Electron microscopes

- microscopy limited to resolution of $\frac{1}{2}\lambda$ so light → UV → e^-
- advantages - charged ∴ easy to accelerate + focus using EM fields
  - their λ is inversly proportional to their momentum $\lambda \propto \frac{1}{p}$ so the more they are accelerated the smaller the λ

- Electron optics

non-relativistic wavelength: $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mT}}$ where $T = \frac{1}{2}E$

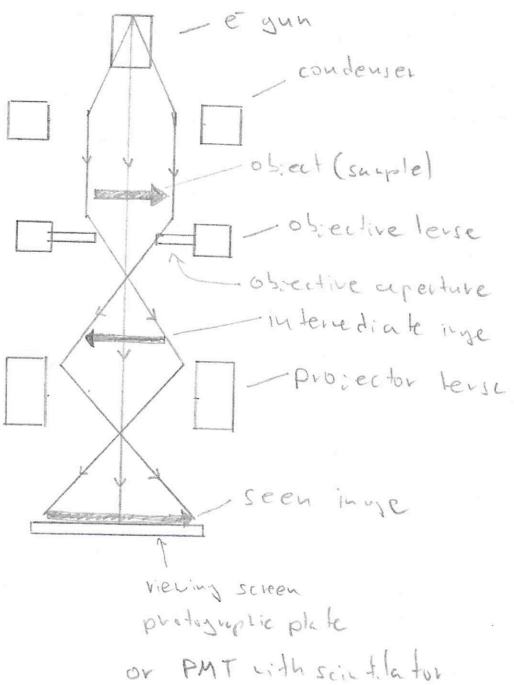
relativistic wavelength: $p \approx \frac{E}{c}$ $\lambda = \frac{hc}{E}$ E = total energy

use relativistic equation if $v > 10\%$ of c so accelerated by about 2500 V so $\lambda \approx 2.5 \times 10^{-11}$ m

- Electrostatic focusing

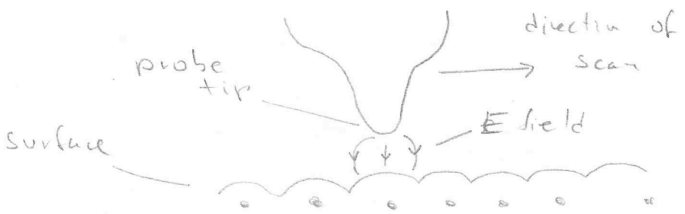
e^- beam focused as they pass through a pair of cylindrical anodes held at different potentials. the paths "refract" towards the field lines

- Magnetic focusing - can be used as well
- although e^- have shorter λ the magnetic lenses can't have a large apperture to eliminate spherical abberation (range of focal points for different λ of e^-). Also so-scanning object with e^- can damage it and it needs to be deposited with conductive material - magnetron sputter

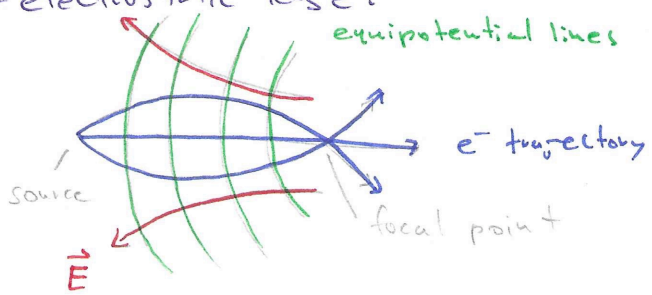


- Types of e^- microscopes
  - Scanning e^- microscope - SEM
    - used for forming 3D images of surface, tightly focused e^- beam scanned the surface. scattered + secondary ejected e^- are captured and produce I. Mag ≈ 100,000
  - Transmission e^- microscope - TEM
    - unlike SEM 1 wide beam of e^- passes (transmitted) through sample and e^- hit screen on the other side producing an image only thin samples can be used but Mag ≈ 1 million
  - Scanning tunneling e^- microscope - STM
    - uses quantum tunneling and can be used to resolve individual atoms on the surface.
    - very fine needle with tip as small as 1 atom is held a fraction of a nanometre above surface and scanned across it. Small voltage is then able to tunnle across the gap. As tip moves closer the I ↑ so 3D image of surface is constructed
  - Atomic force microscope (AFM)
    - similar principle to STM but now repulsive force between surface + tip of probe is monitored. Again a 3D map of surface can be constructed

- AFM and STM can be used to pick up + move individual atoms



- electrostatic lense:



- magnetic lense: