Monday, August 24, 2009
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# CE-297 BASIC MECHANICS I - STATICS

## Chapter 1: Introduction

### 1.1 What is mechanics? Why should we study it?

- Fill in the blank: ________________ mechanics
  - Structural
  - Fluid
  - Thermal
  - Solid
  - Continuum
  - Space / Celestial
  - Molecular
  - Quantum
  - •
  - •
  - •
- Mechanics is the study of how things (anything) works!
- In Civil & Mechanical engineering applications, mechanics is the science that governs the state of rest or motion of bodies.
- Mechanics can be classified as mechanics of:
  - Particles
  - Rigid Bodies
  - Deformable bodies
  - Fluids
  - etc.
- It can also be divided in 2 groups:

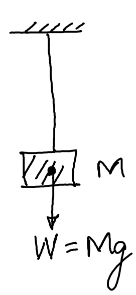
  STATICS
  
  Study of force systems in "equilibrium"

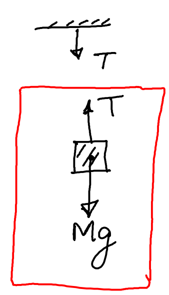
  DYNAMICS
  
  Kinematics: Description of the motion
  
  Kinetics: Study of force system NOT in equilibrium (causing motion)

- Why study Rigid Body mechanics?
  - Serves as a good mathematical model for real-life problems
  - Allows us to determine the forces being carried by structural members (even if they are NOT rigid)

Example:

"FREE-BODY DIAGRAM" (FBD)




T: Tension in the rope

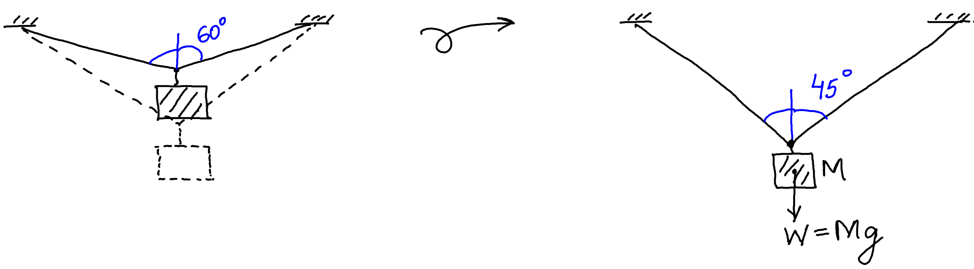
"EQUILIBRIUM" of the mass

→ $T = Mg$

Knowing T, one can design so that the rope can carry the weight.

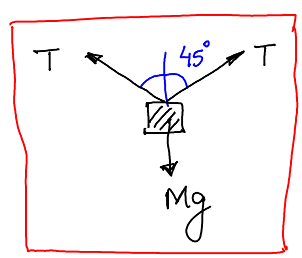
- The principles of Statics of Rigid Bodies are valid for deformable bodies also.

  Example: Consider flexible string:




"Equilibrium" holds in the deformed configuration

FBD:



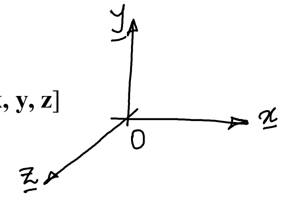

$$\Rightarrow \quad 2T\cos(45^\circ) = Mg$$

$$\Rightarrow \quad \boxed{T = \frac{Mg}{2\cos(45^\circ)}}$$

**Note:**

- We treated the flexible string as a rigid body in the deformed configuration and figured out the forces (tension) it was carrying using the principles of **Statics**.
- Statics is extremely important. You will use it in every future course on mechanics.

## 1.2 Fundamental Concepts and Principles




- Space, Time, Mass are abstract quantities that cannot be defined in an absolute sense.

  Space: Can be defined in terms of a coordinate system with some **origin** and **unit vectors** [O, **x, y, z**]
  Mass: Property of a body that occupies space and is affected by gravity.
  Time: Defines a sequence of events.

- Derived Quantities:
  Force, Energy, Momentum etc.

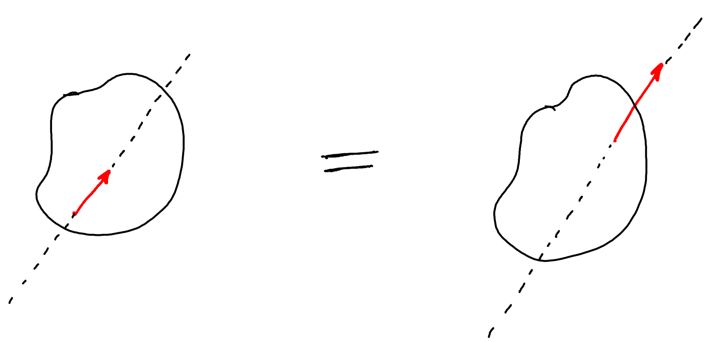
- **SCALARS and VECTORS**

  Scalars: Characterized by magnitude only.
  Example: mass, temperature, density etc.

  Vectors: characterized by magnitude and direction.
  Example: velocity, Force, momentum etc.

- Vector Algebra: Addition, Subtraction (Parallelogram Rule)
  Vector Products:
  - scalar & vector to give a vector
  - vector & vector to give scalar
  - vector & vector to give vector

- Principle of **Equivalent Forces** (Transmissibility)
  Two forces will have the same effect on the state of rest or motion of a rigid body if the **line of action** of the two forces is the same. These two forces are said to be **equivalent**.



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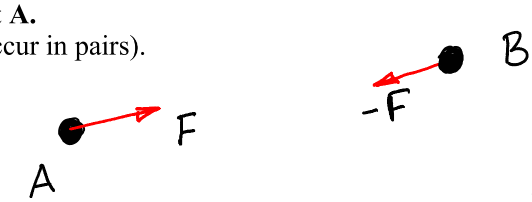
# NEWTON's LAWS OF MOTION

1. First Law: An object at rest (or in uniform motion) remains at rest (or in the uniform motion) if there is **no unbalanced external** force acting on it (with respect to an inertial frame of reference).

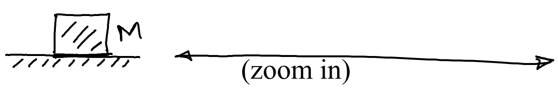
2. Second Law: If an unbalanced force is acting on an object, then this force is given by the **rate of change of linear momentum** of the object.

$$\underline{F} = \frac{d\underline{p}}{dt} = \frac{d(m\underline{v})}{dt} = m\left(\frac{d\underline{v}}{dt}\right) = m\,\underline{a}$$

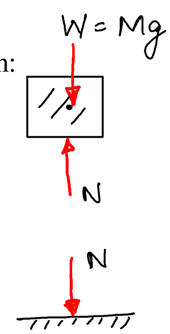
3. Third Law: Every action has an equal and opposite reaction.
   If an object **A** exerts a force **F** on another object **B**, then the object **B** will always exert a force **-F** on object **A.**
   (Forces always occur in pairs).




Example: Block resting on table:

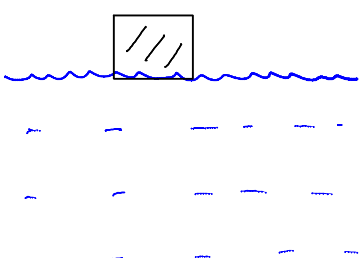



Free Body Diagram:

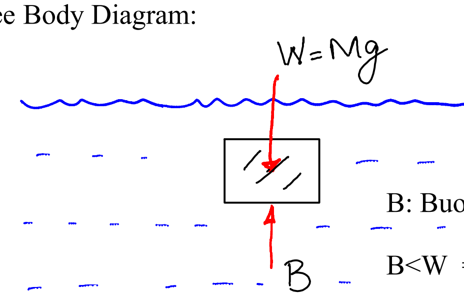



N: Normal reaction

Example: Heavy block sinking in water



Free Body Diagram:




B: Buoyancy Force

B<W => Block sinks

Note: The water is only able to provide a force B to the block, Thus the block is also only able to exert the same force B to the water (and not its full weight W)

NOTE:

According to Newtonian mechanics, All three **LAWS** hold true everywhere at all times.

Later it was found that Newtonian mechanics does not predict reality well at the very small scale (where Quantum mechanics holds) and the very large scale (where Einstein's General theory of relativity holds).

However, for common everyday engineering problems Newtonian mechanics yields extremely accurate results. Therefore, as engineering students, we must learn and master Newtonian mechanics.

## Newton's Law of Gravitation

Gravitational force between 2 masses is given by:

$$F = \frac{G\, m_1 m_2}{r^2}$$

G: Universal constant of gravitation G = $6.67\times10^{-11}$ $m^3\,kg^{-1}\,s^{-2}$

## 1.3-1.4 System of Units & Conversion

| | | SI Units | US Customary Units |
|---|---|---|---|
| • Basic (Fundamental) Units | | | |
| | LENGTH, | 1 m | 1 ft = 0.3048 m |
| | MASS, | 1 kg | 1 slug = 14.59 kg |
| | TIME | 1 s | 1 s |
| • Derived Units | | | |
| | Force, | 1 N = 1 kg m/s$^2$ | 1 lb = 1 slug ft/s$^2$ = 4.448 N |
| | Energy, | 1 J | |
| | Momentum | 1 kg m/s | |

- Refer to Tables 1.1, 1.2 and 1.3 in your book (Beer & Johnston) for more information.

## 1.5-1.6 Problem solving & Numerical Accuracy

Steps

- Problem statement
- Draw the **Free Body Diagram**
- Enforce the principles of **Statics** to the problem
- Sanity **check**

Accuracy of your final answer depends upon the accuracy of the given data. Use common sense ~0.2% error.

Word of Advice:

Mechanics and engineering is serious business.
As an engineer, people lives are in your hands. Be a good engineer!