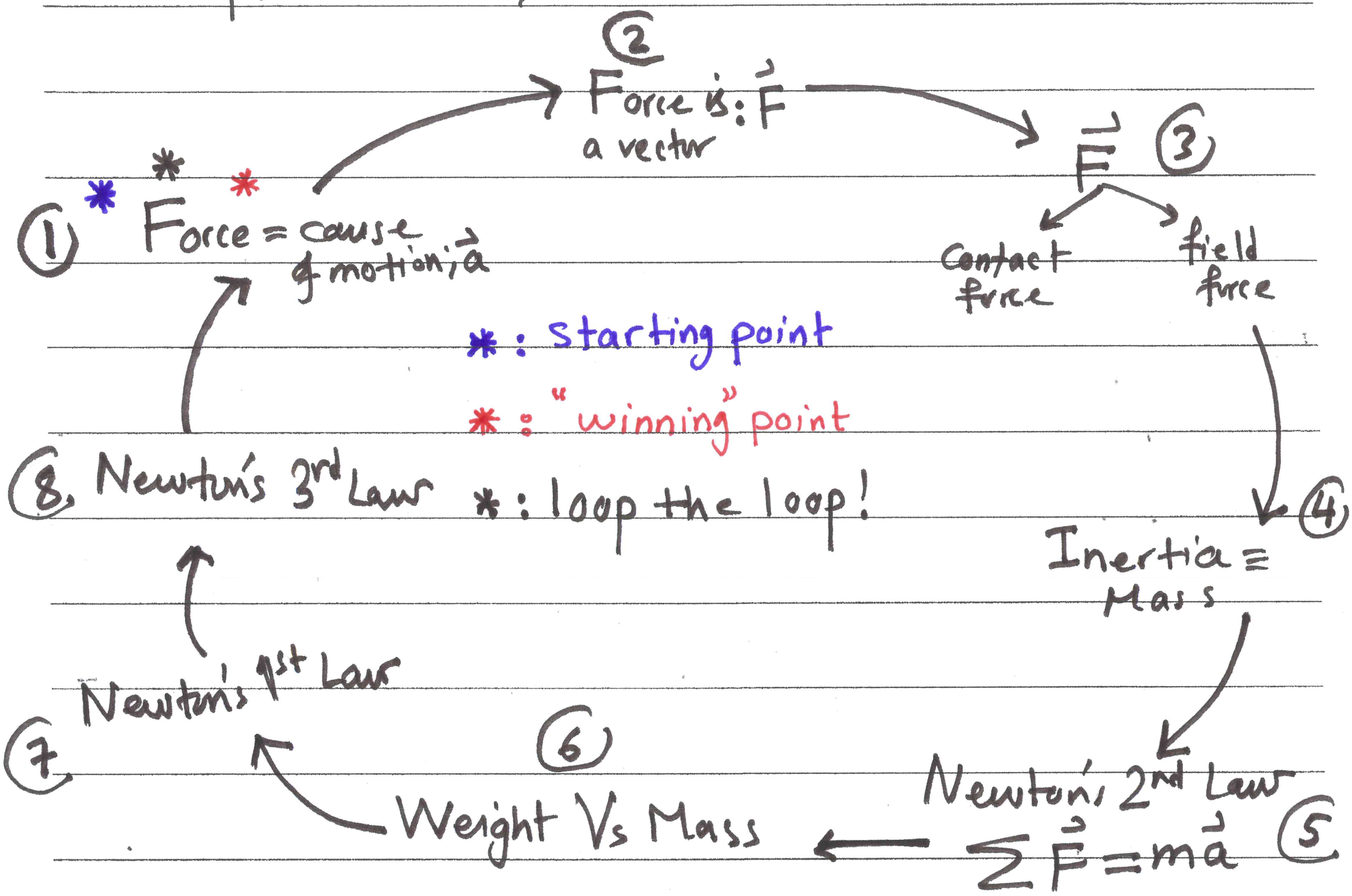
Chapter 4: Dynamics :-



⇒ This loop covers the materials of the first 7 sections of chapter 4; namely: see 4.1 ⟶ 4.7.

Let's start the race; if you don't mind!

[1] The force is the cause of motion and acceleration.

Causality: cause precedes effect. ⇒ The force is the cause, and the acceleration is the effect.

2) The force is a vector quantity ; $\vec{F}$. Obviously, vector sum (chapter 3) is needed to determine the net (total, resultant) force acting upon an object. ⇒ $\sum \vec{F}$ is a vector sum, not an algebraic sum.

3) Generally, forces can be categorized into two broad classes or types:

i) Contact forces : a push or a pull force: physical contact is required: ex ⇒ normal force, tension force.

ii) Field forces: act through empty space: no physical contact is required: ex ⇒ gravitational force, electromagnetic force, nuclear force.

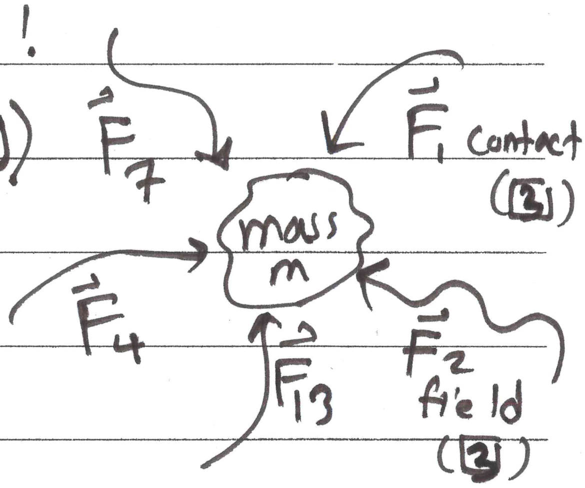
4) Inertia: is the property of an object that specifies the tendency to <u>resist</u> changes in its velocity. Mass: is the property of an object that specifies the amount of matter in it.

A more <u>massive</u> object has a greater <u>tendency</u> to resist changes in its velocity.

- Cambridge university Library holds the largest collection of Newton's manuscripts. Newton used the terminology inertia. We can "safely" use mass as a measure of inertia.
- For physicians, mass of a human body is the "sum" of the "stuff" in skeleton, flesh, blood, fluids...etc. Thus, mass is a scalar quantity ⇒ SI unit: kg.

5 Newton's 2^{nd} law: is an empirical law (تجريبي، استقصائي) based on observations and experiments, i.e., it's not derivable mathematically!

- Empirically: the vector sum (2) of the forces acting <u>on</u> an object of mass m (4) equals ⇒ $\boxed{\sum \vec{F} = m\vec{a}}$



$\therefore \vec{a} = \dfrac{\sum \vec{F}}{m} \Rightarrow \therefore \vec{F}$ is the cause of $\vec{a}$ (1)

$\therefore \vec{a}$ is <u>inversely</u> proportional to m (4).

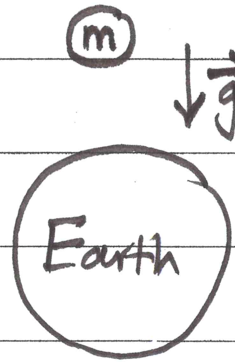
- $\Sigma \vec{F} \equiv$ the vector sum $\equiv$ net, total, resultant.
- $\Sigma \vec{F} = m\vec{a}$: this expression is not a single equation!
  It holds component by component :-

$\Sigma \vec{F}_x = m\vec{a}_x$ and $\Sigma \vec{F}_y = m\vec{a}_y$ and $\Sigma \vec{F}_z = m\vec{a}_z$.

- The SI unit of force is: kg (4) * ms^{-2}

$\Rightarrow kgms^{-2}$ = N (newton), named after Newton.

6 Weight Vs Mass:



Weight is the gravitational field force (3) exerting on an object of mass m.

Apply Newton's 2nd law (5) $\Rightarrow$:-

$\vec{F}$ exerted by the field $\vec{g}$ on the mass m is

$\vec{F}_g = m * [\vec{a} = \vec{g}] = m\vec{g}$. The weight of the object is $m\vec{g}$. The weight has a magnitude of mg (N) and points downward ↓.

- Recall point 5 : $\Sigma \vec{F} = m\vec{a}$, m is always +ve, thus $\vec{F}$ and $\vec{a}$ are parallel: as $\vec{g}$ points downward, the weight points downward accordingly.

[7] Newton's 1st law: The 2nd law describes what happens if a net (resultant) force __is__ exerted on m. The 1st law, on the other hand, determines what happens if the net force (the vector sum [2]) equal zero! It is extremely important to distinguish between the absence of forces acting on m and the absence of a net force acting on m!

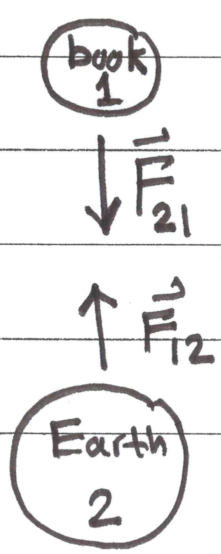
If $\sum \vec{F} = 0$, then: $m\vec{a} = 0 \Rightarrow \vec{a} = 0 = \frac{\Delta \vec{V}}{\Delta t} \Rightarrow \Delta \vec{V} = 0 = \vec{V}_f - \vec{V}_i \Rightarrow$

$\therefore$ $\vec{V}$ (velocity) is constant: the object moves with a constant speed in a __straight__ line. If you walk $4\,ms^{-1}$ west, then you continue walking $4\,ms^{-1}$ west, and if you are at rest (@JU!), then you will remain so!

[8] Newton's 3rd law: Action – Reaction law

Take: $\vec{F}_{21}$: force exerted __by__ object 2 __on__ object 1 (weight of book [6]).

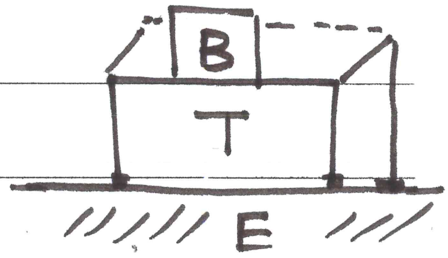
Take: $\vec{F}_{12}$: force exerted __by__ object 1 __on__ object 2.

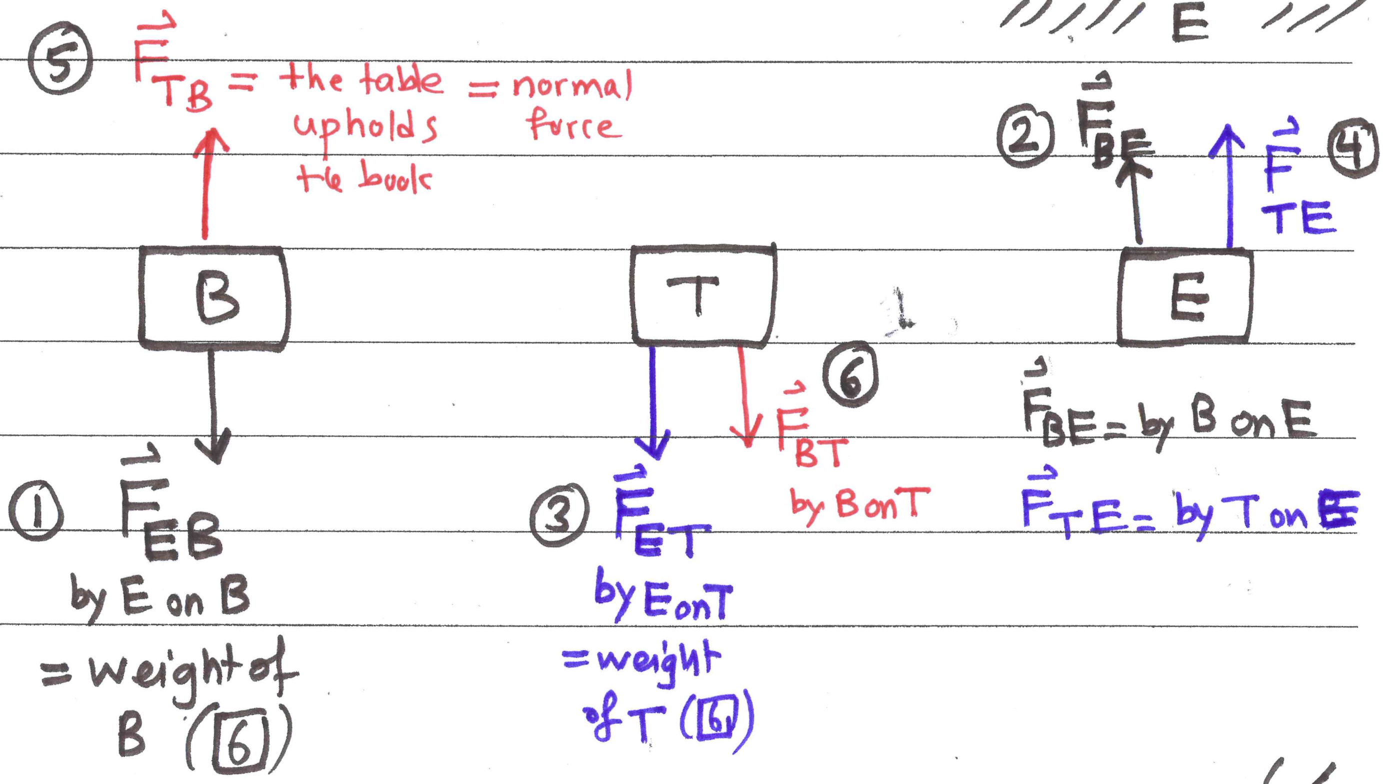


$\Rightarrow$ Newton's 3rd law: $\vec{F}_{21} = -\vec{F}_{12}$

- Newton's 3rd law acts on pair of objects!
  The 2 forces act on different objects!
- The "action" force is equal in magnitude to the "reaction" force and opposite in direction. It does not matter which is considered the "action" and which is considered the "reaction".
- Consider a book (B) resting on a table (T), and the latter rests on the earth (E).

Let's analyze the forces between each pair: (B, E), (T, E), (B, T).





- The 2 forces $\vec{F}_{EB}$ and $\vec{F}_{BE}$ are action-reaction pair.
- The 2 forces $\vec{F}_{ET}$ and $\vec{F}_{TE}$ are action-reaction pair.
- The 2 forces $\vec{F}_{TB}$ and $\vec{F}_{BT}$ are action-reaction pair.
- The 2 forces $\vec{F}_{EB}$ and $\vec{F}_{TB}$ are NOT action-reaction pair
- The book is at rest because it helds up by the table: Newton's 2nd law (not 3rd law) tells us that the vector sum of the forces acting on B $\Rightarrow \vec{F}_{EB} + \vec{F}_{TB} = 0$

∴ $\vec{F}_{TB} = mg \uparrow$: this force is a contact force (3), and acts perpendicular to the bottom surface of B.

$\vec{F}_{TB}$ is called normal force, in the sense that it acts perpendicular to the surface: { $\uparrow$ ✓ $\nwarrow$ ✗ }.

- Caution: it just happened that $\vec{F}_{EB}$ (weight) $= -\vec{F}_{TB}$ (normal) but it is not always the case because the 2 forces act on the same object (the book) and not on pair of objects.
- The two upward forces acting on E: $\vec{F}_{BE}$ and $\vec{F}_{TE}$:- the mass of the earth is of order of 10^{24} kg so $\vec{a}_E \simeq 0$!
- The two downward forces acting on T: $\vec{F}_{ET}$ and $\vec{F}_{BT}$:- cause a table dent in carpet!