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Period _____
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Applied Knowledge of Forces
The Friction Circle Model
A Discovery Exercise
Section 1

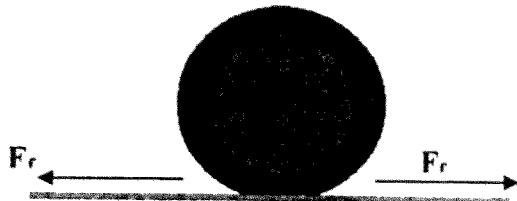
Background:

Since the dawn of the automobile, people have been working to make them faster, safer, and more reliable. The most important item in vehicle safety and performance is the small patch where your tires make contact with the road. Cleverly enough, this is called a "Contact Patch". It is only about $.01 \text{ m}^2$ per tire! So your entire contact with the ground is $.04 \text{ m}^2$ (assuming you have 4 tires). Understanding how forces and friction interact with your tires is critical to driving safety and performance.

Part I

Background Science

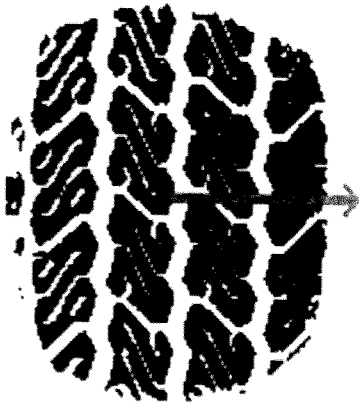
The maximum traction that a tire generates can be described by the simple equation $F_f = mg \mu_k$ (since $\cos 0^\circ = 1$).



The illustration above shows the traction force to the front or rear; however, the traction force can be generated to the side or any other direction in the horizontal plane. Because the tire can develop the force in any direction on the horizontal plane, it provides the basis for the friction circle theory.

Another View

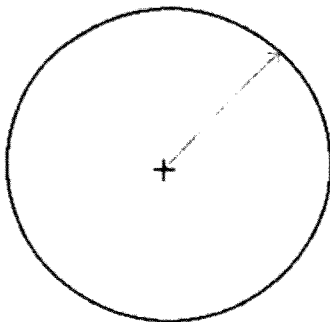
Rather than looking at the traction force from the side view of the tire, the friction circle looks at the traction force at the contact patch. The illustration below shows a force arrow to the right indicating that the traction force is being used to resist lateral motion.



If all of the available traction were to be used in the rearward direction, as during acceleration, then the traction force arrow would be pointing to the rear as seen below.



Because the tire's traction force can be in any direction, the force arrow can also point in any direction. So now imagine the force arrow was to sweep 360 degrees, like the hands on a clock. The limit of the arrow would then describe a circle (see example below).



This is the basis of the friction circle theory. The circle is simply a graphic means of illustrating that the tire's maximum traction can be developed in any direction.

Part II

You will work on a simplified version of the forces on the contact patch.

Large Acceleration = 2499 N in the positive Y direction
Large Braking = 2499 N in the negative Y direction
Full Turn = 2499 N in the positive X direction

Fill in the matrix with the resultant force magnitude and angle for each combination (use the Pythagorean Theorem).

	No Turning	Full Turn
No Acceleration		
Full Acceleration		
No Braking		
Full Braking		

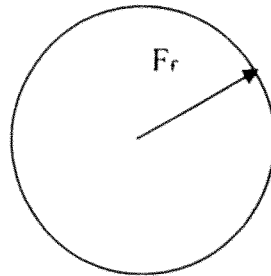
Part III

Now calculate the maximum Force of Friction, F_f for one tire using $F_f = mg \cos \Theta \mu$. Assume the car has a mass of 1,500 kg evenly distributed across the four tires (divide by 4 to get the mass per tire). The tires for this exercise have a coefficient of friction of μ_k of .68.

$F_f =$ _____ N

Part IV

The F_f (force of friction) calculated in part III is the maximum force of friction from the tire. Exceeding that limit results in sliding or skidding. Since this F_f is the limit in any direction it creates a circle of maximum force allowed. This is called the Friction Circle.



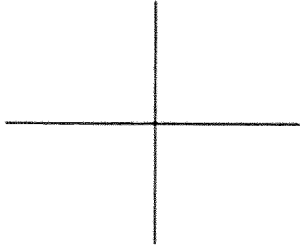
Put the value from Part III on the circle. This is the maximum force per tire available as friction.

Stop! Show your work to the instructor before proceeding to the next part of this exercise.

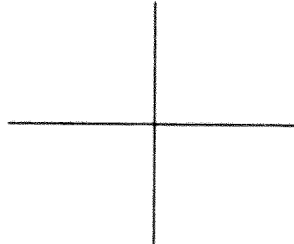
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Part V:

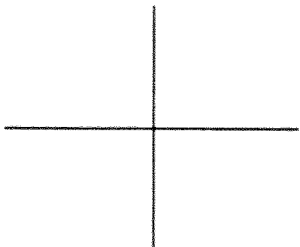
Now it is time to overlay the Force Vectors onto your tire's Friction Circle.
Draw eight circles below with radii corresponding to the F_f calculated in part IV.
Add the vectors from your table part II. Be sure to draw them to the same scale as your F_f .
Add the result for each case (skid or no skid).



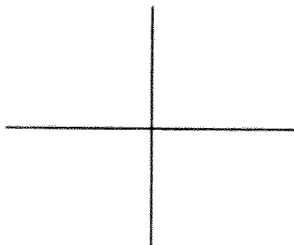
No Acceleration
No Turning
Result: _____



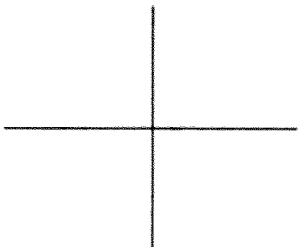
No Acceleration
Full Turning
Result: _____



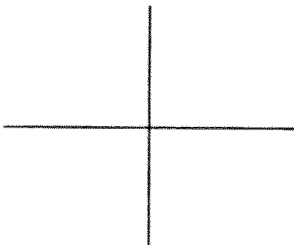
Full Acceleration
No Turning
Result: _____



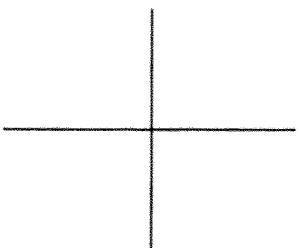
Full Acceleration
Full Turning
Result: _____



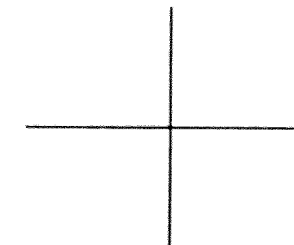
No Braking
No Turning
Result: _____



No Braking
Full Turning
Result: _____



Full Braking
No Turning
Result: _____



Full Braking
Full Turning
Result: _____

Part VI: Analysis and thought

1. Is it possible to have full braking and full turning at the same time?

Why or why not?

2. How would you change your force vectors in Part V to remain in the limits of traction?

Redraw the circles that had skidding with vectors that will be safe (within the F_f limits of the tire).

3. Describe in a paragraph what this really means about driving a car around corners. Include what you can do with the gas, brake, and steering.

4. Remembering that $F_f = mg (\cos \Theta) \mu$, what can you do to increase the size (the allowable forces) of the friction circle? Describe at least two practical methods to increase the size of the circle.

