21486 MagLev Activity Track

A Teacher-Friendly Guide for the MagLev Activity Track

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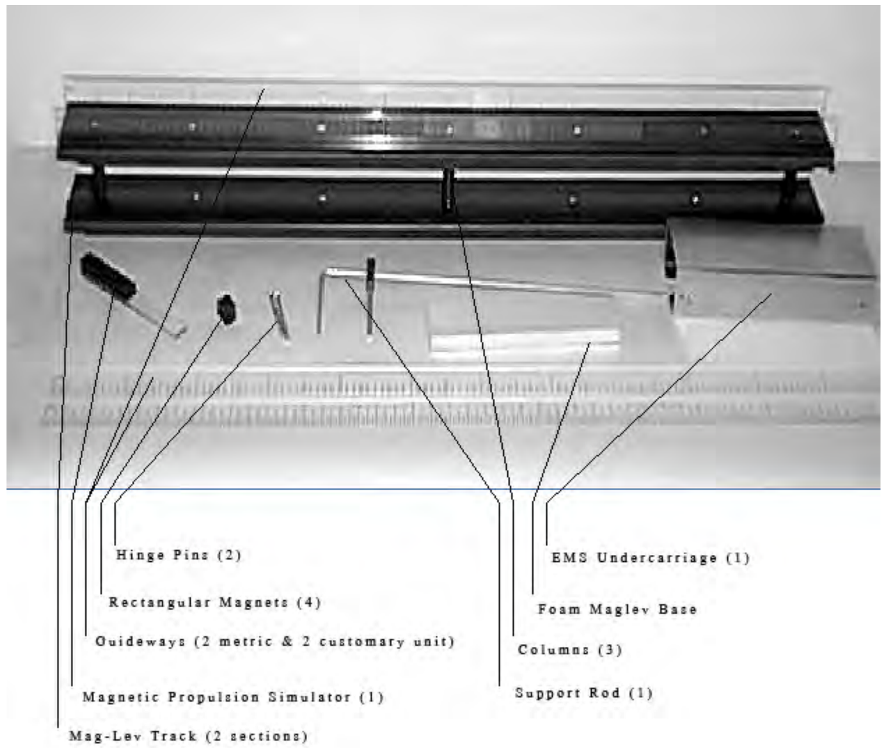
The following pages may be reproduced by teachers for classroom use only: the 3-page “Helpful Hints for Students” and the “Maglev Data Log”.

Kit Contents:

Two (2)	Bases (4ft long) with attached magnetic strip assemblies
Four (4)	Magnetic strips (4ft long)
Two (2)	Clear Plastic Guideways marked in inches
Two (2)	Clear Plastic Guideways marked in centimeters
One (1)	Magnetic Wand, (Magnetic Propulsion Simulator)
Three (3)	Columns (2.75inches long)
Six (6)	Flat Head Screws (for mounting bases to columns)
Four (4)	Flat Head Screws, XXin long, (for attaching magnetic strip assemblies to the wooden bases)
Two (2)	Hinge Pins
One (1)	Styrofoam Block (repulsion model blank)
Four (4)	Rectangular Ceramic Magnets
One (1)	Electromagnetic Suspension Vehicle Undercarriage (with Magnetic Strips Attached)
One (1)	Styrofoam Block (Electrodynamic Suspension Vehicle Body)



Preface

In 1992 Virginia Moore, a fourth grade teacher, and William Kaszas, a middle school technology education teacher, joined forces to demonstrate that elementary children could experience, in a meaningful way, the thrill of learning about a cutting-edge form of train transportation called magnetic levitation, popularly known as Maglev.

The topic of Maglev has been taught in grades 7-12 in New York State for the past several years. The authors have developed activities for grades 4-6 and elaborated on activities for grades 7-12. Their interdisciplinary unit can now be utilized by teachers in grades 4-12. Their work, "All Aboard! For a Lesson on Magnetic Levitated Trains," was published in the February, 1995, issue of Science and Children.

The United States has been experiencing a renewed interest in further developing its own maglev technology. Capitalizing on the heavy publicity accompanying this interest, the authors felt maglev would be the catalyst which could tie together many topics from the other disciplines and encourage problem solving strategies.

Maglev train technology involves the magnetic levitation and propulsion of a vehicle over, around, or within a guideway. The authors are teachers, not engineers. While we can provide the reader with a basic knowledge of maglev in a teacher-friendly manner, we refer you to the Resources in the back of this guide for a fuller description of the technology involved.

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Historical Synopsis

In 1909, Robert Goddard, sometimes known as the "Father of Rocketry," suggested in the magazine Scientific American that a tunnel could be built from Boston to New York in which cars could ride in a partial vacuum while suspended and propelled by the "magic power of magnetism."

Just a few years later, in 1912, Emile Bachelet, a New Yorker, obtained the first United States patent on his forty-foot long track and thirty-three pound maglev train model. It was levitated above a continuous row of electromagnets supplied with alternating current. His son recalls that it had sufficient momentum and power to crash through the side of the house and out into the yard!

The following year Bachelet took a miniature model, dubbed the "Wonderful Flying Train" to London where it was exhibited to royalty. Sir Winston Churchill was reported to have exclaimed, "By George, it's great!" Unfortunately, it consumed too much power to ever become a practical method for lifting a 40-ton vehicle. In addition, the invention was soon overshadowed by the development of the Wright Brothers' airplane and the advent of the first World War.

Years later, in 1933, Germany's Hermann Kemper mastered the problem of controlling levitated vehicles by using electromagnets.

However, the idea of magnetic levitated transportation lay dormant until the 1960's when James Powell, an engineer from Brookhaven National Laboratory on Long Island, New York, got caught in a traffic jam on the Throg's Neck Bridge. He envisioned a vehicle that would liberate him from highway gridlock forever.

Powell, who was unacquainted with Bachelet's work, sought out colleague Gordon Danby, a physicist. Their main insight was that sufficient lifting force could be achieved by using superconducting magnets, i.e. magnets which had been cooled to four kelvins with liquid helium. Once suspended, the train still had to move forward and backward. To accomplish this, the same magnets used for levitation were pushed then pulled by fields of alternating polarity generated by current supplied to magnetic coils in the guideway. Speed, acceleration, and deceleration (braking) are controlled by varying the frequency and intensity of the current.

In 1966 the two researchers published a paper on superconducting maglev entitled, "High Speed Transport by Magnetically Suspended Trains," and two years later received a patent on their work. Maglev had been resurrected!

Soon thereafter, Henry Kolm and Richard Thornton, researchers at MIT, began developing the magneplane, a machine which is levitated six inches above a trough-like guideway. With a $650,000 grant from the National Science Foundation, they, with the help of 80 graduate students, built a 1/25th scale model vehicle which raced down its guideway in 1973.

While United States funding for maglev was curtailed in 1975 by the White House Office of Management and Budget, other countries were quick to see the potential for a form of transportation that was more energy efficient, less polluting, and could attain speeds up to 300 miles per hour. Great Britain, Romania, West Germany, and Japan initiated their own maglev programs in the 1960's and Canada followed suit in the 1970's. At present, the German Transrapid is the only passenger-carrying Maglev train in the world.

On October 28, 1994, ground-breaking for a Maglev research and development center was held at Stewart Airport in Orange County, New York. Former Governor Mario Cuomo strongly supported the new technology; however, due to the recent change in administration in Albany and lack of federal support, the future of Maglev in New York is uncertain.

But while the benefits and drawbacks of Maglev are being debated at the highest levels of state and federal governments, school children can experience the excitement of a form of transportation that may well define the 21st Century!

In February, 1994, John Shafer, Executive Director of the New York State Thruway Authority addressed fourth and fifth graders and their parents at the Pakanasink Elementary School maglev competition in Circleville, N.Y. He stated that although maglev had gotten a late start in the United States, it was through their participation in competitions such as the one held that evening and attention to their studies that would make them the future scientists, mathematicians, and engineers who would perfect American maglev technology!

Interdisciplinary Activities in Science, Technology, & Math

The Development of Essential Questions
A popular technique in curriculum development today is the creation of several essential questions which focus the students' learning on a particular topic and enhance the overall understanding of the unit of study.

We found that the following questions embodied the most important understandings in our unit on Maglev. These essential questions were displayed in the classroom:

- How have people met their transportation needs in the past?
- How will maglev affect people's lives in the future?
- How can I become a better problem solver?

Process Skills
These are some of the process skills that students will use in the course of this maglev unit:

- Observation
- Measurement
- Manipulating materials
- Recording and interpreting data
- Making decisions

Science Concepts
These are some of the concepts that can be taught to students in the elementary and middle grades:

- Magnetism: Like poles repel; unlike poles attract.
- Laws of Motion: The speed of a vehicle increases with an increase in slope.
- Friction: The force which resists the motion of one body against another.
- Aerodynamics: The study of the forces acting upon bodies in motion through the air.

Technological Understandings
The following understandings would be suitable for the Middle Level and High School student:

- Many of people's needs are met by advances in transportation technology.
- Advances in science and technology can produce negative as well as positive outcomes.
- The problem solving process includes design, planning, the generation of alternatives, and implementation.
- Advances in science and technology lead to new careers.

Background for the Teacher

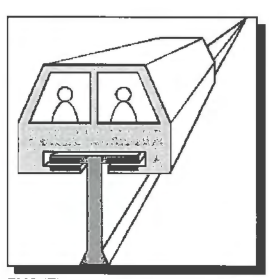
The science of the maglev train is based on two systems: the ***Suspension System*** and the ***Propulsion System.***

In the Suspension System, maglev vehicles are elevated above a guideway by the attractive or repulsive forces of powerful magnets. There are two types of suspension system:

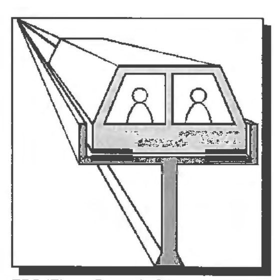
1) The EDS (ElectroDynamic Suspension) System which works on the repulsion of like magnetic poles.

2) The EMS (ElectroMagnetic Suspension) System which works on the attraction of unlike magnetic poles.

Both systems are being developed in different countries. The Germans have developed in different countries. The Germans have developed the EMS System and the Japanese have developed the EDS System.



EMS (ElectroMagnetic Suspension) System. The magnets on the track attract the magnets on the train.



EDS (ElectroDynamic Suspension) System. Magnets on the track repel the magnets on the train.

In the Propulsion System, linear electric motors built into the guideway generate a “traveling” magnetic field that always remains ahead of the vehicle and pulls the train along. The train can reach speeds of 300 miles per hour in short distances.

These two systems offer the following advantages over trains with wheels. Because there is no contact with the guideway, maglev vehicles produce less friction and vibration. They provide a smoother and faster ride with less noise and with low maintenance requirements.

Teacher Demonstrations

Demonstration #1 The Repulsion Suspension System

(In technical terms this is called the Electrodynamic Suspension System or EDS. This suspension system is based on the repulsion of like magnetic fields.)

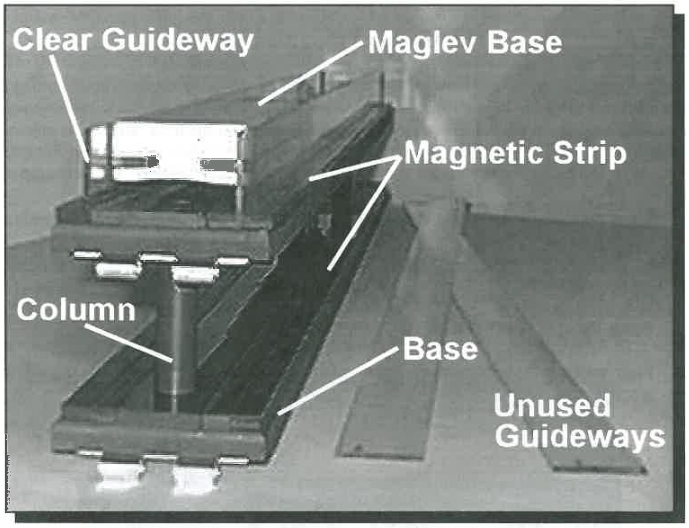


Figure 1: The MagLev Track.

Objectives:

- To teach the Law of Magnetic Attraction/Repulsion which states: like poles repel; unlike poles attract.
- To teach students that people have applied this law in the construction of a practical means of transportation known as maglev.

Procedures:

1. Set up the track with the clear plastic guideways as in figure #1.

2. Slide the rectangular magnets into the grooves of the one-inch styrofoam maglev base so that the North surface faces downward repelling the strip on the track. Have students discuss their observations. (The vehicle floats above the track.)

Conclusion:
The North Poles on the vehicle repel the North Poles on the track causing the vehicle to levitate, proving that like poles repel.

3. Turn over the magnets on the vehicle so that the South Poles face downward. Place the vehicle on the track again and have students discuss their observations. (Vehicle does not levitate and appears to be "stuck" to the track.)

Conclusion:
The South Poles of the vehicle's magnets were attracted to the North Poles on the track's magnetic strips, proving that unlike poles attract.

Demonstration #2 The MagLev Propulsion System

Placing the propulsion simulator beneath te guideway will allow you to manually move a magnetic field down its length and attract the train. In real life a moving electromagnetic field in the guideway is governed by a computer to attract the train down the guideway. In essence, the magnets on the train “chase” the electromagnetic field on the guideway.

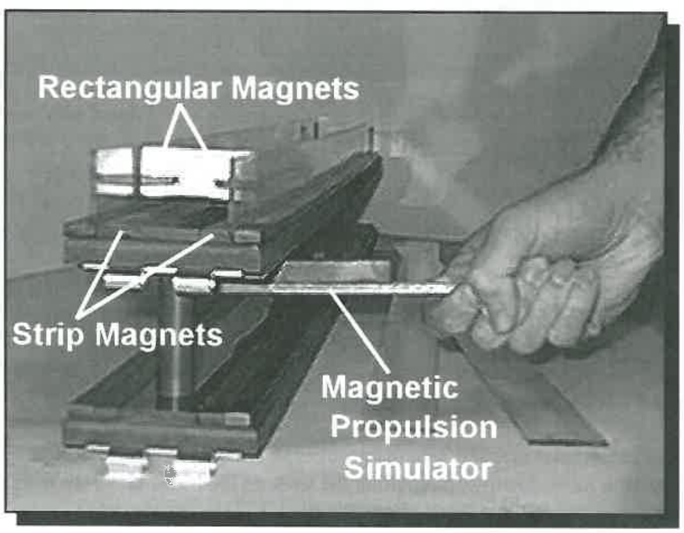


Figure 2: The Magnetic Propulsion Simulator.

Objective:
Via a simulation activity students will learn about the maglev propulsion system, which is based on moving magnetic fields.

Procedures:

1. Set up the 4' track as in figure #1.

2. Place the Propulsion Simulator on one end of the track as in figure #2. Slide it down the track until it reaches the column.

3. Place the one-inch styrofoam maglev base (with grooves) in the guideway facing the Propulsion Simulator and directly over it. (This

is the maglev base that levitates by repulsion.) Magnets are inserted in grooves with north side down.

4. Pull the Propulsion Simulator toward the end of the track and observe the maglev base pursuing the Propulsion Simulator's moving magnetic field.

Conclusion: Vehicle propulsion can be achieved by the attraction of magnetic fields.

Note to the teacher: In this demonstration the vehicle is being moved mechanically (guided by hand), as opposed to electromagnetically as in the case of the real maglev where electromagnets on the track are being switched on and off.

The propulsion simulator can only be used with the repulsion (EDS) model because the magnets on the propulsion simulator lack the strength to move the heavier attraction (EMS) model.

Demonstration #3 The Attraction Suspension System

(In technical terms this is called the Electromagnetic Suspension system or EMS. This suspension system is based on the attraction of unlike magnetic fields.)

Objectives:

- To teach the Law of Magnetic Attraction which states, in part, that unlike poles attract.
- To teach that people have applied this law in the construction of a practical means of transportation known as maglev.

EMS Model

Procedures:

1. Remove the two plastic guideways from the upper track

2. Turn the track upside down.

3. Slide the EMS (electromagnetic suspension) undercarriage over the end of the track.

4. Equalize the EMS model with weight (washers, paperclips, etc...) to adjust the levitation of the vehicle.

Observations:
Magnets on the bottom of the EMS undercarriage are attracted to those on the track, causing the vehicle to levitate. Once levitation has been achieved, the undercarriage can be moved back and forth on the track by hand. (The gap screws on the EMS model ensure the space between the track magnets and the magnets on the EMS model.)

Conclusion:
Levitation of the maglev vehicle can be achieved through the attraction of unlike poles. (Note:In the real maglev train, adequate levitation is achieved by balancing the vehicle's weight combined with its payload with the strength of the electromagnetic field.)

Note to the teacher: The propulsion simulator wand cannot be used for this demonstration because the magnets in the wand are not strong enough to move the EMS model.

Demonstration #4 The Relationship of Velocity & Slope (The Math Connection)

Additional devices needed which are not included with the track: a photoelectric timer which can measure time to the thousandths of a second, and a protractor to measure the angle of slope.

Objective:
To teach that the velocity of a vehicle increases as the slope increases.

Procedures:
1. Place a large protractor at the base of the track in order to show the angle of slope. (The larger the protractor the better, so angles can be easily seen by students.)

2. Set up the 4' track at a 30 degree angle as in figure #4.

3. Place destination timer at the bottom of the slope and the entry timer about two feet up the slope. The timer emits a beam of light which, when broken, starts or stops the timer. Therefore, the timer must be adjusted so that its beam of light is not positioned higher than the vehicle.

4. Release the maglev repulsion vehicle at the top of the incline and record the elapsed time. The teacher or a student using a calculator may then find the velocity by dividing the distance between the two timers by the elapsed time.

5. Repeat the trials two more times by making the track's angle of incline 20 degrees and then 10 degrees, thereby decreasing the slope. This presents an opportunity to review acute angles (those less than 90 degrees) in geometry and provide comparative data to the results recorded in Step #4.

Conclusion: The steeper the angle of slope, the faster a vehicle will travel.

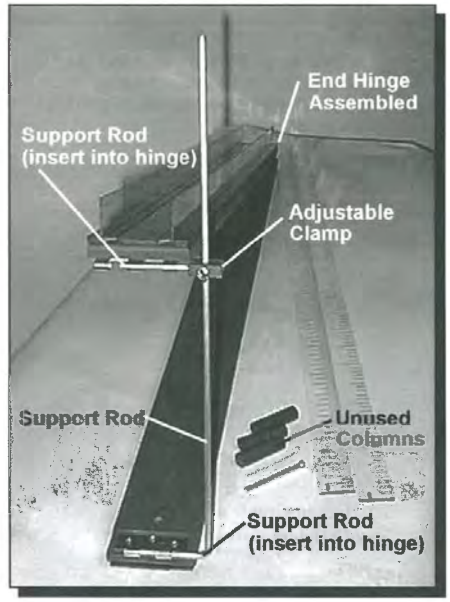


Figure 4: Adjusting Mechanism.

Demonstration #5a How to Create a Series Circuit (This demonstration requires the "Circuit City" accessory)

Additional device needed which is not included with the track: "Circuit City"

Objective:
To teach that a series circuit requires an uninterrupted electrical path.

Procedures:
1. Insert the banana plugs in "Circuit City" so they connect the battery, bulb, and conductor plates in series.

2. A levitating vehicle with a strand of conducting wire passing through it should make the final connection of the series circuit.
3. Disconnect any one of the banana plugs.

Observation:

The bulb goes out.

Conclusion: The bulb went out because the circuit was incomplete (interrupted).

Demonstration #5b How to Create a Parallel Circuit (This demonstration requires the "Circuit City" accessory)

Additional device needed which is not included with the track: "Circuit City"

Objective:
To teach that a parallel circuit will allow one portion of the circuit to be broken and still allow electricity to flow through other parts of the circuit.

Procedures:
1. Connect the banana plugs so they join the battery, bulb, and buzzer in a parallel circuit.

2. Remove the banana plug from either the bulb or the buzzer.

Observation:
If the buzzer is disconnected, the buzzer stops functioning while the bulb remains lit. If the bulb is disconnected the bulb goes out while the buzzer remains on.

Conclusion: If a parallel circuit is broken in one portion of its path, electricity will still flow through other portions of that circuit.

Student Activities

Student Activity #1 Magnetic Polarity Experiment (Individual or Cooperative Learning Activity)

Objective:
Students will identify the North Pole, also known as the North-seeking Pole, of a magnet.

Materials:
One directional compass for teacher use. Each student or pair of students will need the following: 2 paper cups (6 inches high or taller); one pencil at least 6 inches long; 12 inches of cotton thread; 2 rectangular ceramic magnets with center holes (1" X 3/4" X 1/8").

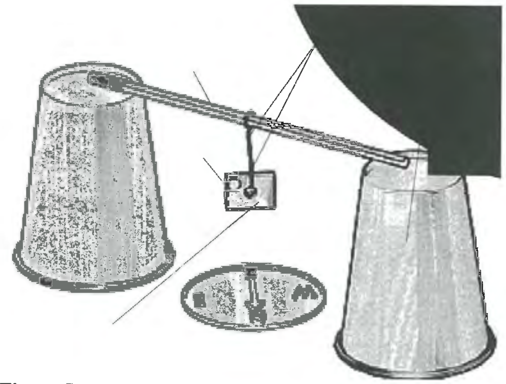


Figure 5:
Finding the north pole of your magnet.

Procedures:
1. Using a compass the teacher must identify the classroom's Northern orientation.

2. Students set up the experiment as in figure #5

   A. Invert the paper cups on a flat surface.

   B. Bridge the distance between the cups with the pencil.

   C. Suspend the magnet from the pencil with the thread going through the hole of the magnet. (Separate knots must be made around the magnet and the pencil.)

   D. When the magnet stops spinning have the student mark the side facing the North end of the room with a dot of white paint or correction fluid. This is called the North-seeking Pole or the North Pole of the magnet.

Teacher Note:
The teacher should be aware that the North-seeking Pole is in reality a South Pole because it is attracted to the earth's North Magnetic Pole. Common usage by scientists over time is responsible for this discrepancy. This information, however, should be reserved for high school students, as younger students would be confused by it.

Teacher Note:
Please be advised that a hair dryer or fan will be needed for Student Activities 2, 3A, 3B, 4 and 5.
(Wind source clamp accessory available, for use in 4' double deck position.)

Student Activity #2 Measuring the Effect of Wind Power and Aerodynamic Design.

Objective:
Students will calculate how far a two-inch rectangular block of levitating styrofoam will travel, propelled by the energy from a wind source. (The purpose of this activity is to establish a base line or reference point for the activities to follow.)

Procedures:
1. Set up the 8' track as in figure #6. Position the hair dryer or fan at one end of the track.

2. Have each student insert magnets with the North side facing down in the grooves along the bottom edge of the one-inch block of styrofoam so that they repel those on the track.

3. The two-inch block of styrofoam will not yet be shaped to the student's design, but must be attached to the one-inch maglev base with wooden toothpicks or velcro. (Avoid using anything metallic.)

4. Using a hair dryer (we prefer this to a fan) as a source of energy, students will measure how far their vehicle travels down the track.

5. Students will record this information in their maglev data log so that they can compare it to later measurements taken when they create a wind sail and later still, when they shape the two-inch thick block of styrofoam to their unique design.

Teacher Questions:

- Is the vehicle making full use of all the wind power?
- How can you capture more of the wind to propel your vehicle further down the track?

Student Prediction:
Have students predict how far their vehicle will travel after a wind sail is attached.

Student Activity #3a Wind Sail Experiment - Aerodynamics (Cooperative Learning Option)

Objectives:
- Students will compare different kinds of wind sails to determine which is aerodynamically superior.
- Students will learn that a concave wind sail facing a source of energy, captures that energy, and deflects the resistance in front of it better than a flat or convex sail.

Procedures:
1. Set up the 8' track as in figure #6.
2. Give each student a grooved maglev base made of styrofoam into which they insert magnets with North facing downward so that they repel those on the track.
3. Divide students into three groups and instruct them to design their wind sails as follows:

Group A: All students are instructed to design their individual wind sails so that a convex (curved like the exterior portion of a sphere) surface faces the source of energy (the wind).

Group B: All students are instructed to design their individual wind sails so that a concave (curved like the inner surface of a sphere) surface faces the source of energy (the wind).

Group C: All students are instructed to design individual flat wind sails.

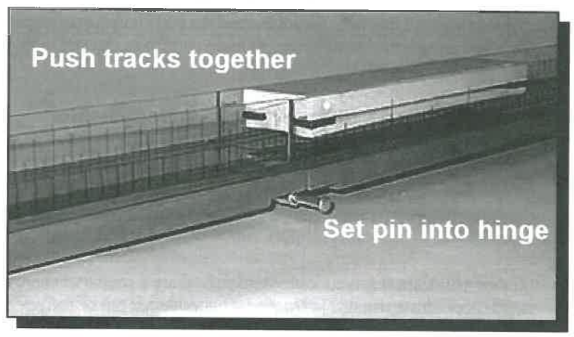


Figure 6:
Joining Tracks end to end.

4. Students test their vehicles with sails and measure how far they traveled down the track. Students add this individual data to their maglev data log. After three trials the results may be averaged.
5. All students compare the results obtained when their vehicle had no sail (Student Activity #2) to the results in this activity.
6. Individual averages of all group members may again be averaged to determine their group average (A, B, or C).

Note:
This information will enable students to design a wind sail for their vehicle based upon the conclusions from their experimental data.

Teacher Question:
How accurate were students in their predictions at the end of Activity #2? (As you recall, students were to predict how much further their vehicle would travel with a wind sail.)

Conclusions:

- A sail capturing an energy source (wind) improves the distance traveled over a vehicle without a wind sail.
- A concave surface facing the wind will capture its energy better than other types of sails and therefore propel the maglev vehicle further down the track.

Note to teacher:
Caution students to check their "Helpful Hints for Students" handout to be sure when making their sail that they do not exceed the outside dimensions permissible with the track and any photoelectric timer, should you plan to use one in later experiments.

Student Activity #3b Wind Sail Experiment - Aerodynamics (Individual Experiment Option)

Objectives:

- Student will compare different kinds of wind sails to determine which is aerodynamically superior.
- Student will learn that a concave wind sail facing a source of energy, captures that energy, and deflects the resistance in front of it better than a flat or convex sail.

Procedures:

1. Set up the 8' track as in figure #6.
2. Give each student a grooved maglev base made of styrofoam into which they insert magnets with North facing downward so that they repel those on the track.
3. Each student experiments with concave, convex, or flat sails as in Activity 3A where they are described, and records data in log.
4. Student compares results gotten with no wind sail (See Student Activity #2) to the results gotten with the three different types of wind sails.
5. Student determines which type of sail better captures the wind and propels his or her vehicle the greatest distance. Student may wish to average the results of three trials.
6. Student may compare his or her results with those achieved by other students.

Teacher Question:
How accurate was the student's prediction at the end of Activity #2? (As you recall, each student was to predict how much further their vehicle would travel with a wind sail.)

Conclusions:

- A sail capturing an energy source (wind) improves the distance traveled over a vehicle without a wind sail.
- A concave surface facing the wind will capture its energy better than other types of sails, and therefore propel a vehicle further down the track.

Note to teacher:
Caution students to check their "Helpful Hints for Students" handout to be sure when making their sail that they do not exceed the outside dimensions permissible with the track and any photoelectric timer, should you choose to use one in later experiments.

Student Activity #4 Aerodynamics and Body Design

Objective:
To have students observe and record the effects of body design on the performance of their maglev vehicle (aerodynamics).

Procedures:

1. Set up the 8' track as in figure #6.
2. Allow students to design the body of their vehicle using paper and pencil, staying within the parameters listed in the "Helpful Hints for Students" handout.

Or students may design their vehicle using the "Car Builder" software listed in the Resources in the back of this guide. This program allows the user to design, modify, and then test a vehicle in a simulated wind tunnel and on a roadway.

3. Students then cut out and attach their design to the side of the two-inch block of styrofoam with pins and trace the outline with pencil or marker.

(Note: It is recommended that elementary students not alter the bottom or the width of the vehicle in any way as they risk carving away the grooved "home" for the magnets. As a result, the vehicle will not levitate properly. Older students may possess enough imagination to alter the bottom surface as long as they retain enough of it to accept the four magnets.)

4. Wearing safety glasses, students may construct their vehicles using either coping saws or a nichrome wire cutter. In either case strict supervision is necessary with younger children.

If your students will be doing Activities #5-7, it will be necessary for them to complete this additional step now:

5. Wearing safety glasses, students carve a depression for the egg passenger or the weight carrier using a grapefruit spoon (which has serated edges).

6. Allow students to decorate and name their vehicles. They may also be given a VIN (Vehicle Identification Number) which may be placed on a license plate (key tag) and attached to the rear of the vehicle.

7. Students insert magnets in the grooves of the base so they repel those on the track.

8. Students attach the two-inch shaped vehicle to the one-inch maglev base. White glue is good.

9. Finally, students attach their wind sail. Hint: Vehicle balance will affect levitation and/or propulsion. Have students check to be sure their vehicle is properly balanced.

10. Students may now conduct trials for distance with their shaped vehicle and attached wind sail. Students should log their data.

11. Students examine the results of all experiments conducted to date and circle the best performance recorded.

Conclusion:
Body design has an effect on the distance traveled by a vehicle.

Student Activity #5 Distance/Mass Experiment (Math connections)

Objectives:

- Students will observe and record the effects of vehicle design on the distance a given mass can be carried down the track.

- Students will compare the results of their vehicle's performance to that of other students.

Teacher Note for Objective 1:
For the purpose of this experiment we have devised a simple method of mathematically comparing performance results. Students can multiply the distance traveled by the mass carried to produce a Numerical Performance Result (NPR), which can then be easily compared with later trials or to other students' results. The vehicle achieving the highest number would be considered the best performing vehicle.

(For example: 24 cm traveled X 5 grams = 120 NPR.)

This is a teacher-created measurement and is not valid for other kinds of experiments.

Procedures:
1. Set up the 8' track as in figure #6.

2. Students place gram masses, or pennies, or some other standardized units in the depression made in the vehicle. (If pennies are selected, use only those minted beginning in 1982 as they have been standardized at 2.50 grams each- Information Source:U.S. Mint.) Or students may attach a small cup to their vehicle to which the units of mass are added. The cup may be attached to the vehicle with a thin nail which may later be removed when the cup is no longer needed.

3. With the wind sail in place, students then test their vehicles (using wind power from a hair dryer) to see how much mass they can carry down the track. (Note: start with 5 grams and work upward in increments of 5 grams.) Students record their Numerical Performance Results in their log.

4. Students can now compare their Numerical Performance Results with those of other students as described below.

Teacher Note for Objective 2:
The best student's result is the basis for comparison and becomes the denominator of a fraction; the other student's NPR becomes the numerator. By dividing the numerator by the denominator a percentage is determined. For the purpose of this experiment we will call this the Performance Percentage.

For example:
250 NPR/300NPR = 250 divided by 300 = 83% Performance Percentage
In this example the student has determined that his vehicle traveled 83% as well as the top performing vehicle.

5. Students can now determine which body designs were the most successful. Did the location of the units of mass (in the depression versus the attached cup), cause any difference in the performance of the vehicles?

6. Students should now modify their designs and test vehicles again. This is a most important aspect of this problem solving activity!

Conclusion:
Body design does affect the distance a vehicle can carry a given mass.

Optional methods of conducting this activity:

A.)Keep the distance constant and vary the mass carried.

B.)Keep constant the mass carried and vary the distance.

Student Activity #6 Wind Sail, Slope and Velocity (Math Connection)

Additional materials needed which are not included with the track: a large protractor (12 inches or larger) and a photoelectric timer which can measure time to the thousandths of a second.

Objective:
Students will compare the speeds of vehicles with a variety of wind sails and body designs.

Procedures:
1. Set up the 4' track at a 30 degree angle as in figure #4.

2. Place a large protractor at the base of the track in order to show the angle of slope. (The larger the protractor, the better, so angles can be easily seen by students.)

3. Set up the photoelectric timer: Place the destination timer at the bottom of the slope and the entry timer about two feet up the slope. The timer emits a beam of light which, when broken, starts or stops the timer. Therefore, the timer must be adjusted so that its beam of light is not positioned higher than the vehicle.

4. Students release their vehicles at the top of the incline and record the timed results in their maglev data log.

5. Then students compute the velocity of their vehicle by dividing the distance between the two timers by the elapsed time. This may be done quickly with a calculator. Record velocity.

6. Repeat the trials two more times by making the track's angle of incline 20 degrees and then 10 degrees, thereby decreasing the slope. This presents an opportunity to review acute angles (those less than 90 degrees) in geometry and provide comparative data to the results recorded in Steps 4 and 5.

Conclusion:
The steeper the angle of slope the greater the speed of the vehicle.

Student Activity #7 Passenger Impact Safety Experiment

Additional materials needed for this activity which are not included with the track: large sized protractor and photoelectric timer.

Objective:
To have the student design a maglev vehicle in such a way as to assure the safety of its passenger, a raw egg.

Procedures:
1. Set up the 4' track at a 30 degree incline as in figure #5.

2. Students will check their "Helpful Hints for Students" handout for instructions on creating a harness and cushioning to protect their egg passenger. In addition, a bumper must be created and attached to the front of the vehicle to help it withstand a crash into a wall. The wall is to be placed at the bottom of the inclined track. (We used bricks.)

3. Students may decorate their raw egg passenger before its journey begins down "Scrambled Egg Drop."

4. Position the vehicle containing its passenger at the top of the track. Release the vehicle and check to see if the egg passenger survives the impact into the wall.

Teacher Note:
Alert students that their egg passenger will be checked at the conclusion of its journey to be sure it is raw! The Water Friction Demonstration on page 20 will show you how this can be done.

Conclusion:
Student determines that the survival of the egg passenger is dependent on vehicle design.

Extension Activity:
The egg passenger experiment can be run again using the photoelectric timer as in Student Activity #6. Determining the velocity of each vehicle with its egg passenger aboard is a good tie-breaker for a competition!

Student Activity #8 The “Circuit City” Math Challenge

Additional materials needed for this activity which are not included with the track: “Circuit City”

Objective:
Student will modify his/her maglev vehicle so that it can become part of a series circuit that will either ligth a bulb or sound a buzzer as it passes through “Circuit City”.

Procedures:

1. The teacher should provide the student with a variety of wires (different guages, lengths, and types of metal). Students could also expand their experimentation with various other electrical conducting materials such as strips of thin, flat surfaced metals such as tin plate.

2. The student must determine the best height at which to place a wire through or across his/her vehicle in order for the ends of the wire to make contact with both conducting plates of “Circuit City”.

3. If the student desires to place a wire hole through the vehicle, then careful measurement is necessary. The student must make two measurements:

a) Using a ruler, measure the height of the guideway. Record this information.

b) Then meassure the height of the conducting plate. Record this information.

c) Now that the student knows the range (the distance from the top of the guideway to the top of the conductinig plate), the student can measure his or her vehicle and select the proper place to position a wire so that it will touch the two plates as it passes through “Circuit City”.

Notes: The authors have found that a thin strand from common multi strand wire works well, but students should be allowed to experiment with many types of wires. Also, a thin knitting needle wirks well for poking a hole through the styrofoam vehicle. A butterfly style paperclip straightened out could also be substituted for the knitting needle.

Hints for Students:
Regardless of the conductor chosen, consideration should also be given to different methods of attaching the conductor to the maglev vehicle such as glue, screws, rubber bands, tape, etc.

Observations:
Students should observe their vehicle to see if it lights the bulb or causes the buzzer to sound. If this does not occur, students should evaluate the cause of the problem (incomplete circuit), and make modifications.

Several possible causes could be:

1) Inaccurately placed wire due to incorrect measurement (of the contact area on the plates or of placement of the wire on the vehicle).

2) Measurement is correct, but the wire is not contacting both conducting plates with enough pressure.

3) Inappropriate flexibility of the wire: The wire may be too stiff to allow the vehicle to enter "Circuit City", or it may be overly flexible which does not allow for sufficient contact to both plates.

Conclusion:
When a wire is properly placed so as to complete an electrical circuit, a bulb in that circuit will light or a buzzer will be activated.

Teacher Demonstration   Water Friction Lesson

Materials:
1 raw and 1 hard-boiled egg; a smooth tray

Procedure:
1. Spin both eggs on the tray simultaneously.

2. Observe the length of time and how evenly each egg spins. (The hard-boiled egg will spin longer and more evenly.)

3. Ask students if they can pick the raw egg. Have them state a reason for their choice.

A hard-boiled egg will spin longer and more evenly than a raw egg because the hard-boiled egg is solid all the way through. The inside and the shell spin together so there is no friction between them.

But the raw egg has a hard shell and a soft, watery inside. The shell and the liquid inside don't spin together, so there is friction between the two parts which eventually slows the spinning.

Constructing Your MagLev Vehicle

Helpful Hints for Students:

If you follow these guidelines carefully, your vehicle will be able to successfully complete its journey on the maglev track.

Vehicle Design
- Design your vehicle using Computer Aided Design (CAD).

The Car Builder software allows you to design a vehicle, test for aerodynamic properties, and print out your final design. OR you may choose to design your vehicle using paper and pencil. In either case save your printout or drawing.

- Wear safety glasses for this step. You will be given a piece of high density styrofoam two inches (5cm) high, nine inches ((23cm) long and two and one-half inches (6.3cm) wide. The top and ends of the styrofoam may be shaped to your design, but do not change the bottom or the width of the vehicle or it may not levitate properly or glide down the track.

Construct your vehicle carefully using a coping saw or a nichrome wire cutter. Smooth any rough edges using sandpaper, being careful to always sand in one direction. Experience has shown that the longer your vehicle is, the better it will perform on the track.

- Wear safety glasses for this step. Next make a depression or "seat" for your egg passenger using a grapefruit spoon. This depression may also be used to hold units of mass for one of the experiments. (An alternative would be to use a short nail to attach a small cup to the vehicle which can hold the units of mass. The cup may then be removed when it is not needed.)

Creating a Wind Sail
- Experiment with different types of wind sails: convex, concave, and flat.

- Keep the height of the wind sail low or it will cause your vehicle to tip sideways and touch the rails of the maglev track.

- Be sure your sail is no more than three and one-half inches (9cm) wide.

- Check to see that your wind sail is centered on your vehicle.

Passenger Safety

- You will supply a raw, fresh egg, decorated if you wish, for one of the activities.

- You are to design a bumper for the front of your vehicle and a safety belt/harness/airbag, as well as cushioning material to secure your egg passenger in its seat.

- Your egg passenger may sit upright or lie down in the "seat" you have made for it.

Attachment of Magnets

- Position the magnets in the grooves in the one-inch base of the maglev vehicle so that they repel those on the track. Attach the base to the two-inch piece of styrofoam you carved out earlier. White glue is good.

Balance

- The balance of your vehicle will determine its ability to levitate. Try to keep the mass of the vehicle, passenger and wind sail as evenly distributed as possible.

Vehicle Identification Number

- The number which your teacher gives you will be placed on your license plate (key tag) and attached to the rear of your vehicle.

Finishing Touches

- Decorate your vehicle. Avoid using spray paints as some will dissolve the styrofoam. Make your vehicle unique! Give it a name which emphasizes its special qualities. Then have fun with this extraordinarily challenging activity!

With your teacher, brainstorm a list of items you could experiment w3ith to create a wind sail, harness, bumper, and cushioning. Some possible ideas are:

Wind Sail:
Paper attached to plastic straws
Curved section cut from plastic soda bottle
French fry container from fast food restaurant
Material attached to dowels or popsicle sticks
Styrofoam or plastic cup attached with short nail

Bumper:
Bubble Wrap
Sponge (soaked in water just before racing)
Small balloon, partially inflated
Accordion pleated paper
Click pen spring

Safety belt / Harness / Air bag:
Egg carton helmet
Wide rubber bands or elastic attached to vehicle with pins
Small balloon, partially inflated

Cushioning:
Cotton Balls
Rubber bands cut into small pieces
Bubble Wrap

Additional Competition Guidelines:

1) Your egg passenger must have eyes, nose, and mouth drawn on it. Magic marker is good. Can you give it a suprised or excited expression?

2) Any passenger protection you design must not blind or suffocate your passenger, just as in the real world! For example, a canopy surrounding your egg is allowed as long as it can see and breathe.

3) Your teacher may wish to set a particular mass that your egg may not exceed. Please check.

Resources

Car Builder software program. (1993). (Available from Optimum Resource, Inc., 5 Hiltech Ln., Hilton Head, S.C. 29926; Tel. 800-327-1473.) Can be purchased for either Apple or IBM compatible computers.

Cuomo, M.M. and Lundine, S. (1994). Moving toward the 21st century: A proposal for high speed ground transportation in the State of New York. (Available from New York State Department of Transportation, Commercial Transport Division, 1220 Washington Ave., Albany, N.Y. 12232-0876.)

Flad, M.M. (1992, January/February). The man who planted the maglev seed. UpRiver/DownRiver, pp.18-19.

Jacobs, H.H. (1991) Planning for curriculum integration, Educational Leadership, 49(2), 27-28.

Magnuson, A. (1992, January/February). Maglev in the Hudson Valley: Tomorrowland or Fantasyland? UpRiver/DownRiver, p.26-27.

Moynihan, D.P. (1989). How to lose: The story of maglev. Scientific American, 261(5), 130.

Peterson, T. (1992, October). High-speed rail. American City & County, pp. 56-62.

Pope, G.T. (1993, June). Livingroom levitation. Discover, p.24.

Rutland, J. (1978). The young engineer book of supertrains. Usborne Publishing Ltd., 20 Garrick St., London WC2E9BJ.

Sands, S. (Ed.) (1992, November). Kids Discover- Trains.
170 Fifth Avenue, New York, N.Y. 10010.

Stix, G. (1992). Air Trains. Scientific American, 267(2), 102-113.

Maglev Data Log

Student Name:				
Vehicle Name / Identification Number:				
Student Activity #	Trial #1	Trial #2	Trial #3	Trial #4
Activity #2 Distance Traveled with grooved base				
Activity #3 Convex Sail				
Activity #3 Concave Sail				
Activity #3 Flat Sail				
Activity #4 Distance Traveled (shaped vehicle with sail)				
Activity #5 Distance/Mass				
Activity #5 Performance Percentage				
Activity #6 Slope /Velocity (30°, 20°, 10°)				
Activity #7 Passenger Impact Safety: Describe appearance of egg after impact (did it remain in vehicle? Egg fractured? Scrambled Egg? etc.)				