Chapter 1 Introduction

1.1 What is Mechanics ?

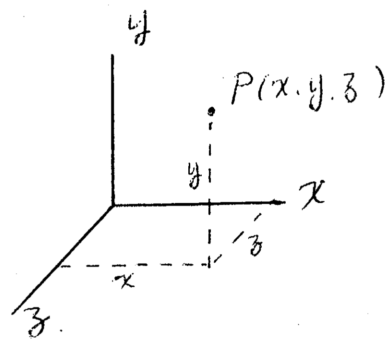
Mechanics : to describe and predict the conditions of rest or motion of bodies under the action of forces

1. Mechanics of rigid bodies : Statics - rest ; Dynamics - motion
2. Mechanics of deformable bodies : Strength of Materials
3. Mechanics of fluids : Fluid Mechanics

Statics and Dynamics : assume the bodies are perfectly rigid

1.2 Fundamental Concepts and Principles

Fundamental Concepts used in Mechanics



Space : define the position of point P by three lengths measured from a reference point in three given directions, right-handed coordinate system are used

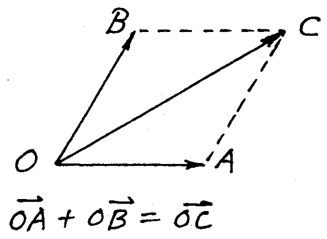
time : for particle (body) in motion, time is an additional parameter to define the event

mass : it is used to characterize and compare bodies on the basis of certain fundamental mechanical experiments, two bodies has the same mass that means they will be attracted by the earth in the same manner

force : the action of one body on another -- actual contact or at a distance (gravitational force and magnetic force etc.), force is characterized by its point of application, its magnitude and its direction

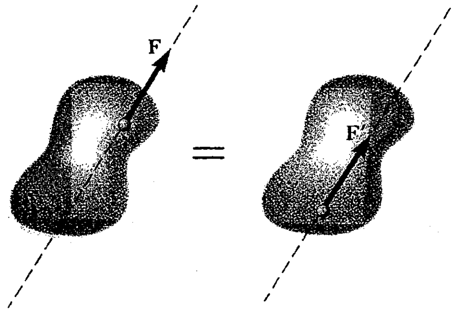
Six fundamental principles (based on experimental evidence)

1. the parallelogram law for addition of force:



two forces action on a particle may be replaced by a single force, called resultant

2. the principle of transmissibility



the condition of equilibrium or of motion of rigid body will remains unchanged if a force $\boldsymbol{F}$ acting at the given point is replaced by a force $\boldsymbol{F}'$ of the same magnitude and same direction, but acting at different point, provided that the two forces $\boldsymbol{F}$ and $\boldsymbol{F}'$ have the same line of action

3. Newton's 1st law

if the resultant force acting on a particle is zero, the particle will remain rest (chapter 2) or will move with constant speed in a straight line (Dynamics)

4. Newton's 2nd law

if the resultant force acting on a particle is not zero, the particle will have an acceleration proportional to the magnitude of the resultant and in the direction of this resultant force

$$\Sigma \boldsymbol{F} = m\,\boldsymbol{a} \qquad \text{(Dynamics)}$$

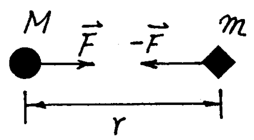
5. Newton's 3rd law

the force of action and reaction between bodies in contact have the same magnitude, same line of action and opposite sense (chapter 6)

6. Newton's law of gravitation

two particles of mass M and m are mutually attracted with equal and opposite forces $\boldsymbol{F}$ and $-\boldsymbol{F}$, where

$$\boldsymbol{F} = \frac{G M m}{r^2}$$



G : universal constant called the constant of gravitation (Dynamics)

r : center to center distance of two bodies

on the surface of earth, the force F exerted by the earth on the particle (body) is defined as the weight W of the particle (body)

introducing the constant g

$$g = \frac{G M}{R^2}$$

where M : mass of earth R : radius of earth

then $$W = m g$$

$\because$ R depends upon the elevation of the point considered on the surface of the earth, then

$$g = 9.781 \sim 9.833 \text{ m/s}^2 \qquad \text{(equator} \sim \text{poles)}$$

in average $g = 9.81 \text{ m/s}^2$ (used in engineering)

1.3 Systems of Units

International system of units (SI units)

length : m (meter), defined as 1/10,000,000 from equator to the poles

now, defined as 1,650,763.73 wave lengths of the orange-red line of Krypton 86

km : 1000 m cm : 1/100 m mm : 1/1000 m

mass : kg (kilogram), 0.001 m^3 mass of water (approximately)

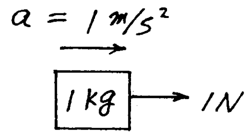
actually defined as the mass of a platinum standard kept at the International Bureau of Weight and Measures at Sevres, near Paris, France

g : 1/1000 kg Mg : 1000 kg

time : sec (second), 1/86,400 of the mean solar day actually defined as the duration of 9,192,631,770 cycles of the radiation associated of Cesium atom

min : 60 sec   hr : 3,600 sec

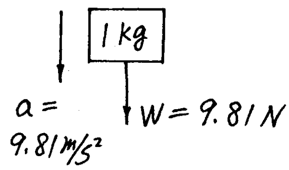
force : N (Newton), defined as the force which given an acceleration of $1\ m/s^2$ to a mass of 1 kg



i.e. $1\ N = 1\ kg \cdot 1\ m/s^2$

$= 1\ kg\text{-}m/s^2$

weight of a body of 1 kg mass



$W = m\,g = 1\ kg \cdot 9.81\ m/s^2$

$= 9.81\ N$

$kN = 1{,}000\ N \qquad MN = 10^6\ N$

SI units are said to form an absolute system of units, independent of location where measurements are made, may be used on other planet

note : the unit of angle is radian -- "rad"

the multiples and submultiples of this unit are

G : giga	10^9
M : mega	10^6
k : kilo	10^3
c : centi	10^{-2}
m : milli	10^{-3}
μ : micro	10^{-6}

other units used in mechanics can be derived from the three based units

velocity	v :	m/s
acceleration	a :	m/s^2
area	A :	m^2
volume	V :	m^3
moment	M :	N-m

pressure p : Pa (N/m^2)

stress σ : MPa (N/mm^2)

energy, work J (N-m)

power J/s (N-m/s)

US Customart Units

force : lbf mass : slug

length : ft

time : second

standard pound : weight of a platinum standard, called standard pound, kept in National Institute of Standards

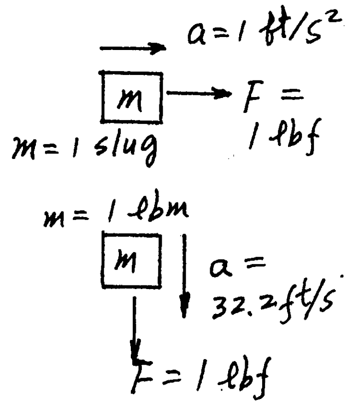
$F = m\,a$ 1 lbf = (1 slug) (1 ft /s^2)

pound mass : lbm

$W = m\,g$ 1 lbf = (1 lbm)(32.2 ft/s^2)

1 ft = 12 in 1 yard = 3 ft 1 mile = 5280 ft

1 kip = 1000 lb 1 ton = 2000 lb



1.4 Conversion from one System of Units to Another

1 ft = 0.3048 m 1 mile = 1.609 km 1 in = 25.4 mm

1 lbm = 0.4536 kg

W = m g 1 lbf = (1 lbm)(32.2 ft/s^2)

1 lbf = (0.4536 kg)(9.807 m/s^2) = 4.448 kg-m/s^2

1 lbf = 4.448 N

1.5 Method of Problem Solution

the solution must be based on the six fundamental principles or on theorems

the statement of a problem should be clear and precise, separate diagram, called free body diagram, should be drawn, the fundamental principles of mechanics will used to write equations expressing the conditions of rest or motion of the bodies considered.

after the answer has been obtained, it should be carefully checked, mistakes in reasoning can often be detected by checking the units

1.6 Numerical Accuracy

the accuracy of the solution of a problem depends upon two items :

1. the accuracy of the given data
2. the accuracy of the computations performed

e.g. if the loading applied is 40,000 kg with possible error of 50 kg, the accuracy of the given data is

$$50 / 40000 = 0.00125 = 0.125\ \%$$

then the accuracy of computing reaction cannot be greater than 0.125 %

if the reaction is 253.42 kN, then the possible error is

$$253.42 \times 0.125\ \% = 0.30\ \text{kN}$$

thus the answer should be properly recorded as (253.4 ± 0.3) kN

also, in engineering problem, the data are seldom known with an accuracy greater than 0.2 %, a practical rule is to use 4 figures to record numbers beginning with a "1" and 3 figures in all other cases

e.g. 40 N should be read 40.0 kN

15 N should be read 15.00 N