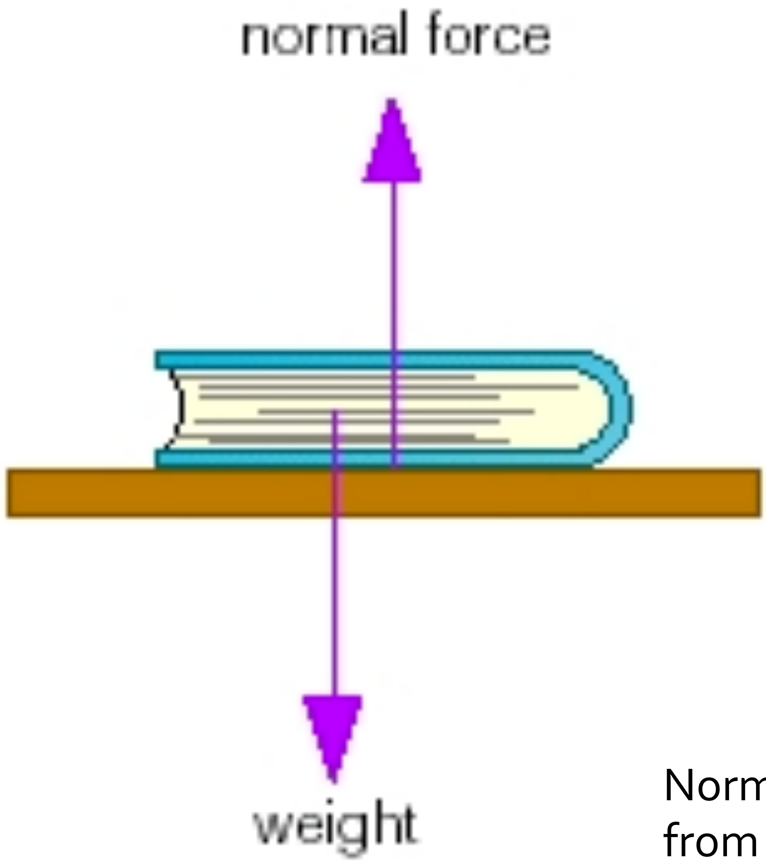
College Physics I: 1511 Mechanics & Thermodynamics

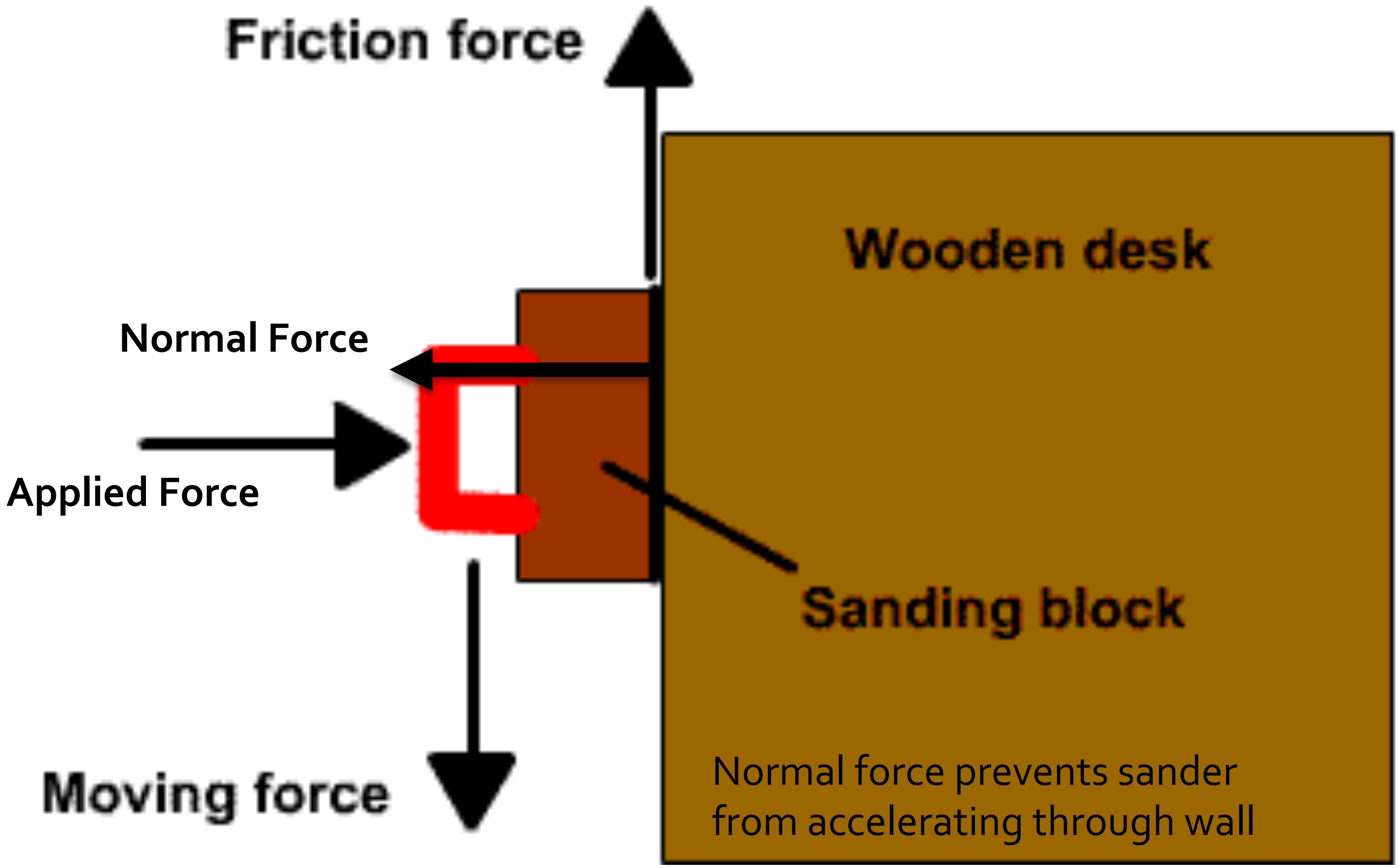
Professor Jasper Halekas
Van Allen Lecture Room 1
MWF 8:30-9:20 Lecture

Normal Force

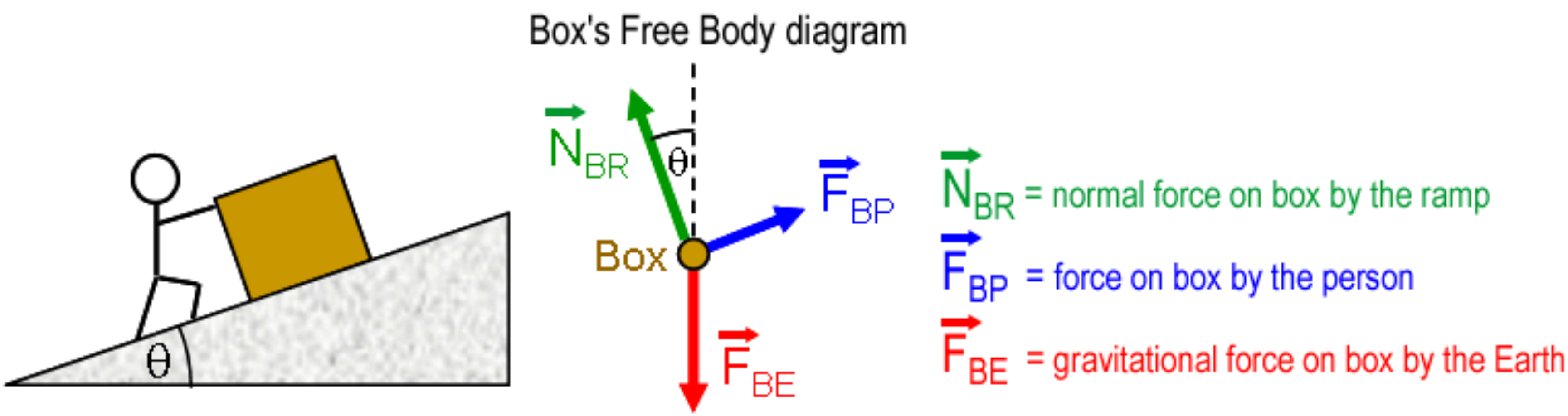


Normal force prevents book from accelerating downwards!

Normal Force



Normal Force



Normal force keeps object from accelerating through ramp

-It could still slide (if no person)

Concept Check

Consider a car at rest. We can conclude that the downward gravitational pull of Earth on the car and the upward normal force of Earth on it are equal and opposite because

A: the two forces form an "action reaction" pair.
B: the net force on the car is zero.
C: neither of the above
D: both of the above

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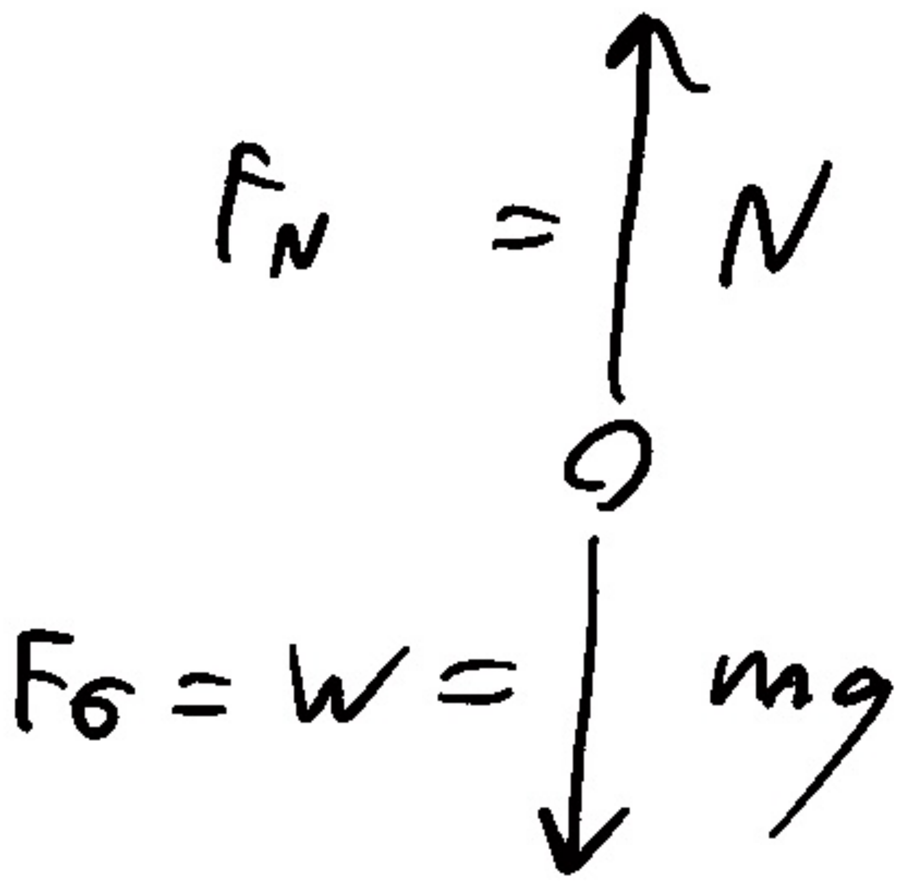
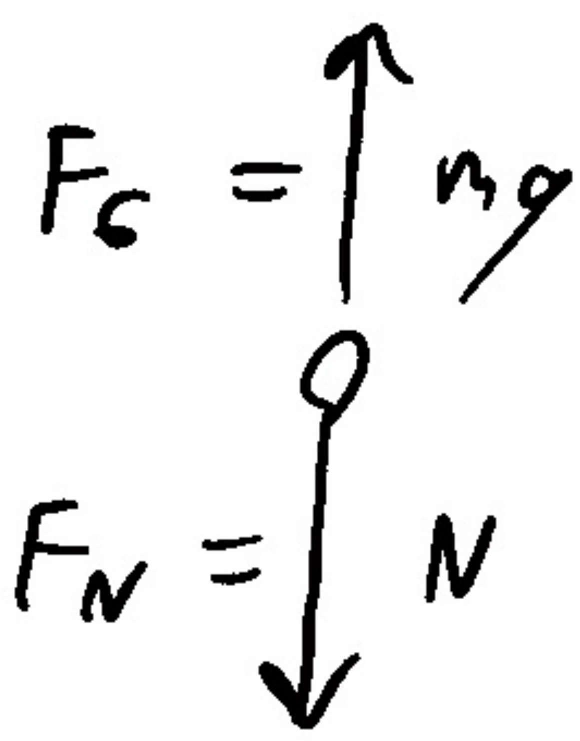
Car



Earth



Concept Check

You are a passenger in a car and not wearing your seat belt. Without increasing or decreasing its speed, the car makes a sharp left turn, and you find yourself colliding with the right-hand door. Which is the correct analysis of the situation?

A: During the turn, there is a rightward force pushing you into the door.

B: During the turn, the door exerts a leftward force on you.

C: both of the above

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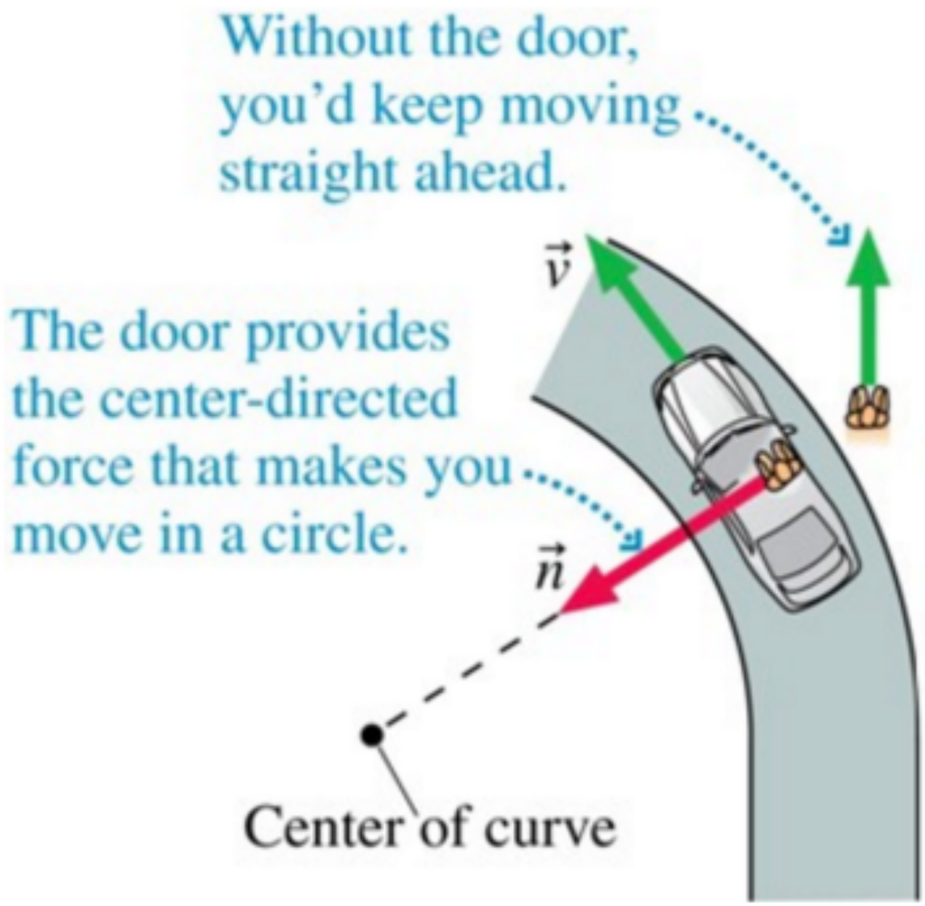
Car II

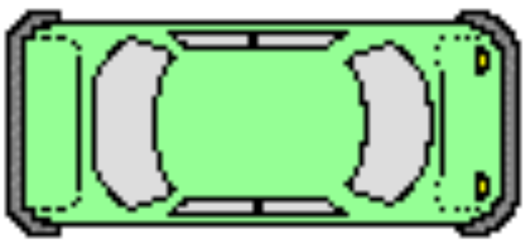
Free-body for person

Turning Car


Without the door, you'd keep moving straight ahead.
$\vec{v}$
The door provides the center-directed force that makes you move in a circle.
$\vec{n}$
Center of curve

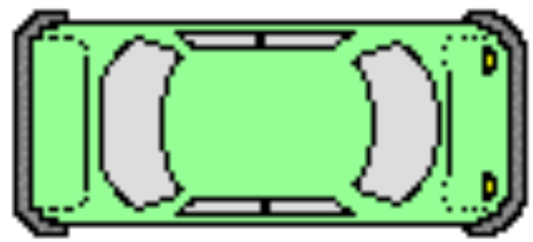
Braking/Accelerating Car

Car Starts from Rest



A passenger at rest would remain at rest, thus causing the "sensation of a backwards acceleration."

Moving Car Brakes to Stop

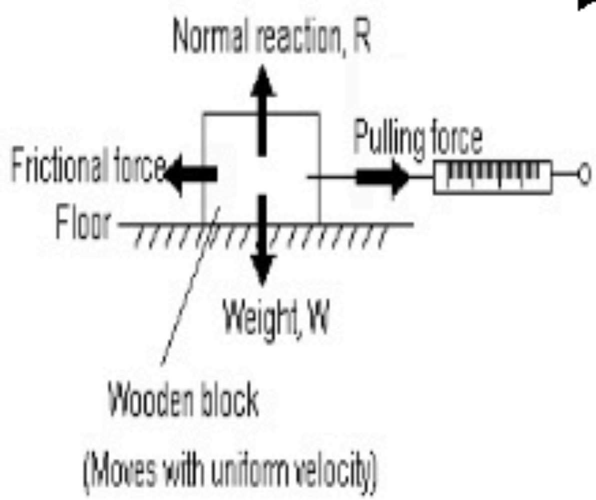


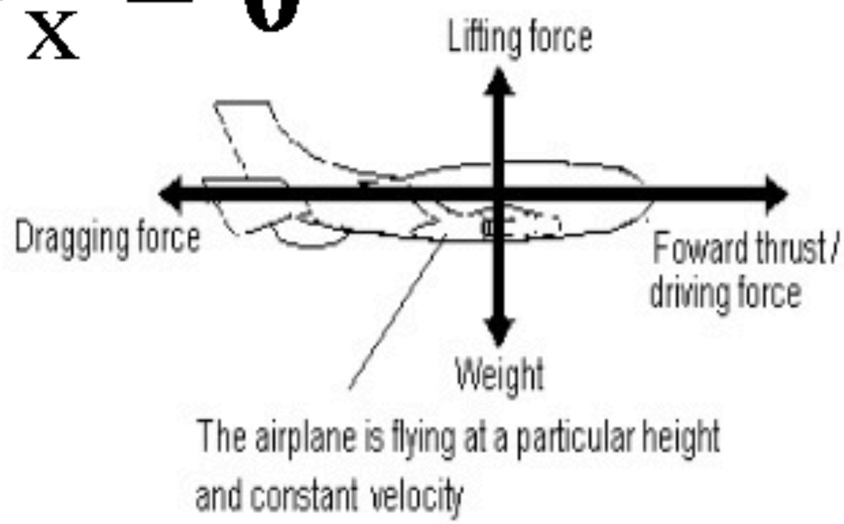
A passenger in motion would remain in motion, thus causing the "sensation of a forwards acceleration."

Forces in Equilibrium

$$+\uparrow \sum F_y = 0$$

$$\overset{+}{\rightarrow} \sum F_x = 0$$





Weight = Normal reaction

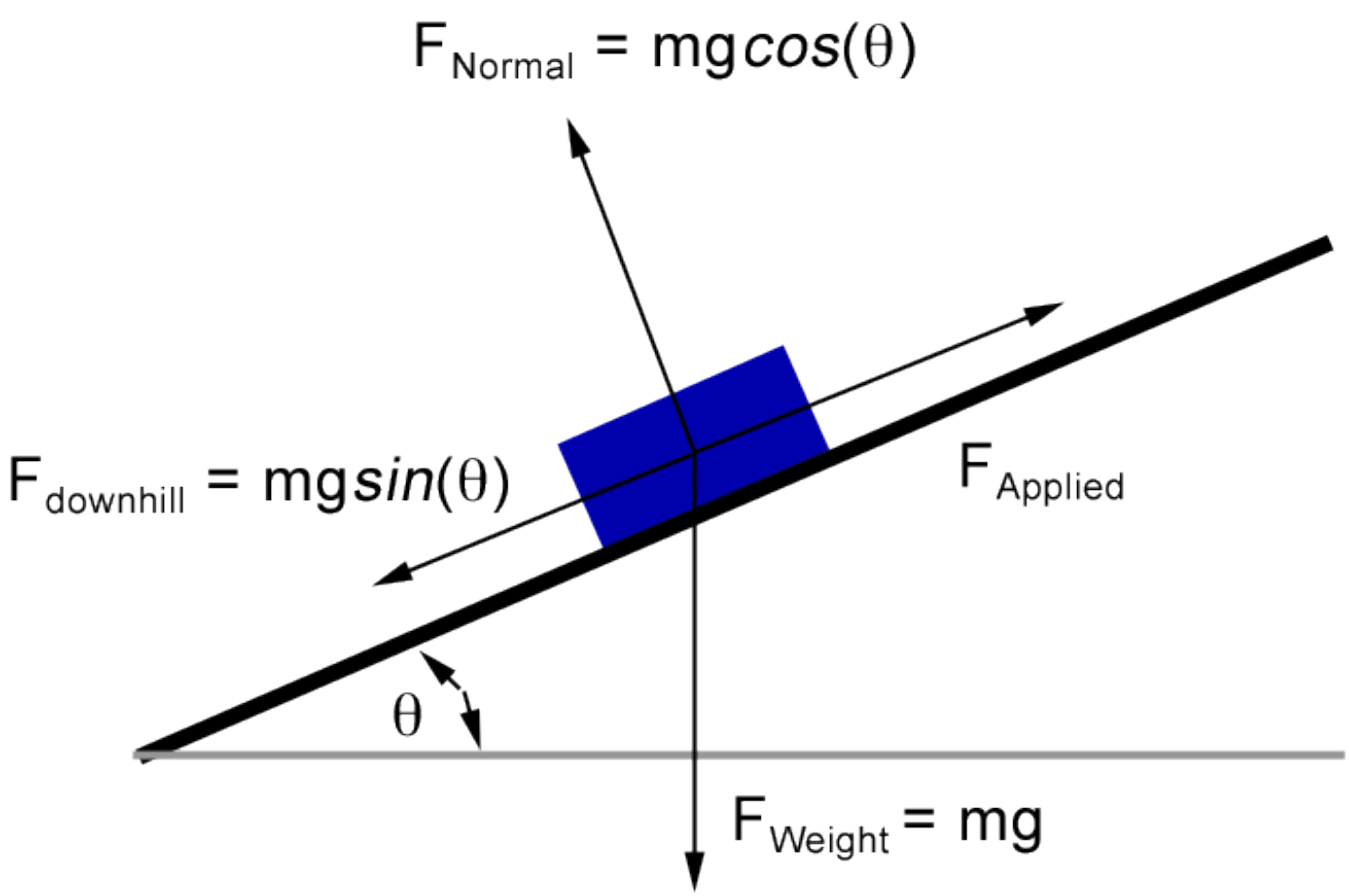
Pulling force = Frictional force

Weight = Lifting force

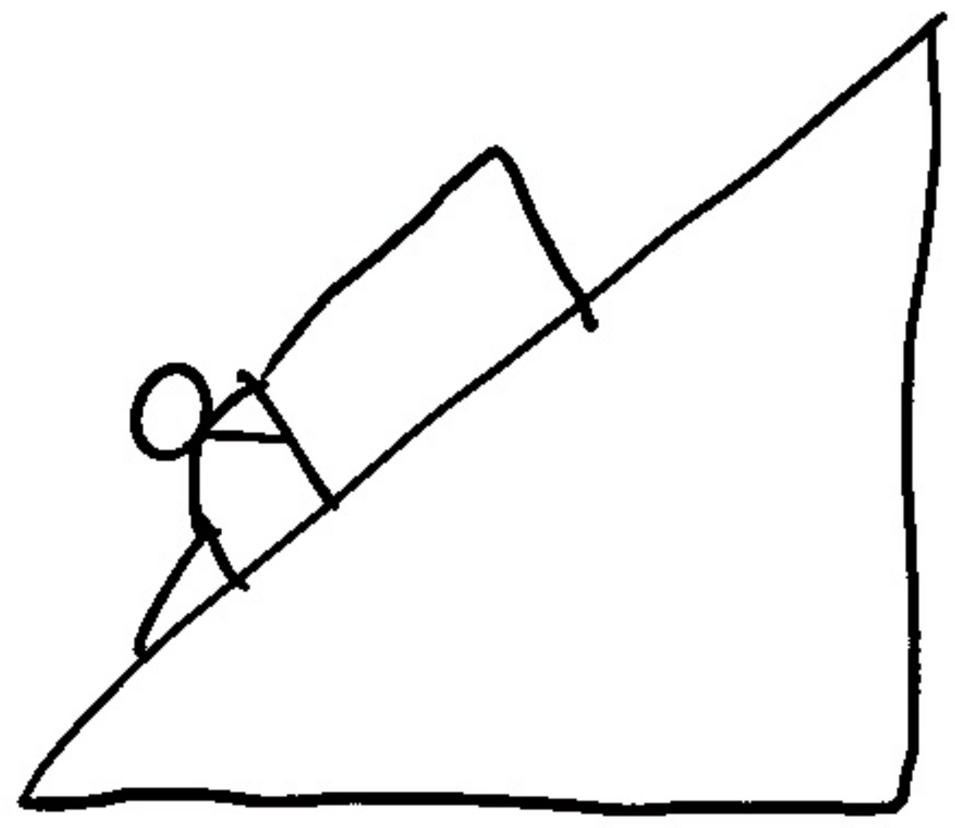
Driving force = Dragging force

If forces are un-balanced in any direction, then there is acceleration in that direction!

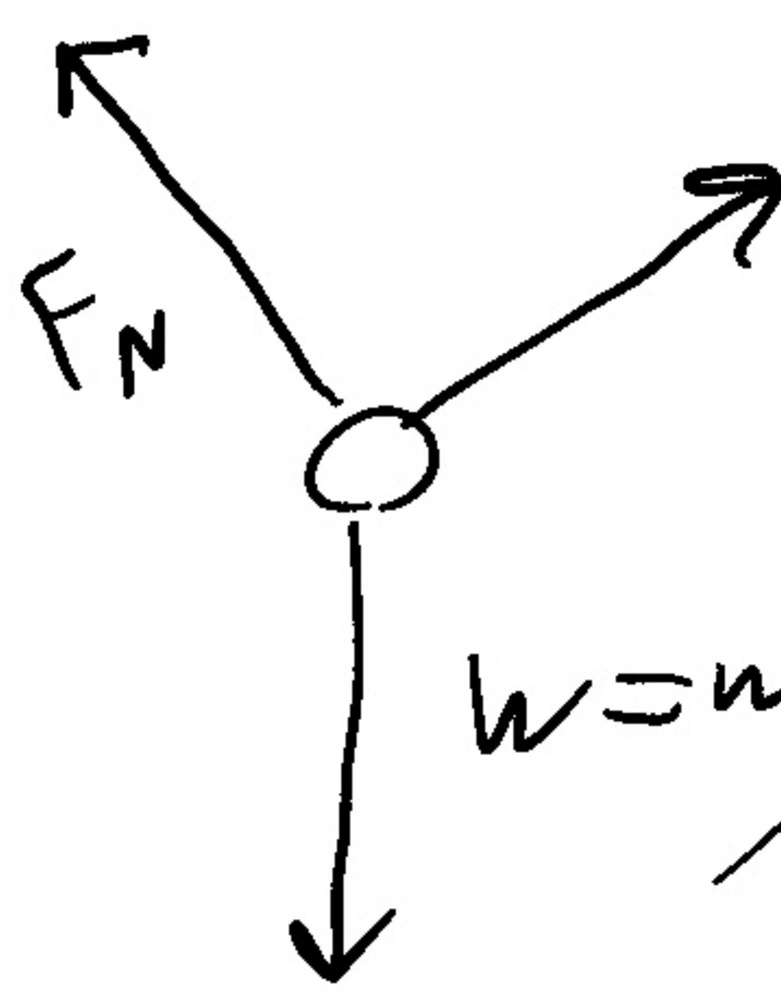
Normal Force on Incline



Incline



Free-body

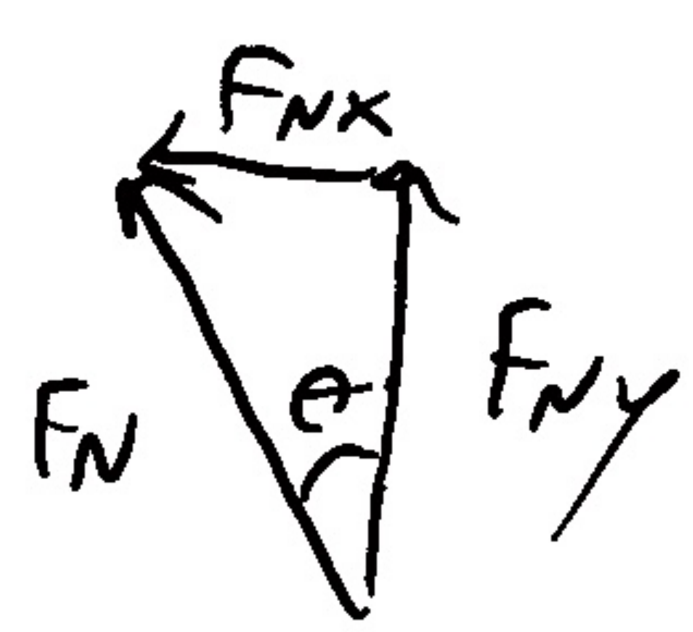


What are F_N, $F_{applied}$ if forces balanced.

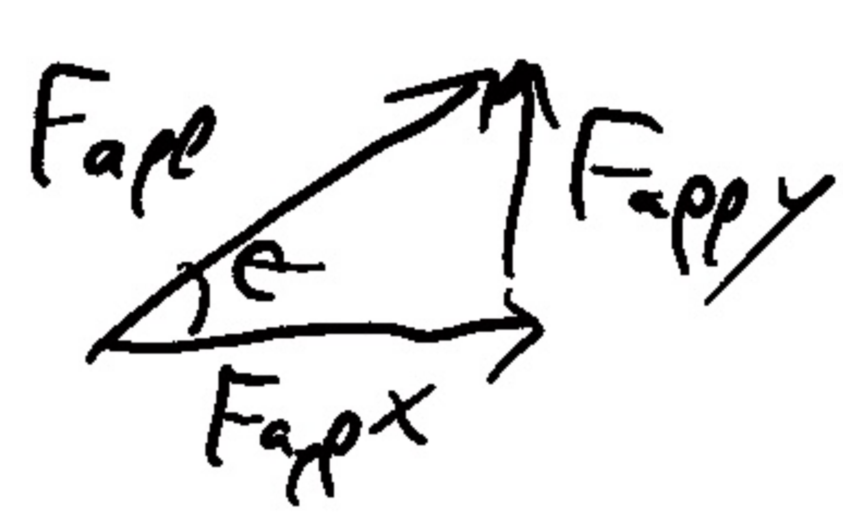
Method 1: x, y components

$$F_x = F_{Nx} + F_{appx} = 0$$

$$F_y = F_{Ny} + F_{appy} - mg = 0$$



$$F_{Nx} = -F_N \sin\theta$$
$$F_{Ny} = F_N \cos\theta$$



$$F_{app\,x} = F_{app} \cos\theta$$
$$F_{appy} = F_{app} \sin\theta$$

x : $F_{app} \cos\theta - F_N \sin\theta = 0$

y : $F_{app} \sin\theta + F_N \cos\theta - mg = 0$

solve x-equation

$$F_{app} \cos\theta = F_N \sin\theta$$

$$F_{app} = F_N \sin\theta / \cos\theta$$

sub. into y-equation

$$F_N \sin^2\theta / \cos\theta + F_N \cos\theta - mg = 0$$

or $F_N \sin^2\theta + F_N \cos^2\theta - mg\cos\theta = 0$

but $\sin^2\theta + \cos^2\theta = 1$

$$\Rightarrow F_N - mg\cos\theta = 0$$

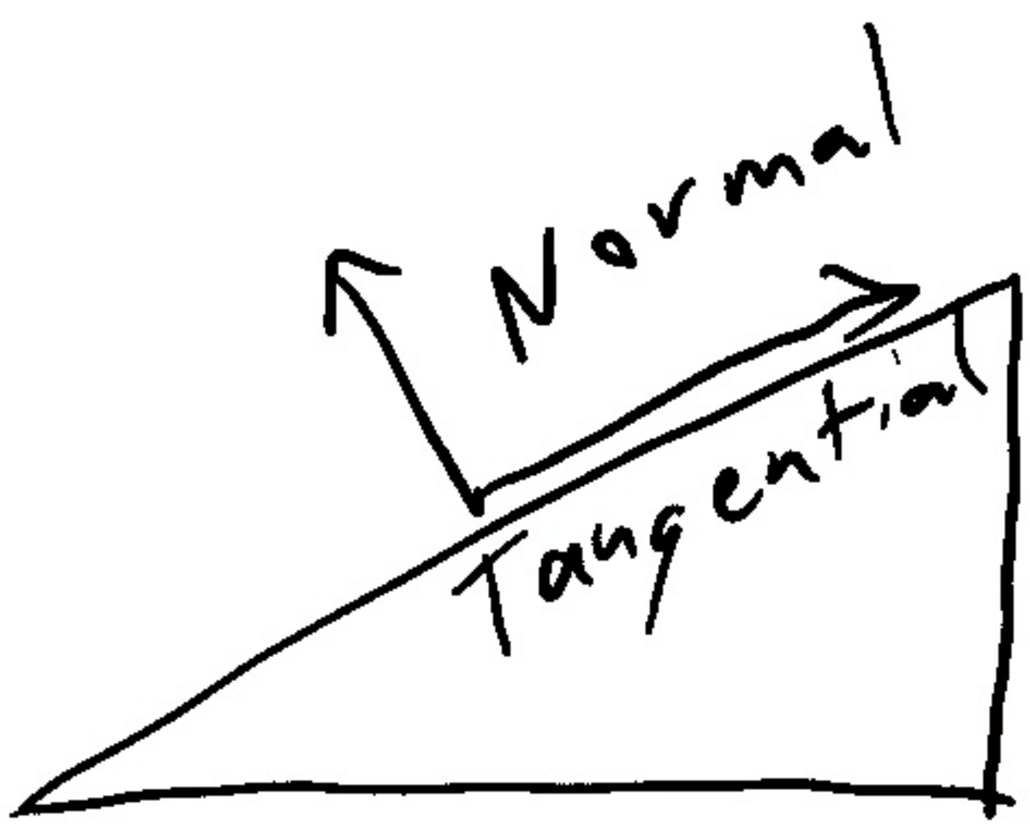
$$\Rightarrow \boxed{F_N = mg\cos\theta}$$

$$F_{app} \cos\theta = F_N \sin\theta$$

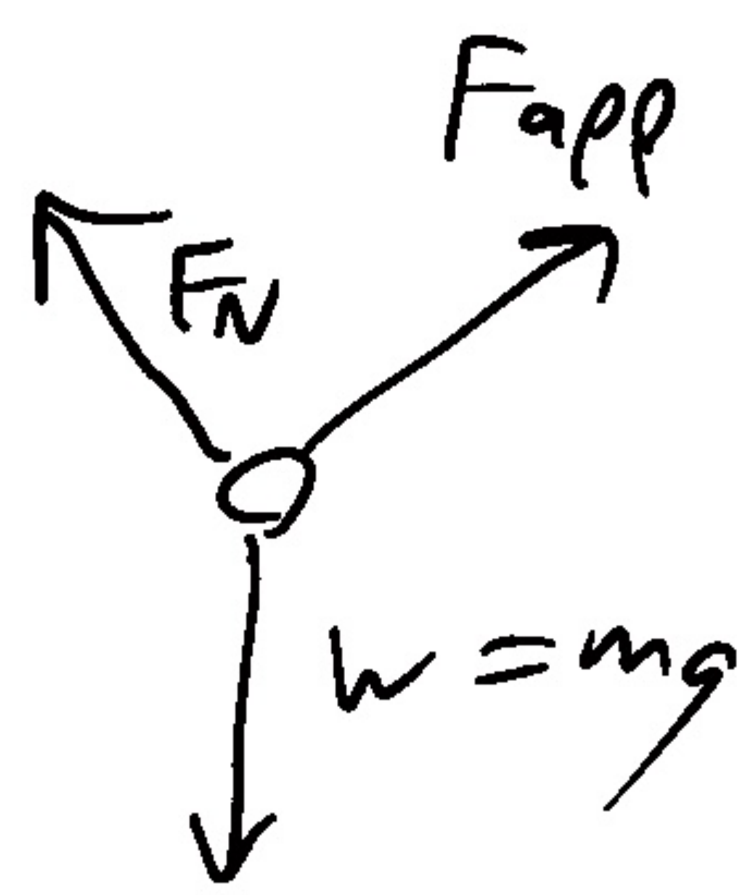
$$\Rightarrow F_{app} = F_N \sin\theta / \cos\theta$$

$$\boxed{F_{app} = mg\sin\theta}$$

Easier way!

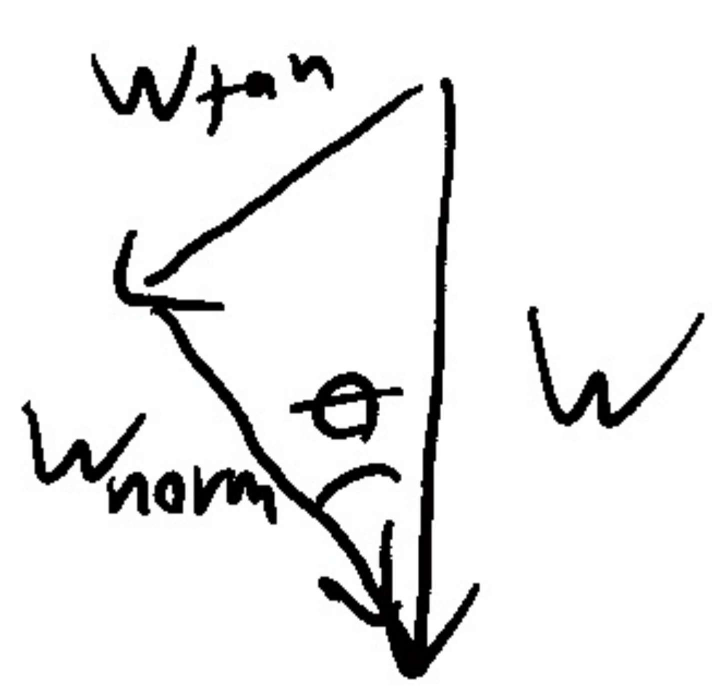


Use different axes!



Normal : $F_N - W_{normal} = 0$

Tangential : $F_{app} - W_{tangential} = 0$



$W_{normal} = mg\cos\theta$

$W_{tan} = mg\sin\theta$

$F_N - mg\cos\theta = 0$

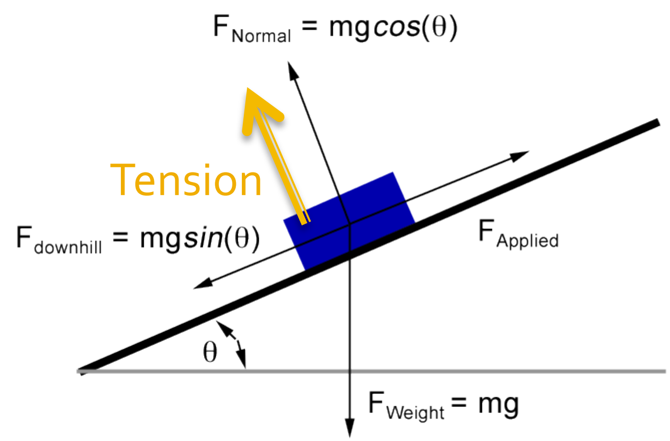
$\Rightarrow \boxed{F_N = mg\cos\theta}$

$F_{app} - mg\sin\theta = 0$

$\Rightarrow \boxed{F_{app} = mg\sin\theta}$

Concept Check

- What happens if I impose a small outward tension force (normal to the ramp) to this balanced block?
  - A. It accelerates outward from the ramp
  - B. It stays in place
  - C. It slides down the ramp
  - D. It screams in protest and disintegrates



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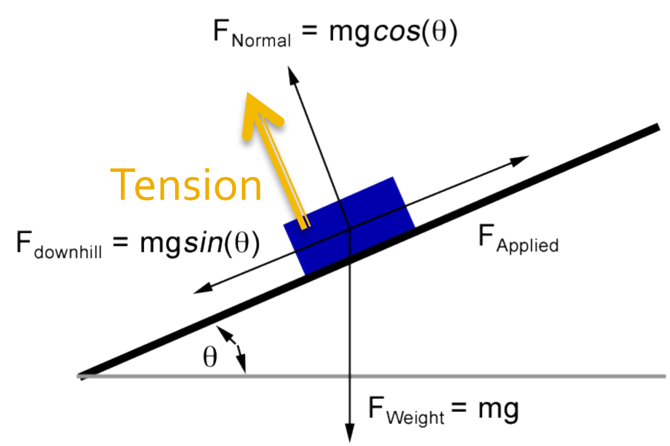
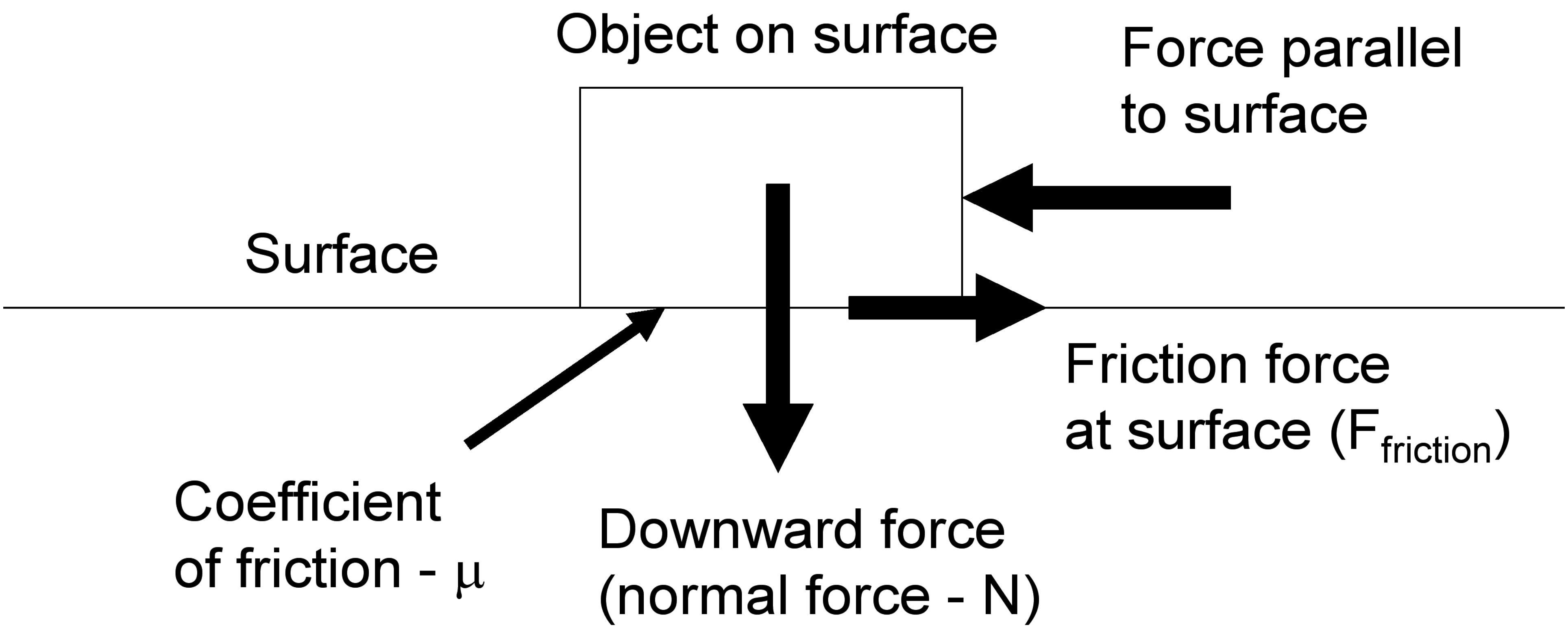


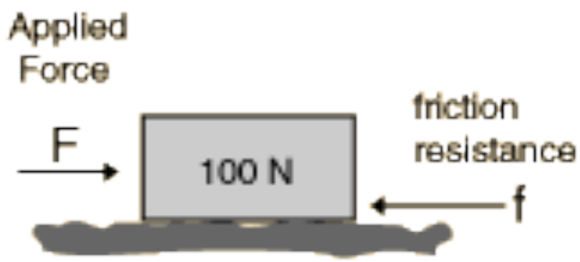
Idealized Physics

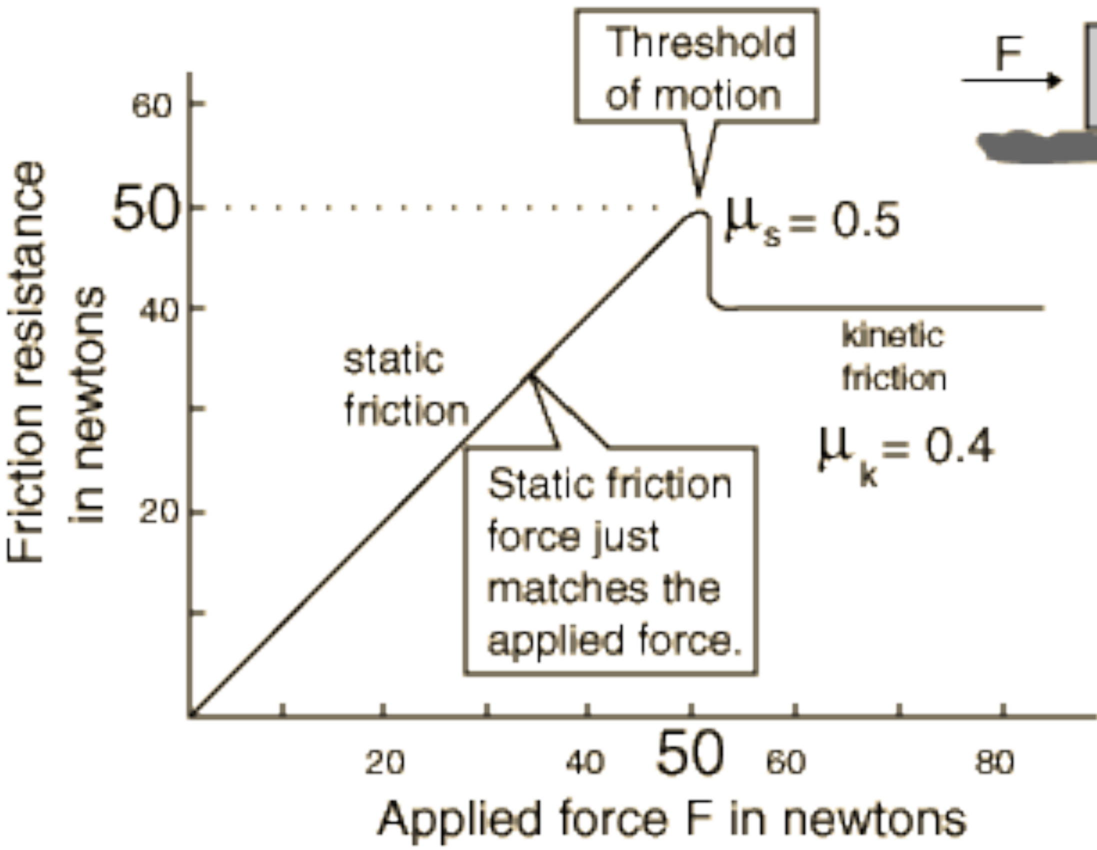
Frictional Forces



$$F_{friction} = \mu N$$

Static Vs. Kinetic Friction





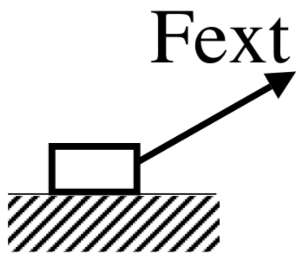
The relationship

$f_{max\ static} = \mu_s N$

applies only to the threshold of motion. For lower applied forces the static friction will just match the applied force to prevent motion.

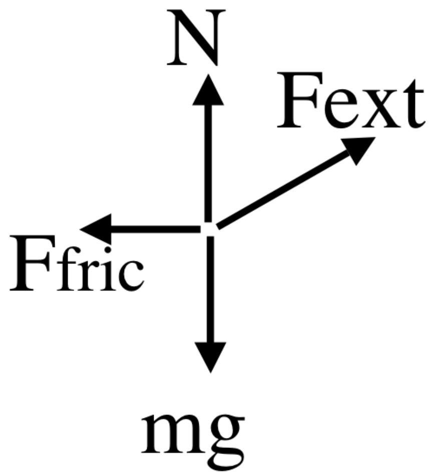
Concept Check

A mass m is pulled along a rough table at constant velocity with an external force F_{ext} .



The magnitudes of the forces on the free-body diagram have not been drawn carefully, but the directions are correct.

Which statement below *must* be true?



A: $F_{fric} > F_{ext}$, $N > mg$.

B: $F_{fric} < F_{ext}$, $N < mg$.

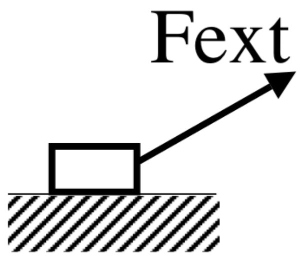
C: $F_{fric} > F_{ext}$, $N < mg$.

D: $F_{fric} < F_{ext}$, $N > mg$.

E: None of these.

Concept Check

A mass m is pulled along a rough table at <u>constant</u> velocity with an external force F_{ext} .



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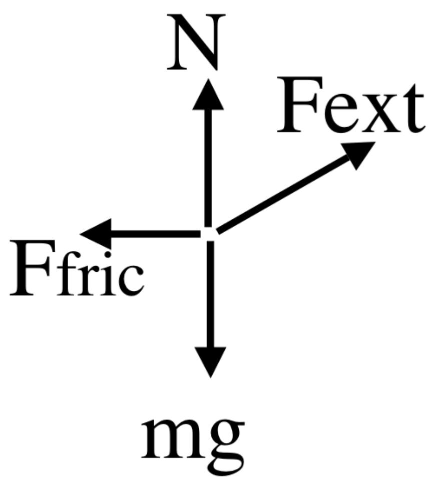

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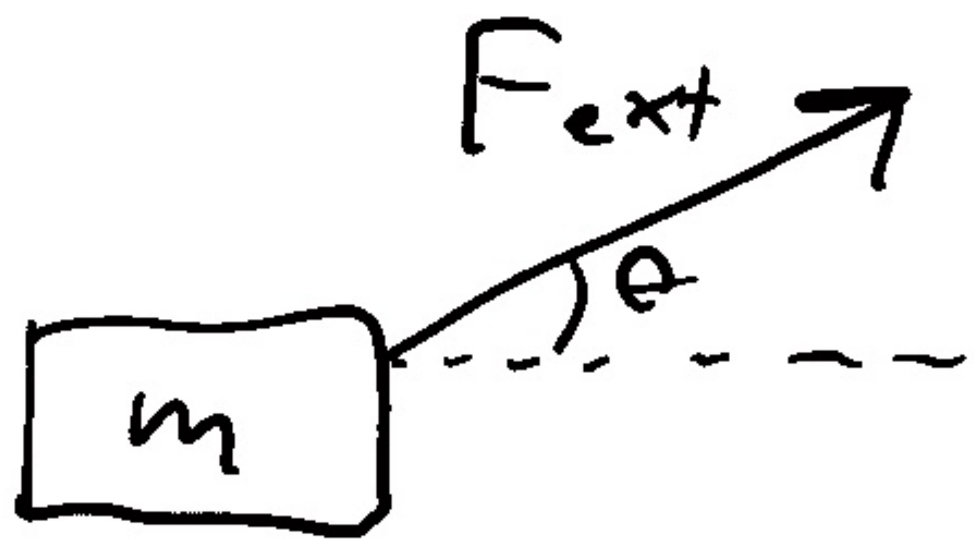
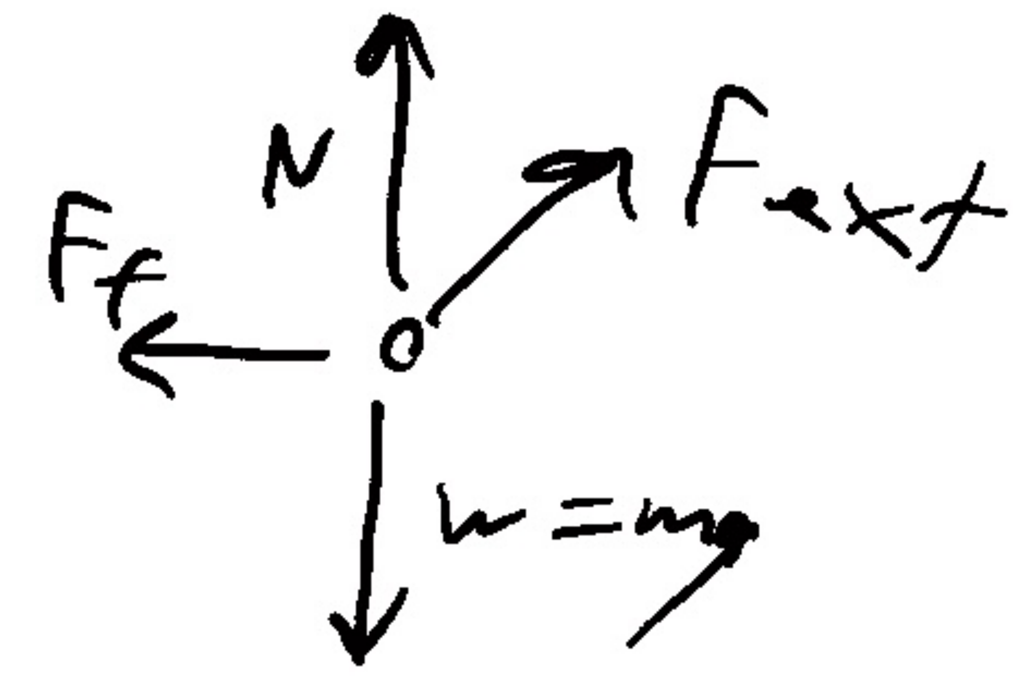
Friction





constant velocity so $\sum \vec{F} = 0$

$$F_x = F_{ext}\cos\theta - F_f = 0$$
$$F_y = N + F_{ext}\sin\theta - mg = 0$$

$$F_{ext}\cos\theta = F_f$$
so $F_f < F_{ext}$

$$N = mg - F_{ext}\sin\theta$$

so $N < mg$

$$F_f = \mu_k N = \mu_k (mg - F_{ext}\sin\theta)$$