Investigating Newton's Inverse Square Law

-A New Pendulum -

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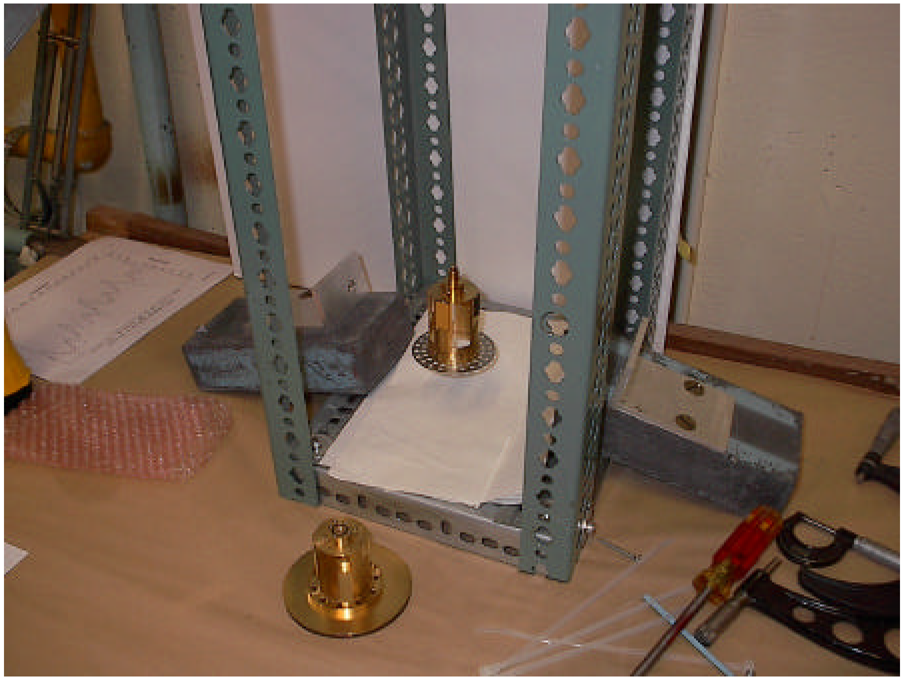
This should sound familiar.

- Two other presentations.
- Same topic, same motivation.
- I'll try to make this a bit different.
- Why this design?
- What I actually did.

But first - a review.

- Gravity was the first of the fundamental forces to be discovered, but we still don't get it.
- As gravity spreads in three dimensions (a sphere) it is 'diluted' over the surface area which increases as 4 p r^2
- Thus gravity in the world around us is proportional to $1/r^{2.}$
- Problems with the standard model, gravity is too weak, extra dimensions, support for string theory, planet formation…

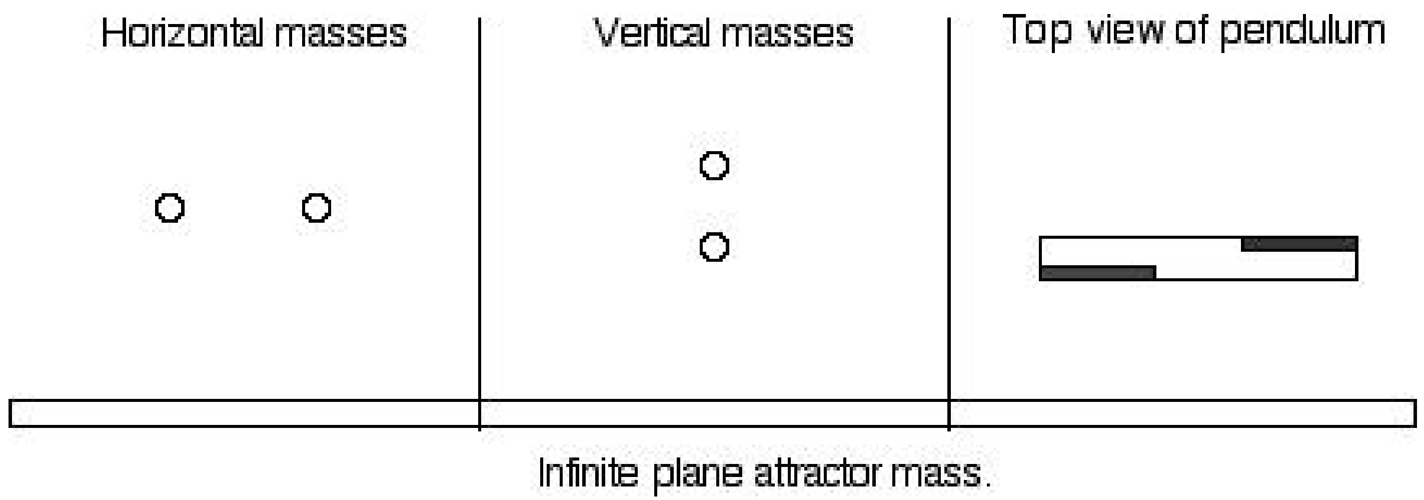
How has this been looked at so far?



- Here at UW - torsion pendulum, carefully aligned holes, rotating attractor mass.
- Elsewhere - some people are using parallel plate attractors with very small mechanics, micro machining.
- If our method works it could be on the order of 100 times better.

The premise…

- The gravitational attraction between a mass and an infinite plane is the same regardless of the placement of the mass.
- Clearly true side to side.
- Less obvious up and down - it still works out - but only for $1/r^2$.
- So if we put a flat 'step' pendulum next to an infinite plane attractor mass - the gravitational attraction on each side is the same.



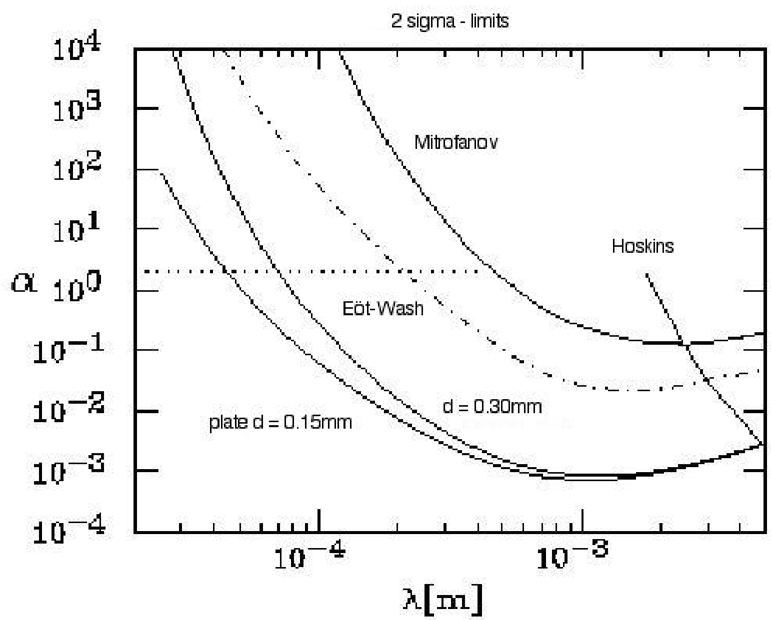
So how do we make use of this…

- Large, flat, moveable attractor mass - not really infinite, but a good approximation at small separations.
- Smaller flat step pendulum - hangs vertically.
- Steps in the pendulum take advantage of the uniform gravity near our ‘infinite’ plane.
- This holds only for the $1/r^2$ law, if the law changes (is violated), the pendulum experiences a torque.
- Laser setup and optics allows detection of nanoradian deflections.

But they already have a pendulum that works…

- ~100x improvement over previous measurements.
- Unrelated NASA project has questions we can answer.
- We made it all ourselves.

Proposed Limits with Parallel Plate Setup



d = distance between the plates
These limits are for Θ < 5 nrad.
The limits get better as S^3 , where S is the typical lateral dimension of the pendulum (here S = 3 cm).

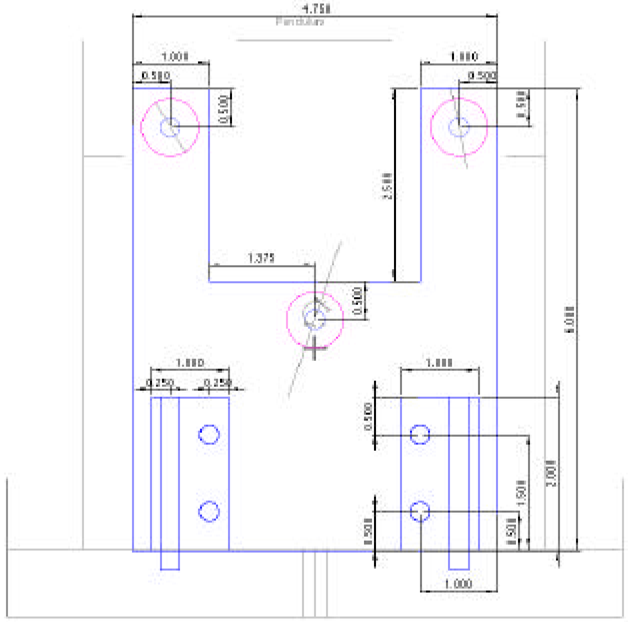
No, really, I mean it…

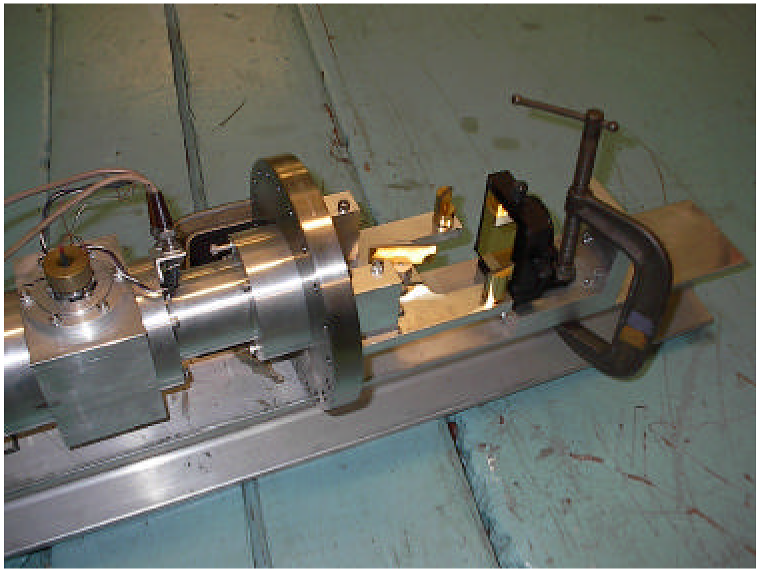
- We accomplished a lot.
- One of the best parts is that we could build nearly everything ourselves (Cost of parts for 10 weeks of building - $0).
- The design is much more forgiving.
- So here is what I worked on…

Vacuum chamber

- We scavenged and assembled the housing of the experiment from around the lab.
- On top you can see the translation stage that allows for some adjustment of the pendulum position.
- Not visible is the interior mechanisms for damping out vibrations in the pendulum while it hangs.
- The copper plate is pretty interesting all by itself.

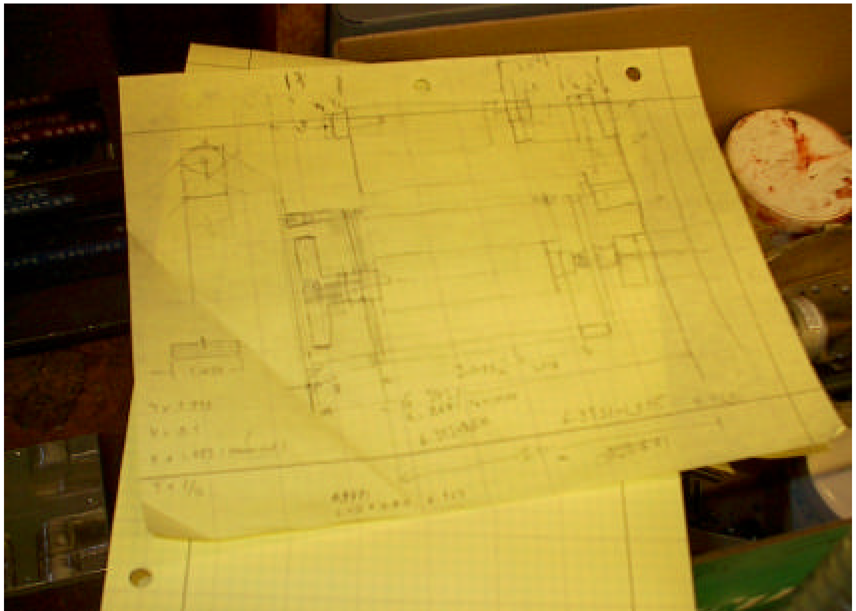
Optics





- Required to detect tiny deflections in the pendulum - nanoradians.
- Because the pendulum may not be as reflective as desired - had to be designed to allow the beam to hit the pendulum at a 30° angle.
- Aligned using a visible laser, then replaced with the infrared laser.

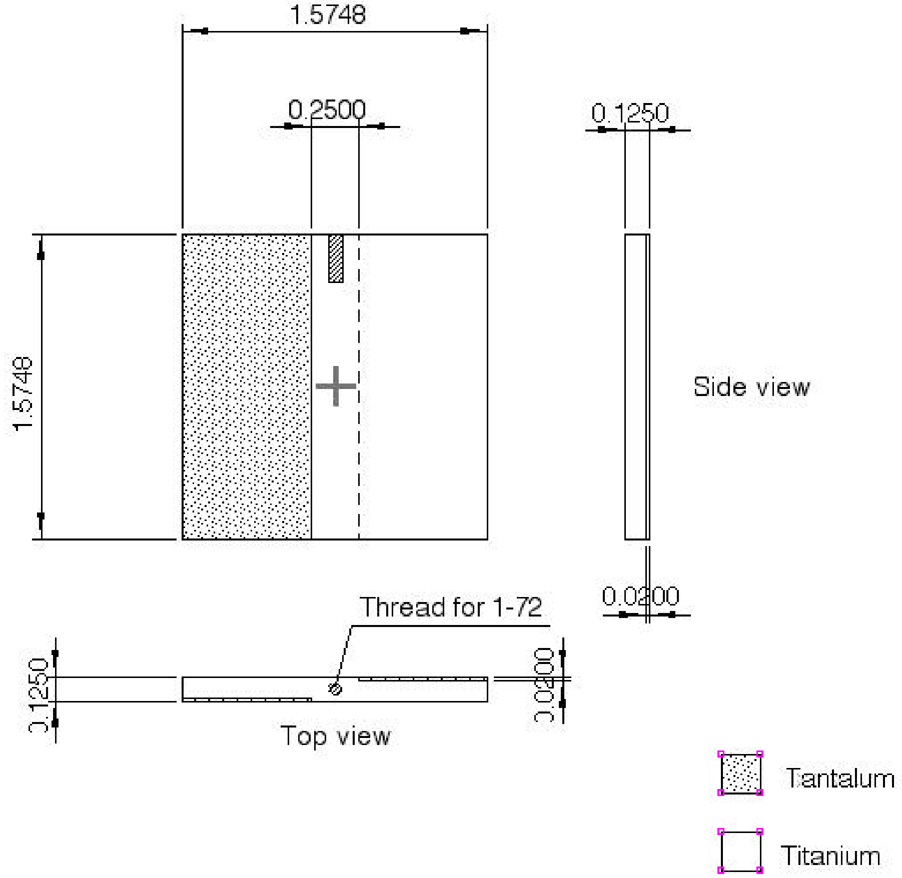
Attractor mass



- Must be movable without causing anything that the pendulum could “see”.
- All ‘non-mechanical’ design for smooth movement.
- Capacitive feedback.

It’s been designed…

- Just over 1.5 inches square.
- 1/8 of an inch thick Titanium.
- With 20 mill Tantalum inserts.
- Polished to a mirror surface.
- Unfortunately, it’s impossible.
- But that won’t stop us.
- Fortunately, there are still things to do before this is resolved.



Thanks to..

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