After this, you can
- discuss Newton's first law and how it applies to physical problems
- differentiate between situations where Newton's first law does and does not apply

Newton's First Law
- Law of Inertia
- Law of Equilibrium

- An object at rest tends to remain at rest and an object in motion continues in motion unless an external force acts on it
- An object at rest has a net force of zero. An object moving with constant speed in a straight line also has net force of zero.

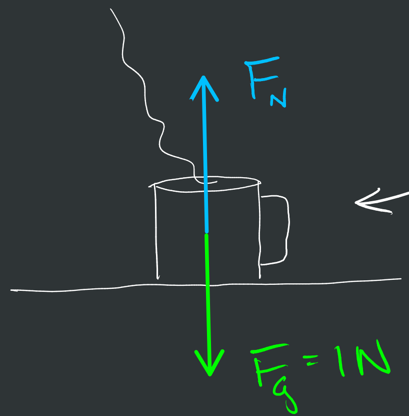
Net Force - vector sum of the individual forces on an object

$$\vec{F}_{NET} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \ldots = \sum \vec{F}_n$$

$$\hookrightarrow \left.\begin{aligned} F_{NET,x} &= F_{1x} + F_{2x} + F_{3x} + \ldots \\ F_{NET,y} &= F_{1y} + F_{2y} + F_{3y} + \ldots \end{aligned}\right\}$$

the subsequent motion of an object depends on the net force (magnitude and direction)

$-$ If $\vec{F}_{NET} = 0$, $\begin{cases} \text{continues to be motionless} \\ \text{or} \\ \text{continues in motion} \begin{cases} \text{same speed} \\ \text{same direction} \end{cases} \end{cases}$

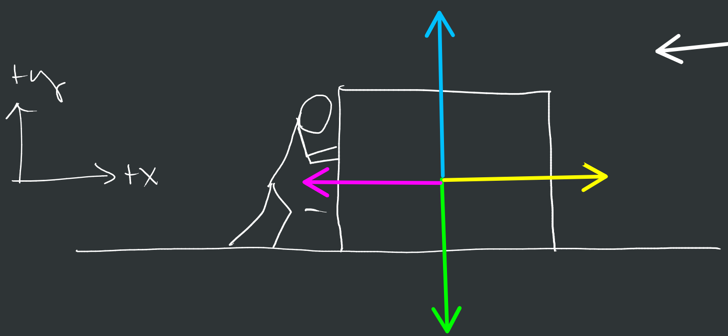



"observe" no motion

$\therefore \vec{F}_{NET} = 0$

$F_N + (-1N) = 0$

$F_N = +1N$




constant motion
- constant speed
- straight path

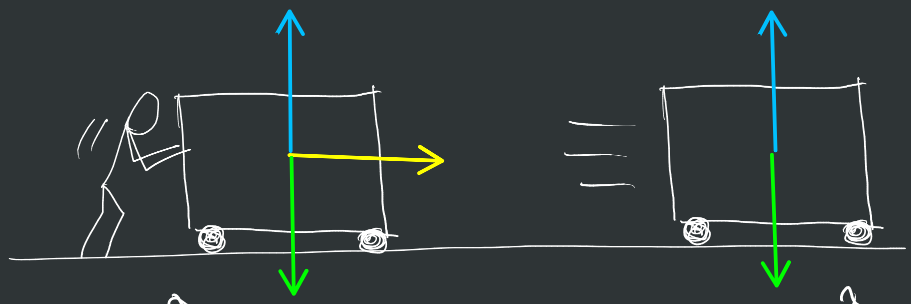
$\vec{F}_{NET} = 0$

$\hookrightarrow F_{NET,x} = 0 = +F_A + (-F_f)$

$\hookrightarrow F_{NET,y} = 0 = F_N + (-F_g)$

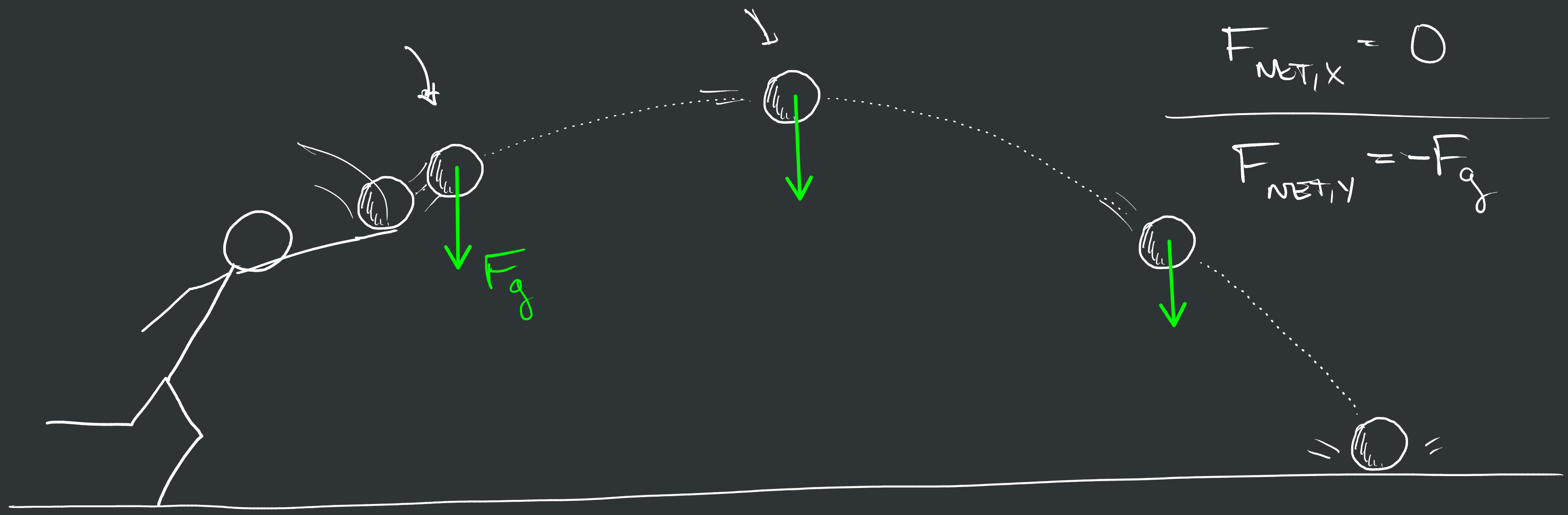
- If $\vec{F}_{NET} \neq 0 \longrightarrow$ Newton's 2nd Law

  - object w/ speed up or slow down
  - path will curve



while I push
- speed up
- net force +x direction

after I stop pushing
- constant speed
- $\vec{F}_{NET} = 0$




$F_{NET,x} = 0$

$F_{NET,y} = -F_g$

$\vec{F}_{NET}$ while
I am throwing

# Gravitational Force

mass of object being pulled

$$F_g = m_1 \cdot \vec{g}$$

← gravitational field strength produced by the object doing the pulling

$$[N] = [kg] \cdot \left[\frac{N}{kg}\right]$$

$$g = \frac{G \cdot m_0}{r^2} \qquad \left[\frac{N}{kg}\right]$$

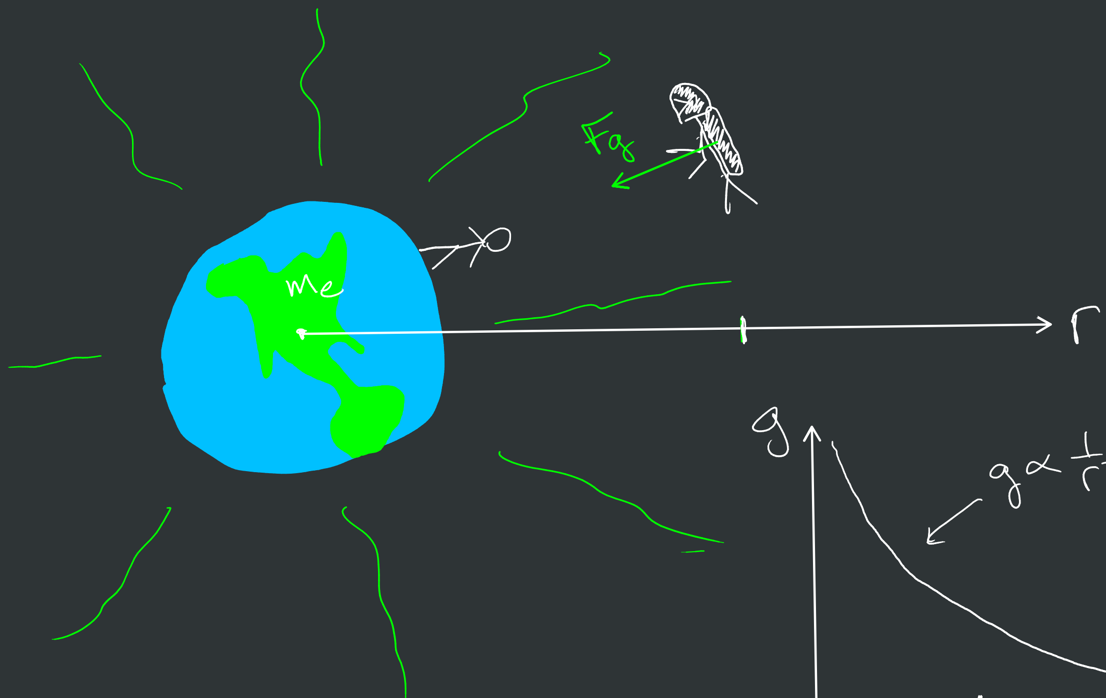
mass doing the pulling

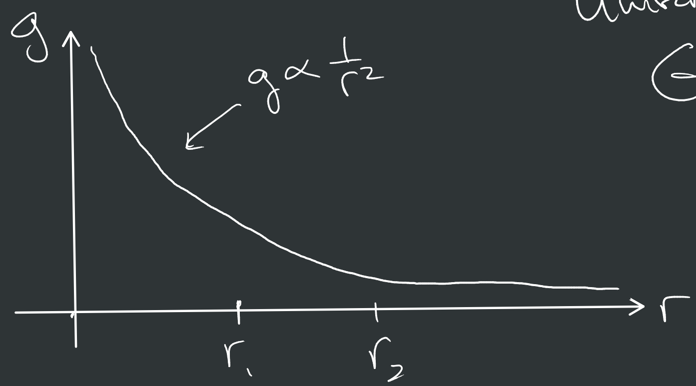
distance from the object doing the pulling

constant of proportionality

Universal Gravitational Constant

$$G = 6.67 \cdot 10^{-11} \frac{N m^2}{kg^2}$$




$$\frac{g_2}{g_1} = \left(\frac{r_2}{r_1}\right)^{-2}$$

$$\frac{g_2}{g_1} = \left(\frac{r_1}{r_2}\right)^2 = \left(\frac{1}{2}\right)^2$$

$$\frac{g_2}{g_1} = \frac{1}{4}$$

$M_e = 5.972 \cdot 10^{24}\ kg$

$r_e = 6.37 \cdot 10^{6}\ m$

$$g(\text{surface of the earth}) = \frac{6.67 \cdot 10^{-11}\ \frac{Nm^2}{kg^2} \cdot 5.972 \cdot 10^{24}\ kg}{(6.37 \cdot 10^{6}\ m)^2}$$

$$\longrightarrow \underline{g = 9.82}\ \frac{N}{kg}$$

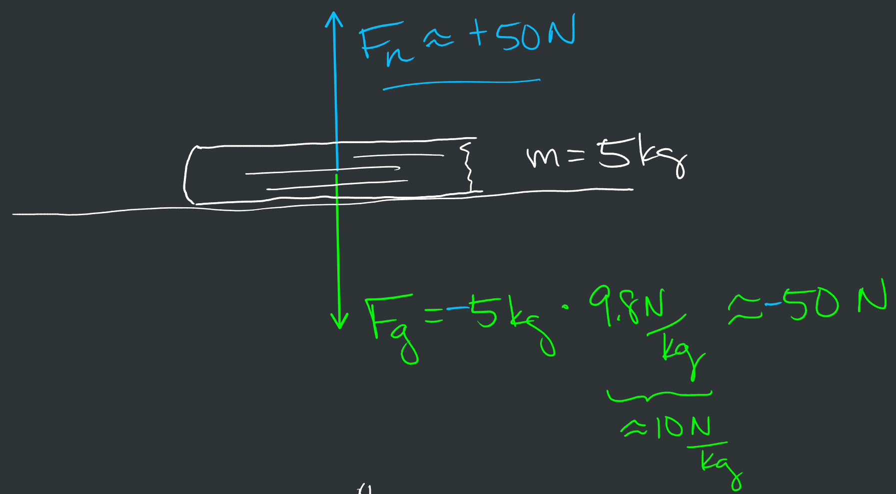
So what is my weight?

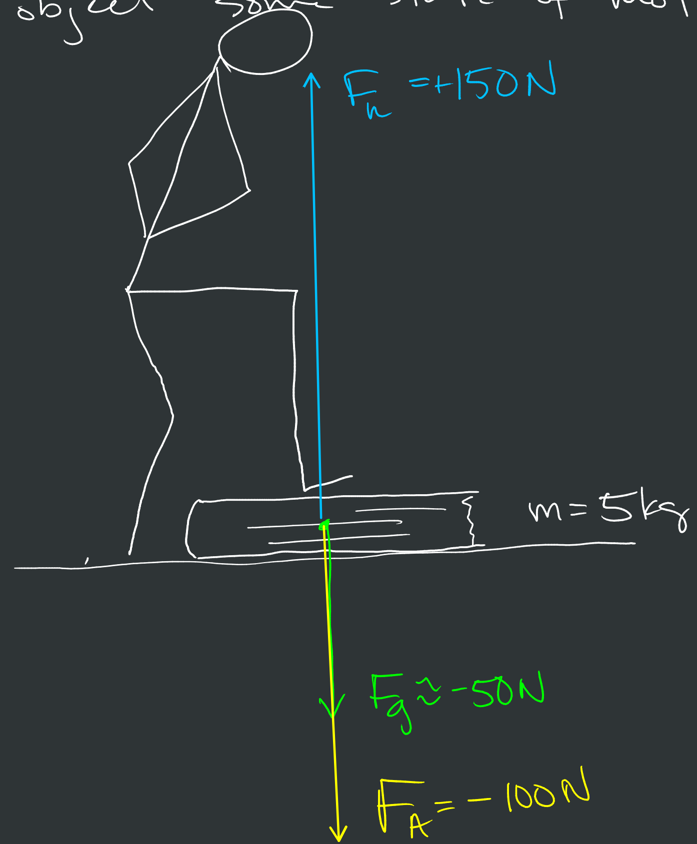
$m = 75\ kg$

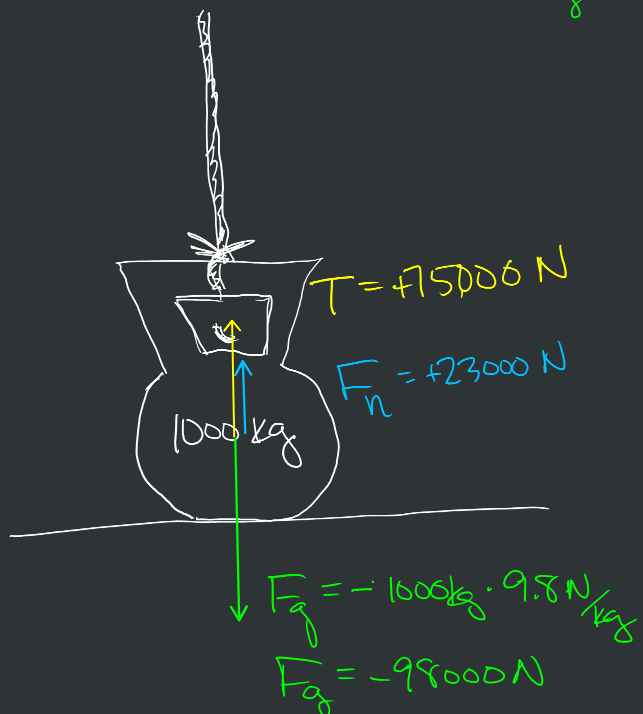
$F_g = 75\ kg \cdot 9.8\ \frac{N}{kg} = 735\ N$

# Normal Force

↳ force of constraint - can react by increasing or decreasing to give an object some state of motion




$$F_{NET} = 0 = +75000\,N + F_n - 98000\,N$$

$-75000 \qquad +98000$

$$F_n = 23{,}000\,N$$

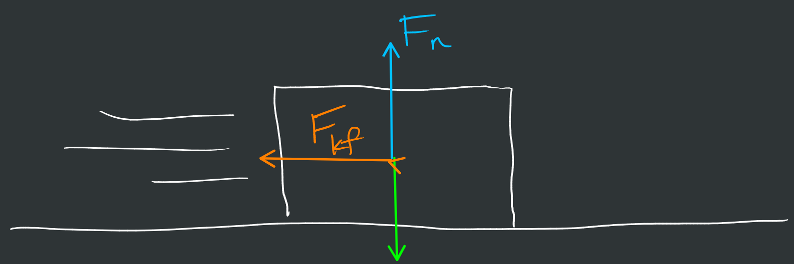
# Friction

## Kinetic friction

- object is sliding along a surface
- constant no matter how fast the object is sliding
- always points in the opposite direction to motion
- directly proportional to normal force

$$F_{kf} = \mu_K \cdot F_n \longrightarrow \mu_K = \frac{F_{kf}}{F_n}$$

"mu" (constant of prop.)
coefficient of kinetic friction



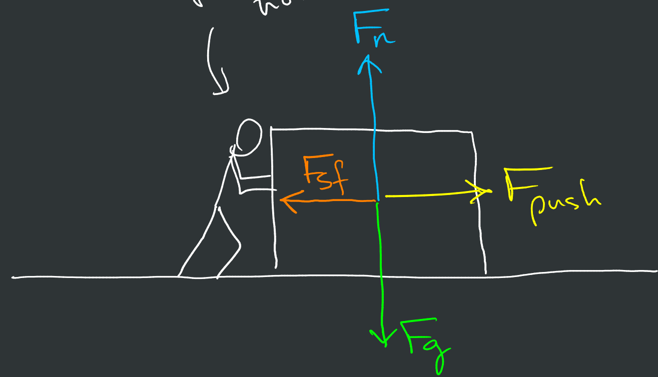

## Static friction

- object is motionless on surface
- points in the direction that prevents motion
- can be any value from zero up to some maximum value

$$F_{sf} \leq \mu_s \cdot F_n$$

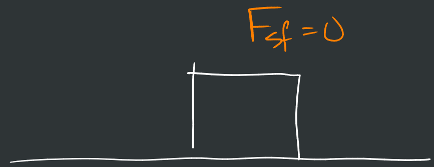
$$F_{sf,max} = \mu_s \cdot F_n$$

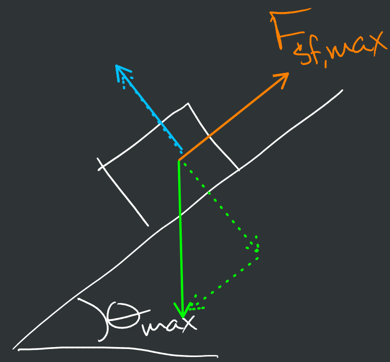
push but do not move

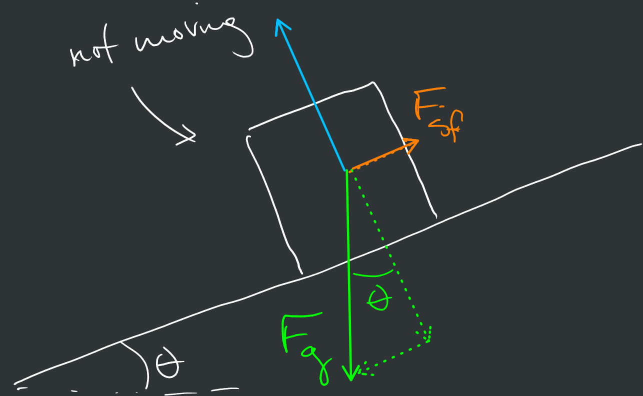


$\mu \rightarrow$ coefficient of friction

- experimental value
- different for each combination of materials in contact
- unitless
- $\mu_s > \mu_k$



After this you can:

- discuss Newton's 2nd Law and its applications
- differentiate between Newton's 1st and 2nd laws
- discuss the terms displacement, velocity and acceleration and their relationship

week 4

A net force causes an object with mass to accelerate. The acceleration of the mass is directly proportional to the net force and inversely proportional to the mass.

$$\rightarrow a \propto F_{NET}^{1} \cdot m^{-1}$$

$$a = F_{NET} \cdot m^{-1}$$

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

$$\boxed{\vec{F}_{NET} = m \cdot \vec{a}}$$

$$F_{NET,X} = m \cdot a_X$$

$$F_{NET,Y} = m \cdot a_Y$$

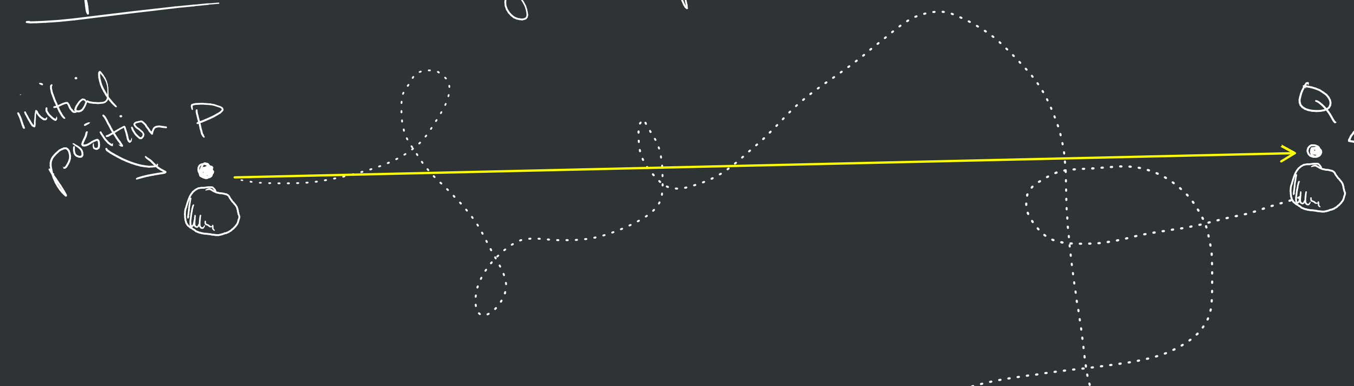
$$F_{NET} = m \cdot a$$

if $a = 0$

then what?

$F_{NET} = 0 \leftarrow$ Newton's 1st Law $(a = 0)$ $(F_{NET} = 0)$

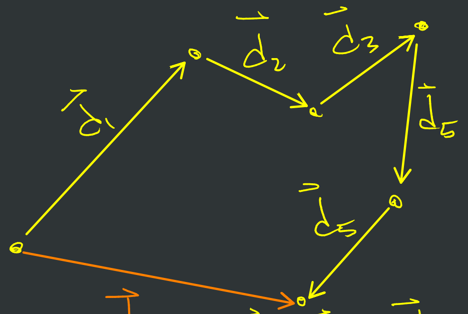
displacement → change in position




final position

← path or trajectory

distance - length of its path




$\vec{d}_{total} = \vec{d}_1 + \vec{d}_2 + \vec{d}_3 + \vec{d}_4 + \vec{d}_5$

$\Delta$ → change in

$\Delta x, \Delta y, \Delta \vec{r}$

$$\vec{V} = \frac{\text{displacement}}{\text{time}}$$

Velocity → ratio of displacement + time

→ rate of change of position

→ vector

- magnitude → speed
- direction

→ components

$$\vec{V} = \frac{\Delta \vec{r}}{t}$$

units

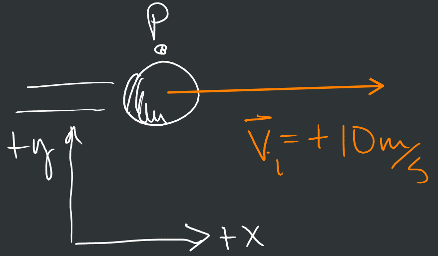
$\Delta r$ → meter

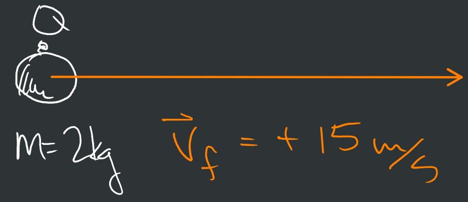
$t$ → seconds

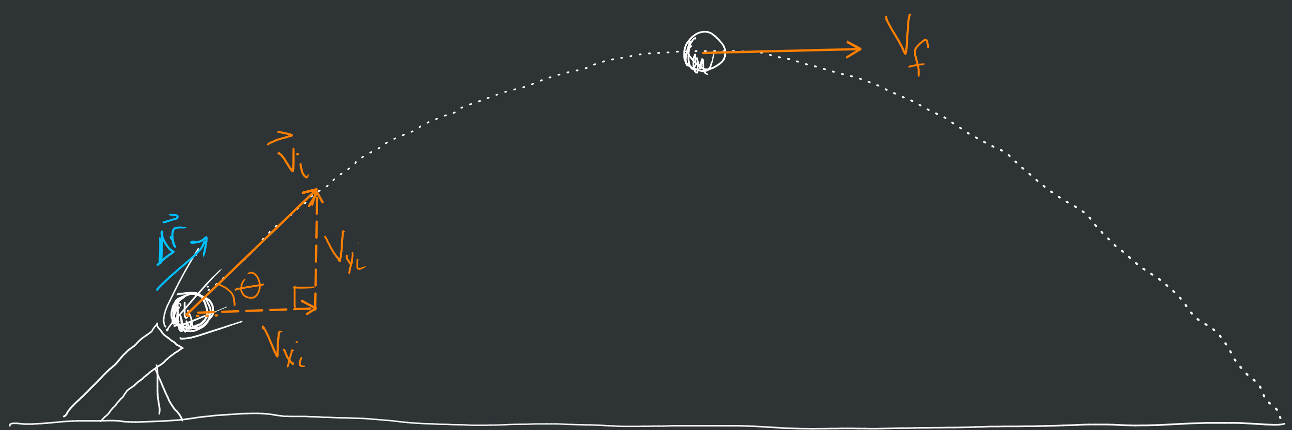
$V \rightarrow \left[\frac{m}{s}\right] \left[\frac{\text{miles}}{\text{hour}}\right]$

$\Delta x = x_f - x_i$

$\Delta y = y_f - y_i$




$\Delta V = 15\,m/s - 10\,m/s$

$\Delta V = 5\,m/s$

$t = 10\,s$

$a = \dfrac{5\,m/s}{10\,s} = 0.5\,m/s/s$

$\rightarrow a = 0.5\,\dfrac{m}{s^2}$

$F_{NET} = 2\,kg \cdot 0.5\,\dfrac{m}{s^2}$

$F_{NET} = 1\,\underbrace{\dfrac{kg\,m}{s^2}}_{= \text{Newton}}$

$F_{NET} = 1\,N$

acceleration $\rightarrow$ ratio of the change in velocity to the time it took to change

$$a = \frac{\text{change in velocity}}{\text{time}}$$

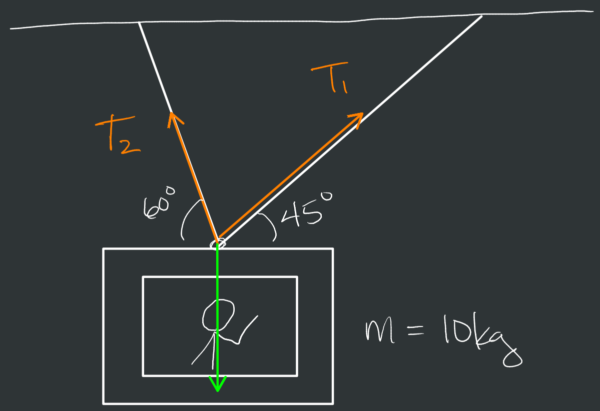
$$a = \frac{\Delta V}{t} = \frac{V_f - V_i}{t}$$

units

$\Delta V \rightarrow \left[\dfrac{m}{s}\right]$

$a \rightarrow \left[\dfrac{\frac{m}{s}}{s}\right] = \left[\dfrac{m}{s^2}\right]$

# Examples

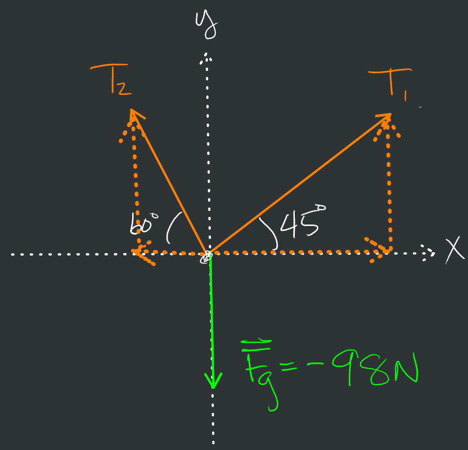



$m = 10\,kg$

$F_g = m \cdot g$

$= 10\,kg \cdot 9.8 \frac{N}{kg}$

$|F_g| = 98\,N$



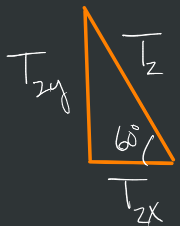

| | x | y |
|---|---|---|
| $T_1$: | $+0.71\,T_1$ | $+0.71\,T_1$ |
| $T_2$: | $-0.5\,T_2$ | $+0.866\,T_2$ |
| $F_g$: | $0$ | $-98\,N$ |
| $F_{NET}$: | $0\,N$ | $0\,N$ |

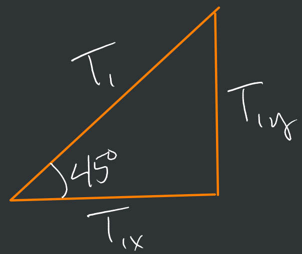
x-dir → $0.71\,T_1 - 0.5\,T_2 + 0 = 0$

y-dir → $0.71\,T_1 + 0.866\,T_2 - 98 = 0$

simultaneous equations

system of equations




substitution method

$\cos 60^\circ = \frac{T_{2x}}{T_2}$

$T_2 \underbrace{\cos 60^\circ}_{0.5} = T_{2x}$

$\boxed{0.5\,T_2 = T_{2x}}$

$\sin 60^\circ = \frac{T_{2y}}{T_2}$

$T_2 \underbrace{\sin 60^\circ}_{0.866} = T_{2y}$

$\boxed{0.866\,T_2 = T_{2y}}$

$T_{1x} = T_1 \cos 45^\circ$

$\boxed{T_{1x} = 0.71\,T_1}$

$T_{1y} = T_1 \sin 45^\circ$

$\boxed{T_{1y} = 0.71\,T_1}$

$0.71\,T_1 - \cancel{0.5\,T_2} \cancel{+0} = 0$ $\quad +0.5\,T_2 \quad +0.5\,T_2$

Solve for $T_1$

$\frac{\cancel{0.71}\,T_1}{\cancel{0.71}} = \frac{0.5\,T_2}{0.71}$

→ $T_1 = \boxed{0.704\,T_2}$

$0.71\,T_1 + 0.866\,T_2 - 98 = 0$

only one type of variable $\longrightarrow$ $\underbrace{0.71(0.704T_2)}$ $+ 0.866T_2 - 98 = 0$

$+98 \quad +98$

$$\underbrace{0.5T_2 + 0.866T_2} = 98$$

$$1.37T_2 = 98$$

$$T_2 = \frac{98}{1.37} = 71.5\text{ N}$$

$$\boxed{T_2 = 71.5\text{N}}$$

$$\boxed{T_1 = 0.704T_2}$$

$$T_1 = 0.704(71.5\text{N})$$

$$\boxed{T_1 = 50.4\text{N}}$$

# Vector Addition Lab Notes