Forces - the cause of change in motion

- push or pull
- attempt to change velocity
- multiple forces combine and act at the same time on an object

The amount of velocity change depended on

$$\text{change in velocity} = \frac{\text{Force} \cdot \text{time}}{\text{mass}}$$

$$(m)\Delta v = \frac{F \cdot \Delta t}{m}(m)$$

$$\frac{m \cdot \Delta v}{\Delta t} = \frac{F \cdot \cancel{\Delta t}}{\cancel{\Delta t}}$$

← come back in Ch. 7

$$F = \frac{m \cdot \Delta v}{\Delta t}$$

$$\boxed{F_{NET} = m \cdot a}$$

Force = mass · acceleration

Contact Forces

* push/pull
* tension - force on an object through a rope/wire/chain
* normal force - force due to contact with a surface. Always directed perpendicularly to the surface
* friction - force between surfaces directed parallel to the surface
* spring force - force is proportional to amount of stretch/compression

on earth

$$F_g = \text{weight} = \underbrace{\text{mass}}_{[kg]} \times \underbrace{9.8\ m/s^2}_{g}$$

Non-contact forces

weight

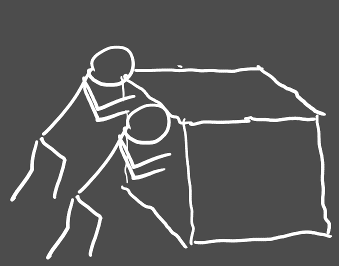
Fundamental Forces:

long-range
* gravitational force - force between any objects that have the property of mass
* electromagnetic force - force between any objects that have the property of charge

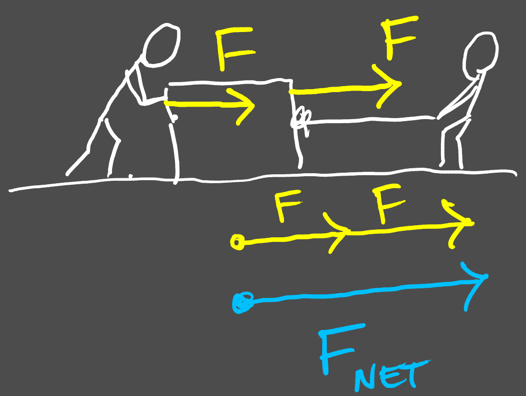
* weak force
* strong force

very short range

What about multiple forces?

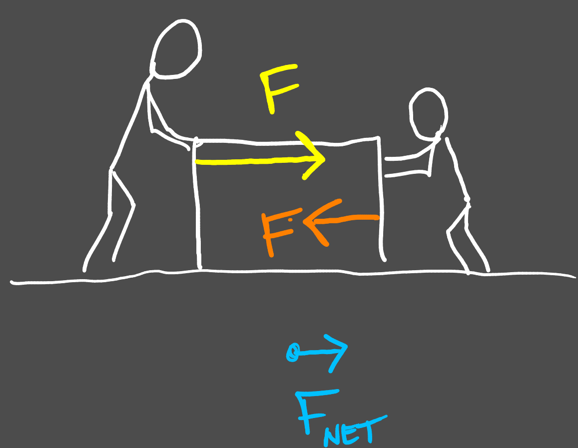


2 standard push work together to double the force.



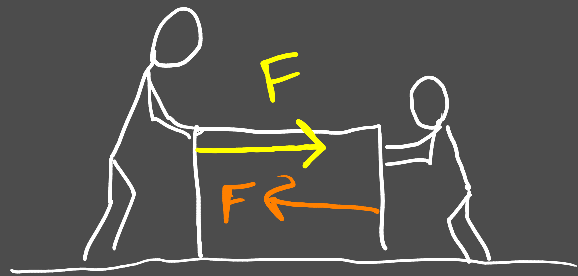
2 push act together in way that is indistinguishable from a single **net force**

→ effective force

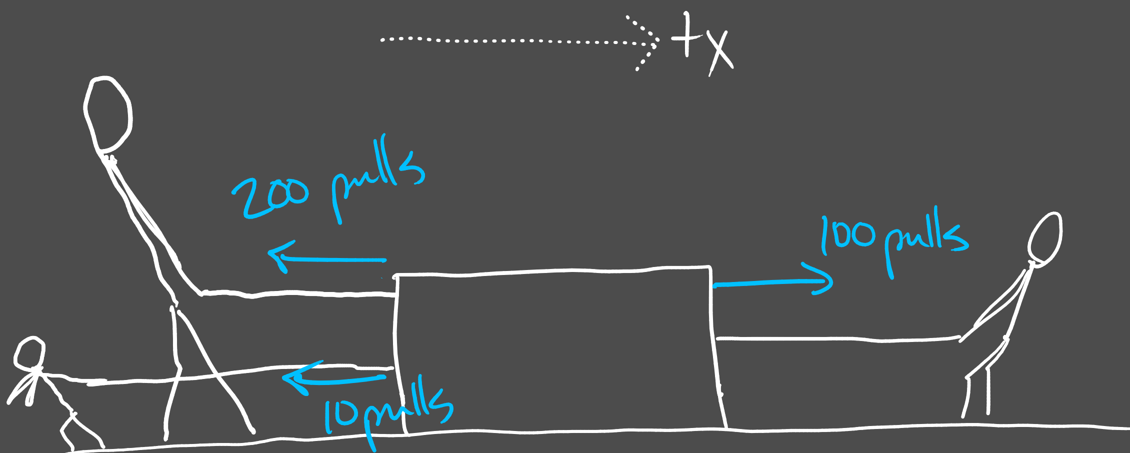


forces in opposing directions work to diminish the **net force**

Adding forces up to find the net force.



$F_{NET} = 0$



$$F_{NET} = +100 + (-200) + (-10)$$

$$F_{NET} = -110 \text{ pulls}$$

Newton's Laws

Newton's 1st Law - what happens when no net force acts
* if the object is not moving, it continues to not move
* if the object is moving, it continues to move in the same direction at the same speed (constant velocity)

if $a = 0$
then no net force

Newton's 2nd Law - law of motion
* net force causes acceleration
* net force = mass * acceleration

$$F_{NET} = m \cdot a$$

Newton's 3rd - law of interaction
* forces always occur in pairs
* every action has an equal and opposite reaction

careful

LAB | Measuring forces - we want to reliably measure a push/pull

↳ units   1 standard push = 1 ~~Remington~~

= 1 Newton

$$F_{NET} = m \cdot a$$

$$[kg]\left[\frac{m}{s^2}\right] = 1\frac{kg\,m}{s^2} = 1 \text{ Newton}$$

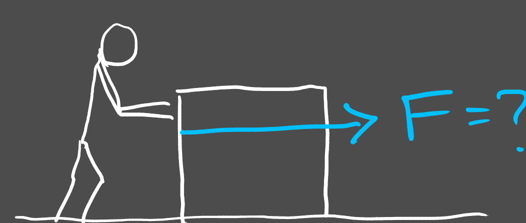
→ 1st way - measure the force's effect

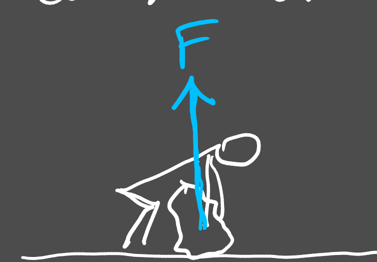
$$m, \Delta v, t \rightarrow \underline{\underline{F_{NET}}}$$

→ 2nd way - compare all push/pulls to force of gravity

$$F_g = m \cdot 9.8\,m/s^2$$

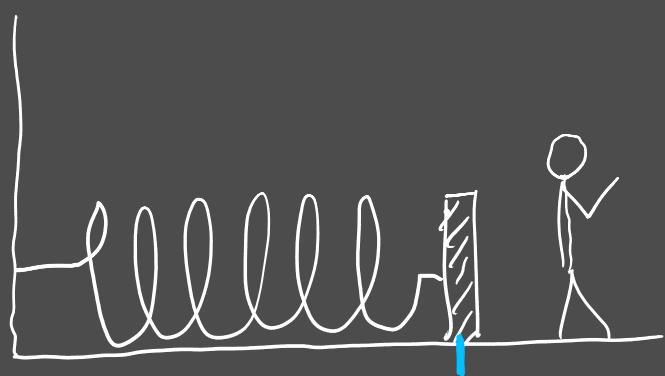
- consistent amounts of mass cause consistent force

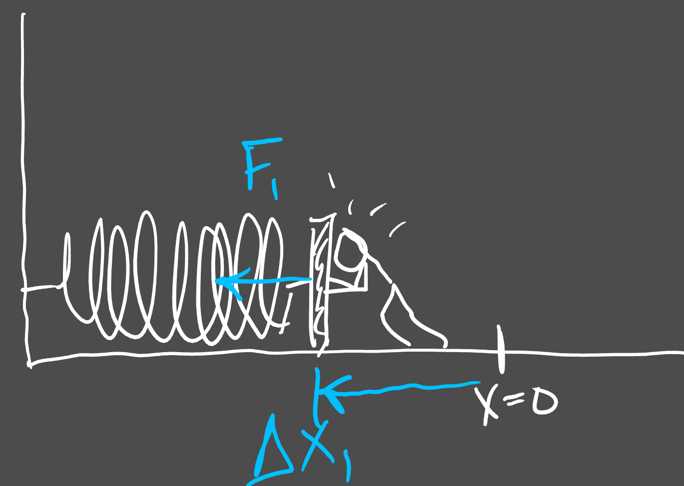




→ 3rd way → use a spring!

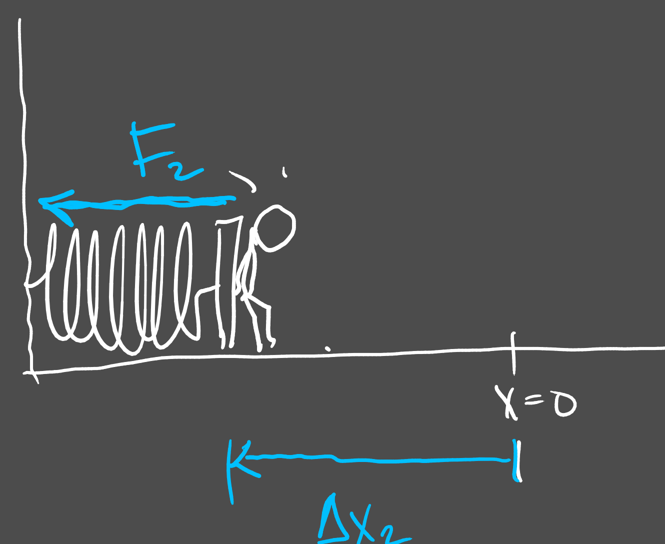
- portable
- reliable
- need to calibrate





$$\frac{F_1}{\Delta x_1} = \frac{F_2}{\Delta x} = k$$

k ← spring constant → measure of stiffness



Examples:

Newton's $2^{nd} \rightarrow F_{NET} = ma$

$\hookrightarrow a = \frac{F}{m}$

$a = \frac{500N}{100kg}$

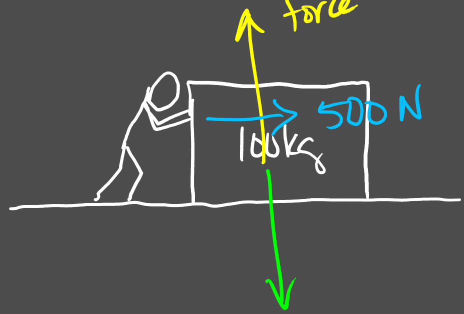
$a = 5\ m/s^2$

$\boxed{F_{NET}} \rightarrow$ sum of the individual forces

$\hookrightarrow$ seperat net force for vertical and horizontal motion

$\hookrightarrow$ we observe no vertical motion, so Newton's 1st tells us the F_{NET} in that direction is zero

normal force $= +980N$



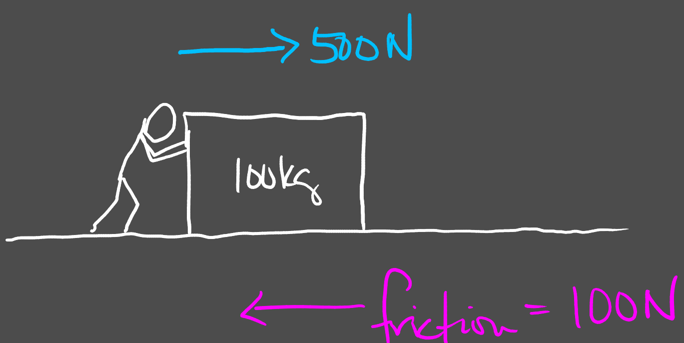
$F_g = m \cdot g$

$F_g = 100kg \cdot 9.8\ m/s$

$F_g = 980N$

$F_g = -980N$

$\longrightarrow +x$



$F_{NET} = +500N + (-100N)$

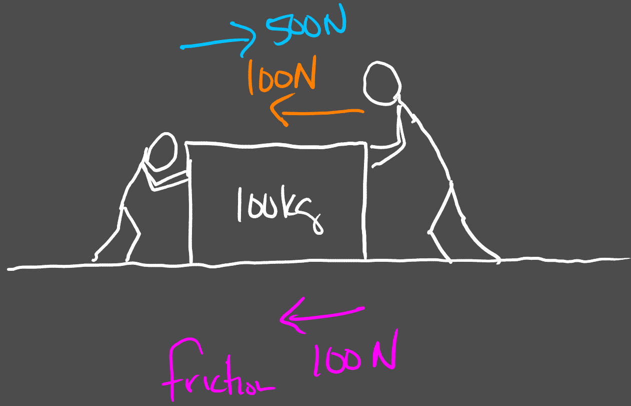
$= +400N$

$F_{NET} = ma$

$400N = 100kg \cdot a$

$\downarrow$

$a = 4\ m/s^2$



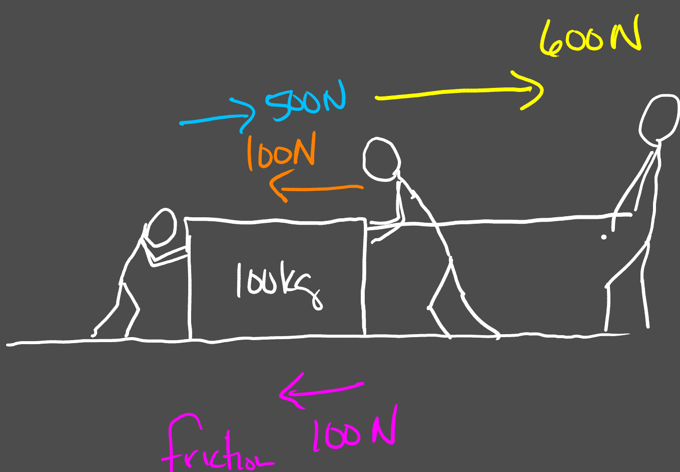
$F_{NET} = +500N + (-100N) + (-100N)$

$= 300N$

$F_{NET} = m \cdot a$

$300N = 100k \cdot a$

$a = 3\ m/s$

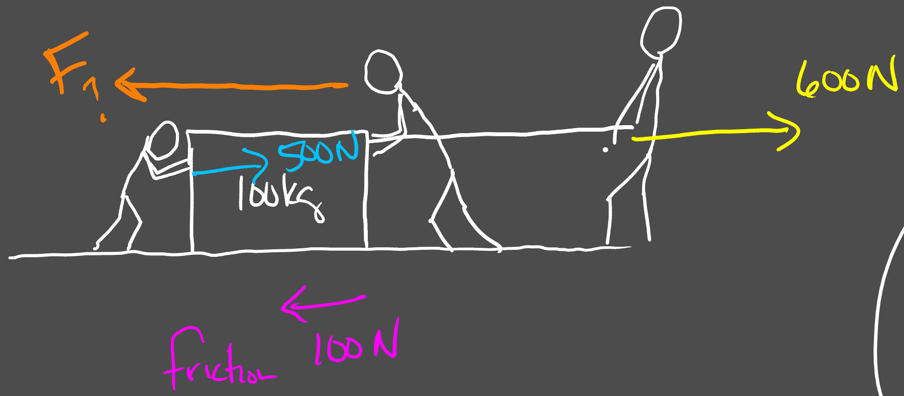


$F_{NET} = 500N - 100N - 100 + 600N$

$= 900N$

$900N = 100kg \cdot a$

$a = 9\ m/s^2$



$$F_{NET} = 0 = \underbrace{500N - 100N + 600N}_{} + F_?$$

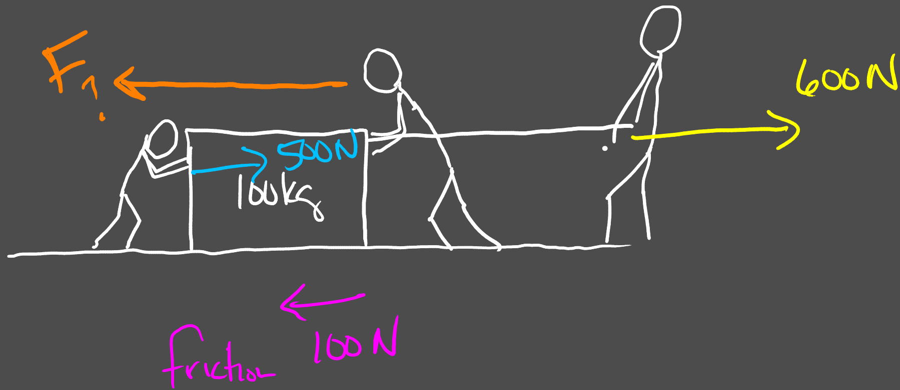
$$0 = 1000N + F_?$$

$$\boxed{-1000N = F_?}$$

$$F_{NET} = 0, \quad a \overset{!}{=} 0$$

Can the object be in motion? YES!
it can have a constant velocity

can the object be at rest? YES!
(motionless)
0 m/s is still a constant velocity



$$a = 7\,m/s^2$$

$$F_{NET} = m \cdot a$$

$$F_{NET} = 100kg \cdot 7\,m/s^2$$

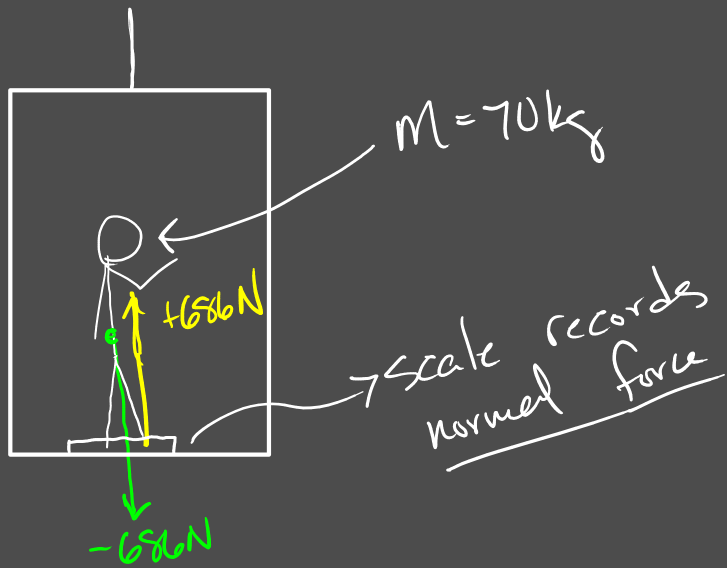
$$F_{NET} = 700N$$

$$700N = \underbrace{500N + 600N - 100N}_{1000N} + F_?$$

$$700N = 1000N + F_?$$

$$-300N = F_?$$

Vertical Forces/Motion:



#1 | elevator is motionless

weight: $-686N = m \cdot g = 70kg \cdot 9.8 m/s^2$

normal: 686N ← b/c elevator is not moving

#2 | elevator is going up at constant speed:

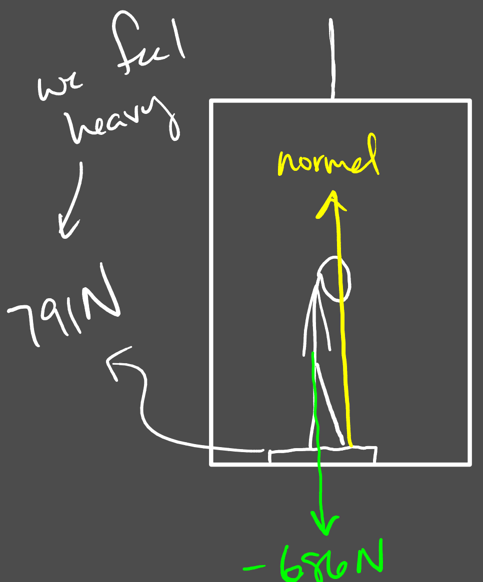
weight: -686N

normal: 686N

#3 | elevator is accelerating upward $+1.5\ m/s^2$

weight: -686N

normal:



$F_{NET} = 70kg \cdot 1.5 m/s^2$

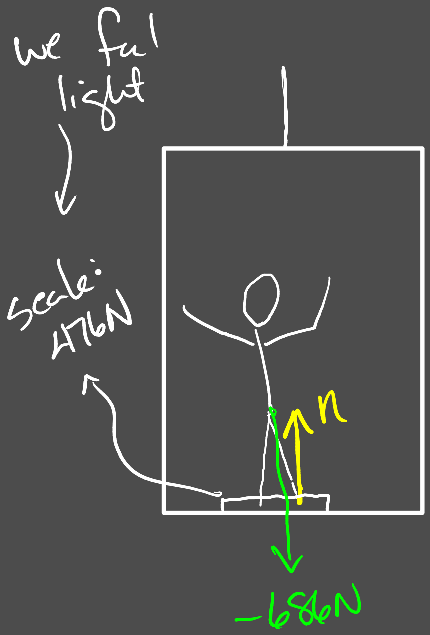
$F_{NET} = 105\ N$

normal + weight = F_{NET}

normal + (−686N) = 105N

$n = 105N + 686N$

$\boxed{n = 791N}$



$F_{NET} = 70kg \cdot (-3 m/s^2)$

$F_{NET} = -210 N$

$-210N =$ normal + weight

$-210N = n + (-686N)$

$+686 \qquad +686$

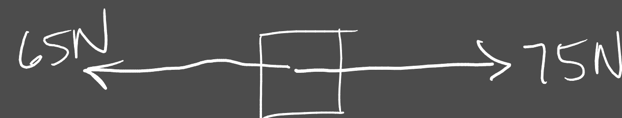
$n = +476 N$

#4] acceleration is downward

$-3 m/s^2$

weight: $-686N$

normal: $+476N$



If two forces act in opposite directions on a 10 kg object, one 75 N and the other 60 N, then what will be the acceleration of the object?

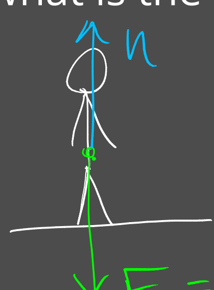
$F_{NET} = m \cdot a$

$75N + (-60N) = 15N$

$\frac{F_{NET}}{m} = a$

$\frac{15N}{10kg} = 1.5 m/s^2$

If a 70 kg person accelerates downward in an elevator at 1.5 m/s^2 then what is the force of the floor on the person's feet (normal force)?



$F_g = 70kg \cdot 9.8 m/s^2 = 686N$

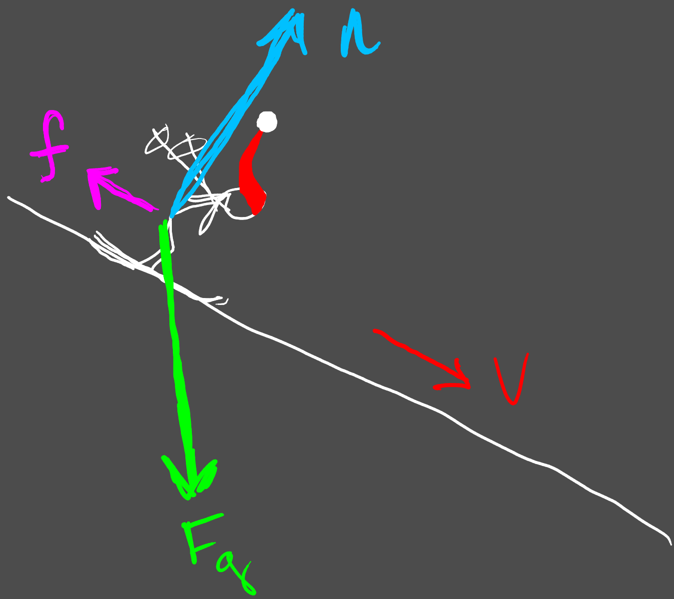
$F_{NET} = ma = 70kg \cdot 1.5 m/s^2$

$+686N + n = 105 N$

$-686N \qquad -686$

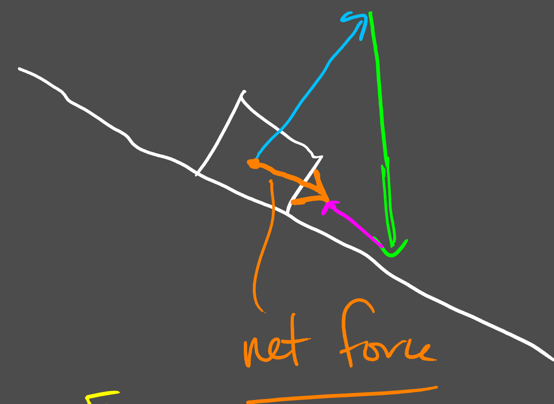
$n = -581 N$

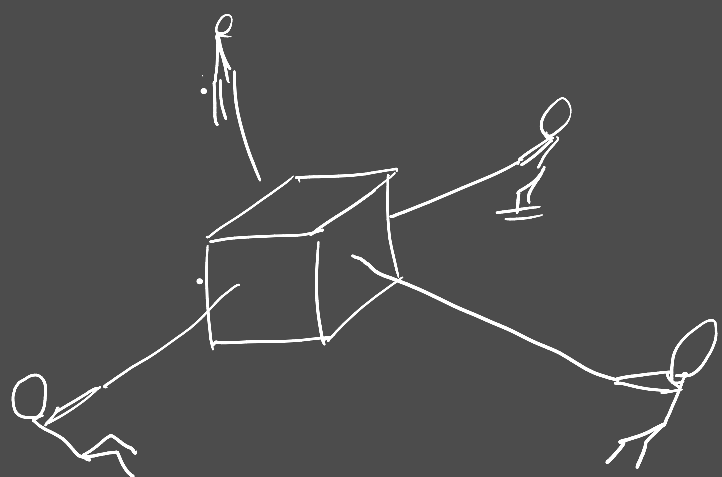
- forces in two dimensions

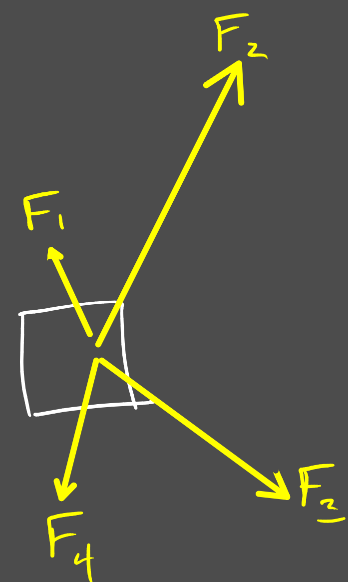


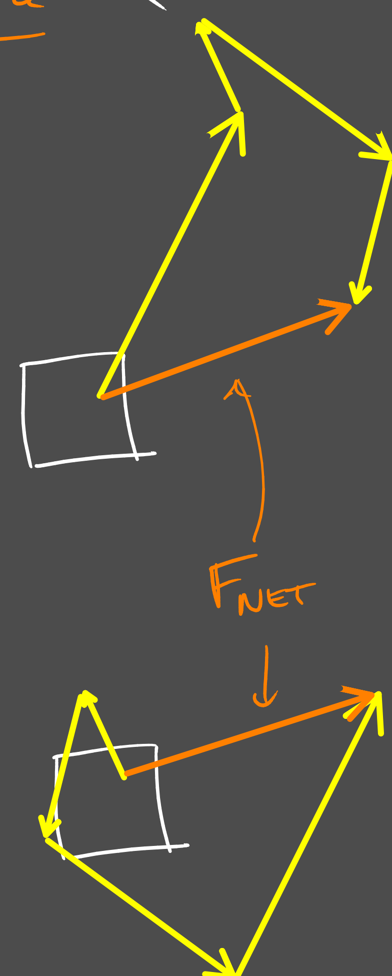
tail-to-head graphical method

↳ adding vectors



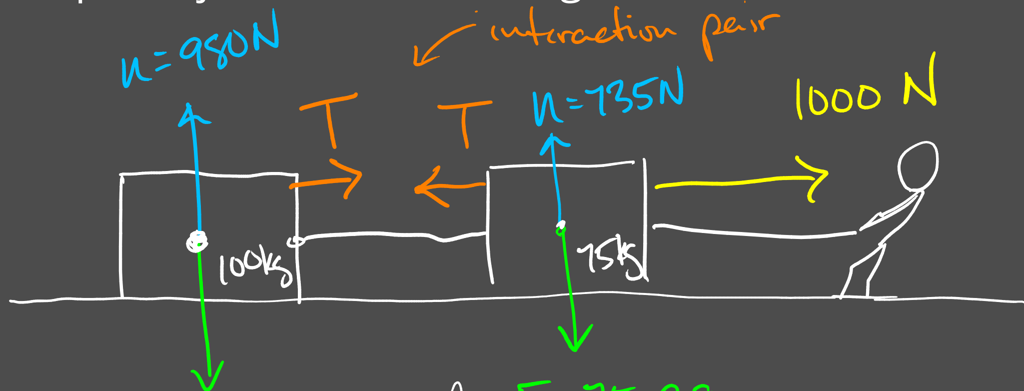






- length of the arrow is proportioned to magnitude of the force
- direction is direction

- Multiple objects connected together



$F_g = 100 \cdot 9.8$

$F_g = 980N$

$F_g = 75 \cdot 9.8$

$F_g = 735N$

$\underline{a = 5.7\ m/s^2}$ → applies to both objects

$T = ?$

$F_{NET} = 100kg \cdot 5.7\ m/s^2$

$\boxed{F_{NET} = 570N = T}$

$F_{NET} = 75kg \cdot 5.7\ m/s^2$

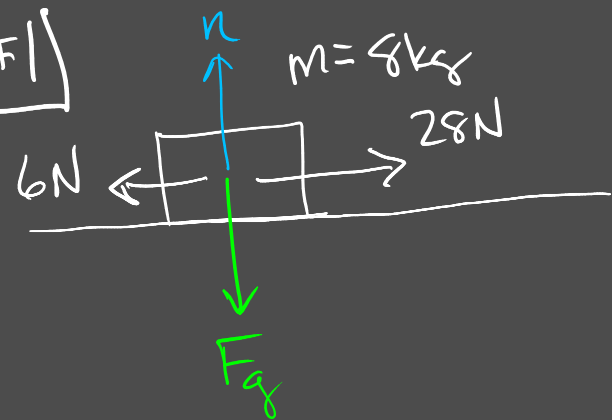
$\boxed{F_{NET} = 427N}$

$F_{NET} = 427N = 1000N + (-570N)$

$430N \approx 430N$

Synthesis Problems:

#1)



a. $F_{NET} = 28N - 6N = 22N$

$F_{NET} = ma$

$22N = 8kg \cdot a$

$a = \frac{22N}{8kg} = \boxed{2.75 \, m/s = a}$

b. $v_f = v_i + at$

$v_f = 0 \, m/s + 2.75 \, m/s^2 \cdot 3s$

$\boxed{v_f = 8.25 \, m/s}$

c. $\Delta x = \cancel{v_i t}^{\,0} + \frac{1}{2}at^2$

$\Delta x = \frac{1}{2}(2.75 \, m/s^2)(3s)^2$

$\boxed{\Delta x = 12.4 \, m}$

#2)

a. $a = \frac{v_f - v_i}{t} = \frac{9 \, m/s - 1 \, m/s}{2s} = \frac{8 \, m/s}{2s} = \boxed{4 \, m/s^2 = a}$

b. $F_{NET} = m \cdot a$

$F_{NET} = 40kg \cdot 4 \, m/s^2$

$\boxed{F_{NET} = 160 \, N}$

c. sum of forces = F_{NET}

$$+350N + f = 160N$$

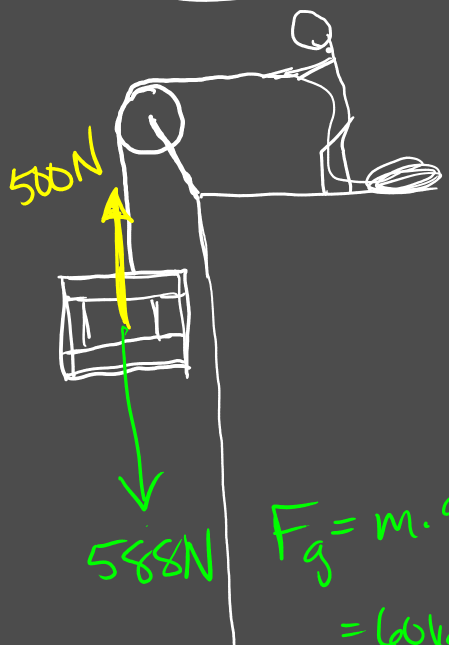
$$\boxed{f = -190N}$$

d. $F_{string} + f = 0 \leftarrow F_{NET}$

$$F_{string} - 190N = 0$$

$$\boxed{F_{string} = 190N}$$

#4



$$F_g = m \cdot 9.8\,m/s^2$$
$$= 60kg \cdot 9.8\,m/s$$
$$= 588N$$

a. F_{NET}?

a?

b. $F_{NET} = 88N = m \cdot a$

$$88N = 60kg \cdot a$$

$$a = 1.47\,m/s^2$$

↑ down

c. $\Delta y = \cancel{v_i}^{\,0} t + \frac{1}{2} a t^2$

$$\Delta y = \frac{1}{2} a t^2$$

$$1.4m = \frac{1}{2} \cdot 1.47\,m/s^2 \cdot t^2$$

$$2.8m = 1.47\,m/s^2 \cdot t^2$$

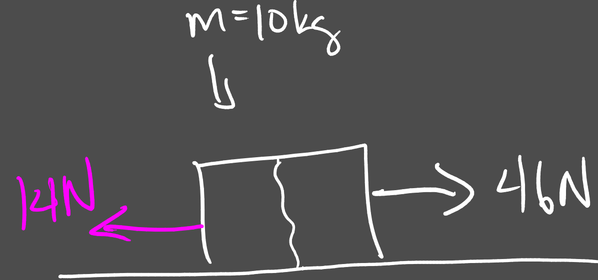
$$\sqrt{1.9s^2} = \sqrt{t^2}$$

$$\boxed{t = 1.38s}$$

d. $v_f = \cancel{v_i}^{\,0} + at$

$$v_f = 1.47\,m/s^2 \cdot 1.38s$$

$$v_f = 2.03\,m/s$$



a. $F_{NET} = 46N - 6N - 8N$

$= 32N$

b. $F_{NET} = m \cdot a$

$32N = 10kg \cdot a$

$\boxed{a = 3.2\,m/s^2}$

c. $F_{NET,\,3kg} = m_{3kg} \cdot a$

$= 3kg \cdot 3.2\,m/s^2$

$F_{NET,\,3kg} = 9.6N = T - 6N$

$T = 9.6N + 6N$

$\boxed{T = 15.6N}$

c. $F_{NET,\,7kg} = 46N - 8N - 15.6N = 22.4N$

$22.4N = m \cdot a$

$22.4N = 7kg \cdot a$

$\boxed{a = 3.2\,m/s^2}$

#6

a. $F_g = m \cdot g$

$= 85\,kg \cdot 9.8\,m/s^2$

$\underline{F_g = 833\,N}$

weight

b. $F_{NET} = m \cdot a$

$= 85\,kg \cdot (-1.3\,m/s^2)$

$F_{NET} = -110.5\,N$

c $n + F_g = F_{NET}$

$n - 833\,N = -110.5\,N$

$\boxed{n = 722.5\,N}$