Forces – Dynamics

I. Laws of Motion: 1 & 2
- inertia, force, mass
- weight

II. Law 3
- interaction & nature of force
- types of force: normal, **friction**
- air resistance, terminal velocity

III. Applications/Problem Solving
- components, inclines

	The student will be able to:	HW:
1	State Newton's 1st and 2nd Laws of Motion and apply these laws to physical situations in order to determine what forces act on an object and to explain the object's resulting behavior.	✓ 1 – 5
2	Recognize and state the proper SI unit of force and give its equivalence in fundamental units and use the relation $\mathbf{F}_{net} = m\mathbf{a}$ to solve problems.	✓ 6 – 10
3	Recognize the difference between weight and mass and convert from one to the other.	✓ 11 – 18
4	State and utilize Newton's 3rd Law to solve related problems.	✓ 19 – 21
5	Understand and utilize the concept of the normal force to solve related problems.	✓ 22 – 25
6	Understand and utilize the relation between friction force, normal force, and coefficient of friction for both cases: static and kinetic.	26 – 32
7	State the factors that influence air resistance and describe qualitatively the effect of each factor on the magnitude of the frictional force. And explain what is meant by "terminal velocity".	33 – 35
8	Resolve forces into components using trigonometry and use the results to solve related force problems.	36 – 40
9	Apply the concept of force components to objects on an incline and solve related problems.	41 – 47

What is "friction"?

- Friction is a "contact force" that opposes *relative* motion of one object sliding across another.
- Friction is always directed parallel to the surfaces of the objects.
- Like all forces, friction occurs in equal and opposite pairs.

What determines the amount of friction?

The type of surfaces influences the amount of friction. Generally rougher surfaces result in greater friction.

The greater the amount of normal force pressing objects together, the greater the amount of friction.

The simple model of friction:

$$F_f = \mu F_N$$

where: F_f = magnitude of friction
μ = coefficient of friction
F_N = magnitude of normal force

The coefficient of friction is a constant of proportionality depending on the surfaces.

Types of Friction

- If one object slides across another it is called *kinetic friction* or *sliding friction*.
- If an object is at rest against another object there may be *static friction*.
- The maximum amount of static friction is sometimes called the *starting friction*.

The model can be used for each type of friction:

<u>kinetic friction</u>:

$$F_f = \mu_k F_N$$

<u>static friction</u>:

$$F_f \leq \mu_s F_N$$

The coefficients are typically not the same for a given scenario. Generally speaking:

$$0 < \mu \leq 1$$

$$\mu_k \leq \mu_s$$

Example Coefficients of Friction		
Materials	μ_s	μ_k
steel/steel	0.74	0.57
glass/glass	0.94	0.40
wood/wood	0.5	0.3
tire/dry road	1.0	0.8
tire/wet road	0.7	0.5
teflon/teflon	0.04	0.04

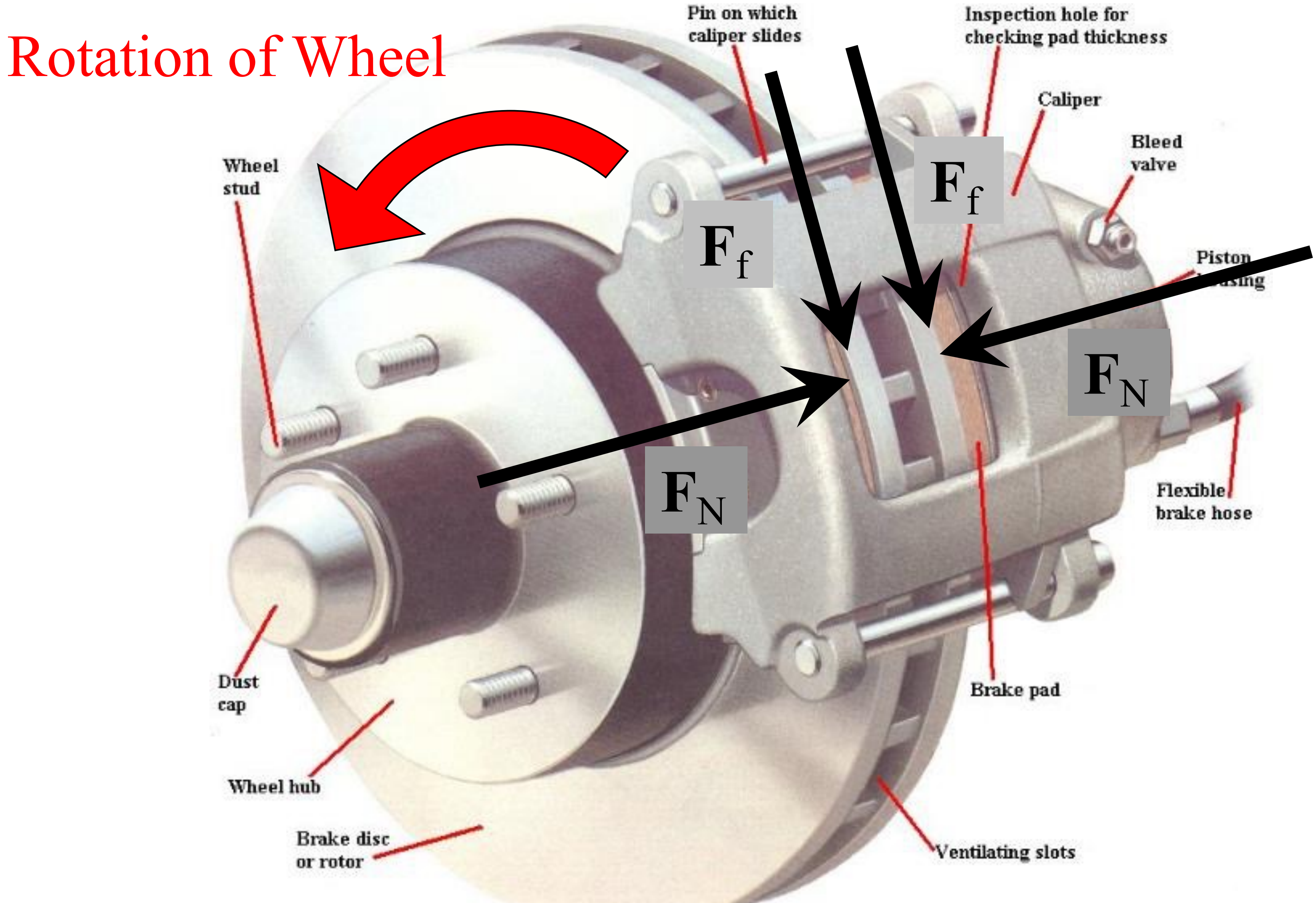
The Physics of Braking

Friction on a Car

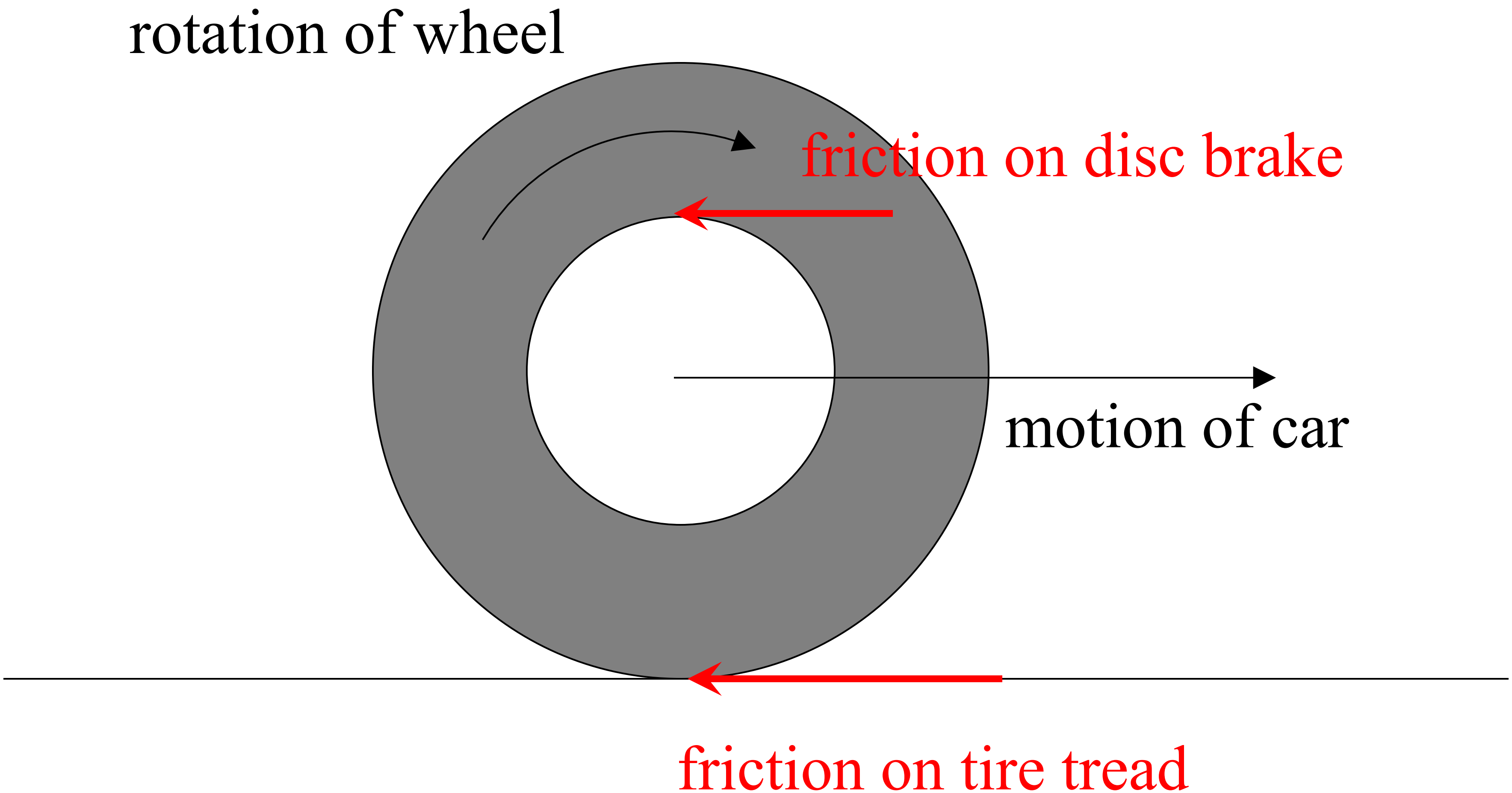
Why are ABS brakes better than standard brakes?

If brakes are prevented from locking will stopping distance increase or decrease?

Brakes are a wonderful illustration of the classical friction equation: $F_{\mathrm{f}} = \mu F_{\mathrm{N}}$

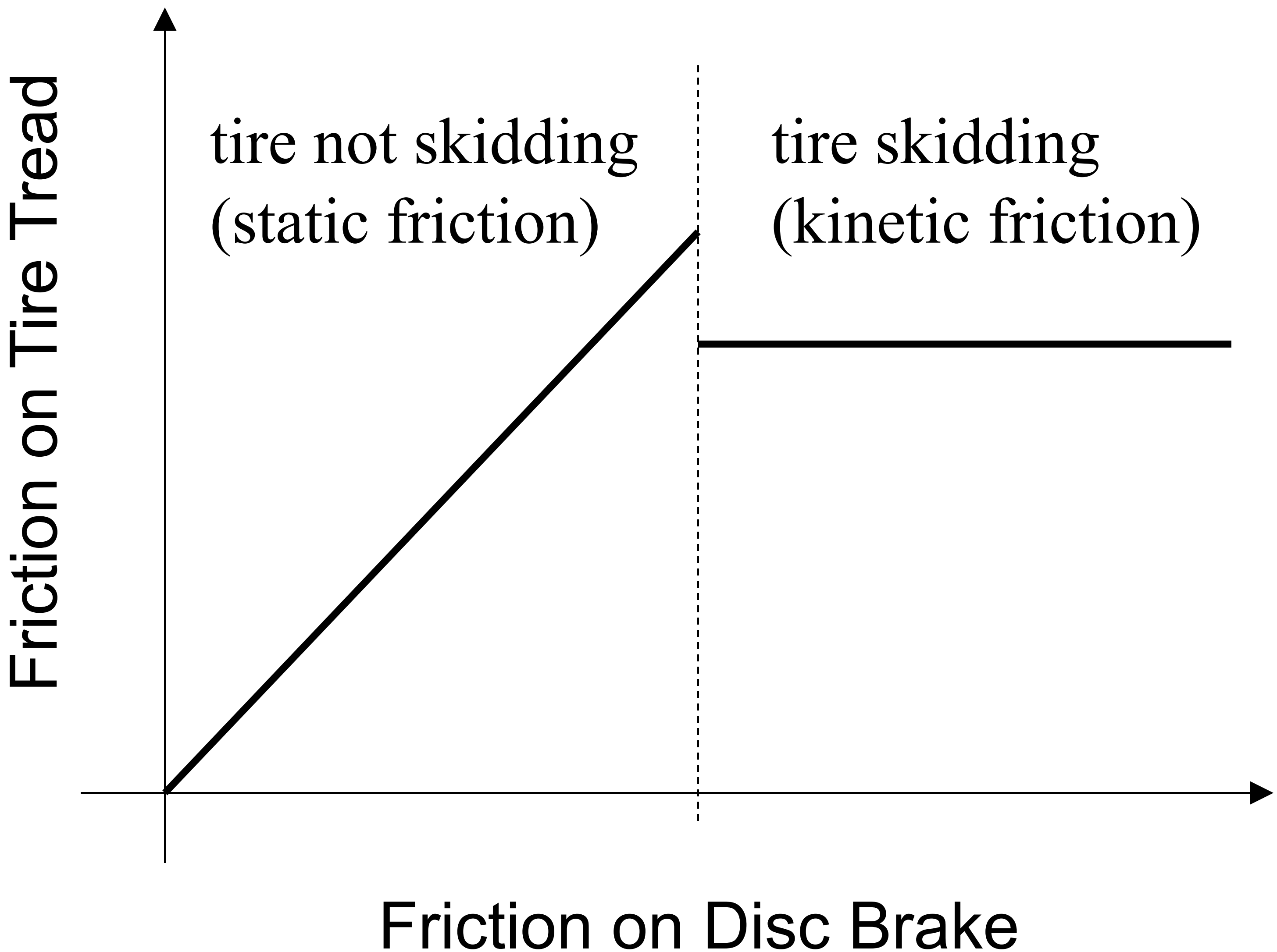


As the brake pedal is depressed, the pads move inward, creating greater normal force on the disc. This in turn produces greater friction opposing the rotation of the wheel.

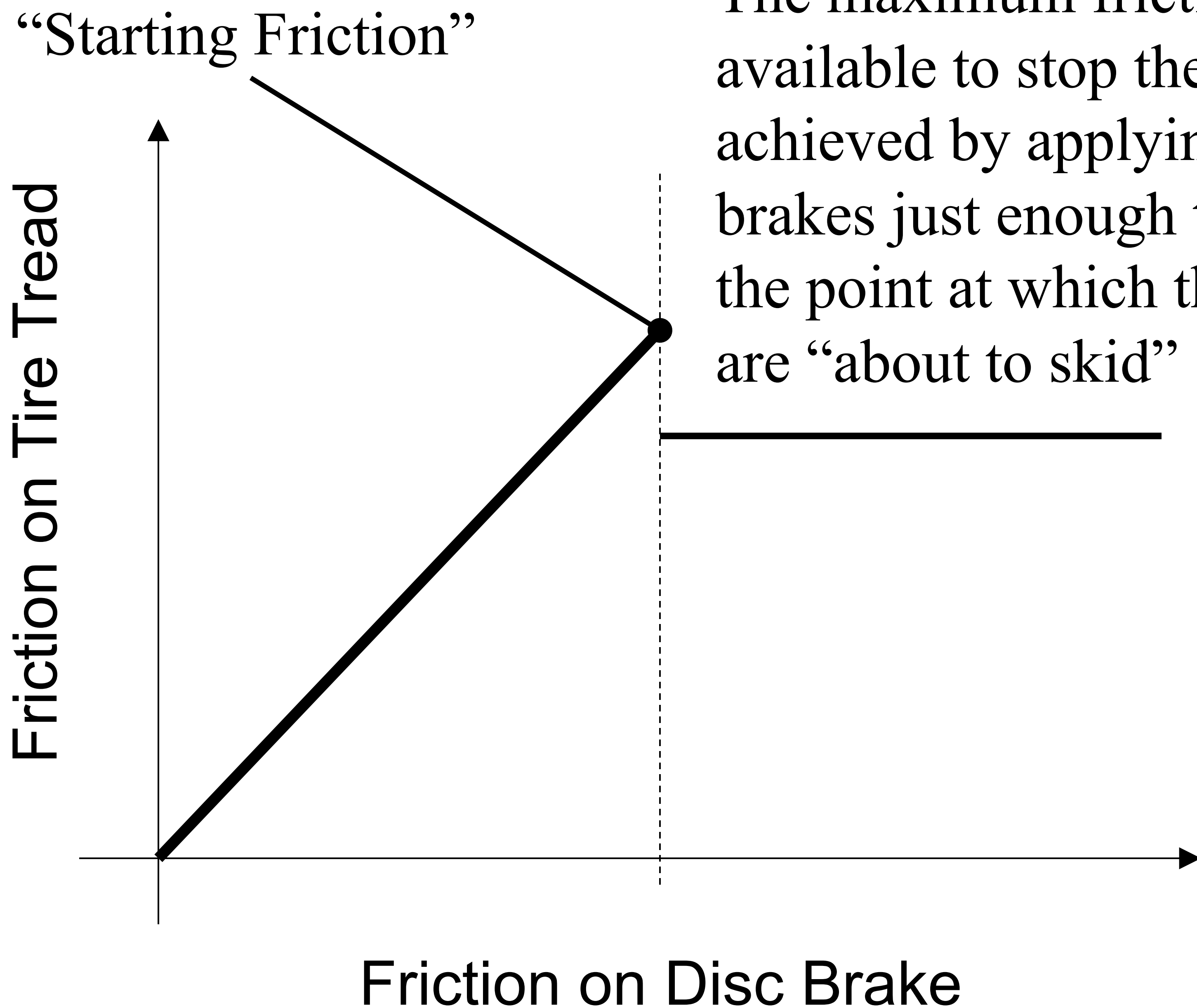


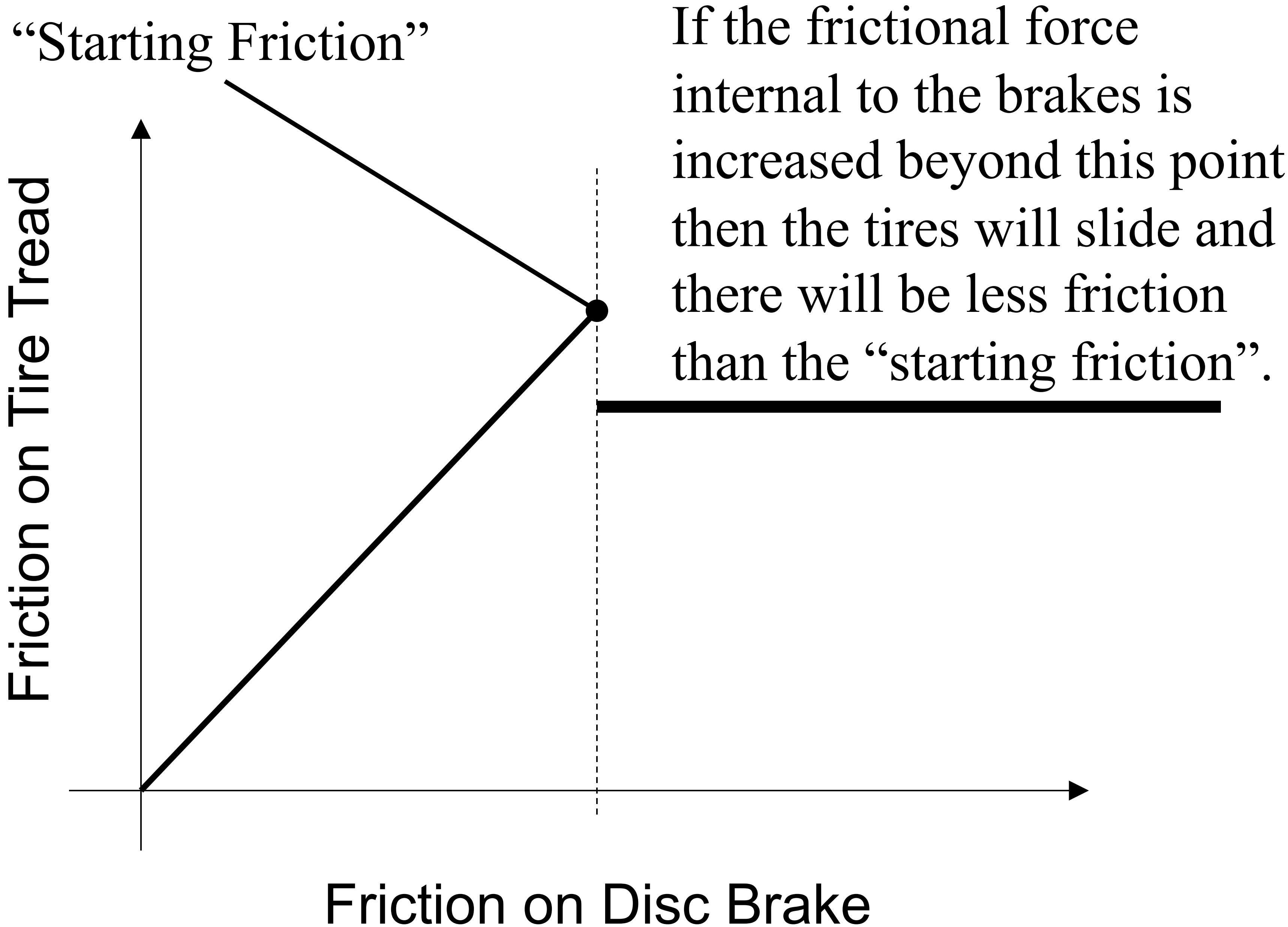
Q. Which frictional force actually stops the whole car?

A. The friction of the road surface acting on the tire tread.


Friction on Tire Tread
tire not skidding
(static friction)
tire skidding
(kinetic friction)
Friction on Disc Brake

The maximum friction available to stop the car is achieved by applying the brakes just enough to reach the point at which the tires are "about to skid"




"Starting Friction"
If the frictional force internal to the brakes is increased beyond this point then the tires will slide and there will be less friction than the "starting friction".
Friction on Tire Tread
Friction on Disc Brake

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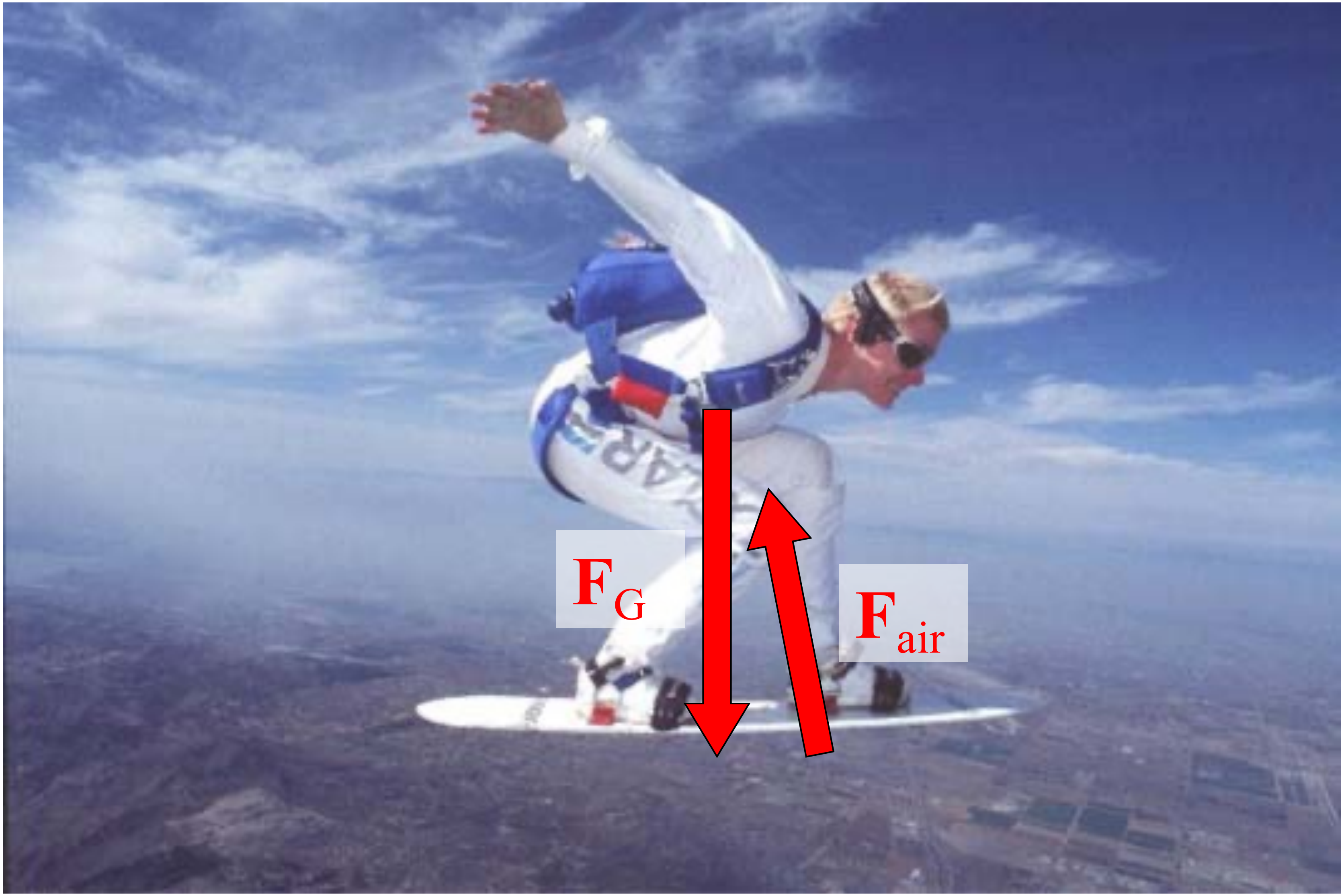
Modeling Motion through Air

- Air resistance is a force that always opposes an object's motion through air.
- The amount of air resistance depends on speed, cross-sectional area, density of the air, and the aerodynamic shape (*i.e.* how "streamlined")
- Usually it is assumed that air resistance is proportional to speed or that it is proportional to the square of the speed.
- Although neither assumption is exactly correct, the latter is usually more accurate


F_G
F_{air}

What's happening here?

Terminal Velocity

- A falling object may (or may not) reach a state known as terminal velocity.
- At terminal velocity the object ceases to accelerate and maintains a constant speed.
- In this state the force of air resistance is equal and opposite to the force of gravity (*i.e.* the two forces are balanced such that the net force is zero).


F_G
F_{air}