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Review of Magnetic Levitation (MAGLEV): A Technology to Propel Vehicles with Magnets

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Abstract - The term "Levitation" refers to a class of technologies that uses magnetic levitation to propel vehicles with magnets rather than with wheels, axles and bearings. Maglev (derived from magnetic levitation) uses magnetic levitation to propel vehicles. With maglev, a vehicle is levitated a short distance away from a "guide way" using magnets to create both lift and thrust. High-speed maglev trains promise dramatic improvements for human travel widespread adoption occurs. Maglev trains move more smoothly and somewhat more quietly than wheeled mass transit systems. Their nonreliance on friction means that acceleration and deceleration can surpass that of wheeled transports, and they are unaffected by weather. The power needed for levitation is typically not a large percentage of the overall energy consumption. Most of the power is used to overcome air resistance (drag). Although conventional wheeled transportation can go very fast, maglev allows routine use of higher top speeds than conventional rail, and this type holds the speed record for rail transportation. Vacuum tube train systems might hypothetically allow maglev trains to attain speeds in a different order of magnitude, but no such tracks have ever been built. Compared to conventional wheeled trains, differences in construction affect the economics of maglev trains.

Keywords : maglev levitation, propel, vehicle, trains, vacuum tube.

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REVIEW OF MAGNETIC LEVITATION MAGLEV A TECHNOLOGY TO PROPEL VEHICLES WITH MAGNETS

Review of Magnetic Levitation (MAGLEV): A Technology to Propel Vehicles with Magnets

Monika Yadav [α], Nivritti Mehta [σ], Aman Gupta [ρ], Akshay Chaudhary [Ѡ] & D. V. Mahindru [¥]

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Maglev trains move more smoothly and somewhat more quietly than wheeled mass transit systems. Their non-reliance on friction means that acceleration and deceleration can surpass that of wheeled transports, and they are unaffected by weather. The power needed for levitation is typically not a large percentage of the overall energy consumption. Most of the power is used to overcome air resistance (drag). Although conventional wheeled transportation can go very fast, maglev allows routine use of higher top speeds than conventional rail, and this type holds the speed record for rail transportation. Vacuum tube train systems might hypothetically allow maglev trains to attain speeds in a different order of magnitude, but no such tracks have ever been built. Compared to conventional wheeled trains, differences in construction affect the economics of maglev trains. With wheeled trains at very high speeds, the wear and tear from friction along with the concentrated pounding from wheels on rails accelerates equipment deterioration and prevents mechanically-based train systems from routinely achieving higher speeds. Conversely, maglev tracks have historically been found to be much more expensive to construct, but require less maintenance and have low ongoing costs. Across the world, Engineering has the common language and common goal-"Improving the Quality of Life" of mankind without any boundary restrictions. To bring about this much needed change, Science and Technology need transformation by the frantic pace of market dynamics. What we need today is "Change Leaders" to bring about innovation, growth and a totally new work culture. Levitation is one such remarkable technology that is revolutionizing the technology to propel vehicles:

- In the present work, extensive literature survey has been carried out A demo model has been prepared and the same has been put to operation. The results are very encouraging .Maglev trains use magnets to levitate and propel the trains forward.
- Only the part of the track that is used will be electrified, so no energy is wasted.
- Since there is no friction these trains can reach high speeds.
- It is a safe and efficient way to travel.
- Governments have different feedbacks about the technology. Some countries, like China, have embraced it and others like Germany have balked at the expense.

Keywords : maglev levitation, propel, vehicle ,trains, vacuum tube.

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I. Introduction

Maglev (derived from magnetic levitation) uses magnetic levitation to propel vehicles with magnets rather than with wheels, axles and bearings. With maglev, a vehicle is levitated a short distance away from a guide way using magnets to create both lift and thrust. High-speed maglev trains promise dramatic improvements for human travel if widespread adoption occurs.

Maglev trains move more smoothly and somewhat more quietly than wheeled mass transit systems. Their non-reliance on friction means that acceleration and deceleration can surpass that of wheeled transports, and they are unaffected by weather. The power needed for levitation is typically not a large percentage of the overall energy consumption most of the power is used to overcome air resistance (drag), as with any other high-speed form of transport. Although conventional wheeled transportation can go very fast, maglev allows routine use of higher top speeds than conventional rail, and this type holds the speed record for rail transportation. Vacuum tube train systems might hypothetically allow maglev trains to attain speeds in a different order of magnitude, but no such tracks have ever been built.

II. Description

- Principle of Maglev

Maglev is a system in which the vehicle runs levitated from the guide way (corresponding to the rail tracks of conventional railways) by using electromagnetic forces between superconducting magnets on board the vehicle and coils on the ground. The following is a general explanation of the principle of Maglev.

a) Principle of magnetic levitation

The "8" figured levitation coils are installed on the sidewalls of the guide way. When the on-board superconducting magnets pass at a high speed about several centimeters below the center of these coils, an electric current is induced within the coils, which then acts as electromagnet temporarily. As a result, there are forces which push the superconducting magnet upwards and ones which pull them upwards simultaneously, thereby levitating the Maglev vehicle.

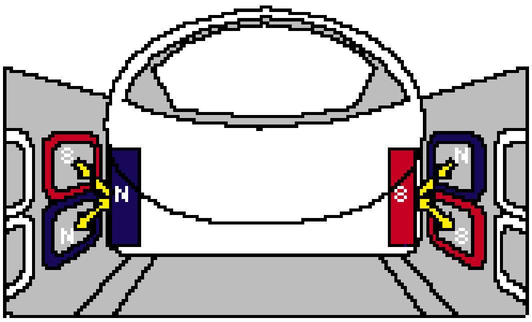


Figure 1: Principle of Magnetic Levitation

b) Principle of lateral guidance

The levitation coils facing each other are connected under the guide way, constituting a loop. When a running Maglev vehicle, that is a super conducting magnet, displaces laterally, an electric current is induced in the loop, resulting in a repulsive force acting on the levitation coils of the side near the car and attractive force acting on the levitation coils of the side farther apart from the car. Thus, a running car is always located at the center of the guide way.

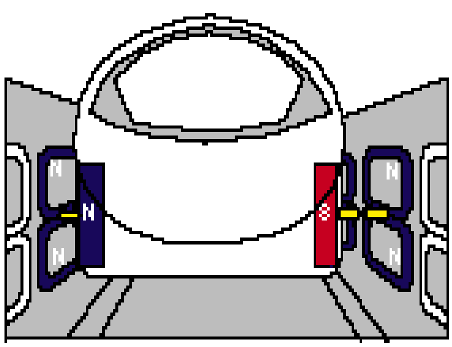


Figure 2 : Principle of Lateral Guidance

c) Principle of Propulsion

A repulsive force and an attractive force induced between the magnets are used to propel the vehicle (superconducting magnet). The propulsion coils located on the sidewalls on both sides of the guide way are energized by a three-phase alternating current from a substation, creating a shifting magnetic field on the guide way. The on-board superconducting magnets are attracted and pushed by the shifting field, propelling the Maglev vehicle.

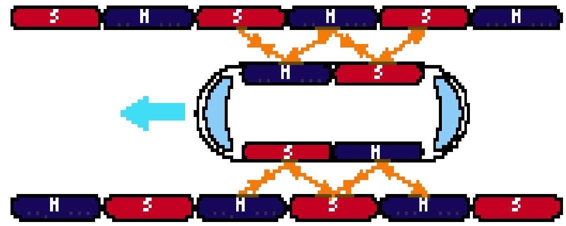


Figure 3 : Principle of Propulsion

III. Basic Concept

Magnets repel each other when they're placed with their like poles together because they create a magnetic field when they're created. While scientists don't rightly know why electromagnetic fields take the shape that they do, their general consensus states that the field leaves one pole and tries to reach the nearest opposite pole that it can, and when you place the like poles together the opposing fields repel one another.

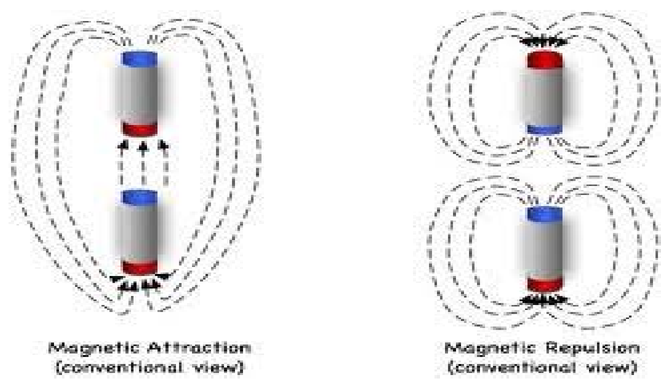


Figure 4 : Attraction and Repulsion of Poles

IV. Fabrication of Demo Model

a) Materials Used

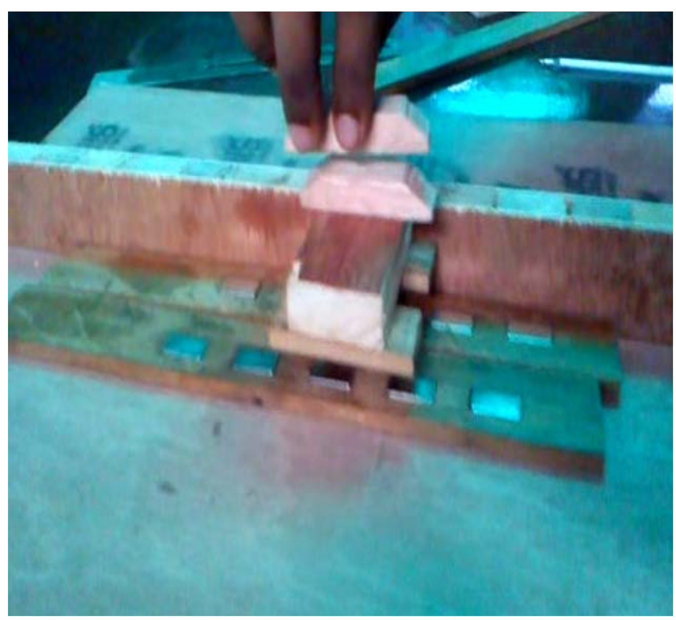
- Sagwan wood for track
- Pine wood for train
- Permanent magnets of area 2*1 cm^2

b) Construction of Demo Model

- Build a magnetic base track of length 30 cm
- Remove material with the help of chisel
- Stick permanent magnets at a distance of 1.5 cm each
- 5 magnets are placed on each side of the track
- Make guide rails to prevent the train from slipping sideways
- Make the train of pine wood and stick the magnets on them also in the same way and maintain equal distance.

V. Procedure for Assembly

- Place the track on flat base of Sagwan wood.
- The two tracks should be placed in such a way that the magnets of the two tracks are not in the same line.
- Now place the guide rails on each side of the tracks in such a way that it prevents the sideward motion of the train.
- After that place the train in centre position.
- Remove 1 guide rail after the train has levitated.
- Place some weight on the levitating train.
- Check if the weight is balanced by the magnetic levitation force.



Pictures of demo model created by our team in mechanical workshops, SRMGPC

VI. Chronological History of Maglev

1750 - The first beginnings of magnetic levitation can be traced back to John Mitchell where he noticed the repulsion of two magnets when the same pole of each was put together.

Early 1900s - Emile Bachelet in France and Frank Goddard in the United States discussed the possibility of using magnetically levitated vehicles for high speed transport.

1922 - Hermann Kemper in Germany pioneered attractive-mode (EMS) Maglev and received a patent for magnetic levitation of trains in 1934.

1934 - On August 14, Hermann Kemper of Germany receives a patent for the magnetic levitation of trains.

1962 - Research of linear motor propulsion and non-contact run started.

1965 - Maglev development in the U.S. began as a result of the High-Speed Ground Transportation (HSGT) Act of 1965.

1966 - In the USA, James Powell and Gordon Danby propose the first practical system for magnetically levitated transport, using superconducting magnets located on moving vehicles to induce currents in normal aluminum loops on a guideway. The moving vehicles are automatically levitated and stabilized, both vertically and laterally, as they move along the guideway. The vehicles are magnetically propelled along the guideway by a small AC current. The original Powell-Danby maglev inventions form the basis for the maglev system in Japan, which is currently being demonstrated in Yamanashi Prefecture, Japan. Powell and Danby have subsequently developed new Maglev inventions that form the basis for their second generation M-2000 System. Powell and Danby were awarded the 2000 Benjamin Franklin Medal in Engineering by the Franklin Institute for their work on EDS Maglev.

1969 - Groups from Stanford, Atomics International and Sandia developed a continuous-sheet guide way (CSG) concept.

1970 - Study of electro dynamic levitation systems using superconducting magnets started formally.

1972 -LSM-propulsion experimental superconducting Maglev test vehicle (LSM200) succeeded in levitated run. LIM-propulsion experimental vehicle (ML100) succeeded in levitated run.

1977 - April, Miyazaki, Japan 7 km. maglev test track was opened. In July, test run of ML-500 inverted-T guide way started at the Miyazaki Test Track.

1979 - In January, a simulated tunnel run tested. May, a run with helium refrigerator on-board tested (ML-500R) and in December, a run of 517 km/h run was attained. (321 MPH).

1980 - November, a test run of MLU001 on U-type guide way started on the Miyazaki Maglev Test Track in Japan.

1982 - November, a manned two-car train test run started.

1984 - Research on the idea was quickly started and a small train was unveiled in Birmingham, England. It was used to ferry people between the town's airport and the city's main train station.

1986 - December, a three-car train registered 352.4 km/h run. (219 MPH)

1987 - January, an unmanned two-car train attained 405.3 km/h (252 MPH). February, a 400.8 km/h run of manned two-car train attained (249 MPH). April,

1989 - March, aerodynamic brake system tested (MLU001). November, 394 km/h run attained (MLU002) (245 MPH).

1990 - March, test of traverser-type turnout started. November, start of initial phase in construction of the Yamanashi Maglev Test Line celebrated.

1991 - National Maglev Initiative receives one billion dollars federal government funding. *5* June, test run using sidewall levitation system started. Test run energized by inverters started. October, the MLU002 burned down in a fire accident.

1992 - The Federal Government in Germany decides to include the 300 km long super speed Maglev system route Berlin-Hamburg in the 1992 Federal Transportation Master Plan.

1993 - January, Test run of MLU002N started.

1994 - February, the MLU002N attained 431 km/h. (268 MPH).

1995 - February, the MLU002N attained 411 km/h (manned). (255 MPH).

1997 - April, the running test of MLX01 on the Yamanashi Maglev Test Line started. December, the MLX01 attained 531 km/h (manned) (330 MPH). MLX01 attained 550 km/h (unmanned)(342 MPH).

1998 - In June, the US congress passes the Transportation Equity Act for the 21st Century (TEA 21). The law includes a Maglev deployment program allocating public funds for preliminary activities with regard to several projects and, later on, further funds for the design, engineering and construction of a selected project. *2* December, test of two trains passing each other at a relative speed of 966 km/h (600 MPH).

2000 - March, The Committee of the Ministry of Transport of Japan concluded "Maglev has the practicability for ultra high speed mass transportation system." August, a cumulative traveled distance exceeded 100,000 km.

2001 -In January, in the US, Transportation Secretary Rodney Slater selects the Pittsburgh and the Washington -Baltimore routes for detailed environmental and project planning. Later that month in China, a contract is concluded between the city of Shanghai and the industrial consortium consisting of Siemens, ThyssenKrupp, and Transrapid International to realize the Shanghai airport link. In March, the construction of the Shanghai project begins. *2* Their Imperial Highnesses Prince and Princess Akishino experienced Maglev trial ride.

2002 - Sout hern California Association of Governments Maglev proposed a 275 mile network and a 54 mile Initial Operating Segment (IOS) was approved December 5 running from West Los Angeles to Ontario Airport. *5* February, cumulative traveled distance exceeded 200,000 km. March, number of passengers for Maglev trial ride exceeded 30,000 persons. July, test run of new train set including MLX01-901 started.

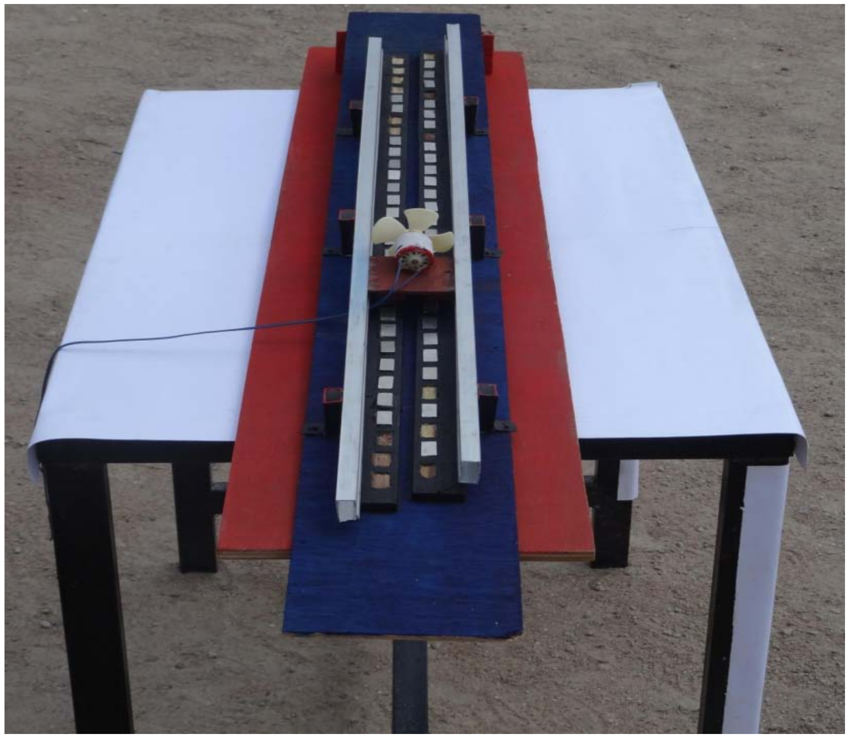
2003 - March, longer traveled distance 1,219 km in a day was attained. July, cumulative traveled distance exceeded 300,000km and the number of passengers for Maglev trial ride exceeded 50,000 persons. November, longest traveled distance 2,876 km in a day was attained. December, the MLX01 arranged in a three-car train set attained 581 km/h (manned).

2004 - August, the number of passengers for Maglev trial ride exceeded 80,000 persons. October, the cumulative traveled distance exceeded 400,000 km. November, a test of two trains passing each other at a maximum relative speed of 1,026 km/h.

2005 - January, His Imperial Highness Crown Prince Naruhito experienced Maglev trial ride.

2006 - Chinese developers unveiled the world's first full-permanent magnetic levitation (Maglev) wind power generator at the Wind Power Asia Exhibition 2006 held June 28 in Beijing, according to Xinhua News. On August 11, the Shanghai maglev caught fire from an onboard battery. September 22, an elevated Transrapid train collided with a maintenance vehicle on a test run in Lathen (Lower Saxony / north-western Germany). Twenty-three people were killed and ten were injured.

2008 - Elevators controlled by magnetic levitation are set to debut.



A. B.

Demo Model at SRMGPC, Lucknow2013'May

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VII. The Technology

a) Magnet

A magnet is any object that has a magnetic field. It attracts ferrous objects like pieces of iron, steel, nickel and cobalt. In the early days, the Greeks observed that the naturally occurring 'lodestone' attracted iron pieces. From that day onwards began the journey into the discovery of magnets.

These days' magnets are made artificially in various shapes and sizes depending on their use. One of the most common magnets - the bar magnet - is a long, rectangular bar of uniform cross-section that attracts pieces of ferrous objects. The magnetic compass needle is also commonly used. The compass needle is a tiny magnet which is free to move horizontally on a pivot. One end of the compass needle points in the North direction and the other end points in the South direction.

The end of a freely pivoted magnet will always point in the North-South direction.

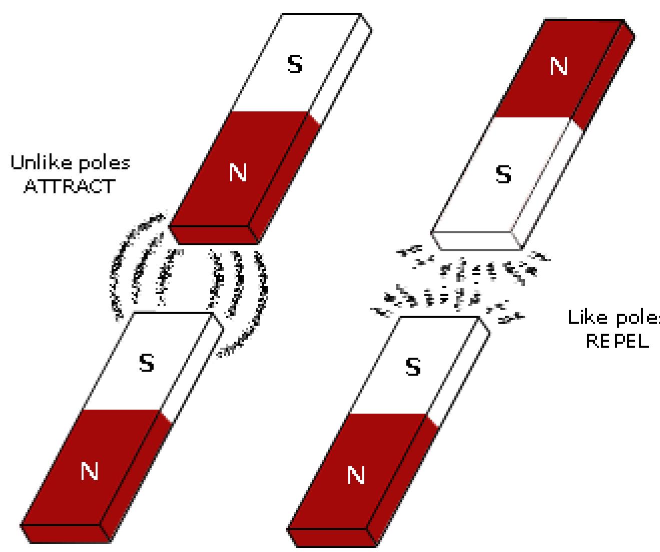

Figure 6.1 : Property of Magnet

The end that points in the North is called the North Pole of the magnet and the end that points south is called the South Pole of the magnet. It has been proven by experiments that like magnetic poles repel each other whereas unlike poles attract each other.

i. *Magnetic Fields*

The space surrounding a magnet, in which magnetic force is exerted, is called a magnetic field. If a bar magnet is placed in such a field, it will experience magnetic forces.

ii. *Magnetic Lines of Force*

Just as an electric field is described by drawing the electric lines of force, in the same way, a magnetic field is described by drawing the magnetic lines of force. When a small north magnetic pole is placed in the magnetic field created by a magnet, it will experience a force. influence of a magnetic field is called a magnetic line of force. In other words, the magnetic lines of force are the lines drawn in a magnetic field along which a north magnetic pole would move.

The direction of a magnetic line of force at any point gives the direction of the magnetic force on a north pole placed at that point. Since the direction of magnetic line of force is the direction of force on a North Pole, so the magnetic lines of force always begin on the N-pole of a magnet and end on the S-pole of the magnet. A small magnetic compass when moved along a line of force always sets itself along the line tangential to it. So, a line drawn from the South Pole of the compass to its North Pole indicates the direction of the magnetic field.

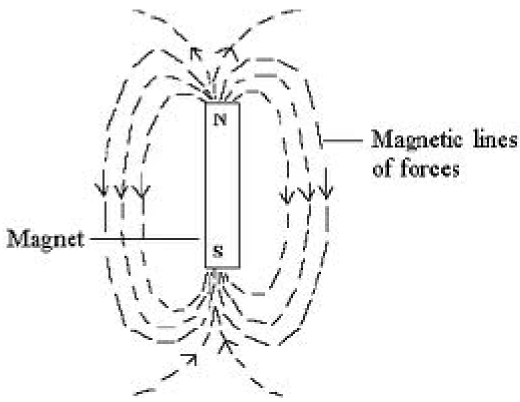

Figure 6.2 : Magnetic Field

iii. *Properties of the magnetic lines of force*

1. The magnetic lines of force originate from the North Pole of a magnet and end at its South Pole.
2. The magnetic lines of force come closer to one another near the poles of a magnet but they are widely separated at other places.
3. The magnetic lines of force do not intersect (or cross) one another.
4. When a magnetic compass is placed at different points on a magnetic line of force, it aligns itself along the tangent to the line of force at that point.
5. These are just some of the basic concepts of magnetism. One cannot possibly grasp the depth and appreciate the versatility of magnets without reading more about the uses of magnets, the

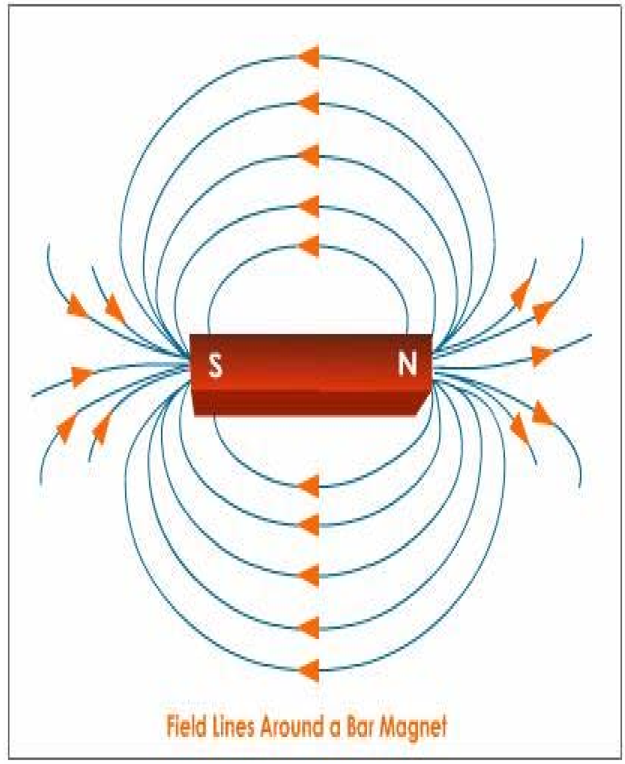

Figure 6.3 : Magnetic Field Lines

b) Types of Magnets

There are various types of magnets depending on their properties. Some of the most well known are listed below.

i. *Permanent Magnets*

These are the most common type of magnets that we know and interact with in our daily lives. E.g. The magnets used in our refrigerators. These magnets are permanent in the sense that once they have been magnetized they retain a certain degree of magnetism. Permanent magnets are generally made of ferromagnetic material. Such material consists of atoms and molecules that each have a magnetic field and are positioned to reinforce each other.

Figure 6.4 : Permanent Magnets

ii. *Classification*

Permanent Magnets can further be classified into four types based on their composition: 1. Neodymium Iron Boron (NdFeB or NIB) 2. Samarium Cobalt (Sm Co) 3. Alnico 4. Ceramic or Ferrite.

NIB and SmCo are the strongest types of magnets and are very difficult to demagnetize. They are also known as rare earth magnets since their compounds come from the rare earth or Lathanoid series of elements in the periodic table. The 1970s and 80s saw the development of these magnets.

Permanent Magnets can also be classified into Injection Moulded and Flexible magnets. Injection molded magnets are a composite of various types of resin and magnetic powders, allowing parts of complex shapes to be manufactured by injection molding. The physical and magnetic properties of the product depend on the raw materials, but are generally lower in magnetic strength and resemble plastics in their physical properties.

iii. *Shape & Configuration*

Permanent magnets can be made into any shape imaginable. They can be made into round bars, rectangles, horseshoes, donuts, rings, disks and other custom shapes. While the shape of the magnet is important aesthetically and sometimes for experimentation, how the magnet is magnetized is equally important. For example: A ring magnet can be magnetized S on the inside and N on the outside, or N on one edge and S on the other, or N on the top side and S on the bottom. Depending on the end usage, the shape and configuration vary.

iv. *Demagnetization*

Permanent magnets can be demagnetized in the following ways: - Heat - Heating a magnet until it is red hot makes it loose its magnetic properties. - Contact with another magnet - Stroking one magnet with another in a random fashion, will demagnetize the magnet being stroked. - Hammering or jarring will loosen the magnet's atoms from their magnetic attraction.

v. *Temporary Magnets*

Temporary magnets are those that simply act like permanent magnets when they are within a strong magnetic field. Unlike permanent magnets however, they loose their magnetism when the field disappears. Paperclips, iron nails and other similar items are examples of temporary magnets. Temporary magnets are used in telephones and electric motors amongst other things.

vi. *Electromagnets*

Had it not been for electromagnets we would have been deprived of many luxuries and necessities in life including computers, television and telephones. Electromagnets are extremely strong magnets. They are produced by placing a metal core (usually an iron alloy) inside a coil of wire carrying an electric current. The electricity in the current produces a magnetic field. The strength of the magnet is directly proportional to the strength of the current and the number of coils of wire. Its polarity depends on the direction of flow of current. While the current flows, the core behaves like a magnet. However, as soon as the current stops, the core is demagnetized.

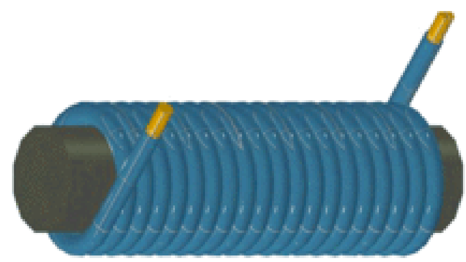

Figure 6.5 : Electromagnet

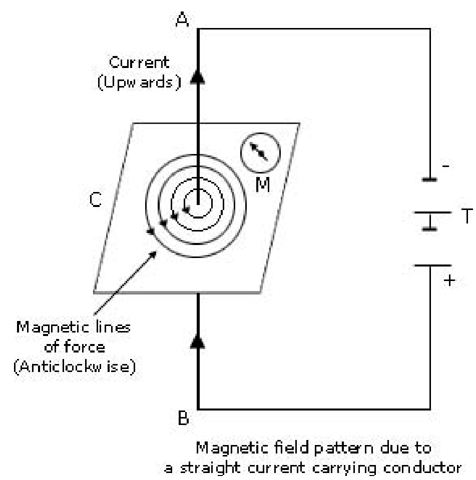

Figure 6.6 : Direction of F, M, I

Electromagnets are most useful when a magnet must be switched on and off as in large cranes used to lift cables and rods in construction.

vii. *Superconductors*

These are the strongest magnets. They don't need a metal core at all, but are made of coils of wire made from special metal alloys which become superconductors when cooled to very low temperatures.

viii. *Electromagn*

An electromagnet is a type of magnet in which the magnetic field is produced by the flow of electric current. The magnetic field disappears when the current is turned off. Electromagnets are widely used as components of other electrical devices, such as motors, generators, relays, loudspeakers, hard disks, MRI machines, scientific instruments, and magnetic separation equipment, as well as being employed as industrial lifting electromagnets for picking up and moving heavy iron objects like scrap iron.

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A simple electromagnet consisting of a coil of insulated wire wrapped around an iron core. The strength of magnetic field generated is proportional to the amount of current.

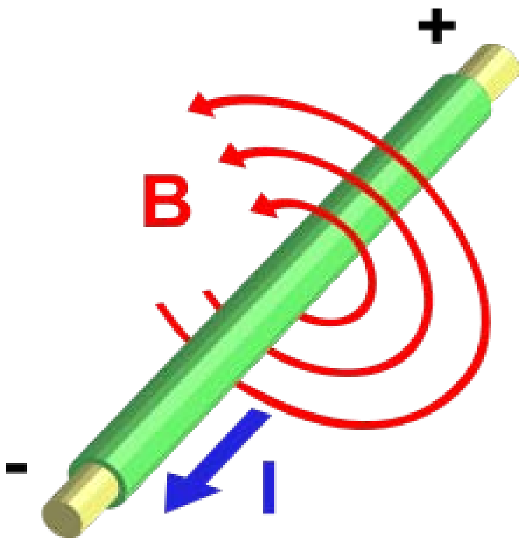

Figure 6.7 : Faraday's Thumb Rule

Current (I) through a wire produces a magnetic field (B). The field is oriented according to the right-hand rule. An electric current flowing in a wire creates a magnetic field around the wire (see drawing below). To concentrate the magnetic field, in an electromagnet the wire is wound into a coil with many turns of wire lying side by side. The magnetic field of all the turns of wire passes through the center of the coil, creating a strong magnetic field there. A coil forming the shape of a straight tube (a helix) is called a solenoid. Much stronger magnetic fields can be produced if a "core" of ferromagnetic material, such as soft iron, is placed inside the coil.

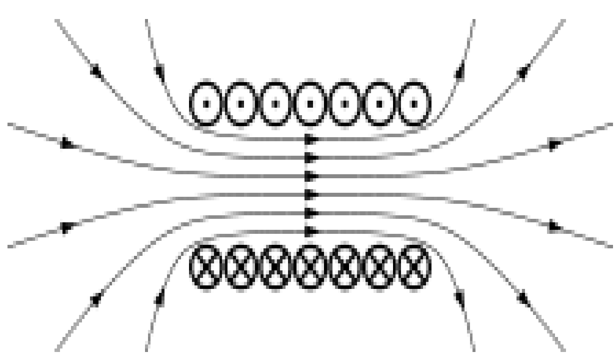

Figure 6.8 : Magnetic field produced by a solenoid

Magnetic field produced by a solenoid (coil of wire). This drawing shows a cross section through the center of the coil. The crosses are wires in which current is moving into the page; the dots are wires in which current is moving up out of the page.

The direction of the magnetic field through a coil of wire can be found from a form of the right-hand rule. If the fingers of the right hand are curled around the coil in the direction of current flow (conventional current, flow of positive charge) through the windings, the thumb points in the direction of the field inside the coil. The side of the magnet that the field lines emerge from is defined to be the north pole.

The main advantage of an electromagnet over a permanent magnet is that the magnetic field can be rapidly manipulated over a wide range by controlling the amount of electric current. However, a continuous supply of electrical energy is required to maintain the field.

How to Make an Electromagnet

To make a simple electromagnet, you can wrap 50 or 100 turns of thin *insulated* copper wire along the length of an iron nail, forming a neat coil of wire tight along and around the nail. (Leave about 9 inches of wire free at each end of the coil to attach to the power source).

1. Wrap the insulated wire around the nail, moving down the nail as you go.
2. Fix the coil of wire in place with some sticky tape.
3. Clean off the insulation at the ends of the extra wire, for about 1 inch, exposing the shiny metal inside.
4. Bend the ends into loops and connect to a LOW VOLTAGE direct-current power supply, such as a model train transformer or a D-cell battery pack.

c) DC Motor

A DC motor is a mechanically the principle commutated electric motor powered from direct current (DC). The stator is stationary in space by definition and therefore its current. The current in the rotor is switched by the commutator to also be stationary in space. This is how the relative angle between the stator and rotor magnetic flux is maintained near 90 degrees, which generates the maximum torque. DC motors have a rotating armature winding (winding in which a voltage is induced) but non-rotating armature magnetic field and a static field winding (winding that produce the main magnetic flux) or permanent magnet. Different connections of the field and armature winding provide different inherent speed/torque regulation characteristics. The speed of a DC motor can be controlled by changing the voltage applied to the armature or by changing the field current. The introduction of variable resistance in the armature circuit or field circuit allowed speed control. The introduction of DC motors to run machinery eliminated the need for local steam or internal combustion engines, and line shaft drive systems.

i. *Brush*

A brushed DC electric motor generating torque from DC power supply by using internal mechanical commutation, space stationary permanent magnets form the stator field. Torque is produced by the principle of Lorentz force, which states that any current-carrying conductor placed within an external magnetic field experiences a force known as Lorentz The actual (Lorentz) force (and also torque since torque is F x l where l is rotor radius) is a function for rotor angle and so the green arrow/vector actually changes length/magnitude force. with angle known as torque ripple) Since this is a single phase two pole motor the commutator consists of a split ring, so that the current reverses each half turn (180 degrees).

The brushed DC electric motor generates torque directly from DC power supplied to the motor by using internal commutation, stationary magnets (permanent or electromagnets), and rotating electrical magnets.

ii. *Brushless*

Typical brushless DC motors use a rotating permanent magnet in the rotor, and stationary electrical current/coil magnets on the motor housing for the rotor, but the symmetrical opposite is also possible. A motor controller converts DC to AC. This design is simpler than that of brushed motors because it eliminates the complication of transferring power from outside the motor to the spinning rotor. Advantages of brushless motors include long life span, little or no maintenance, and high efficiency. Disadvantages include high initial cost, and more complicated motor speed controllers. Some such brushless motors are sometimes referred to as "synchronous motors" although they have no external power supply to be synchronized with, as would be the case with normal AC synchronous motors.

Figure 6.9 : DC Motor

iii. *Uncommutated*

Other types of DC motors require no commutation. Homopolar motor – A homopolar motor has a magnetic field along the axis of rotation and an electric current that at some point is not parallel to the magnetic field. The name homopolar refers to the absence of polarity change.

Homopolar motors necessarily have a single-turn coil, which limits them to very low voltages. This has restricted the practical application of this type of motor. Ball bearing motor – A ball bearing motor is an unusual electric motor that consists of two ball bearing-type bearings, with the inner races mounted on a common conductive shaft, and the outer races connected to a high current, low voltage power supply.

iv. *Connection Types*

There are three types of electrical connections between the stator and rotor possible for DC electric motors: series, shunt/parallel and compound (various blends of series and shunt/parallel) and each has unique speed/torque characteristics appropriate for different loading torque profiles/signatures.

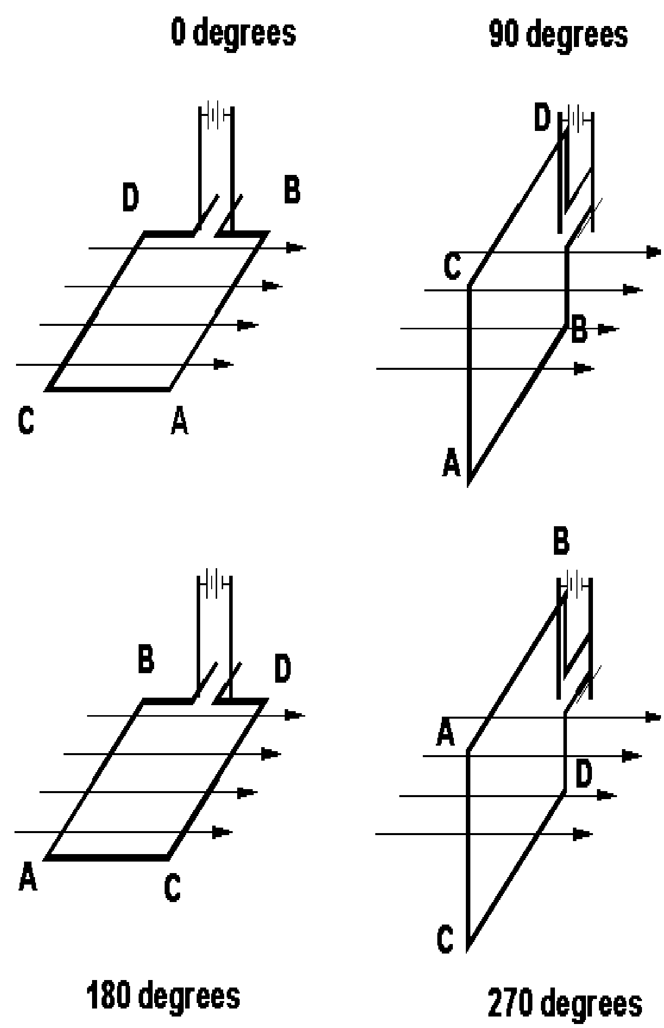

Figure 6.10 : Working of Dc Motor

v. *Series Connection*

A series DC motor connects the armature and field windings in series with a common D.C. power source. The motor speed varies as a non-linear function of load torque and armature current;

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current is common to both the stator and rotor yielding I^2 (current) squared behavior. A series motor has very high starting torque and is commonly used for starting high inertia loads, such as trains, elevators or hoists. This speed/torque characteristic is useful in applications such as dragline excavators, where the digging tool moves rapidly when unloaded but slowly when carrying a heavy load.

With no mechanical load on the series motor, the current is low, the counter-EMF produced by the field winding is weak, and so the armature must turn faster to produce sufficient counter-EMF to balance the supply voltage. The motor can be damaged by over speed. This is called a runaway condition.

Series motors called "universal motors" can be used on alternating current. Since the armature voltage and the field direction reverse at (substantially) the same time, torque continues to be produced in the same direction.

vi. *Shunt Connection*

A shunt DC motor connects the armature and field windings in parallel or shunt with a common D.C. power source. This type of motor has good speed regulation even as the load varies, but does not have the starting torque of a series DC motor.

vii. *Compound Connection*

A compound DC motor connects the armature and fields windings in a shunt and a series combination to give it characteristics of both a shunt and a series DC motor. This motor is used when both a high starting torque and good speed regulation is needed. The motor can be connected in two arrangements: cumulatively or differentially. Cumulative compound motors connect the series field to aid the shunt field, which provides higher starting torque but less speed regulation.

VIII. Analysis

- For Motor

Power = V*I = 2πNT/60

12*2 =2*3.14*4400*T/60

T= 0.0521 N-m

- For the track

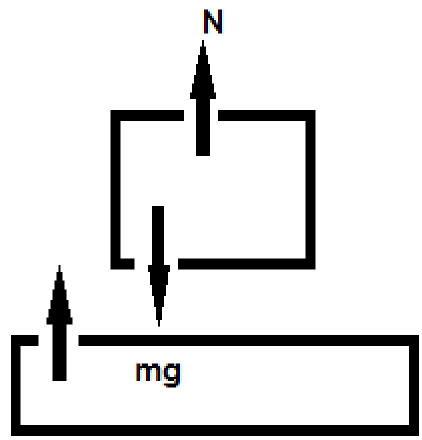
Length of track = 2*n + total gap between magnets (n= number of magnets)

Total gap between magnets= (n-1)*1

Thus, Total length of track= 2*30 + (30-1)*1= 89cm =.89m

- For Train

Mass of the bogie=41.7gm=.0417kg



Force between the bogie and track,

$$F = AB^2/2\mu 0 = mg$$

A-Total area of the magnets under the bogie

B-Flux density

We have,

A=area of one bar * no. of bars under bogie and track

A= .02*.01*8= .0016

$B = 3.1*10^{-2}$ T

$F = AB^2/2\mu 0 = .6118$ N

Now we have,

Weight of the bogie, W= .0417*9.81=.409N

As, F>W so bogie is balanced by the magnetic force and thus the bogie is levitated.

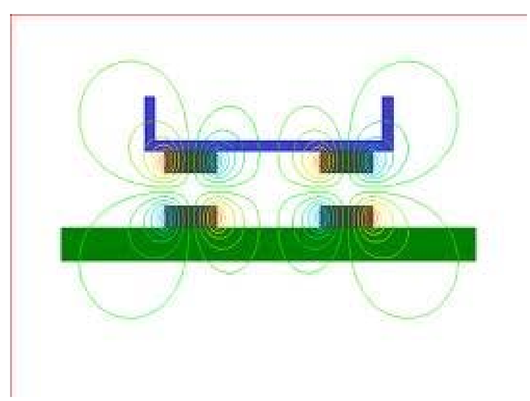


Figure 7.1 : Levitation is Possible

Thrust calculation-

1. Voltage = 12V , Current = 1.9Amp

x= 9.2-7.8

= 1.4cm

$h = x\,(S_h / S_o - 1)$

= (1.4/100) (1750/1000 -1)

$= (1.4/100) \text{ X } 0.75$

$= 0.0105 \text{ m}$

$= 1.05 \text{ cm}$

Velocity of air:

$$V = C_v \sqrt{2gh}$$

$$\text{Let, } C_v = 1$$

$$V = \sqrt{2 \times 9.81 \times 0.0105}$$

$$= 0.45388 \text{ m/sec}$$

Thrust force:

Thrust = (dm/dt) × V

Mass flow rate (dm/dt) = ρav

So, Thrust = $\rho av \times v = \rho av^2$

$$= 1.75\times 1000 \times (\pi/4) \times 0.08^2 \times 0.45388$$

$$= 1.8114 \text{ N}$$

2. Voltage = 12V, Current = 1.7 Amp

$$x = 9 - 7.8$$

$$= 1.2 \text{ cm}$$

$$h = x (S_h/ S_o -1)$$

$$= 0.75 \times (1.2/100)$$

$$= 9 \times 10^{-3} \text{ m}$$

Velocity of air:

$$V = \sqrt{2gh}$$

$$= \sqrt{2} \times 9.81 \times 0.009$$

$$= 0.4202 \text{ m/sec}$$

Thrust force:

Thrust = (dm/dt) × V

Mass flow rate (dm/dt) = ρav

Thrust = ρav^2

$$= 1.75\times 1000 \times (\pi/4) \times 0.08^2 \times 0.4202^2$$

$$= 1.5532 \text{ N}$$

3. Voltage = 12V , Current = 1.5 Amp

$$x = 8.75 - 7.8$$

$$= 0.95 \text{ cm}$$

$$h = x (S_h/ S_o -1)$$

$$= 0.75 \times (0.95/100)$$

$$= 7.125\times 10^{-3} \text{ m}$$

Velocity of air:

$$V = \sqrt{2gh}$$

$$V = \sqrt{2} \times 9.81 \times 0.007125$$

$$= 0.3738 \text{ m/sec}$$

Thrust force:

Thrust = (dm/dt) × V

Mass flow rate (dm/dt) = ρav

Thrust = ρav^2

$$= 1.75\times 1000 \times (\pi/4) \times 0.08^2 \times 0.3738^2$$

$$= 1.2296 \text{ N}$$

4. Voltage = 12 V , Current = 1.3Amp

$$x = 8.6 - 7.8$$

$$= 0.8 \text{cm}$$

$$h = x (S_h/S_o -1)$$

$$= 0.75\times (0.8/100)$$

$$= 6\times 10^{-3} \text{ m}$$

Velocity of air:

$$V = \sqrt{2gh}$$

$$V = \sqrt{2} \times 9.81 \times 0.006$$

$$= 0.34310 \text{ m/sec}$$

Thrust force:

Thrust = (dm/dt) × V

Mass flow rate (dm/dt) = ρav

Thrust = ρav^2

$$= 1.75\times 1000 \times (\pi/4) \times 0.08^2 \times 0.34310^2$$

$$= 1.0355 \text{N}$$

5. Voltage = 12V , Current = 1.1Amp

$$x = 8.45 - 7.8$$

$$= 0.65 \text{cm}$$

$$h = x (S_h/S_o -1)$$

$$= 0.75\times (0.65/100)$$

$$= 4.875\times 10^{-3} \text{m}$$

Velocity of air:

$$V = \sqrt{2gh}$$

$$V = \sqrt{2} \times 9.81 \times 0.004875$$

$$= 0.3092 \text{ m/sec}$$

Thrust force:

Thrust = (dm/dt) × V

Mass flow rate (dm/dt) = ρav

Thrust = ρav^2

$$= 1.75\times 1000 \times (\pi/4) \times 0.08^2 \times 0.3092^2$$

$$= 0.84135 \text{N}$$

6. Voltage = 12 V, Current = 1.08Amp

$$x = 8.2 - 7.8$$

$$= 0.4 \text{ cm}$$

$$h = x (S_h/S_o -1)$$

$$= 0.75\times (0.4/100)$$

$$= 3\times 10^{-3} \text{ m}$$

Velocity of air:

$$V = \sqrt{2gh}$$

$$V = \sqrt{2} \times 9.81 \times 0.003$$

$$= 0.2426 \text{ m/sec}$$

Thrust force:

Thrust = (dm/dt) × V

Mass flow rate (dm/dt) = ρav

Thrust = ρav^2

$$= 1.75\times 1000 \times (\pi/4) \times 0.08^2 \times 0.2426^2$$

$$= 0.51775 \text{N}$$

Maglev Track
with Floating
Train in Place
(end view)

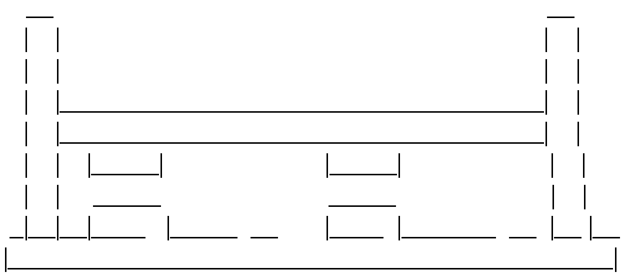


Figure 7.2 : Floating Train

Calculation for the speed of bogie at different angles of inclination:

1. Angle of elevation is 0^0:

Speed = $[0.17\times (1/5.6) \times (18/5)]$

$= 0.10928$ m/sec

2. For angle of 12^0 :

a) While running down the plane

Inclination (θ) = 12°

Speed $= [(9.2/100) \times (1/7.21)\times (18/5)]$

$= 0.0459$ m/sec

3. For various angles while going up the plane:

i. Inclination (θ) = 12°

Speed = 0.036 m/sec

ii. Inclination = 11.5°

Speed = 0.04001 m/sec

iii. Inclination = 11°

Speed = 0.03912 m/sec

iv. Inclination = 10.5°

Speed = 0.0385 m/sec

v. Inclination = 10°

Speed = 0.0386 m/sec

Multiple Regressions

Formulae of multiple regressions:

$$y = a + bx + cz$$

$$\sum y = na + b\sum x + c\sum z$$

$$\sum xy = a\sum x + b\sum x^2 + c\sum xz$$

$$\sum zy = a\sum z + b\sum xz + c\sum z^2$$

Where,

y= Speed of bogie (m/sec)

x= Thrust (N)

z= Inclination (degrees)

Putting the values from the table in the equations:

0.20213= 5a+6.411b+0.9641c Equation1

2.655= 6.411a+8.4854b+1.223c Equation 2

0.039= 0.9641a+1.223b+0.187c Equation 3

After solving equations 1, 2 and 3

We get,

a = -78.576

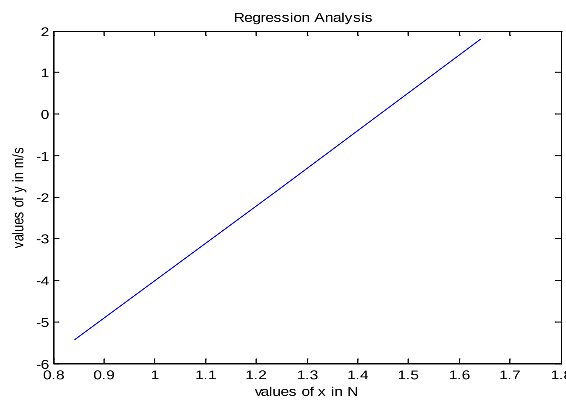
b = 22.089

c = 260.84

e = error

$$\boxed{y = 22.089x+260.84z-78.576+e}$$

Graph derived from the above analysis:



IX. Indian -Initiative

- Pune (Pimple Saudagar) – Mumbai (Panvel) : The Indian Ministry is currently in the process of reviewing a proposal to start a Maglev train system in India.[11] It has already been estimated that the cost to complete this process would be over $30 Billion. The company who sent the proposals is a company based in the United States. There have been feelers sent to Lalu Prasad, Railway Minister, in which the advantages of a Maglev train system were presented. Although still at a preliminary stage, if completed, the train travel time between the two cities will be reduced to three hours, compared to an original 16 hours. travel daily, making fuel consumption at .2 million liters a day . The business proposal is to reduce the fuel consumption and

y(m/s)	x(N)	z(degrees)	x^2	Xy	xz	Yz	z^2
0.0386	0.84315	0.209	0.70786	0.03247	0.1758	0.00806	0.04386
0.0385	1.0355	0.2007	1.0722	0.03986	0.2078	0.00772	0.04028
0.03912	1.2296	0.194	1.5119	0.0481	0.23851	0.00758	0.03685
0.04001	1.5532	0.1832	2.4124	0.0621	0.2845	0.00732	0.03558
0.0459	1.8114	0.1745	3.2811	0.083	0.31608	0.00801	0.03046
$\sum y$=0.20213	$\sum x$=6.411	$\sum z$=0.9641	$\sum x^2$=8.4854	$\sum xy$=2.655	$\sum xz$=1.223	$\sum yz$=0.039	$\sum z^2$=0.187

promote Maglev by income from Carbon Credit Sales.

- Mumbai – Delhi
  A maglev line project was presented to the then Indian railway minister (Mamta Banerjee) by an American company. A line was proposed to serve between the cities of Mumbai andDelhi, the Prime Minister Manmohan Singh said that if the line project is successful the Indian government would build lines between other cities and also between Mumbai Centraland Chhatrapati Shivaji International Airport.
- Mumbai - Nagpur
  The State of Maharashtra has also approved a feasibility study for a maglev train between Mumbai (the commercial capital of India as well as the State government capital) and Nagpur (the second State capital) about 1,000 km (620 mi) away. It plans to connect the regions of Mumbai and Pune with Nagpur via less developed hinterland (via Ahmednagar,Beed, Latur, Nanded and Yavatmal).
- Chennai - Bangalore - Mysore
  Large and Medium Scale Industries Minister of Karnataka Mr. Murugesh Nirani, a detailed report will be prepared and submitted by December 2012 and the project is expected to cost $26 million per kilometer of railway track. The speed of Maglev will be 350 kmph and will take 30 mins from Chennai to Mysore via Bangalore.
- KochiMetro
  Union Minister of State for Consumer Affairs, Food and Public Distribution K. V. Thomas proposed that Kochi Metro can adopt same technology as present in South Korea.

X. Conclusion

- We were able to successfully demonstrate with our model the feasibility of Levitation as a "Powerful Source" to propel vehicles
- Dimension of the track and vehicle should be accurate in order to get better results.
- The train is best levitated in center position.