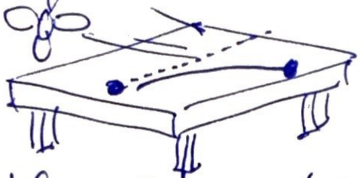
Chapter 4A Newtons Laws

Newton's Contributions:

- Calculus: the mathematic of change
- Optics: prisms showed that light is made up of colors
- Forces and Acc'ln
- Law of Gravity

⊛ 3 Laws

1. Objects moving in a straight line remain so unless acted up by a force.



2. The acc'ln of an object is proportional to the force applied and inversely proportinl to its mass.

$$a \propto F$$

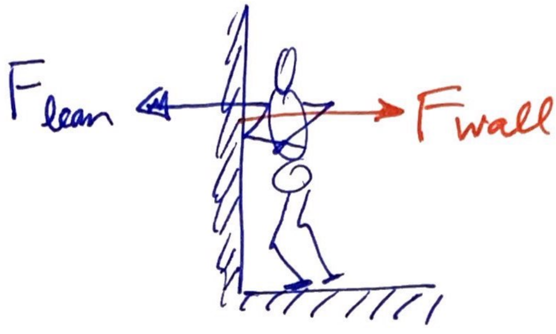
constant of proportionality

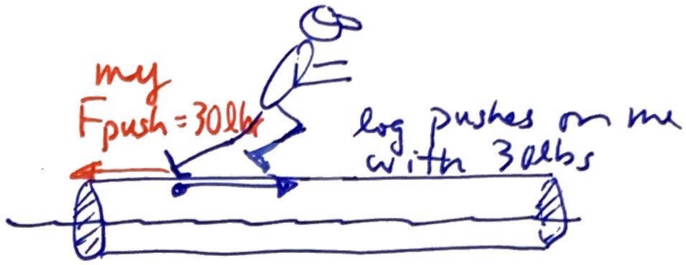
$$\left.\begin{array}{l} a = C\cdot F \\ a \propto \frac{1}{m} \end{array}\right\} \Rightarrow \boxed{a = \frac{F}{m}} \Rightarrow \boxed{F=ma}$$

{ the latter form tells us that the constant of proportionality is mass: "inertia"
A cargo ship has more inirtia than a yacht meaning its harder to stop. Or like a rail car vs. an automobil or a Cesna vs. 747 }

$\boxed{\text{Mass} \propto \text{the number of atoms}}$

$\boxed{3}$ A object experineing a force on it will react to that force in an equal and opposite direction.





"$\boxed{4}$" The force of one object under the influence of another is goverened by

$$\boxed{F = G\frac{M_1 M_2}{D_{12}^2}}$$

Force of Gravity

F $\propto$ product of the masses

F inv. $\propto$ to the seperation squared

{this law came into effect after Newton devised Law #1 but asked "why the planets do not travel in a straight line"}

EX

$M = 30\,kg$

$F = 10$ Newtons

$$\Rightarrow a = F/M = \frac{10\,N}{30\,kg} = \underline{\underline{0.33\ m/s^2}}$$

$[N] = (kg)\,m/s^2$

- units: kg = kilogram = 1000 gm

$1\,gm = 1\,cm^3$ of H_2O

↖ sugar cube

{one large apple is about 1 kg ?
mass of 1 liter of water}

EX your "weight" is about 70 kg. How many Newton's is that?

acc'ln due to gravity : $9.8\ m/s^2$

$$F = mg$$

your weight

your mass

US: 154 lbs

UK: 70kg

$$= (70\,kg)(9.8\ m/s^2)$$

$$= \underline{\underline{686\,N}}$$

- Convert to lbs:

$\boxed{0.225\,lbs = 1\,N}$

$\boxed{1\,lbs = 4.44822\,N}$

$$686\,\cancel{N}\left(\frac{1\,lb}{4.45\,\cancel{N}}\right)$$

$$= \boxed{154\,lbs}$$

⊛ In the USCS system mass is measured by "slugs"

$$\boxed{1 \text{ slg} = 14.59 \text{ kg}}$$

Q: How many slugs is my mass?

$$\boxed{g = 9.8 \, m/s^2 = 32 \, ft/s^2}$$

$$F = mg$$

$$m = F/g$$

$$m = \frac{185 \text{ lbs}}{32 \, ft/s^2}$$

$$\boxed{m = 5.78 \text{ slugs}}$$

- On the moon $g = \frac{9.8 \, m/s^2}{6} = 1.6 \, m/s^2, \; \frac{32 \, ft/s^2}{6} = 5.33$

Q: How much does the bathroom scale read when I step on it

$$F = mg$$

$$= (5.78 \text{ slgs})(5.33 \, ft/s^2)$$

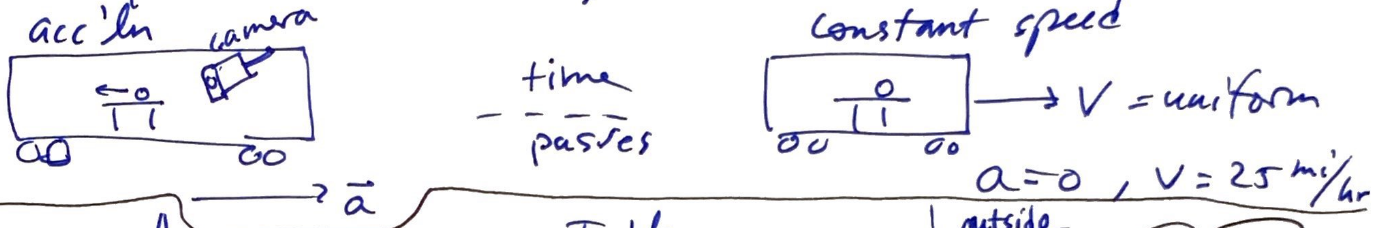
$$\boxed{F = 30.8 \text{ lbs}} \text{ vs } 185 \text{ lbs on Earth.}$$

Inertial Reference Frame

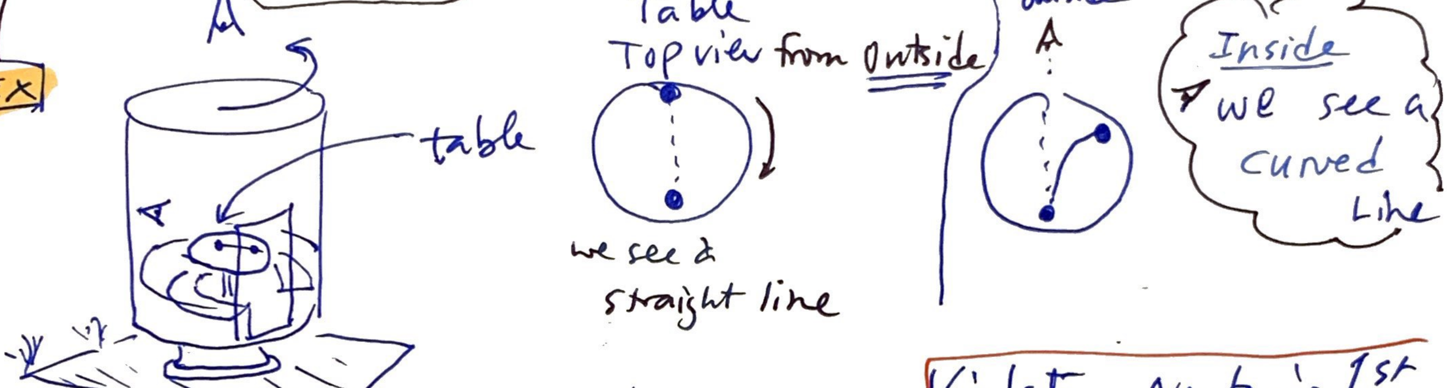
In any laboratory where $F = ma$ we call such an inertial frame

But if the Lab is on a rocket that is acc'l'n then $F \neq ma$ seen from within (not knowing you are acc'l'n)

Ex



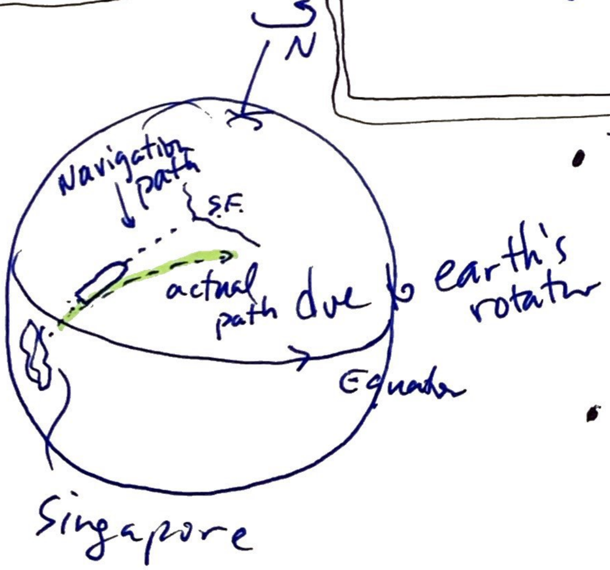
Ex



{try this on a merry-go-round}

Violates Newton's 1st Law so this is a non-inertial Frame

Ex



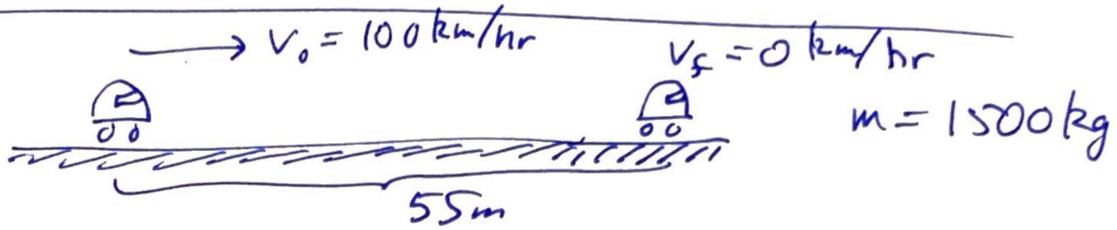
- The earth is a non-inertial reference frame
- However for most practical experiments we assume a inertial frame.

"Coriolis Force" = Fictitious force

A car of mass 1500 kg is decellerating from 100 km/hr to 0 km/hr. over a 55 m distance

Q: what is the direction and magnitude of the Braking forces

(i) Diagram:



(ii) Freebody diagram: $F_B \longleftarrow \overset{\text{car}}{\bullet}$

(iii) Laws or Equations : $\overset{\text{want}}{F} = m\overset{\text{need}}{a}$

$$a: \left.\begin{array}{l} V_f = 0 \\ V_0 = 100\,km/hr \\ d = 55\,m \\ a = \text{need} \end{array}\right\} \quad \boxed{V_f^2 = V_0^2 + 2a\Delta x}$$

uses no time

(iv) math

$$a = \frac{V_f^2 - V_0^2}{2\Delta x}$$

$$a = \frac{0^2 - \left[100\,km/hr\left(\frac{1\,hr}{3600\,s}\right)\left(\frac{1000\,m}{1\,km}\right)\right]^2}{2 \cdot 55\,m}$$

$$\boxed{a = \underbrace{-7.01\,m/s^2}_{\text{decellerating}}}$$

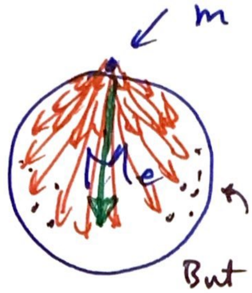
$$F = ma$$

$$= (1500\,kg)(-7.01\,m/s^2)$$

$F = 10,520\,N$ acting in the opposite direction

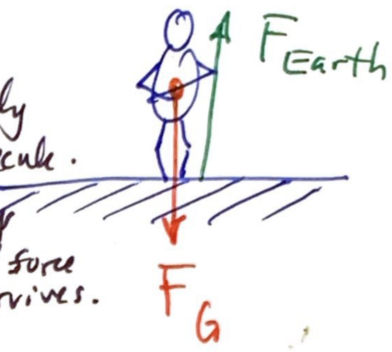
⊗ vertical force of gravity

$F_G = mg$ towards the center of the earth

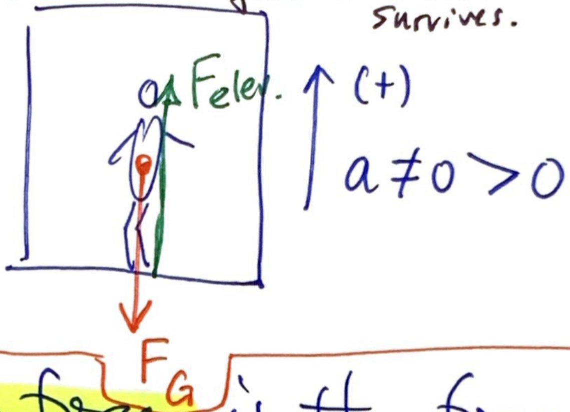


every molecule is gravitationaly attracted to every other molecule.

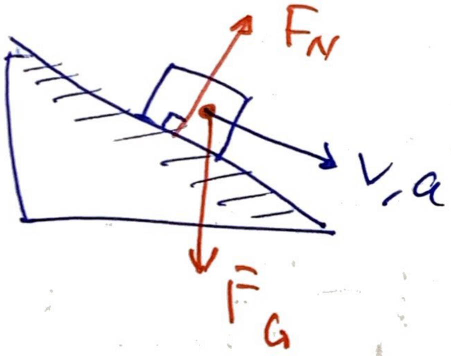
But symmetry cancels out side-ways components – only downward force survives.

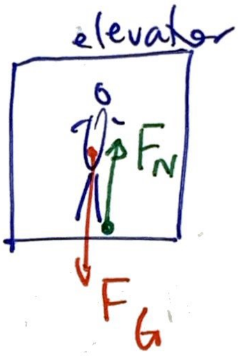


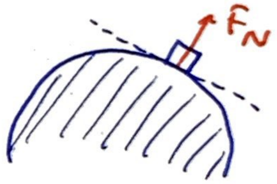
- Elevator



⊛ **The normal force is the force an object feels from the surface it sits upon.**







- Insert a bathroom scale between your feet {or your bottom if seated} the read out is that normal force.

read out = Normal Force.

EX A box sits on a table:

Newton's Law $\boxed{\sum F = ma}$

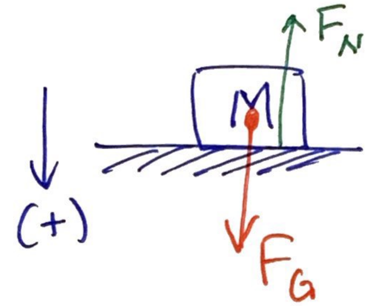
mass of box

acc'ln of box

sum of forces on the box

(a) At rest what is the normal force?

(i) Diagram



(ii) Free body

(iii) Equations of motion

$$\boxed{\sum F = Ma}$$

$$F_G + F_N = M\cancel{a}^{\,0}$$

let m = 10 kg

then

(iv) Solve

$$\boxed{F_N = -F_G}$$

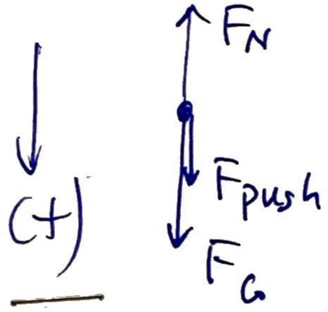
$$F_N = -[Mg] \quad (+)$$

$$= -(10\,kg)(9.8\,m/s^2)$$

$$\boxed{F_N = -98\,N}$$

opposite of down = upward

(b) Push down on the Box with 40N, what is F_N?



$$\sum F = ma$$

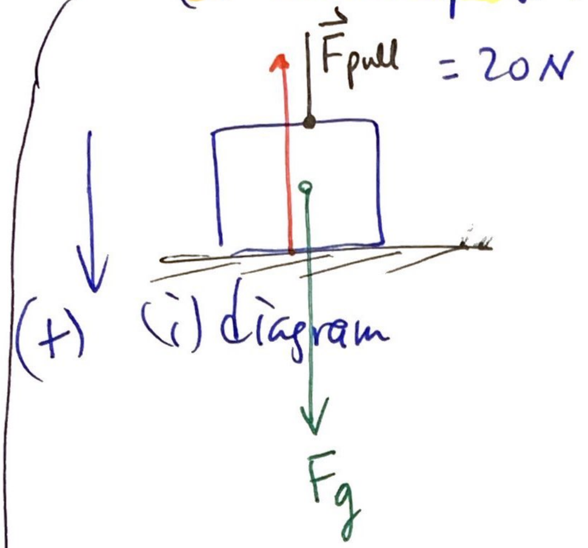
$$\boxed{F_{push} + F_G - F_N = M \cdot 0}$$

$$F_N = F_{push} + F_G$$

$$= 40N + (98N)$$

$$\boxed{F_N = 138\,N}$$

(c) Pull up on a string attached by force of 20N.



(i) diagram

(ii) Free-body diagram

$$\sum F = Ma$$

$$F_g - F_p - F_N = (10kg)(0\,m/s)$$

$$\boxed{F_N = F_g - F_{pull}}$$

(iii) Eqns

$$\boxed{F_{pull} < F_g}$$

(iv) Solve the eqn.

$$F_N = Mg - 20N$$

$$= (10kg)(9.8) - 20N$$

$$= -78N \text{ or } \boxed{78N \text{ upward}} \text{ vs } \boxed{98N} \text{ w/o pull}$$

(d) Pull up w/ 100 N:

$$\sum F = Ma$$

$$F_g - F_p - F_N = Ma^{\neq 0}$$

since $F_{pull} = 100N \geq 98N$
$\Rightarrow$ Box starts to lift off

(e) Find the acc'n since $F_N = 0$ once the box starts to lift off the table

$$\frac{F_g - F_{pull} - \cancel{F_N}^{0}}{M} = a$$

$[N] = kg\,m/s^2$

$$a = \frac{-2N}{10kg}$$

$$\frac{98N - 100N}{(10kg)} = a$$

$$\boxed{a = -0.2\,m/s^2}$$

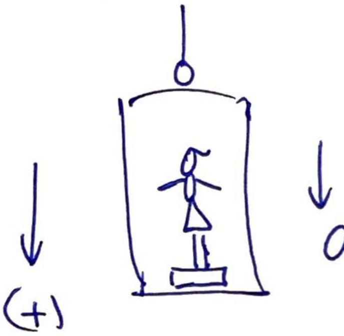
upwards

@ 1s = 0.2 m/s, @ 2s = 0.4 m/s, @ 3s = 0.6 m/s

EX Elevator

A 65 kg woman descends in an Elevator. when the elevator starts to move down it's accl'n is 0.2g downwards {then soon the elevator acheives A constant velocity and so a=0]

(a) What is her apparent weight loss?



$$a = 0.2g = (0.2)\,9.8\,m/s^2 = \underline{\underline{1.96\,m/s^2}}$$

(i) diagram

(ii)

(iii) eqns

$$\sum F = ma$$

$$F_G - F_N = ma$$

$$-F_N = ma - F_G$$

$$\boxed{F_N = F_G - ma}$$

(iv)

$$F_N = mg - ma$$

$$= (65\,kg)(9.8\,m/s^2) - (65\,kg)(1.96\,m/s^2)$$

$$= 637\,N - 127.4\,N$$

$$= \boxed{509.6\,N} \Rightarrow m = \frac{W}{g} = \frac{509.6\,N}{9.8\,m/s^2} = \boxed{52\,kg}$$

apparent "weight"

She has "lost" 13 kg of "weight"

(b) once up to speed what does the bathroom scale say?

$$F_N = mg - m\overset{\nearrow 0}{\cancel{a}}$$

$\boxed{F_N = 637\,N}$, her actual weight

(c) when slowing down her deceleration is 0.2g upward.

$$F_N = mg - ma$$
$$= (65)(9.8) - (65)(-0.2g)$$
$$= 637\,N + 127.4\,N$$
$$= 764.4\,N$$

scale : $m = \frac{W}{g} = \frac{764.4\,N}{9.8} = \underline{78\,kg}$