Magnetic Perturbations

Create endless variations of "perturbed" motion!

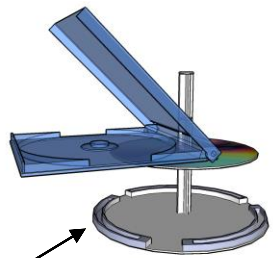
Topics: Magnetism, Potential and Kinetic Energy Conversions, Coordinate pairs

Materials List

- ✓ CD jewel case, regular size
- ✓ Rubber steel (best) or paperclips, 20+
- ✓ Printed grid, (pg. 3)
- ✓ CD
- ✓ Base and post from a bulk container for 100 CD's or DVD's
- ✓ Binder clip, medium size
- ✓ Wooden stir stick (not a craft stick)
- ✓ Straws, drinking, 1 uncut and 1 half
- ✓ Thread or string
- ✓ Paperclip
- ✓ 10 "pill" magnets, 1 cm (3/8") diameter
- ✓ Hot glue gun/glue
- ✓ Permanent marker or small dot stickers

This activity can be used to teach:
Next Generation Science:

- Forces & Motion (Physical Science, Grade 3, 2-1 & 2-2; Middle School, 2-2; High School, 2-1)
- Magnetic interactions and magnets (Physical Science, Grade 3, 2-3, 2-4; Middle School, 2-3, 2-5)
- Science & Eng. Pract. (Grades 3-12)



Add hot glue to 1/3 of the upper rim of the base, the part that will be covered by the jewel case

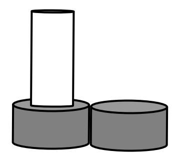
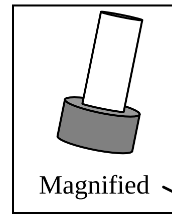
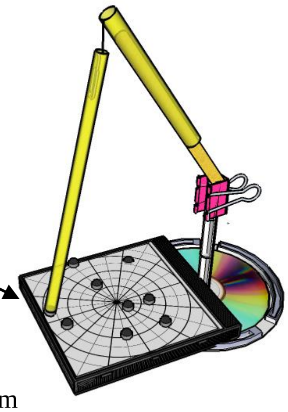


Figure 1

Add dot to bottom

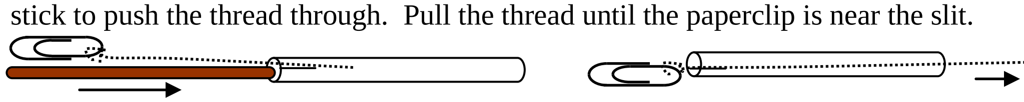




Explore the interactions of magnetic fields as a swinging magnet weaves an intricate path influenced by the variable placement of other magnets on a coordinate grid.

Assembly

1. Open a CD jewel case. Cut a 12 cm (4-3/4") square of rubber steel. If rubber steel is unavailable then place 20+ paperclips, in a single layer, on the media tray.
2. Copy the blackline grids on the last page and cut between the double lines of the borders. Mark the grid(s) as desired (see **To Do and Notice**), place the desired grid on top with the rubber steel underneath. Slip both under the jewel case cover, where the cover notes would go. Make sure the grids and the rubber steel, if used, are between the cover and the "D" shaped tabs.
3. Close the case. If the case does not close easily, then reposition the materials.
4. Hot glue a CD to the bottom of the CD jewel case positioned with the hinge edge very near, but not covering, the center hole in the CD.
5. Add hot glue to a third of the top of the rim of the 100 CD container base. Place the CD, with the attached jewel case uppermost, over the post and press the jewel case down into the hot glue. See the illustrations above.
6. Make a 1 cm (3/8") slit at the end of the half drinking straw.
7. Tie the end of a 30 cm (12") length of thread to a paperclip's narrow end. Insert the thread's untied end into the half straw starting from the slit end. Use the stir stick to push the thread through. Pull the thread until the paperclip is near the slit.



8. Open a medium size binder clip and carefully position around the post, near the top, while inserting a wooden stir stick at angle, as shown at the top right. Insert the end of the straw with the loose end of thread over the wooden stir stick.
9. Rotate the straw so the slit is downward and then slip the thread into the slit.
10. Glue the end of an uncut drinking straw to the flat surface of a pill magnet. Insert the tied paperclip; wide end first, into the unglued end of the straw.
11. Adjust the wooden stir stick, height and angle, and slide the half straw until the magnet at the end of the straw is positioned over the center of the grid.
12. Adjust the magnet's height by pulling on the thread, adjusting the stir stick angle, and/or sliding the half straw along the stir stick until the bottom of the magnet is 2 to 3 times the height (thickness) of the magnet, above the jewel case cover.
13. Place a pill magnet side by side with the glued magnet (Figure 1). Remove and put a dot on the bottom of the loose magnet. Repeat with the other loose magnets.

Developed and written by Michael Pollock (RAFT)

To Do and Notice

1. Different math skills can be practiced depending on which grid, square or circular (polar), is selected and on how the students label the grid. Some possibilities are coordinate pairs, map coordinates, polar coordinates, and clock/distance orientations.
2. Place a loose pill magnet, dot side down on the center of the grid. If paperclips are in the jewel case, rather than rubber steel, then shake the jewel case until a paperclip is attracted to the magnet.
3. Pivot the glued magnet toward the post and release when the magnet touches the post. What happens?
4. Add other pill magnets, dot side down, to any desired location on the grid. Repeat step 3. What happens?
5. Create a different pattern of magnets by placing magnets in different positions, using different numbers of magnets and/or placing one or more magnets with the dot side upward. Magnets could even be stacked.
6. Repeat step 3. Record positions and observations for each pattern.
7. Challenges could be presented to the students such as trying to find a placement of magnets that will cause the glued magnet to trace a figure "8" pattern when released.

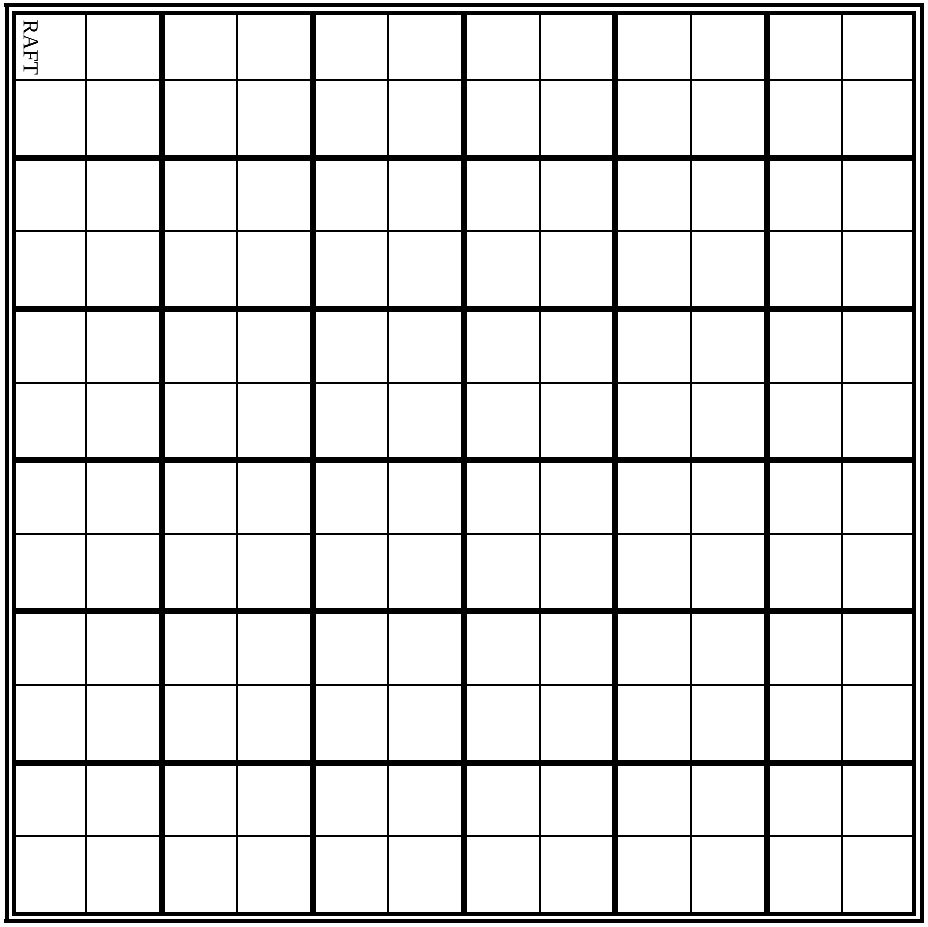
The Science Behind the Activity

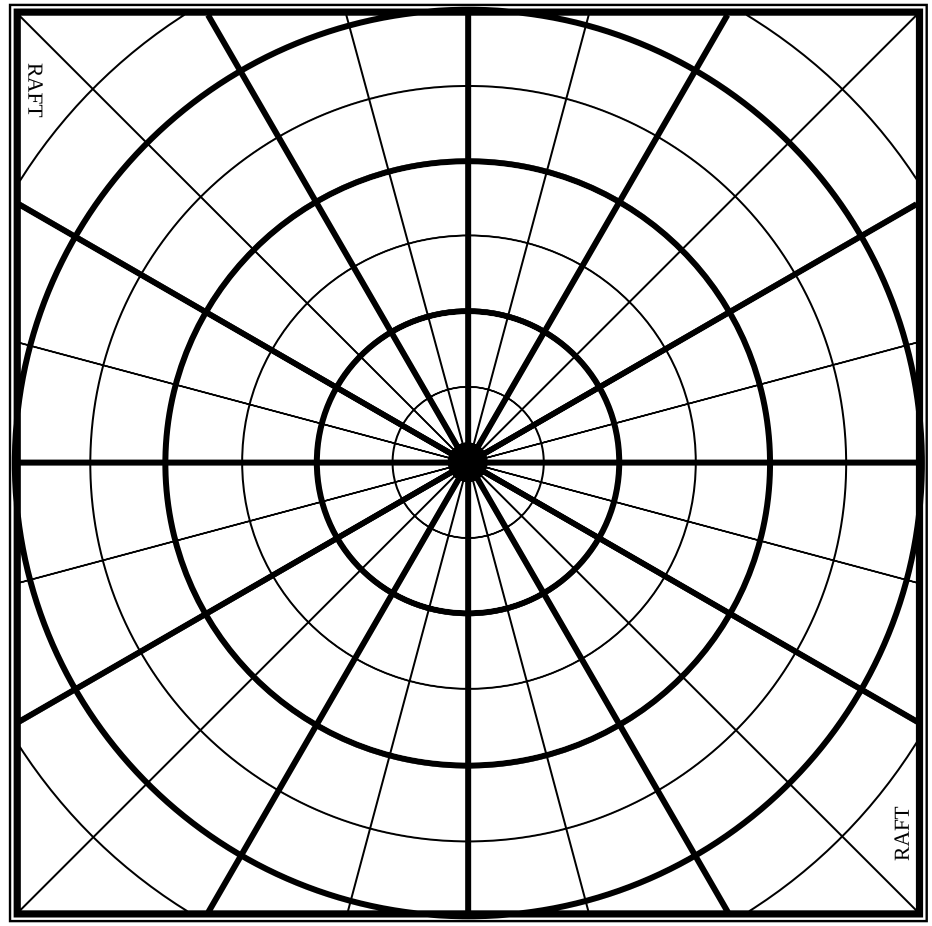
Most magnets have a single pair of magnetic poles, the two places where the magnetic attraction is the strongest, located on opposite sides, faces, or ends of the magnet. Pill magnets usually have a pole on the top and bottom. The poles are identified as being a north or a south magnetic pole depending on which direction the pole faces when the magnet is suspended, and can pivot freely, from point midway between the poles. Like poles (south – south and north – north) of 2 magnets will repel each other equally. The repelling force becomes greater as the like poles of the magnets are brought closer together. Opposite poles (south-north) of 2 magnets will attract each other equally. The attraction becomes stronger as the opposite poles of the magnets are brought together.
When the glued magnet is pivoted and raised toward the post, the magnet gains height (gravitational potential energy). When the magnet is released the potential energy is transformed into motion (kinetic energy) and a small amount of heat. As the magnet swings back upward most of the kinetic energy is transformed back into gravitational potential energy. With each back and forth conversion of potential energy and kinetic energy a small amount of energy is "lost" to the friction of the magnet and the straw moving through the air and the twisting of the thread, slightly heating both. When the like (same) magnetic poles of 2 magnets approach each other the momentum of the motion is opposed by the force of magnetic repulsion of the like poles. The pivoting magnet, which can move, is forced to change direction. The interplay of the gravitational and magnetic forces will cause the pivoting magnetic to move in a continually changing pattern for a relatively long time, depending on the placement of the magnets, as only a little energy is lost during each swing of the magnet.
Placing a pill magnet with the opposite pole upward adds an attractive magnetic force. The pivoting magnet will move toward the attracting magnet and then, at first, swing away, sometimes with increased speed. This magnetically induced increase in speed models the gravitational assist (called "slingshot") used to increase the speed of a satellite by having the satellite move near a planet with a large mass and thus a strong gravitation field.
The seeming randomness of the motion of the pivoting magnet is due to the fact that the starting conditions, where and how the pivoting magnet is released, will always be slightly different. In a chaotic system multiple variables, combined with slight changes in starting conditions, can lead to very different outcomes, sometimes referred to as the "butterfly effect". Computer simulations of the motion create interesting fractal patterns (see **Web Resources**).

Taking it Further

- How are Newton's 1st and 2nd laws of motion demonstrated by this device?
- Build a similar device but glue a steel washer (contains iron) to the straw instead of the magnet. What changes?
- Can a random generator be created? The final position of the glued magnet will depend on the placement of the loose magnets. Can an arrangement be created that has 2, or more, equally possible final resting positions?

Web Resources (Visit www.raft.net/raft-idea?isid=522 for more resources!)
Motion as fractals - http://nylander.wordpress.com/2007/10/27/magnetic-pendulum-strange-attractor/





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