GYAN-VIGYAN SARITA: शिक्षा

A non-remunerative, non-commercial and non-political initiative to Democratize Education as a Personal Social Responsibility (PSR)

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Contents:

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Coming together is beginning;

keeping together is progress;

working together is success.

- Henry Ford

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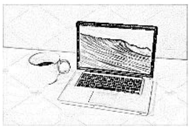

Editorial

Teaching-Learning-Teaching

Teaching-Learning-Teaching (TLT) completes the circuit of becoming a learned. Good teachers always try to make their disciples better than themselves. This making of better is done by imparting knowledge being at the learner's level and making the things understandable perfectly. If the things taught are not learnt in the same spirit in which it were communicated, then the learning is not complete. If the teacher cannot convert the disciple into a new teacher, neither the learning is complete nor is the teaching complete. This TLT process is completed if both the learners and the teachers have the same basic qualities: Extemporaneity, Perseverance, and Observance. These are the virtues that never become old.

Extemporaneity is the perfect delivery of the facts with reasoning. Perseverance means practicing the learned things faultlessly to the extent of best delivery to other learners. Observance is the thirst of learning which is never quenched until the teacher says, "you know all that I know".

Let us start with awakening the individuals with the hope that these individuals with awakened mind will take responsibility to awake the masses to prepare the life of the people, and not the people for the life.

Mathematically, the investment in knowledge is supposed to be the best because it pays the greatest interest in the form of genius minds who change the mirrors into windows through educating the neediest. Never forget that the roots of learning are bitter but its fruits are sweet.

This issue contains the regular study material on Physics, Chemistry and Mathematics under the Heading "Grow with the concepts".

The development of the common sense is the crucial need of the time. Common sense plays an important role in life. Common sense without education is better than education without common sense. Mentors of **Gyan Vigyan Sarita** are proficient in divulging their knowledge using this sense.

If you give a man a fish, you feed him for a day;

if you teach a man to fish, then you feed for a lifetime.

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GROWING WITH CONCEPTS

Concepts of an expert are not like a static foundation of a huge structure; rather it is like blood flowing in a vibrant mind.

During growing into an expert, each one must have used best of the books available on subject and received guidance of best of the teachers. Authors might have had limitations to take every concept thread bare from first principle and so also must be the constraint of teacher while mentoring a class with a diversity of inquisitiveness and focus. As a result, there are instances when on a certain concept a discomfort remains. The only remedy is to live with the conceptual problem and continue to visualize it thread bare till it goes to bottom of heart and that is an ***ingenious illustration****.*

In this column an effort is being made to take one topic on Mathematics, Physics and Chemistry in each e-Bulletin and provide its illustration from First Principle. We invite all experts in these subjects to please mail us their ingenious illustrations and it would be our pleasure to include it in the column.

We hope this repository of ingenious illustrations, built over a period of time, would be helpful to ignite minds of children, particularly to aspiring unprivileged students, that we target in this initiative, and in general to all, as a free educational web resource.

This e-Bulletin covers – a) Mathematics, b) Physics , and c) Chemistry. This is just a beginning in this direction. These articles are not replacement of text books and reference books. These books provide a large number of solved examples, problems and objective questions, necessary to make the concepts intuitive, a journey of educational enlightenment.

This column in next e-Bulletin shall contain Straight Lines in Mathematics, Fluid Mechanics in Physics and last Part VII of the series of articles on Organic Chemistry, basic principles and techniques.

Coordinator's Views

Value of Education vis-à-vis Cost

In an highly materialistic and competitive global market administrative, executive and business decision are having a leaning on **Return on Investment (ROI)**. In administrative decision focus on return is the compliance of directives; in execution focus is on completion of project or assigned tasks; while in business and commercial process is focus is on ratio of gain and investment. This ROI is based on discounted value of investments made over a period of time vis-à-vis discounted value of perpetual gains accrued out of the investments. The ROI is seen in two perspectives one is ratio of perpetual gains during the currency of the investment and second is cut off time of gains to reap out the investment.

The ROI concept has a validity in business environment. Nevertheless, over a period of economic recovery, post World War-II, impact of a business activity on social environment gained importance and ROI was rephrased as **Social ROI** (SOI). Companies walked extra mile to invest a part of their profits in philanthropy and was coined as **Corporate Social Responsibility (CSR)**. The central idea behind the CSR was to make social environment at place of the production or business conducive and supportive to their business objective. During the era of manpower intensive production process welfare of employees and their families was primarily aimed to maintain continuity of manpower to sustain the growth of production, and in turn the company. In present era of automation the CSR has extended beyond area of production and penetrated in consumers' domain. *It is experienced that generally corporate houses are siphoning statutory provisions under CSR for brand building and open up new business opportunities, rather than catering to the objective behind it; a new kind of politico-economics*. Most of successful business houses have entered into education compounding commercialization of education. Constraints of the state and the country to support quality education have created a new pasture for corporate houses and philanthropists to carry on with their business. *Such a scenario is leading to severe commercialization in education and in turn decline in quality of education*. Thus ROI of parents and students is constricted to worth of campus placement vis-à-vis money spent in the process preparing and acquiring the degree. If that be not the case, how come level of misappropriations, social injustice, crime, pollution etc., are seen to be rampant in elite societies.

Progressively, deterioration in educational quality has reached a brink where perceivable recourse is either the state and the country take ownership of educational domain and pump mammoth resources in a well-designed calibrated manner or elite section of society pro-acts to collectively complement, without discrimination, to *groom competence to compete* with a sense of **Personal Social Responsibility (PSR)** with *emphasis to unprivileged children*, spirit of **democratization in education**. While maintaining continuity, consistency and perseverance to groom competence is essential and a necessity of quality education. Government can blend such initiatives in their programmes such that state run schools and institutions promote such pro-active groups working with PSR to collectively complement each other.

Educational transformation is a slow process and the PSR model is seen as a reform where education is just not aimed a grooming competence to compete, but to create a process where our beloved descendants carry on a *legacy of human-values and –sensitivity and grow with coexistence in a sustainable and trustful environment*.

State-of-the-Art Technology opens up in an affordable and sustainable manner where passionate persons sow seed of the reform, and state and society nurture it to a level where fruits of reform yield value of education would be unimaginably higher than the cost.

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Remember your dreams and flight for them. You must know what you want from life. There is just one thing that makes your dream become impossible; the fear of failure.

- Paule Coelho

DANCE UPON A DREAM

Sandhya Tanwar

How does it feel when you see your dreams transforming into reality. It feels great! And when it happens, in that very moment, it becomes difficult to emote that situation. Life is all about achieving your dreams.

This is the story of a little girl who saw a dream in her childhood – to give a dance performance on a big stage. She was a bright student, who was always among top ten rankers but the area of dancing was never explored by her. It was her school's annual function at Talkatora Stadium, when she was in eighth standard. As they say, dance is a form of art and it has to be learnt, she gave audition for dance performance but could not be selected. She was passionate about music and used to sing a lot which gave an edge to her from others and luckily, she got selected to be a part of the choir for singing background songs for skits, kid's performances etc. She was deeply disheartened when her classmates and seniors were performing on- stage and she was performing on back-stage. Many of us are like that, we want to be in front of the audience or in client facing role so that our efforts get recognized. But, she could not gather that courage and confidence to go on-stage and perform, all she could do was to sing at the back-stage. Generally, kids in their childhood dream about becoming a doctor, engineer, lawyer etc. but this rejection paved her way to achieve a dream to become a dancer. She started believing that the best way to emote yourself was through dance. When you dance you forget everything for few minutes and you throw yourself into the sea of music and its lyrics. She never discussed her dream with anyone; it was residing in a tiny place deep in her heart. With her age, this dream also grew-up in her heart. She used to imitate dance steps from songs in the television and practice in a closed room by hiding it from everyone in the family. She never showed the steps she had learnt. Days, weeks, months and years gone by and she continued this practice. There happened to be a little achievement when she started dancing in small groups on the floor at several occasions like weddings, office parties etc. She gained little confidence when people started appraising her by saying – hey! you are a fantabulous dancer. Such compliments and praises acted like morale boosters for her and she started re-living her childhood dream to become a great dancer. Whenever she became happy or sad, she used to dance to emote her emotions. Someone told her that dance is like meditation where you forget everything and concentrate only on the rhythm. She never tried to explore this talent, never joined any dance classes and never shared this dream with anyone. However, she did not stopped dreaming about this dream.

One fine day, she was randomly discussing with one of her friends that she wanted to join some dance classes. That friend suggested a dance studio to her. It's always good to share dreams, because when you share, firstly you take it out from your heart and then the whole universe starts working on it along with you to conquer it.

To her surprise, that studio was about to start a workshop for their annual show in Talkatora Stadium. Without having any second thought she joined it. As the saying goes, where there is a will there is a way. She tried and managed to find time from her busy work schedule to attend these classes. This was the first time that this studio has conducted classes over weekends for working professionals. She gave her full time and dedication to attend the extra classes for long hours to excel the dance choreography. And she was quite successful in managing everything. It was like, the destiny has planned it for her exactly the way she wanted.

Finally, the D-day of performance came up. On that day, when she reached the stadium, she visualized her childhood, when she wanted to perform but could not do that due to the lack of the skill to dance. It made her little emotional and strong at the same time with a feeling that today is the day when her dream is on the path of its accomplishment. But somewhere, someone was praying for her best performance and after two trek-runs on stage, she gained more confidence and with full focus, determination and without any nervousness she performed it really well in the finale.

It gave her a feeling of utter joy and happiness when she danced upon her dream. She was herself surprised the way she gave her first full performance on stage. It feels awesome when you see your dream coming true. She is a more confident person now who have had an opportunity to perform in front of thousands of audiences in the stadium.

You will get whatever is meant to be yours, you will get whatever the destiny has planned for you but at the right time in a right way. All we have to do is to keep dreaming and making efforts to achieve it in whichever ways we can by overcoming all impediments in the path of this journey. Like dance, other skills needs to be learnt, be it singing music, excelling in academics, any adventure, sport, public speaking etc. Nobody is born with a complete skill-set of activities. We have to learn it and master it. If one perform without practice or preparation, there are high chances of failure or embarrassment. For any performance, one has to be prepared, nothing goes well without preparation. But when performing, give your full dedication; and success is bound to touch your feet.

NEVER STOP DREAMING, DANCE UPON YOUR DREAM. IT GIVES YOU A PURPOSE TO LIVE AND A WAY FORWARD TO AN AMAZING LIFE FULL OF HAPPINESS.

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IMORTANCE OF MUSIC EDUCATION IN ENHANCING LEARNING AND SKILL BUILDING IN CHILDREN

Aarti Sharma

Music education is of great importance for children as they climb the ladder of formal learning. A music-rich experience in the form of singing and listening as well as playing different kinds of instruments is immensely helpful in the psycho emotional and pedagogic development of the child.

Learning of music not only facilitates learning of diverse academic concepts but also enhances multifarious skills that children can use in other areas. Besides, it is a very integrating and stimulating pastime activity.

A child learning about music gets to tap into multiple skill sets, often simultaneously as they get to use their ears and eyes as well as different kinds of muscles. A curriculum integrating musically rich environment with academics benefits the children in following spheres.

1. Language Development: Growing up in musical surroundings is beneficial for children's language development. As children come into the world ready to decipher sounds and words, music education aids in augmenting those natural abilities.

The impact of music education can be seen in advancement of brain. Musical training physically develops the left side of the brain known to be involved with processing language and can actually wire the brain's circuits in specific ways. Relating common recognisable rhythms and tunes to various academic concepts can greatly helps imprint the knowledge on young minds.

This relationship between music and language development is also socially advantageous to young children as language proficiency is at the root of social skills and music education helps to strengthen the verbal expertise (which is a prerequisite for social skills) in the children .

2. Increased IQ: Imparting music education positively impacts the IQ of the young minds . This important finding was substantiated by a study conducted at University at Toronto in 2004. Under the study, nine months of piano and voice lessons were provided to a group of dozen six-year-olds on weekly basis. It was found that the children who were given music lessons tested an average three IQ points higher than the other groups.

3. Honing of Motor Skills: Motor skill are the skills required for controlling movements of different bodyparts. by involving the coordination of diverse muscles. Continuous exposure to music education provides improved sound discrimination and improvement of precision and coordination which is a must for development of fine motor skills in the children as they are required for performing numerous day to day functions such as writing, turning page , using computer system key boards, holding different items, cutting with scissors.

4. Development of Apatial-Temporal Skill: Spatial-temporal skills are the psychical ability to conjure and envision image, structural or geographical patterns and shapes using vision of mind. They not only help in navigation and visualization of objects but also hone problem-solving skill and organizational skills. Though nearly everyone has the capacity for this kind of reasoning, these abilities often vary from person to person.

Spatial Intelligence is particularly required in the field of architecture, engineering, maths, art, gaming, and working with computers. Music and spatial intelligence have a great linkage. Music education consistently helps to improve spatial-temporal skills in children and over a time eventually helping them in solving various multistep problems with spatial judgment abilities.

5, Just Being Musical: Notwithstanding the above enumerated benefits of music in formal learning and skill enhancement¸ there are many intrinsic benefits that accrue upon imparting music education to children including enhancement of concentration, Emotional Quotient EQ and a sense of discipline. It enriches children's enthusiasm for rhythm and melody, which create diiferent kind of emotional experiences and thus it not only bring pleasure but also make them happy and satiated.While they enjoying the nuances of music , they learn to respect the process of learning an instrument or learning to sing, which has its own merits.

The greatest benefit of music education is that it gives the child a better understanding of himself/herself in relation to the surrounding. Thus it broadens learning horizons children are involved in learning of music.

Author is Senior Audit Officer working with the office of Comptroller & Auditor General of India. She is a regular writer on issues of diverse nature having impact on education, health, environment, and social psychology and dynamics. **e-Mail ID:** aartiissar04@gmail.com

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GROWING WITH CONCEPTS - Mathematics

(Contd…)

LET's LEARN OUR NUMBER SYSTEMS

Prof. SB DHAR

We shall discuss here the

(a) Binary Number System,
(b) Octal Number System, and
(c) Hexadecimal Number System

Earlier to this we studied the **Decimal Number System** containing the digits 0,1,2,3,4,5,6,7,8, and 9 (i.e 10 digits).

The base of the **Decimal Number System** is 10 (equal to the digits available for indicating a number).

BINARY NUMBER SYSTEM

It consists of only two digits 0 (ZERO) and 1 (ONE). The base of this number system is 2.

The modern binary system was devised by the mathematician **Gottfried Leibnitz** in 1679.

Binary Number System uses two types of electronic pulses: **Absence** of pulse shows **0** and the **Presence** of pulse shows **1**.

Each binary digit is called as **bit**. Left-most bit of a number is known as Most Significant Bit (MSB) and the Right-most bit is known as Least Significant Bit (LSB).

Decimal	**Binary**	**Read as**
0	0	Zero
1	1	One
2	10	One Zero
3	11	One One
Decimal	Binary	Read as
4	100	One Zero Zero
5	101	One Zero One
6	110	One One Zero
7	111	One One One
8	1000	One Zero Zero Zero
9	1001	One Zero Zero One
10	1010	One Zero One Zero

Explanation:

Take a number 193.

It is a decimal number. It is mathematically written to be identified as $(193)_{10}$.

It means $(193)_{10} = 1x10^2 + 9x10^1 + 3x10^0$

Take another number $(1879.345)_{10}$.

It means $(1879.345)_{10} = 1x\ 10^3 + 8x10^2 + 7x10^1 + 9x10^0 + 3x10^{-1} + 4x10^{-2} + 5x10^{-3}$

Similarly, in Binary

(a) $(10)_2 = 1x2^1 + 0x2^0$ (in decimal)
(b) $(010101)_2 = 0x2^5 + 1x2^4 + 0x2^3 + 1x2^2 + 0x2^1 + 1x2^0$ (in decimal).
(c) $(1101001.101)_2 = 1x2^6 + 1x2^5 + 0x2^4 + 1x2^3 + 0x2^2 + 0x2^1 + 1x2^0 + 1x2^{-1} + 0x2^{-2} + 1x2^{-3}$ (in decimal).
(d) $(10)_2$ has 2 bits.
(e) $(010101)_2$ has 6 bits.

Positional Value

In Decimal Number System, the positions are: Ones, Tens, Hundreds, Thousands etc., from the RIGHT.

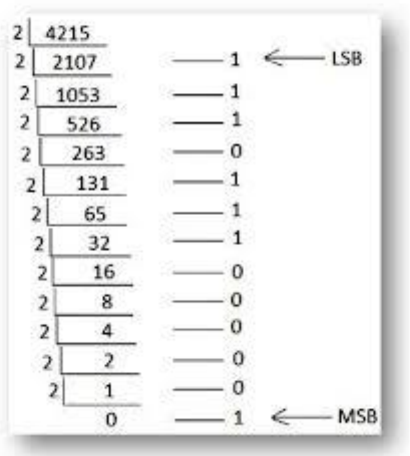
In Binary Number System, the positions are: Ones, Twos, Fours, Eights, etc.

As we move further Left, every number place gets 2 times bigger.

Note:

(a) A group of 4 bit is called **nibble** and group of 8 bit is called **byte**.
(b) Value of digit is determined by the position of digit in the number, where lowest value is for the Right-most position and each successive position to the Left has a higher place value.

Conversion from Decimal to Binary



$(4215)_{10} = (1000001110111)_2$, Or

$4x10^3 + 2x10^2 + 1x10^1 + 5x10^0 = 1x2^{12} + 0x2^{11} + 0x2^{10} + 0x2^9 + 0x2^8 + 0x2^7 + 1x2^6 + 1x2^5 + 1x2^4 + 0x2^3 + 1x2^2 + 1x2^1 + 1x2^0$

MSB (Most Significant Bit) is written in the extreme LEFT and the LSB (Least Significant Bit) is written in the extreme RIGHT (i.e. from Bottom to Top).

Operations

Addition

The RULES for addition are as under:

0 + 0 = 0

0 + 1 = 1

1 + 0 = 1

1 + 1 = 0, carry 1 to be added to the LEFT column.

Example:

```
 1 1 1       Carried digits
   0 1 1 0 1 0
  +1 0 1 1 0 0
  --------------
 1 0 0 0 1 1 0
  ---------------
```

Explanation:

$(011010)_2 = (26)_{10}$, and

$(101100)_2 = (44)_{10}$

$\Rightarrow 26+44=70 \Rightarrow (1000110)_2=(70)_{10}$

Multiplication

The RULES for multiplication are as under:

1 x 0 =0

0 x 1 =0

1 x 1 =1

It is done as in the Decimal Number System.

Example:

```
     1 1 1 0
  x     1 0
  ............
    0 0 0 0
  1 1 1 0 x
 ...............
 1 1 1 0 0
 .............
```

Check:

$(1110)_2 = (14)_{10}$

$(10)_2 = (2)_{10}$

$14 \times 2 = (28)_{10}$ and $(11100)_2 = (28)_{10}$

Subtraction

0 − 0 = 0

0 − 1 = 1, borrow 1

1 − 0 = 1

1 − 1 = 0

Example:

```
  1 1 0 0 1 1
  − 1 0 1 1 1
----------------
   1 1 1 0 0
....................
```

Check:

$(110011)_2=(51)_{10}$

$(10111)_2=(23)_{10}$

$(51)_{10}- (23)_{10}= (28)_{10}=(11100)_2$

Division

Division is done as in decimal.

```
       1 0 1
    _____________
1 0 1 ) 1 1 0 1 1
     − 1 0 1
      -----
        1 1 1
      −  1 0 1
        -----
         1 0
```

Check:

Divisor $(101)_2 = (5)_{10}$

Dividend $(11011)_2 = (27)_{10}$

Quotient $(101)_2 = (5)_{10}$

Remainder $(10)_2 = (2)_{10}$

Dividend = (Divisor)(Quotient)+(Remainder)

OCTAL NUMBER SYSTEM

It consists of 8 digits from 0 to 7 i.e., 0, 1, 2, 3, 4, 5, 6, and 7. It contains 8 digits, so the base of this number system is 8.

Octal numerals can be made from binary numerals by grouping consecutive binary digits into groups of three (starting from Right).

Example:

(a) Binary representation for $(75)_{10}$ (in decimal) is $(01001011)_2$

Hence, the octal of $(75)_{10}$ is

$(001)_2\ (001)_2\ (011)_2 = (113)_8$

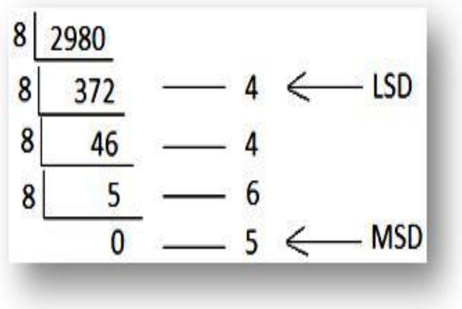
$= 1x8^2+1x8^1+3x8^0$

(b) The other examples are :
$(03105)_8$, and
$(4237.23)_8$

Note:

(a) It takes exactly three binary digits to represent an octal digit.
(b) Binary 000 is same as octal digit 0, binary 001 is same as octal 1, and so on.

Conversion from Decimal to Octal



Therefore,

$(2980)_{10} = (5644)_8$

HEXADECIMAL NUMBER SYSTEM

It consists of 16 types of digits from 0 to 9 and alphabets A, B, C, D, E, F. The base of number system is 16.

Digits from 10 to 15 are represented by A for 10, B for 11, C for 12, D for 13, E for 14, and, F for 15.

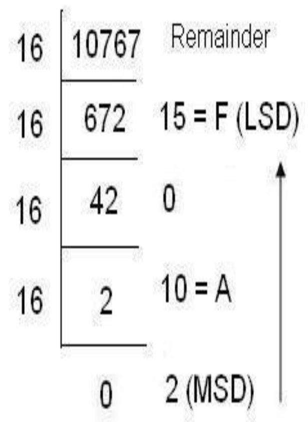
As numeric digits and alphabets are used to represent digits, this number system is also called as **Alphanumeric Number System**.

It is widely used in computer system.

Examples:

1. $(AF38)_{16}$
2. $(CE7.5B)_{16}$

Conversion from Decimal to Hexadecimal



i.e. $(10767)_{10} = (2A0F)_{16}$

Dr S.B. Dhar, is **Editor of this Quartrerly e-Bulletin**. He is an eminent mentor, analyst and connoisseur of Mathematics from IIT for preparing aspirants of Competitive Examinations for Services & Admissions to different streams of study at Undergraduate and Graduate levels using formal methods of teaching shared with technological aids to keep learning at par with escalating standards of scholars and learners. He has authored numerous books – Handbook of Mathematics for IIT JEE, A Textbook on Engineering Mathematics, Reasoning Ability, Lateral Wisdom, Progress in Mathematics (series for Beginner to Class VIII), Target PSA (series for class VI to class XII) and many more.
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A creative man is mitivated by the desire to achieve, not by desire to defeat others.

\- **Ayn Rand**

INVITATION FOR CONTRIBUTION OF ARTICLES

Your contribution in the form of an article, story poem or a narration of real life experience is of immense value to our students, the target audience, and elite readers of this Quarterly monthly e-Bulletin ***Gyan-Vigyan Sarita: शिक्षा****, and thus create a visibility of the concerns of this initiative. It gives them a feel that you care for them, and they are anxiously awaiting to read your contributions. We request you to please feel free to send your creation, by* ***20th of this month*** *to enable us to incorporate your contribution in next bulletin, subhashjoshi2107@gmail.com.*

We will be pleased have your association in taking forward path our plans as under-

- ***Next monthly Supplement to Quarterly e-Bulletin Gyan-Vigyan Sarita: शिक्षा shall be brought out 1st Dec'16***
- ***And this cycle monthly supplement to Quarterly e-Bulletin Gyan-Vigyan Sarita: शिक्षा shall continue endlessly***

We believe that this quarterly periodicity of e-Bulletins shall make it possible for our esteemed contributors to make contribution rich in content, diversity and based on their ground level work.

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ABOUT US

This is an initiative, not an abrupt eruption, but driven by spirit of returning back to society with a spirit of Personal Social Responsibility (PSR) by a team of co-passionate persons who have survived many decades of rough weather conditions. It is not an organization, and it aims at Democratization of Education, in spiritual sense.

It works on non-remunerative, non-commercial and non-political manner. Its financial model is based on Zero-Fund-&-Zero-Asset, wherein participation is welcome from those who wish to contribute, with तन और मन. As and when the feel need of धन to supplement the initiative ownership of Funds and Assets is theirs, we are just user if it.

OUR MENTORING PHILOSOPHY: Mentoring is not teaching, neither tuition nor coaching. It is an activity driven by passion and commerce has no place in it. In this effort is to caution students that -

- This place is not where they will be taught how to score marks and get higher ranks, but to conceptualize and visualize subject matter in their real life so that it becomes intuitive.
- This place is not to aim at solutions but inculcate competence to analyze a problem and evolve solution.
- This place does not extend selective and personalized attention, rather an opportunity to become a part of which is focused on learning and problem solving ability collectively.
- This place provides an opportunity to find students above and below one's own level of learning. Thus students develop not in isolation but learn from better ones and associate in problem solving to those who need help. This group dynamics while create a team spirit, an essential attribute of personality, while one learns more by teaching others.
- This place has strategically chosen Online Mentoring, so that those who are unprivileged can gather at one point and those who can facilitate learning of such students by creating, necessary IT setup. Aseperate **Mentor's Manual** is being developed to support the cause.
- We are implementing this philosophy through **Online Mentoring**

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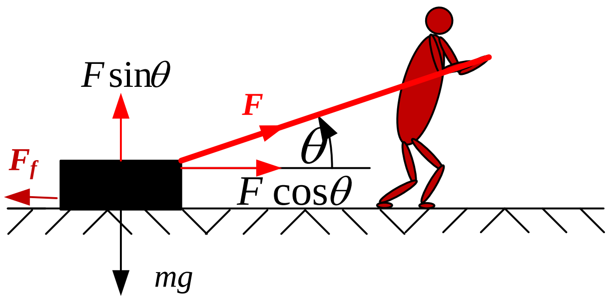
Contents

GROWING WITH CONCEPTS- Physics

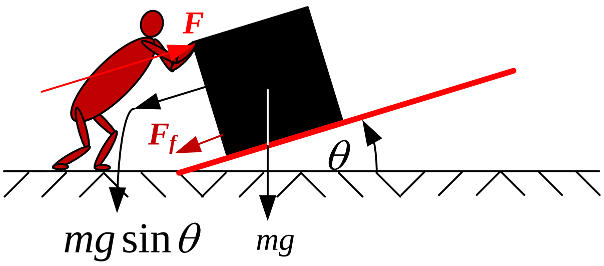
MECHANICS-III: Rotational Mechanics and Gravitation

Dr. Subhash Joshi

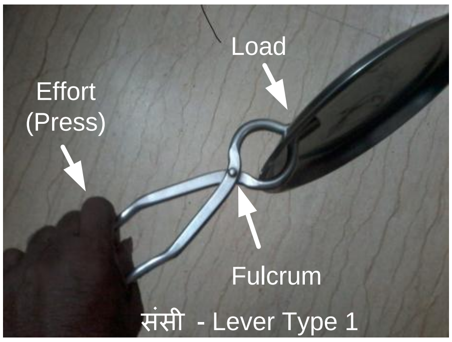
Advent of mechanics has been from predator age of human civilization. Then people used mechanics to manage their effort to suit their capacity and body posture out of their experience. Accordingly, their tools of hunting, pulling their prey to their destination, cutting, chopping etc. to consume their prey. Galileo and Newton formalized these experiences into asset of laws for a better understanding and appreciation of happening in the surrounding and improve effectiveness at work. Three examples, which everyone must have used since immemorial times are wedge, liver and pulley. It is time to see how basic laws of kinematics and dynamics apply in these rudimentary examples and set up a platform for wider understanding of physics and its analysis for enhancing effectiveness at work.

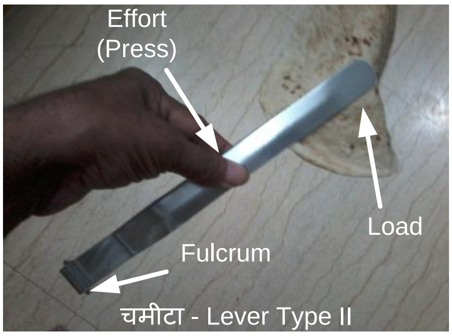


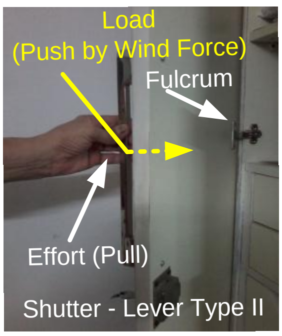
Pulling a heavy object with an inclined string is a basic example of managing a load within capacity with a body posture.. In either case effective force is less than the actual force F applied at work. While, pulling the force $\boldsymbol{F}$ is being used to overcome horizontal friction ($\boldsymbol{F_f}$). In this case vertical component of Force ($F\sin\theta$) being less than weight of the object (***mg***) there is no vertical lift of the object. Whereas, in case of pushing an object on an inclined plane , the applied force along the plane is used to overcome friction ($\boldsymbol{F_f}$) and component of the weight of the object along the inclined plane ($F\sin\theta$), These, two concepts have been in use out of experience and learned by descending generations by observation who have been close to ground realities, without knowing resolution of forces. These are now a matter of intuition and not by learning physics.



Uses of kitchen sansi, kitchen chamita and pilling a shutter against wind force are intuitive, but the underlying concepts of physics i.e. ***Torque of force ($\bar{\tau}$)*** *involves identifying fulcrum, distance of point of application of force from fulcrum ($\bar{r}$ a vector), the force ($\bar{F}$ another vector) and* ***cross product of displacement*** $\bar{\tau} = \bar{r} \times \bar{F}$ needs to be discussed. Analysis of these devices in physics is called Lever where three new terms are being introduced.

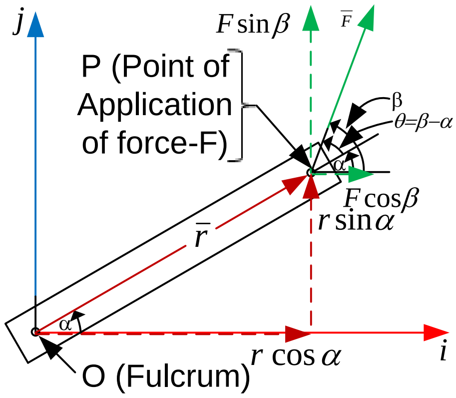




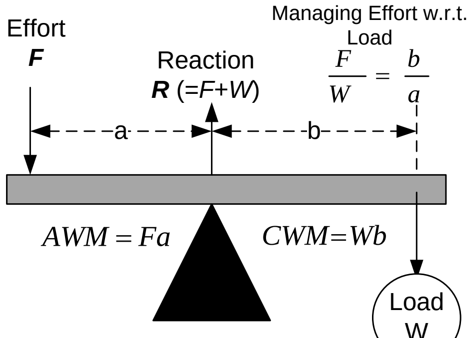


Contents

Principle of moment when in a state of equilibrium it becomes a subject matter of statics and is analysed by equating ***clock-wise moment (CWM)*** to ***anti-clockwise moment (AWM)*** i.e. $\tau_C = \tau_A$. Whereas, in a state of in-equilibrium i.e. $\bar{\boldsymbol{\tau}} \neq \mathbf{0}$ it causes rotational motion and is a subject matter of rotational dynamics. This is explained with a generic example where an arm of length ***r*** is hinged at point **O** called fulcrum and force $\bar{F}$ is applied at Point **P** at an angle $\boldsymbol{\beta}$ with the arm (line joining points **O** and **P** i.e. $\bar{\boldsymbol{r}}$.

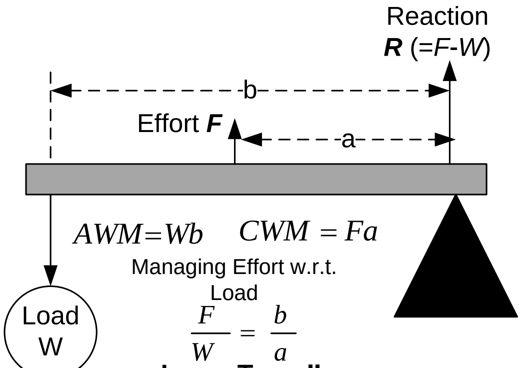


Considering principles of moment, CWM $= \tau_C = (F\cos\beta)(r\sin\alpha)$, and AWM $= \tau_A = (F\sin\beta)(r\cos\alpha)$. For equilibrium to exist or $\tan\alpha = \tan\beta$, or $\alpha = \beta$, or $\theta = 0$ or π i.e. force vector ($\bar{F}$) is co-linear with displacement vector ($\bar{r}$) for equilibrium condition to exist. While, considering principle of torque $\bar{\tau} = \bar{r} \times \bar{F} = rF\sin\theta\,\bar{z}$. Thus for anti-clockwise rotation i.e. as per right-hand-screw-rule in vector cross-product $\sin\theta > 0$, or $0 < \theta < \pi$, and for clockwise rotation $\sin\theta < 0$, or $\pi < \theta < 2\pi$.

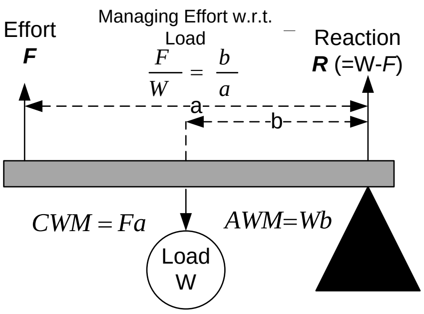


Lever Type-I

Considering the aforesaid principle of moment, the three types of lever are conceptualized here. It is seen that moment is in conformance with the definition of torque. In this Fulcrum is the fixed point with respect to load and effort. Accordingly, distances of point of application of effort and load are calculated from it. Moreover, angle between Effort or Load and line joining the point of its application and fulcrum are perpendicular (angle being 90^0). If seen from the perspective of torque CWM and AWM are straight product of Load/Effort and their distances from fulcrum, since $\sin 90^0 = 1$. Thus, is concluded that principle of moment is in conformance with the definition of torque. These types of lever are generic in nature and it is just a matter of observation and identifying Effort, Load and Fulcrum in the surrounding and establish its relevance to one of the three types. Another, important inference is management of effort w.r.t. load by manipulating ratio of ***b*** and ***a*** so as to accomplish required task within one's own capacity to apply effort.

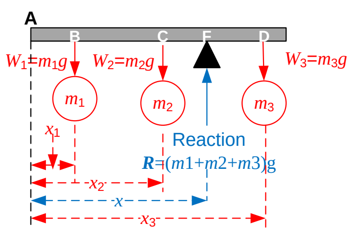
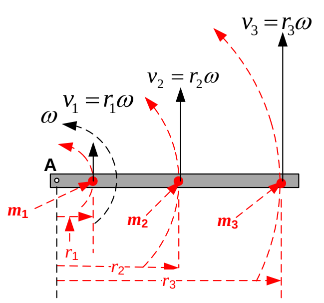


Lever Type-II

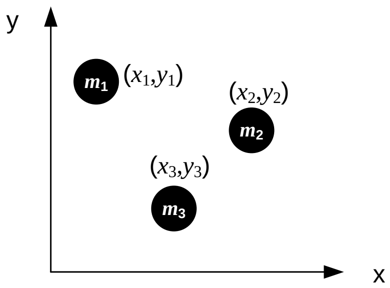


Lever Type-IIi

This is the point where understanding of ***Centre of Mass (COM)*** and ***Moment of Inertia (MOI)*** becomes essential to make a headway to continue journey into concepts of physics and being developed in parallel, for a better appreciation of the underlying concepts. Here, emphasis is on ***system of particles or rigid bodies***, having a unique property *where, relative distance between particles constituting the system or the shape of* *the body remains un-affected*. Accordingly, for illustrations a system of masses is considered which has a light bar is considered having three masses m_1, m_2 and m_3, at distance x_1, x_2 and x_3, respectively, ***on a line***, from end **A** us being considered for arriving at COM and pivot **A** for MOI. Here, introduction of a new term ***Angular Momentum*** : $(\bar{L})$, is essential. It is like torque which causes angular rotation

Centre of Mass		**Moment of Inertia**	
	Let bar with three masses is in equilibrium when wedge is placed at point F, at a distance x from end A. As per NTLM in IFOR, Reaction $R = (m_1 + m_2 + m_3)g$. Further, in a state of equilibrium CWM =AWM. Accordingly,		Here, system particles is moving with a constant angular velocity ω, about the pivot A. Thus linear momentum of three masses shall be $P = m_1v_1 + m_2v_2 + m_3v_3 = m_1r_1\omega + m_2r_2\omega + m_3r_3\omega$.
$\left((m_1g)x_1 + (m_2g)x_2 + (m_3g)x_3\right) = \left((m_1 + m_2 + m_3)g\right)x$, or $x = \frac{m_1x_1 + m_2x_2 + m_3x_3}{m_1 + m_2 + m_3}$		And angular momentum of the system about pivot A is: $\bar{L} = \sum \bar{r}_i \times \bar{p}_i = \sum m_i r_i^2 \bar{\omega} = I\bar{\omega}$, or $I = \sum m_i r_i^2$	

Likewise, for ***a system of particles on a plane, the concept of COM and MOI*** goes as under:

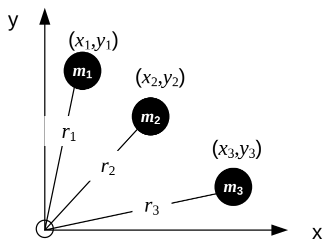


Extending the concept of COM for mass distributed along a line to that distributed on a plane, coordinates of COM are:

$$x = \frac{\sum m_i x_i}{\sum m_i}, \text{ and}$$

$$y = \frac{\sum m_i y_i}{\sum m_i}$$

This is known as ***Perpendicular Axis Theorem of COM***



Likewise,

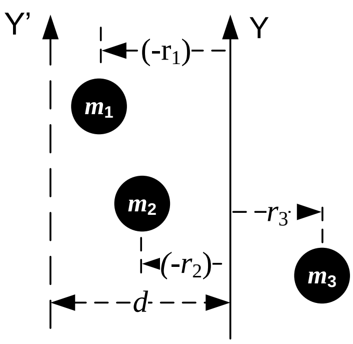
$$I = \sum m_i r_i^2$$
$$= \sum m_i (x_i^2 + y_i^2)$$
$$= \sum m_i\, x_i^2 + \sum m_i\, y_i^2$$
$$= I_x + I_y$$

This is known as ***Perpendicular Axis Theorem of MOI***

And, if the mass distribution is in the space the concept COM and MOI is an extrapolation of the above in third dimension (**z**) is under -

$$x = \frac{\sum m_i x_i}{\sum m_i},\ y = \frac{\sum m_i y_i}{\sum m_i} \text{ and } z = \frac{\sum m_i z_i}{\sum m_i}$$

$$I_x = \sum m_i\,(y_i^2 + z_i^2)\ ;\ I_y = \sum m_i\,(x_i^2 + z_i^2)\ I_y = \sum m_i\,(x_i^2 + y_i^2)$$



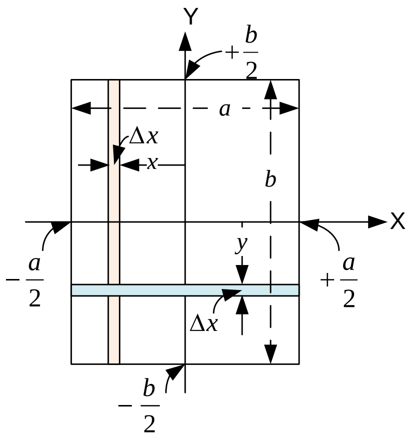
This leads to ***Parallel Axis theorem of MOI,*** which is about determining MOI along a *new axis (**Y'**) parallel to the axis (Y) which passes through COM of the system of masses and MOI along Y is known..*

$$I'_y = \sum m_i (r_i + d)^2 = \sum m_i \left(r_i^2 + d^2 + 2r_i d\right) = I + \sum m_i d^2 + 2\sum m_i r_i$$

$= I + \sum m_i d^2$; Since Y is passing through COM and hence $\sum m_i r_i$,=0 .

Considering the mathematical formulation of *COM is a point at which summated moment of mass distribution about a fixed axis is equal to moment of total mass*. Likewise, *MOI is double moment, i.e. moment of moment, of mass distribution about a fixed axis.*

But, mostly one encounters rigid bodies made of same material in which distribution mass is continuous and uniform. It is illustrated through COM and MOI for a rectangular sheet having uniform mass density ρ.

Rectangular Sheet	**Centre of Mass**	**Moment of Inertia**
	Let, x be the distance of COM from Y axis, and y from X axis, then $x = \int_{-\frac{a}{2}}^{\frac{a}{2}} (\rho b \Delta x) x = \rho b \int_{-\frac{a}{2}}^{\frac{a}{2}} x \Delta x$ $= \rho b \left[\frac{x^2}{2}\right]_{-\frac{a}{2}}^{\frac{a}{2}} = 0$ $y = \int_{-\frac{b}{2}}^{\frac{b}{2}} (\rho a y) y = \rho b \int_{-\frac{b}{2}}^{\frac{b}{2}} y \Delta y$ $= \rho b \left[\frac{y^2}{2}\right]_{-\frac{b}{2}}^{\frac{b}{2}} = 0$ Since, $x - 0$ *and* $y = 0$, COM is at origin.	Let, x be the distance of COM from Y axis, and y from X axis, then $I_x = \int_{-\frac{a}{2}}^{\frac{a}{2}} (\rho a \Delta x) x^2 = \rho a \int_{-\frac{a}{2}}^{\frac{a}{2}} x^2 \Delta x$ $= \rho b \left[\frac{x^3}{3}\right]_{-\frac{a}{2}}^{\frac{a}{2}} = \frac{\rho b}{3}\left[\frac{a^3}{8} - \left(-\frac{a^3}{8}\right)\right] = \frac{pa^3 b}{12}$ $I_y = \int_{-\frac{b}{2}}^{\frac{b}{2}} (\rho a y) y^2 = \rho b \int_{-\frac{b}{2}}^{\frac{b}{2}} y^2 \Delta y$ $= \rho a \left[\frac{y^3}{3}\right]_{-\frac{b}{2}}^{\frac{b}{2}} = \frac{\rho a}{3}\left[\frac{b^3}{8} - \left(-\frac{b^3}{8}\right)\right] = \frac{pab^3}{12}$ This, $I_x = \frac{Ma^2}{12}$ and $I_y = \frac{Mb^2}{12}$; Here, $M = \rho ab$

Likewise, all other typical shapes of rigid bodies are cases of application of integration and are summarized below.

Shape	**Centre of Mass**	**Moment of Inertia**
Circular plate on XY Plane	COM at Centre of Circle	$I_z = \frac{MR^2}{2}; I_x = I_y = \frac{MR^2}{4}$
Thin circular rim	COM at Centre of Circle	$I_z = \frac{MR^2}{2}; I_x = I_y = \frac{MR^2}{4}$
Sold Cylinder along Z axis	COM on the axis of Cylinder	$I_z = \frac{MR^2}{2}$
Hollow Cylinder along Z axis (Inner and Outer radii ***a*** and ***b***)	COM on the axis of Cylinder	$I_z = M\left(\frac{b^2}{2} - \frac{q^2}{2}\right)$
Thin hollow Sphere	COM at Centre of Hollow Sphere	$I_z = \frac{2}{3} MR^2$
Solid Sphere	COM at Centre of Sphere	$I_z = \frac{2}{5} MR^2$

The MOI for different shapes has been ***normalized into Radius of Gyration (ROG 'k')*** such that $I = Mk^2$. It may be observed from the MOI of a few cross-sections brought out above, as mass is distributed along perimeter, created a void within, the MOI increases, or conversely with hollow cross-sections same MOI is achievable for lesser mass and thus conserving the material. Therefore, *coming up with different cross-sections conveys and their related MOI and ROG is just not a quest of mathematician or a physicist but is to increase capacity for same effort.* This is in accordance with NSLM applicable to rotational mechanics, as may be seen in comparison of translational and rotational mechanics. This the reason why use of different cross-sections viz. cylinder pipe, tee , angle, I–section are made in various structure that have been created around.

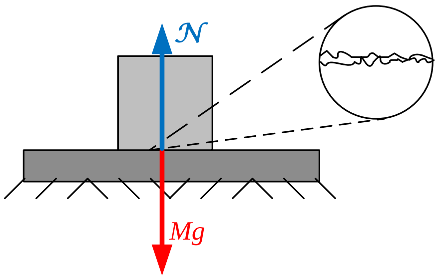
Comparison of Translational and Rotational Mechanics: Translational kinetics and dynamics, like rotational mechanics have identical set of equations except interchange of variables, where *Moment of Inertia can be called Rotational Inertia,* as under –

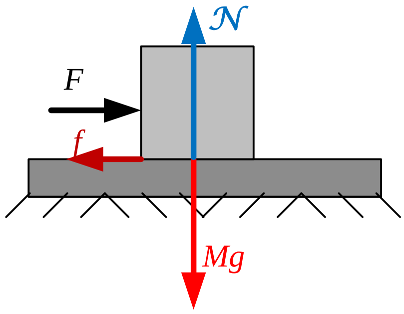
Displacement: $\bar{\boldsymbol{x}} \leftrightarrow \bar{\boldsymbol{\theta}}$; Velocity :$\bar{\boldsymbol{v}} \leftrightarrow \bar{\boldsymbol{\omega}} = \frac{d\bar{\theta}}{dt}$; Momentum: $\bar{\boldsymbol{P}} = \boldsymbol{m}\bar{\boldsymbol{v}} \leftrightarrow \bar{\boldsymbol{L}} = \boldsymbol{I}\bar{\boldsymbol{\omega}}$; Acceleration: $\bar{\boldsymbol{a}} \leftrightarrow \bar{\boldsymbol{\alpha}} = \frac{d\bar{\omega}}{dt}$;
Impulse: $\bar{\boldsymbol{J}} = \int_{t_1}^{t_2} \bar{\mathrm{F}}\mathrm{dt} \leftrightarrow \bar{\boldsymbol{J}} = \int_{t_1}^{t_2} \bar{\Gamma}\mathrm{dt}$; **Effort:** $\bar{\boldsymbol{F}} = \boldsymbol{m}\bar{\boldsymbol{a}} = \frac{d\bar{P}}{dt} \leftrightarrow \bar{\Gamma} = \mathrm{I}\bar{\boldsymbol{\alpha}} = \frac{d\bar{\omega}}{dt}$; **Energy:** $\boldsymbol{mgh} = \frac{1}{2}\boldsymbol{mv^2} \leftrightarrow \frac{1}{2}\boldsymbol{I\omega^2}$

Accordingly, ***First, Second and Third Equations for Rotational Motion*** (**ERM**) are –

$\omega = \omega_0 + \alpha t$: FERM; $\theta = \omega_0 t + \frac{1}{2}\alpha t^2$: SERM; $\omega^2 = \omega_0^2 + 2\alpha\theta$: TERM.

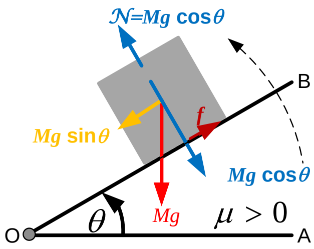
Friction: Resistance to motion is quite frequently talked about and this called ***friction***. This a resistance is offered by irregularities of surfaces of two object coming in contact during displacement. Howsoever a surface be polished, when it is viewed with a magnifier, surface irregularities can be observed, higher the magnifying power more prominently the irregularities become visible. These surface irregularities could be in the form of surface dips or spikes, as shown in the inset, and these my get interlocked while in contact with each other. Unless, an external force is applied to either crush away such interlocks or ride over the spikes relative displacement of the objects cannot take place. In a *frictionless surface, a hypothetical case*, slightest horizontal force on mass $\boldsymbol{M}$ would be sufficient to cause its acceleration as per NSLM, component $\boldsymbol{g}$ along the surface, and the force, is ZERO; as a result the object would start sliding on the surface. But, friction is a reality and external force (F) required to cause relative displacement and this called Frictional force (*f*). Nature of this static friction force is non-conservative (*f*), i.e. it is non-recoverable, unlike the conservative force of spring and gravitational pull. Here a new term ***Coefficient of Friction*** **($\boldsymbol{\mu}$)** is introduced. It has two forms ***Static Coefficient of Friction*** *(μ,) and* ***Kinetic Coefficient of Friction*** **($\boldsymbol{\mu_k}$)**. It is to be noted that always $\boldsymbol{\mu_k < \mu}$ and its reason is required *and kinetic friction, unlike static friction, is conservative this would be elaborated in illustration of translational-cum-rotational motion.*





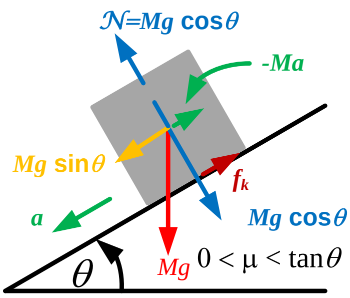
As per laws of conservation of energy (LCE) energy spent in overcoming frictional force gets transformed into heat; this process continues until relative displacement continues. This heat being localized is enough to soften tiny result is a kind of momentary lubrications. As soon as motion stops, softened surface dissipates heat into surrounding matter and surface irregularities reappear. Implications of ***Coefficient of Friction*** on inclined plane are as under.

a. Static Friction On an Inclined Plane: Two planks OA and PB are hinged at O are placed horizontally. A block of mass M is placed on the plank OB. Gradually, the edge at B of the plank OB is lifted, keeping plank B horizontal such that an angle $\boldsymbol{\theta}$ is formed. It is seen that, with $\boldsymbol{g}$ acting vertically downward components of the weight along the plane $mg \sin \theta$ tends to slide down the block and it should as per NSLM, but it does not so. This continues until a particular angle for a specific combination of plank and the block. It the friction that is preventing the relative displacement of the block. Its cause is the component of weight perpendicular $mg \cos \theta$ across the plank, as per NTLM, causes interlocking of surface irregularities of the plank and the block. In the process, as $\boldsymbol{\theta}$ increases, $mg \sin \theta$ also increases, while force responsible for friction $mg \cos \theta$ decreases until $mg \sin \theta = mg \cos \theta$ when just the block tends to slide. It leads to critical angle $\boldsymbol{\theta}$ which goes into defining ***coefficient of friction*** ($\boldsymbol{\mu}$) such that $\mu = \tan \theta = \frac{Force\ of\ Friction}{Normal\ Reacton}$. There are other method of determining μ, while this is considered to be the simplest method.

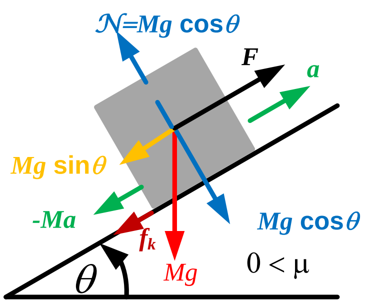


It needs to be reasoned out what happen to friction when $\theta < \tan^{-1}\mu$, does friction cease to exist, if that be the so as per NSLM, the acceleration should start as soon as $\theta > 0$, which does not happen, the reason is that *friction neither an external force nor a self-generating force, it a reaction of the force tending to cause relative displacement, and thus it would not exceed the force causing displacement.*

b. Kinetic Friction Under Gravity: In this setup angle $\boldsymbol{\theta}$ is so chosen that $\tan \theta > \mu$, and this would lead to $mg \sin \theta > f$, and causes a relative acceleration ($\boldsymbol{a}$) of the block as per NSLM. Accordingly, a pseudo force $-Ma$ appears on the body such that $a = \frac{\boldsymbol{mg \sin \theta - f_k}}{\boldsymbol{M}}$. It is to be noted in this equation of acceleration instead of $\boldsymbol{f_k}$ for frictional force has been used instead of $\boldsymbol{f}$. Since body is accelerating, i.e. in a state of motion and hence work done in overcoming friction is causing softening of surface and thus momentary lubrication and hence ***frictional force under dynamic state is less than static friction and so also*** $\boldsymbol{\mu_k < \mu}$ ***.***

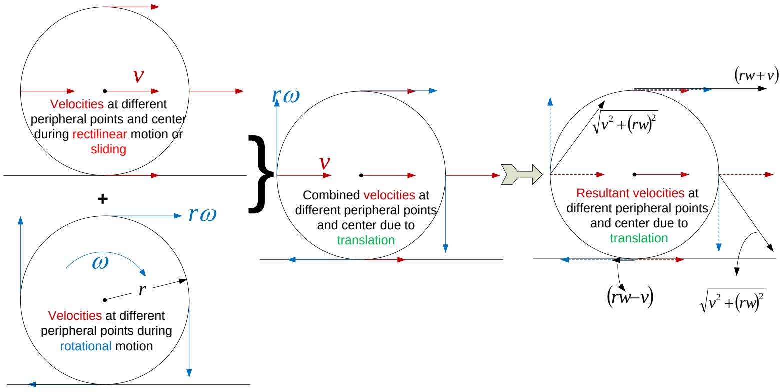


c. **Dynamic Friction Under Upward Pull on an Inclined Plane:** On an inclined plane such that $\theta > \tan^{-1}\mu$, there is a natural tendency of the block to slide, but it can be made to slide upwards inly on application of an external force $\boldsymbol{F}$ such that $F > (mg \sin \theta + f)$, and once it starts moving then $F > (mg \sin \theta + f_k)$. It is to be noted that f_k, in this case is downwards the slope and against the cause of action $\boldsymbol{F}$ and motion of the block**.** The acceleration $\boldsymbol{a}$ of the block remains as per NSLM and is $a = F - (mg \sin \theta + f_k)$. As the journey of rolling motion starts it is interesting to reveal that f_k is against the cause of action i.e. the force causing motion, but not always against the direction of motion.



It is ironical about friction that at some occasions effort is to reduce using lubricant, viz cycle chain running hard, while it uses friction is used to control stopping of motion; friction is a cause of motion, rolling and speed control it is helpful to keep persons, objects and structure to remain in place despite various perturbations and impacts. Better appreciation and understanding of friction would grow with the in-depth application through problems solving. At this point it is relevant to correlate basic concepts correlating translational and rotational in under force(s) acting on a body.

Translational and Rotational motion: In the kinematics covered earlier ***translational or rectilinear motion*** *(even called linear motion) were considered discretely. It is the time to extend both the types of motions in conjunction in a rigid body. It is essential to define rigid body as the one which traverses displacement without changing its either shape or relative position of particles w.r.t. each other.* This is true in case of sliding, but in case of rolling while a body performs rotational motion, it changes its position also and such a kind of motion is called translational motion. Simplest example is rolling of a wheel. All particles in cylinder performing rectilinear motion travel same distance at any time. While, in the cylinder performing rotational motion axis remains stationary, while all particles traverse same angular displacement at any time. Both the motions are emulated in same cylinder and to facilitate analysis, rectilinear velocities and tangential velocities of particles on four diametric opposite points are shown separately, combined and so also resultant velocities. In the instant diagram tangential velocity being greater than rectilinear velocity. Conceptually there are three cases that emerge out of it.

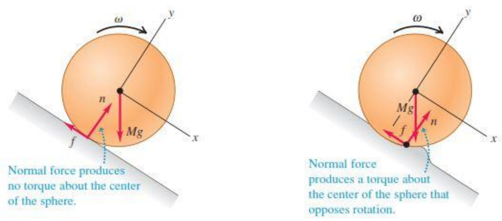


Case 1 $(= |\bar{r} \times \bar{\omega}| = |\bar{v}_t| = v_t$: This is case of matching tangential velocity and translational velocity at the line of contact point of the cylinder with horizontal surface, i.e. perfect rolling. In this velocity of the line of contact shall be Zero Velocity. And with slightest increase in $\boldsymbol{\omega}$ the rotational motion would start slipping on the direction of angular velocity $\boldsymbol{\omega}$, and hence friction at this point would be forward, i.e. opposite to the direction of motion of cylinder w.r.t. horizontal surface, the IFOR.

Case 2 $((r\omega > v_t)$: In this case rotational motion of the cylinder would start ***slipping*** in the direction of angular velocity i.e. $\boldsymbol{\omega}$, which is against translational velocity. Hence, friction at this point would be forward, and thus exert a torque which tends to retard $\boldsymbol{\omega}$. *Example of slipping is when despite paddling, flywheel fails to catch up motion.*

Case 3 $((r\omega < v_t)$: In this case rotational motion of the cylinder would start ***skidding*** in the direction of translational motion i.e. and hence friction at this point would be backward and tending to accelerate angular velocity i.e. $\boldsymbol{\omega}$. Example of *skidding is a vehicle in high speed fails to stop translational motion despite applying brakes.*

At this point it is relevant to discriminate between kinetic friction, caused by translational motion and rolling friction caused by rotational motion. This requires a close examination of contact surface are in case of rolling which is a point in case of sphere and a line in case of cylinder. This point or line of contact creates high pressure at that which causes deformation of the contacting surfaces. Thus obstruction to the motion in case of rolling is not due force causing tearing of surface, rather it is in riding mitigation of undulation which keep advancing in the direction of rolling and is best explained in case of rolling on an inclined plane (Ref.: University Physics, 13th Edn., pp 320). This phenomenon can ve experienced by rolling a bar on a compressible surface.



These concepts, are sufficient to start analysis of kinematics of translational-cum-rotational motion which are, otherwise, mutually independent. It requires use of ***D' Alembert's Principle to analyse independence of dynamics of translational motion and rotational motion***.

Any number forces acting on an object can be resolved into an equivalent force ($\bar{F}$), which is Zero in case of equilibrium and when non-zero the object is experiencing translational motion as per NSLM. Each of the force may or may not exert a torque, which depends on point of application of force. Accordingly, for convenience of expressions, resultant force shall be taken along $\hat{x}$ and rotational torques on $\hat{y}-\hat{z}$ plane.

Translational Motion of a Rigid Body: Let there be a particle of mass m at a point $(x,y,z))$ and is experiencing a force $\bar{F}_x = m\frac{d^2\bar{x}}{dt^2} = F_x\hat{x}$. Taking this particle to be a part of a rigid body. Therefore, under influence of an *external force* $\bar{F}_{e-x}$ along $\hat{x}$, which create an *internal force* $\bar{F}_{i-x}$ as a reaction of the external force. Accordingly, *effective force* on the particle would be $\bar{F}_x = \bar{F}_{e-x} + \bar{F}_{i-x}$. This is true along all the three orthogonal axes ***x*, *y*,** and ***z***. Accordingly, $\bar{F}_y = m\frac{d^2\bar{y}}{dt^2}$, and $\bar{F}_z = m\frac{d^2\bar{z}}{dt^2}$.

Applying NSLM to the system of particles, constituting a rigid body,$\sum\bar{F}_x = \sum m\frac{d^2\bar{x}}{dt^2}$; $\sum\bar{F}_y = \sum m\frac{d^2\bar{y}}{dt^2}$; and $\sum\bar{F}_z = \sum m\frac{d^2\bar{z}}{dt^2}$. Here, $\sum m = M$, i.e. mass of the rigid body. These set of equations are being used to analyse translational motion of a rigid body. Let, (x_0, y_0, z_0) be the coordinates of the Centre of Mass (COM), and $(x', y', z'))$ be coordinates of a particle w.r.t. to COM, then $= x_0 + x'$; $y = y_0 + y'$; and $z = z_0 + z'$. This leads to a set of equations as under-

$\sum\bar{F}_x = \sum m\frac{d^2\bar{x}}{dt^2} = \sum m\frac{d^2}{dt^2}(x_0 + x') = \sum m\frac{d^2}{dt^2}x_0 + \sum m\frac{d^2}{dt^2}x' = M\frac{d^2}{dt^2}x_0$; since for a rigid body about COM $\sum m\frac{d}{dt}x' = \sum m\frac{d^2}{dt^2}x' = 0$. Thus, ***it is observed that external forces resolved along an axis causes a rigid body to move whole mass of the bode is collected at COM and accordingly it produces translational acceleration (TA) of its COM***.

Rotational Motion of a Rigid Body: Extending the above concept of translational motion of a rigid body to rotational motion about ***x*-axis** the equation would be-

$$\bar{\tau}_x = \tau_x\hat{x}; \text{Hence, } \tau_x = \sum(\bar{y}\times\bar{F}_z + \bar{z}\times\bar{F}_y) = \sum(yF_z - zF_y) = \sum m\left(y\frac{d^2z}{dt^2} - z\frac{d^2y}{dt^2}\right)$$

$$= \sum m\left((y_0+y')\frac{d^2}{dt^2}(z_0+z') - (z_0+z')\frac{d^2}{dt^2}(y_0+y')\right)$$

$$= M\left(y_0\frac{d^2}{dt^2}z_0 - z_0\frac{d^2}{dt^2}y_0\right) + \sum m\left(y'\frac{d^2}{dt^2}z_0 - z'\frac{d^2}{dt^2}y_0\right) + \sum m\left(y_0\frac{d^2}{dt^2}z' - z_0\frac{d^2}{dt^2}y'\right) + \sum m\left(y'\frac{d^2}{dt^2}z' - z'\frac{d^2}{dt^2}y'\right)$$

$$= M\left(y_0\frac{d^2}{dt^2}z_0 - z_0\frac{d^2}{dt^2}y_0\right) + \left(\frac{d^2z_0}{dt^2}\sum my' - \frac{d^2y_0}{dt^2}\sum mz'\right) + \left(y_0\sum m\frac{d^2}{dt^2}z' - z_0\sum m\frac{d^2}{dt^2}y'\right) + \sum m\left(y'\frac{d^2}{dt^2}z' - z'\frac{d^2}{dt^2}y'\right)$$

$$= \sum m\left(y'\frac{d^2}{dt^2}z' - z'\frac{d^2}{dt^2}y'\right)$$

Here, $\sum my' = \sum mz' = 0$ and $\sum m\frac{d^2}{dt^2}y' = \sum m\frac{d^2}{dt^2}z' = 0$, on the lines similar to that, while determining acceleration of rigid body. Moreover, while, object is performing translational motion along $\hat{x}$, the $y_0$and z_0 remain constant therefore, $\frac{d^2}{dt^2}y_0 = 0$ and likewise $\frac{d^2}{dt^2}z_0 = 0$

Transforming, Cartesian coordinates (***y'*, *z'***)of each point w.r.t. COM into polar form $r'\angle\theta'$ such that $y' = r'\cos\theta'$, and $z' = r'\sin\theta'$, it leads to: $y'\frac{d^2}{dt^2}z' = (r'\cos\theta')(r'\alpha\cos\theta' - r'\omega^2\sin\theta') = r'^2(\alpha\cos^2\theta' - \omega^2\sin\theta'\cos\theta')$ and likewise, $z'\frac{d^2}{dt^2}y' = (r'\sin\theta')\big(-(r'\alpha\sin\theta' + r'\omega^2\cos\theta')\big) = -r'^2(\alpha\sin^2\theta' + \omega^2\sin\theta'\cos\theta')$. Accordingly,

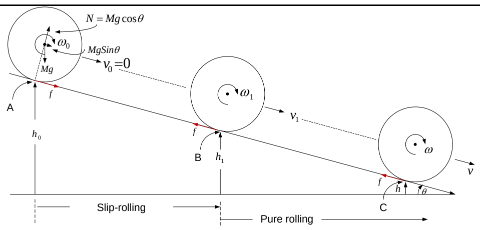
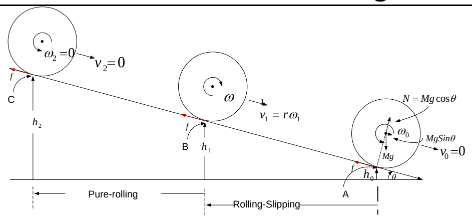
$$\tau_x = \sum m\left(y'\frac{d^2}{dt^2}z' - z'\frac{d^2}{dt^2}y'\right) = \sum m\left(r'^2\left(\alpha\cos^2\theta' - \omega^2\sin\theta'\cos\theta'\right) - \left(-r'^2\left(\alpha\sin^2\theta' + \omega^2\sin\theta'\cos\theta'\right)\right)\right)$$

$$= \alpha\sum mr'^2 = I\alpha$$

Thus, it is evident that angular acceleration (AA) of a body about its COM is the same as if it were fixed and the same set of forces act upon the body.

Dynamics of Rotational-cum-Translational Motion on an Inclined Plane: *It is interesting to analyse dynamics of rotational motion, which in presence of friction becomes translational and vice-versa and how does the friction becomes a conservative force.* In this text the object us considered to be either spherical or cylindrical, and it is most common in application. Once an analysis on an inclined plane is done, it can be easily transformed to motion on a plane by substituting making angle of inclination $\theta = 0$. In this three types of forces and associated accelerations come into play: **a)** Force causing motion, **b)** Gravitational Force and **c)** Frictional Force. Various cases of rolling and translational motion (combined) of an object viz. circular ring, hollow/solid cylinder, circular disc solid/punched, hollow/solid sphere, having mass M and radius r, on an inclined plane at an angle θ can be classified as: a) Rolling in the direction of slope, b) Rolling against direction of slope. Each of this has three possibilities, slipping, pure rolling and skidding as discussed earlier.

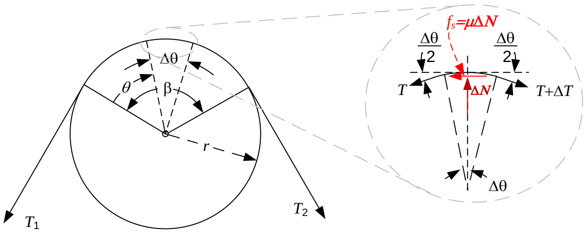
From consideration of friction, at point of contact relative velocity between two surfaces is zero and this makes it a case of static friction. While, in case of slipping or skidding the relative velocity is non-zero and hence it becomes a case of kinetic friction. Here, while driving shaft torques is ignored, initial angular velocity of the rolling body $(\omega_0)$is assumed.

<table>
<tr><th>Direction of Rotation Clockwise Towards the Slope</th><th>Direction of Rotation Anti-clockwise Against the Slope</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>Proposition: A solid cylinder of radius (r) is having an clockwise angular velocity $(-\boldsymbol{\omega_0})$, and axis horizontally perpendicular to the line of slope, is brought in contact with a plane having an angle of inclination (θ). At time t_0, initial translational velocity $v_0 = 0$.</td><td>Proposition: A solid cylinder of radius (r) is having an anti-clockwise angular velocity $(\boldsymbol{\omega_0})$, and axis horizontally perpendicular to the line of slope, is brought in contact, at point A, with a plane having an angle of inclination (θ), At time t_0, initial translational velocity $v_0 = 0$, and $\mu_k g\cos\theta > g\sin\theta$ for above. If $\mu_k g\cos\theta < g\sin\theta$, it would slip down.</td></tr>
<tr><td>Motion from A to B: Rolling-cum-Slipping, since $rw > v$ and kinetic friction retards ω, while v would tend to increase.
TA: $a = g\sin\theta + \mu_k g\cos\theta$; AA: $\alpha = \frac{\mu_k g\cos\theta}{I}$</td><td>Motion from A to B: Rolling-cum-Slipping, since $rw > v$ and kinetic friction retards ω, while v would tend to increase. In the process, it would roll upwards on the plane.
TA: $a = g\sin\theta - \mu_k g\cos\theta$; AA: $\alpha = -\frac{\mu_k g\cos\theta}{I}$</td></tr>
</table>

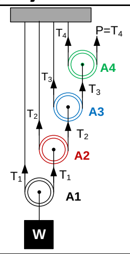
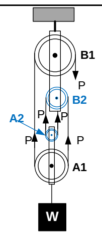
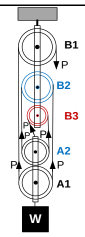
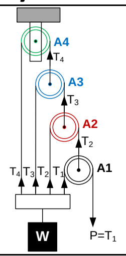
$v_1 = 0 + at = (\sin\theta - \mu_k g\cos\theta)t;\ \omega_1 = -\omega_0 + \alpha t$ As per COE: $mg(h_0 - h_1) + \frac{1}{2}I\omega_0^2 = \frac{1}{2}I\omega_1^2 + \frac{1}{2}mv_1^2$ **Motion from B to C: *Pure rolling,*** $rw > v$, and static friction comes into play against direction of motion, as shown, and tend to increase both ω and v. TA: $a_1 = g\sin\theta - \mu g\cos\theta$; AA: $\alpha_1 = -\frac{\mu g\cos\theta}{I}$ $v = v_1 + a_1 t = (\sin\theta - \mu g\cos\theta)t;\ \omega = -\omega_1 + \alpha_1 t$ As per COE: $mg(h_0 - h) + \frac{1}{2}I\omega_0^2 = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$	$v_1 = 0 + at = (\sin\theta - \mu_k g\cos\theta)t;\ \omega_1 = \omega_0 + \alpha t$ As per COE: $mg(h_1 - h_0) + \frac{1}{2}I\omega_0^2 = \frac{1}{2}I\omega_1^2 + \frac{1}{2}mv_1^2$ **Motion from B to C: *Pure rolling,*** $rw > v$, and static friction tend to increase both ω and v. TA: $a_1 = g\sin\theta - \mu g\cos\theta$; AA: $\alpha_1 = -\frac{\mu g\cos\theta}{I}$ $v_2 = v_1 + a_1 t = (\sin\theta - \mu g\cos\theta)t;\ \omega_2 = -\omega_1 + \alpha_1 t$ As per COE: $mg(h_0 - h) + \frac{1}{2}I\omega_0^2 = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$ **Motion After Reaching C:** it is downward pure rolling

Having attained pure rolling if the surface changes to that of lower μ_k, it will lead to translational speed greater than corresponding angular velocity ($v > rw$) and this is a situation of skidding.

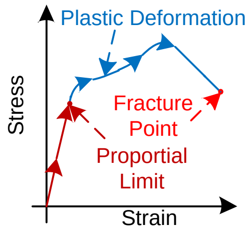
Friction of a Pulley on a Circular Surface: This is another interesting case of friction when a rope or a belt passes over a circular surface, it could be a static pulley or a drum, as shown in the figure. In this case unlike ideal pulley tension along the rope or belt is not uniform. Different tensions T_1 and T_2 on two ends of the rope having angle of contact β is analysed within inset for an element of rope with contact angle $\Delta\theta$. Applying conditions of equilibrium along tangential line and radial lines independently $\sum F_t = 0;\ -T\cos\frac{\Delta\theta}{2} + (T + \Delta T)\cos\frac{\Delta\theta}{2} - \mu\Delta N = 0$ and likewise, $\sum F_e = 0; -T\sin\frac{\Delta\theta}{2} - (T + \Delta T)\sin\frac{\Delta\theta}{2} + \Delta N = 0$. Under limiting condition $\Delta\theta \to 0$, these equation lead to $dT = \mu dN$, and $-Td\theta + T\frac{d\theta}{2} = dN = \frac{dT}{\mu}$, or $Td\theta = \frac{dT}{\mu}$. Alternatively, $\frac{dT}{T} \approx \mu d\theta$. Integrating this equality over contact angle β, $\int_{T_1}^{T_2}\frac{1}{T}dT = \int_0^{\beta}d\theta; \ln\frac{T_2}{T_1} = \theta$. Alternatively $T_1 = T_2e^{\theta}$.

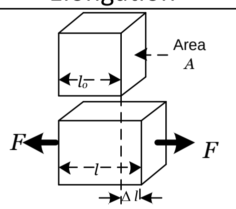
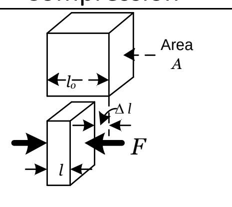
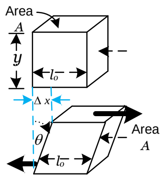
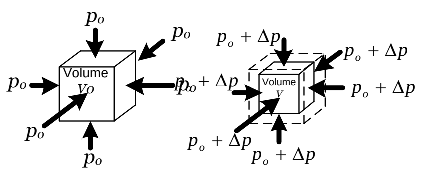


Pulley Systems: Despite friction being a retardant in rigid pulleys, rolling pulleys are in extensive use, where it is assumed that pulley moves with the rope, but has a frictionless rotation about its axel. This leads to $T_1 = T_2$ and development of pulley systems, involving more than one pulley, which are classified into three main types as under.

Pulley System : Type-I	**Pulley System : Type-II**		**Pulley System : Type-III**
			
Let, *n* be the number of pulleys system	a. It uses a continuous rope and hence each pulley experiences equal pull. b. Distance between Two block of Pulleys is large enough to consider, each section of continuous rope to be nearly vertical. c. Let , *n* be the number of pulleys in lower block, Each block od pulleys is rigid		Let , *n* be the number of pulleys system
W=2T_1, T_2=2T_1, T_3=2T_2, P=T_4=2T_3 In a system of ***n*** Pulleys, W = 2^nP	W=2*n*P	W=(2*n*+1)P	P=T1, T2=2T1, T3=2T2, T4=2T3, W=T1+T2+T3+T4=P+2P+4P+8P In a system of n pullets N Pulleys $W = \left(\frac{2^n - 1}{2 - 1}\right)P = (2^n - 1)P$
Upward displacement of load is : ***x*** Disp. of A1=2^1x, Disp. of A2=2^2x Disp. of A3=2^3x, Disp. of A4=2^4x	Disp. of load is : ***x*** Disp. effort =2*nx*	Disp. of load is : ***x*** Disp. effort =(2*n*+1)*x*	Upward displacement of load is : ***x*** Disp. of A3=2^1x, Disp. of A2=2^2x Disp. of A1=2^3x, Disp. of A4=$(2^4-1)x$
a. In this analysis, pulleys and rope are assumed to be weightless and frictionless b. **Work done on Load is equal to work done by effort**			

Physical Deformation of Solids: *Action of force or torque on a solid body if causes relative displacement of molecules, it leads to physical deformation, which causes internal stresses till an equilibrium is reached between external force and internal stress.* ***Robert Hook*** *formally stated this phenomenon in 1676, later* ***Thomas Young*** *established proportionality of stress to the deformation of the body known as* ***Young's Modulus****. A typical stress-strain curve shows loss of proportionality and that is the stress level where plastic deformation takes place with thinning of cross-section and ultimate fracture. Study of this deformation and its restoration after removal of external stress is broadly called* ***Elasticity****. Intrinsically there are three types of deformations and physical property of solids are classified as under –*



Linear *Deformation*		**Surface Deformation**	**Bulk Deformation**
Tensile Stress	Compressive Stress	Shear Force	Compressive Force
Elongation	Compression	Slippage	Compression
			
$\text{Stress}[\boldsymbol{\sigma}] = \frac{\text{Force}[F]}{\text{Cross}-\text{sectional area Perpedicular to the area}[A]}$ Dimension of Stress: $[ML^{-1}T^{-2}]$ Unit: N/m^2		Shear Stress$[\boldsymbol{\tau}] = \frac{\text{Tangential Force}[F]}{\text{Cross-sectional of the Tangential surface}[A]}$ Dimension of Stress: $[ML^{-1}T^{-2}]$ Unit: N/m^2	Pressure on all faces (P), it is uniform all along the surface area of the solid. Dimension of Stress: $[ML^{-1}T^{-2}]$ Unit: N/m^2
$\text{Strain}[\boldsymbol{\varepsilon}] = \frac{\text{Change in length under stress}[\Delta l]}{\text{Original length }[l_0]}$ Dimension Less Unit : Per Unit		Shear Strain $[\boldsymbol{\gamma}] = \frac{\text{Slip of opposite faces under shear stress}[\Delta x]}{\text{Perpendistance between opposite faces }[y]} = \tan\theta$ Dimension Less Unit : Per Unit	Volumetric Srain $[\boldsymbol{\theta}] = \frac{\text{Change in volume under compresseion }[\Delta V]}{\text{Perpendistance between opposite faces }[V_0]}$ Dimension Less Unit : Per Unit
$Young's\ Modulus\ of\ Elasticity\ [\boldsymbol{E}\ or\ \boldsymbol{Y}] = \frac{Stress\ [\sigma]}{Strain\ [\varepsilon]}$ Dimension of $\boldsymbol{E}$ or $\boldsymbol{Y}$: $[ML^{-1}T^{-2}]$ Unit of $\boldsymbol{E}$ or $\boldsymbol{Y}$: N/m^2		Shear Modulus of Elasticity $[\boldsymbol{G}\ or\ \boldsymbol{S}] = \frac{Stress\ [\boldsymbol{\tau}]}{Strain\ [\boldsymbol{\gamma}]}$ Dimension of $[\boldsymbol{G}\ or\ \boldsymbol{S}]$: $[ML^{-1}T^{-2}]$ Unit of $[\boldsymbol{G}\ or\ \boldsymbol{S}]$: N/m^2	Bulk Modulus of Elasticity $[\boldsymbol{K}\ or\ \boldsymbol{B}] = \frac{Stress\ [\boldsymbol{P}]}{Strain\ [\boldsymbol{\theta}]}$ Dimension of $[\boldsymbol{K}\ or\ \boldsymbol{B}]$: $[ML^{-1}T^{-2}]$ Unit of $[\boldsymbol{K}\ or\ \boldsymbol{B}]$: N/m^2
Visible effect:		**Visible Effect:** Rectangles become Parallelograms	**Visible Effect:** Volume changes but shape does not change.
Longer and Thinner	Shorter and Fatter		
Effect on exceeding elastic limits:		**Effect on exceeding elastic limits**:	**Effect on exceeding elastic limits**:
Starts with Plastic elongation and ends up in breakage	Starts with plastic compression and ends up in fusion or crushing.	Starts with plastic slippage with chipping i.e. shearing off of material.	Starts with plastic deformation and ends up in fusion or crushing

Here, Force is the cause, while stress is the intensity of the cause. Deformation is the effect, while strain is the relative deformation. And the proportionality constant between intensity of cause and relative deformation is the physical property of the material.

Torque causing rotational motion of a shaft causes torsional stresses in it and it akin to shear stress at cross-sections of the shaft intervening rotational torque at one end and driven revolving load at the other end. A typical representation of failure of shaft of a pump under torsion, in the event of excessive corrosion leading to reduction in area of cross-section of the shaft is shown. This is more a case of engineering application of the concept. ***In***

every man-made system stress-strain analysis and limiting deformation within permissible limits elasticity corresponding, a property of material used, is implicit in its design and engineering.

Gravitation: Understanding of gravitation has its roots in understanding of cosmos. Sky, rise and fall of sun changes in phases of moon, and stars in sky in various formations must have been mystery as well as a fascination to observe. This had become been an integral part of culture and spiritual believes prevalent in Egyptian, Indian, Chinese and Greek cultures, with their own model of universe. It was Nicolas Copernicus who published heliocentric model in 1543, in which Sun is positioned near the centre of universe. After him, Tycho Brahe in later half of 16th century recoded his observations with naked eye on Moon orbiting Sun and planets around the Sun. But, mistakenly considered Sun to be revolving around the Earth. Johannes Kepler analysed observations of Tycho and in 1609 he published Two laws of planetary motion and published third law in 1619. Galileo Galilei, developed telescope to propound the authenticity of heliocentric model of Copernicus, proposed about a century ago. He also analysed motion of free fall of bodies known as Kinematics. By then sequence of discoveries had speeded up and it prompted Isaac Newton to propound Laws of Motion and Gravitational Force so as to authenticate Kepler's Laws of planetary motion. After almost Three centuries, in 1915 Albert Einstein in his General Theory of Relativity predicted Gravitational waves, and a century later in Sept'2015 ripples of gravitational waves were detected using highly sophisticated Two Laser Interferometer Gravitational-wave Observatory (LIGO) detectors in USA and Australia. These ripples were caused by collision of Two black holes estimated to have occurred about 1.3 billion years ago.

This makes Kepler's laws quite inquisitive to appreciate beauty of mathematics and physics which aims at discovery of nature. Accordingly, after illustrating Laws of Gravitation, derivation of Kepler's Laws would help to connect the two as a natural consequence of painstaking and honest observations, and analysis made by these forerunner of science.

Newton's Laws of Gravitation:

Inquisitive Newton tried to relate planetary motion to factors that determine acceleration of celestial bodies and guessed that –

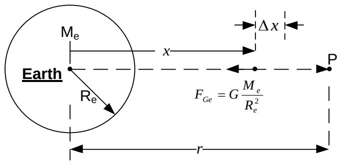
a. Acceleration $(\alpha)$of a body towards earth is inversely proportional to the square of distance of the body from the centre of earth (r), i.e.$\alpha = \frac{1}{r^2}$.
b. Force (F) of attraction towards centre of earth is proportional to the mass of object (m), i.e. $F\alpha\frac{m}{r^2}$, and is in accordance with NSLM.
c. Force (F) on a body due to earth must be equal to the force on the body by mass of earth proportional to mass of earth (M), in accordance with NTLM and thus $F\alpha\frac{Mm}{r^2}$.

Combining these Three postulates he proposed a ***universal constant of gravitation*** (***G***) and the statement $\bar{F} = -G\frac{Mm}{r^2}\hat{r}$ is known as ***universal law of gravitation (ULG)***. Experimentally value of $G = 6.67 \times 10^{-11}\ \mathrm{N-m^2/kg^2}$ has been determined. Experimental set-up and method of determining G has been brought out in references.

Gravitational field of a body of mass M on another unit mass displaced at $\bar{r}$ from the centre of the body is $\bar{E} = -G\frac{M}{r^2}\hat{r}$. *On the earth's surface $\bar{E} = -G\frac{M_e}{R_e^2}\hat{r} = \bar{g}$, the gravitational field is also called acceleration due to gravity $\bar{\boldsymbol{g}}$.*

Gravitational potential: Work done in moving a unit mass from Earth's surface, against the gravitational pull, up to a point P at a radial distance r := $\sum \Delta w = \int_{R_e}^{r}\left(G\frac{M_e}{x^2}(-\hat{x})\right)\cdot d\bar{x} = GM_e\left[\frac{1}{x}\right]_{R_e}^{r} = GM_e\left[\frac{1}{r} - \frac{1}{R_e}\right] = \frac{GM_e}{r}\Big|_{taking,\frac{GM_e}{R_e}=0}$

Here, gravitational force, is in direction $-\hat{x}$; while displacement Δx is also in direction $\hat{x}$.



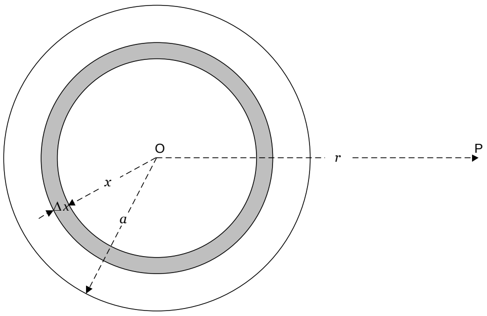
Further, in above derivation, it is assumed that Potential at Earth's surface is Zero and hence the PE at point P, calculated above can be called as relative Potential or Difference in Potential w.r.t. Earth's surface. The moment mass of the object being moved is considered, i.e. other than unity, it becomes **Potential Energy** of the mass at that point.

These illustrations lead to the following conclusions:

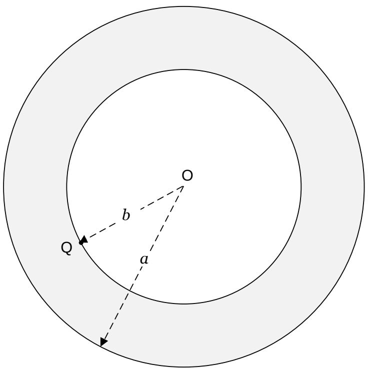
(a) It is to be noted that PE is scalar, while Gravitational Field is same as acceleration due to gravity and is vector.

(b) (-ve) sign to $\bar{E}$ or $\bar{g}$ indicates that direction of Field or acceleration is opposite to $\hat{r}$, unit displacement vector.

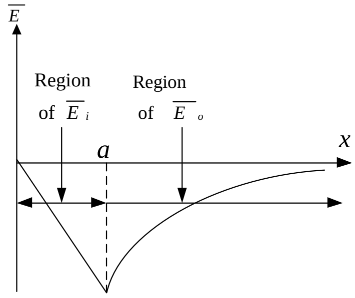
Concept of gravitational field for typical, but uniform mass distribution, using ULG, is application of definite integral as done earlier for COM and MO, and is covered in references cited below. Nevertheless, gravitational field in case of earth at its surface, below the surface and above it, and is of specific relevance is illustrated here under. This analysis in different forms shall also be applicable in electrostatics.



The problem is being solved considering integration of gravitational field, caused at a point P, at a distance r from the centre O of a solid sphere of uniform density ρ, due to an elemental-thin-hollow-spheres of thickness of mass dm such that $dm = (4\pi x^2 dx)\rho$, and $\rho = \frac{M}{\frac{4}{3}\pi a^3}$. Thus $-\bar{E} = \int d\bar{E} = -G\int_0^a \frac{dm}{r^2}\hat{r} = -G\left[\int_0^a \frac{(4\pi x^2 dx)\left(\frac{M}{\frac{4}{3}\pi a^3}\right)}{r^2}\right]\hat{r} = \left[-G\frac{3M}{a^3r^2}\int_0^a x^2 dx\right]\hat{r} = \left[-G\frac{3M}{a^3r^2}\left[\frac{x^3}{3}\right]_0^a\right]\hat{r} = \left[-G\frac{3M}{a^3r^2}\frac{a^3}{3}\right]\hat{r} = -G\frac{M}{r^2}\hat{r}$. This is same as a gravitational at point P field point mass M is placed at O.



Now consideration of gravitational field at point Q inside a solid sphere which is at a distance b from O. This problem is decomposed into two parts, First part is $\bar{E}_1$ with mass contained in that portion of concentric shells which fall outside radial b, and Second Part is $\bar{E}_2$ constituting mass contained in concentric shells starting from O upto radial b. Accordingly, $\bar{E}_1 == -G\int_0^b \frac{dm}{r^2}\hat{r} = -G\frac{M_i}{b^2}\hat{r}$. This is in accordance with analysis of solid sphere, brought out above. Here, $M_i = \left(\frac{M}{\frac{4}{3}\pi a^3}\right)\frac{4}{3}\pi b^3 = M\frac{b}{a^3}$.



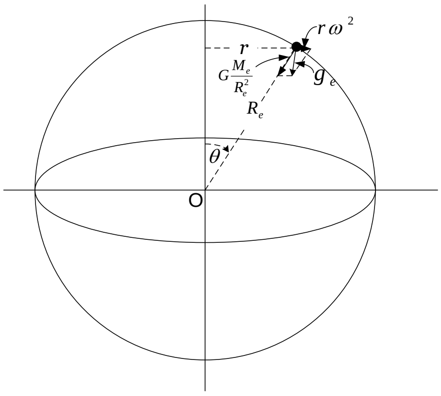
Accordingly, $\bar{E}_1 = -G\left(M\frac{b^3}{a^3}\right)\frac{1}{b^2}\hat{r} = -G\left(\frac{M}{a^3}b\right)\hat{r}$. And $\bar{E}_2 = 0$ at any point inside a hollow shell. Thus gravitational field at any point inside a solid sphere is: $\bar{E}_{i-b} = \bar{E}_1 + \bar{E}_2 = -G\left(\frac{M}{a^3}b\right)\hat{r}$.

This is the equation of a central force acting towards a central point and proportional to the distance from the central point. This is the case of Simple Harmonic Motion (SHM), which would be illustrated separately in Waves and Motion. Nevertheless, hypothetically a diametric tunnel is dug through the centre of the earth and an object is placed on the one end of tunnel, it would keep oscillating in the tunnel. The combined effect of the E due to a solid sphere, at a point inside i.e. $\bar{E}_i$ and outside $\bar{E}_o$ the sphere are shown in the adjoining graph.

Variation of acceleration due to gravity i.e. $\bar{g}$ above the earth's surface is dependents on many parameters and are illustrated below-

a. **Height above Earth's Surface:** Let, h be the height above Erath's surface and this would lead to acceleration due to gravity $g' = G\frac{M_e}{(R_e+h)^2} = G\frac{M_e}{R_e^2\left(1+\frac{h}{R_e}\right)^2} = G\frac{M_e}{R_e^2}\left(1+\frac{h}{R_e}\right)^{-2} = g\left(1+\frac{h}{R_e}\right)^{-2}$. But, **when $h \ll R_e$, the higher order terms of $\frac{h}{R_e}$ becomes insignificant and $g' = g\left(1-2\frac{h}{R_e}\right)$.**

b. **Rotation of Earth:** Rotation of earth creates an another centrifugal acceleration vector $r\omega^2$ which is outwards and perpendicular to the axis of rotation of the earth. While, acceleration due to gravity $g = G\frac{M_e}{R_e^2}$ is towards, the centre of the earth O. **Accordingly, effective acceleration g_e is the vector sum of the earlier Two, but its direction is not towards O, rather drifted away from it towards the object.**



c. **Shape of the earth:** Mean radius of the earth is 6.37x10^3 km, while at the equator radius is 21 km ($\approx 0.3\%$) larger than that at the pole$\approx 0.3\%$. This shape of earth influences in three way, -

i) at poles effective radius is lesser that at equator, and it is inversely proportional to the square of the radius,

ii) effective mass of earth which is in cubic proportion to radius,

iii) Influence of rotation, discussed above is highest at equator, and Zero at poles, radius is a parameter in determining

Resultant acceleration due to gravity at poles is greater than that at equator.

d. **Non- Homogeneity of Earth:** All the above derivation are based on a homogeneous mass distribution, but sea, minerals, mountains and valley do affect the mass distribution and locally influence value of **g.**

Escape Velocity: It that minimum velocity with which a particle projected vertically would reach beyond a point where gravitational field of the earth becomes ineffective and then it would not return back to it. Initial energy of the projectile at the earth's surface is = KE + PE = $\frac{1}{2}mu^2 + G\frac{M_e m}{R_e}$, where u is the vertical velocity of the projectile. Let, at height h, vertical velocity of the projectile is v., its total energy would be $=\frac{1}{2}mv^2 + G\frac{M_e m}{R_e+h}$. Assuming, that travel of the projectile is resistance free then as per principle of conservation it would imply that : $\frac{1}{2}mu^2 - G\frac{M_e m}{R_e} = \frac{1}{2}mv^2 - G\frac{M_e m}{R_e+h}$. For the projectile to escape the earth's gravity $v \geq 0$ and thus: $v^2 = \left(u^2 - \frac{GM_e}{R_e}\right) + \frac{GM_e}{R_e+h}$. One inference can be drawn that if $u^2 - \frac{GM_e}{R_e} = 0$, or minimum value of the initial velocity of projectile: $u_{min} = \sqrt{\frac{GM_e}{R_e}}$, would lead to $v \geq 0$ such that at any value of h, vertical velocity of the projectile be always +ve, and hence it would not return to earth. Accordingly, : u_{min} is called escape velocity of a projectile and it is independent of the mass of the projectile.

Kepler's Laws : A beginning into the understanding of Kepler's Laws is made from their statements and are as under -

Kepler's First Law (KFL): Each planet describes an ellipse having sun in one of its foci.

Kepler's Second Law (KSL): Area described by the radii drawn from the planet to the sun are, in the same orbit, proportional to the times of describing them.

Kepler's Third Law (KTL): Square of the periodic times of the various planets are proportional to the cube of the major axis of their orbit.

Circular motion of a point object around a central mass is understandable with balancing of **Centripetal Force (CPF)** caused by *gravitational force due to central mass as per Newton's Universal Law of Gravitation*, and **Centrifugal Force**

(CFF), a pseudo force, caused by *acceleration responsible for circular motion.* This goes well to describe KSL and KTL, for motion of Earth around Sun in a circular orbit as under-

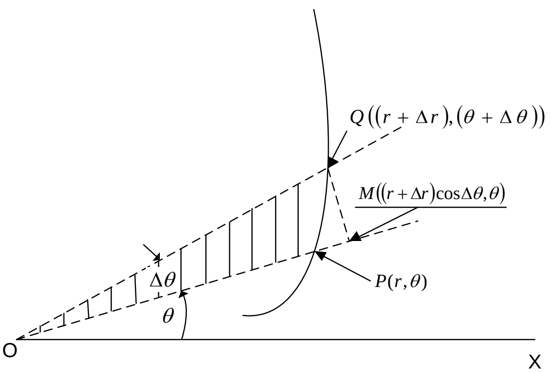
CPF=$\frac{GM_sM_e}{R^2}$; here G – Gravitational constant, M_s – mass of Sun and M_e- Mass of Earth, and R – radial distance between centre of mass of Sun and Earth.

CFF=$M_eR\omega^2 = M_eR(2\pi/T)^2 = \frac{4\pi^2M_eR}{T^2}$; here T- is the time period of circular motion of earth.

Basic premise of circular motion is that angular velocity (ω) remains constant in circular motion and hence area described by radii (A) over a period is shall be $A = \pi R^2\left(\frac{\omega T}{2\pi}\right) = \left(\frac{\omega R^2}{2}\right)T$, or $A \propto T$, and is in accordance with the KTL; and this shall be true for all planetary motion.

Now, imposing condition of circular motion of earth, $\frac{GM_sM_e}{R^2} = \frac{4\pi^2M_eR}{T^2}$; $T^2 = \left(\frac{4\pi^2}{GM_s}\right)R^3$, or $T^2 \propto R^3$, and is in accordance with KTL, with a moderation radius of earth's orbit is replaced with major axis of elliptical orbit. This is explained with the help of coordinate geometry where, $r = \frac{l}{1+\epsilon\cos\theta}$; here, l- is the Semi-latus-rectum of the Ellipse, ϵ- is the eccentricity of polar orbit, r – is radial distance of earth from Sun, θ – is the angle between earth's position and from its closest position such that (R,θ) are the polar coordinates of earth. Since, in case of Circular motion $\epsilon = 0$, it leads to $R = l$. Some of the properties of ellipse are as under –

a. Correlation between Major Axis (a), Minor Axis (b) and eccentricity $(\epsilon)$is $a^2(1-\epsilon^2) = b^2$
b. Correlation between Major Axis (a), Minor Axis (b) and Semi-Latus- Rectum (l) is $l = \frac{b^2}{a}$



In circular motion $\epsilon = 0$, a special case of an ellipse, it leads to $a = b = 2R$ or $R = \frac{a}{2}$ i.e. semi-major axis this translates $T^2 = \left(\frac{4\pi^2}{GM_s}\right)R^3 \to T^2 = \left(\frac{\pi^2}{2GM_s}\right)a^3$; or $T^2 \propto a^3$, without changing basic nature of KTL. Further in an ellipse $l = \frac{b^2}{a}$.

Since, proportionality constant involves parameters independent of any planet; it is common for all planets, and so also the relationship.

Next is the obvious curiosity is explanation of elliptical orbit as per postulate of KFL, and relevance of KSL and KTL in this context. ***A simplistic explanation for elliptical motion as per KFL, without going into intricate dynamics of rigid bodies distributed in space, is the basic configuration of solar system which is not a two body system. Thus the resultant of forces on a planet as it revolves around the earth keep changing. Accordingly, the resultant closed orbit, under influence of net central force towards Sun, is an ellipse***. During motion net velocity and acceleration of the object is towards focus (u,α) and that along tangent (v,β) are required to be determined. Here, $OP = r$, and $OQ = r + \Delta r$ and O represents focus of the orbital motion of planet i.e. Sun.

$$u = \frac{OM-OM}{\Delta t}\bigg|_{\Delta t\to 0} = \frac{(r+\Delta r)\cos\Delta\theta - r}{\Delta t}\bigg|_{\Delta t\to 0} = \frac{dr}{dt};\ v = \frac{QM}{\Delta t} = \frac{(r+\Delta r)\sin\Delta\theta}{\Delta t}\bigg|_{\Delta t\to 0} = \frac{(r+\Delta r)\Delta\theta}{\Delta t}\bigg|_{\Delta t\to 0} = r\frac{d\theta}{dt}$$

Likewise,

$$\alpha = \frac{((u+\Delta u)\cos\Delta\theta - (v+\Delta v)\sin\Delta\theta) - u}{\Delta t}\bigg|_{\Delta t\to 0} = \frac{\Delta u - v\Delta\theta}{\Delta t}\bigg|_{\Delta t\to 0} = \frac{du}{dt} - v\frac{d\theta}{dt}$$

$= \frac{d^2r}{dt^2} - \left(r\frac{d\theta}{dt}\right)\frac{d\theta}{dt} = \frac{d^2r}{dt^2} - \left(r\frac{d\theta}{dt}\right)^2 = -P$; here P is indicative of centripetal acceleration.

$\beta = \frac{((u+\Delta u)\sin\Delta\theta + (v+\Delta v)\cos\Delta\theta) - v}{\Delta t}\Big|_{\Delta t\to 0} = \frac{u\Delta\theta + \Delta v}{\Delta t}\Big|_{\Delta t\to 0} = u\frac{d\theta}{dt} + \frac{dv}{dt} = \frac{dr}{dt}.\frac{d\theta}{dt} + \frac{d}{dt}\left(r\frac{d\theta}{dt}\right) = 2\frac{dr}{dt}.\frac{d\theta}{dt} + r\frac{d^2\theta}{dt^2} = \frac{1}{r}\frac{d}{dt}\left[r^2\frac{d\theta}{dt}\right]$

In planetary motion acceleration is always towards Sun (focus) i.e. $\alpha = \frac{d^2u}{dt^2} \neq 0$ and $\beta = \frac{d^2v}{dt^2} = 0$. It implies angular momentum of the revolving planet $(P = m(\bar{r} \times \bar{v}) = m(\bar{r} \times (r\bar{w})) = m\left(\bar{r} \times \left(r\frac{d\bar{\theta}}{dt}\right)\right) = m\bar{h}$; here $h = |\bar{h}| = r^2\frac{d\theta}{dt}$. It leads to $\frac{d\theta}{dt} = \frac{h}{r^2} = hu^2$; here, u is substituted for $\frac{1}{r}$ for mathematical convenience. In definition of h it is to be noted that *if radial distance of revolving body increases the its angular velocity decreases in square-root proportion, and accordingly instantaneous linear velocity* $(= r\frac{d\theta}{dt})$.

With this illustration sectorial area OPQ swept by the radial shall be $\Delta A = \frac{1}{2}OP \cdot OQ\sin\Delta\theta\Big|_{\Delta\theta\to 0} = \frac{1}{2}r\cdot(r+\Delta r)\sin\Delta\theta\Big|_{\Delta\theta\to 0}$.

Accordingly, rate of describing the sectorial area by the radial shall be $\frac{dA}{dt} = \frac{\Delta A}{\Delta t} = \frac{1}{2}\frac{r\cdot(r+\Delta r)\sin\Delta\theta}{\Delta t}\Big|_{\Delta t\to 0} = \frac{1}{2}\left(\frac{r\cdot(r+\Delta r)\sin\Delta\theta}{\Delta\theta}\right)\frac{\Delta\theta}{\Delta t}\Big|_{\Delta t\to 0}$.

Thus, $\frac{dA}{dt} = \frac{1}{2}r^2\frac{d\theta}{dt} = \frac{1}{2}h = Const$. ***This is the mathematical justification of postulate contained in KSL.***

Properties of h are important in illustration of elliptical orbits and are –

a. Since, orbital motion has only central force, tangential acceleration is Zero,
b. The (a) above leads to Angular moment of a mass is constant,
c. The proportionality constant of angular momentum is mass of the body moving in an elliptical orbit,
d. The h is equal to the twice the rate of describing area the radial of the elliptical orbit.
e. Thus area described by radial in completing one orbit is $= 2hT$, here T is the time period of the orbital motion.

Now remains KTL and for elliptical motion and it involves redefining . This is done by first solving its Two addends.

Initially, $\frac{dr}{dt} = \frac{d}{dt}\left(\frac{1}{u}\right) = -\frac{1}{u^2}\frac{du}{dt} = -\frac{1}{u^2}\left(\frac{du}{d\theta}\right)\left(\frac{d\theta}{dt}\right) = -\frac{1}{u^2}\left(\frac{du}{d\theta}\right)hu^2 = -h\frac{du}{d\theta}$. Accordingly, first addend is -

$$\frac{d^2r}{dt^2} = \frac{d}{dt}\left(-h\frac{du}{d\theta}\right) = -h\frac{d}{dt}\left(\frac{du}{d\theta}\right) = -h\frac{d}{d\theta}\left(\frac{du}{d\theta}\right)\left(\frac{d\theta}{dt}\right) = -h\left(\frac{d^2u}{d\theta^2}\right)\left(\frac{d\theta}{dt}\right) = -h\left(\frac{d^2u}{d\theta^2}\right)(hu^2) = -h^2u^2\frac{d^2u}{d\theta^2}$$

The second addend solves to $-r\left(\frac{d\theta}{dt}\right)^2 = -\frac{1}{u}(hu^2)^2 = -h^2u^3$.

Further, equation of an ellipse in polar form leads to $r = \frac{l}{1+\epsilon\cos\theta}$ and it leads to $u = \frac{1}{r} = \frac{1}{l} + \frac{\epsilon}{l}\cos\theta$ Taking second differential of u w.r.t θ resolves into : $\frac{d^2u}{d\theta^2} = -\frac{\epsilon}{l}\cos\theta$. Now combing equation of ellipse with α leads to -

$$\alpha = -h^2u^2\frac{d^2u}{d\theta^2} - h^2u^3 = -h^2u^2\left(\frac{d^2u}{d\theta^2} + u\right) = -h^2u^2\left(\left(-\frac{\epsilon}{l}\cos\theta\right) + \left(\frac{1}{l} + \frac{\epsilon}{l}\cos\theta\right)\right) = -\frac{h^2}{l}u^2.$$

Now that central acceleration varies inversely as square of the distance of revolving planet from the focus Sun, and it is $= -\frac{\mu}{r^2} = -\mu u^2$; here, μ is constant determined by all celestial bodies influencing net gravitational pull.. Equating this central acceleration to α leads to $\mu u^2 = \frac{h^2}{l}u^2$, or $h^2 = \mu l$, or $h = \sqrt{\mu l}$. Here, l is Semi-Latus-rectum of the elliptical orbit.

Moreover area of an ellipse is $= \pi ab$, here while a is major axis of the ellipse, b is the minor axis of the orbit. Thus equating the Two representation of the area of the elliptical orbit, together with Second property of ellipse, it leads to –

$\frac{1}{2}hT = \pi ab$; or $\frac{1}{2}\sqrt{\mu l}T = \pi ab$ => $\frac{1}{2}\sqrt{\mu\left(\frac{b^2}{a}\right)}T = \pi ab$ => $\frac{1}{2}\left(b\sqrt{\frac{\mu}{a}}\right)T = \pi ab$ => $\frac{1}{2}\left(\sqrt{\frac{\mu}{a}}\right)T = \pi a$ => $T^2 = \frac{4\pi^2}{\mu}a^3$ => $T^2 \propto a^3$.

This is the mathematical justification of KTL.

It is pertinent to highlight academic requirement at school level is the knowledge of Kepler's Laws and not its derivation. Likewise, each concept has been deliberately stretched a bit beyond, calling upon the knowledge of mathematics and physics of the target audience, and thus ignite a desire to understand nature in an out-of-box manner, a pre-requisite of an inquisitive mind and an aim of education.

Summary: *Analysis of varieties of problems, representing different situation involve concepts of Newton's Laws of Motion, Circular Motion, Work-power-energy, and conservation of energy and momentum.-Many such situations are observed in real life. Examples drawn from real life experiences is to build a visualization and an insight into the phenomenon occurring around. A deeper journey into the problem solving would make integration and application of concepts intuitive. This is absolutely true for any real life situation which requires multi-disciplinary knowledge in skill for evolving solution. Thus, problem solving process is more a conditioning of the thought process, rather than just learning the subject. Practice with wide range of problems is the only pre-requisite to develop proficiency and speed of problem solving, and making formulations more intuitive rather than a burden on memory, as much as overall personality of a person.*

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Author is coordinator of this initiative Gyan-Vigyan Sarita, a non-organizational entity of co-passionate persons who are dedicated to the mission. He had his career as a power engineer, and after superannuation he did his Ph.D, from IIT Roorkee. Soonafter the Ph.D. in 2012, he took a plunge into mentoring unprivileged children with Sarthak Prayashm an NGO. Thereafter for about for One Year till Sept'16 he was Founder-cum-Chairman of Subofh Foundation.
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Together **E**ach **A**chieves **M**ore
(**TEAM**)

GROWING WITH CONCEPTS - Chemistry

(....Contd.) ORGANIC CHEMISTRY : BASIC PRINCIPLES AND TECNIQUES

Kumud Bala

IUPAC Nomenclature of organic compounds containing one functional group

1. **Haloalkanes:** Halogen derivatives of alkanes are called haloalkanes. They are further classified as mono, di, tri, and tetrahaloalkanes, etc. as they contain one, two, three, four, etc. halogen atoms respectively in their molecules.

(a) **Monohaloalkanes**: The monohalogen derivatives of alkanes are called alkyl halides.
General formula: $C_nH_{2n+1}x$ where n = 1, 2, 3, ……..etc. X=F, Cl, Br, or I
Or R-X where R is any alkyl group
Functional Group: X (halogen)
Secondary prefix= halo
Common name : Add the word halide (fluoride, chloride, bromide, iodide) to the name of the group i.e. Alkyl + halide =Alkylhalide
IUPAC names: Add the secondary prefix 'halo' to the name of the corresponding alkane . i.e. Halo+alkane= Haloalkane. For example

Formula	Common name	IUPAC name
CH_3Cl	Methyl chloride	Chloromethane
CH_3CH_2-Br	Ethyl bromide	Bromoethane
$CH_3CH_2CH_2$-I	n-Propyl iodide	1-Iodopropane
CH_3CHI-CH_3	Isopropyl iodide	2-Iodopropane

(b) **Dihaloalkanes**: Alkanes containing two halogen atoms per molecule are called dihaloalkanes. General Formula: $C_nH_{2n}X_2$ where n=1,2,3,……etc.
Common name: For purpose of naming, dihalogen derivatives of alkanes, are divided into three categories :

(i) Alkylidene dihalides:- Dihalogen derivatives of alkanes in which the two halogen atoms are attached to the same carbon atom are called alkylidene dihalides or alkylidene halides.

(ii) Alkylene dihalides :- Dihalogen derivatives of alkanes in which the two halogen atoms are attached to adjacent carbons of chain are called alkylene dihalides or simply alkylene halides.

(iii) Polymethylene dihalides:- Dihalogen derivatives of alkanes in which the two halogen derivatives are present on the terminal carbon atoms ,i.e., α,ω, positions of the carbon chain are called polymethylene dihalides.

IUPAC name:- In the IUPAC system, all type of dihalides are called dihaloalkanes, the position of the halogen atoms being indicated by lowest possible Arabic numerals. The common and IUPAC names of some dihalogen alkanes are given below:

Formula	**Common name**	**IUPAC name**
CH_2Cl_2	Methylene chloride	Dichloromethane
CH_3CH-Br_2	Ethylidene dibromide	1,1-dibromoethane
Br-CH_2CH_2-Br	Ethylene dibromide	1,2-dibromoethane
$CH_3CH_2CHCl_2$	Propylidene dichloride	1,1-dichloropropane
$CH_3CHClCH_2Cl$	Propylene dichloride	1,2-dichloropropane
$CH_3C(Cl_2)CH_3$	Isopropylidene dichloride	2,2-dichloropropane
Cl-$CH_2CH_2CH_2$Cl	Trimethylene dichloride	1,3-dichloropropane

(c) **Tri- and tetrahaloalkane**:- General Formula of trihaloalkanes= $C_nH_{2n-1}X_3$ while that of terahaloalkane is $C_nH_{2n-2}X_4$, where n=1,2,3,4…….etc. and X=F , Cl , Br, I.
IUPAC name:- In the IUPAC system, these are called trihaloalkanes and tetrahaloalkanes. The

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position of the halogen atoms on the carbon chain being indicated by Arabic numerals.

Common names: -Trihaloalkanes are best known by their common names i.e., haloform, tetra halogen derivatives of methane are called carbon tetrahalides . While symmetrical tetra halogen derivatives of ethane are called acetylene tetrahalides.

For example:-

Formula	Common name	IUPAC name
CHF_3	Fluroform	Trifluromethane
$CHCl_3$	Chloroform	Trichloromethane
$CHBr_3$	Bromoform	Tribromomethane
CH_3CCl_3	-	1,1,1-trichloroethane
Cl-CH_2-$CHCl_2$	-	1,1,2-trichloroethane
CCl_4	Carbon tetrachloride	Tetra chloromethane
Br_2CH-$CHBr_2$	Acetylene tetra bromide	1,1,2,2-tetrabromoethane
$ClCH_2$-CCl_3	-	1,1,1,2-tetrachloroethane

2. **Alcohols or Alkanols**:- Alcohols are classified as monohydric, dihydric, trihydric and polyhydric according as their molecules contain one, two, three and many hydroxyl groups respectively. Since presence of two or more hydroxyl groups on the same carbon atom makes the molecules unstable, therefore, in di, tri, and polyhydric alcohols, each hydroxyl group is present on a different carbon atom.

(a) Monohydric alcohols:- General formula: $C_nH_{2n+1}HO$ where n=1,2,3,…….ect. or R-OH where R is any alkyl group. Functional group: -OH (hydroxyl) Secondary suffix: ol

Common name : Add the word alcohol to the name of the alkyl group ,i.e., Alkyl+ alcohol = Alkyl alcohol.

IUPAC name :- Replace the terminal 'e' form the name of the corresponding alkane by the suffix 'ol', i.e., Alkane –e + ol =Alkanol . Some important examples are :

Formula	Common name	IUPAC name
CH_3OH	Methyl alcohol	Methanol
CH_3CH_2-OH	Ethyl alcohol	Ethanol
$CH_3CH_2CH_2$-OH	n- propyl alcohol	Propan-1-ol
$CH_3CH(OH)CH_3$	Isopropyl alcohol	Propan-2-ol

(b) Dihydric alcohols :- General Formula : $C_nH_{2n}(OH)_2$ where n= 2,3,4, …….. etc.

Classification :- Because of their sweet taste, dihydric alcohols are called glycols . Depending upon the relative position of the two hydroxyl groups, they are further classified as $\alpha,\beta,\gamma,\omega$ glycols etc. Thus α- glycol is 1,2 -glycol, β- glycol is 1,3-glycol and ω- glycol is one in which the two –OH groups are attached to the terminal carbon atoms of the chain.

Common names:- α-glycols are named as by adding word glycol to the alkylene . β,γ,ω -glycols are named as polymethlene glycol.

IUPAC name:- add the suffix 'diol' to the name of the alkane containing the same number of carbon atoms as the diol . Alkane + diol =Alkanediol

The position of the two hydroxyl group is indicated by Arabic numerals .

Examples are ;

Formula	Common name	IUPAC name
HO-CH_2-CH_2OH	Ethylene glycol	Ethane-1,2-diol
$CH_3CHOHCH_2OH$	Propylene glycol	Propane-1,2-diol
$HOCH_2CH_2CH_2OH$	Trimethylene glycol	Propane-1,3-diol

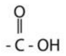
(c) Trihydric alcohol:- General formula : $C_nH_{2n-1}(OH)_3$

IUPAC name: Add the suffix 'triol' to the name of the alkane containing the same number of carbon atoms as the triol . Alkane + triol = Alkanetriol . The position of the hydroxyl group is indicated by Arabic numerals. Examples are

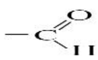
Formula	Common name	IUPAC name
$OHCH_2$-CHOH-CH_2OH	Glycerol or glycerin	Propane-1,2,3-triol

3. Ethers or Alkoxyalkane:- General formula: R-O-R' where R and R' are same or different alkyl groups .If R=R , ethers are called simple ethers and if R≠R', then ethers are mixed ethers. Functional group: -O-
Secondary prefix : Alkoxy
Common name:- In case of mixed ethers, add the word ether to the names of the alkyl group arranged in alphabetical order. In case of simple ethers, the numerical prefix 'di' is added to the name of the alkyl group followed by the word ether.
IUPAC name:- In the IUPAC system ,ethers are called alkoxyalkanes. The smaller alkyl group forms a part of the alkoxy group while the bigger alkyl group forms a part of the alkane. The names of the ethers are then derived by adding the suffix alkoxy to the name of the alkane i.e., Alkoxy +alkane= Alkoxyalkane.
Examples are:-

Formula	Common name	IUPAC name
CH_3-O-CH_3	Dimethyl ether	Methoxymethane
CH_3-O-CH_2CH_3	Ethyl methyl ether	Methoxyethane
CH_3CH_2-O-CH_2CH_3	Diethyl ether	Ethoxyethane

4. **Monocarboxylic acids or Alkanoic Acids : G**eneral formula: C_nH_{2n+1}COOH where n= 0,1,2,3,4…… etc. or R-COOH where R=H or any alkyl group Functional group :  (carboxyl) secondary suffix: oic acid
Common name: - These are derived from the name of the plant or animal from which they were first isolated.
IUPAC name :- Replace terminal 'e' from the name of the corresponding alkane by the suffix oic acid i.e., Alkane-e + ioc acid = Alkanaoic acid.
Some important examples are :

Formula	Common name	IUPAC name
H-COOH	Formic acid	Methanoic acid
CH_3COOH	Acetic acid	Ethanoic acid
CH_3CH_2COOH	Propionic acid	Propanoic acid
$CH_3CH_2CH_2$COOH	n-Butyric acid	Butanoic acid
$CH_3CH_2CH_2CH_2$-COOH	n-valeric acid	Pentanoic acid

5. **Aldehydes or Alkanals:-** General formula : C_nH_{2n+1}CHO where n=0,1,2,3,……. etc. or R-CHO where R=H or any alkyl group Functional group :- 
(aldehyde) Secondary suffix : - al
Common name :- Acetic acid - ic acid + aldehyde = Acetaldehyde.
IUPAC name :- Alkane –e + al =Alkanal
Eaxmples are:-

Formula	Common name	IUPAC name
H-COOH	Formaldehyde	Methanal
CH3-CHO	Acetaldehyde	Ethanal
CH_3CH_2-CHO	Propionaldehyde	Propanal
CH3CH2CH2-CHO	n-butyraldehyde	Butanal

6. **Ketones or Alkanones:-** General formula: C_nH_{2n+1}CO C_nH_{2n+1} where n= 1,2,3, …….. etc. R-CO-R' where R and R' , may be same or different alkyl groups . if R=R' , ketones are called simple ketones and if R≠ R' , ketones are called mixed ketones . Functional group : >C=O (ketonic) Secondary suffix: one
Common name :- in case of mixed ketones , name the alkyl groups in alphabetical order and then add the word ketone . In case of simple ketones , the numerical prefix 'di' is used before the name of the alkyl group.
IUPAC name :- Replace terminal 'e' from the name of the corresponding alkane by the suffix 'one' i.e., Alkane – e + one =Alkanone
Some example are:

Formula	Common name	IUPAC name
CH_3-CO-CH_3	Dimethyl ketone or Acetone	Propanone
CH_3-CO-CH_2CH_3	Ethyl methyl ketone	Butan-2-one
CH_3-CO-$CH_2CH_2CH_3$	Methyl n-propyl ketone	Pentan-2-one
CH_3CH_2-CO-CH_2CH_3	Dimethyl ketone	Pentan-3-one

7. Acid chloride or Acyl chloride or Alkanoyl chloride:- General formula : RCOCl where R=H or any alkyl group .

Functional group:

Secondary suffix: oly chloride
Common name : Replace 'ic acid' from the common names of the corresponding acid by 'yl chloride' . Acetic acid –ic acid + yl chloride = Acetyl chloride

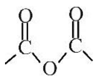
IUPAC name: Replace terminal 'e' from the name of the corresponding alkane by the suffix 'oyl chloride' i.e., Alkane –e +oyl chloride = Alkanoyl chloride

For example:

Formula	Common name	IUPAC name
H-COCl (unstable)	Formyl chloride	Methanoyl chloride
CH_3.COCl	Acetyl chloride	Ethanoyl chloride
CH_3CH_2-COCl	Propionyl chloride	Propanoyl chloride
$CH_3CH_2CH_2$-COCl	n-Butyryl chloride	Butanoyl chloride

8. Acid anhydrides :- General formula: R-CO-O-CO-R' or $(RCO)_2O$ where R or R' may be same or different alkyl group.

Functional group:

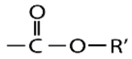


Secondary suffix: anhydride

Common or IUPAC names: - Replace the word acid from the common or IUPAC name of the corresponding acid by the word anhydride . Symmetrical anhydrides of substituted carboxylic acids are named by adding prefix 'bis' to the name to indicate that two identical acyl groups are present. Unsymmetrical anhydride are named by writing the names of the acid alphabetically before the word anhydride. Some important examples are:

Formula	Common name	IUPAC name
$(CH_3CO)_2O$	Acetic anhydride	Ethanoic anhydride
$(CH_3CH_2CO)_2O$	Propionic anhydride	Propanoic anhydride
$(ClCH_2CO)_2O$	Bis(Chloroacetic anhydride)	Bis (Chloroethanoic anhydride)
HCO-O-$COCH_3$	Acetic formic anhydride	Ethanoic methanoic anhydride

9. Ester:-General formula : R-COOR' where R=H or any alkyl group while R' is always an alkyl group

Functional group:  (ester)

Secondary prefix: alkyl , Secondary suffix: oate

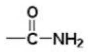
Common or IUPAC names: - Write the name of the alkyl group before the common or IUPAC name of the parent acid with its terminal 'ic acid ' replace by 'oate' .

Some important examples are:

Formula	Common name	IUPAC name
H-$COOCH_3$	Methyl formate	Methyl methanoate
H-$COOC_2H_5$	Ethyl formate	Ethyl methanoate
CH_3-$COOCH_3$	Methyl acetate	Methyl ethanoate
CH_3-$COOC_2H_3$	Ethyl acetate	Ethyl ethanoate

10. Acid amides or Alkanamides : General formula : $RCONH_2$ where R=H or any alkyl group

Functional group : (amide)



Secondary suffix : amide

Common name : Replace 'ic acid ' from the common name of the corresponding acid by the secondary suffix amide.

IUPAC name : - Replace the terminal 'e' from the name of the corresponding alkane by the suffix amide, ,i.e., Alkane –e + amide = Alkanamide.

Some examples are:

Formula	Common name	IUPAC name
H-$CONH_2$	Formamide	Methanamide
CH_3-$CONH_2$	Acetamide	Ethanamide
CH_3-CH_2-$CONH_2$	propionamide	Propanamide

11. Primary Amines :- General formula : R-NH_2 where R is any alkyl group. Functional group : -NH_2 (amino) Secondary suffix : amine

Common names : (i) Add the word amine to the name of the alkyl group ,i.e., alkyl + amine = Alkylamine (ii) Attach the prefix amino to the name of the corresponding alkane i.e., Amino + alkane =Aminoalkane. IUPAC name: Replace the terminal 'e' from the name of the corresponding alkane by the secondary suffix amine i.e., Alkane –e + amine = Alkanamine.

Some important example are :

Formula	Common name	IUPAC name
CH_3-NH_2	Methylamine or Aminomethane	Methanamine
CH_3CH_2-NH_2	Ethylamine or Aminoethane	Ethanamine
$CH_3CH_2CH_2NH_2$	n-propylamine or 1-aminopropane	Propan-1-amine or Propanamine

12. Secondary Amine:- General formula : R-NH-R' where R and R' may be same or different alkyl groups.

Functional group : >NH (imino) Secondary prefix : N-alkyl , Secondary suffix : amine

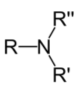
Common name : - (i) Name the alkyl group in alphabetical order and then add the word amine. In case of two alkyl groups are the same , the numerical prefix 'di' is used before the name of the alkyl group . (ii) Add the prefix N-alkyl before the name of the aminoalkane; the smaller alkyl group forming a part of N-alkyl group while the larger alkyl group form a part of the alkane.

IUPAC name : - Add the prefix N-alkyl to the name of the alkanamine corresponding to the larger alkyl group, i.e., N-alkyl + alkanamine = N-alkylalkanamine.

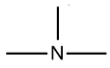
Some important example are:

Formula	Common name	IUPAC name
CH_3NHCH_3	Dimethylamine or N-methylaminomethane	N-Methylmethanamine
$CH_3CH_2NHCH_3$	Ethyl methylamine or N-methyl aminoethane	N-Methylethanamine
$(CH_3CH_2)_2NH$	Diethylamine or N-ethylaminoethane	N-Ethylethanamine

13. Tertiary amines :- General formula :



where R,R',R" may be same or different alkyl groups or two of them may be same while the third may be different. Secondary prefix: N-alkyl, N-alkyl

Functional group :  (tertiary nitrogen),

Secondary suffix : amine

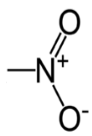
Common name: (i) name the alkyl groups in alphabetical order and add the suffix amine. If two or all the three alkyl groups are same ,the numerical prefixes 'di' and tri are respectively used. (ii) Add the prefixes N-alkyl and N-alkyl (smaller alkyl group) to the name of the amino alkane corresponding to the largest alkyl group.

IUPAC name: Add the prefixes N-alkyl and N-alkyl (smaller alkyl groups) to the name of the alkanamine corresponding to the largest alkyl group.

Some important examples are:-

Formula	Common name	IUPAC name
$(CH_3)_3N$	Trimethylamine or N,N-dimethylaminomethane	N,N-dimethylmethanamine
$CH_3CH_2N(CH_3)_2$	Ethyldimethylamine or N,N-dimethylaminoethane	N,N-dimethylethanamine
$(CH_3CH_2)_2N$-CH_3	Diethylmethylamine or N-ethyl N-methylaminoethane	N-Ethyl,N-methylethanamine
$(CH_3CH_2)_3N$	Triethylamine or N,N-diethyl aminoethane	N,N-diethylethanamine

14. Nitroalkanes : General formula : R-NO_2 where R is any alkyl group .



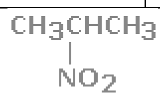
Functional group: (nitro)

Secondary prefix: Nitro

Common name :- there are no common names for nitroalkane.

IUPAC name :- Add the secondary prefix 'nitro' to the name of the alkane, i.e. , nitro + alkane = Nitroalkane

Some important examples are :

Formula	IUPAC name	Formula	IUPAC name
CH_3-NO_2	Nitromethane		2-Nitropropane
CH_3CH_2-NO_2	Nitroethane	$CH_3CH_2CH_2CH_2$-NO_2	1-Nitrobutane
CH_3CH_2C	1-	$CH_3CH(NO$	2-

H_2-NO_2	Nitropropane	$_2)CH_2CH_3$	Nitrobutane

15. Alkyl nitrites :- General formula :- R-O-N=O where R is any alkyl group . Functional group : -O-N=O (nitrite)
Secondary suffix : Nitrite
Common Name :- Add the secondary suffix nitrite to the **name** of the alkyl group .i.e., Alkyl + nitrite =Alkyl nitrite.
IUPAC name :- There are no IUPAC name for alkyl nitrile.
Examples are :-

Formula	Common name	Formula	Common name
CH_3-O-N=O	Methyl nitrite	$CH_3CH_2CH_2$-O-N=O	n-propyl nitrite
CH_3CH_2-O-N=O	Ethyl nitrite	$CH_3CH(ONO)CH_3$	Isopropyl nitrite

16. Alkyl cynide or Alkanenitrile :- General formula : R-C≡N where R is any alkyl group.
Functional group : –C≡N (cyano or nitrile)
Secondary suffix : nitrile
Common name : - (I) Add the suffix cyanide to the name of the alkyl group, i.e., Alkyl + cyanide = alkyl cyanide . (2) Replace 'ic acid' from the common name of the corresponding acid by the suffix 'onitrile. Acetic acid – ic acid + onitrile = Acetonitrile, however , in case of propionic acid, onic acid is replace by 'onitrile' . Propionic acid –onic acid + onitrile= Propionitrile.
IUPAC name : - Add the suffix 'nitrile' to the name of the alkane containing the same number of carbon atoms as the alkyl cyanide. i.e., Alkane + nitrile =Alkanenitrile .
Some important examples are :

Formula	Common name	IUPAC name
CH_3CN	Methyl cyanide or Acetonitrile	Ethanenitrile
CH_3CH_2CN	Ethyl cyanide or Propionitrile	Propanenitrile
$CH_3CH_2CH_2CN$	n-Propyl cyanide or n-Butyronitrile	butanenitrile

17. Isocyanide or Isonitrile : - General formula : R–N≡C where R is any alkyl group .
Functional group : –N≡C (isocyanide or isonitrile)
Secondary suffix : isocyanide or isonitrile
Common name : Add the suffix isocyanide or carbylamines to the name of the alkyl group.

Formula	Common name
CH_3-N≡C	Methyl isocyanide or methyl carbylamine or methyl isonitrile
CH_3CH_2NC	Ethyl isocyanide or ethyl carbylamines or ethyl isonitrile

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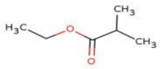
ASSIGNMENT-I

1. The IUPAC name of $CH_3COCH(CH_3)_2$ is :
   [A] 3-Methyl -2-Butanone
   [B] Isopropyl methyl ketone
   [C] 2- methyl-3-Butanone
   [D] 4-Methyl isopropyl ketone
2. The general formula which represents the homologous series of alkanols is:
   [A] $C_nH_{2n}O$ [B] $C_nH_{2n+1}O$
   [C] C_nH_{2n+2} O [D] $C_nH_{2n}O_2$
3. The IUPAC name of ether: CH_3-O-C_2H_5 is
   [A] Methyl ethyl ether [B] Ethoxy methane
   [C] Methoxy ethane [D] Ethyl methyl ether
4. The correct IUPAC name of Acetonitrile is :
   [A] Ethanenitrile [B] Cyanomethane
   [C] Methanenitrile [D] Cyanoethane
5. The IUPAC name of $CH_3COOC_2H_5$ will be:
   [A] Ethyl acetate [B] Ethyl ethanoate
   [C] Methyl propanoate [D] none of these
6. The IUPAC name of the compound, $CH_3CH_2COOCH_3$ is:
   [A] Methoxy propanone [B] Methoxypropanal
   [C] Methylpropanoate [D] Methoxy ethyl ketone
7. The IUPAC name of following compound is:



[A] Ethyl-2-methylpropanoate

[B] 2-Methyl eyhoxy propanone

[C] Ethoxy propanoate

[D] 2-methyethoxy propanone

Answers to Assignments

1. [A] 2. [C] 3. [C] 4. [A] 5. [B] 6. [C] 7. [A]

Author is M.Sc. (Chem.), M.Ed. and Advanced Diploma in German Language (Gold Medallist). She retired as a Principal, Govt. School Haryana, has 3-1/2 years' experience in teaching Chemistry and distance teaching through lectures on Radio and Videos. She has volunteered to complement mentoring of students for Chemistry through Online Web-enabled Classes of this initiative.
e-Mail ID: kumud.bala@yahoo.com

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SOLUTION TO THE CROSSWORD PUZZLE Nov'16: Mathematical Beauty

Prof. SB. Dhar

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--OO--

I am not afraid of an army of lions led by a sheep; I am afraid of an army of sheep led by a lion.

=Alexander the Great

Contents

QUIZDOM – Dec'16

TOPIC:INDIAN FREEDOM MOVEMENT(Part-V)

Phanindra Ivatury, Quiz Host

1. What is the proposal formulated by Rajagopalachari to solve the political deadlock between Congress and the Muslim League in the 1940s(1942?) popularly referred to by the press?
2. Rajagopalachari earned a nickname which had the name of a fruit and a south indian town in it? Which is this nickname?
3. Who regarded Rajaji as his "conscience keeper"?
4. To which of Gandhiji's sons was Rajaji's daughter Lakshmi married to?

   Information: Gandhiji's sons Harilal, Manilal, Ramdas & Devdas

5. In the 1930s, what relevance did a place called Vedaranyam near Nagapattinam in Tamil Nadu have in Rajaji's Life?
6. Which revolutionary organization was established in 1928 by Chandrasekhar Azad and his followers at the Feroz Shah Kotla in New Delhi?
7. In which train robbery or conspiracy case did Chandrasekhar Azad play a major hand?
8. Which leading freedom fighter, despite being a member of the congress used to fund money for a revolutionary like Azad?
9. Azad was encircled by the British Troops in a park in Allahabad. Azad kept on fighting and true to his pledge to never be captured alive by the British, he shot himself dead with the last bullet. What is the original name of this Park which is now renamed as Chandrasekhar Azad Park?
10. "Azad" is a honorary suffix Chandrasekhar acquired. What was his original name?
11. Which Indian Freedom Fighter was the mastermind behind the Delhi Conspiracy Case or the Delhi Lahore Conspiracy Case in 1911 where an attempt was made to assassinate Lord Hardinge, the Vice Roy of India?
    Information-Co Founder of the Indian Independence League, a political organization which existed between 1920s to 1940s which was basically set up to organize movements from outside India seeking the removal of British. The Bomb was thrown on the carriage of Hardinge but the Viceroy and his wife escaped with bruises and burns.

Quiz Host is a Post-Graduate in Public Personnel Management and Winner of Kulapati K.M.Munshi Medal in Public Relations, has quizzing as a hobby. He has so far hosted over 200 Quizzing events on various platforms all over the globe. He currently works with the Comptroller & Auditor General of India, New Delhi having worked on intra/inter-national assignments.
E-mail ID: phanindraivaturi@yahoo.com

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Answers to QUIZDOM : Nov'16

1. FORWARD BLOC OF THE INDIAN NATIONAL CONGRESS; 2. EMILIE SCHENKL; 3. TAIPEI, TAIWAN; 4. FOURTH; 5. PURNA SWARAJ RESOLUTION; 6. THE DISCOVERY OF INDIA; 7. A TRYST WITH DESTINY; 8. DR.DWARAKANATH KOTNIS; 9. MUSSOLINI; 10. MOOK NAYAK; 11. POONA PACT; 12. LAW MINISTRY; 13. SAVITA AMBEDKAR

—00—

Courage is what it takes to stand up and speak; Courage is what it takes to sit down and listen.

- -Winston Churchill

SCIENCE QUIZ - Dec'2016

Kumud Bala

1. The animals which eat only plants are called
   [A] Herbivores [B] Carnivores [C] Omnivores [D] Insectivores
2. Which type of vitamin our body prepares in the presence of sunlight?
   [A] Vitamin A [B] Vitamin B
   [C] Vitamin D [D] Vitamin K
3. 'Pashmina' wool is obtained from:
   [A] Camel [B] Sheep [C] Rabbit [D] Goat
4. Which fiber is obtained from Flax seeds?
   [A] Cotton [B] Jute [C] Linen [D] Nylon
5. The joint which helps in rotating a body in all directions is called ....
   [A] Fixed joint [B] Hinge joint
   [C] Pivot joint [D] Ball and Socket joint
6. Which bone protects the lower abdominal organs such as the urinary bladder, rectum, uterus?
   [A] sternum [B] Pelvic bone [C] spine [D] skull
7. Sea animals like dolphins and whales breathe through........
   [A] Nose [B] Gills [C] Blow holes [D] Fins
8. Which part of the plant gets carbon dioxide from the air for photosynthesis?
   [A] Root hair [B] Stomata
   [C] Leaf veins [D] Sepals
9. Grass is rich in --------- a special kind of carbohydrate which can only indigested by ruminants.
   [A] Glucose [B] cellulose
   [D] Sucrose [D] Fructose
10. The life processes that provides energy is/are
    [A] Nutrition
    [B] Respiration
    [C] Both nutrition and respiration
    [D] Transpiration
11. In addition to the rock particles, the soil contains
    [A] air and water [B] Water and plants [C] Minerals, organic matter, air and water [D] Water, air and plants
12. When we breathe out, exhaled air turns lime water into -------- due to presence of -------- (Fill in the Blanks)
    [A] Orange oxygen [B] Milky oxygen
    [C] Milky carbon dioxide [D] Milky carbon monoxide
13. The organic substance obtained from dead plants and animals wastes a-----------
    [A] Manure [B] Fertilizer [C] Irrigation [D] Agriculture
14. Which of the following bacteria is involved in the fixation of nitrogen in leguminous plants?
    [A] Rod-shaped bacteria [B] Spiral bacteria
    [C] Rhizobium [D] Spherical bacteria
15. The animals which lay eggs are known as ----------
    [A] Oviparous animals [B] Viviparous animals
    [C] Domestic animals [D] Wild animals
16. The plants, animals and microorganisms along with climate, soil, river etc. of an area is referred to
    [A] Fauna [B] Ecosystem
    [C] Species [D] Kingdom
17. Who is known as father of microbiology?
    [A] Alexander Fleming [B] Robert Hook
    [C] Leeuwenhoek [D] E. Adams
18. Living substance of cell is called ------ (Fill in the blank)
    [A] Cytoplasm [B] Protoplasm
    [C] Nucleus [D] Chromos
19. The zygote that develops into tissues and organs of the body is known as -------- (Fill in the blank)
    [A] Fertilization [B] Zygote [C] Embryo [D] Foetus

(Answers to this Science Quiz shall be provided in next e-Bulletin)

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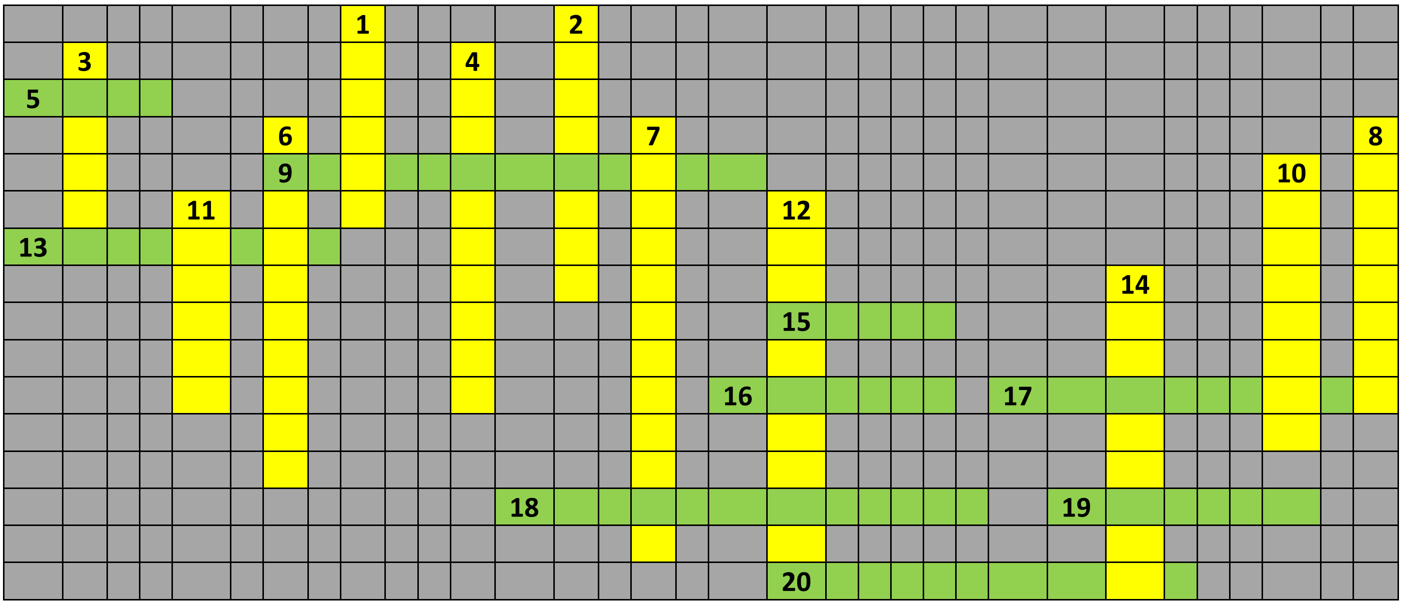
ANSWERS TO SCIENCE QUIZ Oct'16

1. [D]; 2. [B]; 3. [A]; 4. [B]; 5. [D]; 6. [C]; 7. [D]; 8. [B]; 9. [C]; 10. [D]; 11. [C]; 12. [B]; 13. [A]; 14. [C]; 15. [A]; 16. [B]; 17. [C]; 18. [C]; 19. [B]; 20. [C]

CROSSWORD PUZZLE Dec'16 : EDUCATION

Prof. S.B. Dhar



Across

5 Form of puzzle

9 Opposite to extension

13 Scientific and Cultural Community

15 Person incapable of learning

16 Place for learning

17 Study of self-determined learning

18 Mental capacity to reason

19 Ability to make correct judgment

20 Practice of writing pieces of information

Down

1 Unit of Instruction in a subject

2 Process of acquiring knowledge

3 Set of criteria linked to learning objective

4 Set of courses

6 Driving force behind all actions

7 Name for first stage education

8 Science of teaching

10 Manual of instructions

11 Ability of brain to store

12 Integrated education of men and women

14 Removing a student from a school

(Answer to this Crossword Puzzle shall be provided in Qarterly e-Bulletin No 2- Dt. 1st Jan'17)

—00—

Every end, is a pause for a review, before re-continuing of a journey far beyond …

Contents