DYNAMICS OF CIRCULAR MOTION

PART 1: HORIZONTAL CIRCLES

Newton's 1st Law says an object continues in a straight line unless a net force acts on it. To turn, a **Net Force** must point to the center.

NEWTON'S 2ND LAW FOR CIRCLES

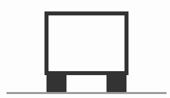
Do not draw a force labeled F_c on an FBD. Identify which **real forces** (Tension, Friction, Normal) point to the center.

$$\Sigma F_{radial} = ma_c \quad \rightarrow \quad F_{in} - F_{out} = \frac{mv^2}{r}$$

WE DO **The Flat Curve**

A 1,500 kg car turns a flat corner ($r = 40$ m). Static friction $\mu_s = 0.8$.

A. Draw FBD (Rear View):



B. Sum of Radial Forces:

Identify the inward force ($F_{friction}$) and set equal to ma_c.

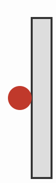
C. Calculate max speed without sliding:

WE DO **The "Rotor" (Gravitron)**

A 60 kg rider is pinned to the wall of a spinning cylinder ($r = 4$ m). The floor drops out.

A. FBD (Side View):

Hint: Which force pushes IN? Which force holds UP?



B. Set up the Equations:

Y-Axis:

Radial (X):

C. Find Min Speed ($\mu_s = 0.4$):

PART 2: VERTICAL CIRCULAR MOTION

Gravity helps pull you in at the top, but fights against you at the bottom.

APPARENT WEIGHT (F_N)

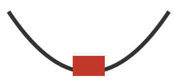
Bottom of Dip:
You feel heavier.
$F_N - mg = \frac{mv^2}{r}$

Top of Loop:
You feel lighter.
$F_N + mg = \frac{mv^2}{r}$

YOU DO **The Roller Coaster Dip**

Mass = 500 kg. Radius = 15 m. Speed at bottom = 20 m/s.

A. Draw FBD (at Bottom):

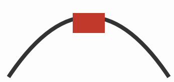


B. Calculate Normal Force:

EXTENSION **Top of the Loop (Optional)**

The cart is now at the very top. Inverted. Calculate the minimum speed to not fall.

A. Draw FBD (at Top):



B. Min Speed Equation:
(Set $F_N = 0$)

Check for Understanding:

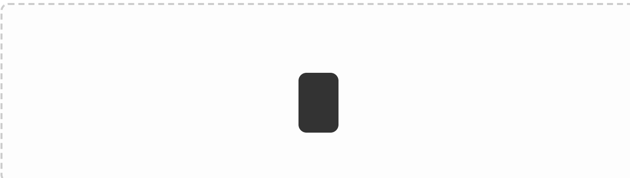
1○ need help	2○ can start	3○ mostly independent	4○ ready to explain

CLASSWORK & PRACTICE

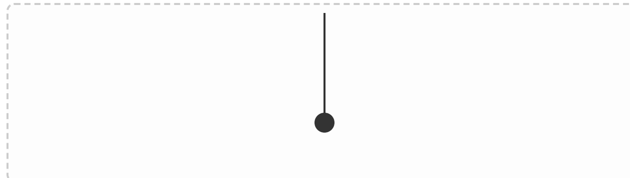
QUALITATIVE **Identifying Net Force**

Draw an arrow representing the direction of the **NET FORCE** (ΣF) for each.

A. Car slowing down while turning Left



B. Pendulum at the very bottom of arc



AP SKILL **Paragraph Argument**

Prompt: A car travels over a hill shaped like a semi-circle (radius R). The driver feels "light" (weightless) at the very top. Using Newton's Laws, explain **why** she feels light. Reference specific forces in your explanation.

SKILL **Proportional Reasoning**

A ball spins on a string on a frictionless table. Tension is T_1.

If mass is doubled $(2m)$, speed is doubled $(2v)$, and radius is doubled $(2r)$, what is the new Tension (T_2) in terms of T_1?

HOMEWORK: DAY 13

Complete this page to prepare for tomorrow's Lab.

☐ Math Tip: Forces at Angles

When the Tension (T) is diagonal, split it into two components:

$T_y = T\cos\theta$ (Balances Gravity)
$T_x = T\sin\theta$ (Points to Center)

The horizontal component of tension supplies the net inward force: $\Sigma F_{radial} = T\sin\theta = \frac{mv^2}{r}$*. (Centripetal force is a ROLE, not a new force.)*

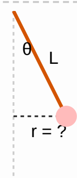
LAB PREP ## The "Flying Pig"

A toy pig flies in a horizontal circle on the end of a string.

- String Length (L) = 1.0 m
- Angle with vertical (θ) = 30°
- Mass (m) = 0.25 kg

Step 1: Geometry

Calculate the Radius (r) of the circle.
Warning: r is NOT the length of the string.



Step 2: The Vertical Component

Write an equation for the Y-axis and solve for Tension (T).

Step 3: The Horizontal Component

Use Newton's 2nd Law in the radial direction ($T_x = mv^2/r$) to find the velocity (v).

CALCULUS CORNER — WHY A POINTS AT THE CENTER (READ-ONLY)

Where does a = v^2/r point-toward-the-center come from? Write circular motion as a position vector and differentiate twice — *read this one; you'll produce it yourself in Unit 7:*

$$r(t) = R\cos(\omega t)\,\hat{\imath} + R\sin(\omega t)\,\hat{\jmath}$$
$$v(t) = dr/dt = -R\omega\sin(\omega t)\,\hat{\imath} + R\omega\cos(\omega t)\,\hat{\jmath}\quad \text{(speed } v = R\omega\text{)}$$
$$a(t) = dv/dt = -\omega^2[R\cos(\omega t)\,\hat{\imath} + R\sin(\omega t)\,\hat{\jmath}] = \mathbf{-\omega^2 \cdot r(t)}$$

The minus sign says a points OPPOSITE r — straight at the center — with magnitude $\omega^2 R = (v/R)^2 \cdot R =$ $\mathbf{v^2/R}$. The formula you've been using all day is two derivatives deep.