15 m/s on a flat surface turns in a circle with a radius of 25 m.

2. What is the centripetal acceleration of the car?

F. 2.4×10^{-2} m/s^2
G. 0.60 m/s^2
H. 9.0 m/s^2
J. zero

End Of Slide
Chapter menu Resources

Gravitational Force

- **Orbiting objects** are in **free fall.**
- To see how this idea is true, we can use a thought experiment that Newton developed. Consider a cannon sitting on a high mountaintop.

Each successive cannonball has a greater initial speed, so the horizontal distance that the ball travels increases. If the initial speed is great enough, the curvature of Earth will cause the cannonball to continue falling without ever landing.

End Of Slide
Chapter menu Resources

Gravitational Force, *continued*

- The **centripetal force** that holds the planets in orbit is the same force that pulls an apple toward the ground—**gravitational force.**
- **Gravitational force** is the mutual force of attraction between particles of matter.
- Gravitational force depends on the **masses** and on the **distance** between them**.**

Newton's Law of Universal Gravitation

Gravitational Force, *continued*

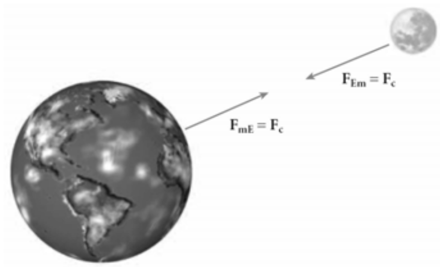
- Newton developed the following equation to describe quantitatively the magnitude of the gravitational force if distance r separates masses m_1 and m_2:

- The constant G, called the *constant of universal gravitation*, equals 6.673×10^{-11} N•m^2/kg.

Gravitational Force, *continued*

- The gravitational forces that two masses exert on each other are always **equal in magnitude** and **opposite in direction**.
- This is an example of **Newton's third law of motion.**
- One example is the **Earth-moon system,** shown on the next slide.
- As a result of these forces, the moon and Earth each orbit the center of mass of the Earth-moon system. Because Earth has a much greater mass than the moon, this center of mass lies within Earth.

Newton's Law of Universal Gravitation



Applying the Law of Gravitation, *continued*

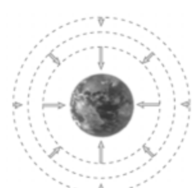
- **Cavendish** applied Newton's law of universal gravitation to find the value of *G* and Earth's mass.
- When **two masses**, the **distance** between them, and the **gravitational force** are known, Newton's law of universal gravitation can be used to find ***G*.**
- Once the value of ***G*** is known, the law can be used again to find **Earth's mass.**

Applying the Law of Gravitation

- Newton's law of gravitation accounts for **ocean tides.**
- High and low tides are partly due to the **gravitational force** exerted on Earth by its moon.
- The tides result from the **difference** between the gravitational force at Earth's surface and at Earth's center.

Applying the Law of Gravitation, *continued*

- Gravity is a **field force.**
- Gravitational field strength, g, equals F_g/m.
- The gravitational field, $\mathbf{g}$, is a vector with magnitude g that points in the direction of $\mathbf{F_g}$.
- **Gravitational field strength** equals **free-fall acceleration.**



The gravitational field vectors represent Earth's gravitational field at each point.

Applying the Law of Gravitation, *continued*

- **weight** = mass × gravitational field strength
- Because it depends on gravitational field strength, **weight changes with location:**

- On the surface of any planet, the value of *g,* as well as your weight, will depend on the planet's **mass** and **radius.**

Multiple Choice, *continued*

4. Earth (m = 5.97 × 10^{24} kg) orbits the sun (m = 1.99 × 10^{30} kg) at a mean distance of 1.50 × 10^{11} m. What is the gravitational force of the sun on Earth? (G = 6.673 × 10^{-11} N•m^2/kg^2)

F. 5.29 × 10^{32} N
G. 3.52 × 10^{22} N
H. 5.90 × 10^{-2} N
J. 1.77 × 10^{-8} N

Weight and Weightlessness

(a) (b) (c)

Multiple Choice, *continued*

5. Which of the following is a correct interpretation of the expression $a_g = g = G\frac{m_E}{r^2}$?

A. Gravitational field strength changes with an object's distance from Earth.
B. Free-fall acceleration changes with an object's distance from Earth.
C. Free-fall acceleration is independent of the falling object's mass.
D. All of the above are correct interpretations.