



Antimatter

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ASTR 311

Presentation Outline



What is Antimatter?¹

- **Misconception:** absence of matter or a 'void'
- It's the **same** as regular matter!

1



Opposite
charge

2



Equal mass

3



Annihilates
matter

What is Antimatter?

 Protons 

 Electrons 

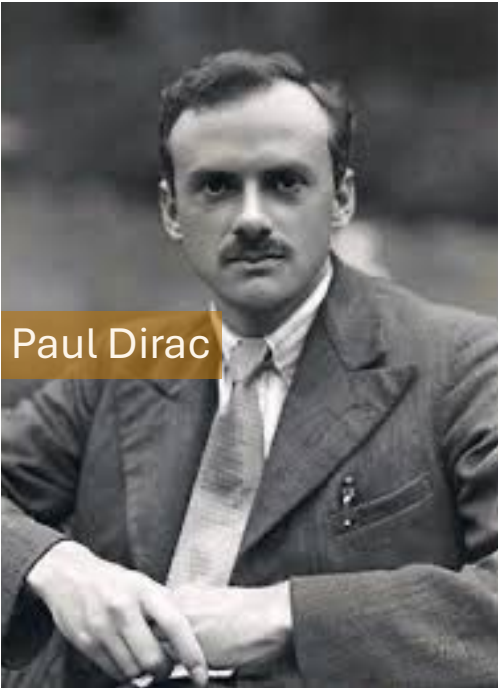
 Neutrons 

 Antiprotons 

 Positrons 

 Antineutrons 





Paul Dirac

Theoretical Prediction²

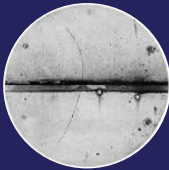
- Dirac's Equation describing the spin of electrons in 1928
 - Relativistic wave equation:

$$(i\partial - m) \psi = 0$$

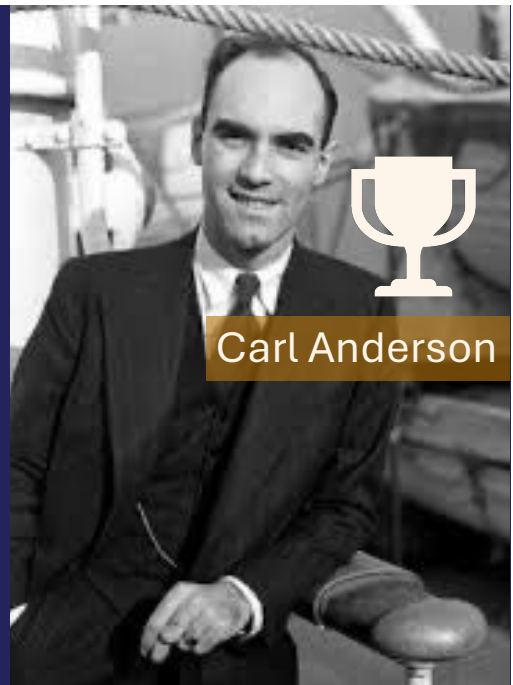
- *STRANGE*: two answers!
 - Positive & negative values
- What does this mean?
- Implies there is an **electron** with a **positive** charge

Experimental Confirmation³

- Studying the tracks of cosmic ray particles in 1930



- Found tracks that were from **positively** charged particles with the same mass as electrons
- 1932: Called them **positrons**, the first known antimatter particle!
- Won the Nobel Prize in physics for his work in 1936



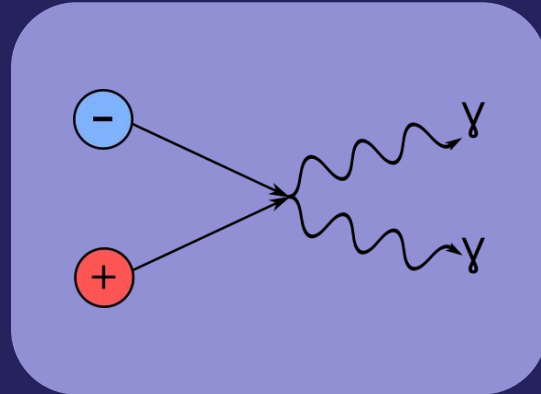
Carl Anderson

The Antimatter Problem⁴

- Big bang suggests: Universe began with **EQUAL** parts matter : antimatter

PROBLEM:

Look around you! What do you see?



- Everything is made of matter! We owe our very existence to this imbalance

Why the Imbalance?

Hypothesis 1



Maybe antimatter is concentrated in another part of the universe?

Hypothesis 2



Differences in the patterns of decay between matter & antimatter?⁵

Hypothesis 3



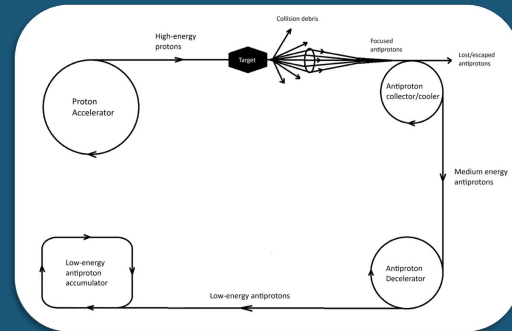
Annihilation between matter & antimatter was not complete?⁶

Antimatter production in the lab

Positrons: beta-plus decay of a proton into a neutron, positron and neutrino¹

Antiprotons: produced from high-energy collisions of a proton beam with heavy atomic nuclei²

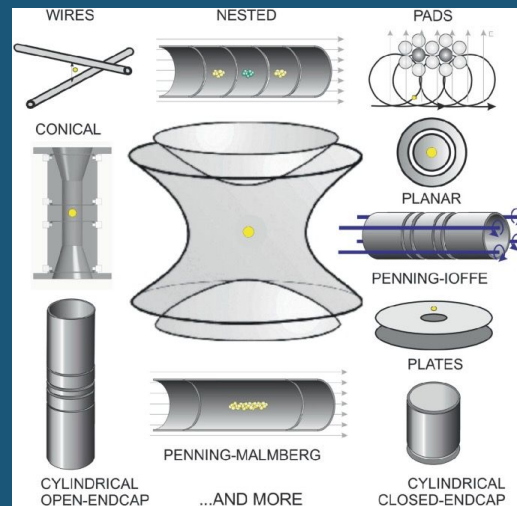
Antiatoms: these particles must each be isolated, cooled/slowed, and allowed to recombine in situ^{3,4}



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(Another) Antimatter problem

- **How do we contain something that will annihilate if it touches... anything?**
 - Ultra-High-Vacuum (UHV) pressures
 - Physical forces
- **Charged** particles (positrons, antiprotons) can be stored in Penning traps
- **Uncharged** particles (Antihydrogen atoms) are stored in Magnetic traps
- Many variations of these technologies exist⁵

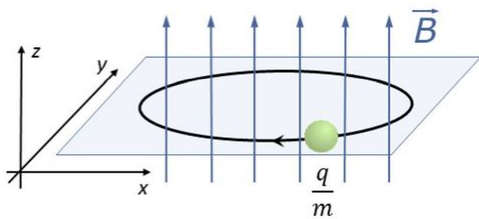


Penning Trap implementation

Principles of Penning traps^{6,7}

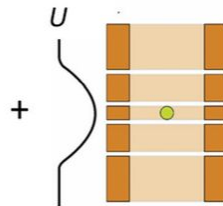
- **Radial Confinement:** restrict the motion of the particle in two dimensions (xy) into a circular "orbit" with a homogenous magnetic field
- **Axial Confinement:** restrict the motion in the third dimension (z) into a harmonic oscillation with a quadrupole electric field
- Electromagnetic field(s) act as immaterial "walls" that force the particle into a form of motion with three modes: Axial, Modified Cyclotron, and Magnetron

(a) strong uniform magnetic field

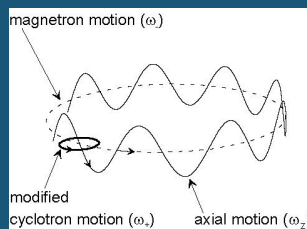
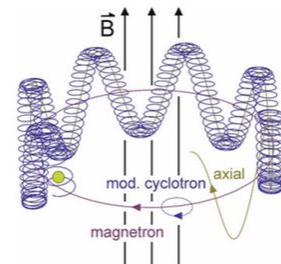


The European Physical Journal A

(b) harmonic electrostatic potential

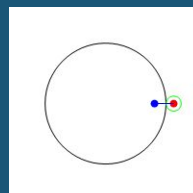
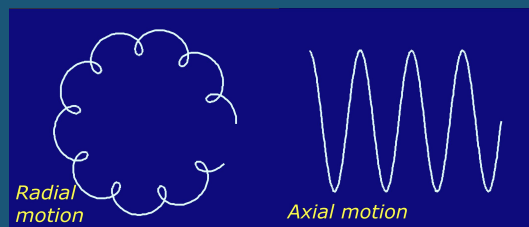


(c) 3 eigenmotions in trap

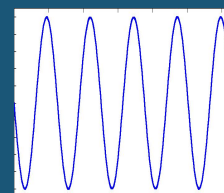


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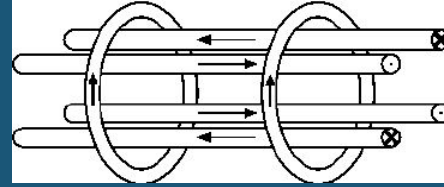


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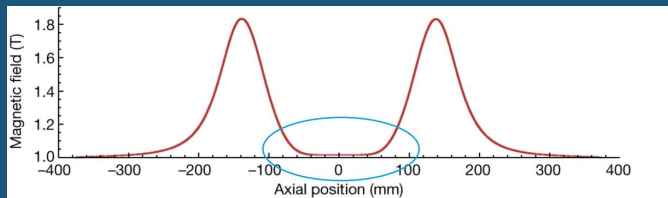
Principles of Magnetic traps: Ioffe trap^{8,9}

Radial confinement: 4 parallel wires with currents moving in *opposite* directions create a magnetically stable point at the center of the xy plane

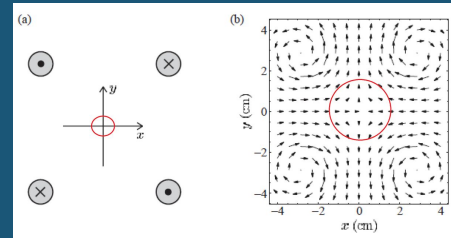
Axial confinement: 2 circular wires with currents moving in the *same* direction create a stable point at the center along the z axis



[Researchgate](#)



[Nature/ALPHA experiment](#)



[Vrije Universiteit Amsterdam](#)

Preventing Progress: Cost and Energy Limitations

Energy

- 1 gram of antimatter = 25 million billion kwh¹



- 1 kwh = 16.5 days²

Cost

- 1 gram of antimatter = \$2700 trillion¹



- 25 million billion kwh = 420 trillion years

Timeline: From Anti-particles to Anti-atoms



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Implications

Anti-particles



Creation of more complex anti-atoms

Implications?

- Could we generate anti-molecules?
- What about anti-humans?



Significance

Hints to why there was a matter/anti-matter imbalance

Space travel – Annihilation reactions

Applicable to medical field - Cancer research⁹

Antimatter in our Daily Lives¹⁰

- PET scan: Positron Emission Tomography
- Medical imaging method
- Uses tracers to look for diseases



PET scanner

Conclusion

1



Antimatter
is cool but it
is scarce!

2

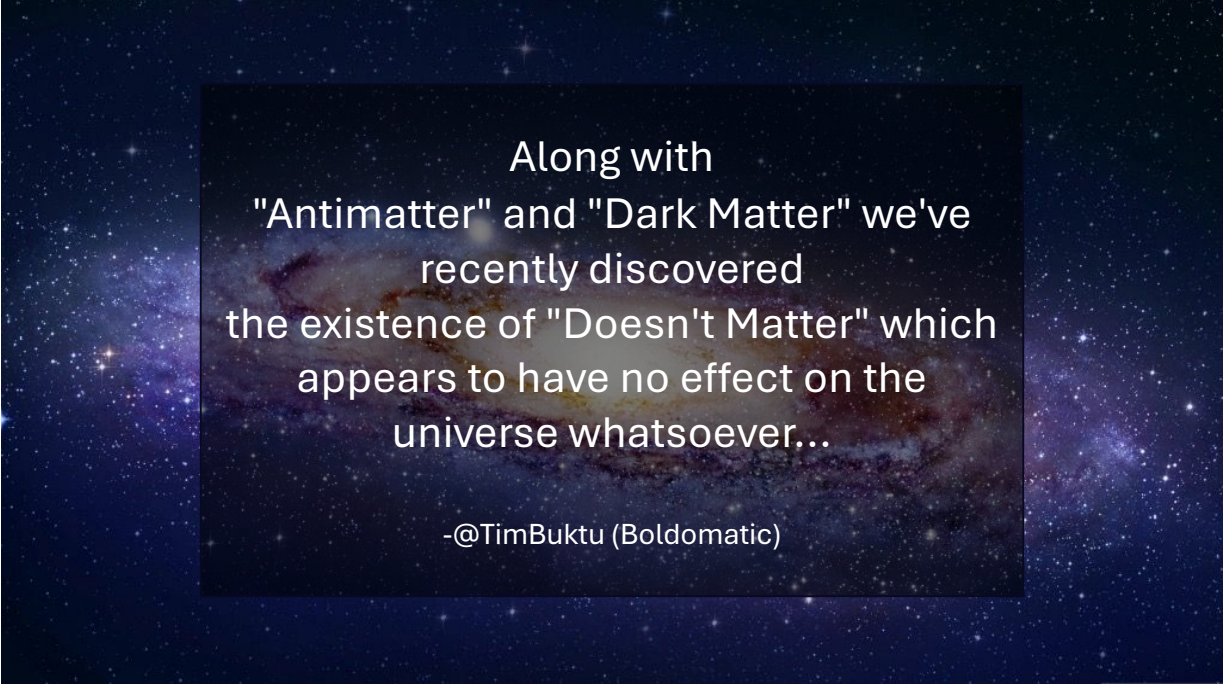


We can make
& store it yet
it's expensive

3



It has real
world
applications!



Along with
"Antimatter" and "Dark Matter" we've
recently discovered
the existence of "Doesn't Matter" which
appears to have no effect on the
universe whatsoever...

-@TimBuktu (Boldomatic)