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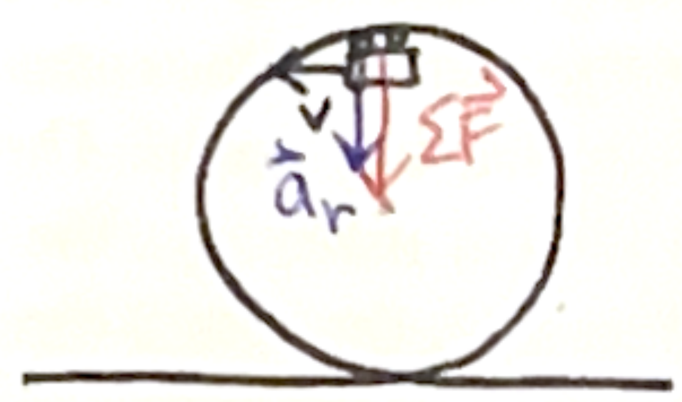
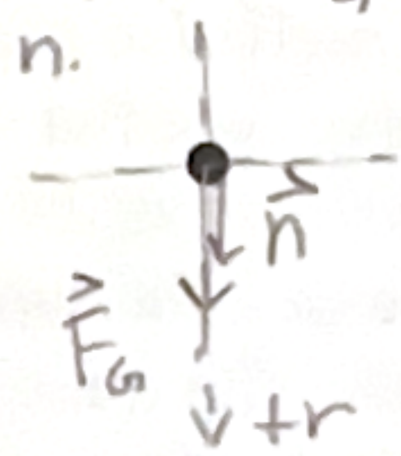
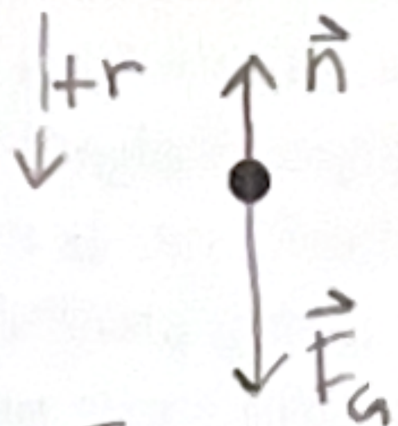
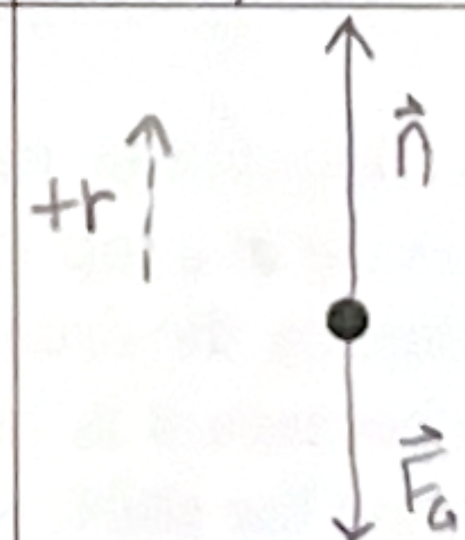
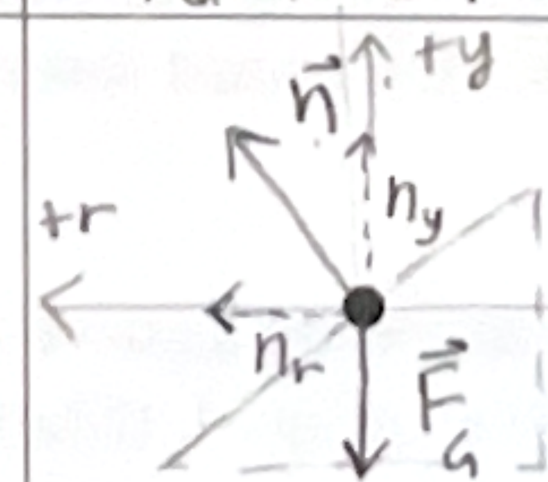
Circular Motion Practice 1

Name: ____________
Date: ____________

1. (*Solutions posted.*) Complete the chart. Assume constant speed for all motions described.

Situation (The system is the object in bold type)	**1. Draw a labeled vector showing $\Sigma\vec{F}_{on\,s}$ at the moment shown in one color. 2. Draw a labeled vector showing the acceleration in another color.**	**3. Draw a labeled force diagram showing all the forces exerted on the system at the exact time shown in the picture.**	**4. Write N2L for the radial direction ($a_r = \frac{\Sigma F_{on\,s\,r}}{m_s}$), expressing $\Sigma F_{on\,s\,r}$ in terms of the force(s) in the radial direction on your force diagram.**	
5. **Rollercoaster car** moving through vertical circular loop (side view) a) For a point at the top		It is not possible to tell how F_G compares to n. 	$a_r = \frac{\Sigma F_{on\,s\,r}}{m_s}$ $a_r = \frac{+n + F_G}{m_s}$	✓
b) For a point at the bottom		 $n > F_G$ because ΣF_r is up	$a_r = \frac{\Sigma F_{on\,s\,r}}{m_s}$ $a_r = \frac{+n + (-F_G)}{m_s}$	✓
6. **Car** driving on a hilly road. a) for a point at the top of a hill		 $n < F_G$ b/c ΣF_r is down	$a_r = \frac{\Sigma F_{on\,s\,r}}{m_s}$ $a_r = \frac{+F_G + (-n)}{m_s}$	✓
b) for a point at the bottom of a valley		 $n > F_G$ b/c ΣF_r is up	$a_r = \frac{\Sigma F_{on\,s\,r}}{m_s}$ $a_r = \frac{+n + (-F_G)}{m_s}$	✓
7. A **car** is on a banked curve in the road, and is not relying on friction to make the turn (cross-section view).			$a_r = \frac{\Sigma F_{on\,s\,r}}{m_s}$ $a_r = \frac{+n_r}{m_s}$ component of $\vec{n}$ in the radial direction (n_y and F_G cancel out)	✓

For each situation, look at the direction of the sum of the forces according to your force diagram and compare it with the direction of the sum of the forces you drew on the picture in the first column. Do they match? If yes, put a ✓ at the right end of the row. If no, find and fix your mistake!

2. Copy all the new physics facts from this week's classwork into your booklet.

3. Read these paragraphs about **Static Friction in Circular Motion:**

Sometimes the force of static friction is involved in circular motion. When a car rounds a curve on a flat road, what force could be providing a sum of the forces that is toward the center of the circle? Static friction! To help grasp this, imagine what would happen if there was no friction between the tires and the road. Can you see that the car would just continue going in a straight line, because without any *sideways force* from the road gripping the tires, there would be no force than could change the *direction* of the car's velocity?

When working with the force of static friction, it is very important to remember that *the force of static friction can take on any value needed to prevent slipping, up to a maximum value*. For example, imagine a car that is going around a curve on a flat road with increasing speed. The acceleration of the car toward the center of the circle is $a_r = v^2/r$, so as the speed of the car increases, the radial acceleration increases. As the radial acceleration increases, the sum of the forces in the radial direction must also increase to keep the car on the circular path. The force of static friction opposes an object's tendency to slip, so as the car's speed increases and the tendency to slip increases, the force of static friction will increase to oppose it. As the speed of the car keeps increasing, the force of static friction will keep on increasing … until it reaches its maximum value (which is related to μ_s and the normal force by $f_{smax} = \mu_s n$)! The maximum speed at which the car can make the turn occurs when the static friction force is at its maximum value. If the car tries to make the turn at a speed that is greater than this maximum speed, the static friction force will not be able to provide the necessary sum of the forces toward the center of the circle, and so the car will slip and not be able to make the turn.

Because the relationship $f_{smax} = \mu_s n$ predicts the maximum value possible for the static friction force, and in most situations the magnitude of the static friction force acting is less than this maximum value, this equation cannot be used in most situations. (Do you usually drive around curves at the fastest possible speed, which puts you on the verge of slipping? I hope not.) The static friction force will occur at its maximum value in situations when a car is moving at the *maximum speed* possible to make a turn of a certain radius, or where a car is going around a turn with the *minimum radius* possible at a certain speed. In situations where the static friction force occurs with a value that is less than its maximum, you can find a value for the static friction force f_s by applying Newton's 2nd Law, but not by using $f_{smax} = \mu_s n$

Sometimes, the force of static friction will be in the vertical direction! For example, imagine a shirt whirling around during the spin cycle in a top-load washing machine. As the shirt goes around in a circle, a force is exerted on the shirt by the drum, and the direction of this force is toward the center of the circle. This is a normal force because it is caused by an interaction with a surface. There is also a downward force exerted by Earth on the shirt, which is F_G. And since we notice that the shirt is not accelerating in the vertical direction, the vertical sum of the forces must be zero. What upward force on the shirt could be balancing the downward force of gravity? It is the force of static friction exerted by the drum on the shirt!

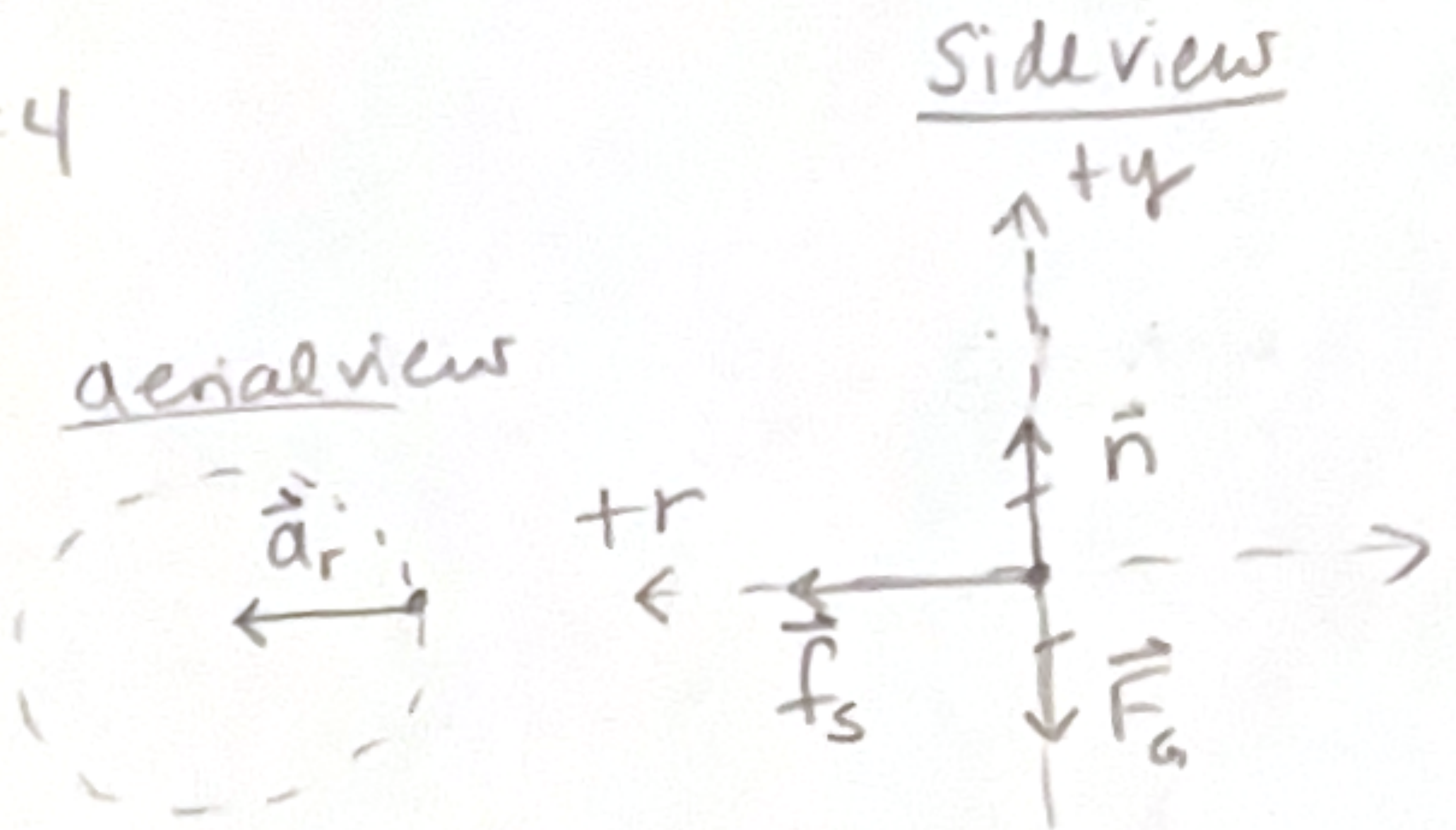
4. (*Solutions posted.*) A car is rounding a curve of radius R on a flat road. The coefficient of static friction is μ_s, and the mass of the car is M. (Show the problem-solving steps.)

a. If the car is traveling at a speed v_o, find the magnitude of the static friction force on the car as it makes the turn, in terms of given variables and fundamental constants.

b. Now the car is traveling at the maximum possible speed to make it around the curve, v_{max}. Find an expression for this maximum speed in terms of given variables and fundamental constants.

Circular Motion Practice 1: #4

a.



$f_s = ?$

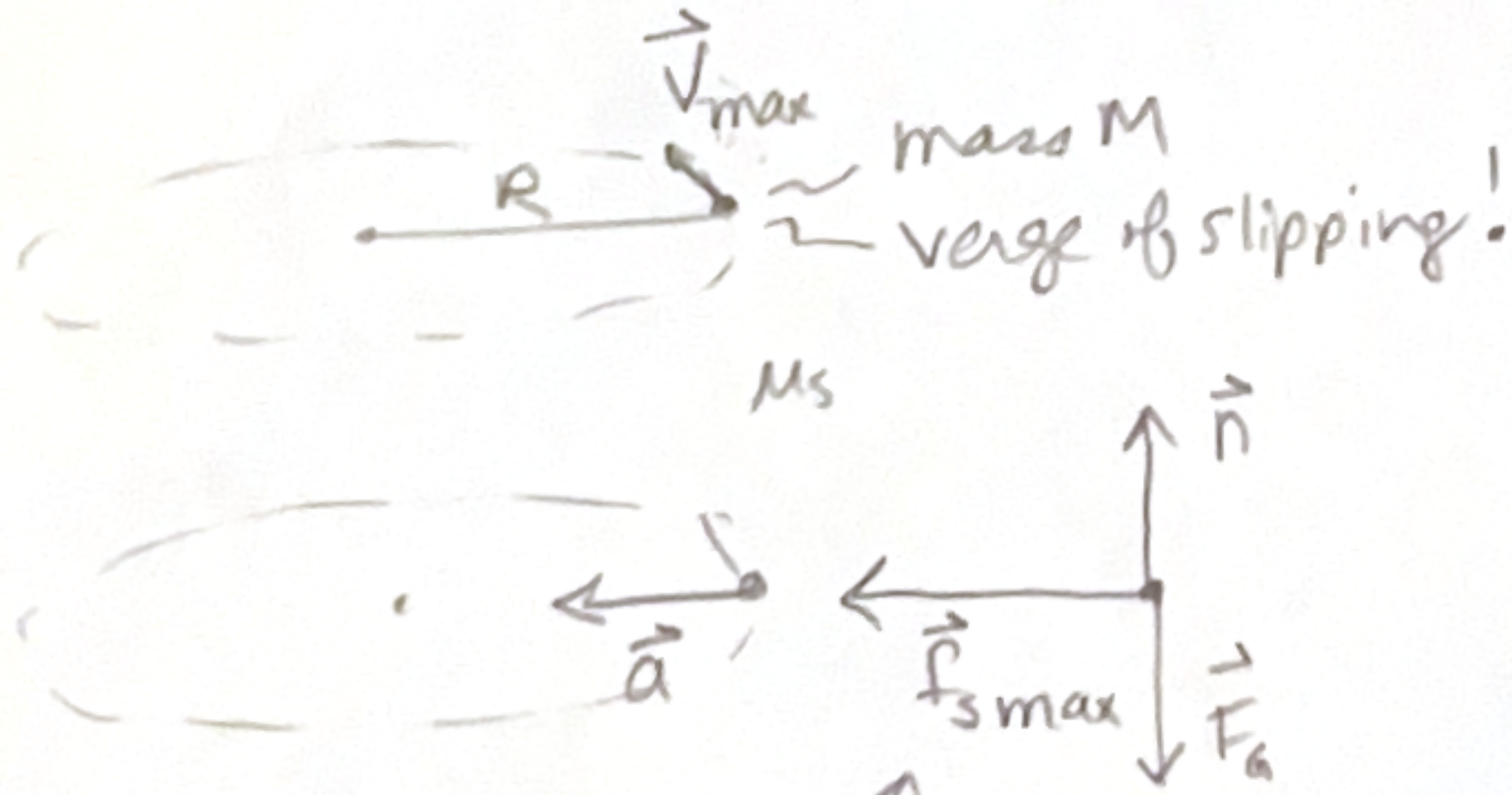
$\vec{F}$	F_r	F_y
$\vec{n}$	$n_r = 0$	$n_y = +n$
$\vec{F}_G$	$F_{Gr} = 0$	$F_{Gy} = -Mg$
$\vec{f}_s$	$f_{sr} = +f_s$	$f_{sy} = 0$

Apply N2L to r-direction: $a_r = \dfrac{\Sigma F_{on\,s\,r}}{m_s}$

$$\frac{v_0^2}{R} = \frac{+f_s}{M}$$

$$\boxed{\frac{M v_0^2}{R} = f_s}$$

b.



I made it bigger than in a.

$\vec{F}$	F_r	F_y
$\vec{n}$	$n_r = 0$	$n_y = +n$
$\vec{F}_G$	$F_{Gr} = 0$	$F_{Gy} = -Mg$
$\vec{f}_{s\,max}$	$f_{s\,max\,r} = +\mu_s n$	$f_{s\,max\,y} = 0$

Apply N2L to r-direction:

$$a_r = \frac{\Sigma F_{on\,s\,r}}{m_s}$$

$$\frac{v_{max}^2}{R} = \frac{+\mu_s n}{M}$$

$$v_{max} = \sqrt{\frac{\mu_s n R}{M}}$$

n is not allowed!

But no problem, I can find n using the y-direction!

$$a_y = \frac{\Sigma F_{on\,s\,y}}{m_s}$$

$$0 = \frac{+n + (-Mg)}{M}$$

$$n = Mg$$

substitute it

$$v_{max} = \sqrt{\frac{\mu M g R}{M}} = \boxed{\sqrt{\mu g R}}$$