Falling Magnets of Autumn

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This is a summary of a brief experimental investigation as to the possibility of whether very strong magnets, affixed face to face forming a quadrapole, exhibit any anomalous free-fall tendencies. It has been reported that such a configuration of magnets may fall at a lesser acceleration/velocity. There is no obvious theoretical basis for such a happening, and in fact, it would violate the Equivalence Principle of General Relativity. However the experiment is easy to do, and serves as a good exercise.

The claim under consideration involves Samarium-Cobalt magnets dropping in air from a height of slightly under 20 meters. The claim is that visual observation showed the magnets reaching the ground noticeably after that of a presumably equal test mass (reportedly 17%). The representation is that both the magnets and test mass were enclosed in similar spherical shells, so similar air resistance would be encountered.

To perform testing under tight controls, it was decided to perform drops over a 2 meter distance, with high precision timing. If a visually noticeable effect is present after 20 meters, precise timing measurements should reveal a similar, though proportionally smaller effect, over a 2 meter drop.

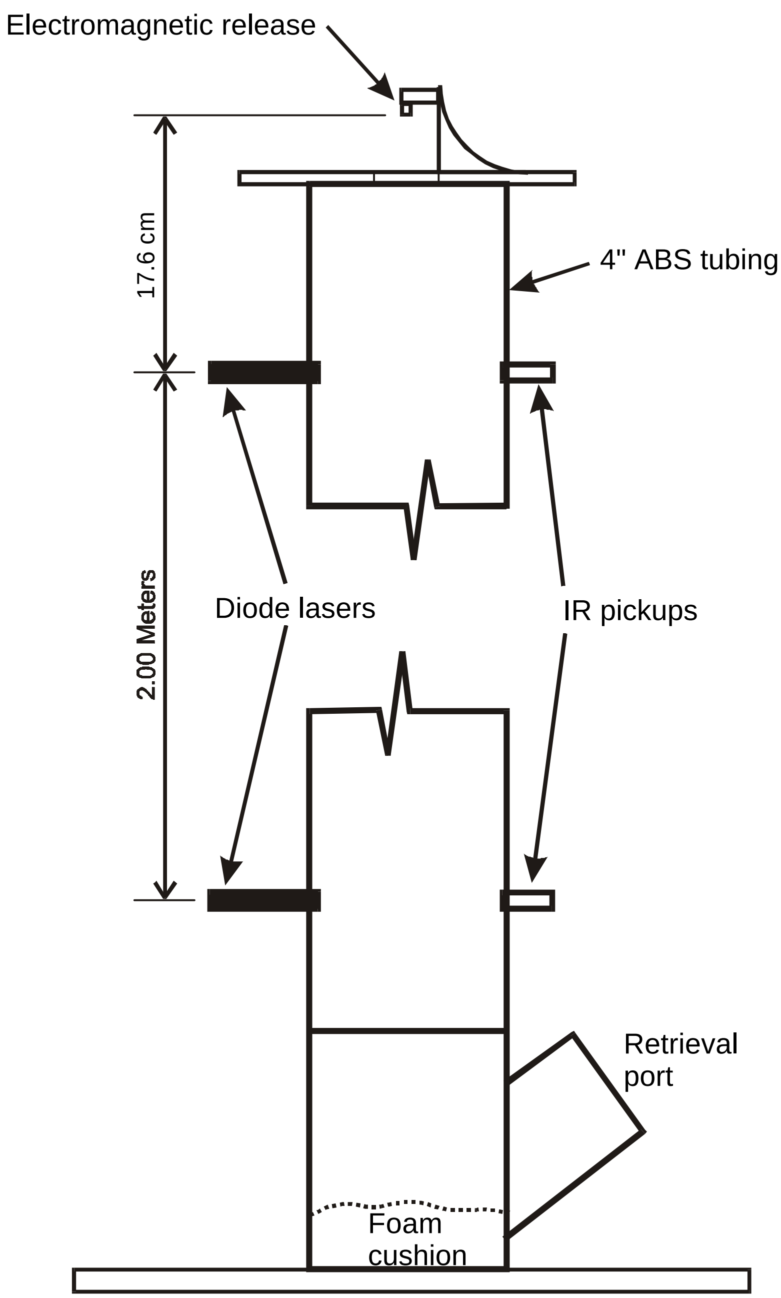
Test Apparatus

The device constructed to perform the testing is shown below. It consists basically of a 2.4 meter length of 4” ID ABS drainpipe, mounted vertically on a wooden base. Test objects may be dropped into the top of the tube, passing through a optical trip setup as they fall, and impact into a foam cushion at the bottom. An access port at the bottom of the tubing provides easy test object retrieval. For this initial testing, a vacuum was deemed unnecessary. At the falling speeds generated, air drag was very minor. However, should anything anomalous be detected, follow-on experiments would be carried out in a vacuum.

Timing is provided by a simple, but highly accurate, laser optical trip system. The heart of the timing system is a crystal clock oscillator operating at 4.91524 MHz. The timing pulses from the clock are passed through a divide by ten IC, resulting in a pulse rate of 491.524 KHz. This rate was checked on laboratory grade frequency counters and found to be accurate and reasonably stable. The pulses are then fed into a 6 digit LCD counter module through a start and stop flip-flop circuit. The counter display has the capability of displaying up to one million counts, so it may be used for timing of periods just over 2 seconds.

The start and stop flip-flops are triggered by the outputs of two IR detectors. The IR detectors are mounted deep within narrow tubes, with the internal tube surface painted black, to provide a very small field of view for each detector. The tubes containing the detectors are attached at right angles to the side of the 4” ABS tube at precisely a 2 meter interval. Diametrically opposite the IR detectors on the ABS tube are mounted generic diode laser pointers providing a very narrow beam into the detectors and creating a narrow trip beam across the diameter of the ABS tube.

In operation, as an object is dropped into the top, open end of the ABS tube, the upper laser beam is broken and the display begins counting at a rate of 491524 counts per second. When the falling object passes through the lower laser beam, the count is then stopped and the number of counts held on the display until reset.

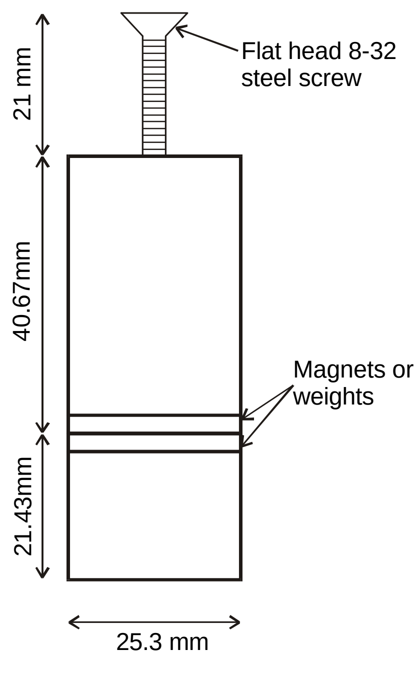


Drop Apparatus

In preliminary testing, it was found seemingly minor differences in the release of test objects (particularly release height) lead to very different timing results. To ensure uniformity, an electromagnetic release was fashioned from an old 24 VDC relay. All test objects had a 10-32 flat head steel screw extending from the upper portion of the test object. The flat head screw was held flush against the bottom of the electromagnet until power was released, at which point the test object fell cleanly and with a minimum of rotation.

All test objects were enclosed within cylindrical carriers. This had the advantage of providing a uniform, flat surface with which to break the laser beams. If a spherical or teardrop shape were used (perhaps to reduce air drag), lack of plumb in the object's fall could cause it to shift to one side, and the beam not be broken by the foremost portion of the leading edge, resulting in a dispersion of timing values.

The first test object is show below, a cylindrical carrier constructed from acrylic tubing. Two carriers were fabricated, as closely matched as possible. One carrier was built to carry two flat, circular Neodymium magnets, and the other to hold steel washers of equal mass. The carrier containing the magnets weighed 50.95 gms and the carrier containing the washers weighed 50.60 gms.



Detail of Acrylic Carrier

The magnets for the first test were two Grade 27 Neodymium discs, each 19 mm in diameter, and 2.57 mm thick, weighing 5.36 gms, with the magnetic field oriented through the thickness. (Neodymium magnets are somewhat more powerful than Samarium-Cobalt magnets, with lower grade Neodymium magnets being roughly equivalent to higher grade Samarium-Cobalt magnets.) The construction of the carrier was such that when assembled, the two disc magnets were clamped with faces of similar polarity forced together, and held in a horizontal orientation.

Methodology and Data

12 drops were made first using the dummy carrier, then 12 drops using the Neodymium magnets and their carrier. The results are tabulated below. No particular purpose was served by converting the raw counts into actual time in seconds, so it was retained as measured (To obtain time in seconds, divide the count by 491524). The lower the count number, the faster the carrier traversed the trap.

	Dummy Weights		Neodymium Magnets	Count Differential
	253484		253464	
	253426		253474	
	253444		253486	
	253453		253490	
	253573		253489	
	253645		253431	
	253541		253423	
	253552		253442	
	253599		253414	
	253577		253397	
	253692		253400	
	253613		253385	
Average:	253550		253441	109
Std. Dev.:	84		38	

The measurements for each carrier are remarkably consistent, with little spread, as evident in the low standard deviation values. The 109 count differential between the magnets and the dummy weights amounts to only a 0.04% difference, with the magnet carrier actually falling faster (not slower) than the dummy weights. However rather than evidence of any strange effect (although it would be the opposite of that claimed), this is most likely due to minor surface and construction differences between the two carriers, the result of air drag differentials.

Additional testing was conducted utilizing Samarium-Cobalt magnets. These were 25.4 mm nominal square, 3.17 mm thick, weighing about 18 gms, with the magnetic field oriented through the thickness. While the grade of the Samarium-Cobalt magnets was not known, their handling characteristics suggested they are similar in strength to the Neodymium magnets already tested. Two sets of Samarium-Cobalt magnets were tested. One set in which like faces of two magnets were forced together, and another set in which opposite faces were allowed to attract.

The carrier used for this phase of testing was a bit simpler than previously used. In order to maintain uniformity between tests, a single carrier was made, whose contents could be changed for the different tests. This would ensure the external characteristics would remain constant for all tests.

An ideal carrier was found in the form of a cylindrical plastic prescription medicine container, with a snap-on lid. The container measured 32.8 mm in diameter and 69.3 mm tall. A steel, flat head 10-32 screw was bolted into the center of the snap-on lid, and extended 25.0 mm above the lid. The total weight of the container and contents was maintained at 59.30 gms for all tests.

For the first pair of tests, a pair of SmCo magnets with like faces clamped together, was inserted into the carrier in a vertical orientation. The magnets were held securely in that position by a generous stuffing of tissue paper. Following 12 drops, that magnet pair was removed from the carrier and replaced in a like manner with a magnet pair whose opposite faces were allowed to clamp themselves together, also in a vertical orientation. The results of those drops are tabulated below.

	SmCo Magnets N to N Pair	SmCo Magnets N to S Pair	Count Differential
	257549	259204	
	257465	259819	
	257487	259754	
	257510	257785	
	257521	257799	
	257687	259795	
	257659	259880	
	257582	259786	
	257549	257769	
	257654	259632	
	257546	257785	
	257630	258525	
Average:	257570	258961	1391
Std. Dev.:	72	945	

This data presents a bit more perplexing picture than previous tests. The N to N pair seem to provide fairly consistent results, as shown by the low standard deviation value. However the N to S pair is a different story. Not only is the data spread significantly higher, the average count for the N to S tests is 0.54 % greater for the N to N tests. This means that the N to S configuration is traversing through the trap 0.54% <u>slower</u> than the N to N configuration.

A possible source for this unexpected turn in the data may have been a readjustment in the experimental setup during the testing. After the completion of the N to N tests, the lower laser beamline was readjusted to make sure it was properly illuminating the IR detector. It seemed possible such a readjustment could possibly shift the beam line enough to induce changes in subsequent data collection. So, it was decided to perform the test sequence again, without making any further adjustments. That data is tabulated below.

	SmCo Magnets N to N Pair	SmCo Magnets N to S Pair	Count Differential	Brass Weights
	257705	259602		257618
	257729	260183		257583
	257694	259509		257568
	257697	258806		257687
	257716	259944		257564
	257719	260126		257576
	257729	260077		257568
	257711	259440		257556
	257694	260015		257595
	257629	260149		257584
	257740	260228		257590
	257743	259414		257573
Average:	257709	259791	2082	257589
Std. Dev.:	30	436		35

As may be readily seen, the anomaly didn't go away, it got larger. The N to N pair continued to show a tight data spread, with an average count very close to previous testing. The spread of N to S pair tightened up a bit, but the average differential between the N to N and the N to S data increased to 0.81%. As before, that data shows the N to S configuration traversing the trap slower than the N to N configuration. Not only was there no apparent reason for this, it also ran counter to the claim being investigated.

Whatever was causing the anomaly seemed to be associated with the N to S configuration, as those data sets had the largest data spread. With the magnets in that orientation, the total magnetic field was much greater than that of the N to N orientation. In the N to S orientation, each magnet's field was reinforced, and with the N to N orientation it was greatly cancelled.

A possibility considered was perhaps eddy currents induced in metal cabinets and shelves a couple of meters away might be acting on the larger magnetic field of the N to S configuration. This was simply tested by moving the apparatus further from the cabinets. Brief testing showed that the N to S configuration was still traversing the trap more slowly and no obvious change in behavior was noted.

Another possibility was an interaction with the Earth's weak magnetic field by the stronger of the two magnet configurations. This was checked by dropping the carrier with the vertically oriented magnet in line with different compass bearings and noting any changes. There were none apparent.

A final possibility considered for this odd behavior was an interaction with the electromagnetic drop mechanism. The idea here is that the much greater magnetic field of the N to S configuration slightly magnetized the steel screw, which is held by the electromagnet. When the electromagnet is cut off, the residual field very slightly slows the fall of the carrier's screw away from the electromagnet. It had already been found that the timing values were very sensitive to initial velocity or position, so this seemed a likely candidate. Also, the surface of the steel screw was not perfectly flat (there was the screw slot), so a small magnetic interaction between the screw and electromagnet might be highly surface sensitive, thus creating the data spread observed.

To check this prospect, the magnets were removed from the carrier and replaced with brass weights. A series of 12 drops (shown in the previous table) show an average and data spread virtually identical to the drops of the weak N to N configuration. Thus it seems highly probable that the differences in drop time are due to the magnetic interaction of the slightly magnetized steel screw with the electromagnet.

To further validate the cause of the different timings being due to the electromagnetic release, three more test sequences were performed, utilizing the original circular Neodymium magnets and carrier.

In the first sequence of 12 drops (tabulated below), the two magnets were placed in the carrier N face to N face. The average count and the data spread matches very well with the initial testing done for that configuration, despite the test apparatus have been moved around and jiggled a bit in the interim.

For the next sequence of 12 drops, the magnets were removed from the carrier, then replaced, but now with a N face allowed to join with a S face, increasing the overall magnetic field emanating from the two magnets. While running the tests, it was noted the grip of the electromagnetic release was noticeably less than the previous test. Examination of the average for the data shows the count to be less than the previous test, which means the carrier was traversing the trap more quickly.

Finally, for the last test, the magnets were again removed from the carrier, and flipped, while allowing the same two faces to remain in contact. The result of this was now the opposite pole of the magnet was in proximity to the steel screw. While testing, it was immediately noticed that the grip of the electromagnetic release was now much stronger. The average count for the sequence backed this up, as the count value increased, indicating the carrier was traversing the trap more slowly. This is consistent with an increased magnetic attraction between the screw and the release. Since it was a DC electromagnet, it had a specific polarity, and when a strong magnetic field (created by two magnets in "series") was nearby, the action of the release changed. When the magnets were placed with like faces together, the result magnetic field was greatly attenuated, and results comparable to dummy weights were obtained.

	Neo Magnets N to N Pair	Neo Magnets N to S Pair	Neo Magnets N to S pair flipped
	253497	253477	254055
	253598	253377	253887
	253629	253490	253776
	253501	253464	253803
	253615	253437	254095
	253634	253472	253713
	253535	253424	254235
	253603	253497	254075
	253634	253498	253726
	253486	253438	253875
	253615	253436	253839
	253628	253326	253900
Average:	253581	253445	253915
Std. Dev.:	59	51	164

Conclusion

The data shows no credible indication of any anomalous fall characteristics of high powered magnets in a quadrapole orientation. Such configurations seem to fall at an identical rate with non-magnetic objects, at least to a precision of 1 part in several thousand. Some variance in fall times were noted, but it was determined to be due to minor magnetic interactions with the release mechanism. Lacking even a weak suggestion of anomalous fall characteristics, it would appear further experimentation, including testing in a vacuum, is not warranted.