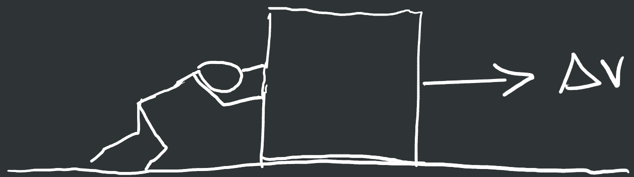
# Forces - the cause of change in motion

- push or pull ~ they are the same
- attempt to change the velocity
- combines with other forces acting on the same object at the same time.



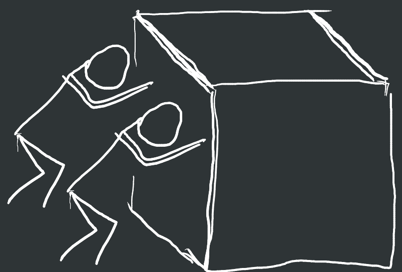

The amount of velocity change depends on:

$$\frac{\Delta v}{time} = \frac{Force \cdot time}{time} \cdot \frac{1}{mass}$$

$$a = \frac{Force}{mass} \rightarrow \boxed{\cancel{Force = m \times a}}$$

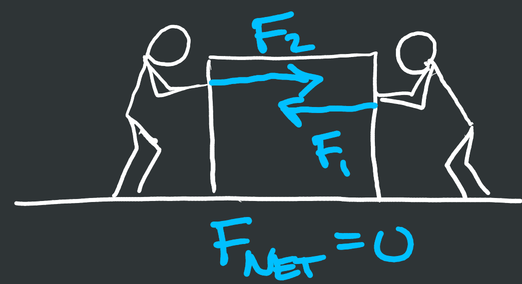
$$F_{NET} = m \cdot a$$

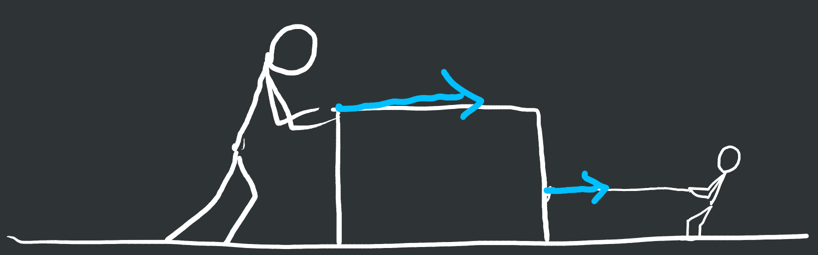
## How do multiple forces work?




2 standard pushes work together to double the force.

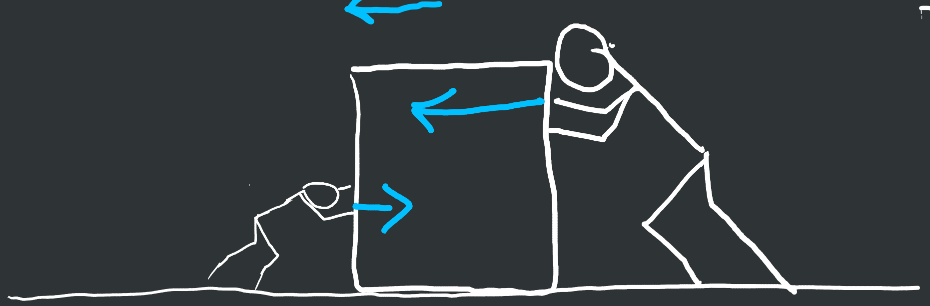
2 standard pushes cancel each other for no force.





1 standard push and 0.5 standard pull = 1.5 pushes

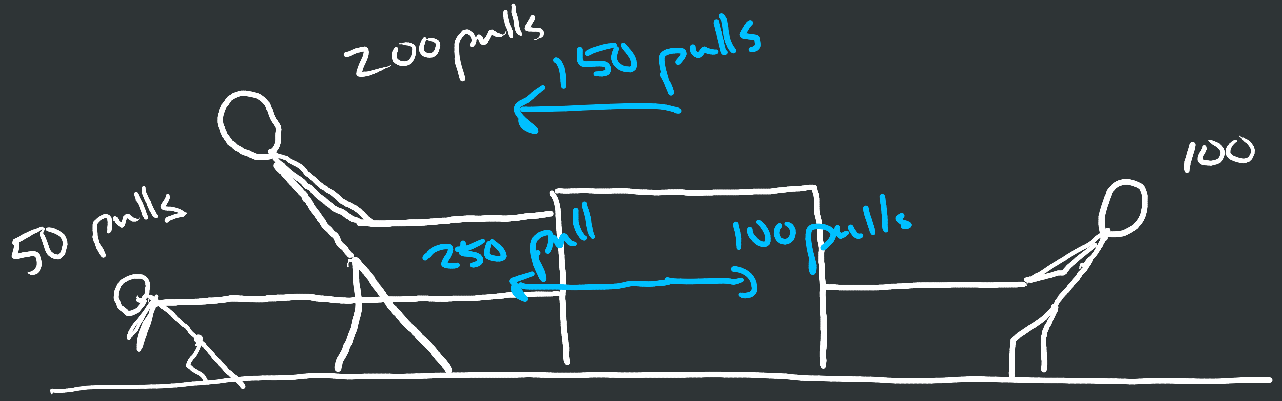
$F_{NET} = 0.7$ left



1 standard push

and 0.3 standard push

0.7 standard push <u>LEFT</u>




$\rightarrow +x$

$F_{NET} = +100 + (-50) + (-200)$

$= -150$

direction

magnitude

Newton's 1st Law - what happens when no 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 speed. (constant velocity)

Newton's 2nd Law - law of motion
* Net force is the cause of acceleration
* Net force = mass * acceleration

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

Types of forces

Fundamental Forces

1. Gravitational Force
2. Electromagnetic Force
3. Weak Force
4. Strong Force

Conventional Forces

1. Weight -> directly proportional to mass

$F_g = \text{Weight} = \text{mass} \times 9.8\, m/s^2$

2. Push/Pull
3. Tension - force through a rope
4. Friction - directed parallel to surface - opposite direction to velocity
5. Normal force - perpendicular to the surface
6. Spring Force

LAB: Measuring forces – we want to reliably measure a push/pull

↳ units  1 standard push = 1 Newton = $m \cdot a = 1\,kg \cdot 1\,m/s^2 = 1$ Newton

↓

→ 1st way – measure the force's effects

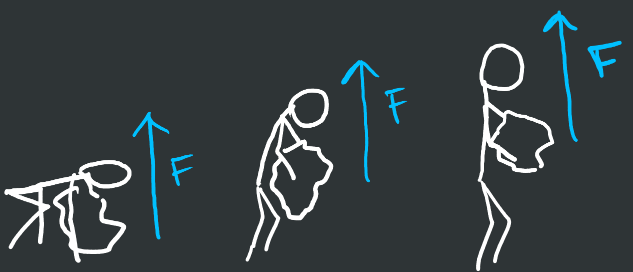
$\Delta V,\ t,\ m \rightarrow F_{NET}$

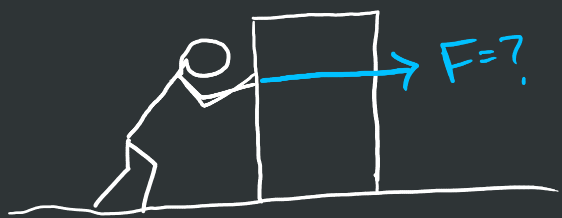
↳ make this the only force

→ 2nd way – compare all push/pulls to weight → mass

– consistent amounts of mass produce consistent forces

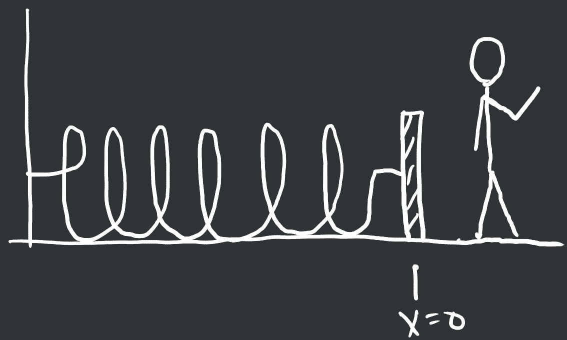
– not convenient or easily variable

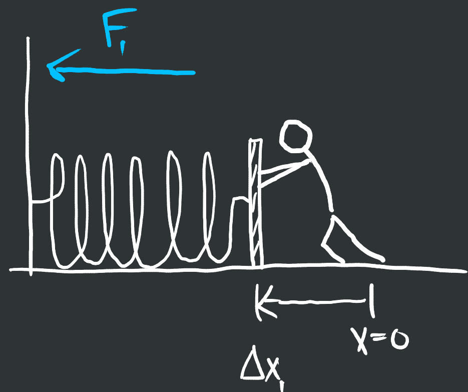


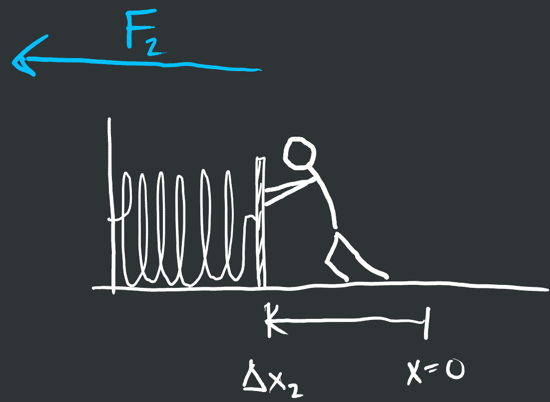
→ 3rd way → measure its effect on a spring!

- portable
- need to calibrate spring




measuring the distance lets us measure the force




$$\rightarrow \frac{F_1}{\Delta x_1} = \frac{F_2}{\Delta x_2} = \frac{F_3}{\Delta x_3} = k$$

spring constant

[Newton's / meter]

# Examples to get started:

$F = 500\,N$ $\rightarrow$


$F_{NET} = m \cdot a$

$500\,N = 100\,kg \cdot a$

$a = 5\,m/s^2$

$500N - 100N = \underline{400N}$

$\downarrow$

$F_{NET} = m \cdot a$

$\frac{400N}{100kg} = a = 4\,m/s^2$

$F = 500\,N$ $\rightarrow$

$\rightarrow +x$


$\leftarrow$ friction = 100N

$F_{NET} = -400N$ $\leftarrow$

$\rightarrow +x$

$F_{NET} = +500N + (-50N) + (-100N)$

$F_{NET} = 350N$

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

$\frac{350N}{100kg} = a = 3.5\,m/s^2$

$F = 500\,N$ $\rightarrow$

$\leftarrow F = 50N$


$\leftarrow$ friction = 100N

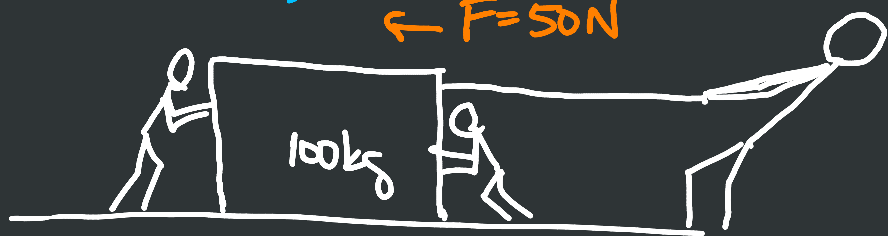
tension

$\rightarrow$ 600N

$F = 500\,N$ $\rightarrow$

$a = ?$

$\leftarrow F = 50N$

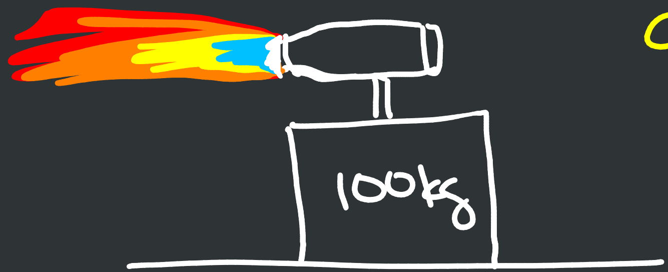



$\leftarrow$ friction = 100N

$+500 + 600N + (-50) + (-100) = 950N = 100kg \cdot a$

$a = 9.5\,m/s^2$

$\rightarrow F = ?$



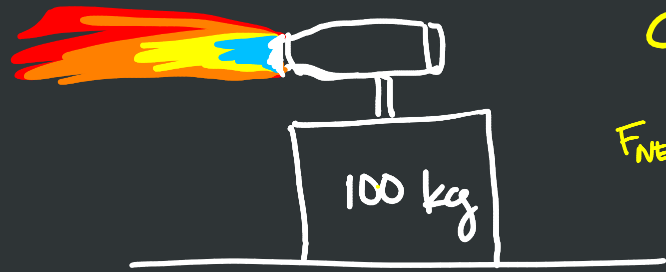
$a = 20\,m/s^2$

$F_{NET} = 100\,kg \cdot 20\,m/s^2$

$F_{NET} = 2000\,N$

$F = 2000\,N$

$\rightarrow F = ?$



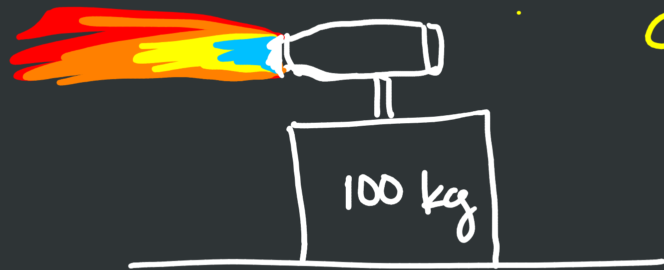
$a = 20\,m/s^2$

$F_{NET} = 2000\,N$

$\leftarrow$ friction $= 100\,N$

$F + \underset{+100\,N}{(\cancel{-100\,N})} = F_{NET} = \underset{+100\,N}{2000\,N} \rightsquigarrow F = 2100\,N$

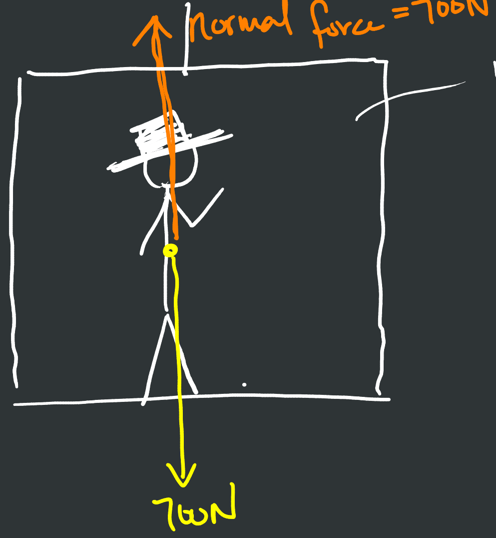
$\rightarrow F = ?$



$a = 0\,m/s^2$

$\leftarrow$ friction $= 20{,}000\,N$

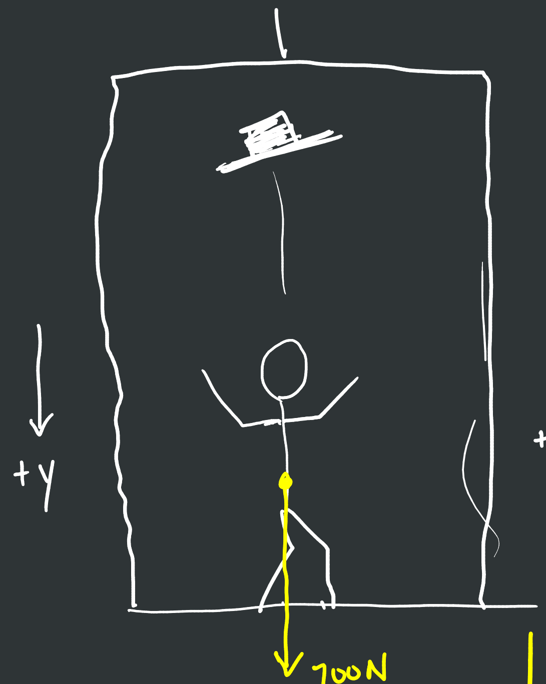
# Vertical Forces/Motion:




mass = 70 kg

$\text{Weight} = 70\,kg \cdot 10\,m/s^2 = 700\,N$

$a = 0$




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

$F_{NET} = +140\,N$

$\cancel{+700N} + F = +140N$

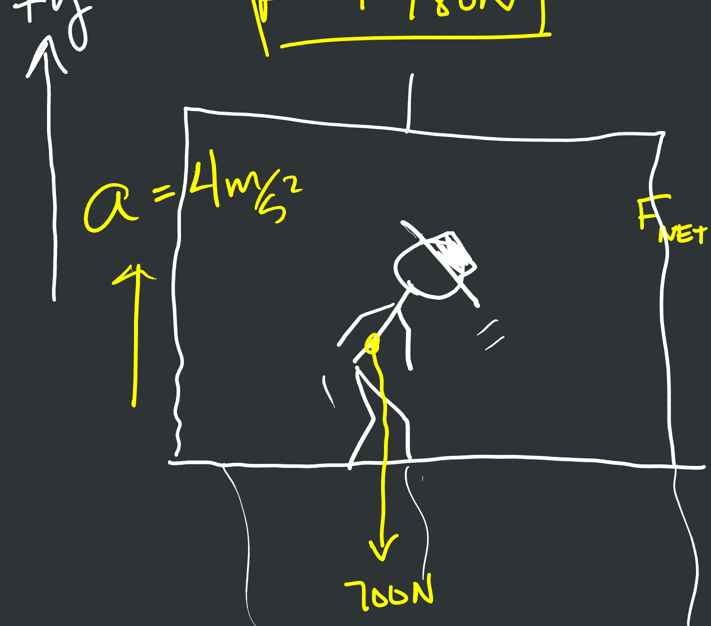
$-700 \qquad\qquad -700$

$\boxed{F = -560N}$ normal force

$\downarrow a = 2.0\,m/s^2$

$-700N + F = +280N$

$\boxed{F = +980N}$




$F_{NET} = 70\,kg \cdot \overset{a}{4}\,m/s^2$

$= 280\,N$

Recall Problem: If two forces act in opposite direction on a 10 kg object, on 75 N and the other 60N, then what will be the magnitude of the acceleration?

$$F_{NET} = 75N + (-60N) = \underline{\underline{15N}}$$

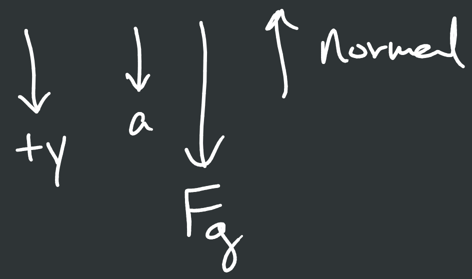
$$F_{NET} = m \cdot a$$

$$15N = 10\,kg \cdot a$$

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

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)?

$$F_{NET} = F_g - \text{normal}$$



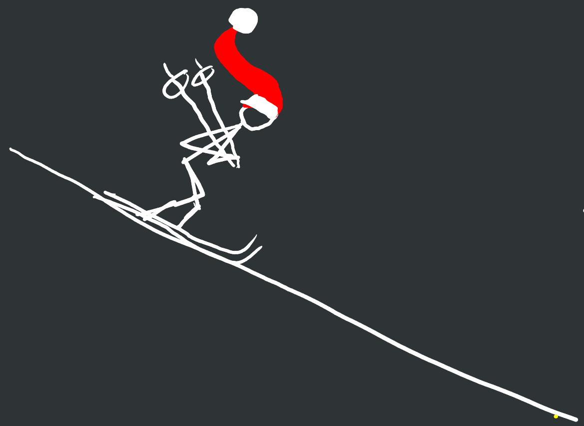

$$F_{NET} = 70kg(10\,m/s^2) - \underline{\underline{\text{normal}}}$$

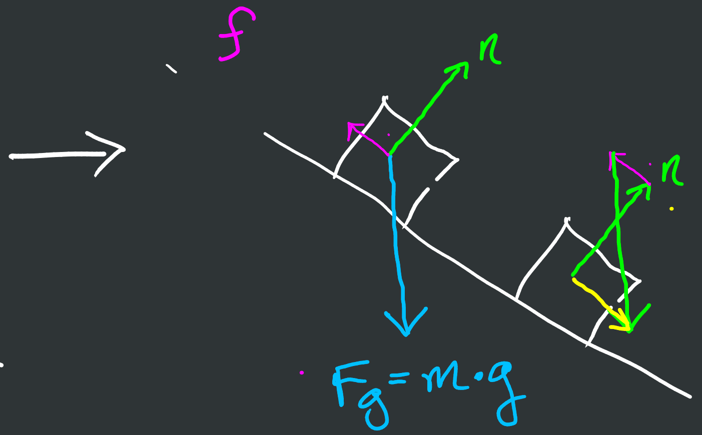
$$70kg \cdot 1.5\,m/s^2 = 70 \cdot 10 - n$$

$$105N = 700N - n$$

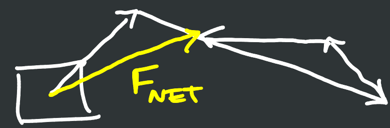
$$n = 700N - 105N = 595N$$

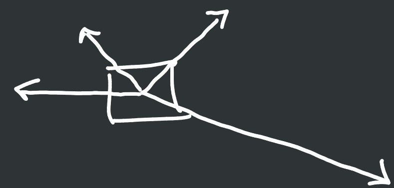
# Forces in two dimensions:

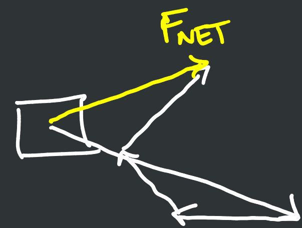




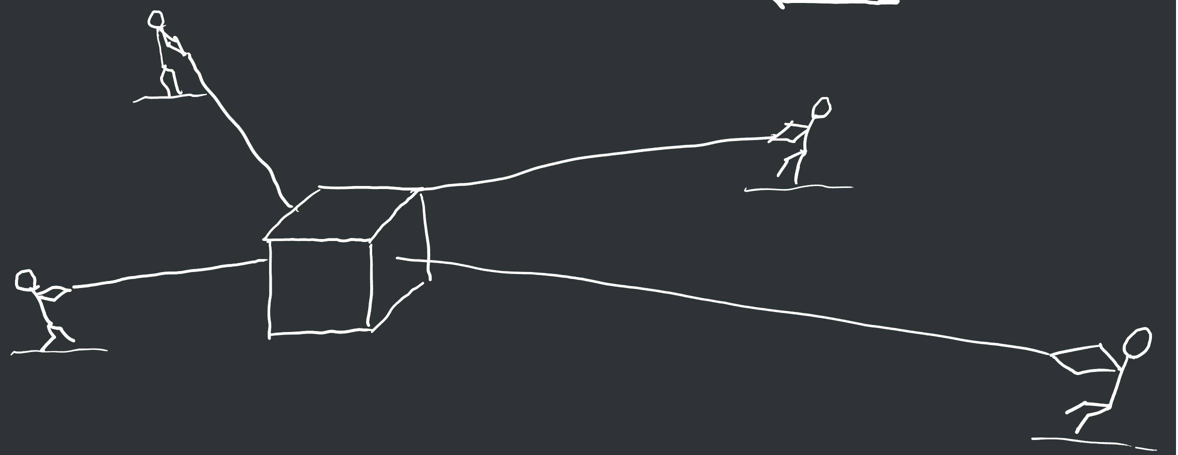

same types of forces as before, but we need to think with vectors.



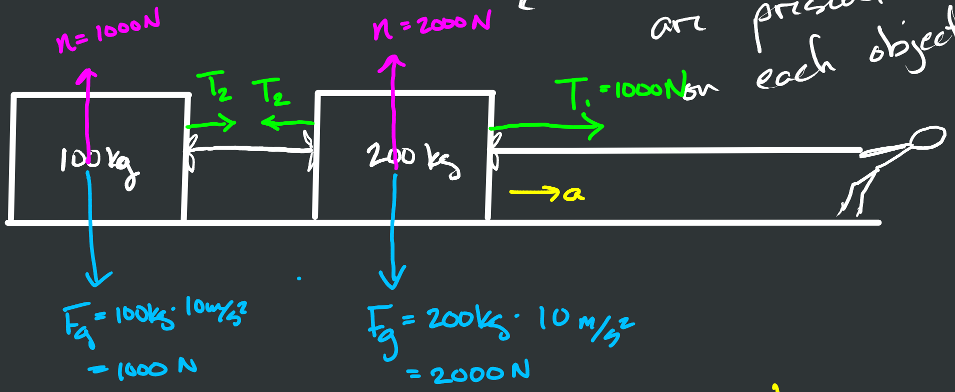



Adding vectors in two dimensions: stack arrows "tail-to-head" to get net force, which is the sum of the forces



# Multiple objects:

what forces are present on each object?




$$1000\,N = (200\,kg + 100\,kg)\cdot a$$

$$\frac{1000\,N}{300\,kg} = a = 3.3\ m/s$$

acceleration of both boxes

rounding error

**200 kg box**

$$F_{NET} = 200\,kg \cdot 3.3\,m/s^2 = 660\,N$$

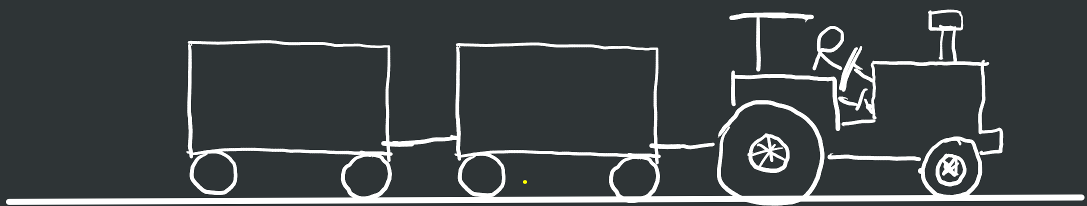
$$660\,N = 1000\,N - T_2$$

$$\boxed{T_2 = 340\,N}$$

**100 kg box**

$$F_{NET} = 340\,N = 100\,kg \cdot a$$

$$a = 3.4\,m/s^2$$



synthesis problems:

1.


a. acceleration = ?

$+30N + (-5N) = F_{NET} = m \cdot a$

$25N = 5kg \cdot a$

$a = 5\,m/s^2$

b. $v_f = v_i + a \cdot t$

$v_f = 0\,m/s + 5\,m/s^2 (3s)$

$v_f = 15\,m/s$

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

$\Delta x = \frac{1}{2} (5\,m/s^2)(3s)^2$

$\underline{\Delta x = 22.5\,m}$

2. a. $a = \frac{\Delta v}{t}$ , $v_f = v_i + a \cdot t$

same equation

$a = \frac{7\,m/s - 1\,m/s}{2s} = \underline{3\,m/s^2}$

b. $F_{NET} = 50kg \cdot 3\,m/s^2$

$= 150N$

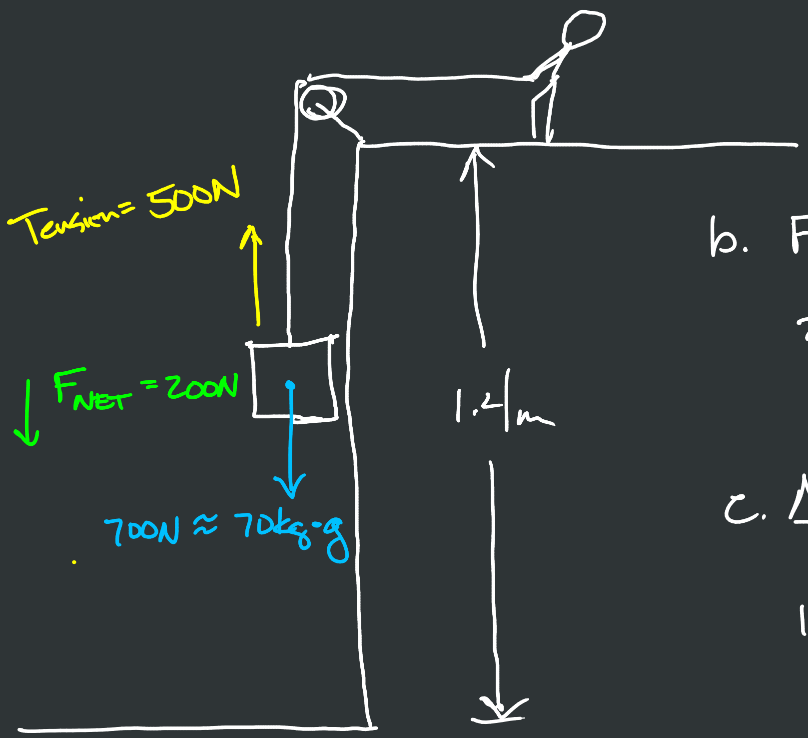
c.


$F_{NET} = F + f$

$150N = +280N - f$

$f = 130N$

d. +130N




b. $F_{NET} = ma$

$200N = 70kg \cdot a$

$a = 2.9 \, m/s^2$

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

$1.4m = \frac{1}{2}(2.9 \, m/s^2)\, t^2$

$.9655 s^2 = t^2$

$\underline{t = 0.98 \, s}$

d. $v_f = (2.9 \, m/s^2)(0.98 \, s)$

$v_f \approx 2.9 \, m/s$

6.

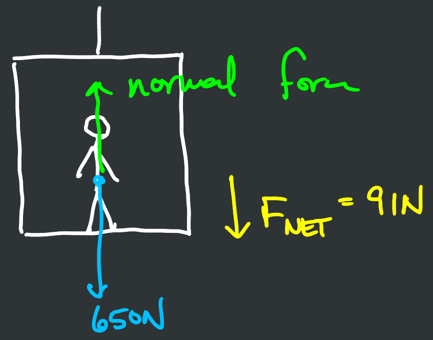
a. $F_g = 65\text{kg} \cdot g \approx 650\text{ N}$

b. $F_{NET} = 65\text{kg} \cdot 1.4\text{m/s}^2 = 91\text{ N}$

c. $F_{NET} = 91\text{N} = +650\text{N} - n$

$$n = 650 - 91$$

$$n = 559\text{ N}$$

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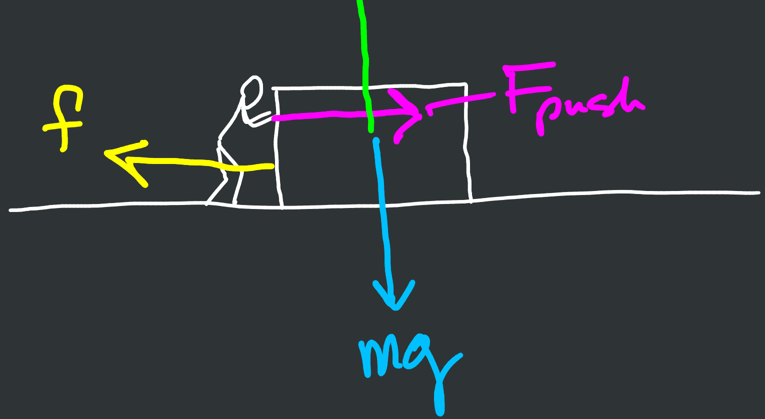
$\Delta v = 0 \leftarrow$ constant velocity




$$\left.\begin{aligned} n &= F_g \\ F_{push} &= f \end{aligned}\right\} \text{ b/c } \Delta v = 0 \rightarrow a = 0 \rightarrow F_{NET} = 0$$

$$100\text{N} = 1\text{kg} \cdot a$$

$$a = 100\text{ m/s}^2$$

$$100\text{N} = 100\text{kg} \cdot a$$

$$a = 1\text{ m/s}$$