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Warm-Up | Circular Motion

Lesson Question

How can circular motion be described and calculated?

Lesson Goals

Describe how circular motion is caused by centripetal force.

Explain the relationship between centripetal force and inertia.

Use centripetal force concepts to solve problems.

Interpret motion maps to describe circular motion.

Words to Know

Fill in this table as you work through the lesson. You may also use the glossary to help you.

motion map	an image that represents the position, velocity, and acceleration of an object at one second intervals
Newton's second law of motion	the law that states that the total net force acting on an object is equal to mass times acceleration
centripetal force	a force directed toward the center of a circle
inertia	the natural tendency of objects to resist a change in motion

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Centripetal Acceleration

- An object moving in a circle is accelerating even if speed is constant.
- The object is accelerating because it is continuously changing direction.
  - Centripetal acceleration

$$a_c = \frac{v^2}{r}$$

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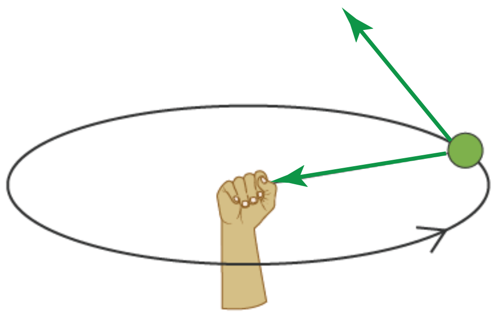
Centripetal Force

- **Centripetal force** is directed toward the center of a circle.
  - The force is perpendicular to the velocity of the object.
  - The object is constantly changing direction but not speed.

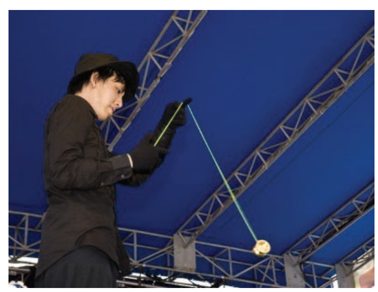


Centripetal Force

Examples of centripetal force:

Gravity

Normal



Tension

- Gravity is a centripetal force causing satellites to revolve around the earth and the planets to revolve around the sun.
- The normal force of the track of a roller coaster provides the centripetal force to move the train in a loop.
- And tension on a string provides the centripetal force needed to perform a yo-yo trick.

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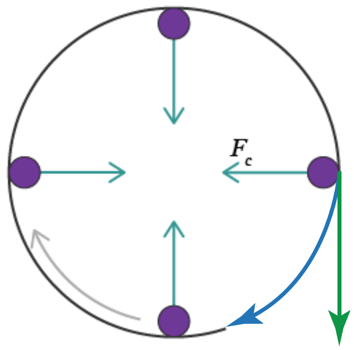
Inertia and Centripetal Force

- **Inertia** causes objects to want to continue moving in a straight line.
- Centripetal force pushes or pulls objects toward the center of a circle.
- The combination of inertia and centripetal force causes objects to move with circular motion.
  - Without inertia, objects experiencing centripetal force would fall to the center of the circle.



Centrifugal Force—a Fictitious Force

MISCONCEPTIONS

- Objects want to keep going straight, but the centripetal force pushes or pulls the object toward the center of the circle.
- The feeling of being pushed or pulled to the outside of a circle comes from inertia.
  - There is **no force** acting to pull or push objects away from the center of the circle.

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Centripetal Force Formula

The formula for centripetal force is derived from **Newton's** second **law of motion**.

- $F = ma$

Centripetal acceleration is shown as:

$$a_c = \frac{v^2}{r}$$

When you combine these two formulas, you get the formula for centripetal force.

$$F_c = \frac{mv^2}{r}$$

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Tangential Speed

- If the radius and time are known, tangential speed can be calculated with the formula

$$v_t = \frac{2\pi r}{t}.$$

- If the radius, centripetal force, and mass are known, tangential speed can be calculated by rearranging the formula

$$F_c = \frac{mv^2}{r}.$$

$$F_c = \frac{mv^2}{r}$$

$$F_c r = \frac{mv^2}{r} r$$

$$F_c r = mv^2$$

$$\frac{F_c r}{m} = \frac{mv^2}{m}$$

$$\frac{F_c r}{m} = v^2$$

$$v^2 = \frac{F_c r}{m}$$

$$v = \sqrt{\frac{F_c r}{m}}$$

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Example of Calculation of Tangential Speed

Haleel, whose mass is 54.4 kg, is swinging from a rope that is 3.7 m long. If the rope is exerting a centripetal force of 115 N, what is Haleel's tangential speed?

- Given:
  - $m = 54.4\ \text{kg}$
  - $r = 3.7\ \text{m}$
  - $F_c = 115\ \text{N}$
- Unknown: v

$$F_c = \frac{mv^2}{r} \text{ rearranged to } v = \sqrt{\frac{F_c r}{m}}$$

$$v = \sqrt{\frac{F_c r}{m}}$$

$$v = \sqrt{\frac{\boxed{115\ \text{N}} \times 3.7\ \text{m}}{54.4\ \text{kg}}}$$

$$v = \sqrt{\frac{425.5\ \text{kg m}^2/\text{s}^2}{54.4\ \text{kg}}}$$

$$v = \sqrt{7.82\ \text{m}^2/\text{s}^2}$$

$$v = \boxed{2.8\ \text{m/s}}$$

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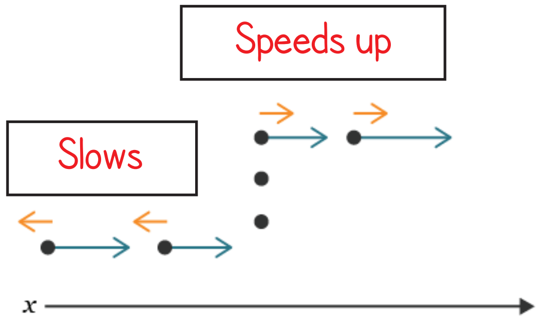
Motion Maps

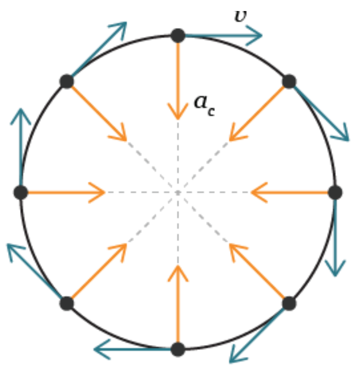
- Dots on a **motion map** represent an object's position at 1-second intervals.
- Vectors attached to the dots represent the object's velocity .
    - The longer the vector, the faster the velocity.

Identify which vector speeds up and which vector slows.



- The vectors above the dots represent acceleration.
    - The direction of the acceleration vector indicates if the object is speeding up or slowing down.

Circular Motion Maps



Remember, objects moving with uniform circular motion have a constant tangential speed. Because the force is constant, the centripetal acceleration must also be constant. Therefore, the acceleration vectors must all be the same length , as well.

Summary | Circular Motion

Lesson Question

How can circular motion be described and calculated?

Answer

(Sample answer) Centripetal force is any force directed toward the center of a circle that causes an object to follow a circular path. Circular motion can be described using motion maps and calculated using the centripetal force formula.

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Review: Key Concepts

- Centripetal force is a force directed toward the center of a circle.
- The combination of inertia and centripetal force causes an object to move in a circle.
- Circular motion can be calculated using the centripetal force formula.
- Circular motion can also be represented visually with motion maps.

$$F_c = \frac{mv^2}{r}$$

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Use this space to write any questions or thoughts about this lesson.