Q2:The Physics of a Microwave Oven

Gal Dor, Ofer Eyal, Moshe Goldstein, Eli Raz

Goals

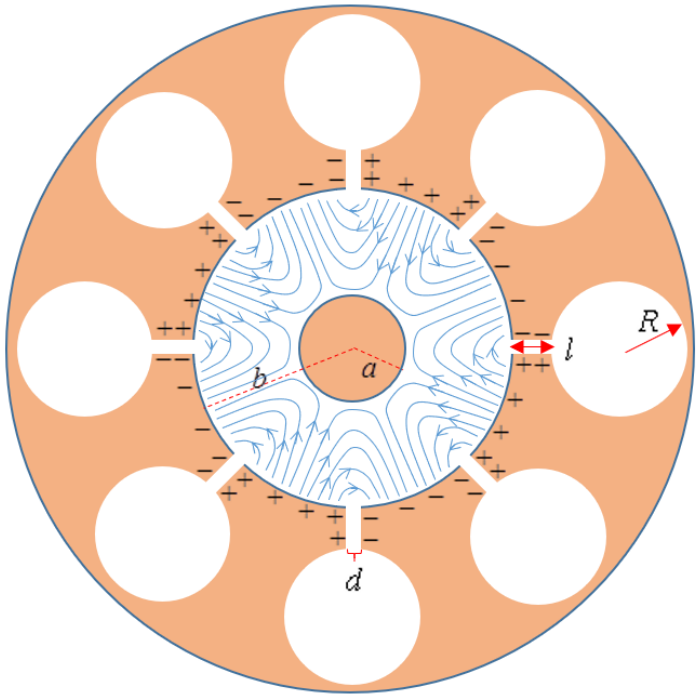
- Part A: Principles of magnetron operation
- Part B: Dielectric absorption of microwave radiation by water

- This talk: very quickly go over key ideas
  - … Apologies in advance for quality of animations.

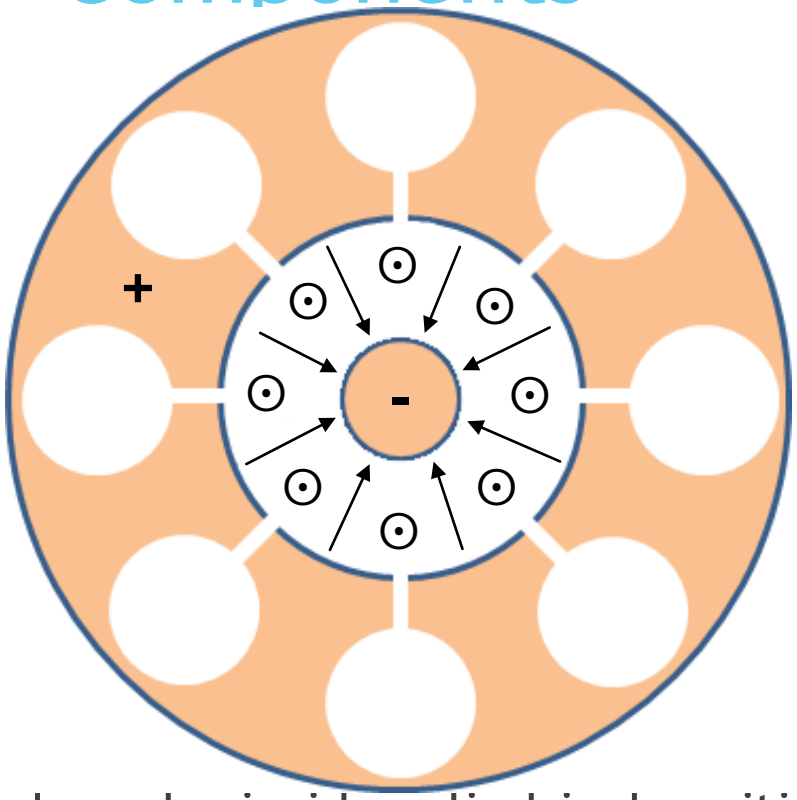
Part A: Magnetron

Magnetron

- Magnetrons are complex, non-linear systems.
- Aim: qualitative understanding of the principles of magnetron operation.
  - Electron drift in electric and magnetic fields
  - Focusing of electrons by oscillating cavities
- Short discussion of magnetron operation.



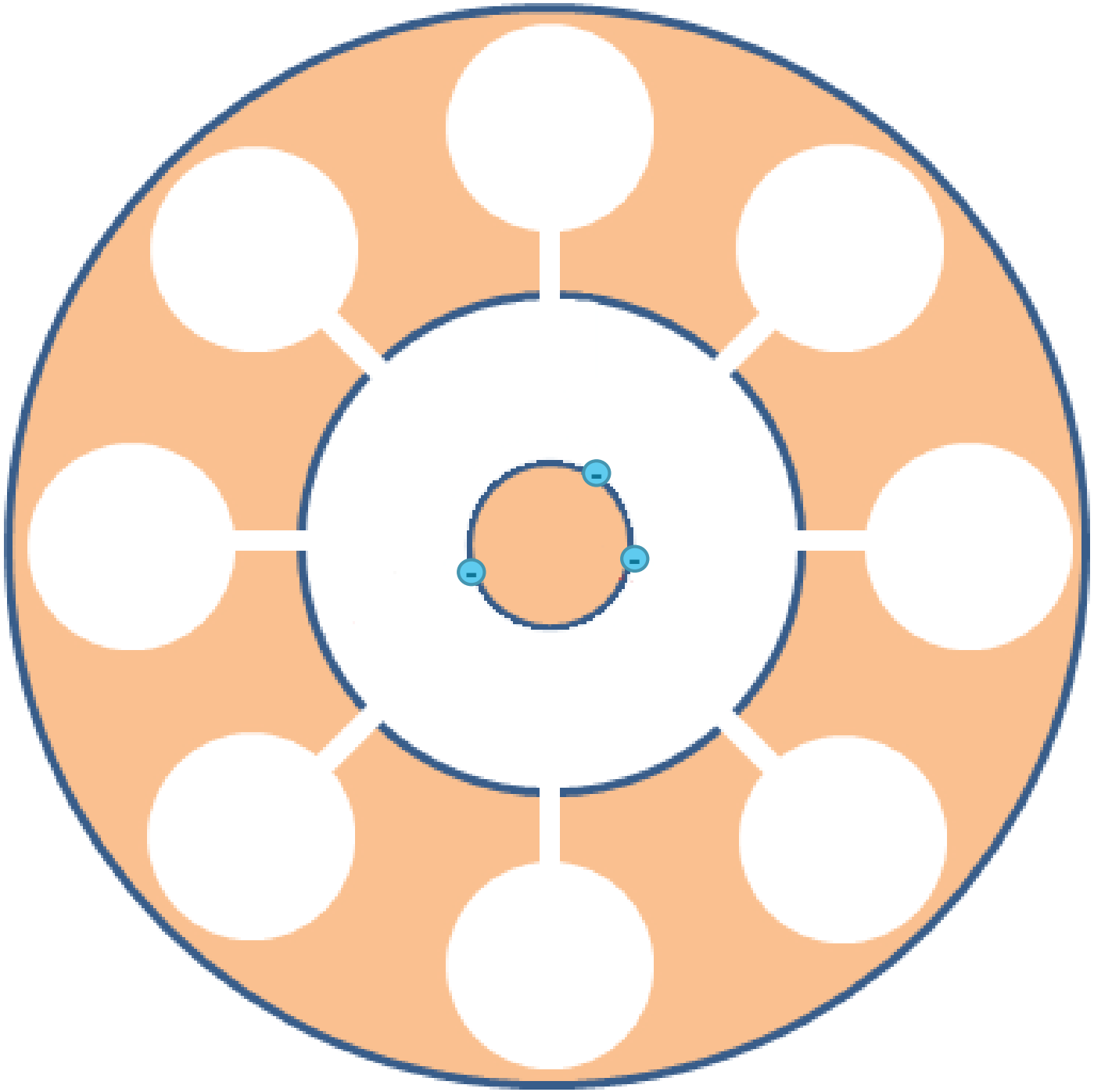
Magnetron - Components



- Negatively charged anode, inside cylindrical positively charged cathode
  - Cavities drilled into cathode
- Strong external magnetic field, along cylinder axis
- Strong electric field between cathode and anode

Magnetron - Operation

- Multiple interacting effects:
  - Electrons boil off anode



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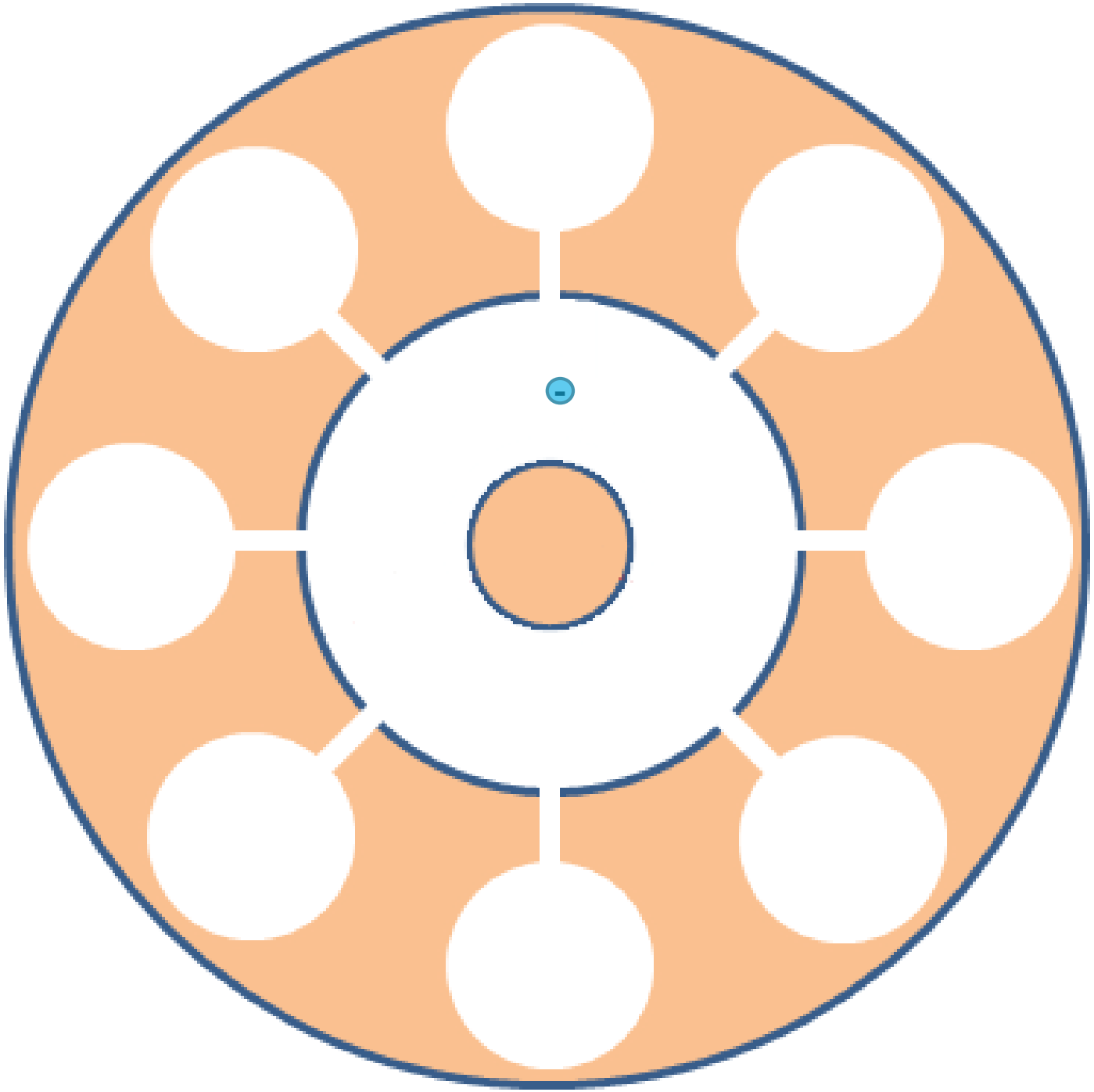
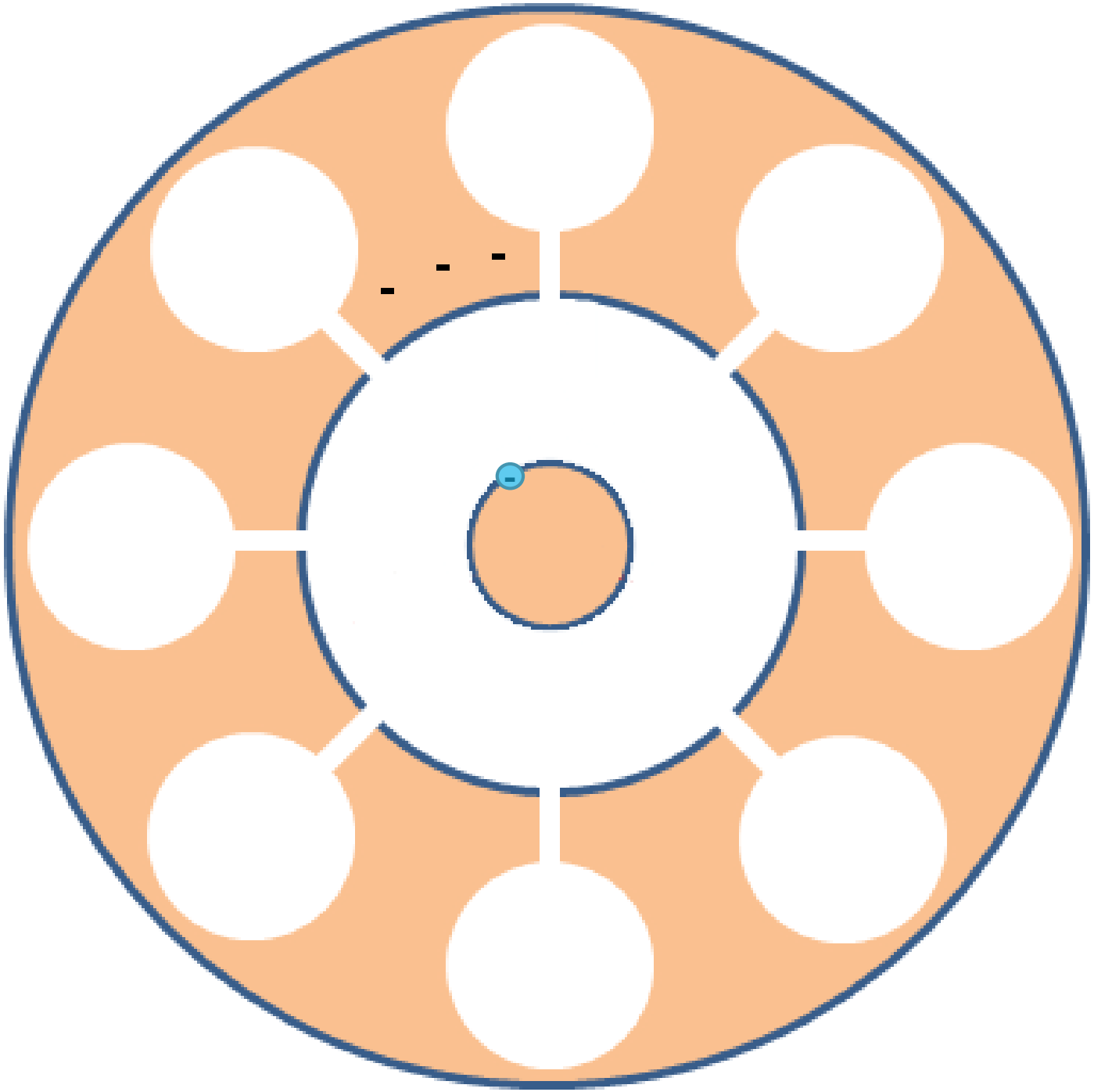
Magnetron - Operation

- Multiple interacting effects:
  - Electrons boil off anode
  - Drift in magnetic and electric fields



Magnetron - Operation

- Multiple interacting effects:
  - Electrons boil off anode
  - Drift in magnetic and electric fields
  - Electrons hit and charge the cavities



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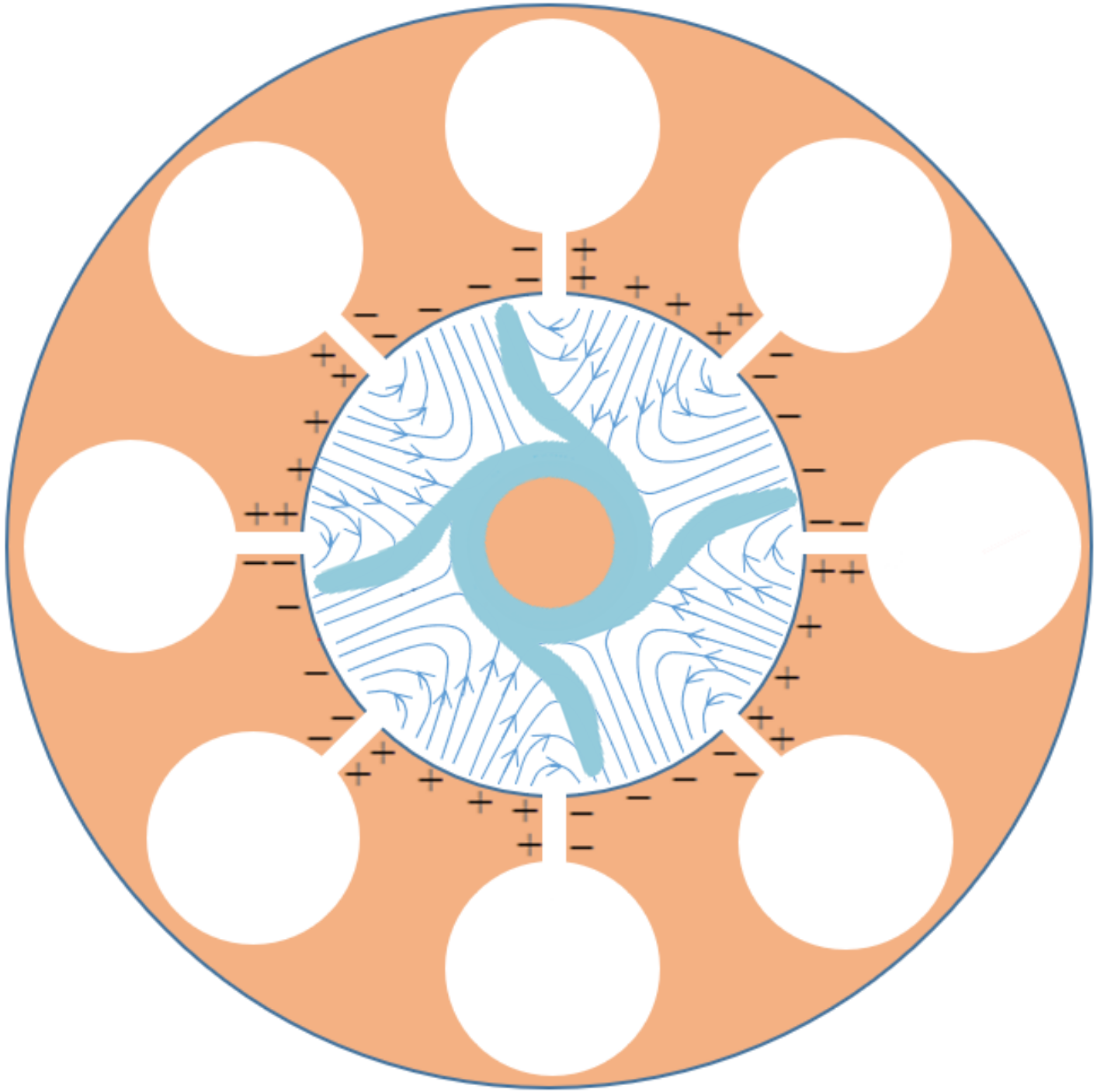
Magnetron - Operation

- Multiple interacting effects:
  - Electrons boil off anode
  - Drift in magnetic and electric fields
  - Electrons hit and charge the cavities
  - Cavities produce electric fields, focusing the electrons
    - Spontaneous symmetry breaking



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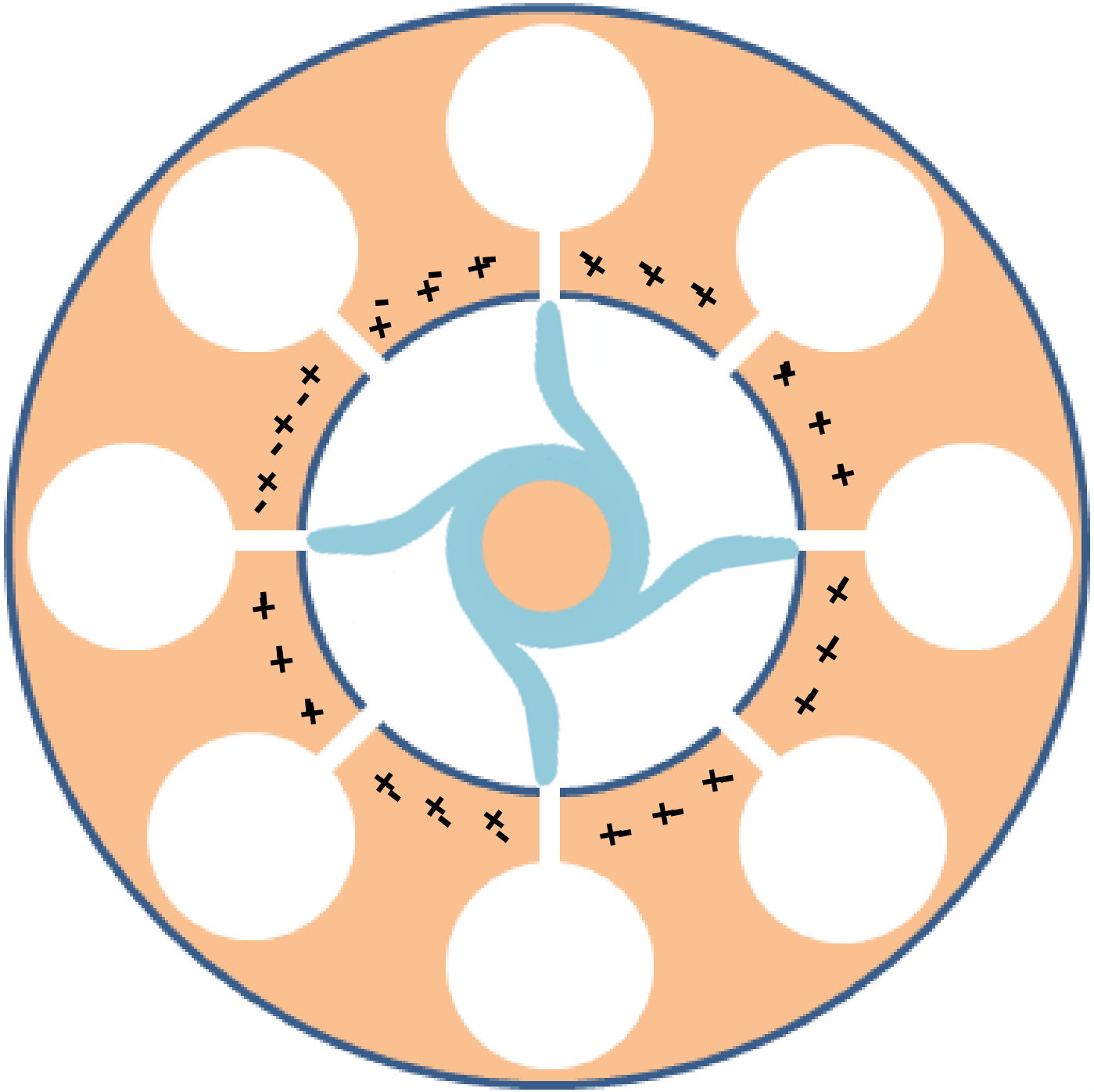
Magnetron - Operation

- Multiple interacting effects:
  - Electrons boil off anode
  - Drift in magnetic and electric fields
  - Electrons hit and charge the cavities
  - Cavities produce electric fields, focusing the electrons
  - Cavities act as resonators, forcing periodic motion
  - External magnetic field rotates the ensemble



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Part B: Absorption of Radiation

Absorption of Microwave Radiation

- Common misconception:
  - Water heats up in microwave ovens due to absorption lines.
- Actually, due to dielectric absorption.
  - Not even the best frequency for absorption by water!
  - Water is partially transparent => more even cooking.

- Aim: Quantitative understanding of dielectric absorption of microwave radiation by water.
  - Dependence of absorption on temperature, salinity

Absorption of Microwave Radiation - Principles

- Water is treated as ensemble of interacting dipoles.
- Traveling EM wave rotates dipoles.
- Interaction between dipoles introduces delay in response.
- Phase difference produces heat.

Questions?