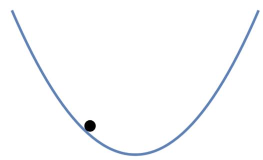
What is ion trapping, and how does it work?

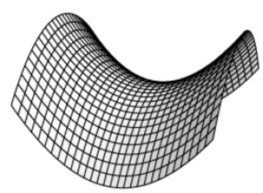
In order to study atoms, we need to hold them in place in the lab. This is the purpose of the ion trap.

Atoms, of course, are incredibly small, which makes this task difficult – since they are so small, tiny disturbances could knock them free if not properly accounted for. We thus need to make sure they can't escape. How do we do this?

A particle is "trapped" if it can be imagined to be at the bottom of a "bowl," so that if it gets pushed in any direction, the particle will "roll" back to the center and remain trapped in the bowl. An example is shown below:

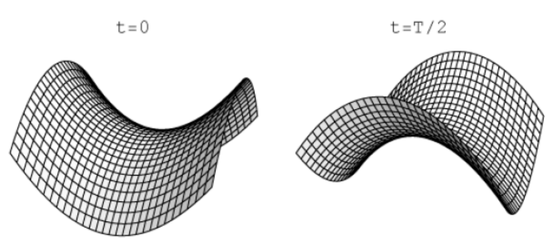


As if the size of the atoms didn't make our job hard enough, the laws of electromagnetism forbid us from making a perfect "bowl" trapping potential. The best we can do is to make a saddle-shaped potential, such as the following:



If you imagine putting a ball at the center, it would begin to roll down the downhill part of the saddle, eventually escaping the trap – this clearly does not work for our purposes! To get around this problem, physicists have come up with a clever solution, which works as follows:

As the ball begins to roll down the downhill part, we fold it upward to "catch" the ball! The shape must remain a saddle, so the previously uphill part folds into a downhill region. The ball will then roll down the new downhill, at which point we invert the saddle again, once more "catching" the ball. When this "flapping" of the saddle is done at the right rate, the ball will remain trapped in the center of the saddle.



To make this easier to visualize, a rotating saddle can be used as an analogy to the alternating "uphill" and "downhill" regions of an ion trap. We have prepared a teaching demo of such a setup that can easily be 3D printed and assembled for classroom use.