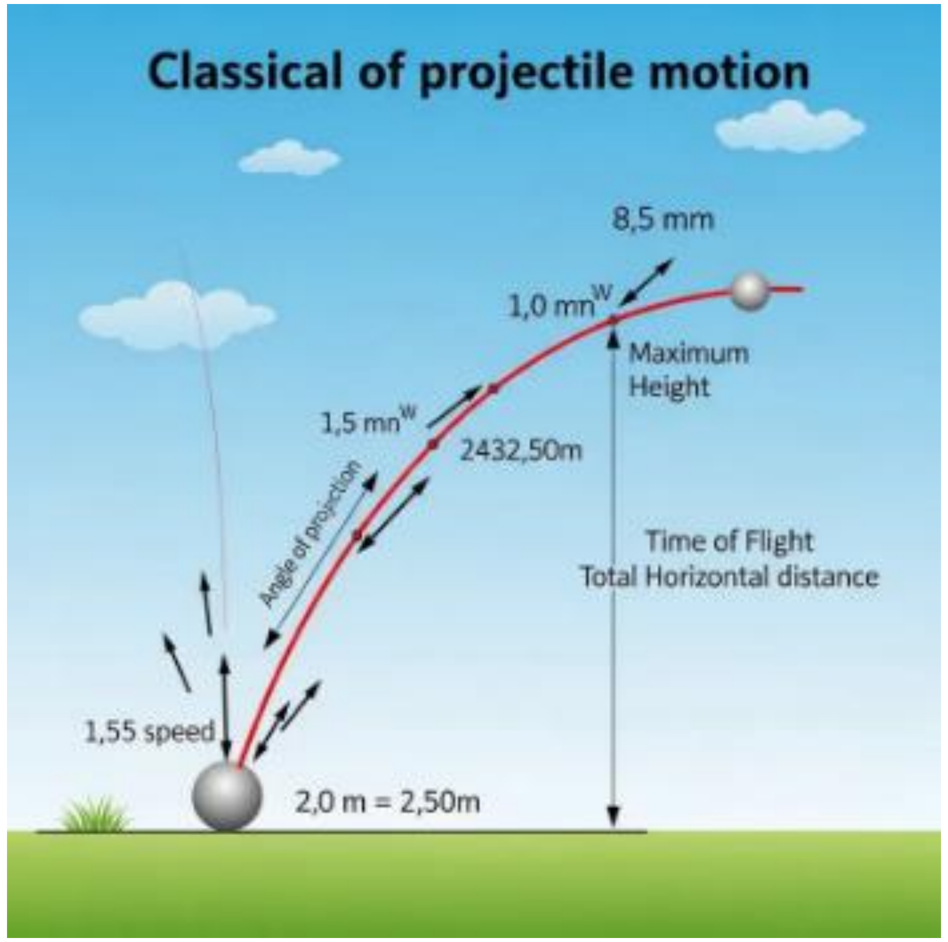
Physics for Physics Teacher 1

Curvilinear Motion & Advanced Dynamics



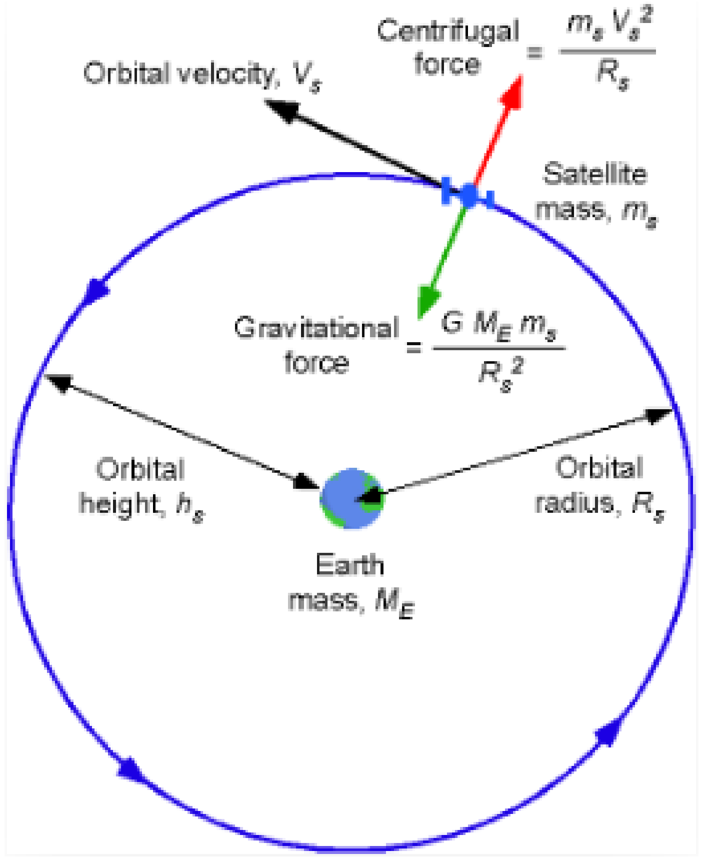
Kittipong S. (Ph.D. Physics)

Department of Physics

Faculty of Science and Technology

Curved Motion

DYNAMICS OF NON-LINEAR TRAJECTORIES

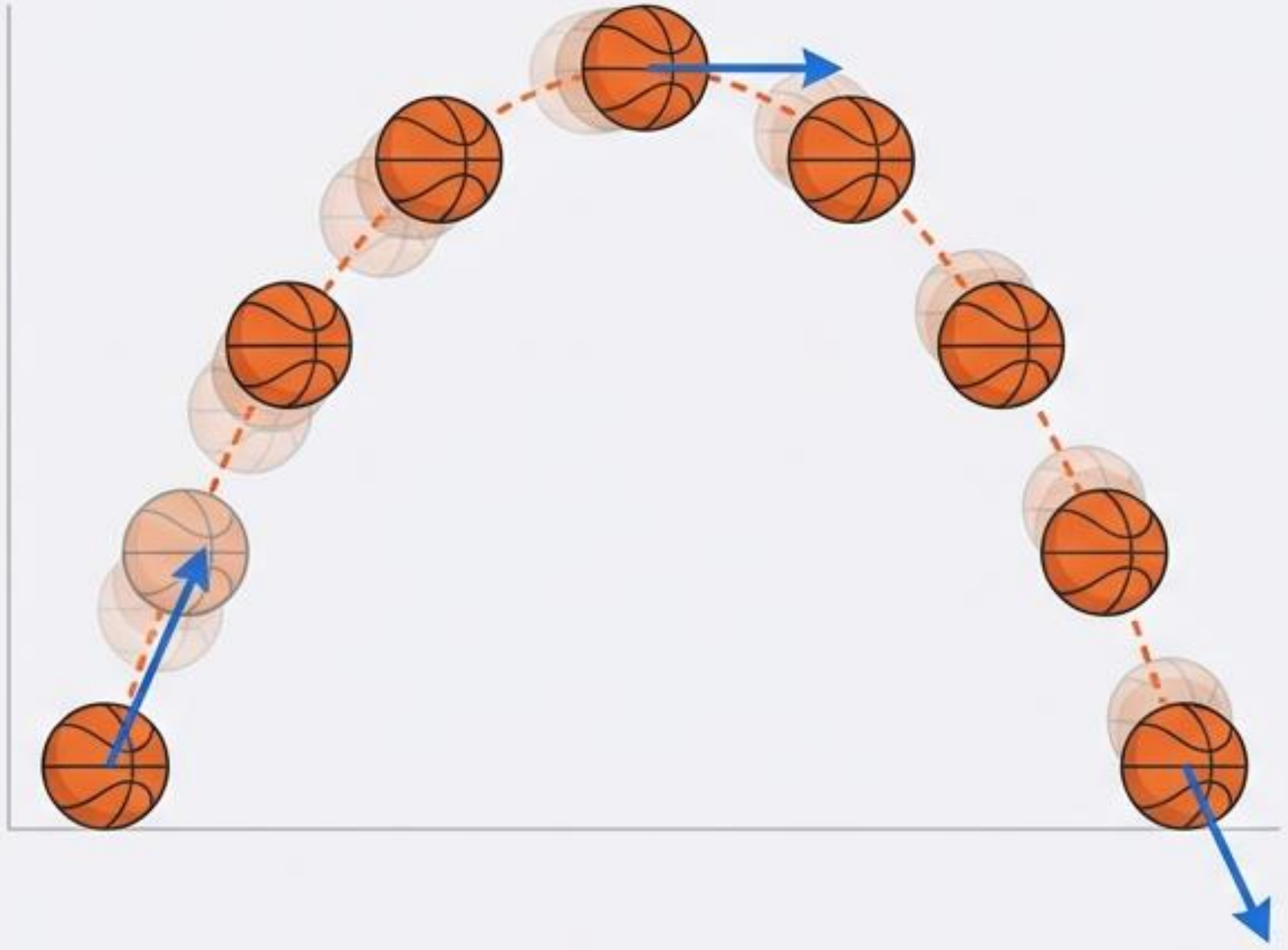


Kittipong S. (Ph.D. Physics)

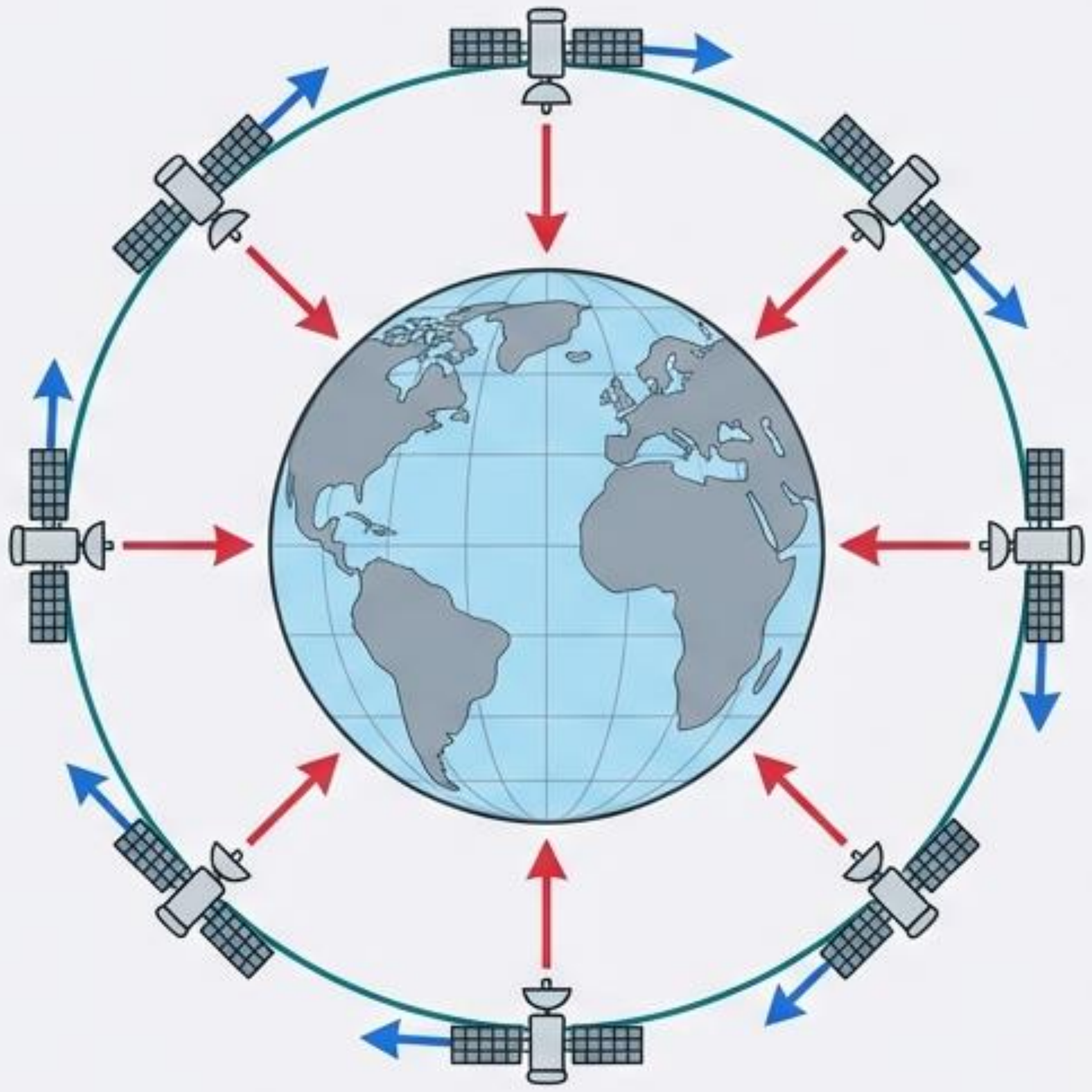
Department of Physics
Faculty of Science and Technology

Curvilinear Motion: Beyond the Straight Line

Decoding the Physics of Projectiles and Circular Dynamics



PROJECTILE MOTION

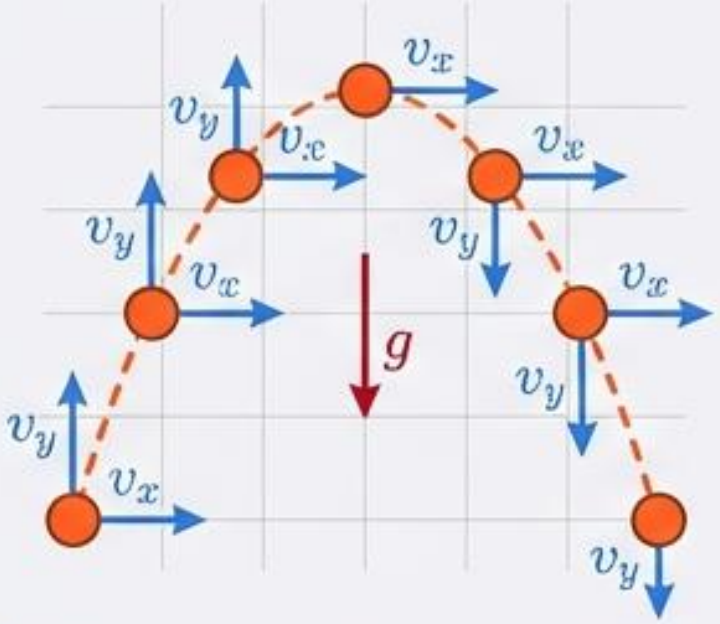


CIRCULAR MOTION

Most motion in the universe is not linear. This chapter dissects 2D motion into two governing archetypes, both defined by forces acting perpendicular to velocity.

Curvilinear Motion

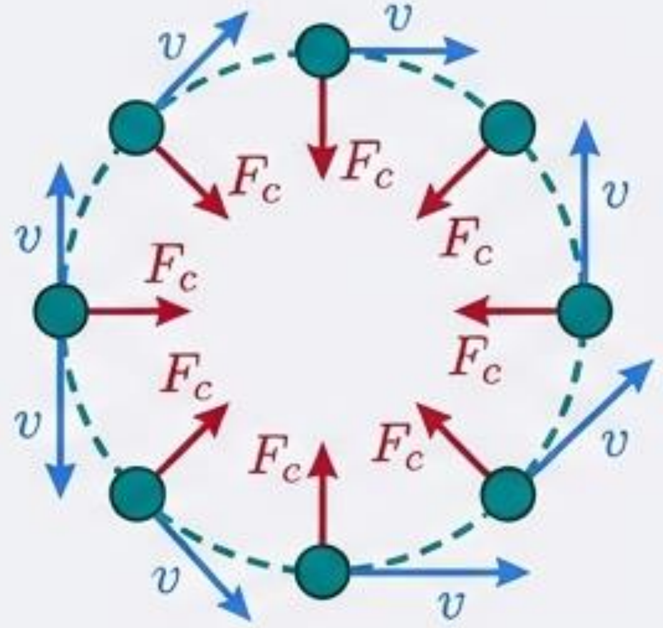
Projectile Motion



- Parabolic Trajectory
- Constant Horizontal Velocity
- Vertical Gravity Acceleration

Uniform Circular Motion

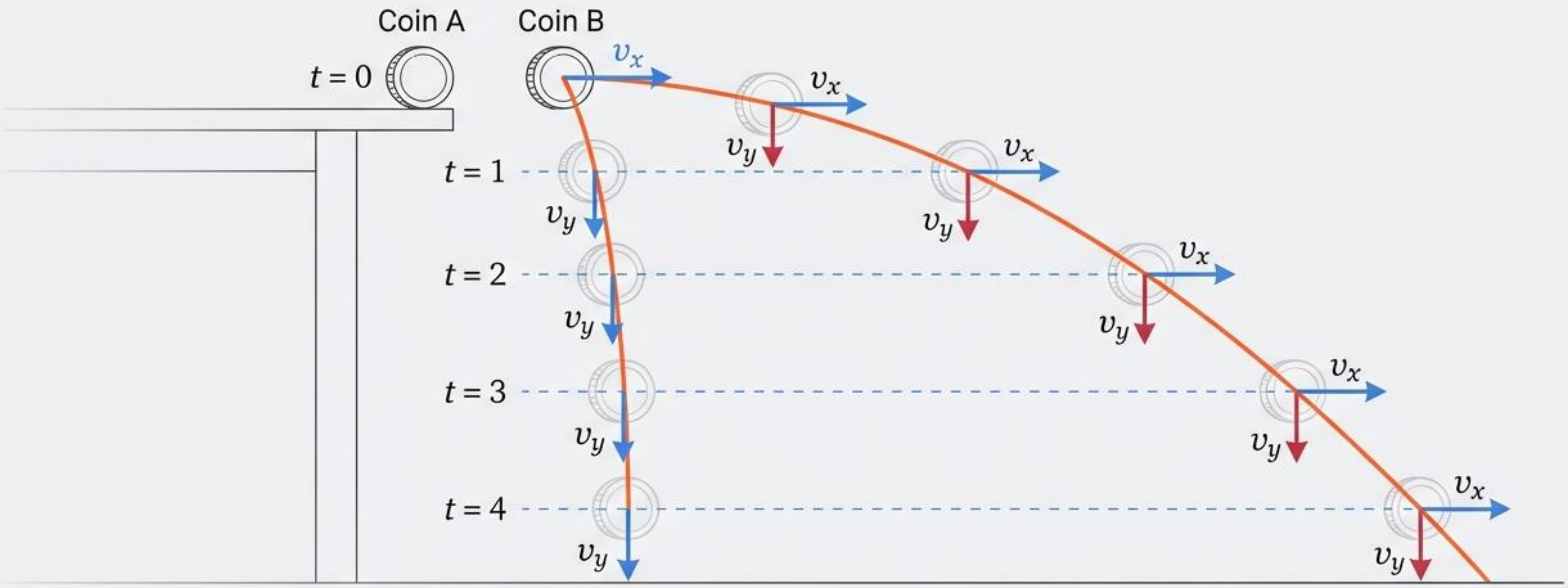
- Circular Path
- Constant Speed
- Changing Direction (Centripetal Force)



Physics Core: Perpendicular Force

The Rule of Independence

Horizontal motion (v_x) and Vertical motion (v_y) are independent. Gravity acts only on the vertical.



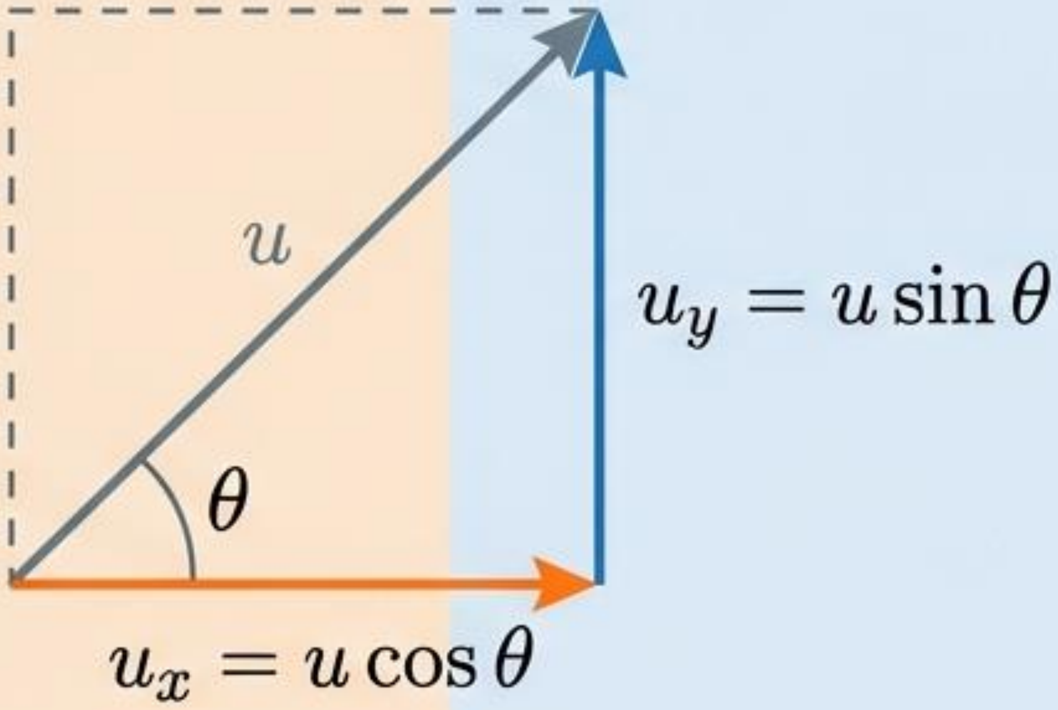
"The horizontal motion has no effect on the vertical fall. They are orthogonal."

The Equations of Trajectory

Horizontal (X-Axis)

No Acceleration ($a_x = 0$). Velocity is constant.

$$\Delta x = u_x t$$



Vertical (Y-Axis)

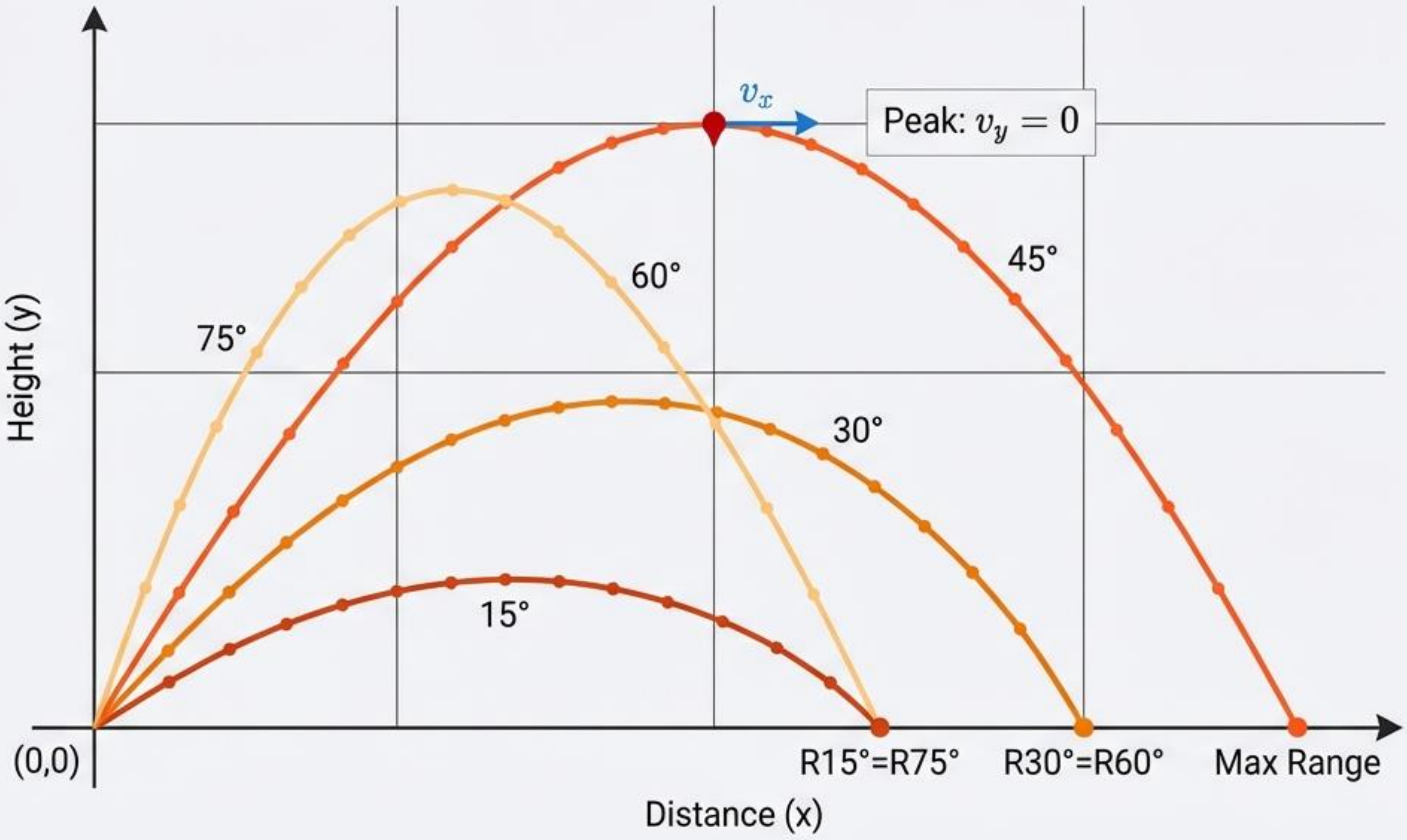
Gravity acts downward ($a_y = -g$).

$$v_y = u_y + a_y t$$

$$\Delta y = u_y t + \frac{1}{2} a_y t^2$$

$$v_y^2 = u_y^2 + 2 a_y \Delta y$$

Rules of the Arc



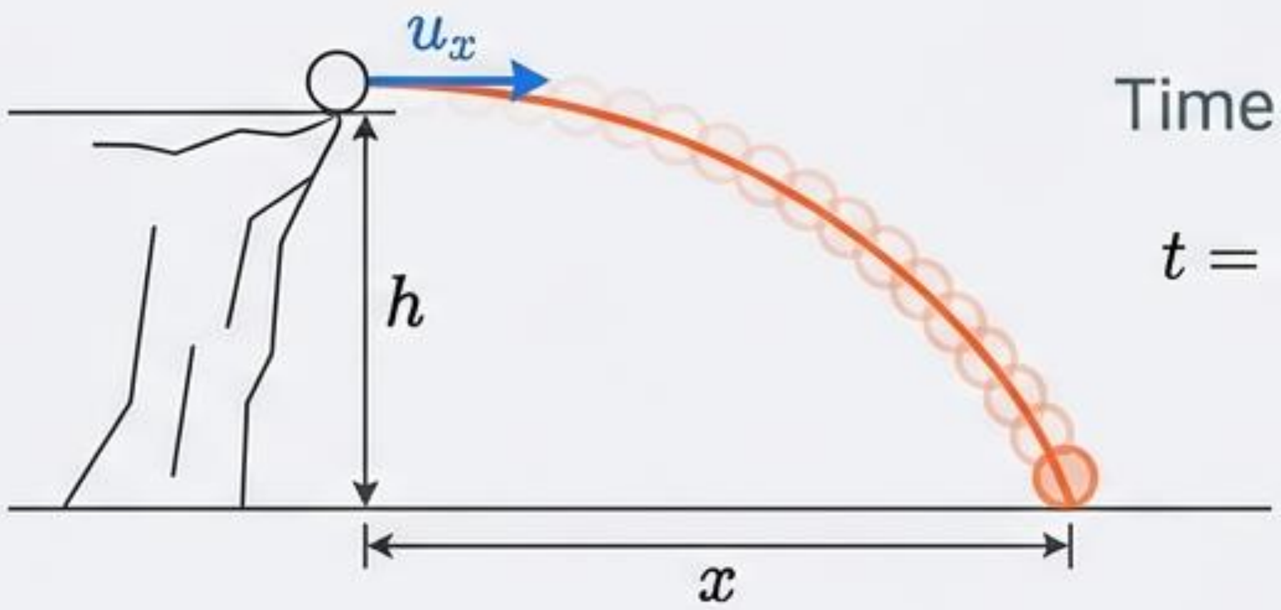
Insight 1: At the peak, vertical velocity is zero. The object moves purely horizontally.

Insight 2: 45° launch angle yields maximum range.

Insight 3: Complementary angles (e.g., 15° & 75°) land at the same spot.

Case Study: The Cliff & The Kick

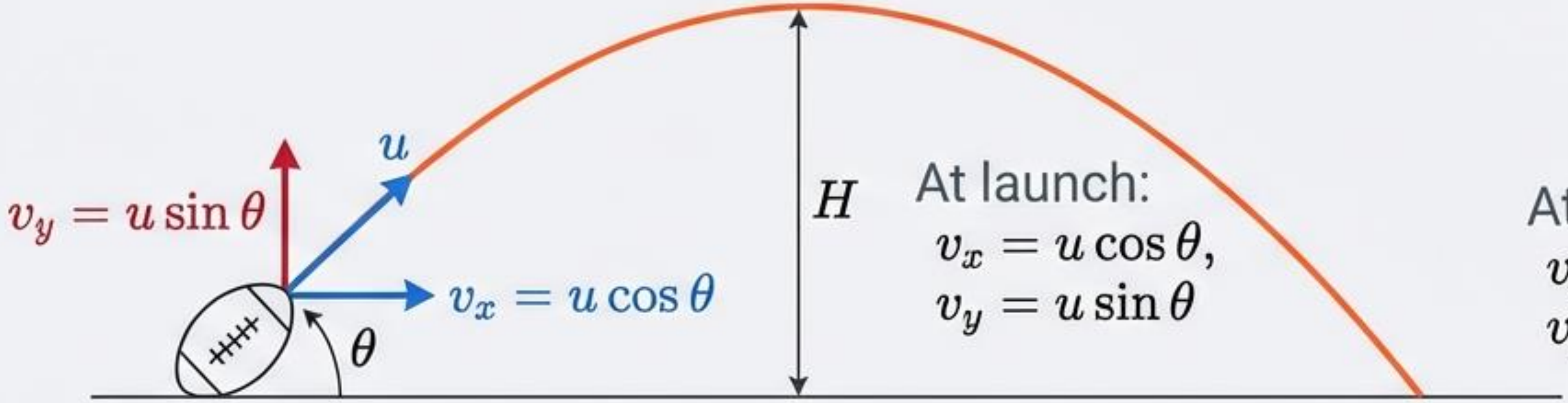
The Horizontal Throw



Time to fall:

$$t = \sqrt{\frac{2h}{g}}$$

The Angled Kick



Time in air depends on vertical trip:

$$t = \frac{2u_y}{g}$$

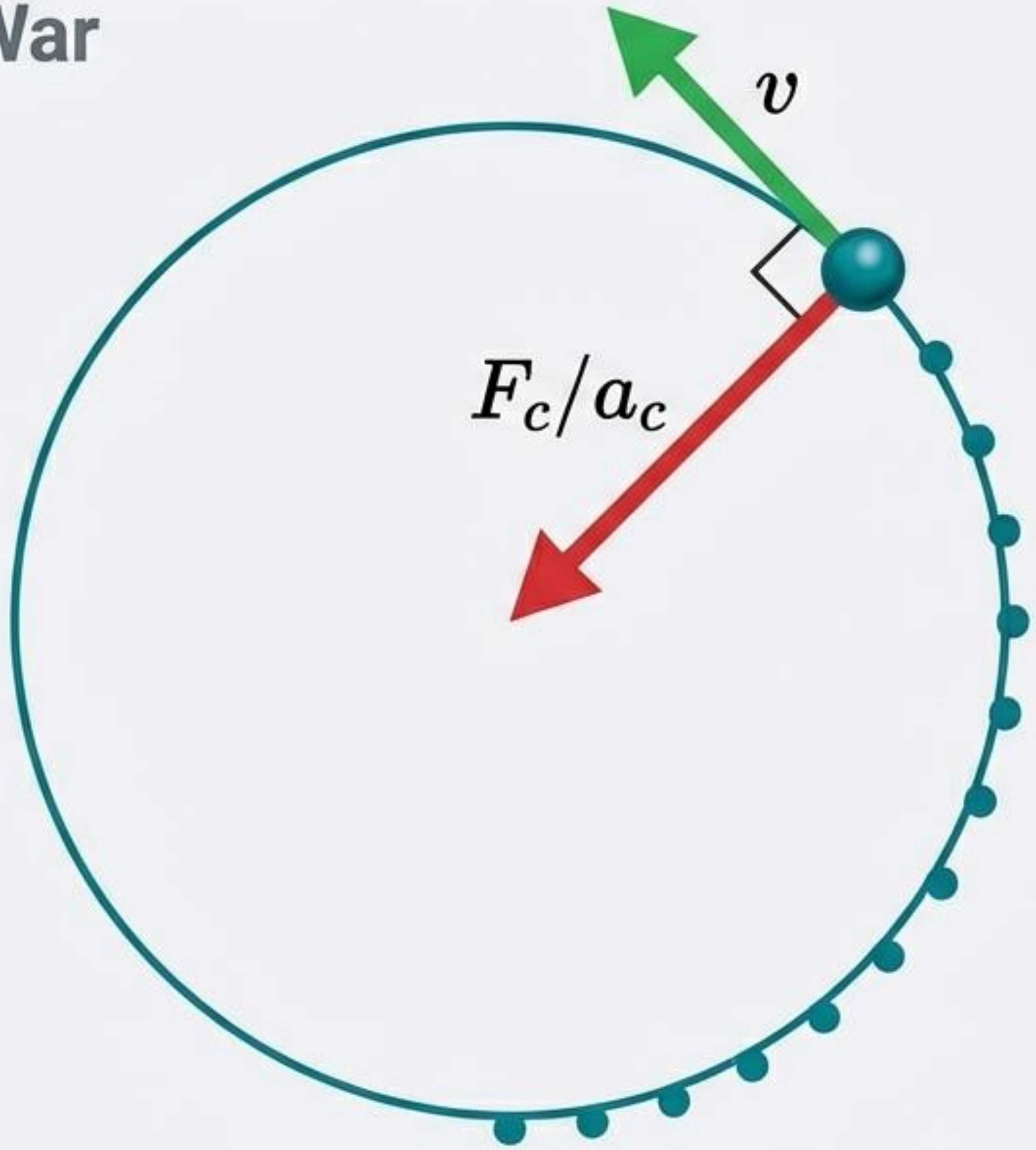
At launch:

$$v_x = u\cos\theta,$$
$$v_y = u\sin\theta$$

Dimension 2: The Circle

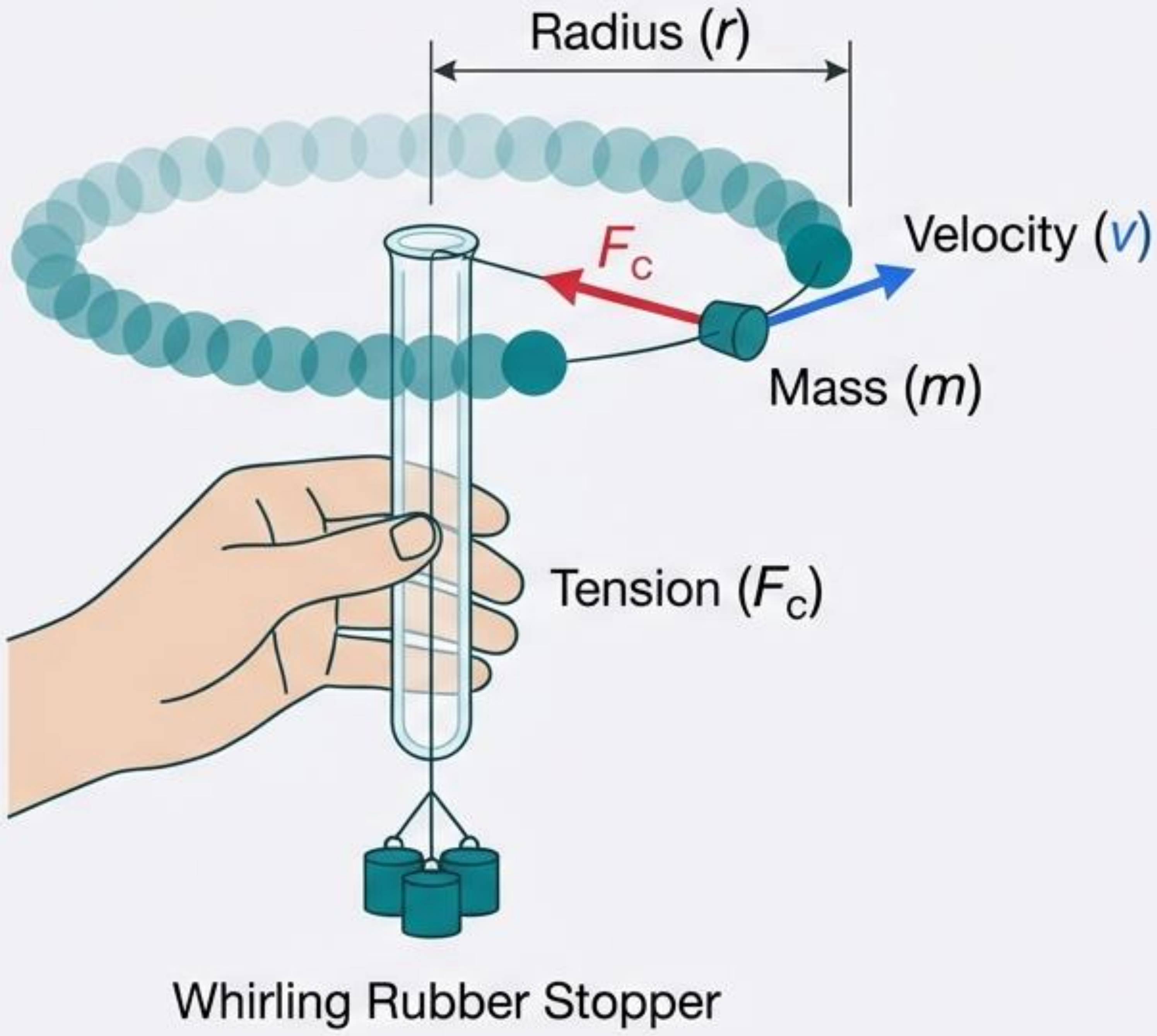
A Constant Tug of War

Uniform Circular Motion: Speed is constant, but velocity changes direction.



The Paradox: Why is there acceleration if speed is constant? Because changing direction requires force.

The Centripetal Equations



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

Force increases with mass and speed squared, decreases with radius.

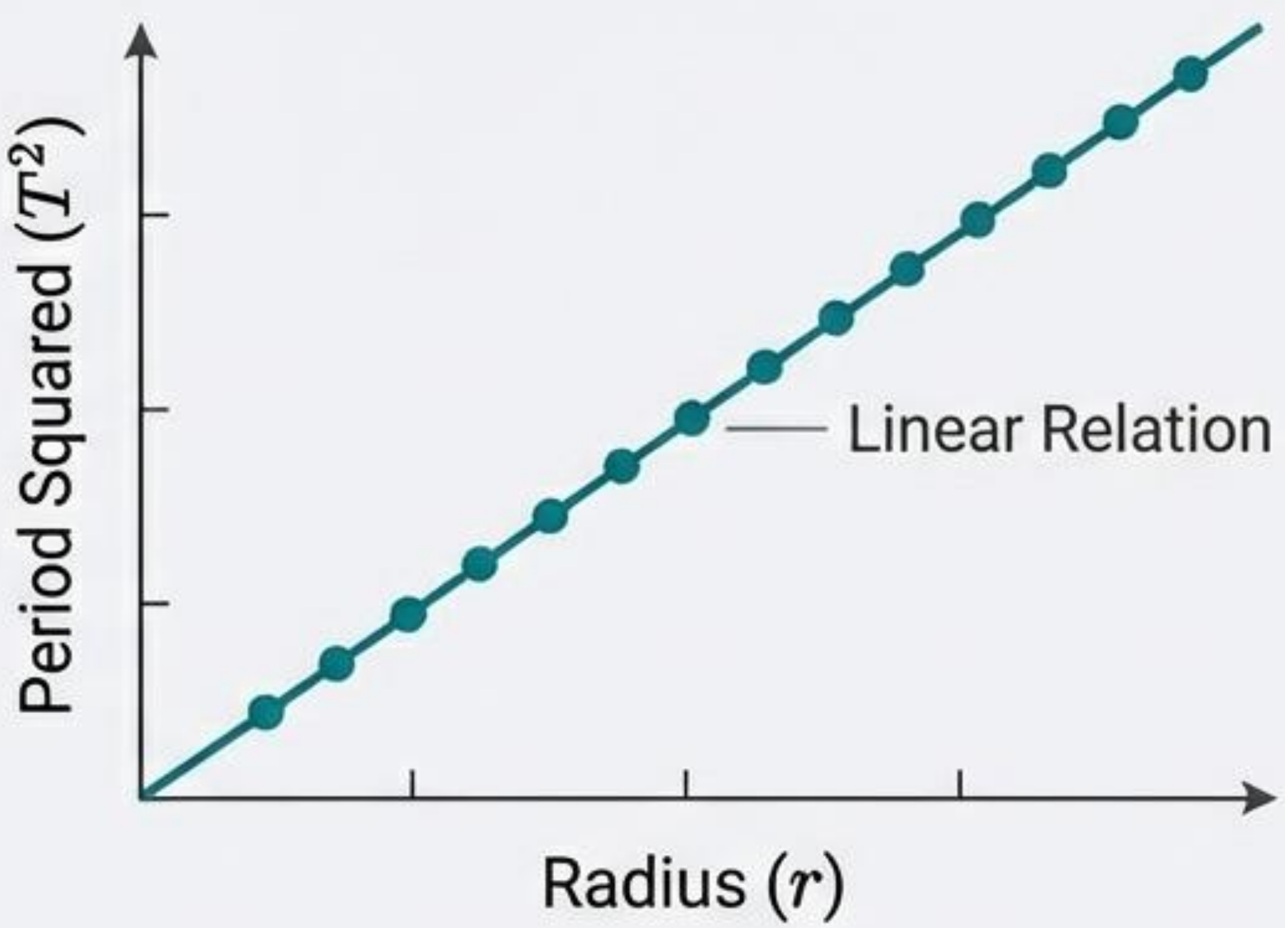
Angular Velocity (ω):

$$v = \omega r$$

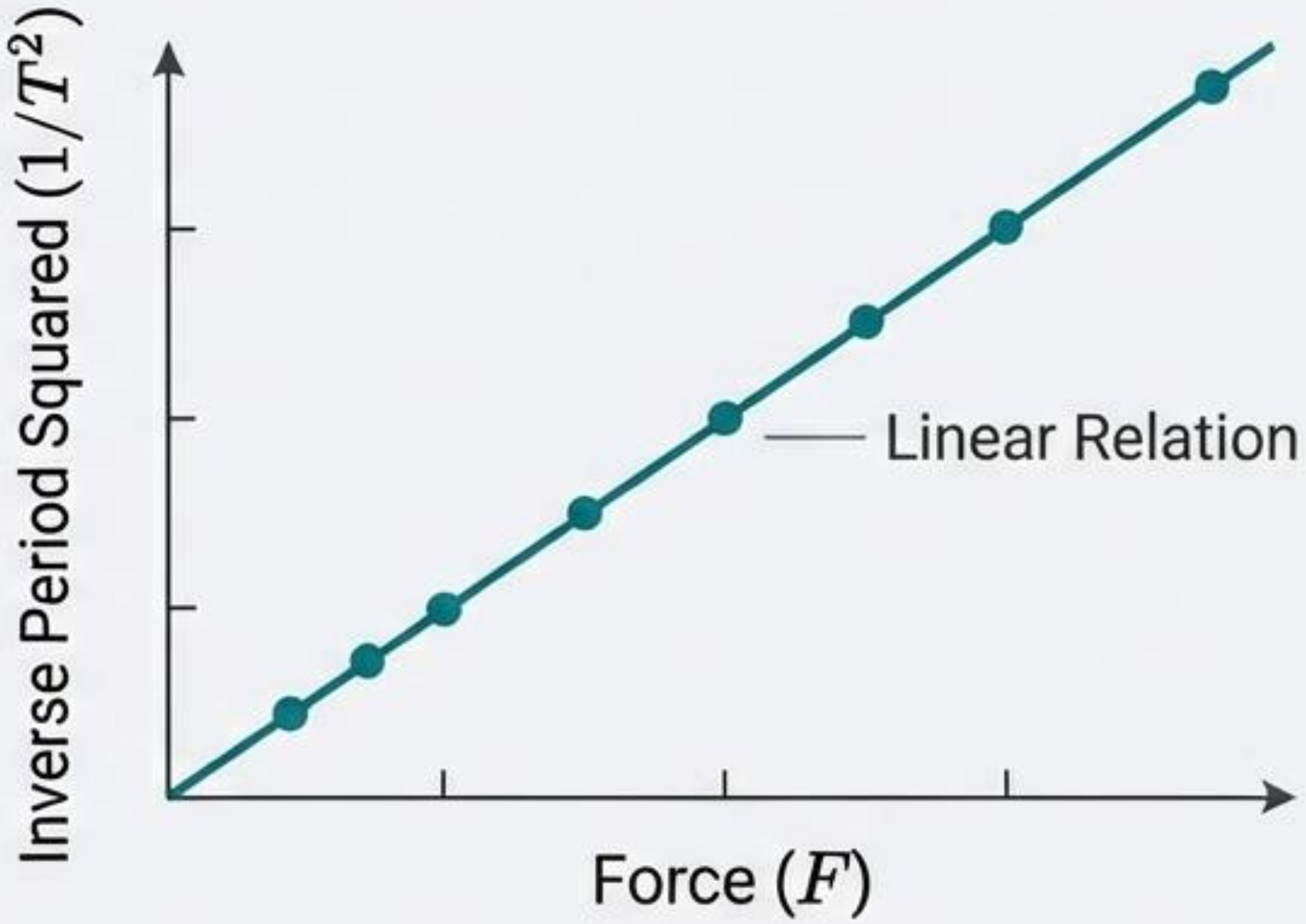
Alternative Form: $F_c = m\omega^2 r$

Experimental Evidence

Data from Activity 7.2



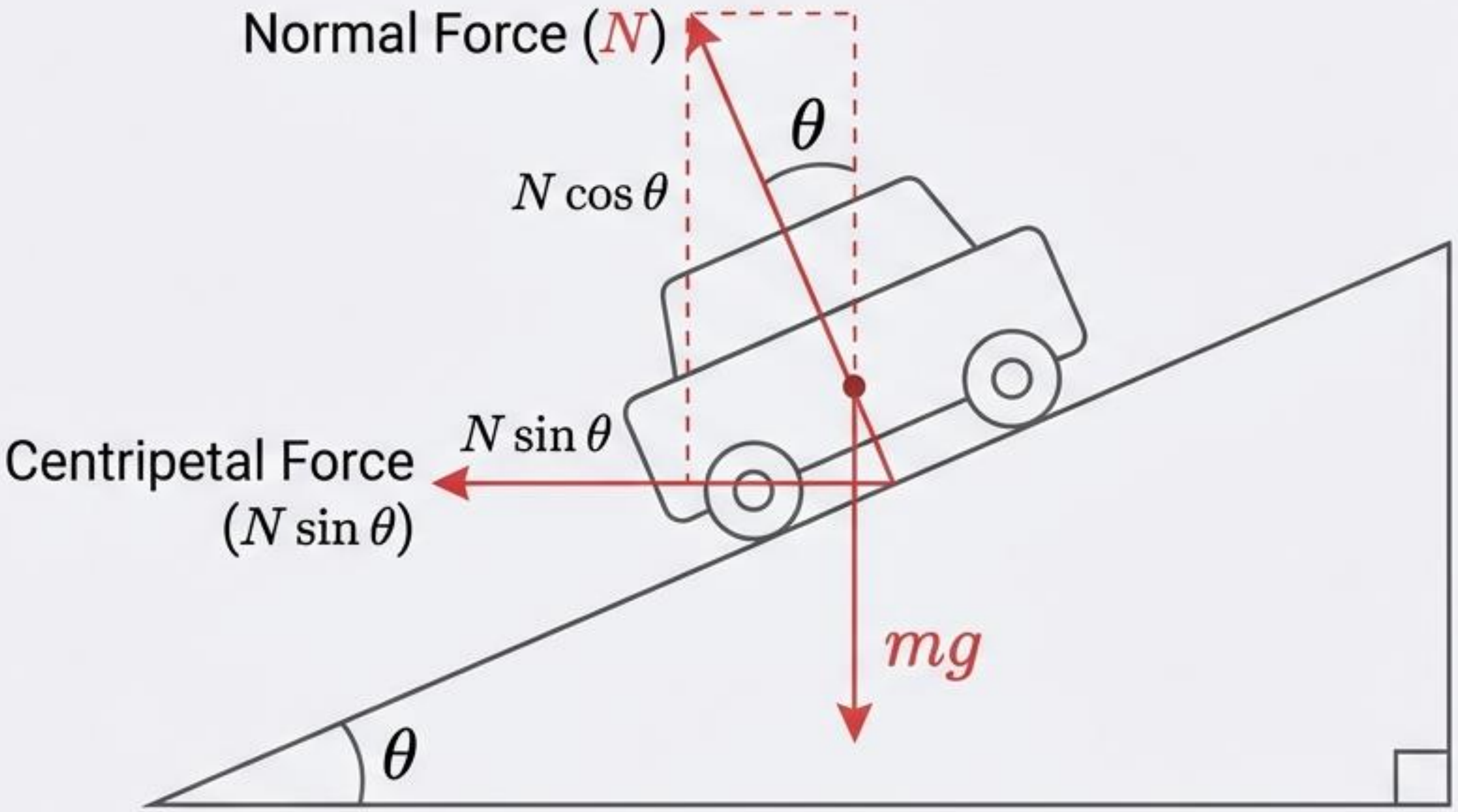
Wider circle = Longer period.



More force = Faster spin.

Conclusion: The data confirms $F_c \propto v^2$ and $F_c \propto 1/r$.

Engineering Curve: The Banked Road



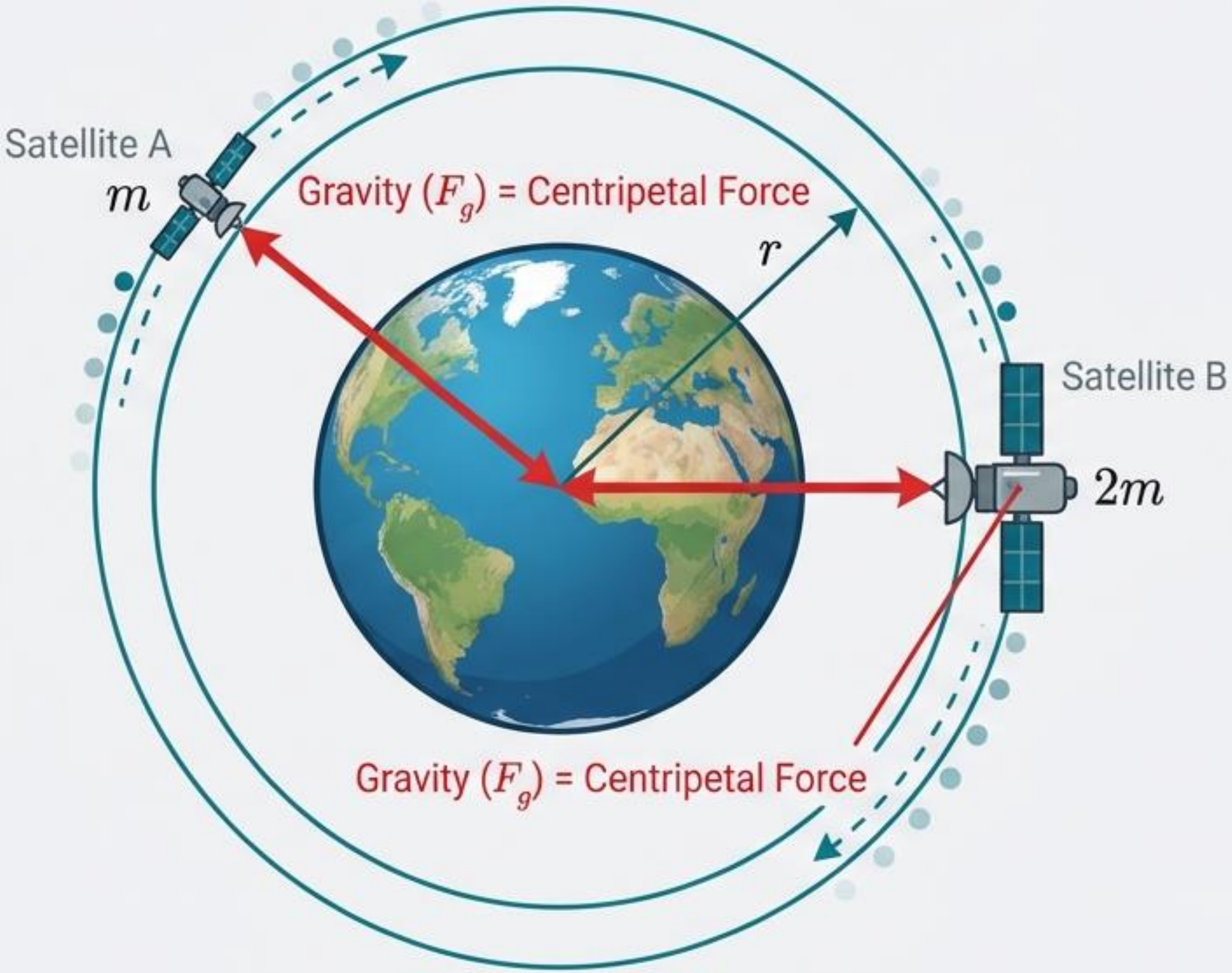
Safe Speed Equation:

$$\tan\theta = \frac{v^2}{rg}$$

Takeaway:

The ideal banking angle depends only on speed and radius. The mass of the car does not matter.

The Infinite Fall: Satellites



Concept: A satellite is a projectile falling around the Earth.

The Math:

Gravity (GmM/r^2) provides the Centripetal Force (mv^2/r).

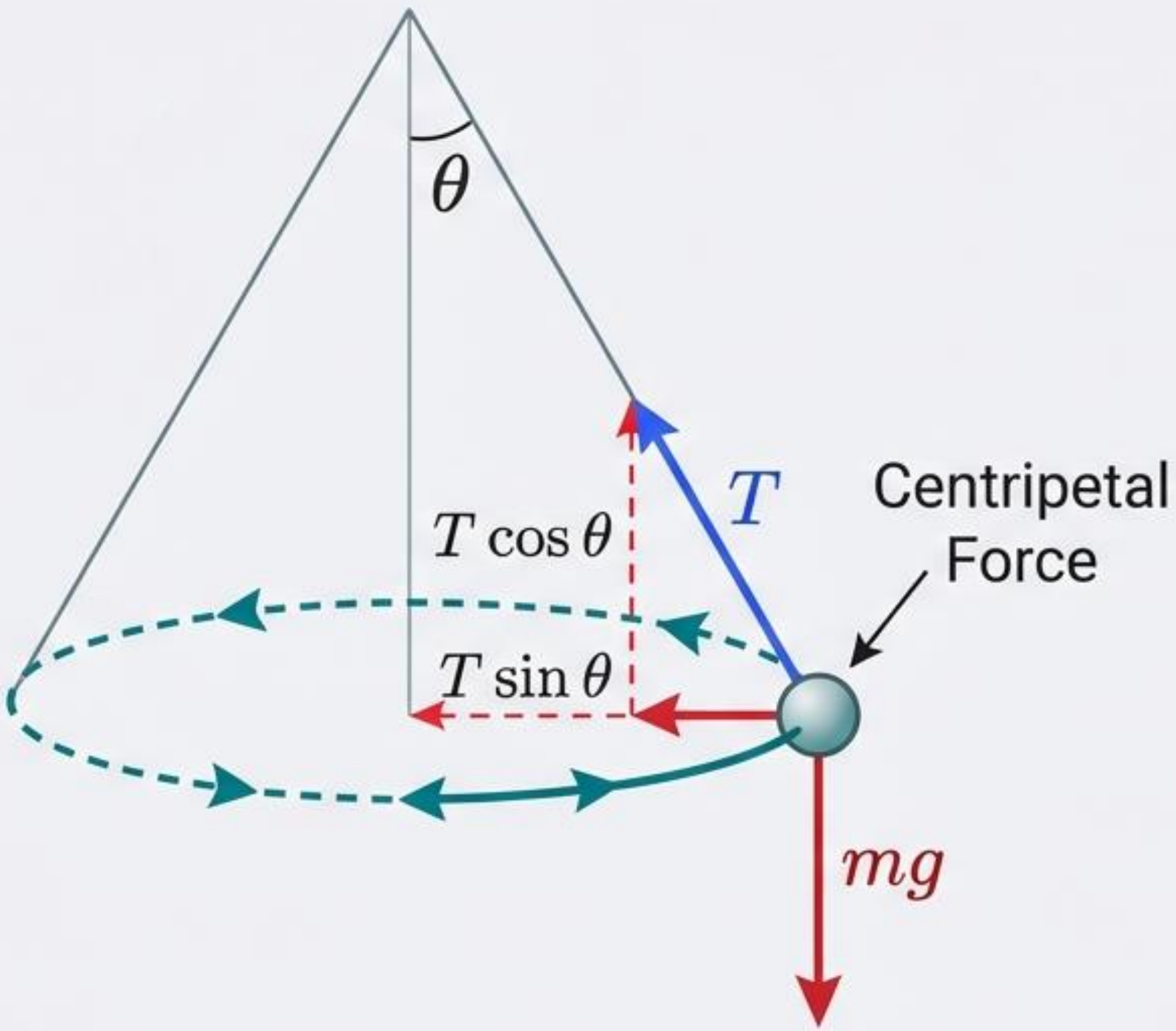
Result:

$$v = \sqrt{GM/r}$$

Insight:

Orbital speed depends only on Earth's mass (M) and distance (r). The satellite's mass (m) cancels out.

The Conical Pendulum



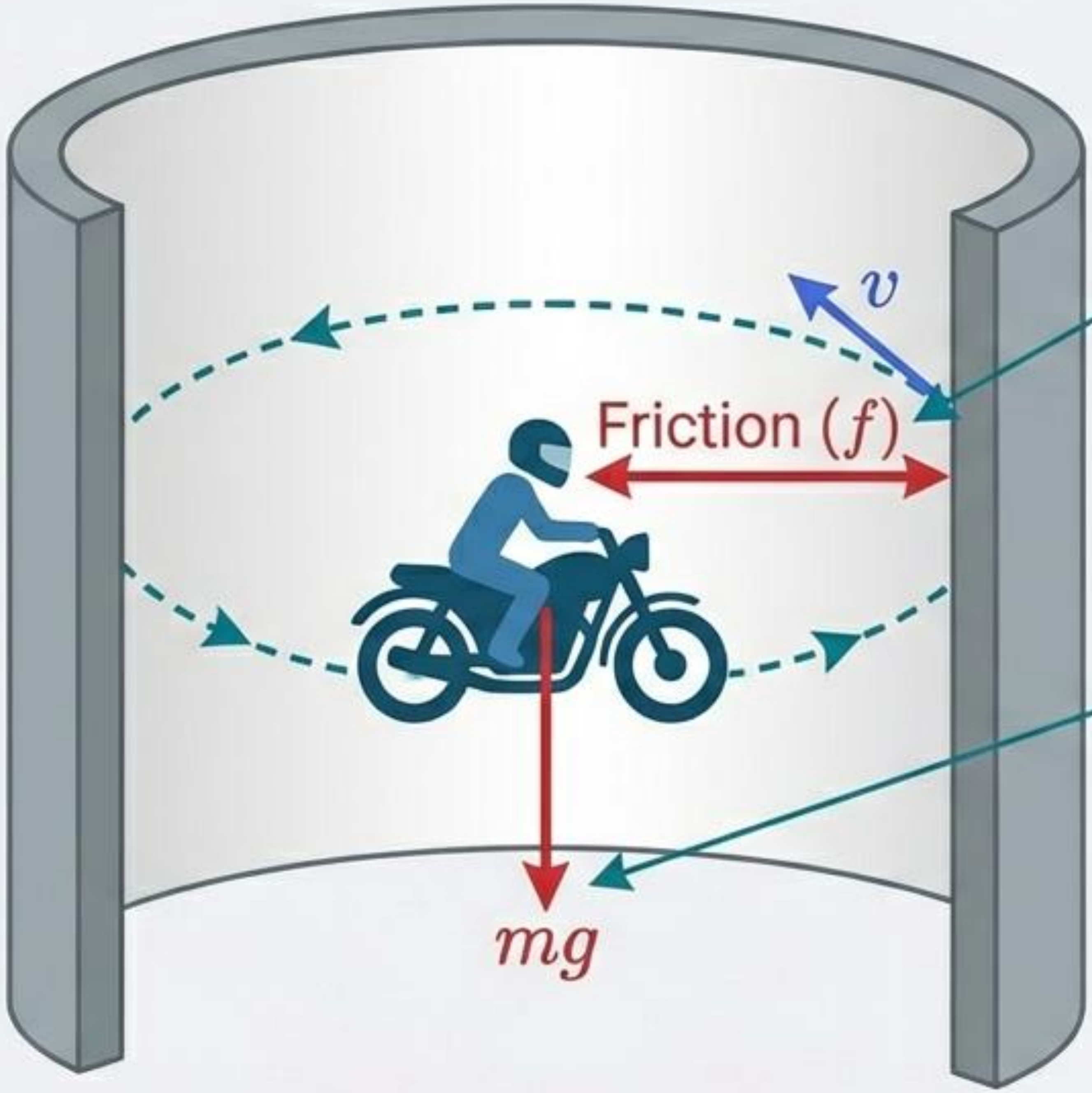
1. Vertical: $T\cos\theta = mg$
2. Horizontal: $T\sin\theta = mv^2/r$

Divide (2) by (1):

$$\tan\theta = v^2/rg$$

Note: The physics is identical to the banked road.

Defying Gravity: The Death Well

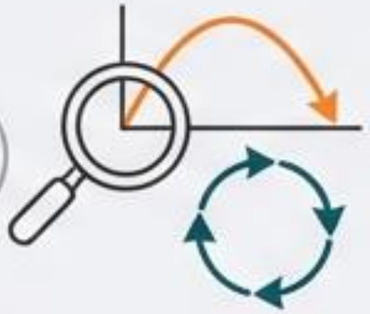


Normal Force (N) acts as the Centripetal Force.

Friction (f) balances Weight (mg).

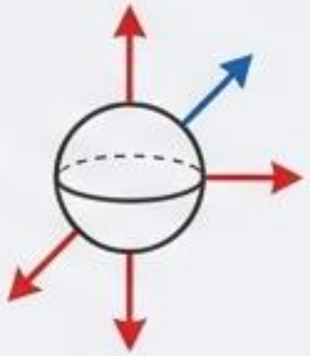
To not slide down, Friction $\geq$ Weight. Since Friction depends on Normal Force $(N = mv^2/r)$, speed must be high.

The Problem-Solving Protocol

1 

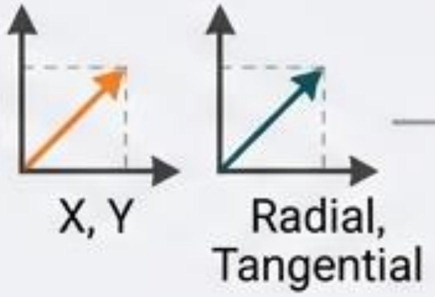
Identify

Projectile or Circular?

2 

Draw FBD

Isolate forces (Weight, Tension, Normal, Friction).

3 

Decompose

Split vectors into X/Y or Radial/Tangential.

4 =

Equate

Projectile: x constant, y gravity.

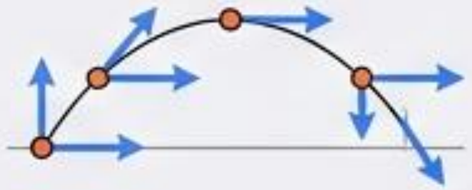
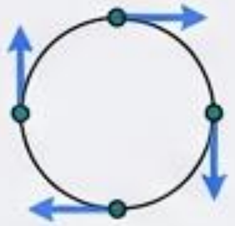
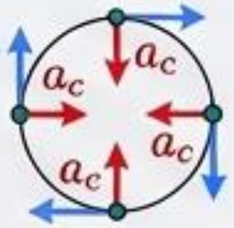
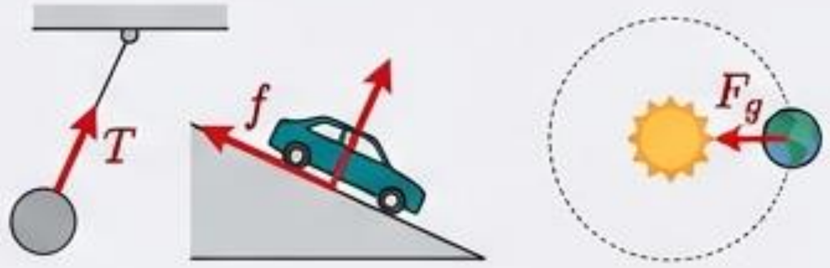
Circular: $\sum F_{radial} = mv^2/r$.

5 

Solve

Substitute and calculate.

Laws of the Curve: Summary

	Projectile Motion	Uniform Circular Motion
Trajectory	Parabolic	Circular
Velocity	v_x constant, v_y changes 	Magnitude constant, Direction changes 
Acceleration	Downward (g) $\downarrow g$	Inward (v^2/r) 
Primary Force	Gravity $\downarrow F_g$	Tension / Friction / Gravity (Center-seeking) 
Key Formula	$\Delta x = u_x t$ $\Delta y = u_y t - \frac{1}{2} g t^2$	$F_c = mv^2/r$

Whether a kicked ball or an orbiting moon, motion is defined by the forces perpendicular to it.