Ankara University
Department of Geological Engineering

GEO222 STATICS and STRENGTH of MATERIALS

Lecture Notes

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CHAPTER 1. INTRODUCTION

The science of “Mechanics” involves in the motion or at rest states of rigid bodies when subjected to several types of forces. Statics covers the basic problems of physics concerning the motion with constant velocity and moment. This course notes are divided into two chapters, namely “Statics” and “Strength of Materials”.

Statics part includes fundamental force and vector applications, moment, support reactions, equilibrium and related problems. Main chapters of “Strength of Materials “ are the stress, strain, shear force-bending moment diagrams. Also the stress transformations and Mohr’s circle applications will be reviewed. Torsion and bending of materials are to be included within the stress-strain chapter thoroughly.

This course notes are prepared for undergraduate geological engineering students. Some chapters related to strength are provided in a brief manner in order to widen the knowledge of the students, however such chapters are not included in details.

Basic Terms and Definitions

Length : The position of a point in space and thereby describe the size of a physical system. Once a standard unit of length is defined, one can then use it to define distances and geometric properties of a body as multiples of this unit.

Time: The succession of events. Although the principles of statics are time independent, this quantity is important in the study of dynamics.

Mass: The measure of a quantity of matter that is used to compare the action of one body with that of another. This property itself as a gravitational attraction between two bodies provides a measure of the resistance of matter to a change in velocity.

Force: A "push" or "pull "' exerted by one body on another. This interaction can occur when there is direct contact between the bodies; such as a person pushing on a wall, or it can occur through a distance when the bodies are physically separated. Force is completely characterized by its magnitude, direction and point of application.

Rigid Body : C*ombination of a* large number of particles in which all remain at a fixed Distance from one another, both before and after applying a load. This model is important because the material properties of any body that is assumed t0 be rigid will not have to be considered when studying the effects of forces (Hibbeler, 2010).

Newton's Laws of Motion

First Law: A particle originally at rest, or moving with constant velocity tends to remain in the same state provided the particle is not subjected to an unbalanced force.

Second Law: A particle acted upon by an unbalanced force experiences an acceleration that has the same direction as the force and a magnitude that is directly proportional to the force. This law is expressed as

"F = m x a" *where; F: force, m : mass, a: acceleration*

Third Law: Mutual forces of action and reaction between two particles are equal, opposite and collinear. (Action-Reaction);

NEWTON'S PRINCIPIA.

THE

MATHEMATICAL PRINCIPLES

OF

NATURAL PHILOSOPHY,

BY SIR ISAAC NEWTON;

TRANSLATED INTO ENGLISH BY ANDREW MOTTE.

TO WHICH IS ADDED

NEWTON'S SYSTEM OF THE WORLD;

With a Portrait taken from the Bust in the Royal Observatory at Greenwich.

FIRST AMERICAN EDITION, CAREFULLY REVISED AND CORRECTED,

WITH A LIFE OF THE AUTHOR, BY N. W. CHITTENDEN, M. A., &c.

NEW-YORK

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AXIOMS, OR LAWS OF MOTION.

LAW I.

Every body perseveres in its state of rest, or of uniform motion in a right line, unless it is compelled to change that state by forces impressed thereon.

PROJECTILES persevere in their motions, so far as they are not retarded by the resistance of the air, or impelled downwards by the force of gravity A top, whose parts by their cohesion are perpetually drawn aside from rectilinear motions, does not cease its rotation, otherwise than as it is retarded by the air. The greater bodies of the planets and comets, meeting with less resistance in more free spaces, preserve their motions both progressive and circular for a much longer time.

LAW II.

The alteration of motion is ever proportional to the motive force impressed; and is made in the direction of the right line in which that force is impressed.

If any force generates a motion, a double force will generate double the motion, a triple force triple the motion, whether that force be impressed altogether and at once, or gradually and successively. And this motion (being always directed the same way with the generating force), if the body moved before, is added to or subducted from the former motion, according as they directly conspire with or are directly contrary to each other; or obliquely joined, when they are oblique, so as to produce a new motion compounded from the determination of both.

LAW III.

To every action there is always opposed an equal reaction: or the mutual actions of two bodies upon each other are always equal, and directed to contrary parts.

Whatever draws or presses another is as much drawn or pressed by that other. If you press a stone with your finger, the finger is also pressed by the stone. If a horse draws a stone tied to a rope, the horse (if I may so say) will be equally drawn back towards the stone: for the distended rope, by the same endeavour to relax or unbend itself, will draw the horse as much towards the stone, as it does the stone towards the horse, and will obstruct the progress of the one as much as it advances that of the other.

Newton's First Law
Applied to Rocket Liftoff

"Every object persists in its state of rest or uniform motion in a straight line unless it is compelled to change that state by forces impressed on it."

Before firing:

Object in state of rest, airspeed zero.

Engine fired:

Thrust increases from zero.

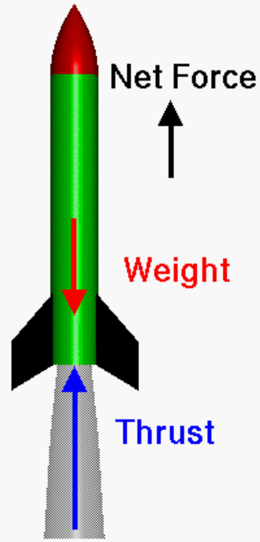
Weight decreases slightly as fuel burns.

When Thrust is greater than Weight:

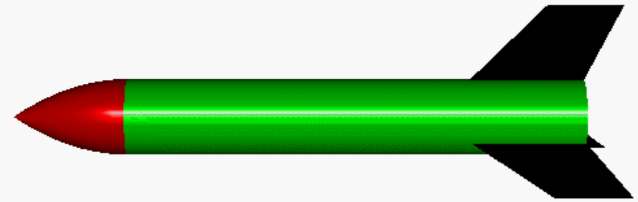
Net force (Thrust – Weight) is positive upward.

Rocket accelerates upward

Velocity increases



Newton's Second Law
Definitions



Differential Form: Force = change of momentum with change of time

$$F = \frac{d\,(mv)}{dt}$$

or:

Force = change in mass X velocity with time

$$F = \frac{(m_1 V_1 - m_0 V_0)}{(t_1 - t_0)}$$

With mass constant: Force = mass X acceleration

$$F = m\,a$$

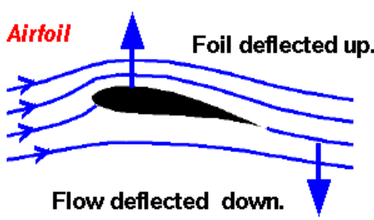
Force, acceleration, momentum and velocity are all vector quantities.

Each has both a magnitude and a direction.

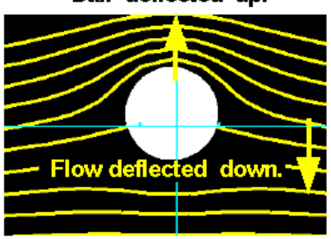
Newton's Third Law
Applied to Aerodynamics

Glenn Research Center

For every action, there is an equal and opposite re-action.

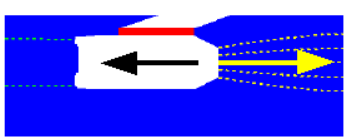


Ball deflected up.



Spinning Ball

Engine pushed forward.



Flow pushed backward.

Jet Engine

Ref: https://www.grc.nasa.gov/www/k-12/BGP/newton.html

Newton's Law of Gravitational Attraction

F	: Force exerted between two particles
G	: Coefficient of gravity (G = 6.673×10^{-11} $m^3/kg.s^2$)
m_1, m_2	: Particle mass
r	: Distance between centers of particles

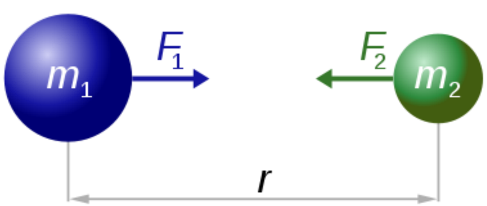
SI Units

F : Newton (N)

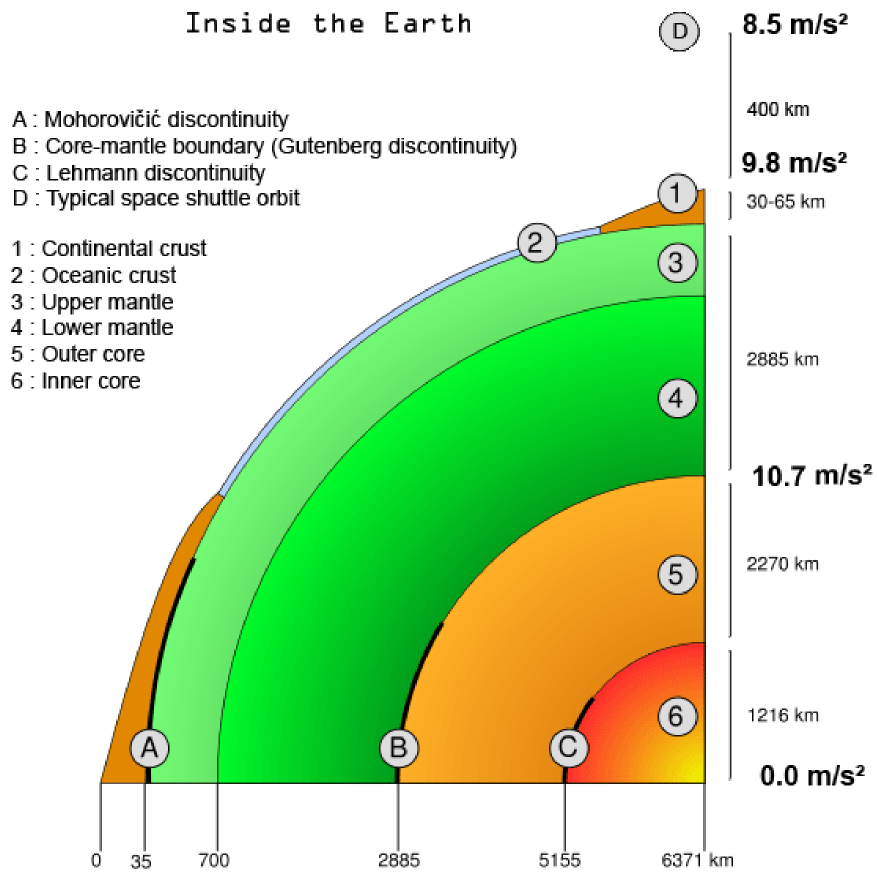
m_1 and m_2 : kilogram (kg)

r : meter (m)

$G = 6.673 \times 10^{-11}$ N m^2 kg^{-2}



$$F_1 = F_2 = G\frac{m_1 \times m_2}{r^2}$$



Ref: Earth-G-force" by Dake (Slice earth.svg)derivative work: KronicTOOL (talk); Software: Photoshop - Slice earth.svg. Licensed under CC BY-SA 2.5 via Commons -https://commons.wikimedia.org/wiki/File:Earth-G-force.png#/media/File:Earth-G-force.png

Weight: Any two particles or bodies have mutual attractive (gravitational) force acting between them. In case of a particle located at or near the surface (If the earth, however, the only gravitational force having any sizable magnitude is that between the earth and the particle. Consequently, this force "*weight" will be* the only gravitational force considered in study of mechanics.

An approximate expression for finding the weight (W) of a particle having a mass m_1=m. If we assume earth to be a non rotating sphere of constant density and having a mass m_2=M, then if "r" is the distance between the earth's center and the particle;

$$W = G\,(mM/r^2);\; g = GM/r^2 \text{ yields;}$$
$$W = m \times g \;(\text{Note; } g = 9.81\ m/s^2)$$

Multiplication Factor	Prefix†	Symbol
1 000 000 000 000 = 10^{12}	tera	T
1 000 000 000 = 10^{9}	giga	G
1 000 000 = 10^{6}	mega	M
1 000 = 10^{3}	kilo	k
100 = 10^{2}	hecto‡	h
10 = 10^{1}	deka‡	da
0.1 = 10^{-1}	deci‡	d
0.01 = 10^{-2}	centi‡	c
0.001 = 10^{-3}	milli	m
0.000 001 = 10^{-6}	micro	μ
0.000 000 001 = 10^{-9}	nano	n
0.000 000 000 001 = 10^{-12}	pico	p
0.000 000 000 000 001 = 10^{-15}	femto	f
0.000 000 000 000 000 001 = 10^{-18}	atto	a

SI Prefixes (Beer, et al. 2011)

Quantity	Unit	Symbol	Formula
Acceleration	Meter per second squared	. . .	m/s^2
Angle	Radian	rad	†
Angular acceleration	Radian per second squared	. . .	rad/s^2
Angular velocity	Radian per second	. . .	rad/s
Area	Square meter	. . .	m^2
Density	Kilogram per cubic meter	. . .	kg/m^3
Energy	Joule	J	$N \cdot m$
Force	Newton	N	$kg \cdot m/s^2$
Frequency	Hertz	Hz	s^{-1}
Impulse	Newton-second	. . .	$kg \cdot m/s$
Length	Meter	m	‡
Mass	Kilogram	kg	‡
Moment of a force	Newton-meter	. . .	$N \cdot m$
Power	Watt	W	J/s
Pressure	Pascal	Pa	N/m^2
Stress	Pascal	Pa	N/m^2
Time	Second	s	‡
Velocity	Meter per second	. . .	m/s
Volume			
Solids	Cubic meter	. . .	m^3
Liquids	Liter	L	$10^{-3}m^3$
Work	Joule	J	$N \cdot m$

Principal SI Units (Beer, et al. 2011)