Day 4:
Circular Motion and Gravitation

SHS Physics Club Summer Camp 2026

Overview

01 HW/Quiz

Brief mcq review quiz, go over HW questions

02 Centripetal Force

Constant speed but changing direction, inward force

03 Circular Motion

Car problems, tether ball problems, slope normal force problems

04 Gravitation

Universal law of gravitation, orbits, orbital speed derivation

01

HW/Quiz

HW/Quiz

- **HW Questions?**

Quiz

- **Quiz**
  - 6 mcq
  - 12 minutes

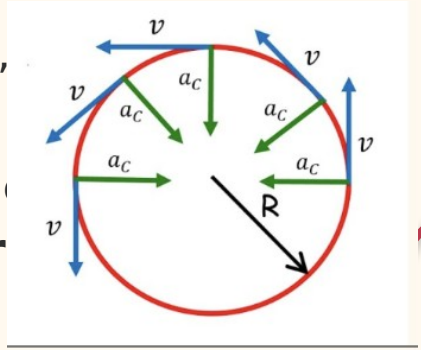
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02

Centripetal Force

Centripetal Acceleration

- **Acceleration Definition**
  - Change in velocity
  - Velocity is a vector
- **Centripetal Acceleration**
  - The acceleration for an object whose velocity is changing directions
  - Always points toward the center of the circle
  - For now, only constant speed or constant direction,
- **$a_c = v^2/r$**
  - v is the tangential speed, r is the radius of the circl
- **Velocity and acceleration will always be per**



Centripetal Acceleration Derivation

Centripetal Force

- **F = ma**
  - Same old equation, this time with acceleration involved
  - Questions are solved in the same way. Use the direction of acceleration to look for relevant forces
- **$F_c = mv^2/r$**
  - Same units as before
- **IMPORTANT**
  - F_c is NOT a new type of force!!! It is the name for the net force toward the center, and varies per problem! The centripetal force is simply a combination of any of the other forces we have already learned! That means no drawing it into a FBD!
- **Car turning example:**
  - If a car is making a turn on flat ground, what force provides the centripetal force?

Practice Problems

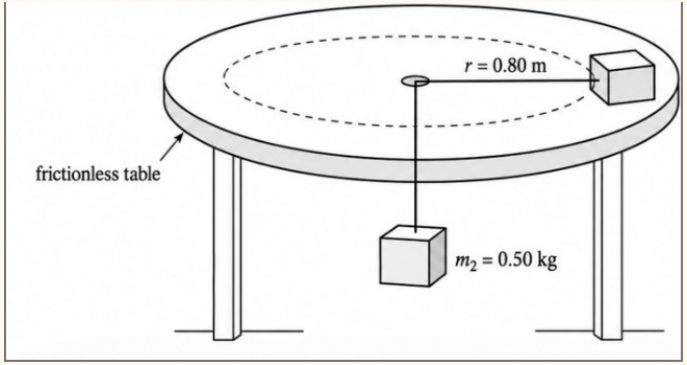
- A 1200 kg car needs to make a right turn with a turn radius of 50m. The coefficient of static friction between the tires and the road is 0.6. What is the maximum speed that the car can hit the turn with without slipping?

- The car must take another turn, this time on a slick road of coefficient 0.4, and cannot slow down. What is the minimum safe turn radius this time?

03

Circular Motion

Practice Problem + Terms



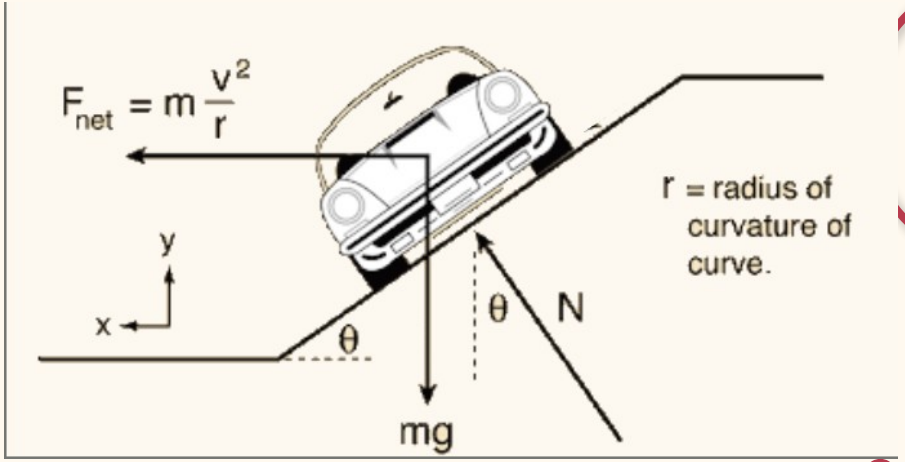
- **Terms:**
  - Turn radius
  - Turn speed
  - Bank
  - Period
  - Frequency

- A 2 kg block rests on the tabletop, and a frictionless, massless string is threaded through a hole in the table such that a 0.5 kg block hangs in the center, below the table. The hanging block remains at rests as the 2 kg block moves in a horizontal circle of radius 0.8 m at a constant velocity.
  - What is the tension in the string?
  - What is the speed of the 2 kg mass?
  - What is the period for this circular motion?

Normal Force and Tension

- **Normal force review**
  - It is always perpendicular to the surface and not necessarily equal to mg

- **2 step problems - example**
  - A car is driving on a frictionless banked surface. How does it not slip?



Banking Practice Problems

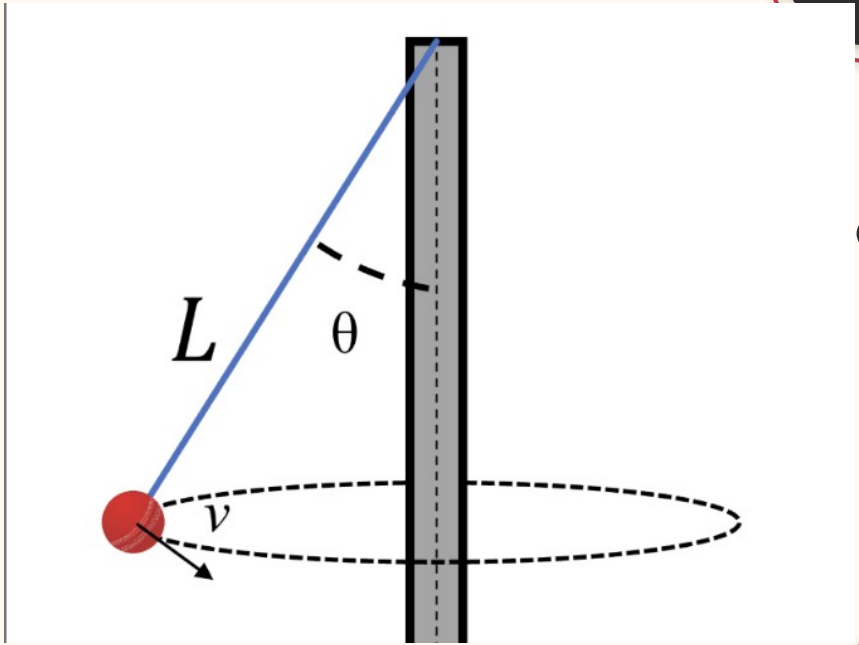
- A 1500 kg car is on another banked race track. What is the minimum necessary banking angle to maintain a speed 25 m/s? The turn radius is 75 m.

- An amusement park ride spins guests and then drops the floor out from under them as they spin. If the surface of the ride is frictionless, for a guest of 50 kg, what what is the perfect turn radius so that the rider will not slide up or down? The banking angle is 75 degrees (steep slope), and the speed of the rider is 15 m/s.

Tetherball Practice Problems

- A playground has a tetherball game. The actual ball has a mass of 3 kg. The length of the rope is 10 m. If the angle between the rope and the pole is 35 degrees, what is the speed of the ball.

- Find the angle if the ball's speed is 15 m/s.



Vertical Circles

- **Strings and normal force - limits**
  - Both of these things cannot “push” outward
  - Only inward force is possible
- **Vertical Circles**
  - Velocity will not be uniform
  - Gravity is constant but tension/normal force will vary
- **Water cup???**
- **Practice Problem**
  - A student swings a cup of water in a vertical circle of radius 0.80 m. At the top of the circle, the cup is moving at 4.0 m/s.
  - a) What is the centripetal acceleration of the water at the top?
  - b) What normal force does the cup exert on 0.25 kg of water at the top?

04

Gravitation

Universal Law of Gravitation

- What is the law?
  - Every object with mass attracts every other object with mass
  - Always attractive
- $F_g = G(m1*m2)/r^2$
  - M1 and M2 represent 2 objects, and F_g is the gravitational force between them
  - r is how far their center of masses are from each other (typically the center of a sphere)
  - G is the universal gravity constant, not to be mixed up with g, which is the acceleration on the surface of the earth
  - $G = 6.67 \times 10^{-11}\ N*m^2/kg^2$
- Calculating “g”, earth's radius is 6371 km

Practice Problems

Planet X has a mass of 8.0×10^{24} kg and a radius of 7.0×10^{6} m. A 500 kg spacecraft is located 3.0×10^{6} m above the planet's surface.

a. What is the spacecraft's distance from the center of Planet X?

b. What gravitational force does Planet X exert on the spacecraft?

Two objects with masses m and 2m are separated by a distance r. Their gravitational force is F. The second object's mass is then increased to 6m, while the distance between their centers is increased to 3r. What is the new gravitational force in terms of F?

Orbital Speed Derivation

A satellite orbits Earth in a circular path at a distance of $7.0 * 10^6$ m from the earth's center. Earth’s mass is $6.0 * 10^{24}$ kg. Calculate the satellite orbit speed.

See you tomorrow!

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