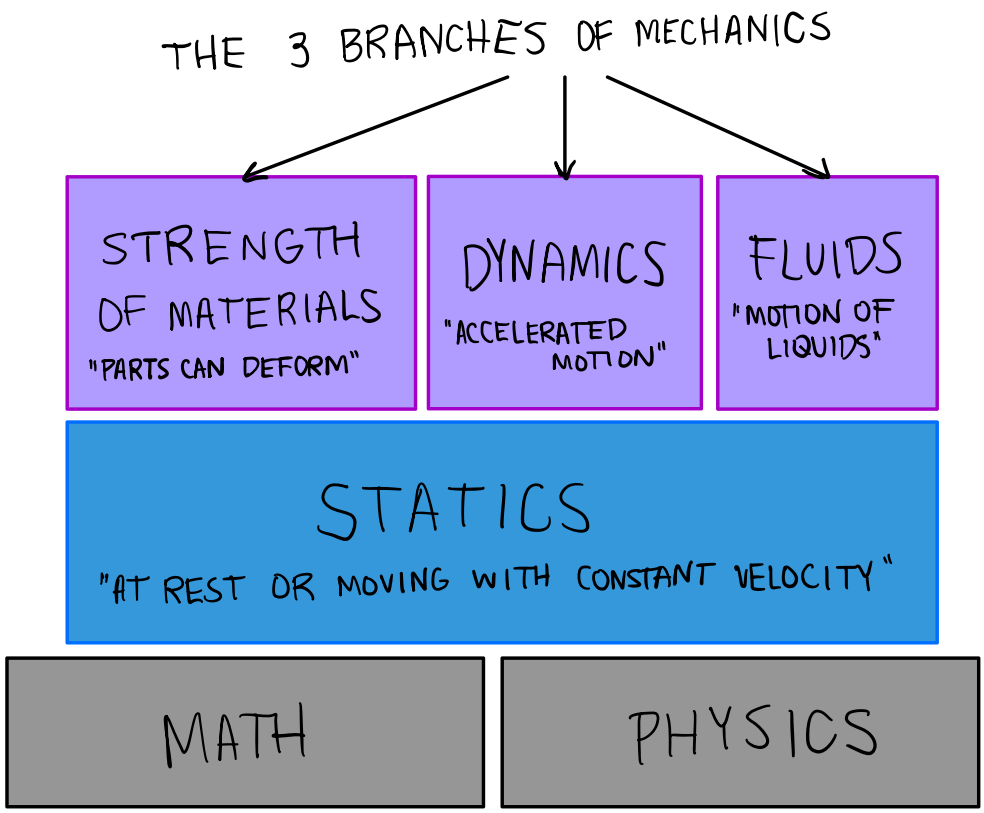
GENERAL PRINCIPLES

— MET 2124 — LECTURE NOTES — PROF. LEAH GINSBERG —

MECHANICS IS THE BRANCH OF THE PHYSICAL SCIENCES THAT IS CONCERNED WITH THE STATE OF REST OR MOTION OF BODIES THAT ARE SUBJECT TO THE ACTION OF FORCES.

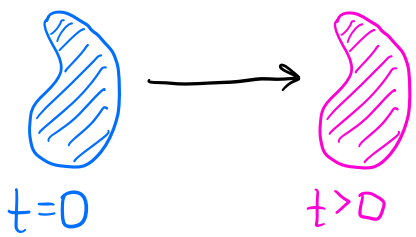


NEWTON'S LAWS OF MOTION

NEWTON'S THREE LAWS OF MOTION FORM THE BASIS OF ENGINEERING MECHANICS. WE WILL DISCUSS TWO DISTINCT COMPONENTS OF MOTION IN THIS CLASS.

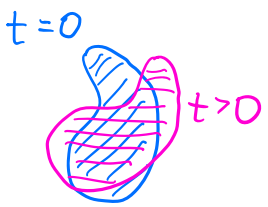
TRANSLATION

A BODY CHANGES POSITION WITHOUT CHANGING ITS ORIENTATION IN SPACE



ROTATION

A BODY SPINS ABOUT AN AXIS FIXED IN SPACE, WITHOUT CHANGING ITS AVERAGE POSITION



NOW, LET'S LOOK AT NEWTON'S THREE LAWS OF MOTION AND THEIR IMPLICATIONS FOR TRANSLATION AND ROTATION.

FIRST LAW. AN OBJECT WILL REMAIN AT REST OR IN UNIFORM MOTION UNLESS ACTED UPON BY AN EXTERNAL FORCE.

EX. YOUR PEN & PAPER WILL REMAIN AT REST UNLESS ACTED UPON BY YOU TO TAKE GOOD NOTES.

EX. SATELLITES ORBITING THE EARTH MAINTAIN A CONSTANT SPEED.

NEWTON'S FIRST LAW ALSO APPLIES TO ROTATION. HOWEVER, INSTEAD OF FORCE, THE RELEVANT QUANTITY WHICH CAUSES OBJECTS TO ROTATE IS CALLED A TORQUE OR A MOMENT.

EX. A SPINNING TOP WOULD CONTINUE TO ROTATE FOREVER IN A FRICTIONLESS ENVIRONMENT.

SECOND LAW. NEWTON'S SECOND LAW IS MOST OFTEN STATED THROUGH THE FAMILIAR EQUATION:

$$\vec{F} = m\vec{a}$$

(FORCE = MASS × ACCELERATION)

NOTE THE ARROWS OVER $\vec{F}$ AND $\vec{a}$ MEAN THAT THESE ARE VECTOR QUANTITIES, HAVING BOTH A MAGNITUDE & A DIRECTION. MASS, m, ON THE OTHER HAND, IS A SCALAR QUANTITY, HAVING ONLY A MAGNITUDE.

IN STATICS, WE FOCUS ON OBJECTS THAT ARE NOT ACCELERATING ($a=0$). THIS SIMPLIFIES NEWTON'S SECOND LAW TO:

$$\Sigma\vec{F} = 0$$

(SUM OF FORCES = ZERO)

FOR ROTATIONAL MOTION, NEWTON'S SECOND LAW CAN BE WRITTEN AS:

$$\vec{M} = I\vec{\alpha}$$

(MOMENT = MASS MOMENT OF INERTIA x ANGULAR ACCELERATION)

NOTE AGAIN THE ARROWS OVER $\vec{M}$ AND $\vec{\alpha}$, INDICATING THAT THEY HAVE BOTH A MAGNITUDE AND A DIRECTION, WHILE I IS A SCALAR QUANTITY.

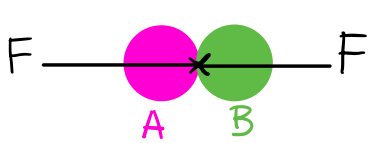
ALSO, IN STATICS, WE FOCUS ON OBJECTS THAT ARE NOT ACCELERATING ($\alpha=0$), SO, WE CAN SIMPLIFY THE ABOVE EQUATION TO:

$$\Sigma M = 0$$

(SUM OF MOMENTS = ZERO)

THIRD LAW. FOR EVERY ACTION THERE IS AN EQUAL AND OPPOSITE REACTION.

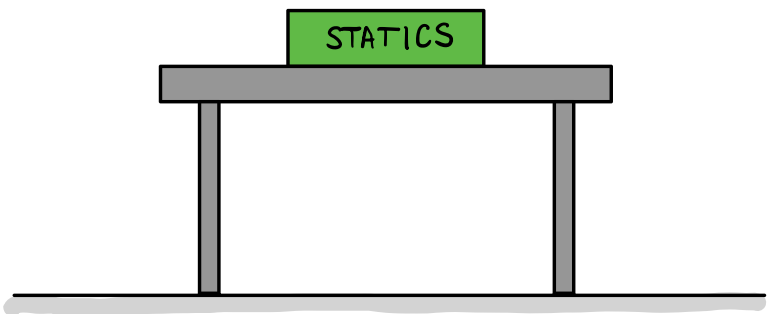
THE ACTIONS AND REACTIONS NEWTON REFERRED TO HERE ARE CALLED FORCES.



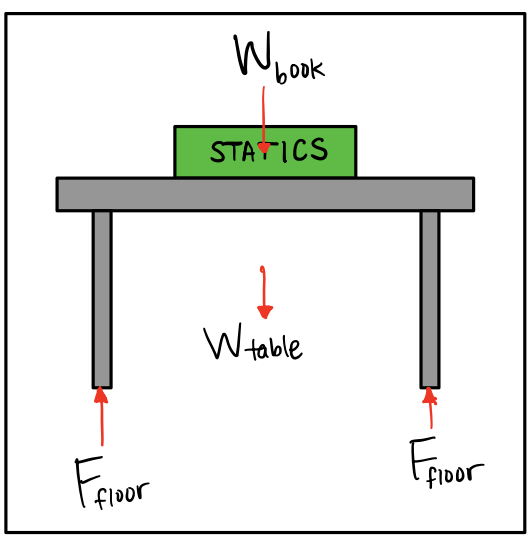
THE FORCE OF A ON B = THE FORCE OF B ON A

IT CAN BECOME CONFUSING TO KEEP TRACK OF THESE ACTION-REACTION PAIRS. TO CLARIFY, WE DRAW FREE-BODY DIAGRAMS IN WHICH WE IDENTIFY AND DRAW ALL THE FORCES ACTING ON THE BODY OF INTEREST.

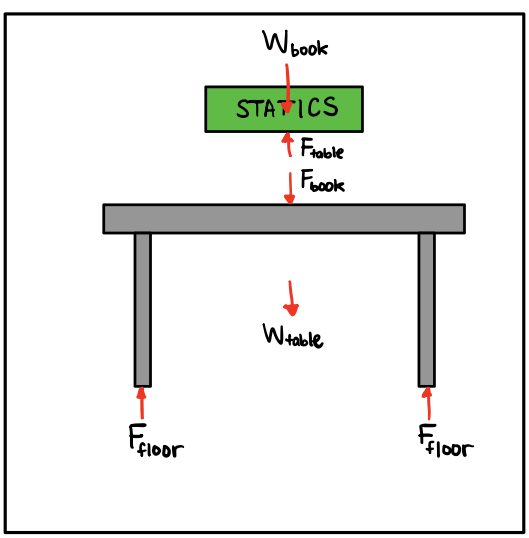
EX. LET'S DRAW A FREE-BODY DIAGRAM (FBD) OF YOUR TEXTBOOK SITTING ON A TABLE.



FBD TREATING THE BOOK AND THE TABLE AS A SINGLE SYSTEM



FBD TREATING THE BOOK AND THE TABLE AS INDEPENDENT



UNITS

QUANTITIES IN ENGINEERING WILL ALWAYS HAVE A NUMERIC VALUE AND AN ASSOCIATED UNIT (UNLESS THE PROPER UNIT IS UNITLESS).

* A NUMBER WITHOUT A UNIT IS MEANINGLESS! *

THE PROPER UNIT TO USE IS ESTABLISHED BY A CONSISTENT UNIT SYSTEM.

ALL UNIT SYSTEMS ARE DERIVED FROM SEVEN BASE UNITS. THE IMPORTANT ONES FOR STATICS ARE:

MASS. [m] A MEASURE OF A QUANTITY OF MATTER.

LENGTH. [L] A MEASURE OF SIZE OF A PHYSICAL SYSTEM, USED TO LOCATE THE POSITION OF A POINT IN SPACE.

TIME. [t] TIME IS CONCEIVED AS A SUCCESSION OF EVENTS

ALL OTHER UNITS ARE FORMED AS COMBINATIONS OF BASE UNITS.

EX. ACCELERATION IS DEFINED AS LENGTH [L] DIVIDED BY TIME [t] SQUARED, SO HAS UNITS

$$a = [L/t^2]$$

EX. FORCE IS RELATED TO MASS AND ACCELERATION BY NEWTON'S SECOND LAW, SO HAS UNITS

$$F = [mL/t^2]$$

WE WILL STUDY TWO DISTINCT UNIT SYSTEMS COMMONLY USED IN THE US.

SI SYSTEM

- ABBREVIATED FROM THE FRENCH, "SYSTÈME INTERNATIONAL D'UNITÉS"
- MOST WIDELY USED SYSTEM WORLDWIDE.

U.S. CUSTOMARY

- THE UNIT OF MASS, CALLED A SLUG IS DERIVED FROM $\vec{F}=m\vec{a}$.
- 1 SLUG IS THE AMOUNT OF MATTER ACCELERATED AT 1 ft/s^2 WHEN ACTED UPON BY A FORCE OF 1 lb.

COMPARING SYSTEMS OF UNITS

NAME	LENGTH	TIME	MASS	FORCE	$\vec{F}=m\vec{a}$
SI SYSTEM	METER (m)	SECOND (s)	KILOGRAM (kg)	NEWTON (N)	$N=\frac{kg\cdot m}{s^2}$
U.S. CUSTOMARY	FOOT (ft)	SECOND (s)	SLUG	POUND (lb)	$slug=\frac{lb\cdot s^2}{ft}$

KEEP IN MIND THAT MASS AND WEIGHT ARE NOT THE SAME THING.

YOU CAN FIND THE WEIGHT OF AN OBJECT FROM ITS MASS BY APPLYING NEWTON'S SECOND LAW ($\vec{F}=m\vec{a}$) WITH THE LOCAL ACCELERATION OF GRAVITY.

$$\vec{W}=m\vec{g}$$

$$g_{EARTH}=9.81\ m/s^2=32.174\ ft/s^2$$

$$g_{MARS}=3.73\ m/s^2=12.2\ ft/s^2$$

EX. ON EARTH, A 1 SLUG MASS WEIGHS 32.2 lb.

EX. ON MARS, A 1 SLUG MASS WEIGHS 12.2 lb.

EX. HOW MUCH DOES A 5 kg BAG OF FLOUR WEIGH?

EX. HOW MUCH DOES A 5 lb BAG OF SUGAR WEIGH?

WHEN A QUANTITY IS VERY LARGE OR VERY SMALL, ITS UNITS MAY BE GIVEN USING A PREFIX.

PREFIX	SI SYMBOL	EXPONENTIAL FORM	NUMBER
GIGA-	G	10^{9}	1,000,000,000
MEGA-	M	10^{6}	1,000,000
KILO-	k	10^{3}	1,000
MILLI-	m	10^{-3}	0.001
MICRO-	μ	10^{-6}	0.000 001
NAND-	n	10^{-9}	0.000 000 001