Circular Motion and Orbits Cheat Sheet

AP Physics 1 · Unit 2 · g = 9.8 m/s² · constant speed unless stated

Burke Tutoring in Fremont
burketutoringinfremont.com
(510) 453-0350

THE RULE

$a_c = \frac{v^2}{r}$, toward the center, even at constant speed.

- $v = \frac{2\pi r}{T}$, $f = \frac{1}{T}$
- Sum of force components toward the center = $\frac{mv^2}{r}$
- "Centripetal force" is that net force. Draw only real forces: tension, gravity, normal, friction.
- No centrifugal force on an AP free-body diagram.

FOUR STEPS

1. Find the center and radius of the circle the object follows.
2. Draw a free-body diagram with real forces only.
3. Point one axis at the center; make the other perpendicular, usually vertical.
4. Toward the center: $\Sigma F = mv^2/r$. Other axis: $\Sigma F = 0$ at constant speed.

FERRIS WHEEL AND VERTICAL CIRCLES

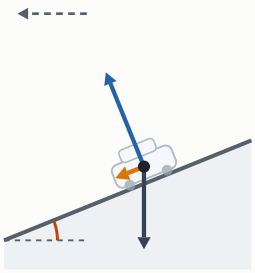
Position	Seat pushes up, F_N
Bottom (a up)	$mg + \frac{mv^2}{R}$: feels heavier
Top (a down)	$mg - \frac{mv^2}{R}$: feels lighter
Level with center	mg, plus $\frac{mv^2}{R}$ sideways toward the center

- Rider floats at the top when $v = \sqrt{gR}$.
- Hill crest: $F_N = mg - \frac{mv^2}{r}$. Dip: $F_N = mg + \frac{mv^2}{r}$.
- Top of a loop, track above: $F_N + mg = \frac{mv^2}{r}$.

BANKED CURVE

- Axes: horizontal (toward the center) and vertical. The acceleration is horizontal.
- No friction needed: $\tan\theta = \frac{v^2}{rg}$, so $v_0 = \sqrt{rg\tan\theta}$; $F_N = mg / \cos\theta$. Mass cancels.
- Faster than v_0: friction down the slope. Slower: up the slope. The AP exam treats this case qualitatively.
- Flat curve: $v_{max} = \sqrt{\mu_s gr}$.
- Enrichment, beyond the AP exam: on a banked curve, $v_{max} = \sqrt{\frac{rg(\tan\theta + \mu_s)}{1 - \mu_s \tan\theta}}$

BANKED CURVE FORCES, REAR VIEW



Key

→	F_g
→	F_N, perpendicular to the road
→	F_f, down the slope when faster than v_0
- - →	Toward the center, horizontal
◺	Bank angle θ

PENDULUM

- Toward the pivot: $F_T - mg\cos\theta = \frac{mv^2}{L}$
- Bottom: $F_T = mg + \frac{mv^2}{L}$, greater than mg; net force up.
- Highest point ($v = 0$): $F_T = mg\cos\theta_0$; net force $mg\sin\theta_0$ along the arc.
- Released from rest at θ_0: $v^2 = 2gL(1 - \cos\theta_0)$, so F_T at the bottom = $mg(3 - 2\cos\theta_0)$.
- Conical pendulum: $\tan\theta = \frac{v^2}{rg}$ with $r = L\sin\theta$.

STRING CUT

- After the cut, gravity is the only force: a projectile with the velocity at the cut, tangent to the circle.
- Cut at the bottom: horizontal launch. $t = \sqrt{\frac{2H}{g}}$, $d = vt$.
- Cut at the highest point: starts at rest and falls straight down.
- It does not move outward along the line of the string.

GRAVITY AND ORBITS

- $F_g = \frac{Gm_1m_2}{r^2}$, r between centers; $g = \frac{GM}{r^2}$.
- Circular orbit: $\frac{GMm}{r^2} = \frac{mv^2}{r}$, so $v = \sqrt{\frac{GM}{r}}$.
- $T^2 = \frac{4\pi^2}{GM}r^3$: farther out, slower and longer.
- Satellite mass cancels. $r = R + h$ when given an altitude h.
- Astronauts float because they fall with the station.

FIVE CHECKS BEFORE YOU HAND IT IN

1. Does every force arrow name the object that exerts it?
2. Did you find the center and radius of the circle the object follows?
3. Is mv^2/r on the ma side, and off the diagram?
4. On a banked curve or conical pendulum, are your axes horizontal and vertical?
5. For an orbit, is r measured from the planet's center?