Why do you feel heavier when you are in an elevator going up, and why do you feel lighter when the elevator is going down?

Normal force in an elevator

10 kg toddler in an elevator :

Elevator has 0 velocity and 0 acceleration

Sum $F_y = 0$, $F_N = F_G = 98.1N$

Elevator at constant velocity (0 acceleration)

Sum $F_y = 0$, $F_N = F_G = 98.1N$

2 m/s^2 acceleration

Sum $F_y = +20$ N

$F_N = 118.1N$

-2 m/s^2 acceleration

Sum $F_y = -20$ N

$F_N = 78.1N$

Free body diagrams (FBD) (”Force Diagrams”)

Draw all the forces acting on an object

Net force is the vector sum of all the forces

- Gravity (F_G)
- Direct push or pull (applied force F_{app})
- Friction (f)
- Tension (F_T): Strings, ropes, etc.
- Normal force (F_N)

Normal force

“Normal” means “perpendicular”

Support force

Finding the normal force

- Normal force is what is necessary to keep equilibrium in the direction **perpendicular to the surface**

Normal force in an elevator

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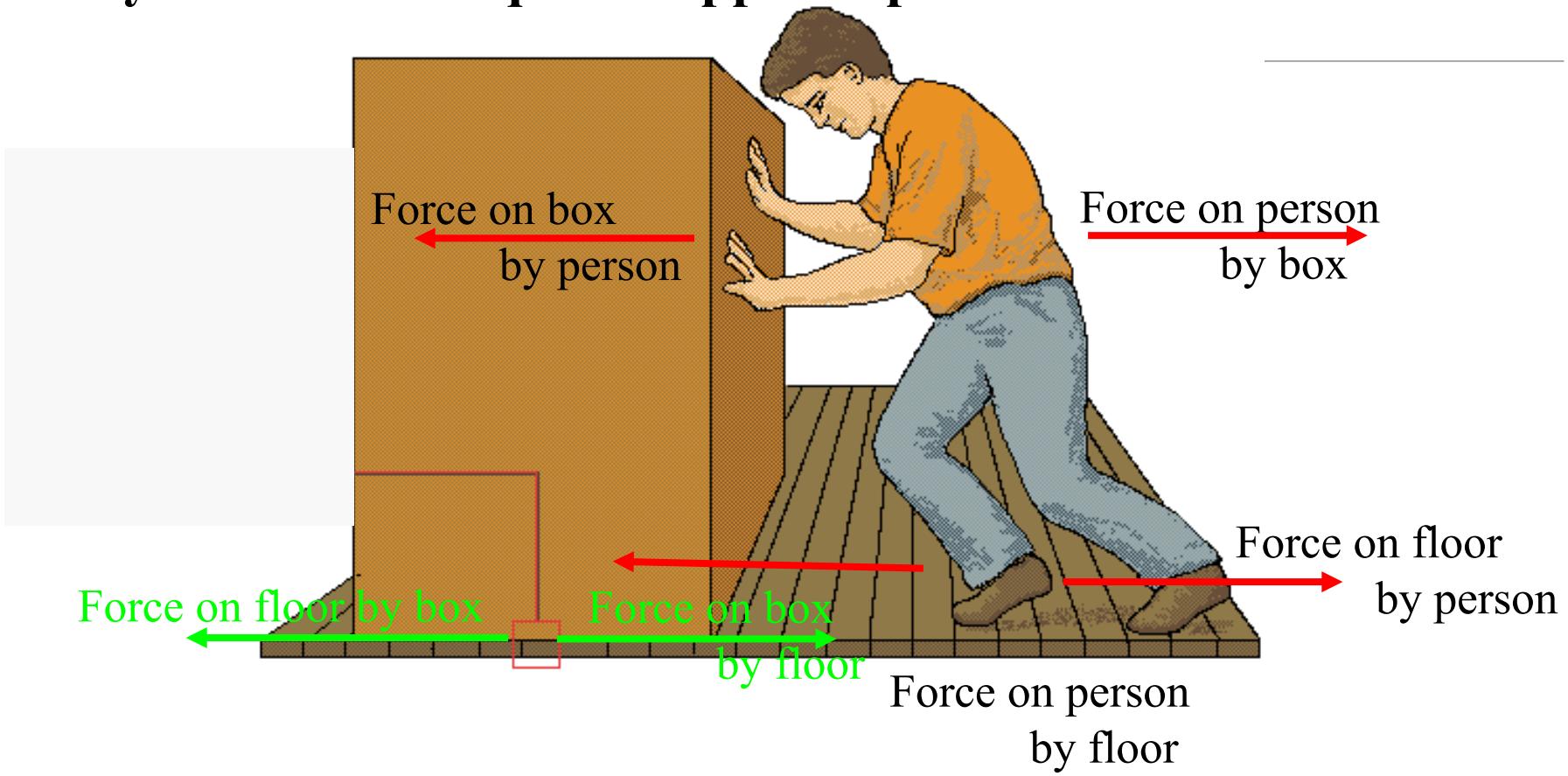
$F_N = 78.1N$

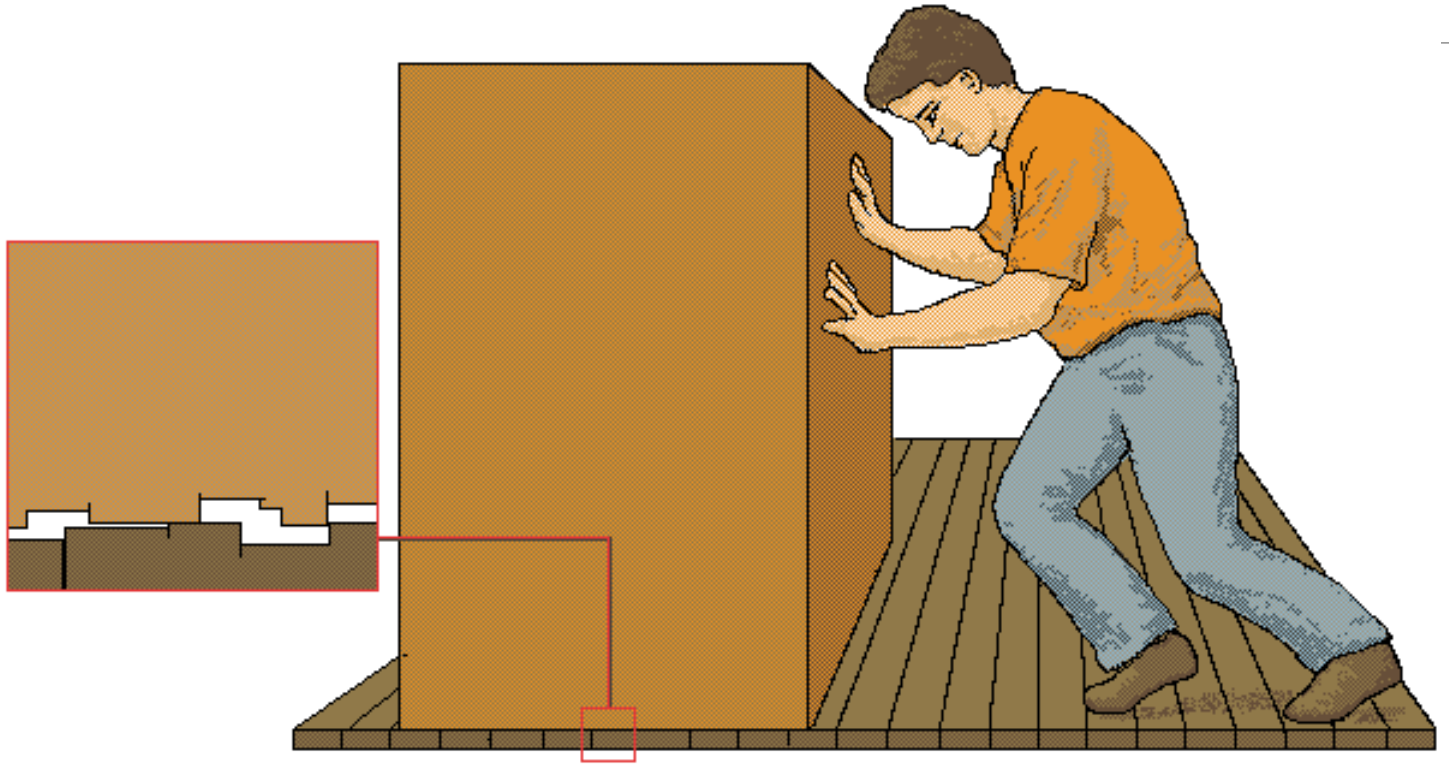
Friction is a Force

It's the sum of all the forces that determines the acceleration.
Every force has an equal & opposite partner.



Friction Mechanism

Corrugations in the surfaces grind when things slide.
Lubricants fill in the gaps and let things slide more easily.

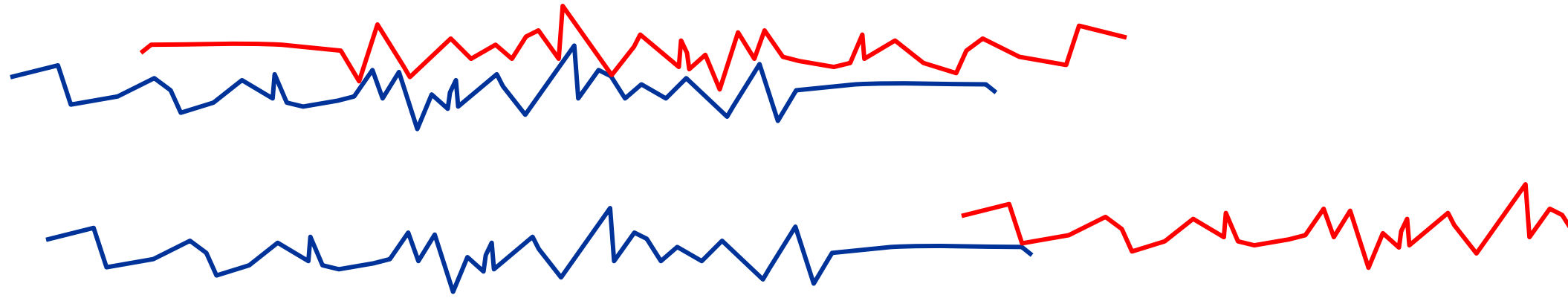


Static and Sliding (Dynamic) Friction

Static frictional force (f_s): in the direction to prevent sliding

Kinetic (sliding) frictional force (f_k): opposite the direction of sliding

Static frictional forces always greater than kinetic ones



Friction Force = Normal Force × (coefficient of friction)

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

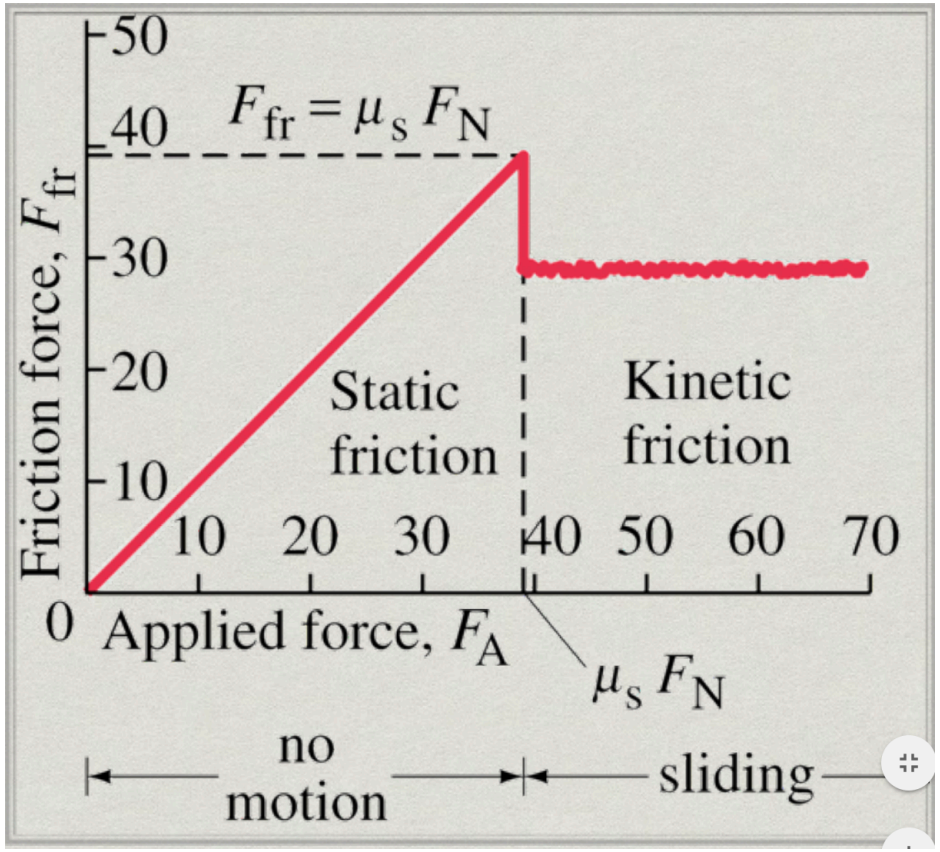
Normal force and friction force are perpendicular to each other

Coefficient of static friction > coefficient of kinetic friction

$F_s < \mu_s F_N$: F_s will match force of the pull in order to keep object in static equilibrium

Maximum $F_{s\,max} = \mu_s F_N$: then the object “slips”

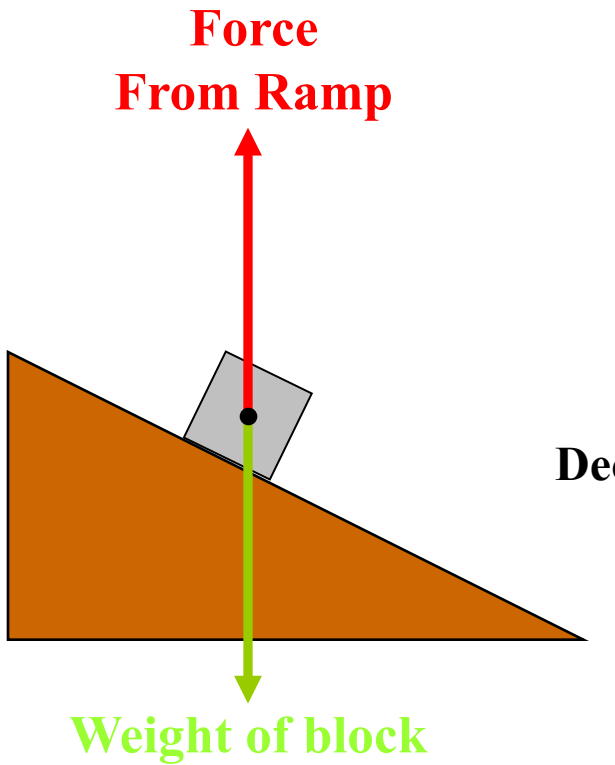
Why friction force can't be more than the force of a pull

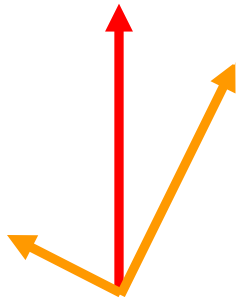


“Normal” Forces and Frictional Forces

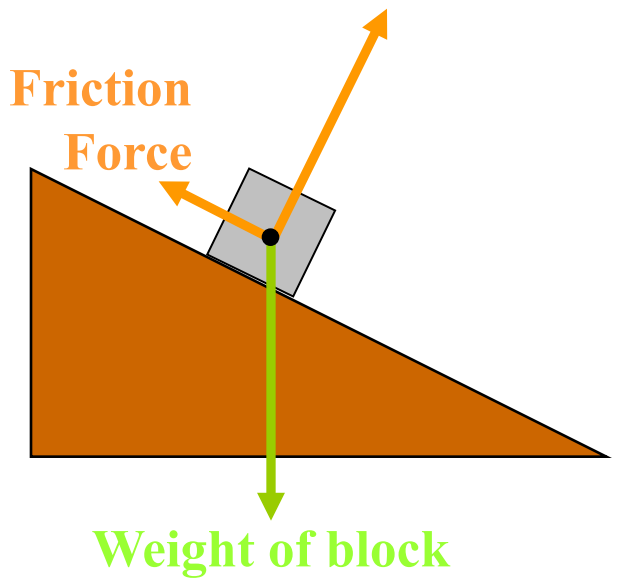
Friction Force = Normal Force × (coefficient of friction)

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





Decompose Vector



“Normal” means **perpendicular**

Jane is pulling a 10.0 kg box with a force of 40.0 N at an angle of 30.0. The coefficient of kinetic friction is 0.1.

A. Draw a FBD with all forces labeled.

B. Determine the horizontal acceleration (Hint: break pulling force into components). Be careful: F_N doesn't equal F_G!

C. How would the horizontal acceleration change if she pushed the box from behind with the same angle and force instead of pulled it?

D. Is it easier to push or pull an object?

A. Why is it more difficult to do a pull-up with 1 arm than 2 arms?

B. If you weigh 700N, How much force is in 1 arm vs. 2 arms?

- 1 arm: 700 N, 2 arms: 350 N

C. If both of your arms were at an angle of 30 degrees from the vertical, what would the force be in each arm?

- 404 N

Tension

When a flexible cord pulls on an object

If the cord is massless, the **tension will be same** along its entire length

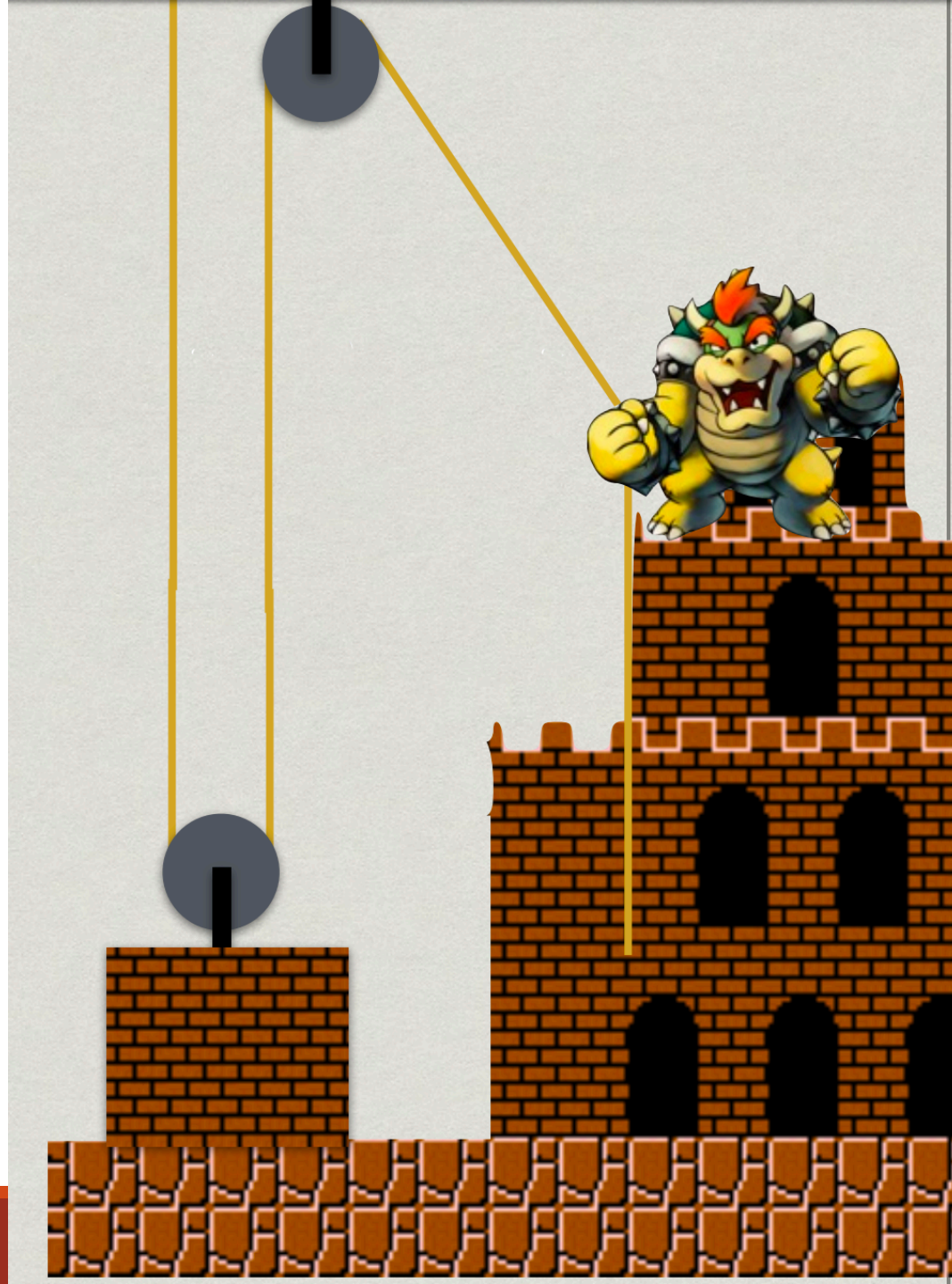
If pulleys are involved, assume they are **massless** and **frictionless**

Ropes and cords can only **pull**

Force always acts along (**parallel to**) the rope or cord

Bowser is using pulleys to lift a block to the top of his castle. He is using a rope looped over 2 pulleys. How much of the block's 2000N weight does he have to pull on the rope?

- 1000N



Problem Solving for Forces

1. Draw a FBD for each object involved
2. Identify the forces in both directions and make a net force equation
3. Is either direction in equilibrium? ($F_{net} = 0$) Are there ways we can simplify the equation?
4. Plug and chug!

Determine the coefficient of kinetic friction of a penguin slipping on flat seaweed if its mass is 21.8 kg and force due to friction is 18.9 N

- 0.08

Maria is sliding down a bannister. If she has a mass of 45 kg and the coefficient of kinetic friction between Maria's PJs and the bannister is 0.20, what is the force due to friction impeding her motion down the bannister?

- 76 N