

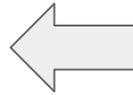
DEMONSTRATING PARTICLE ACCELERATORS IN HIGH SCHOOL CLASSROOMS

**Asaf Maiblatt, Daniel Kaplan, Hasan Khan,
Kenta Takubo, Martina Semesiova,
Siripong Srisuwan**

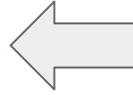
OUTLINE

Overview

Linear Accelerators



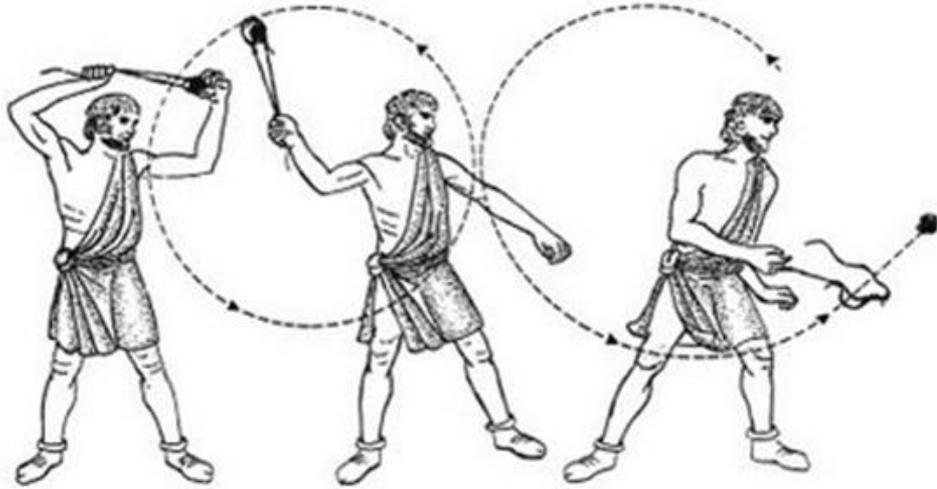
Circular Accelerators



Conclusion

- Demonstrations Developed
- Results
- Lessons Learned

First Particle Accelerator?



- Get a stone →
- Make it go very fast →
- Put it where you want it →
- See what happens →
- Prepare projectile
- Particle Accelerate
- Beam Steer
- Observe results

WIMSHURST MACHINE

Charged induced by rubbing
surface contacts with brushes

Two capacitors to store opposite
sign charge

Random occurrence - Which side
is positive/negative

A Van De Graaff generator is
probably easier for most
classrooms.



ACCELERATION

Acceleration: Charged particle exposed to an electric field.

In real accelerators: The electric field is manipulated: At a specific point in space and time, the electric field gives the charged particle a “kick” in the appropriate direction.

In our case we used different techniques:

Varying the charge on the particle

Moving the location of the electric field

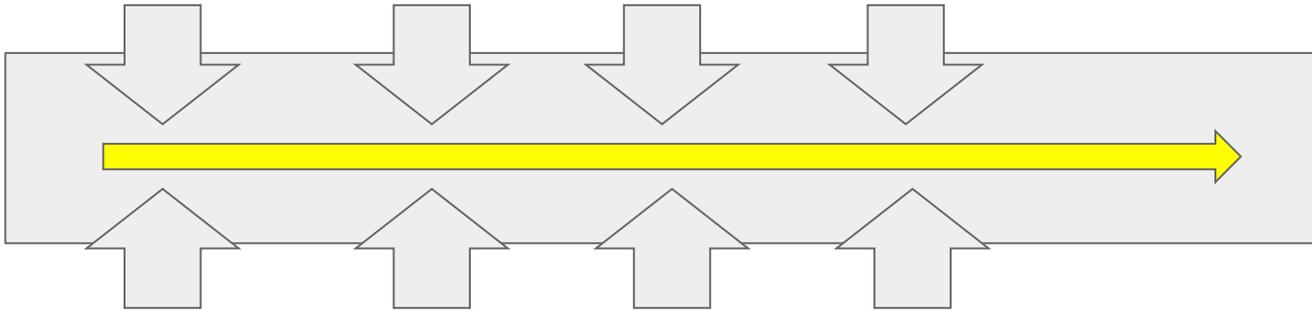
Applying opposite charges to conducting rings inside the
“beam path”

AN ACTUAL LINEAR ACCELERATOR

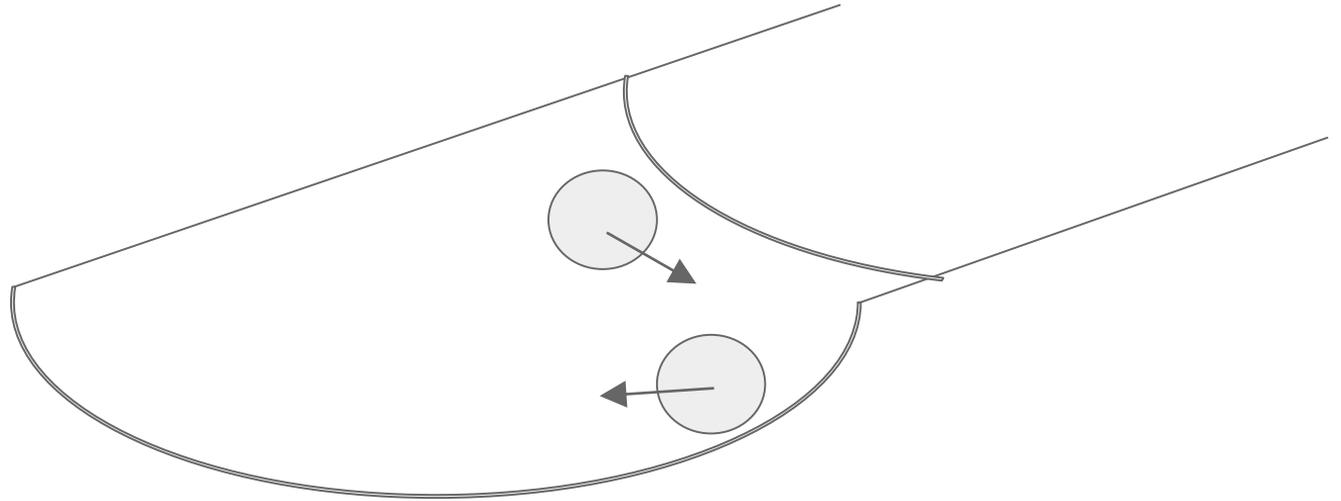
BEAM STEERING AND FOCUSING

Use either electric or magnetic fields

Apply a force perpendicular to the motion

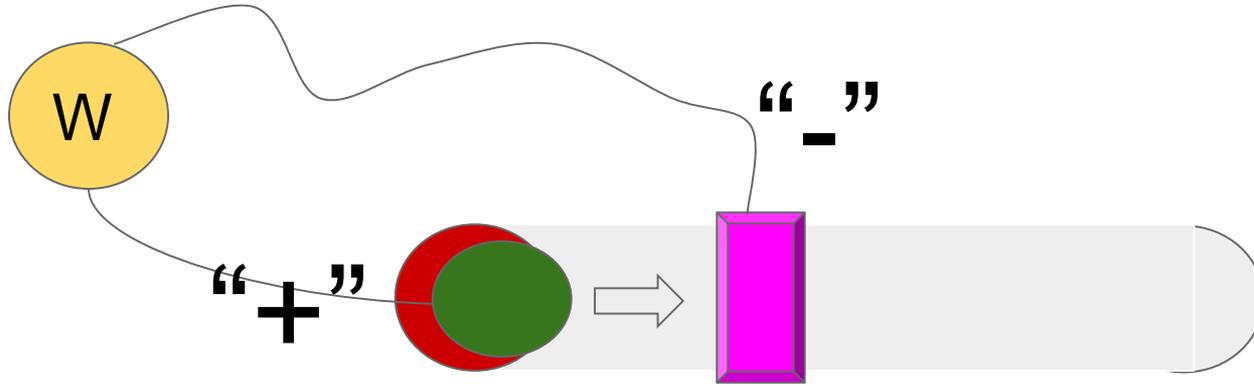


OUR APPROACH - GRAVITY AND NORMAL FORCE



CLASSROOM DEMONSTRATION

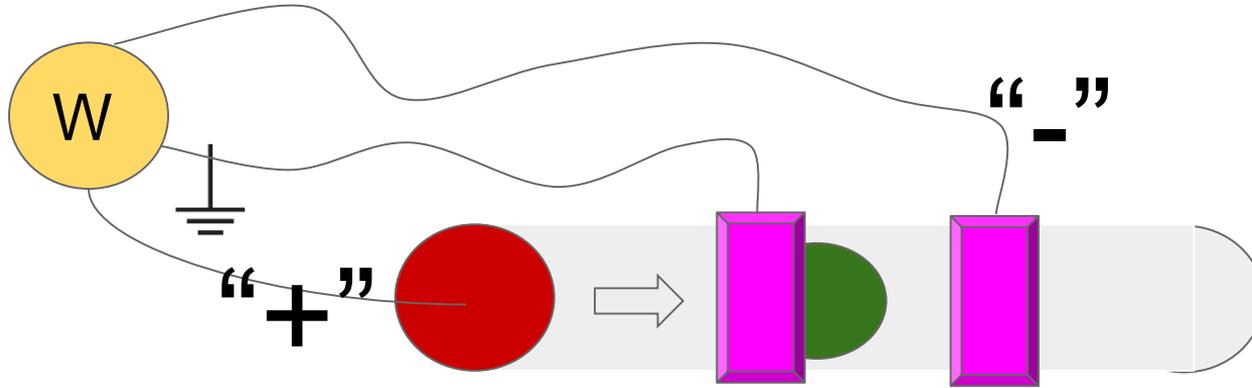
LINEAR ACCELERATOR



Wimshurst machine transfer charge to the ball. The ball is then repelled from one contact and attracted to other contact.

LINEAR ACCELERATOR

Notice the use of the ground port from the Wimshurst Machine.



Wimshurst machine transfer charge to the ball. The ball is then repelled from one contact and attracted to other contact.

OUR FIRST ATTEMPT

2ND:

HOW FAR CAN
WE MAKE THE
BALL ROLL?

IMPROVED

TRAVELING
WAVE

FUTURE?



ASK THE
ACCELERATOR
EXPERT!



LESSONS LEARNED AND SETUP TIPS

Be careful of Wimshurst Zaps!

Don't cross the wires

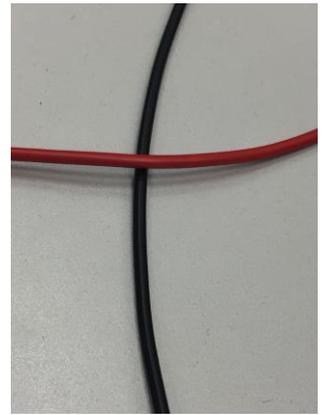
(The plastic insulation is useless at these voltages)

Be sure that foil is contacting the ball

Use a ping pong ball with a conducting coating

Long wires dissipate charge

Plastic tubes can develop a static charge. Then ball is always attracted to that spot.



CYCLOTRON/SYNCHROTRON EXAMPLE

Overview – How a cyclotron works

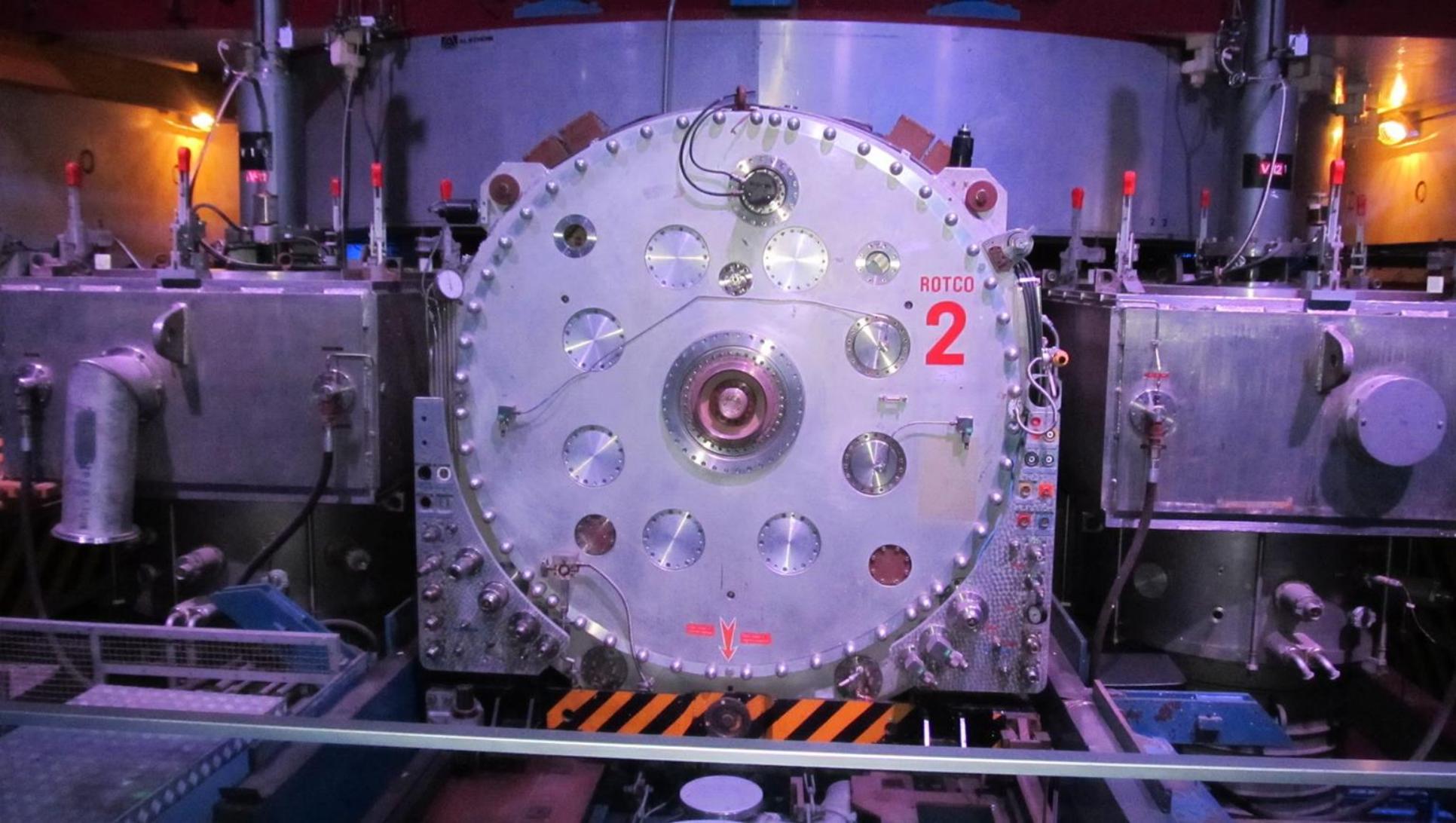
Simulation design

Actual Demonstration

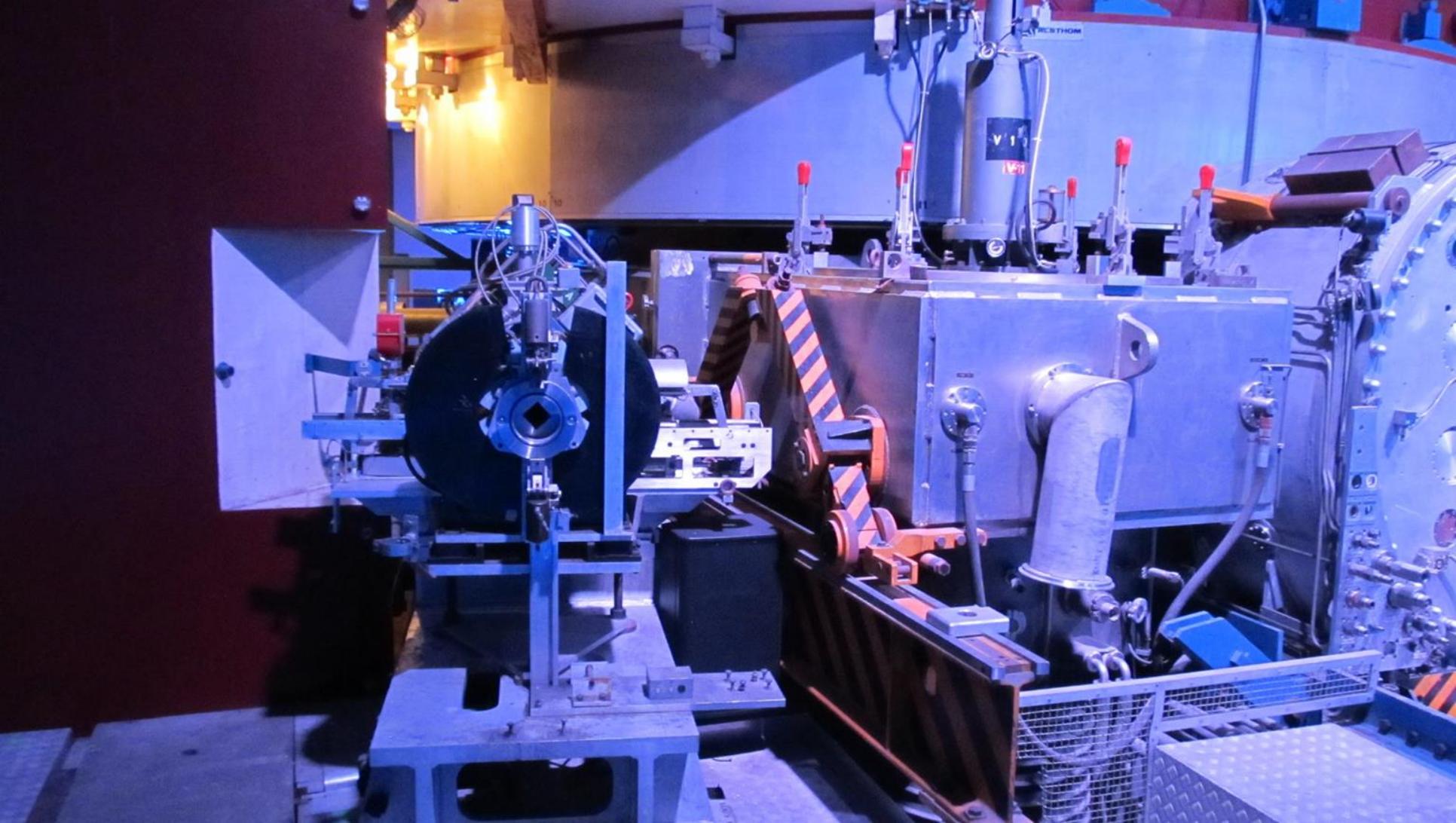
Lesson Learned



WORKING PRINCIPLE OF CYCLOTRON



ROTCO
2





HOW DOES THE DEMONSTRATION WORK?

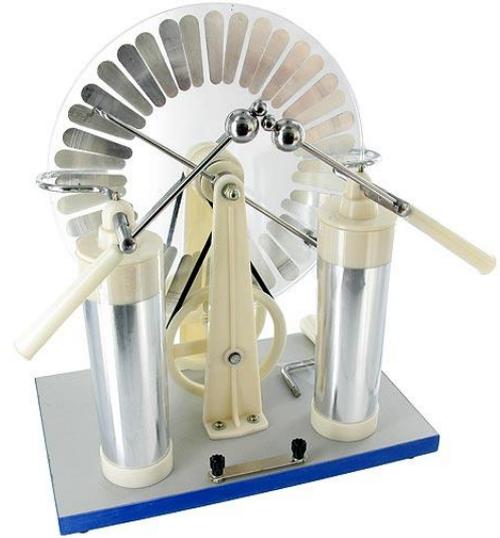
The Wimshurst generator builds up a very high voltage by generating static electricity. (~75000 volt)

The bowl has two sets of strips.

One set of strip crosses over at the center of the bowl and is connected to the high positive voltage.

The rest are connected to the low negative voltage.

The charge on the conducting ball gets switched when it makes contact with one of



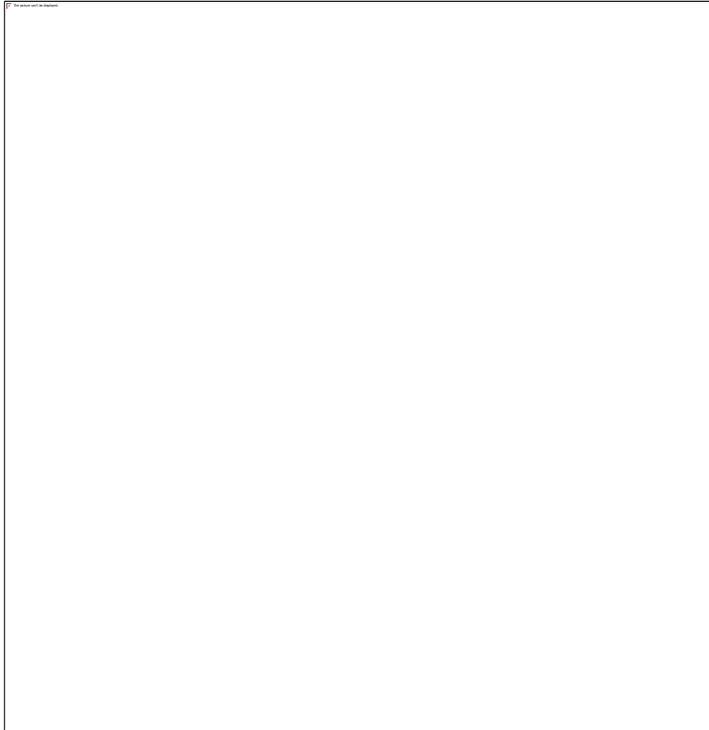
MATERIALS

Generator: Van de graf or Wimshurst. We used a Wimshurst machine, hand operated, produces a DC with high voltage.

A salad bowl, non metallic.

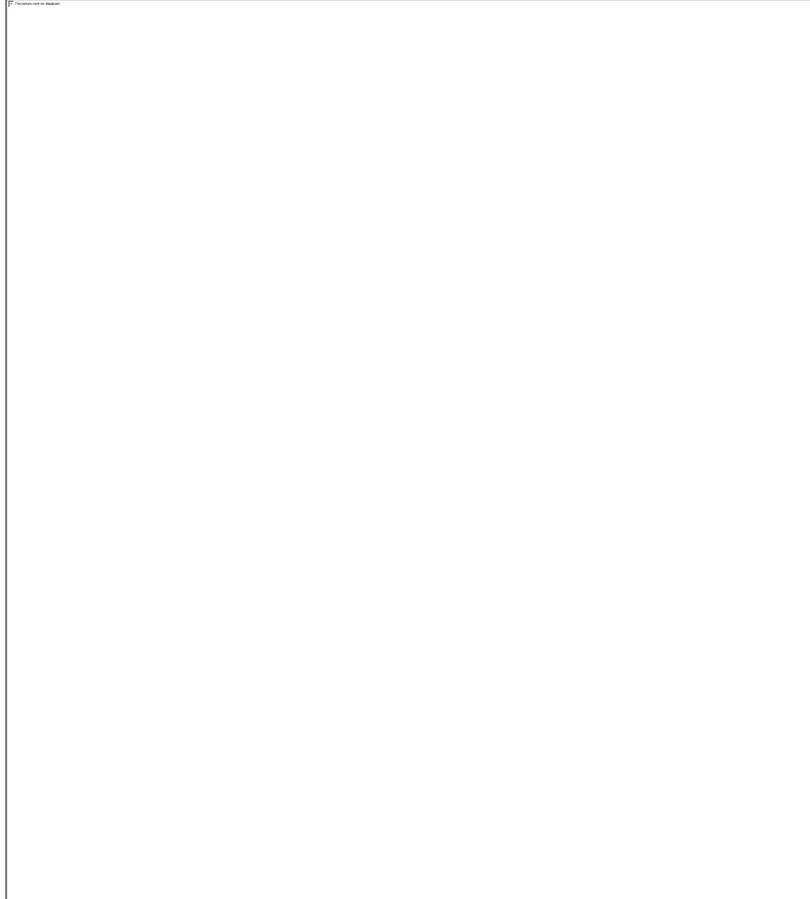
Electrically Conductive Adhesive Transfer Tape (two sizes)

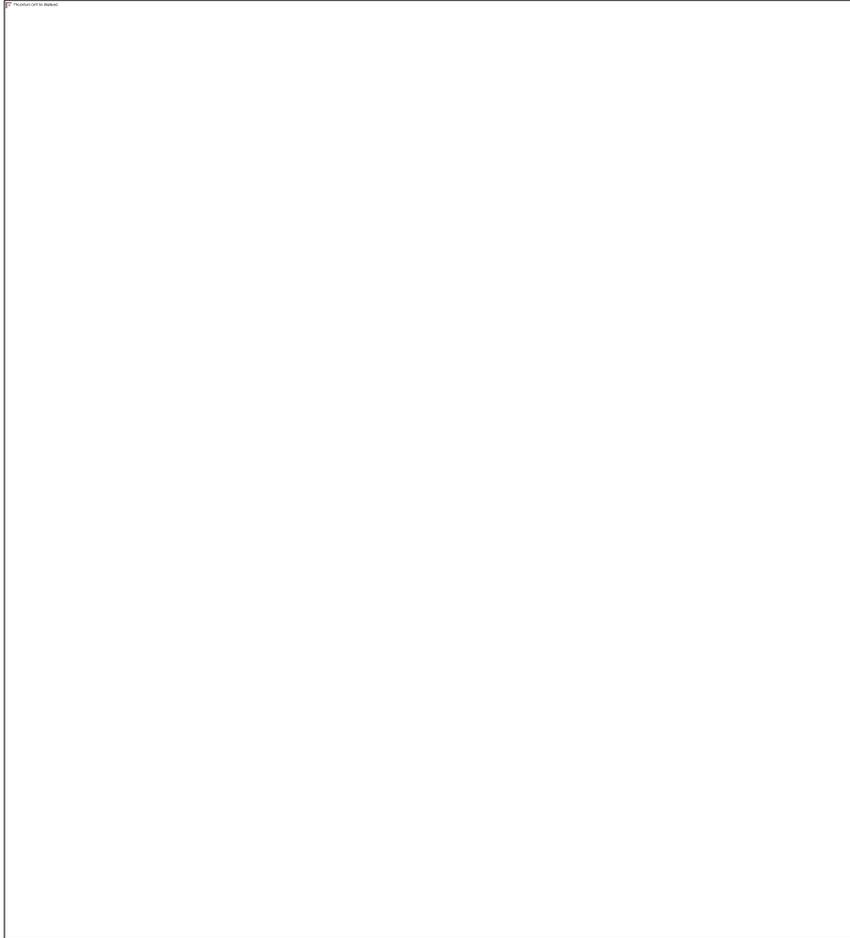
Wires (banana/alligator)



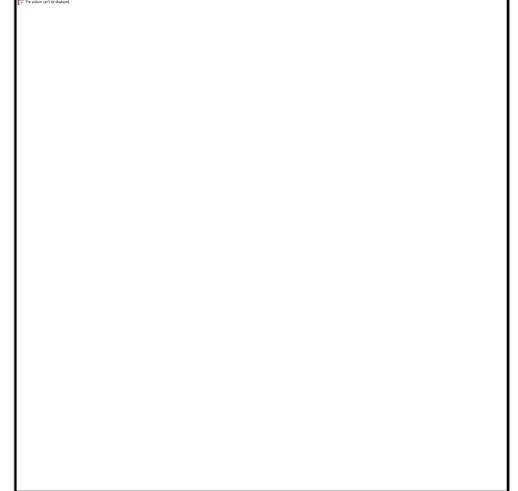
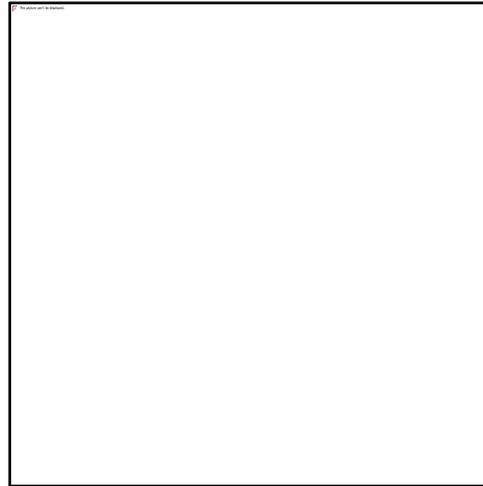
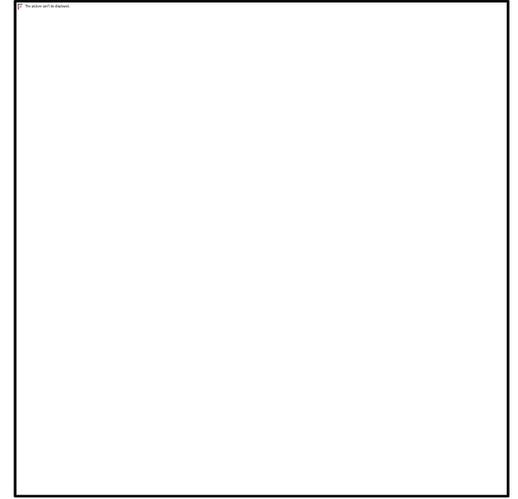
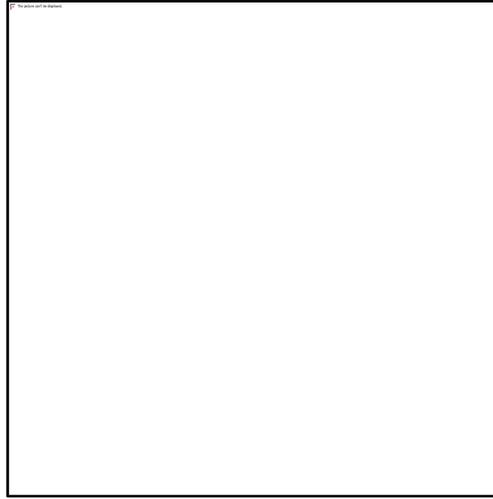






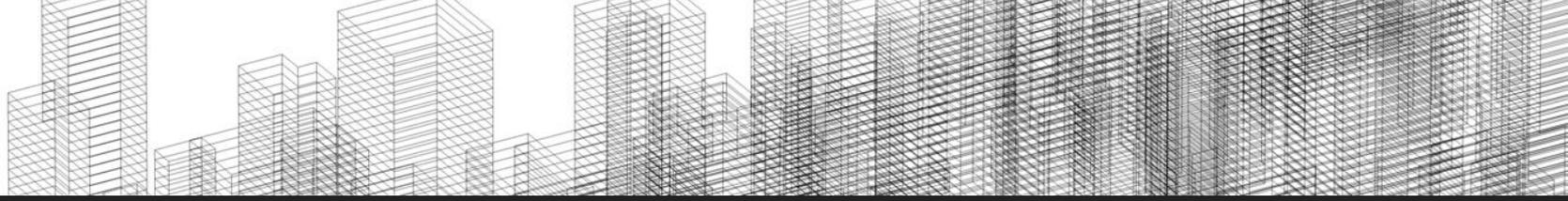


THE ACCELERATOR IN THE MAKING!



SEEING IS BELIEVING!





FAILURES AND IMPROVEMENTS

“Mistakes are
the proof that
you are trying”

Form box 1: A large empty rectangular box with a thin black border, intended for notes or a drawing.

Form box 2: A large empty rectangular box with a thin black border, intended for notes or a drawing.

Form box 3: A large empty rectangular box with a thin black border, intended for notes or a drawing.

Form box 4: A large empty rectangular box with a thin black border, intended for notes or a drawing.

LESSONS LEARNED

Material leakage: When a high voltage was applied across the glass bowl, there was so much leakage that we could not charge the contact.

Sticky metal tape: The glue on the back acts as an insulator and prevents contact with the lower tape. In other cases

We have described a **travelling wave** accelerator. The actual realization of this will occur with the AWAKE





FURTHER IMPROVEMENT/FUTURE SCOPE

3D print design

Improve the trajectory of the particle on the surface.

www.onshape.com (free online-CAD software)



Features (7)

Filter by name or type

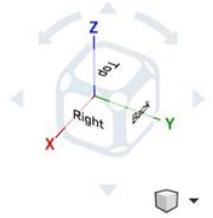
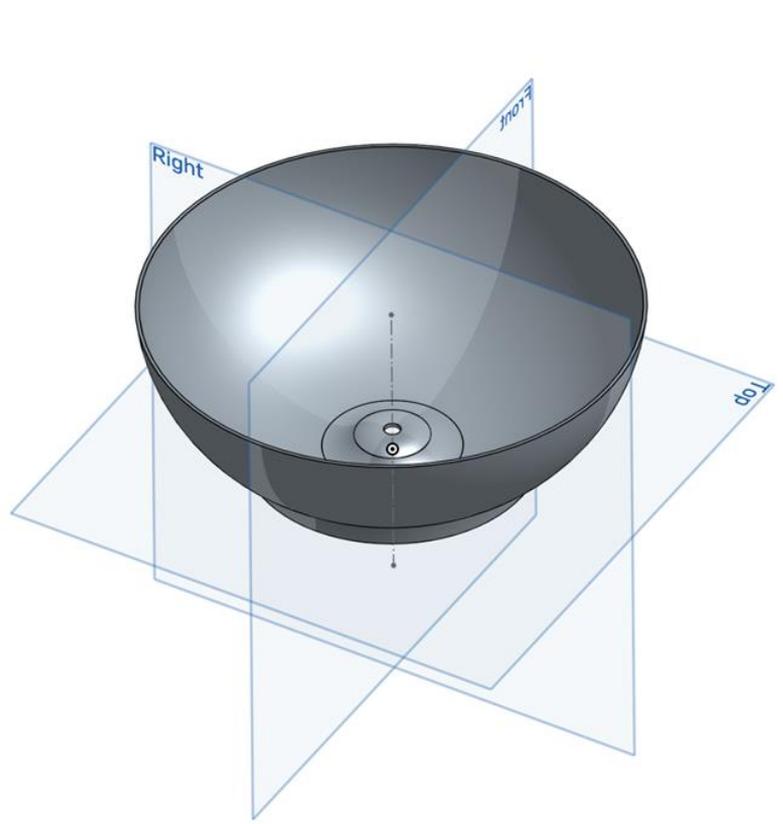
Default geometry

- Origin
- Top
- Front
- Right

- Sketch 1
- Sketch 2
- Revolve 1

Parts (1)

Part 1



POSSIBLE MISCONCEPTIONS TO ADDRESS

Charge on the particle

In an actual accelerator the particle does not
change charge

Size of the particle

One particle vs. trillions of particles

Mechanical force vs. **Magnetic** force



But how???

ACCELERATE SCIENCE WITH THE PARTICLE ACCELERATOR

The accelerator really help the students to understand the concept. (**particle accelerator for accelerating science**)

Be careful to explain the **differences** between actual accelerators and the demonstration versions.

For the demo, plan on spending at least **two hours** to build and test this before you show this to the class.

You will need to be sure to have everything organized, specially **voltage generator**, to make the learning effective and safe.

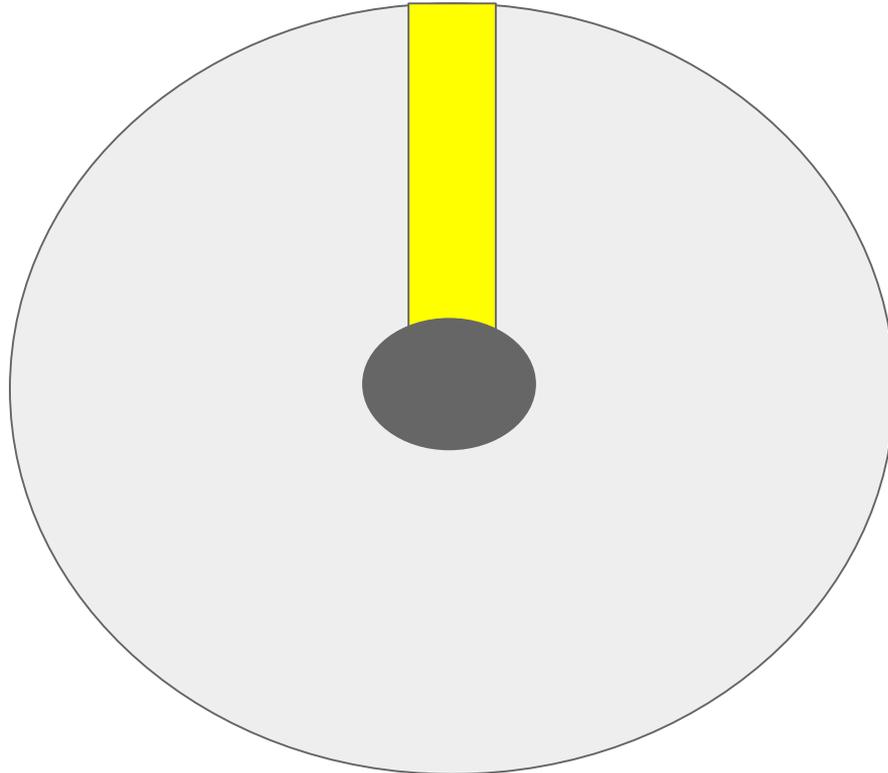
QUESTIONS?



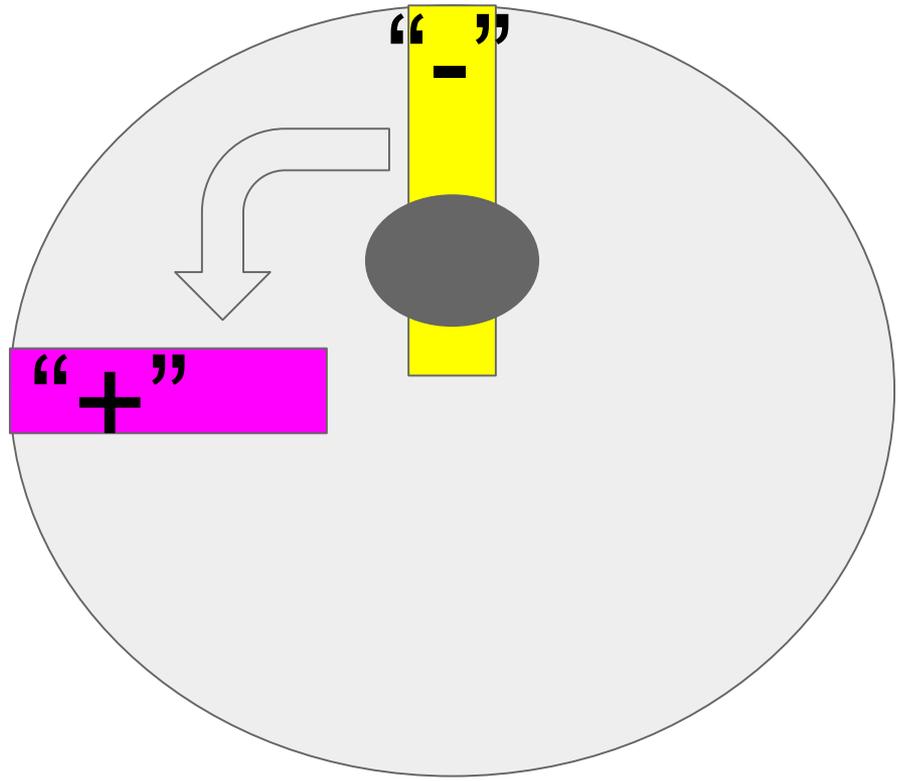
TRANSFER NEGATIVE CHARGE TO BALL

“ ”

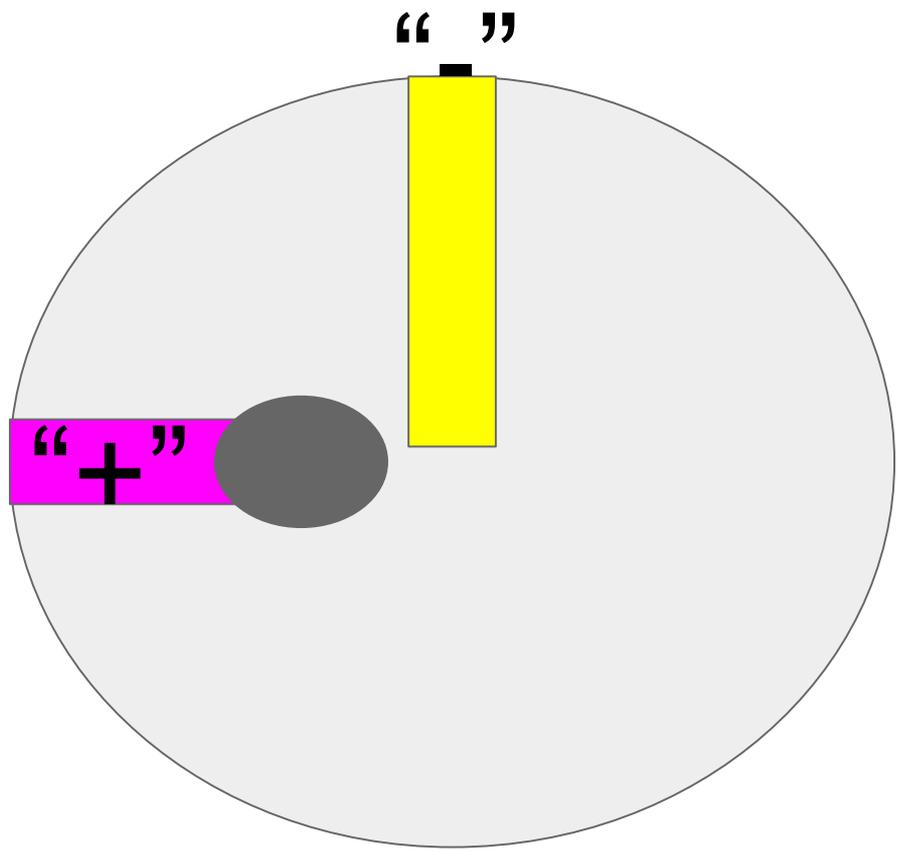
—



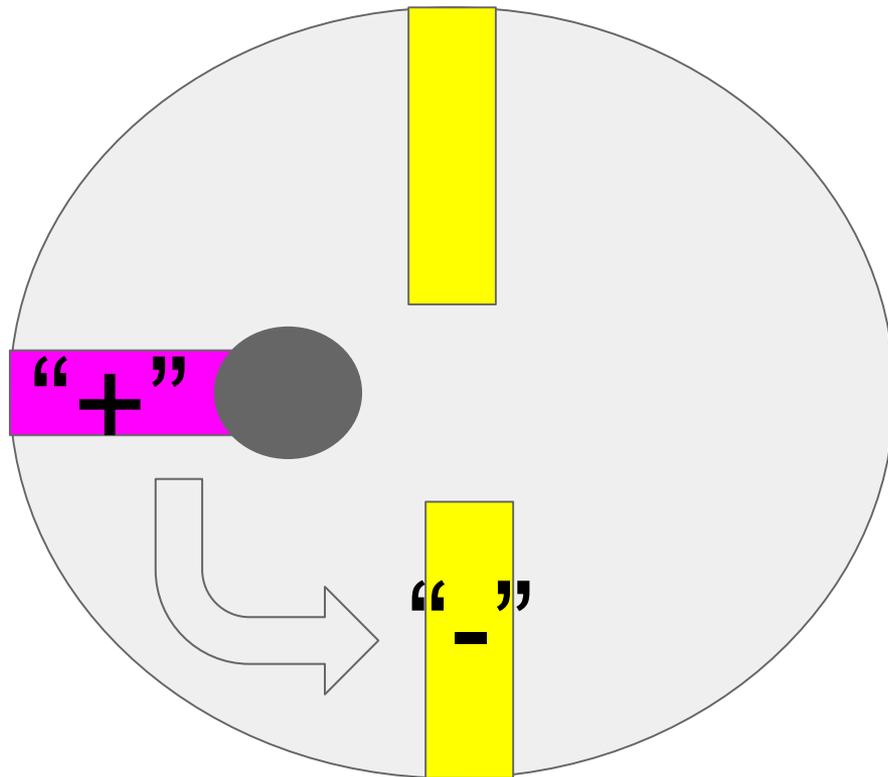
BALL ATTRACTED TO POSITIVE TERMINAL



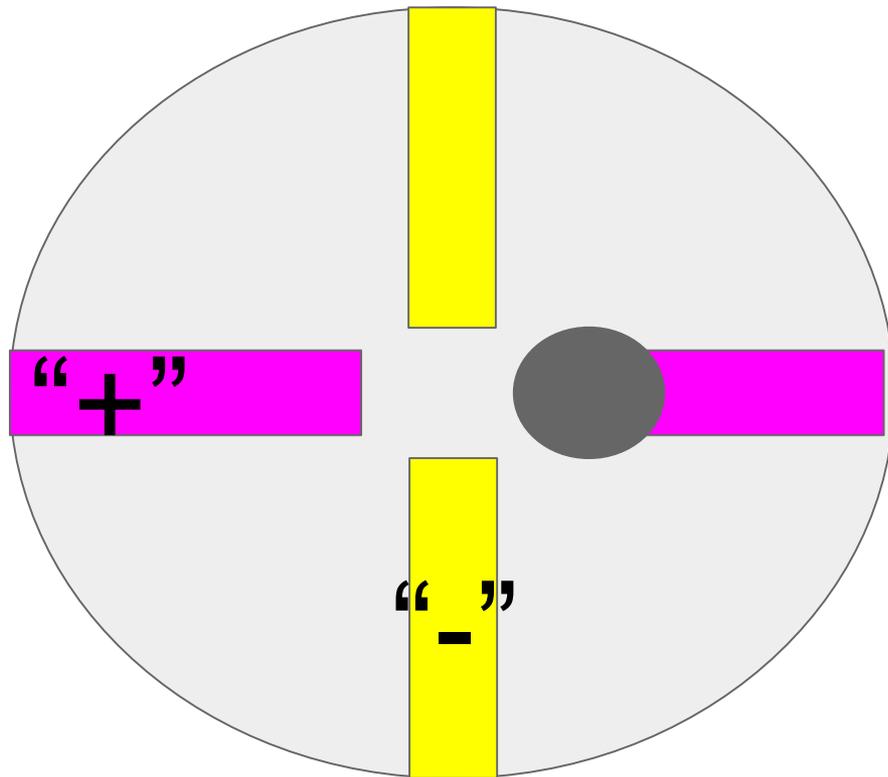
CHARGE ON BALL SWITCHED BY CONTACT



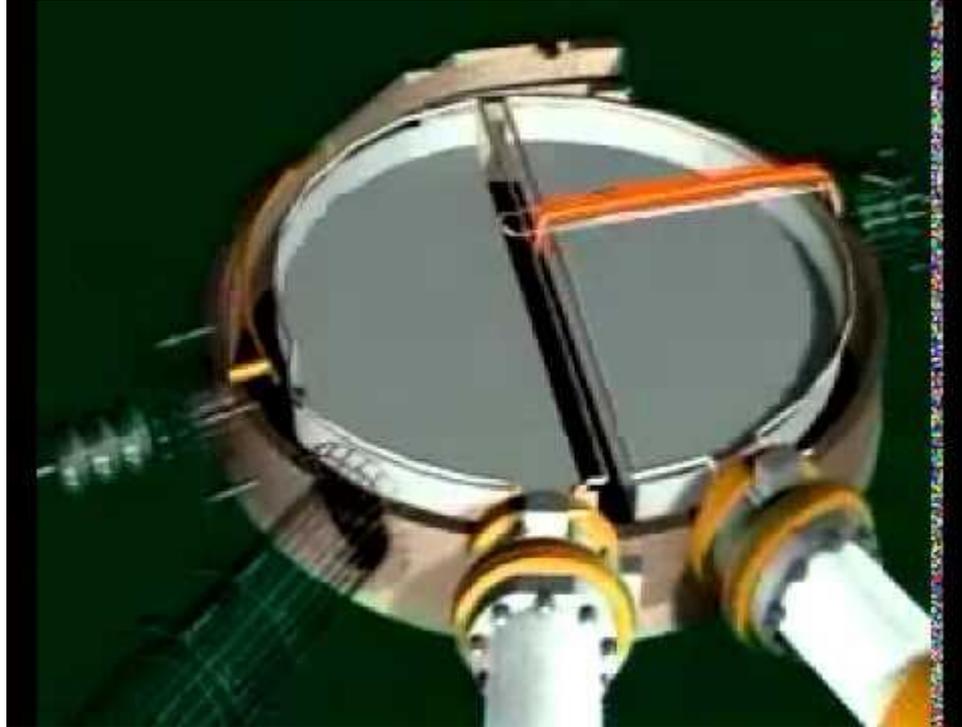
BALL ATTRACTED TO NEXT PAD



BALL ATTRACTED TO NEXT PAD



PRINCIPLES OF A CYCLOTRON



WORKING PRINCIPAL

