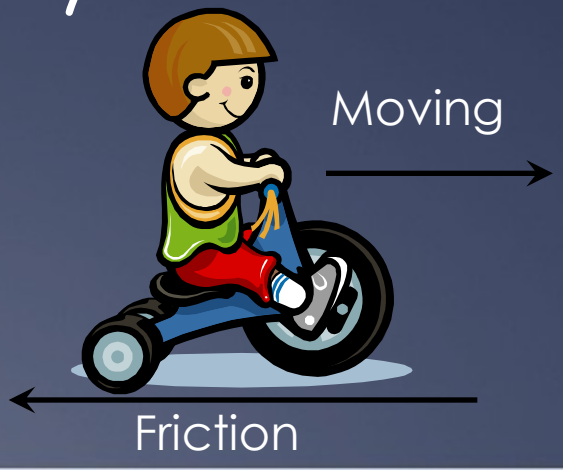
Friction: Its Concept, types & applications

What is Friction?

- Friction is a force between two surfaces that are sliding, or trying to slide across one another, for example when you try to push a toy car along the floor.

- Friction always works in the direction opposite from the direction the object is moving, or trying to move. It always slows a moving object down.



What is Friction?

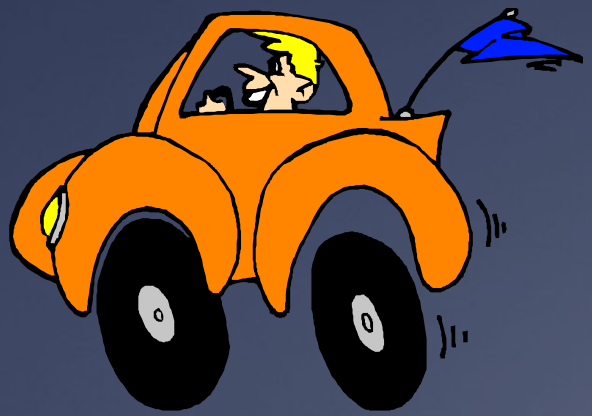
- The amount of friction depends on the materials from which the two surfaces are made. The rougher the surface, the more friction is produced. For example, you would have to push a book harder to get it moving on a carpet than you would on a wooden floor. This is because there is more friction between the carpet and the book than there is between the wood and the book.

What is Friction?

- Friction also produces heat. For example, if you rub your hands together quickly, they get warmer.

Useful Friction and Reducing Friction.

- Friction can be a useful force because it prevents our shoes slipping on the pavement when we walk and stops car tyres skidding on the road.



Useful Friction and Reducing Friction.

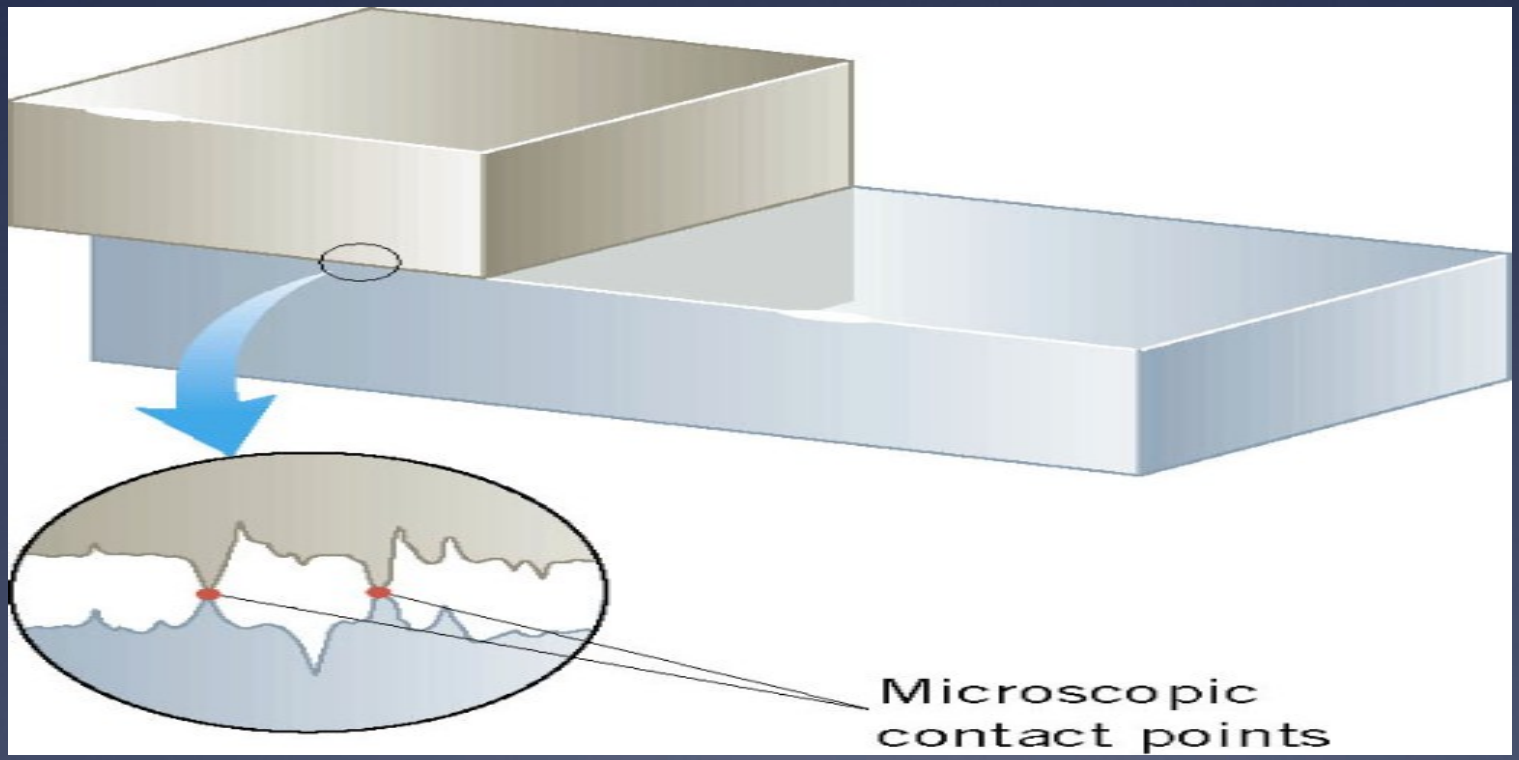
- Ice causes very little friction, which is why it is easy to slip over on an icy day. But this is a good thing for ice skating and sledging.

Useful Friction and Reducing Friction.

- Sometimes we want to reduce friction. For example, moving parts inside a car engine are lubricated with oil, to reduce friction between them. The oil holds the surfaces apart, and can flow between them. The reduced friction means there is less wear on the metal, and less heat produced.

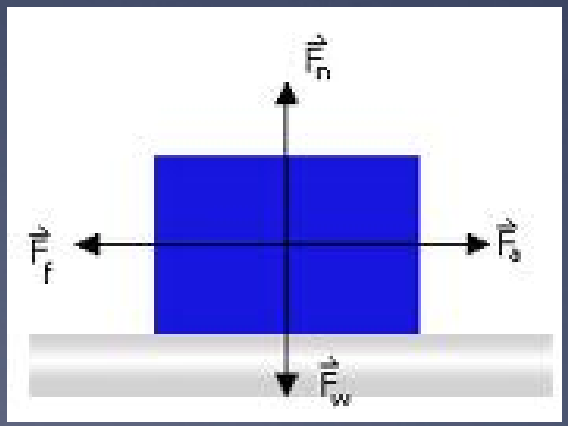
Friction Force

When an object is in contact with a surface there is a force acting on that object. The component of this force that is parallel to the surface is called the ***friction force***. *This resistive force is exerted on a moving object due to viscosity or other types of frictional property of the medium in or surface on which the object moves.* *Always opposite to the movement!!*



The force of friction

- exerted by a surface to resist the motion of an object
- friction is always parallel to the surface and acts in the opposite direction of the object's attempted motion
- the symbol is F_f



Friction: good or bad?

- sometimes friction is a *problem*:
  - a skier puts wax on skis to reduce friction between the skis and the snow
  - synovial fluid helps to reduce friction between the moving bones in joints of the human body
- sometimes friction is *necessary*:
  - a car that is starting to move requires friction
  - a person walking or running depends on friction

Friction

- Friction is the force acting over the area of contact between two surfaces in the direction opposite that of the motion.
- Types of friction forces
  - Static friction
  - Kinetic friction

Static Friction

When the two surfaces are not sliding across one another the friction is called ***static friction***. *The resistive force exerted on the object up to the time just before the object starts moving.*

Static Friction

- the force exerted on a stationary object by a surface that prevents the object from starting to move (F_s)
- the object remains at rest because the static friction is equal in magnitude and opposite in direction to the applied force
- for the object to move, the applied force must overcome the maximum amount of static friction ($F_{s_{max}}$)

Kinetic or Dynamic Friction

- the force exerted on a moving object by a surface (F_k)
- acts in the opposite direction of the motion
- if applied force is equal in magnitude to the force of friction, the object will move with a constant velocity
- if the applied force increases, the object will accelerate

Types of Kinetic Friction

- *sliding* friction : an object is scraping or sliding across a surface
- *rolling* friction : an object rolls across a surface
- *fluid* friction or air resistance : an object travels through water or air and experiences *drag*

Coefficients of friction

- is the ratio of the force of friction to the normal force
- symbol is the Greek letter mu (μ)

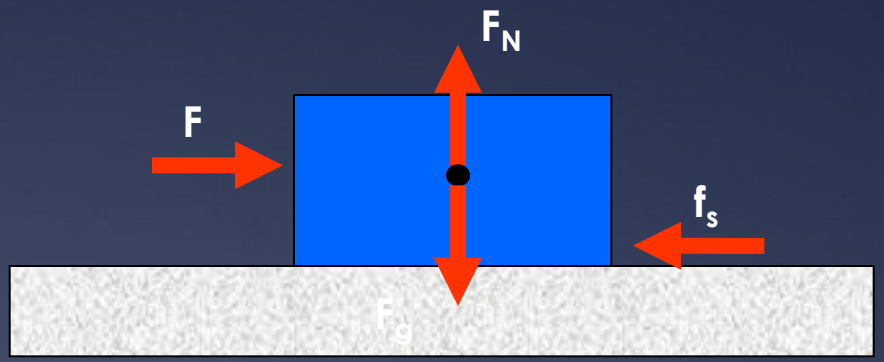
$$\mu = F_f / F_N$$

- the coefficient of friction has no units or direction since it is a ratio
- the coefficient of friction depends *only* on the types of materials and can only be determined experimentally

- for almost all situations the force required to start an object moving is greater than the force required to keep it moving at a constant velocity
- *so*: $F_{s_{max}} > F_k$
- since there are 2 types of friction, there are 2 different coefficients of friction for any two surfaces
  - coefficient of *static* friction (μ_s)
  - coefficient of *kinetic* friction (μ_K)

Static Friction

The Force of Static Friction keeps a stationary object at rest!

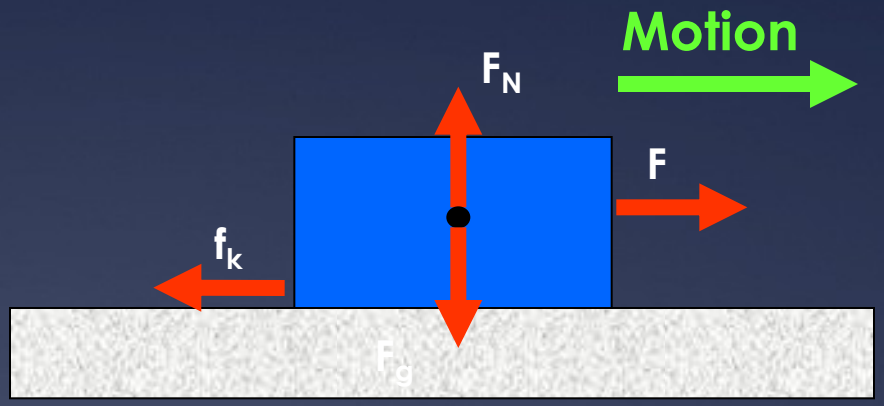


$$f_s = F_N \times \mu_s$$

$$\mu_s = coefficien\,t\ \ of\ \ static\ \ friction$$

Kinetic Friction

Once the Force of Static Friction is overcome, the Force of Kinetic Friction is what slows down a moving object!



$$f_k = F_N \times \mu_k$$

$$\mu_k = coefficien\,t\ \ of\ \ kinetic\ \ friction$$

Kinetic Friction

Static friction opposes the *impending* relative motion between two objects.

Kinetic friction opposes the relative sliding motions that is happening. The resistive force exerted on the object during its movement.

Normally much smaller than static friction!!

$$f_k = \mu_k F_N$$

$0 < \mu_k < 1$ is called the **coefficient of kinetic friction**.

What is the direction of friction forces? **opposite to the movement**

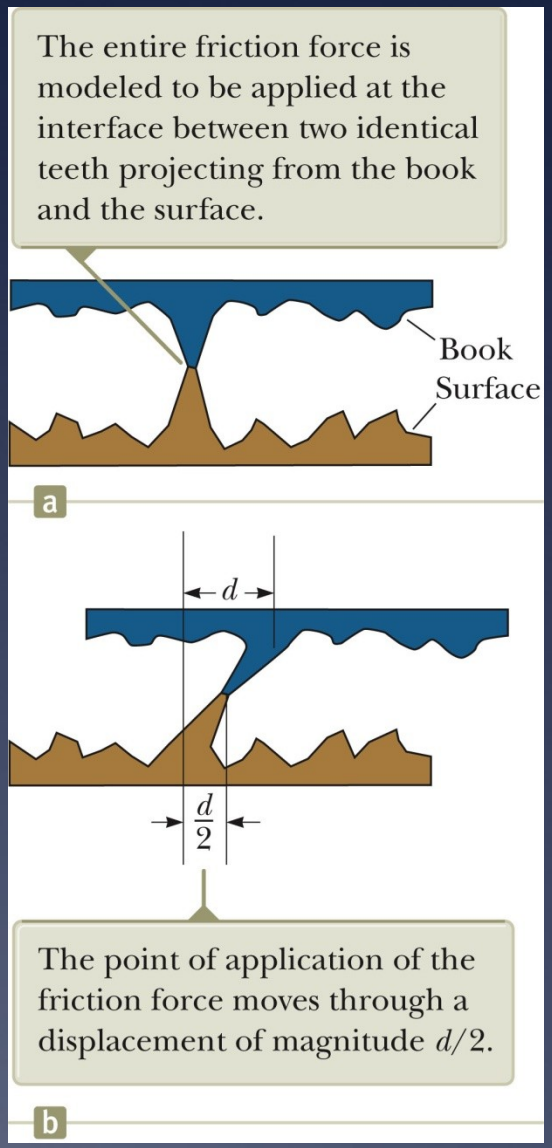
Kinetic Friction

Kinetic friction can be modelled as the interaction between identical teeth.

The frictional force is spread out over the entire contact surface.

The displacement of the point of application of the frictional force is not calculable.

Therefore, the work done by the frictional force is not calculable.



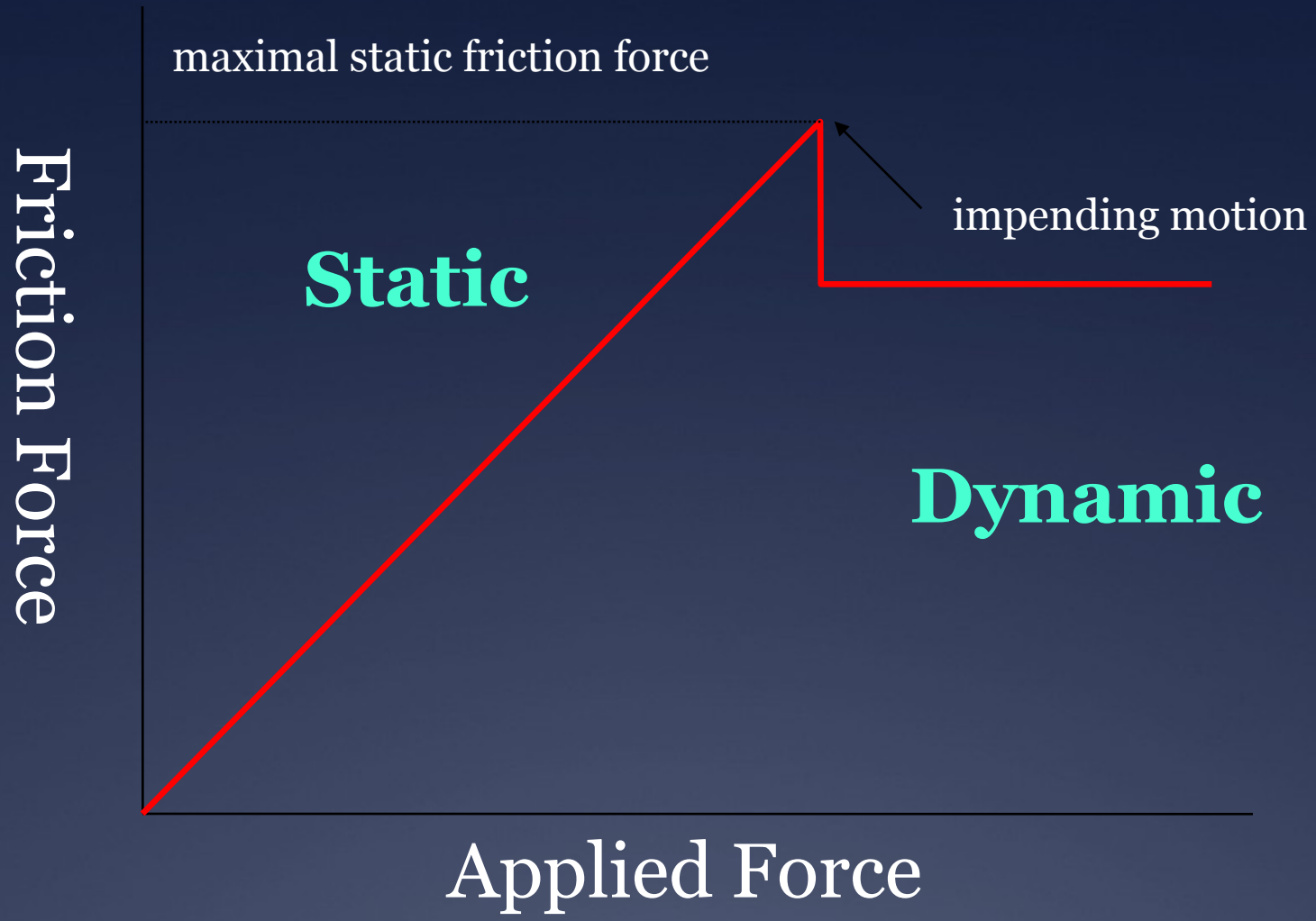
Friction (cont)

Value of friction can be calculated using the coefficient of friction, μ , which depends on materials of object and surface

$F_f = \mu F_N$ where F_N is the "normal force."

Friction

- Static friction: $F_{fr} = \mu * N$
- Kinetic friction: $F_k = \mu * N$



- At some point the pulling force will be great enough so that the friction force cannot prevent movement.

Friction

* The coefficient of static friction is expressed as:

$$\mu_s = \frac{F_{max}}{F_{normal}}$$

where μ_s= coefficient of static friction

F_{normal} = normal force

F_{max} = maximal static friction force

•The coefficient of friction is a dimensionless number. It is unaffected by the mass of the object or the contact area.

•The greater the magnitude of μ_s the greater the force necessary to move the object.

Friction

- As the block moves along the table, there still is a frictional force that resists motion.
- Sliding ,rolling & fluid friction are types of dynamic friction.

$$\mu_d = \frac{F_{frictic}}{F_{Norm}}$$

where μ_d= coefficient of dynamic friction

N = normal force

$F_{friction}$ = force resisting motion

Friction

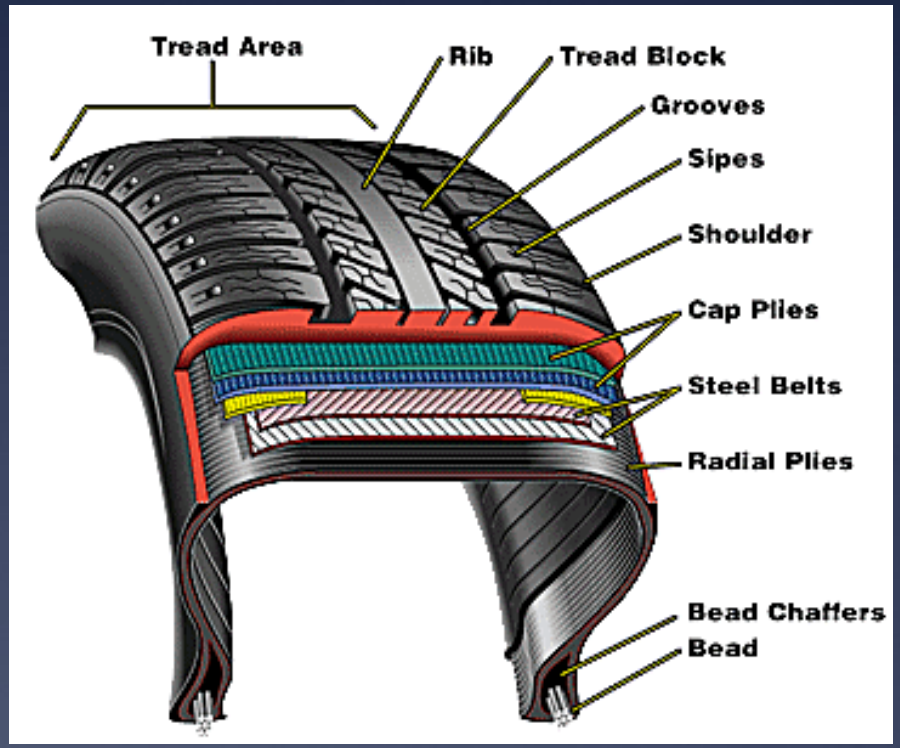
- It has been found experimentally that $\mu_d < \mu_s$.
- μ_d depends of the relative speed of the surfaces.
- At speeds from 1 cm/s to several m/s, μ_d is approximately constant.

The Physics of car tires

- the magnitude of static friction acting on a rubber tire on a road surface depends on the coefficient of friction and the surface area of contact
- race car tires have no treads, so races are sometimes postponed due to rain
- race cars use wide tires to increase surface area to prevent slipping through curves

passenger tires

- need good traction on all road surfaces under all weather conditions
- small and large grooves provide pathways for water and snow to pass beneath the tire while it maintains contact with the road



safe driving

- on wet roads, travelling at a low safe speed allows time for the water to move through the grooves.
- if the driver speeds up, the water starts to build up in front of the tire, causing the tire to lose contact with the road.

controlling friction

- soles of hiking boots and athletic shoes
- artificial joints
- skate and bobsled design
- under and over-inflated tires

Static and Kinetic(Dynamic) Friction

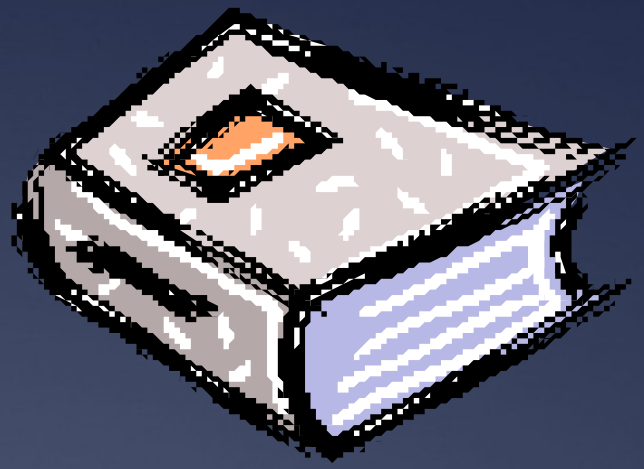
* Static frictional force: when nothing is sliding
* Sliding frictional force: when surfaces are sliding
* Static frictional forces always greater than sliding ones

What is this unbalanced force that acts on an object in motion?

Friction!

- There are five main types of friction:
  - Sliding friction: ice skating
  - Rolling friction: bowling
  - Fluid friction (air or liquid): air or water resistance
  - Static friction: initial friction when moving an object
  - Kinetic Friction: When body is in motion.

Slide a book across a table and watch it slide to a rest position. The book comes to a rest because of the *presence* of a force - that force being the force of friction - which brings the book to a rest position.



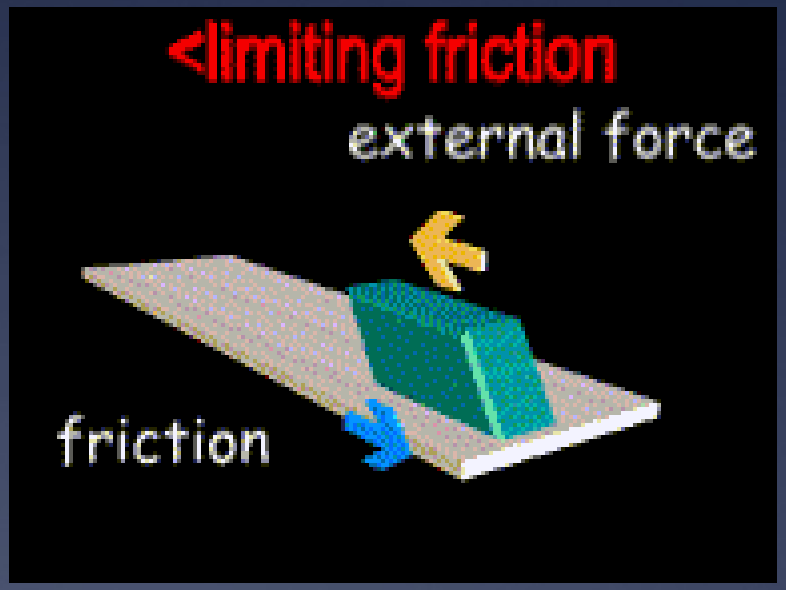
* In the absence of a force of friction, the book would continue in motion with the same speed and direction - forever! (Or at least to the end of the table top.)

Friction?

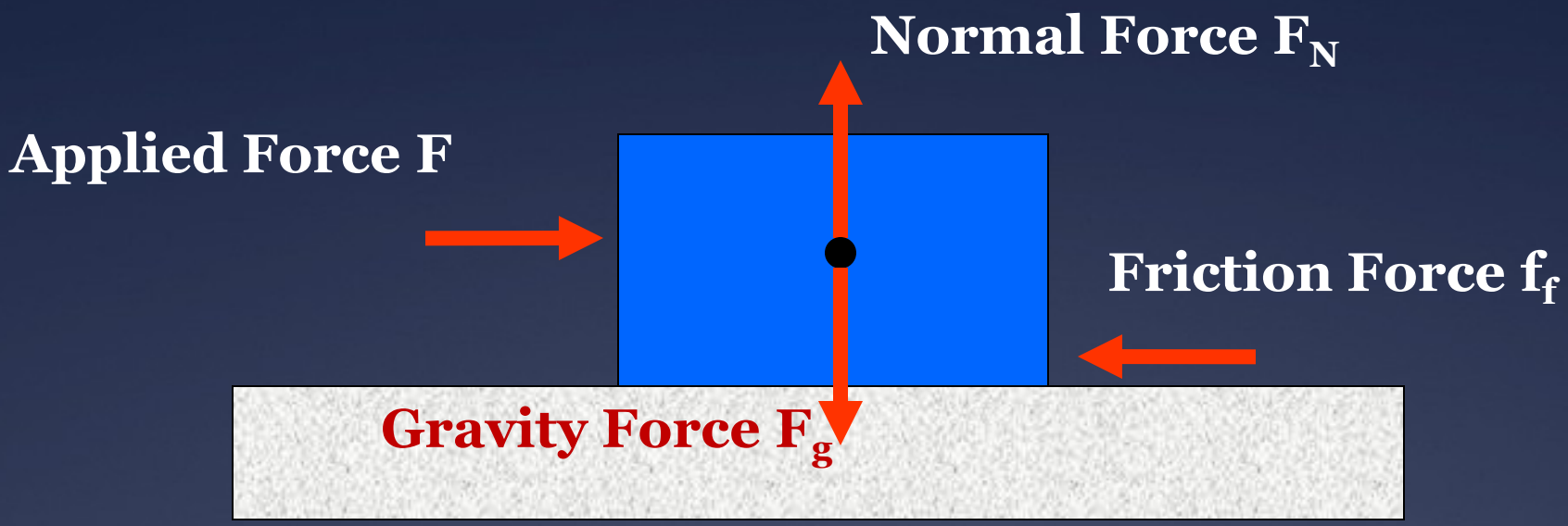
Force that acts oppose the relative motion of two surfaces

High for dry and rough surfaces

Low for smooth and wet surfaces



Free Body Diagram



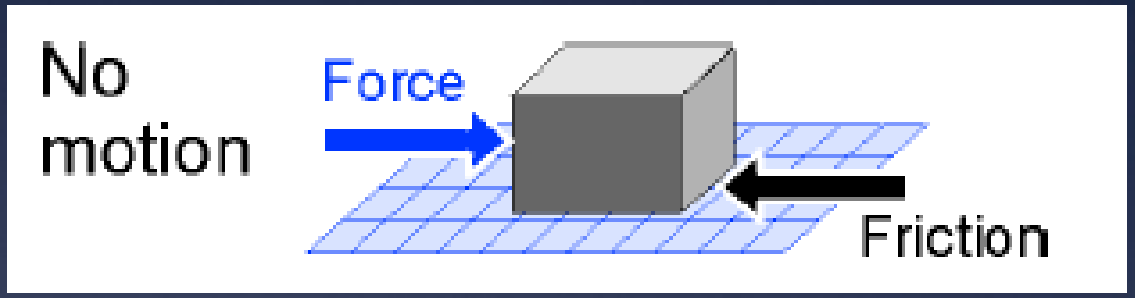
$F_g = mg$

$F_N = F_g$

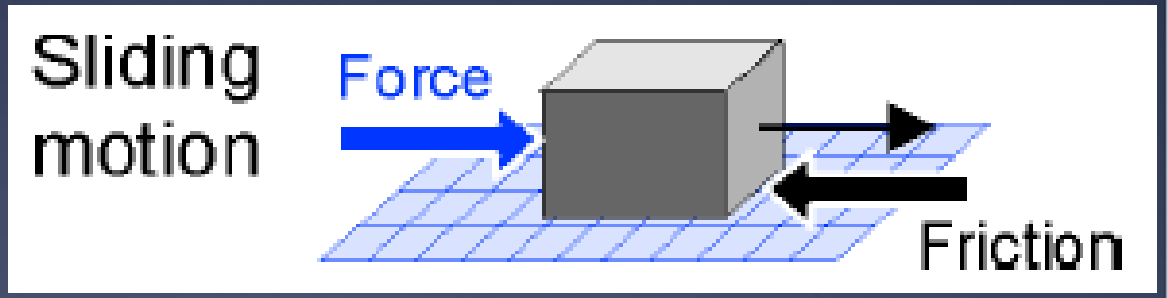
$f_f = F$

Types of Friction

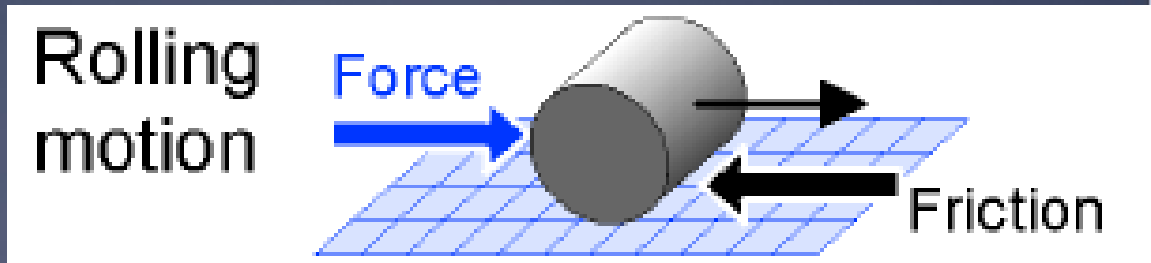
Static friction



Sliding friction



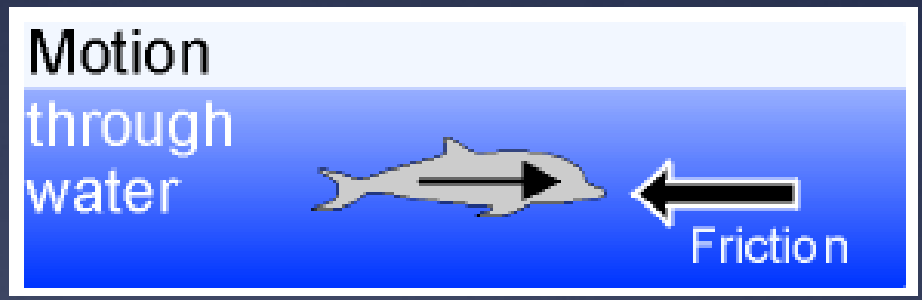
Rolling friction



Types of Friction

Air friction or

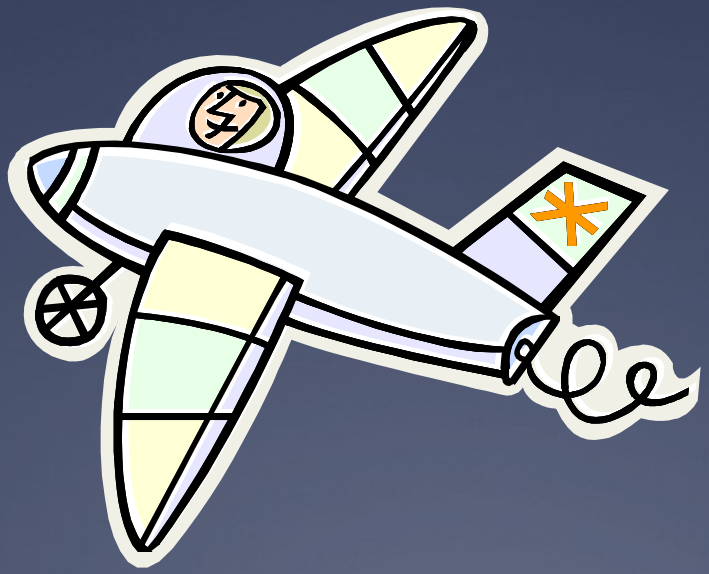
Viscous friction



Kinetic Friction

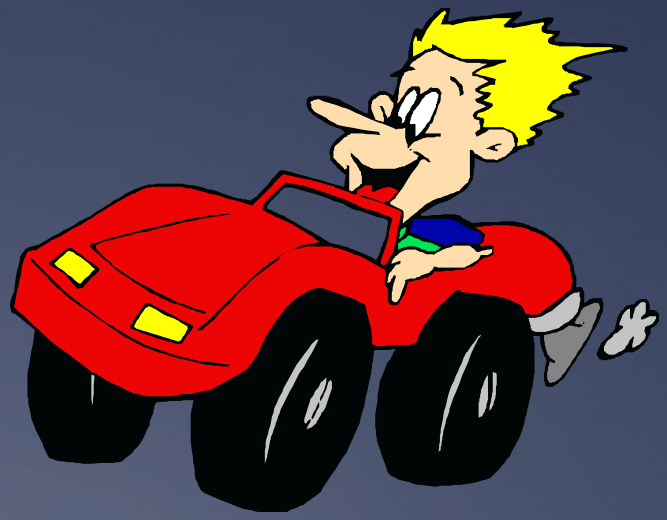
Air Resistance

- Air resistance is a type of friction between air and another material. When an aeroplane flies through the air, for example, air particles hit the aeroplane, making it more difficult for the aeroplane to move through the air.



Air Resistance

- Some shapes, known as streamlined shapes, cause less air resistance than others. Aeroplanes and cars are streamlined, so that they move through the air as easily as possible.

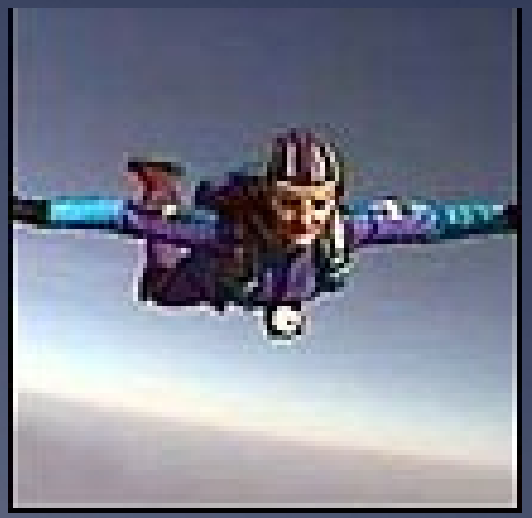


“Fluid” Friction

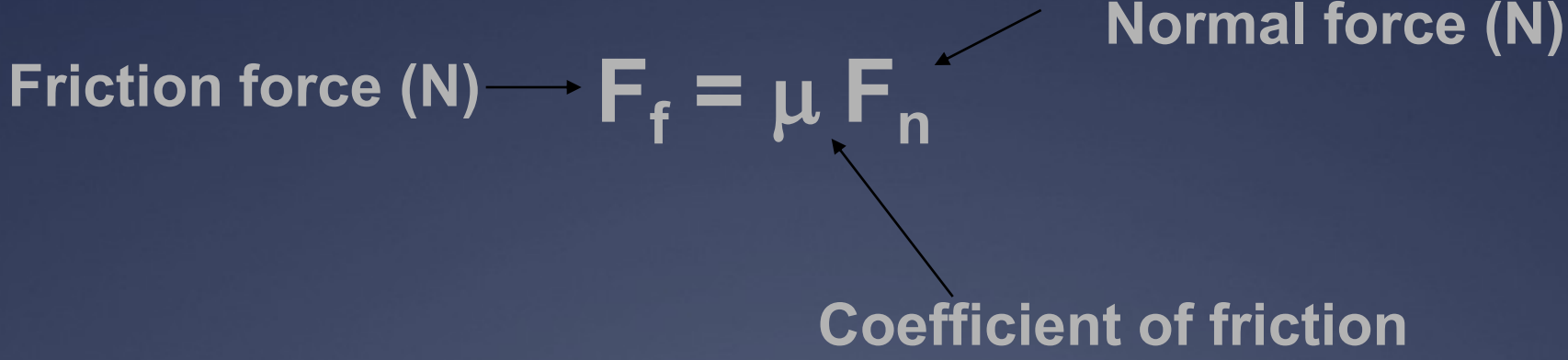
This type of friction is what happens with liquids and gases *(In Physics, liquids and gases are both called "fluids". They behave in similar ways.)*

Fluid friction is also known as "**drag**". On aircraft it's also called "**air resistance**". It depends on:-

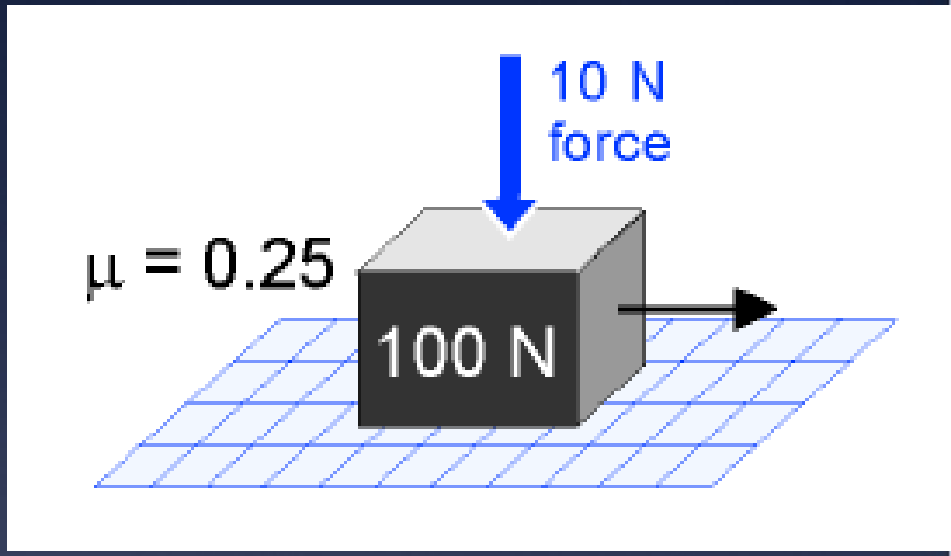
- how thick the fluid is (its "viscosity")
- the shape of the object
- the speed of the object



Friction


Friction force (N)
$F_f = \mu F_n$
Normal force (N)
Coefficient of friction

Calculate force of friction



A 10 N force pushes down on a box that weighs 100 N.

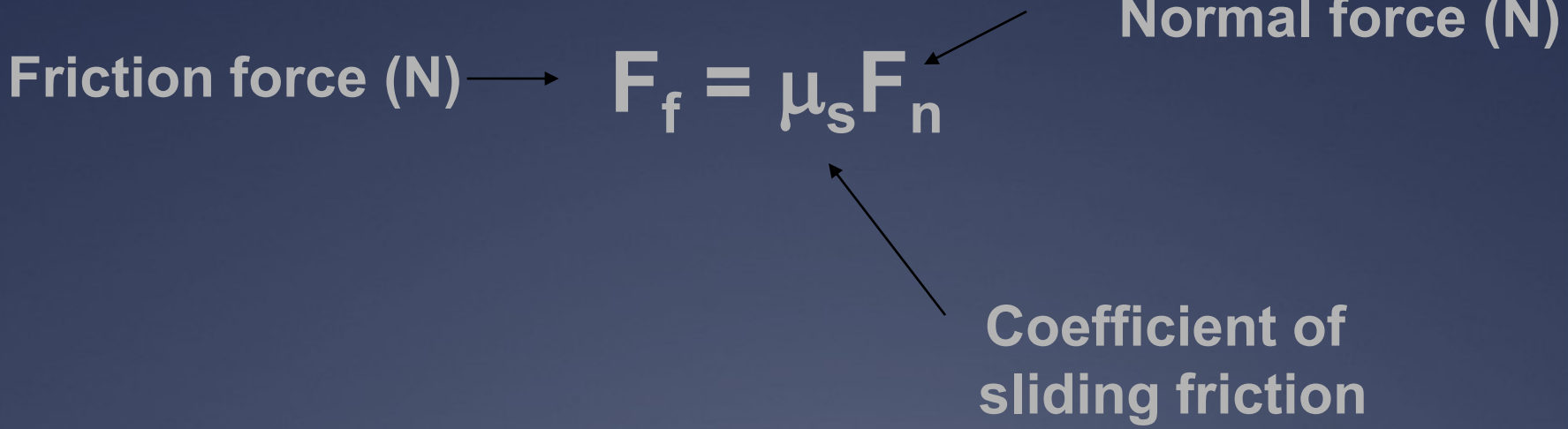
As the box is pushed horizontally, the coefficient of sliding friction is 0.25.

Determine the force of friction resisting the motion.

We know total force acting on the body in downwards direction is : 100+10 N = 110 N.

So Force of friction (F_f) = $\mu * F_N$ = 0.25 * 110 = 27.5 N

Sliding Friction



The magnitude of the friction forces

$$F_{max}=\mu_s N$$

Where μ_s is the coefficient of static friction.
It is independent of normal forces and area of contact.

The general case for equilibrium condition

Once the body starts to slip

$$F=\mu_k N$$

μ_k is the coefficient of dynamic friction

$$\mu_k < \mu_s$$

Friction…

High friction (lots of friction) – will slow something down

Low friction (not much friction) – will keep things moving

Opposing Forces and Application of Forces

- Friction
  - Friction is a force which acts opposite to motion
    - Caused by irregularities in surfaces in contact
    - Amount depends on the materials involved
    - Occurs in fluids as well as in solids
      - Viscosity in liquids
      - Air resistance in air (similar in other gases)
  - Friction causes the need for applied force to keep constant velocity

Walking

- You could not walk without the friction between your shoes and the ground. As you try to step forward, you push your foot backward. Friction holds your shoe to the ground, allowing you to walk. Consider how difficult it is to walk on slippery ice, where there is little friction.

Writing

- Writing with a pencil requires friction. You could not hold a pencil in your hand without friction. It would slip out when you tried to hold it to write. The graphite pencil led would not make a mark on the paper without friction.
- A pencil eraser uses friction to rub off mistakes written in pencil lead. Rubbing the eraser on the lead wears out the eraser due to friction, while the particles worn off gather up the pencil lead from the paper.

Driving car

- Your car would not start moving if it wasn't for the friction of the tires against the street. With no friction, the tires would just spin. Likewise, you could not stop without the friction of the brakes and the tires.

Makes movement difficult

- Any time you want to move an object, friction can make the job more difficult. Excess friction can make it difficult to slide a box across the floor, ride a bicycle or walk through deep snow.
- An automobile would not move forward very well unless its friction was not reduced. Oil is needed to lubricate the engine and allow its parts to move easily. Oil and ball bearings are also used in the wheels, so they will turn with little friction.

Wastes energy

- In any type of vehicle--such as a car, boat or airplane--excess friction means that extra fuel must be used to power the vehicle. In other words, fuel or energy is being wasted because of the friction.
- Fluid friction or air resistance can greatly reduce the gas mileage in an automobile. Cars are streamlined to reduce friction. But driving at highway speeds with your windows open can create enough drag on the car to greatly reduce your gas mileage.

Heats parts

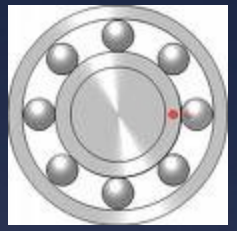
- The Law of Conservation of Energy states that the amount of energy remains constant. Thus, the energy that is "lost" to friction in trying to move an object is really turned to heat energy. The friction of parts rubbing together creates heat.
- You've seen how people will try to start a fire by vigorously rubbing two sticks together. Or perhaps you've seen an automobile spin its wheels so much that the tires start to smoke. These are examples of friction creating heat energy. Just rub your hands together to create the same effect.
- Besides the problem of losing energy to heat, there is also the threat of a part overheating due to friction. This can cause damage to a machine.

Wears things out

- Any device that has moving parts can wear out rapidly due to friction. Lubrication is used not only to allow parts to move easier but also to prevent them from wearing out. Some other examples of materials wearing out due to friction include the soles of your shoes and a pencil eraser.

How can we reduce the friction between 2 objects?

Reduce the contact area by using rollers/ball-bearings/wheels



Change the surfaces of the materials that are touching by using lubrication eg. Oil

Create a cushion of air

Eg. Like a hovercraft or air hockey table

Application Analysis

Sand is often placed on an icy road because the sand:

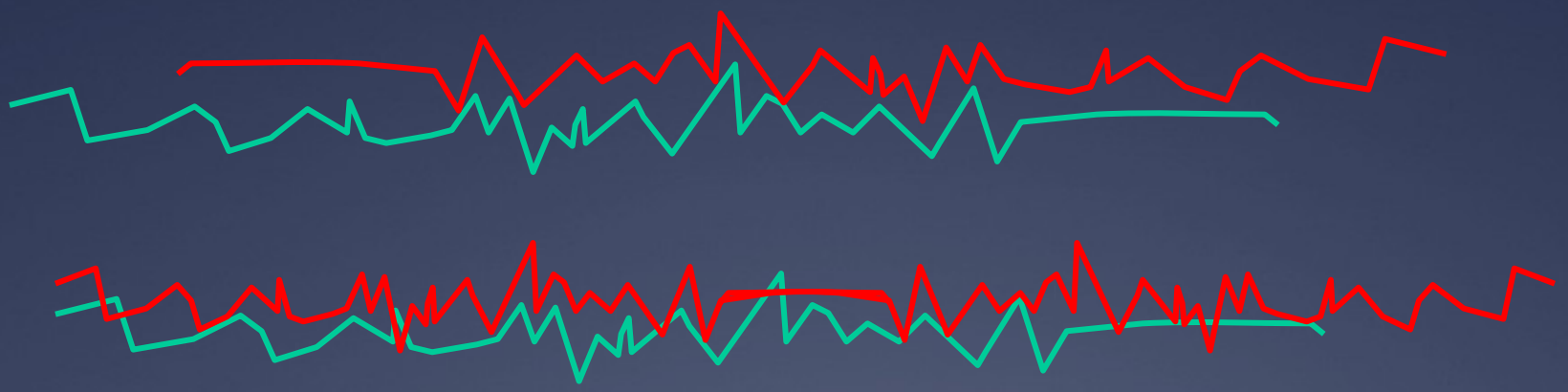
1. Decreases the coefficient of friction between the tires of a car and the road
2. Increases the coefficient of friction between the tires of a car and the road
3. Decrease the gravitational force on a car
4. Increases the normal force of a car on the road

Static and Sliding (Dynamic) Friction

Static frictional force: when nothing is sliding

Sliding frictional force: when surfaces are sliding

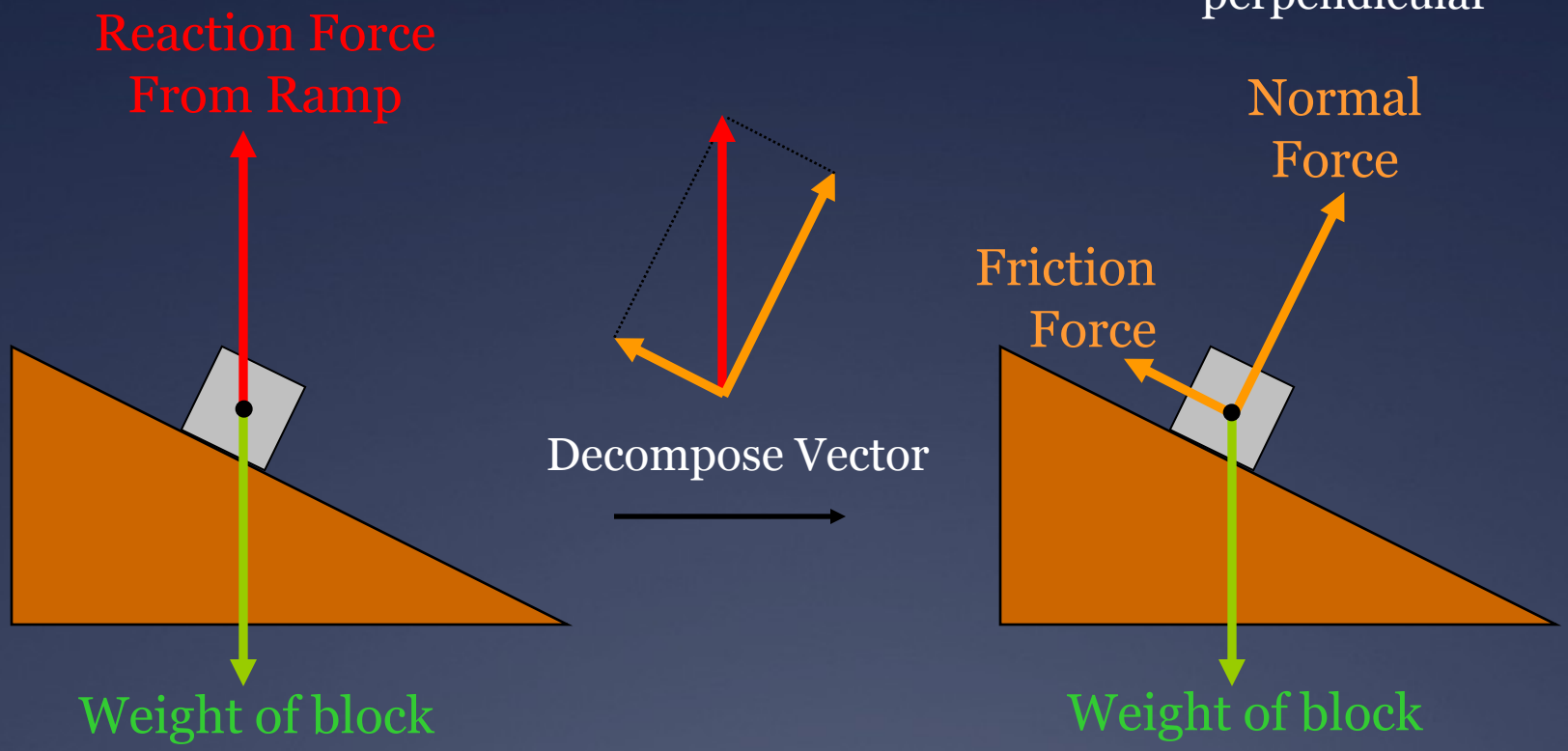
Static frictional forces always greater than sliding ones



- Lubrication provides microscopic rollers between surfaces

“Normal” Forces and Frictional Forces

“Normal” means perpendicular



Friction Force = Normal Force × (coefficient of friction)

$F_{friction} = \mu \cdot F_{normal}$

Aircraft and car designers want to reduce drag, so that the vehicle can go fast without having to waste too much fuel.

How do you think they can do it?

1st Law

* Unless acted upon by an unbalanced force, this golf ball would sit on the tee forever.

Why then, do we observe every day objects in motion slowing down and becoming motionless seemingly without an outside force?

It's a force we sometimes cannot see – friction.

Objects on earth, unlike the frictionless space the moon travels through, are under the influence of friction.