6th Edition
Revised & Updated

A Handbook on

Mechanical Engineering

Contains well illustrated formulae & key theory concepts

for

ESE, GATE, PSUs

& OTHER COMPETITIVE EXAMS

MADE EASY PUBLICATIONS

www.madeeasypublications.org

MADE EASY PUBLICATIONS

MADE EASY Publications Pvt. Ltd.

Corporate Office: 44-A/4, Kalu Sarai (Near Hauz Khas Metro Station), New Delhi-110016

Contact: 9021300500

E-mail: infomep@madeeasy.in

Visit us at: www.madeeasypublications.org

A Handbook on Mechanical Engineering

First Edition: 2012
Second Edition: 2015
Third Edition: 2016
Fourth Edition: 2019
Fifth Edition: 2020
Reprint: 2021
Sixth Edition: 2022
Reprint: 2023
Reprint: 2024

Director's Message

B. Singh (Ex. IES)

During the current age of international competition in Science and Technology, the Indian participation through skilled technical professionals have been challenging to the world. Constant efforts and desire to achieve top positions are still required.

I feel every candidate has ability to succeed but competitive environment and quality guidance is required to achieve high level goals. At MADE EASY, we help you discover your hidden talent and success quotient to achieve your ultimate goals. In my opinion CSE, ESE, GATE & PSUs exams are tools to enter in to the main stream of Nation serving. The real application of knowledge and talent starts, after you enter in to the working system. Here at MADE EASY you are also trained to become winner in your life and achieve job satisfaction.

MADE EASY alumni have shared their winning stories of success and expressed their gratitude towards quality guidance of MADE EASY. Our students have not only secured All India First Ranks in ESE, GATE and PSUs entrance examinations but also secured top positions in their career profiles. Now, I invite you to become an alumnus of MADE EASY to explore and achieve ultimate goal of your life. I promise to provide you quality guidance with competitive environment which is far advanced and ahead than the reach of other institutions. You will get the guidance, support and inspiration that you need to reach the peak of your career.

I have a true desire to serve the Society and the Nation easing path of the education for the people of India.

After a long experience of teaching Mechanical Engineering over a period of time, MADE EASY team realised that there is a need of a good *Handbook* which can provide the crux of Mechanical Engineering in a concise form to the student to brush up the formulae and important concepts required for ESE, GATE, PSUs and other competitive examinations. This *handbook* contains all the formulae and important theoretical aspects of Mechanical Engineering. It provides much needed revision aid and study guidance before examinations.

B. Singh (Ex. IES)
CMD, MADE EASY Group

A Handbook on

Mechanical Engineering

Contents

Chapter 1 :

Fluid Mechanics 1-51

1. Introduction 1
2. Manometry 6
3. Hydrostatic Force 8
4. Buoyancy and Floatation 10
5. Fluid Kinematics 12
6. Fluid Dynamics and Flow Measurements 17
7. Viscous Flow of Incompressible Fluid 21
8. Flow Through Pipes 24
9. Vortex Motion 29
10. Boundary Layer Theory 30
11. Turbulent Flow 33
12. Dimensional Analysis 36
13. Impact of Jet 38
14. Hydraulic Turbines 41
15. Hydraulic Pumps 46

Chapter 2 :

Heat Transfer 52-84

1. Conduction 52
2. Convection 66
3. Heat Exchanger 74
4. Radiation 78

Chapter 3 :

Basic Thermodynamics 85-104

1. Basic Concepts 85
2. Energy Interaction 87
3. First Law of Thermodynamics 89
4. First Law Applied to Flow Process 91
5. Second Law of Thermodynamics 93
6. Entropy 95
7. Available Energy, Availability and Irreversibility 97
8. Properties of Pure Substance 99
9. Properties of Gases and Gas Mixture 101
10. Thermodynamic Relations Equilibrium and Stability 102

Chapter 4 :

Power Plant Engg.......... 105-123

1. Power Plant Economics 105
2. Fuel and Combustion 105
3. Boiler/Analysis Steam Cycle 108
4. Steam Nozzle and Turbine 113
5. Gas Turbine Power Plant 116
6. Compressors 119

Chapter 5 :

Refrigeration & Air-conditioning 124-134

1. Refrigeration 124
2. Air-Conditioning 129

Chapter 6 :

I.C. Engine.. 135-145

1. Air Standard Cycle 135
2. Combustion of Air Fuel Mixture 138
3. Engine Performance Parameter 142
4. Fuel Quality 143

Chapter 7 :

Theory of Machines 146-195

1. Mechanism and Machines 146
2. Velocity Analysis 152
3. Acceleration Analysis 157
4. Cam 159
5. Gear 163
6. Gear Train 173
7. Flywheel 175
8. Balancing 178
9. Governors 181
10. Vibration 187

Contents

Chapter 8 :

Machine Design 196-248

1. Power Screws....................196
2. Rolling Contact Bearing....................204
3. Sliding Contact Bearing....................210
4. Design Against Static Load....................215
5. Welded and Riveted Joint....................222
6. Chain Drive....................229
7. Friction Clutches....................231
8. Belt Drive....................237
9. Shafts, Keys and Couplings....................240
10. Design of Spur Gear....................245

Chapter 9 :

Strength of Materials ... 249-274

1. Properties of Metals, Stress, Strain...249
2. Shear Force and Bending Moment..258
3. Torsion of Shaft....................259
4. Principal Stresses/Principal Strains..262
5. Theory of Failure....................265
6. Columns....................267
7. Springs....................269
8. Pressure Vessels....................271
9. Deflection of Beam....................273

Chapter 10 :

Material Science & Production Engg. 275-349

1. Material Science....................275
2. Welding....................287
3. Metal Casting....................304
4. Metal Cutting and Machine Tools 315
5. Metal Forming....................332
6. Metrology....................345

Chapter 11 :

Industrial Engg. 350-390

1. Break-Even Analysis....................350
2. Inventory / Inventory Control....................352
3. Forecasting....................356
4. Queueing Theory....................360
5. Line Balancing....................363
6. Pert and CPM....................365
7. Quality Control and Analysis....................370
8. Work Study....................377
9. Material Requirement Planning (MRP)....................382
10. Production, Planning and Control ...384
11. Linear Programming....................387

Chapter 12 :

Robotics & Mechatronics.. 391-416

1. Mechatronics....................391
2. Sensors and Other Devices....................396
3. Actuators and Stepper Motor....................402
4. Control System....................405
5. Robotics....................411

Chapter 13 :

Renewable Sources of Energy 417-440

1. Solar Energy....................417
2. Radiation Optics....................421
3. Geothermal Energy....................423
4. PV Cell....................424
5. Fuel Cell....................426
6. Wind Energy....................430
7. Biomass Energy....................435
8. Tidal Energy....................438
9. Ocean Thermal Energy Conversion 440

■■■■

Fluid Mechanics and Hydraulic Machines

1

I Introduction

- **Ideal fluid:** A fluid is said to be ideal if it is assumed to be both incompressible and non-viscous. Its bulk modulus is infinite ($k = \infty$).
- **Real fluid:** Real fluids have viscosity, finite compressibility and surface tension.

Remember:

☑ It encounters zero resistance to motion.
☑ Ideal fluid has no surface tension.
☑ Ideal fluids are imaginary and do not exist in nature.

- **Specific weight or weight density**, $w = \dfrac{\text{Weight}}{\text{Volume}} = \dfrac{mg}{V} = \rho g$

  where, ρ = Density, g = Acceleration due to gravity
  S.I. unit of specific weight is N/m^3
  Specific weight of water = 9810 N/m^3

- **Specific volume,** $v = \dfrac{1}{\text{Density}} = \dfrac{1}{\rho}$

  Specific volume of the water: $v = \dfrac{1}{\rho} = \dfrac{1}{1000} = 0.001\ m^3/kg$

- **Specific gravity (s) or Relative density**

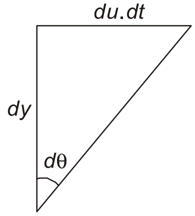
  $$\text{Specific gravity, } s = \frac{\text{Density of fluid}}{\text{Density of standard fluid}}$$

  $$= \frac{\text{Specific weight of fluid}}{\text{Specific weight of standard fluid}}$$

Remember:

☑ Specific gravity for water is 1.0 at 4°C and for mercury it is 13.6.
☑ Specific gravity varies with temperature, therefore it should be determined at a specified temperature (4°C or 25°C).

Newton's Law of Viscosity



$$\tau = \mu \frac{du}{dy} = \mu \frac{d\theta}{dt}$$

where, τ = Shear stress

μ = Coefficient of viscosity or absolute viscosity (or dynamic viscosity)

$\frac{du}{dy}$ = Velocity gradient

$\frac{d\theta}{dt}$ = Rate of angular deformation or Rate of shear strain

- For Newtonian fluid, coefficient of viscosity remains constant.

Dynamic Viscosity and Kinematic Viscosity

Due to viscosity, a fluid offers resistance to flow

(i) Dynamic Viscosity (μ):

- It is defined as shear stress required to produce unit velocity gradient or deformation rate.
- Its SI unit is Pascal-second or **Ns/m² or kg/ms**
- Its CGS unit is poise
- 1 poise = Dyne-s/cm² = **0.1** Ns/m²

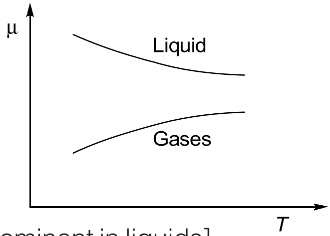
(ii) Kinematic Viscosity, $\nu = \dfrac{\text{Dynamic viscosity } (\mu)}{\text{Mass density } (\rho)}$

- Its SI unit is m²/s
- Its CGS unit is cm²/s or stoke
- 1 stoke = cm²/s = 10^{-4} m²/s

Remember:

☑ Viscosity of **liquids** generally decreases with temperature whereas viscosity of **gases** increases with increase in temperature.

☑ Liquids with increasing order of viscosity are gasoline, water, crude oil, castor oil.



☑ Viscosity of **water** at 20°C is 1 centipoise.

☑ Viscosity is due to

- Intermolecular forces of cohesion [dominant in liquids]
- Transfer of molecular momentum between fluid layers [dominant in gases].

Heat Transfer

2

I Conduction

"Conduction" is the transfer of heat from one part of a substance to another part of the same substance, or from one substance to another in physical contact with it, without appreciable displacement of molecules forming the substance.

Conduction Mechanism in Solid, Liquid, Gas

- Solid: In solids, heat is conducted by two mechanisms.
  (a) Lattice vibrations (b) Transport of free electrons
- Liquid and Gas: Heat is conducted by two mechanisms
  (a) Collisions (b) Diffusion
- Gases: In case of gases, the mechanism of heat conduction is simple. The kinetic energy of a molecule is a function of temperature. The kinetic energy of the molecules is due to their random translational motion as well as their vibrational and rotational motions. These molecules are in a continuous random motion exchanging energy and momentum. When a molecule from the high temperature region collides with a molecule from the low temperature region, it loses energy by collisions.
- Liquids: In liquids, the mechanism of heat transfer is similar to that of gases. However, the molecules are more closely spaced and intermolecular forces come into play.

Fourier's Law of Heat Conduction

The rate of heat conduction through a medium depends on the geometry of the medium, its thickness and material of the medium as well as temperature across the medium.

- Assumptions:
  The following are the assumptions on which Fourier's law is based:
  (i) Conduction of heat takes place under steady state conditions.
  (ii) The heat flow is unidirectional.
  (iii) The temperatures gradient is constant and the temperature profile is linear.
  (iv) There is no internal heat generation.
  (v) The bounding surfaces are isothermal in character.

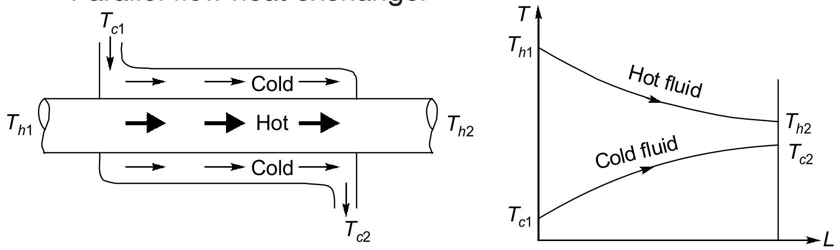
- **Direct transfer type:** Both and hot cold fluids donot have any physical contact between them but heat transfer through pipe wall or separation.
- **Direct contact type:** Both hot and cold fluid physically mixed and heat transfer takes places.

Remember:

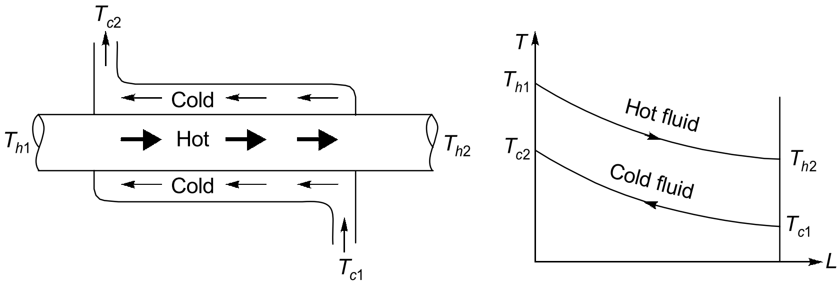
☑ Baffles are used in shell and tube type *H.E.* (Heat exchanger).

On the basis of relative direction of fluid motion:

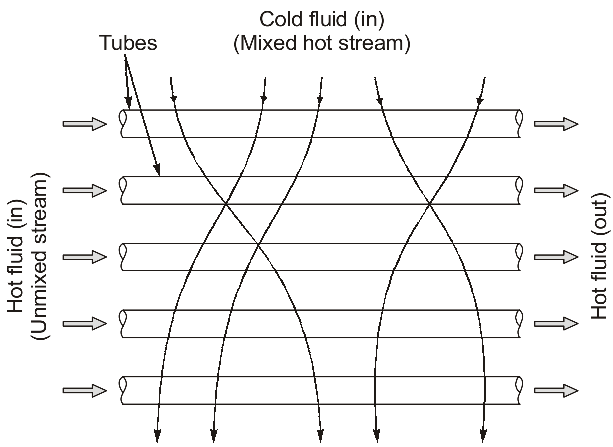
- Parallel flow heat exchanger



- Counter-flow heat exchanger



- Cross-flow heat exchanger



Power Plant Engineering

4

I Power Plant Economics

- **Load Curve:** A curve showing the load demand (variation) of consumer with respect to time is known as load curve. This curve may be for daily, weekly, monthly and on yearly basis. This a graph between **load and duration**.

  The energy consumption of consumer is given by an

  $$kWh = \int_{t_1}^{t_2} (kW) \cdot dt$$

- **Connected Load:** It is the sum of ratings in kilowatt of equipments installed in the consumer House/Area.
- **Demand Factor:** It is expressed as the ratio of maximum demand to the connected load. Its value **can not be** more than unity.
- **Average Load:** It is the ratio of area under load curve (kWh) and time period for which average load is calculated.
- **Load Factor:** It is the ratio of average load for a given period to the peak load during the same period. Its value will be **always less** than one.
- **Plant Use Factor (Plant Load Factor):** It is the ratio of energy produced in a given time to maximum possible energy that could be produced during actual number of hours of operation.

  $$\text{Plant use factor} = \frac{\text{Annual production of energy}}{\text{Operational hour in year x capacity of plant}}$$

II Fuel and Combustion

Type of Coal

- **Anthracite:** Anthracite contains **more than 86%** fixed carbon and less volatile matter, volatile matter helps in the ignition of coal. So it is often difficult to burn anthracite.
- **Bituminous:** It contain **46-86%** of fixed carbon and 20-40% of volatile matter. **Lower** the volatility **higher** will be the heating value.

- **Lignite:** It is the lowest grade of coal containing moisture as high as **30%** and high volatile matter.
- **Peat:** Peat contains up to 90% moisture and is not attractive as a utility fuel.

Coal Analysis

- **Proximate analysis :** The proximate analysis indicates the behavior of coal when it is heated.
  - **Moisture content of coal** : When 1 g sample of coal is subjected to a temperature of about 105ºC for a period of 1 hour, the loss in weight of the sample gives the moisture content of the coal.
  - **Volatile matter**: When 1 g sample of coal is placed in a covered platinum crucible and heated to 950ºC and maintained at that temperature for about 7 min, there is a loss in weight due to the elimination of **moisture and volatile matter**. Volatile matter consists of hydrogen and certain hydrogen - carbon compounds which can be removed from the coal simply by heating it.
  - **Ash content**: By subjecting 1 g sample of coal in an uncovered crucible to a temperature of about 720ºC until the coal is completely burned, a constant weight is reached, which indicates that there is only ash remaining in the crucible.
  - **Fixed carbon**: Fixed carbon is the difference between 100% and the sum of the percentages of moisture ash and volatile matter.

Thus proximate analysis of coal gives

$$FC + VM + M + A = 100\% \text{ by mass}$$

where, FC = Fixed carbon, VM = Volatile matter; M = Moisture, A = Ash

Remember:

☑ More volatile a coal more it will smoke but volatility helps in ignition.

☑ Lower rank coals are characterized by a **greater** oxygen content, that **aids** ignition and enhances combustibility and flame stability.

- **Ultimate analysis**

  The ultimate analysis gives the chemical elements that comprises the coal substance, together with ash and moisture.

$$C + H + O + N + S + M + A = 100\% \text{ by mass}$$

Here, C = Carbon, H = Hydrogen, O = Oxygen, N = Nitrogen, S = Sulphur, M = Moisture, A = Ash

Refrigeration and Air-conditioning

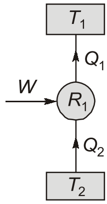
5

I Refrigeration

It is the process of maintaining lower temperature compared to surrounding.

Refrigeration Effect (R.E.)

It is the amount of heat which is to be extracted from storage space in order to maintain lower temperature.



Refrigeration Capacity (R.C.)

R.C. = Refrigeration effect (R.E.) × mass flow rate of refrigerant ($\dot{m}$)

$$\text{C.O.P.} = \frac{\text{R.E.}}{W} \times \frac{\dot{m}}{\dot{m}} = \frac{\text{R.C.}}{P_{\text{input}}} \quad (P_{\text{input}} = \text{Power input})$$

Remember:

☑ The **Kelvin-Planck** statement of second law is related to **heat engines** while the **Clausius** statement pertains to **refrigerators** and **heat pumps**.

☑ Higher the COP, lower will be the running cost.

Unit of Refrigeration (1 TR)

One TR is the amount of heat which is to be extracted from **1 tonne** of **water** at 0°C in order to convert it into ice at 0°C in **24 hours**.

1 TR = 50.4 kcal/min = 211 kJ/min = 3.5 kJ/s

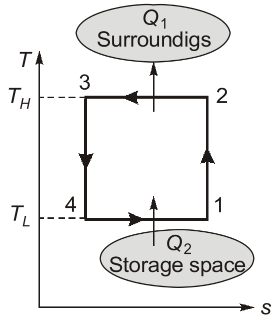
Ideal Refrigeration Cycle

It is **Reversed Carnot** cycle.

$$\text{C.O.P.} = \frac{Q_2}{Q_1 - Q_2} = \frac{T_L}{T_H - T_L}$$

T_H = Temperature of atmosphere

T_L = Temperature of storage space



Remember:

- ☑ All reversible cycles operating between **same** temperature limits have same COP.
- ☑ C.O.P. **does not** depend upon **working substance** in case of reversible Carnot cycle.
- ☑ Carnot C.O.P. for **cooling** varies from 0 to ∞ while for **heating** it varies from 1 to ∞.
- ☑ Heat rejection ratio (H.R.R.) = $\dfrac{Q_1}{RE} = 1 + \dfrac{1}{(COP)_{\text{Refrigeration}}}$

Volumetric Efficiency of Reciprocating Compressor (η_{vol})

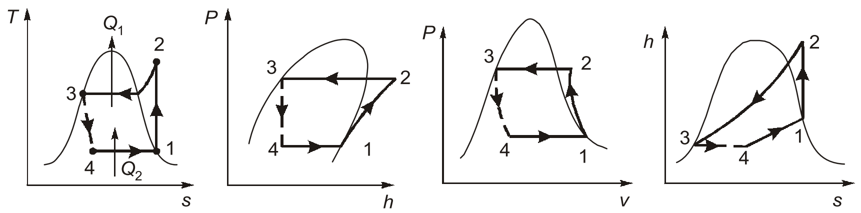
- $$\eta_{vol} = \frac{\text{Actual volume of refrigerant}}{\text{Swept volume}} = \frac{\dot{m}v_1}{\frac{\pi}{4}D^2 L.N.x.}$$

where, $\dot{m}$ = Actual mass flow of refrigerant (kg/min)
D = Diameter of piston, L = Swept length
v_1 = Specific volume at inlet of compressor
N = Speed (rpm), x = Number of cylinders

- $$\eta_{vol} = 1 + C - C\left(\frac{P_2}{P_1}\right)^{\frac{1}{n}}$$

where, C = Clearance ratio = $\dfrac{\text{Clearance volume}}{\text{Swept volume}}$
P_2 = Final pressure, P_1 = Initial pressure,
n = Polytropic index of **expansion**

Vapour Compression Refrigeration Cycle



Simple vapour compression cycle

	Process	Component
1 - 2	Isentropic compression	Compressor
2 - 3	Isobaric heat rejection	Condenser
3 - 4	Isenthalpic expansion	Expansion valve
4 - 1	Isobaric heat absorption	Evaporator

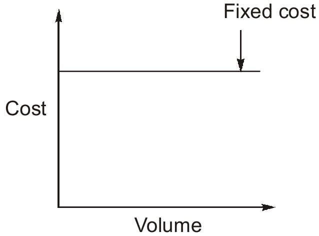
Industrial Engineering 11

I Break-Even Analysis

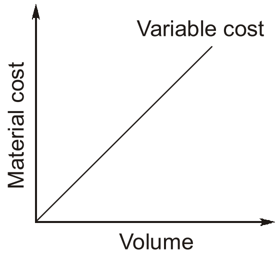
Break-Even analysis establishes the relationship among the factors affecting profit. It is a simple method of presenting to management the effect of changes in volume on profit.

Fixed Cost / Variable Cost / Mixed Cost

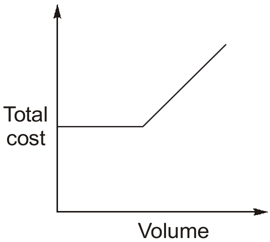
- **Fixed Cost** : The cost which do not change for a **given period**, with **change in volume** of production e.g. rent, taxes, insurance etc.



- Fixed cost does not mean they never change. They are constant upto a specific volume or range of volume.
- **Variable cost:**
  These cost vary directly with output volume.



- The ratio between **change in cost** and change in the level of **output** remain constant.
- **Mixed Cost :** This cost is a combination of semi-variable and semi-fixed cost.

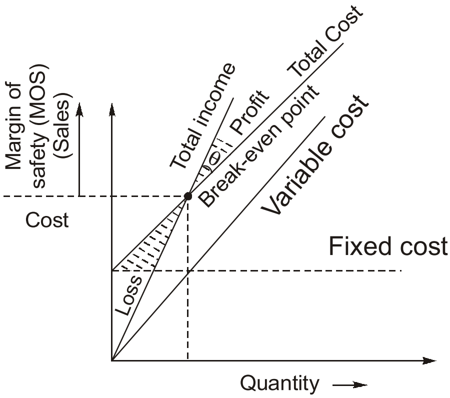


Assumptions in Break-Even Analysis

- Selling price will remain constant.
- **Linear** relationship between sales volume and cost.
- Production and sales quantity are equal.
- No other factor, **except quantity**, will affect the cost.

Break-Even Analysis

Let, assume; F = Fixed cost; v = Variable cost per unit; s = Sales price per unit; P = Profit; Q = Quantity produced and sold; Q^* = Break-even quantity (No loss, No profit point)



$$Q^*.S = F + Q^* \cdot V$$

$$\therefore \quad Q^* = \frac{F}{s - v}$$

$(MOS)_{sales}$ = Sales income at **present capacity** – Sales income at break even point

$$= \frac{P}{(P/V)\text{ ratio}}$$

$$(MOS)_{sales\%} = \frac{(MOS)_{sales}}{\text{Sales at full capacity}} \times 100$$

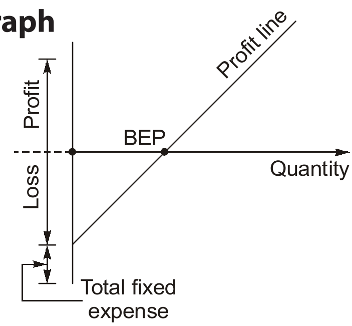
- **Angle of Incidence (θ):** It is the angle at which total sales lines cuts the total cost line.

Remember:

☑ Large angle of incidence (θ) indicates that profit are being made at **higher rate** and vice-versa.

Cost-Volume Profit Analysis / (P/V) Graph

It is used along with break-even graph. In this profit/loss is plotted on y-axis and quantity on x-axis.



$$\left(\frac{P}{V}\right)_{ratio} = \frac{S - V}{S} = \frac{F + P}{S_{(total)}}$$

$S - V$ is contribution margin/gross margin

Here, S = Total sales,

V = Total variable cost

$$\bar{p} = \frac{\sum_{i=1}^{N} pi}{N}, \; CL = n\bar{p}$$

$$\text{UCL} = n\bar{p} + 3\sqrt{n\bar{p}(1-\bar{p})} \; ; \; \text{LCL} = n\bar{p} - 3\sqrt{n\bar{p}(1-\bar{p})}$$

- **Chart 3 : c-chart (count of defect chart)**:

c-chart is made for number of defects which are present in a sample and is made for the situation where the sample size '*n*' is constant, '*n*' can be equal to 1 or more than one.

Sample number	Sample size (n)	No. of defective (d)	$c = \frac{d}{n}$
1	n_1	d_1	$c_1 = \frac{d_1}{n}$
2	n_2	d_2	$c_2 = \frac{d_2}{n}$
3	n_3	d_3	$c_3 = \frac{d_3}{n}$
⋮	⋮	⋮	⋮
N	n_N	d_N	$c_N = \frac{d_N}{n}$

A c-chart is used when it is not possible to compute a proportional defective and actual number of defects must be used.

$$c_L = \frac{\sum_{i=1}^{N} c_i}{N}$$

$$\text{UCL} = \bar{c} + 3\sqrt{\bar{c}} \; ; \; \text{LCL} = \bar{c} - 3\sqrt{\bar{c}}$$

Number of defects when exceed a particular, limit, they make an item defective. For the former case, we make a c-chart and for the later case, we make a np-chart.

- **Chart 4 : u-chart**: This chart is used for the situations where sample size is varying.

Sample number	Sample size (n)	No. of defective (d)	$u = \frac{d}{n}$
1	n_1	d_1	$u_1 = \frac{d_1}{n}$
2	n_2	d_2	$u_2 = \frac{d_2}{n}$
3	n_3	d_3	$u_3 = \frac{d_3}{n}$
⋮	⋮	⋮	⋮
N	n_N	d_N	$u_N = \frac{d_N}{n}$

Mechatronics and Robotics 12

I Mechatronics

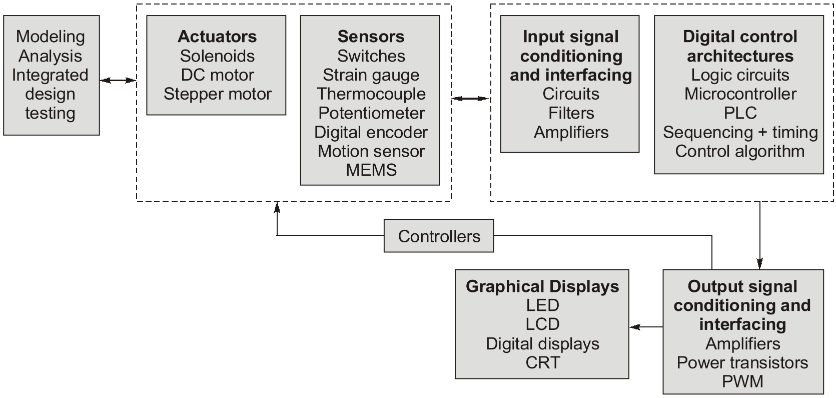
Mechatronics

Integration of electrical devices and electronic devices in the mechanical system leads to the development of mechatronics as technology. In mechatronics engineering, we control mechanical variable in mechanical process with the help of electrical devices and electronic sensor and processor.

Every mechatronics system consist of control operation as well as sensing mechanism.

Elements of mechatronics systems:

1. Information systems
2. Mechanical systems
3. Electrical systems
4. Computer systems
5. Sensors and actuators
6. Real-time interfacing



Key elements of a typical mechatronics system

Mechatronics Design Process: The mechatronics design process is essentially consists of three aspects, which are as follows:

1. **Modeling and simulation:** Here physical systems are represented by a suitable model for describing the behavior characteristics such as block diagram. Numerical or computer simulation methods are used for solving models.

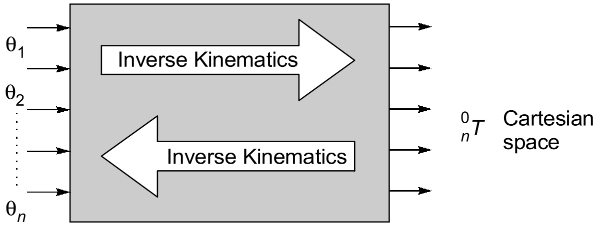


Fig. Schematic representation of forward and inverse kinematics

Denavit Hartenberg (DH) convention

The idea is to represent each homogeneous transform A_i as a product

A_i = $\text{Rot}_{z,\ \theta i} \cdot \text{Trans}_{z,\ di} \cdot \text{Trans}_{z,\ ai} \cdot \text{Rot}\ x,\ \alpha i$

$$= \begin{bmatrix} C\theta_i & -S\theta_i & 0 & 0 \\ S\theta_i & C\theta_i & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \bullet \begin{bmatrix} 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix} \cdot$$

$$\begin{bmatrix} 1 & 0 & 0 & a_i \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \bullet \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & C\alpha_i & -S\alpha_i & 0 \\ 0 & S\alpha_i & C\alpha_i 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

The parameter of transform are known as:

$$= \begin{bmatrix} C\theta_i & -S\theta_i C\alpha_i & S\theta S\alpha_i & a_i C\theta_i \\ S\theta_i & S\theta_i C\alpha_i & -C\theta_i S\alpha_i & a_i S\theta_i \\ 0 & S\alpha_i & C\alpha_i & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

The parameter of transform are known as:

- a_i : link length
- α_i : link twist
- d_i: link offset
- θ_i : link angle

■■■■

Renewable Sources of Energy 13

I Solar Energy

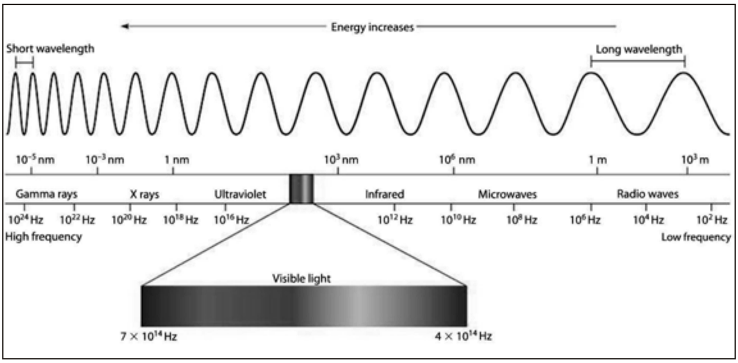
Renewable Energy

It can be defined for the energy flow which occurs naturally, repeatedly and at the replicable rate.

Reneable energy

S.No.	Merits	De-Merits
1.	Free of cost	Energy available in dilute form
2.	Environment friendly	Cost of harnessing energy is high
3.	Inexhaustible	Uncertainty of availability
4.	Low gestation period	Difficulty in storage and transportation

Electromagnetic Radiation Spectrum



Spectral Distribution of Solar Radiation