Normal Force

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Think of the "Normal Force" as a supporting force. If a book sits on a table, gravity pulls down on the book. The table has to push back up on the book to support it. These two forces will be equal, or the book would move in the direction of the stronger (greater) force. If the weight of the book was greater than the table's normal force, then the book would break the table. If the table pushed up greater than the weight of the book, the book would "jump up". (The only way I can think of this happening is if a couple of people held on to the table and pushed on it.)

Example: A 20 N object sits on a table. How much normal force does the table exert?
Answer: 20 N up - equal in magnitude to the objects weight, but opposite in direction.

The normal force to support an object must increase if the weight increases. You know this to be true. Imagine a friend starts to put weights on your hand. As the weights increase, you will have to push back harder: your normal force will increase.

Example: A 5 N rock is placed on top of a 20 N object which sits on a table. How much normal force does the table exert?
Answer: 25 N up - equal in magnitude to the sum of both objects' weights, but opposite in direction. The normal force of the object up on the rock will be 5 N.

But the normal force does not always equal the weight of the object. Imagine a person sits slowly on your lap. As they lower themselves onto your lap, you feel their weight increase. So the normal force can be reduced if another force is pulling up on the object. (Also imagine a parent helping a child do pull-ups by lifting them up. The child doesn't have to pull as hard, because the parent is supporting part of the weight.)

Example: A 20 N object sits on a table and a spring pulls up with 10 N. How much normal force does the table exert? Answer: 10 N up (20 N - 10 N). The spring reduces the weight of the object, making it feel "lighter", so it requires less support from the table.

The normal force is always perpendicular to the surface. If you are holding a book with your hand horizontal to the ground, you have to support all of the weight of the book. But if you start to turn you hand so that the book starts to slip, then the book starts to feel lighter, until you are supporting it at all and it falls. The normal force is always perpendicular to your hand. When you hand is perpendicular to the ground, you aren't supporting any weight, so your normal force is zero. In order to find the amount of normal force of a surface at an angle, trigonometry is necessary. By using complimentary angles, we find that

$F_{normal} = F_{weight}(\cos\theta)$ *where θ is the angle between the surface (ramp) and the ground.*

For a flat surface θ = 0° and cos(0°) = 1.
Then F_{normal} for a flat surface is:

$F_{normal} = F_{weight}(\cos 0°)$
$F_{normal} = F_{weight}(1)$
$F_{normal} = F_{weight}$

… which we already knew.

For a surface at 90° (straight up and down), cos(90°) = 0.
Then F_{normal} for a perpendicular object is:

$F_{normal} = F_{weight}(\cos 90°)$
$F_{normal} = F_{weight}(0)$
$F_{normal} = 0$

Friction

Friction opposes applied force. Friction almost always opposes motion. Friction never starts something moving.

If a car is moving to the right, friction resists to the left. If the car moves to the left, friction opposes to the right. If you slide your hand forward against a table, friction pulls backward. And if you pull your hand backward, friction pulls forward. Notice that friction is opposing all of these actions. A problem doesn't need to give you the direction of friction—you know it will be going opposite the applied force.

Friction is important to the world because it increases the amount of force needed to accomplish tasks. If I'm trying to accelerate a car, by Newton's second law (F = ma) I will need a force to overcome inertia. Yet with the presence of friction, I will need more force to create the same acceleration, since the acceleration is due to the Net Force, not just the applied force.

Example1: In a frictionless world an engine applies 100N of force to a 20 kg object. Because there is no friction, the net force equals the applied force, since it is the only force in the problem. So, F = ma; 100N = 20kg(a); a = 100N/20kg = 5 m/s^2.

Example 2: Now find the above acceleration if friction is 40 N. We don't know the exact direction of the friction because the direction of the force was not given, but we know friction will oppose the 100N force. So, $\Sigma F = 100N—40N = 60$ N. Friction has eaten up 40N of our force!: only 60 N remains to overcome inertia and accelerate the object. $F = ma$; $60N = 20kg(a)$; $a = 60N/20kg = 3m/s^2$. The object accelerates much slower because of friction.

This friction not only slows things down but uses up energy. It takes more energy to do things because of friction. (But friction can be helpful in keeping things from slipping (for instance) as with tires.)

Two Kinds of Friction: There are two main categories of friction that apply to surfaces: static friction and kinetic friction. Static friction tries to hold things in place; it is friction of stationary objects, gripping friction. Kinetic friction happens while an object moves: slipping friction. Static friction is almost always greater than kinetic friction (Teflon is an exception). Both of these frictions still oppose the applied force—they do not cause the motion.

Static friction opposes you trying to move an object: gripping friction. If an object is not moving, you know that $a = 0$ and $\Sigma F = 0$. If you pull on an object with 5N and it doesn't move, then $F_{static} = 5N$ (equal and opposite). If then you pull harder, with 10 N, and it doesn't move, then $F_{static}= 10N$ (equal and opposite). F_{static} will continue to increase and oppose your force up to a point. This point is the maximum static friction available. If $F_{staticmax}= 25N$, then you could pull with 25N and the object would not move. If you pull with 25.000001N, the object will move. If a question says that it takes a certain amount of force "to move an object", that means that's how much force was necessary to break the object free from static friction; it is the maximum amount of static friction for that object on that surface. It is not the force that moved the object.

Kinetic friction opposes moving objects: slipping friction. Once an object is moving the frictional force switches from static friction to kinetic: they never occur together. Static friction tells you how much force you will need to get an object moving, while kinetic friction tells you how much force will be necessary to "keep it moving". Remember, though, that kinetic friction is not the force moving the object, but the amount of force resisting the motion.

Example 1: 15 N pulls on a stationary object, but does not move it. Then $F_{static} = 15N$ (equal and opposite).
Example 2: 20 N is necessary to keep an object in motion. Then $F_{kinetic} = 20N$. If the two forces are equal (the force applied and the kinetic force) then the object will have no net force, no acceleration, remain at constant speed, and be at equilibrium.
Example 3: 30 N is necessary to get an object moving, but only 20N is necessary to keep it moving. $F_{applied} = 40$ N; $F_{static} = 30$ N; $F_{kinetic} = 20$ N. Since $F_{applied} > F_{static}$ (40 N > 30 N), the object will break free and move. Once moving, you must use $F_{kinetic}$ and $\Sigma F = ma$. Since friction opposes motion, it reduces the $F_{applied}$: $\Sigma F = 40N—20N = 20N$. If the mass was known, the acceleration could be calculated.

Equations to find Friction: Friction depends on the surface against which it rubs and on how hard it is pressed against that surface. The coefficient of friction (μ) tells you how rough or smooth the surface is. The normal force (Fn) tells you how hard it is being pressed against the surface (see notes: "Normal Force"). μs is the coefficient of static friction; μk is the coeffient of kinetic friction. μs is almost always greater than μk (except, again, for Teflon: μs = μk).

$$\mu s = \frac{Fs}{Fn} \qquad \mu k = \frac{Fk}{Fn} \qquad \text{Then } Fs = \mu sFn \quad \text{and } Fk = \mu kFn$$

Example: ***A 4kg object sits on a surface with μs = .61 and μk = .34.***
If a 50N force is applied to the object, will it move? If so, what is it's acceleration?

Solution: First find Fn (needed for Fs and Fk). Since the object is on a horizontal surface Fn = 40N (equal and opposite its weight).

$Fs = \mu sFn = .61(40N) = 24.4N$ ($F_{staticmax}$)

$Fk = \mu kFn = .34(40N) = 13.6$ N.

The object will move since $F_{applied}$ (50N) > Fs (24.4N).

Once moving, the applied force will be opposed by $F_{kinetic}$:
$\Sigma F = F_{applied} – F_{static} = 50N – 13.6N = 36.4N$.

Then use $\Sigma F = ma$ to find the acceleration:
$36.4N = 4kg(a)$;
$a = 36.4N/4kg = 9.1m/s^2$.