Analysis of electromagnetic field strength

Protocol for main test:

1. Take a glass test tube and fill it to the brim with gel (ECO Styler professional styling gel with olive oil, Max Hold: 10). Insert the gel into the tube using a 1 ml syringe. Fill from the bottom up and try to avoid creating air bubbles.

2. The test tube rack that holds the tube must have markers for measurement of distance. This can be achieved in multiple ways, such as simply etching a ruler on the surface of the ‘rack’. The marks should designate 1 cm intervals.

3. Insert a small PTFE stir bar (length = 3mm) into the gel. Make sure it is completely submerged. Using a wire, guide the ‘seed’ till it is horizontal and approximately 1.5 cm deep. It should be lying horizontal, parallel with the bench surface.

4. Put the tube in a test tube rack so that it fits snuggly and stands up straight (if feeling extra ambitious, make the test tube rack out by using a drill press to make holes in an old cigar box).

5. Place the electromagnet (Solenoid electromagnet with Iron Core, 6" Length x 2" Width x 2" Height from American Educational Products) in front of the tube. The magnet should be approximately 3 cm from the tube. The seed in the tube should be positioned so that the seed is perpendicular to the electromagnet.

6. Prepare the Gaussmeter (F.W. Bell, model 5080)

1. Plug the gaussmeter into a wall outlet to power it
2. Attach the probe to the main body of the gaussmeter
3. To zero the gaussmeter, set the dial to ‘measurement’, put the tip of the probe into the little black box, and press and hold down ‘zero’ until the measurement stabilizes. Note that it might not stabilize exactly at zero, but it should be fairly close.
4. Remove the tip from the black box. It is now ready to measure.

7. Position the Gaussmeter so that the tip of the measuring tool is right in front of the seed, the flat portion perpendicular to the EMF lines.

8. Turn on device

9. Set software:

1. Set Amplitude
   1. The Amplitude set screen will be the first menu screen to appear. Use the up and down buttons to navigate to one of the three prompts:
      1. UP - Increases Amplitude by 1
      2. DOWN - Decreases Amplitude by 1
      3. BACK - Returns to main menu
   2. Pressing the “select” button will activate the functionality of whichever menu option that the cursor is at. The Amplitude varies from 0 to 10 by increments of 1. The units are arbitrary, with 10 being the highest amplitude option. The default setting is 5
2. Set Frequency
   1. The Frequency set screen can be navigated to on the main menu by using the “up” and “down” buttons to move the cursor to the “set frequency” option, and then press “select”. Use the up and down buttons to navigate to one of the three prompts:
      1. UP - Increases Frequency by 1
      2. DOWN - Decreases Frequency by 1
      3. BACK - Returns to main menu
   2. Pressing the “select” button will activate the functionality of whichever menu option that the cursor is at. The Frequency varies from 0 to 50 by increments of 1. The units are in Hz. The default setting is 1 Hz
3. Set Backlight
   1. The Backlight set screen can be navigated to on the main menu by using the “up” and “down” buttons to move the cursor to the “set backlight” option, and then press “select”. Use the up and down buttons to navigate to one of the three prompts:
      1. UP - Increases Backlight brightness by 1
      2. DOWN - Decreases Backlight brightness by 1
      3. BACK - Returns to main menu
   2. Pressing the “select” button will activate the functionality of whichever menu option that the cursor is at. The Backlight varies from 0 to 6 by increments of 1. The units are arbitrary, with 6 being the brightest option. The default setting is 0.
4. Output desired settings
   1. To output the desired frequency and amplitude settings to the electromagnetic transducer, navigate to the “Start Output” menu option on the main menu, and press select. This will take you to the output menu screen, which displays the current frequency and amplitude output settings, which are now being outputted to the transducer, This will occur indefinitely. To change the settings and turn off the output, press the “up” button, which will return you to the main menu.

10. Record the movement of the seed qualitatively

11. Record the EMF strength from the Gaussmeter

12. Turn off device

13. Reset the seed to be level with the bench top and perpendicular to the EMF lines from the electromagnet.

14. Repeat Steps 5-13 two more times for a total of three trials for this electromagnet position

15. Pull the magnet back 1 cm, increasing the distance from the seed from 3 cm to 4 cm.

16. Repeat Steps 5-14 with the magnet now 4 cm from the seed.

17. Pull the magnet back another 1 cm, so the electromagnet is 5 cm from the seed.

18. Repeat Steps 5-14 with the magnet now 5 cm from the seed.

19. Repeat Steps 5-15 until the magnet is 15 cm away from the seed and all three trials have been completed at this position.

Protocol for visualization using iron shavings:

1. Set electromagnet on a sturdy table or bench, ensuring that the surface is flat.
2. Connect the electromagnet to a power source which has been tuned to provide ~0.5 A to the magnet.
3. Trace the outline of the electromagnet on a piece of plain, unlined white paper.
4. Place a thin piece of cardboard over the electromagnet, also ensuring that it lies flat.
5. Place the white paper with the outline on top of the cardboard, with the trace lining up with the electromagnet properly.
6. Lightly sprinkle the iron filings provided uniformly over the paper.
7. Turn on the power source, allowing current to flow through the electromagnet and create an electromagnetic field.
8. Tap the paper with the iron filings gently to make the filings align with the field.
9. Take a picture of the resulting formation. This is a visualization of the EMF lines.
10. Lift up the paper carefully so as to not spill any of the filings, and funnel them back into your filings jar.

Protocol for visualization using seeds, basic test:

1. Align the electromagnet with the edge of a table, with the long axis of symmetry parallel to the table edge.
2. Tape down a ruler down next to the electromagnet to track seed distance from electromagnet. Origin/zero point is the center of the electromagnet.
3. Tape down calipers ~12 cm from the center of the electromagnet to track seed position along the electromagnet.
4. Arrange the seeds at 20 cm interval 5 cm from the center of the electromagnet (seed at 0 cm, 20 cm, 40 cm,..., 120 cm). **Seeds should be perpendicular to the axis of the magnet.**
5. Starting from 0 A, slowing increase the source current going through the electromagnet. Pause with each current adjustment to allow time for the seeds to adjust. When any of the seeds move, pause and write down which seeds moved (the seeds at 40 cm and 60 cm, for example) and at which current they moved.
6. Keep increasing current till right when the device begins to overload. At this point, stop and reset the current back to zero. Record the overload voltage and the overload current. The trail is over.
7. Take a picture of how the seeds have aligned to the magnetic field.
8. Reset the seeds perpendicular to the magnet.
9. Repeat Steps 5-8 for a total of three trials.
10. Move the seeds up 1 cm further from the magnet (so they are 6 cm from the center) and repeat steps 5-9.
11. Repeat Steps 5-10 till the seeds are 10 cm from the center of the magnet. This is the final measurement.

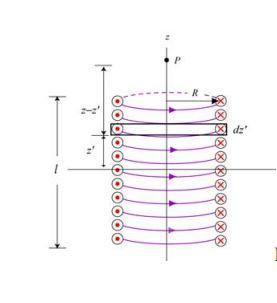
Analysis of data:

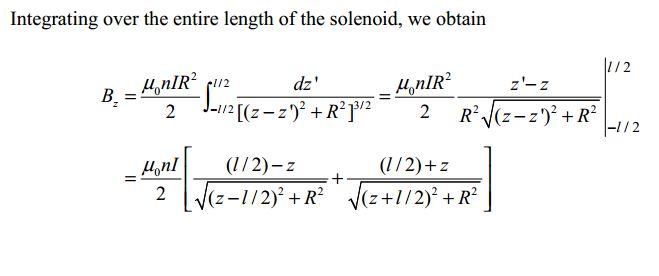
-Statistics on recorded measurements:

-Significance testing comparing the strength of field of the different distances (ANOVA on MATLAB or JMP)

-Significance testing between the measured and calculated electromagnetic fields (two-tailed t-test on MATLAB or JMP)

* Measured will come from gaussmeter, calculated from:





Where μ0 = 4π\*10-7 N/A2, z = the distance of the seed from the center of the electromagnet (on the z-axis), R = radius of the electromagnet (0.625 in), n = number of turns (300), l = length of the electromagnet (4.24 in), I = current

Equation for B distance z away from center of magnet (thank you MIT OCW) pg 9-22): <http://ocw.mit.edu/courses/physics/8-02sc-physics-ii-electricity-and-magnetism-fall-2010/creating-magnetic-fields/biot-savart-law/MIT8_02SC_notes19to20.pdf>

-Compare the magnitude of the movement qualitatively

-Iron shavings for visualizing

Handout (thank you UC Berkeley):

<http://lasp.colorado.edu/home/wp-content/uploads/2011/08/P1-2_3D_field.pdf>

-Other visualization experiment: the experiment we did to visualize the electric field with the seeds lined up perpendicular to the lines and increasing the amp till they moved.

Other relevant documents:

-Data sheet for the electromagnet, committed separately GitHub