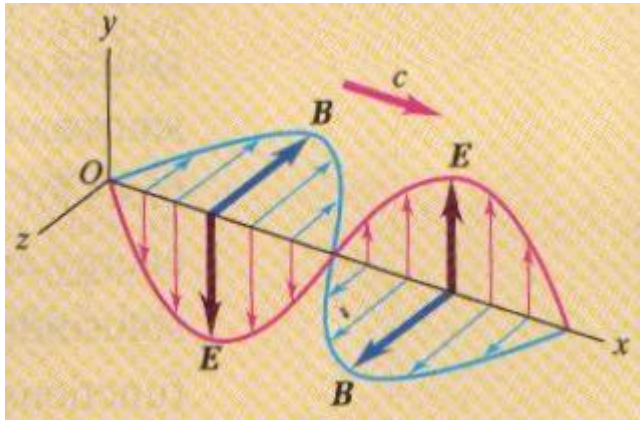
Electrons

- Gas discharge tube gives off Cathode rays.
- They are deflected by electric and magnetic fields --- Electrons
- Work done by a PD. $\frac{1}{2}mv^2 = eV$
- Force in an electric field. $F = eE$
- Force in a magnetic field. $F = Bev$
- Determination of specific charge e/m
- 1897; JJ Thomson found all cathode rays had the same specific charge. All matter must have the same particle – electron.
- Millikans oil drop experiment. Weight = upthrust due to air + viscous drag - $\frac{4}{3}\pi r^3 \rho_0 g = \frac{4}{3}\pi r^3 \rho_a g + 6\pi r \eta v$ also weight = upthrust + Electric force $\frac{4}{3}\pi r^3 \rho_0 g = \frac{4}{3}\pi r^3 \rho_a g + QE$

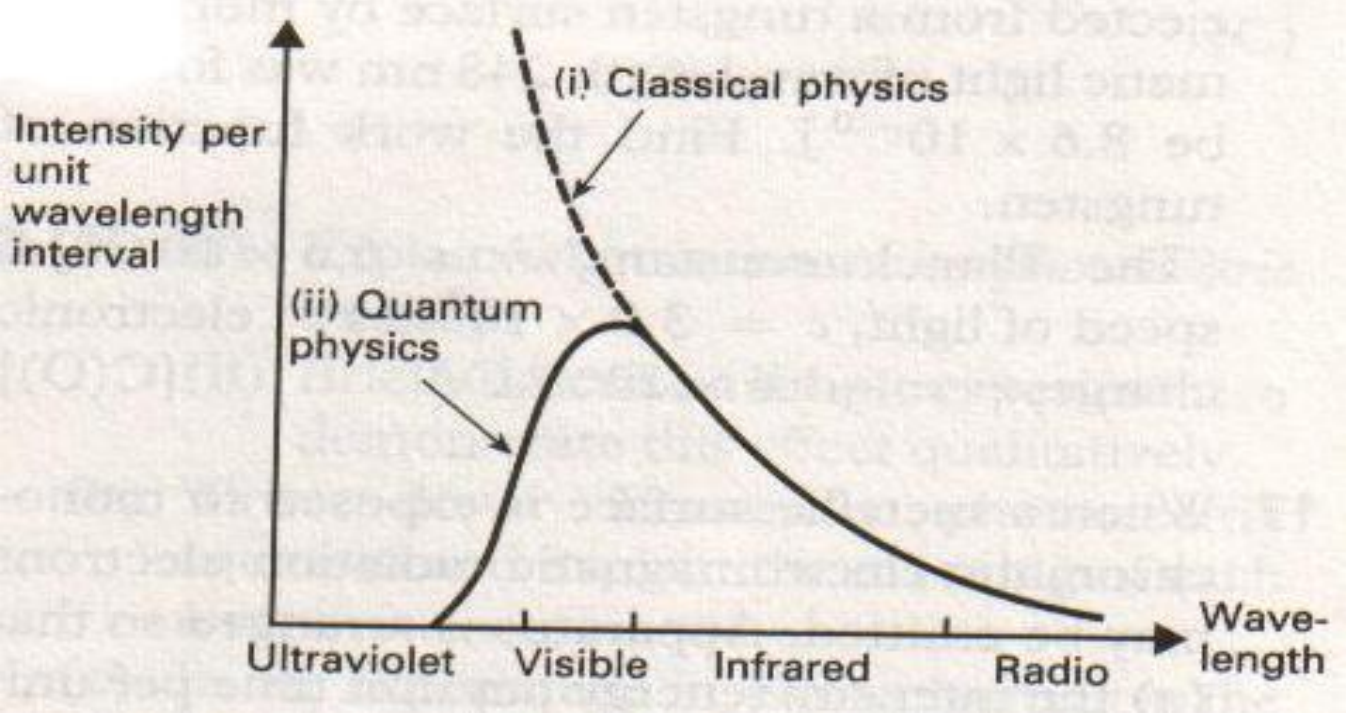
Light – Wave or Particle?

- Newtons Corpuscular theory – explained reflection, refraction and dispersion.
- Could not explain interference due to Youngs slits
- Huygens wave theory of light explained interference.
- Electromagnetic waves – Faraday – Changing magnetic field causes an electric field. Fiels are at right angles and a changing electric field causes a changing magnetic field causes a changing electric field causing ……..
- Hertz discovered radio waves.
- Michelson measured the speed of light. $C = \frac{1}{\sqrt{\mu_o \varepsilon_o}}$



Black box radiation

- A black body absorbs all of the radiation that is incident on it. A black body radiator emits radiation which is a characteristic of its temperature and does not depend on the nature of the surfaces.
- Due to many reflections off the wall and the fact that a good emitter is a good absorber, the radiation is mixed and the temperature is the same on the inner surface.



- Classical theory of harmonic oscillators radiating at all energies failed to predict the experimental result.

- Plank said energy can only be emitted and absorbed at certain energies, $E = hf$, and his theory fitted the experimental results. $E_\lambda = \frac{2\pi hc^2}{\lambda^5}(e^{\frac{hc}{\lambda kT}} - 1)^{-1}$

Photoelectric effect.

- Emission of electrons by photons
- Not explained by wave nature of light.
- Einstein used planks theory and said the photon must give up all of its energy to the electron or be reflected.
- The number of electrons emitted is proportional to the intensity (number of photons) of the radiation. (not the frequency)
- The maximum KE of the emitted electrons increases when the frequency increases.
- $$hf = W + \frac{1}{2}mv^2$$
- The energy of the incident photon = The work function + the maximum KE of the emitted electron.
- The work function is the minimum amount of energy needed to release an electron.
- KE is lost through collisions.

Wave particle duality

De Broglie - If light has a wave-particle duality what about matter
de Broglie wavelength associated with the particle is

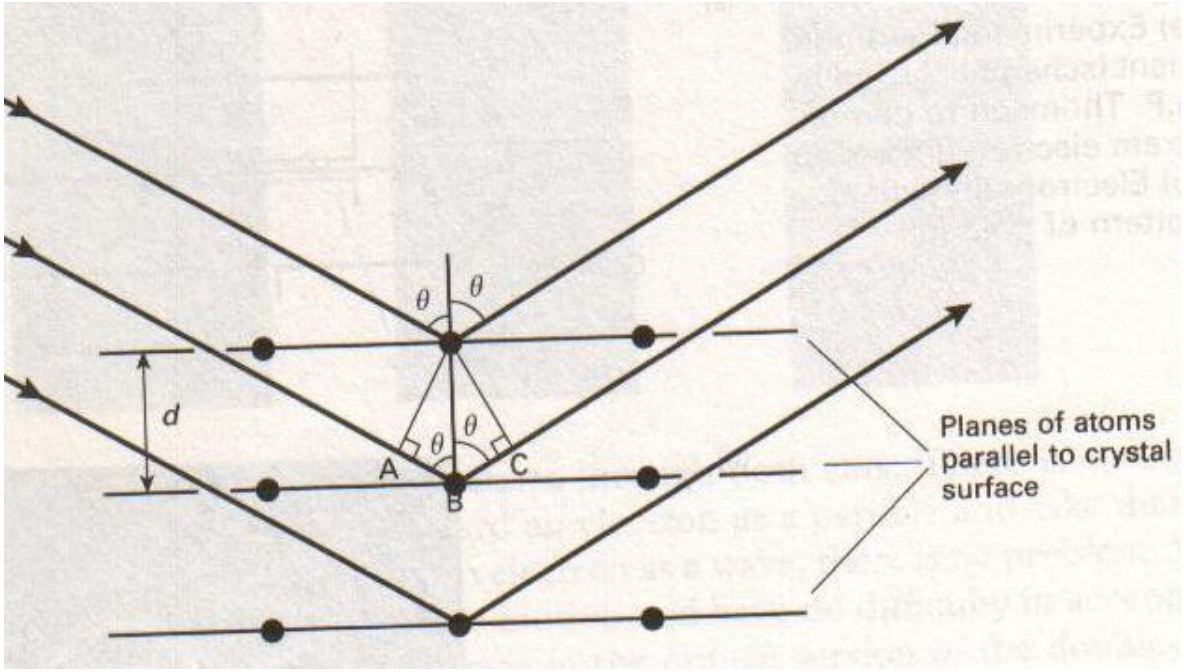
$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

Do not think about these waves being waves of matter. They are probability wave functions.
Schrodinger formulated an equation for the wave function.

$$\frac{\delta^2}{\delta x^2}\varphi(x,t) + \frac{2m(E - V(x))}{h^2}\varphi(x,t) = 0$$

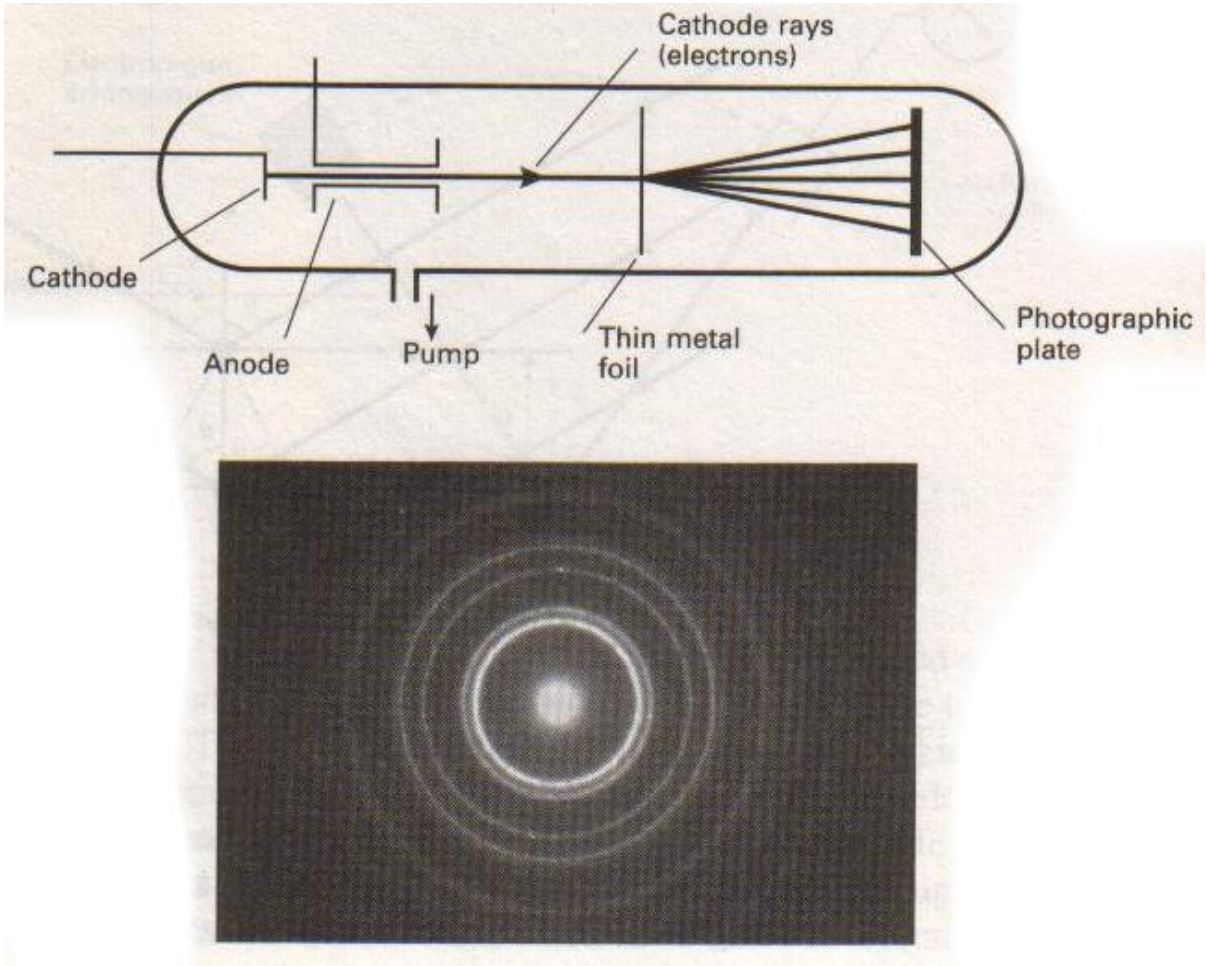
The square of the amplitude of the wave function is equal to the probability of the particle being at that point.

Electron diffraction shows wave behaviour



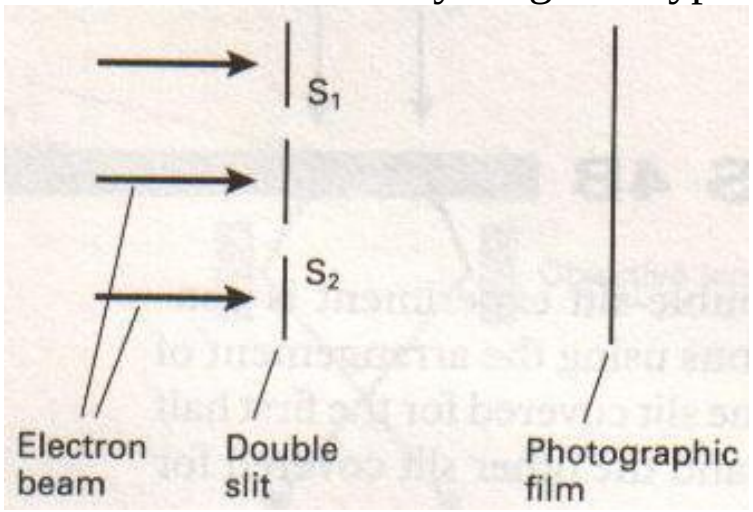
the crystal lattice acts like a diffraction grating to the electron ‘waves’.

In 1928 G.P. Thomson (1928)



Double slit-type experiment.

If we could conduct a young slits type experiment with electrons

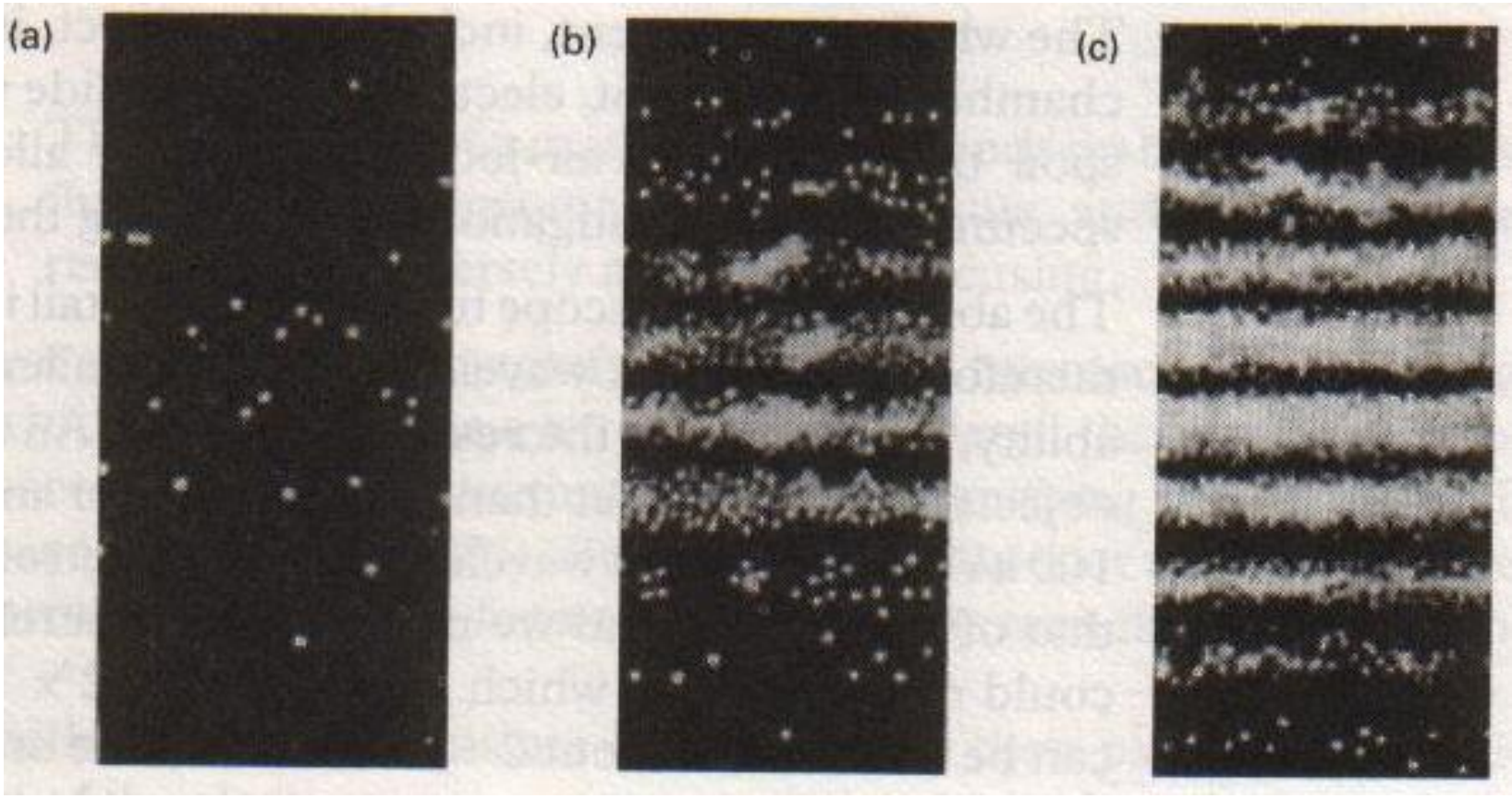


We would find that we get a diffraction pattern even if we let one electron go through the slit at a time.

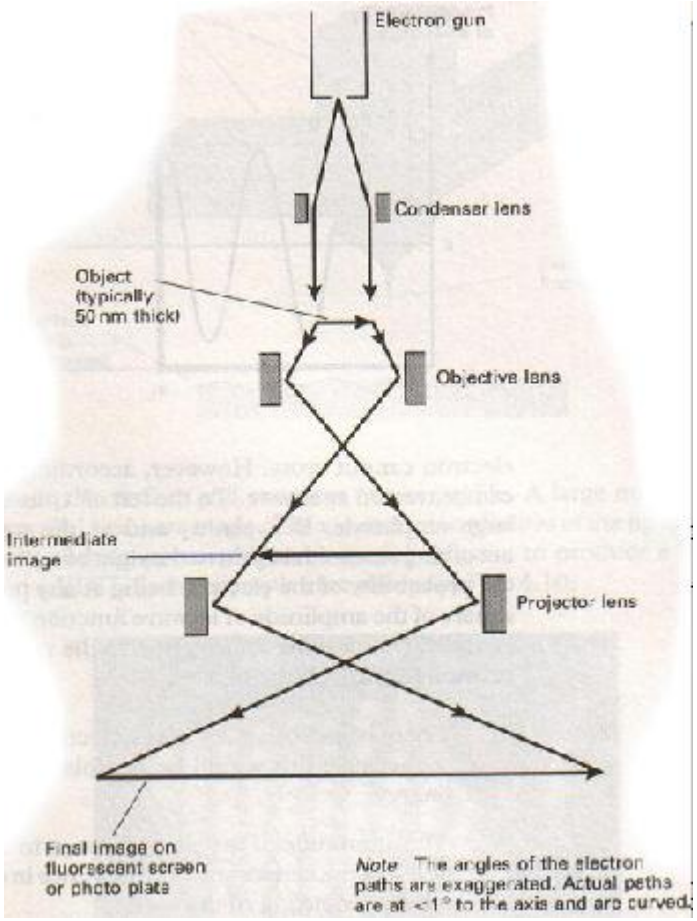
This means that each electron must go through both slits and interfere with itself.

This can only happen if we regard the electron as a ‘wave’.

(since the electrons are randomly emitted they must interfere with themselves in order to be coherent).

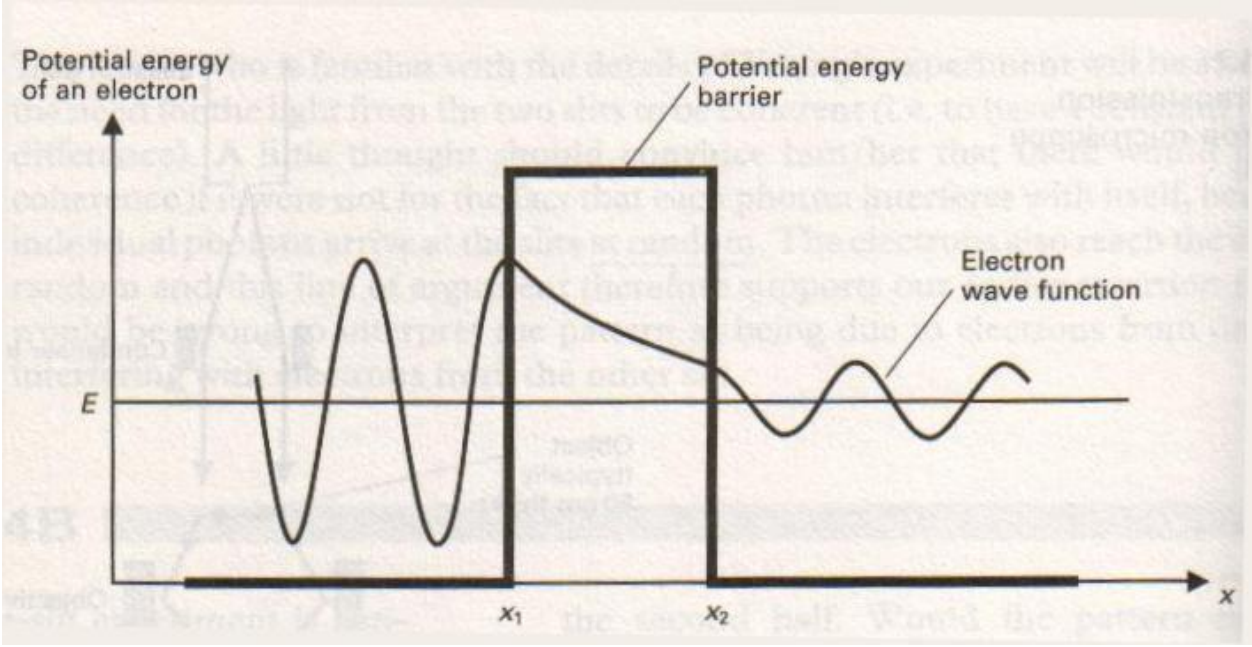

(a)
(b)
(c)

Transmission electron microscope - Path as particle - resolution as wave

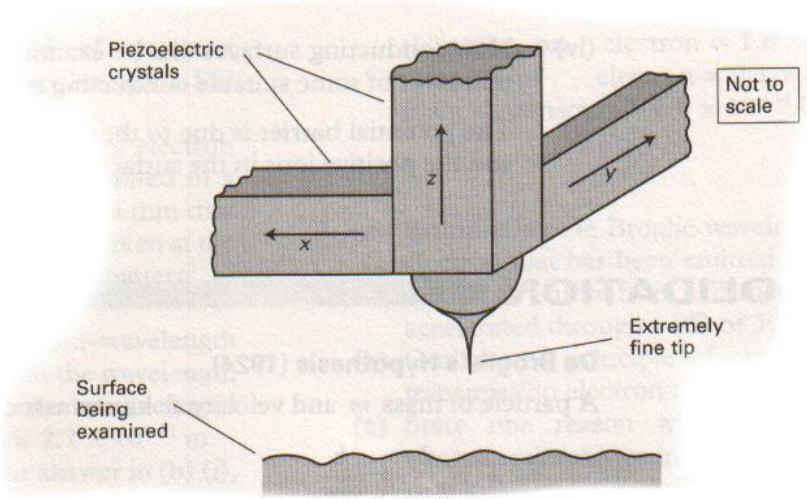


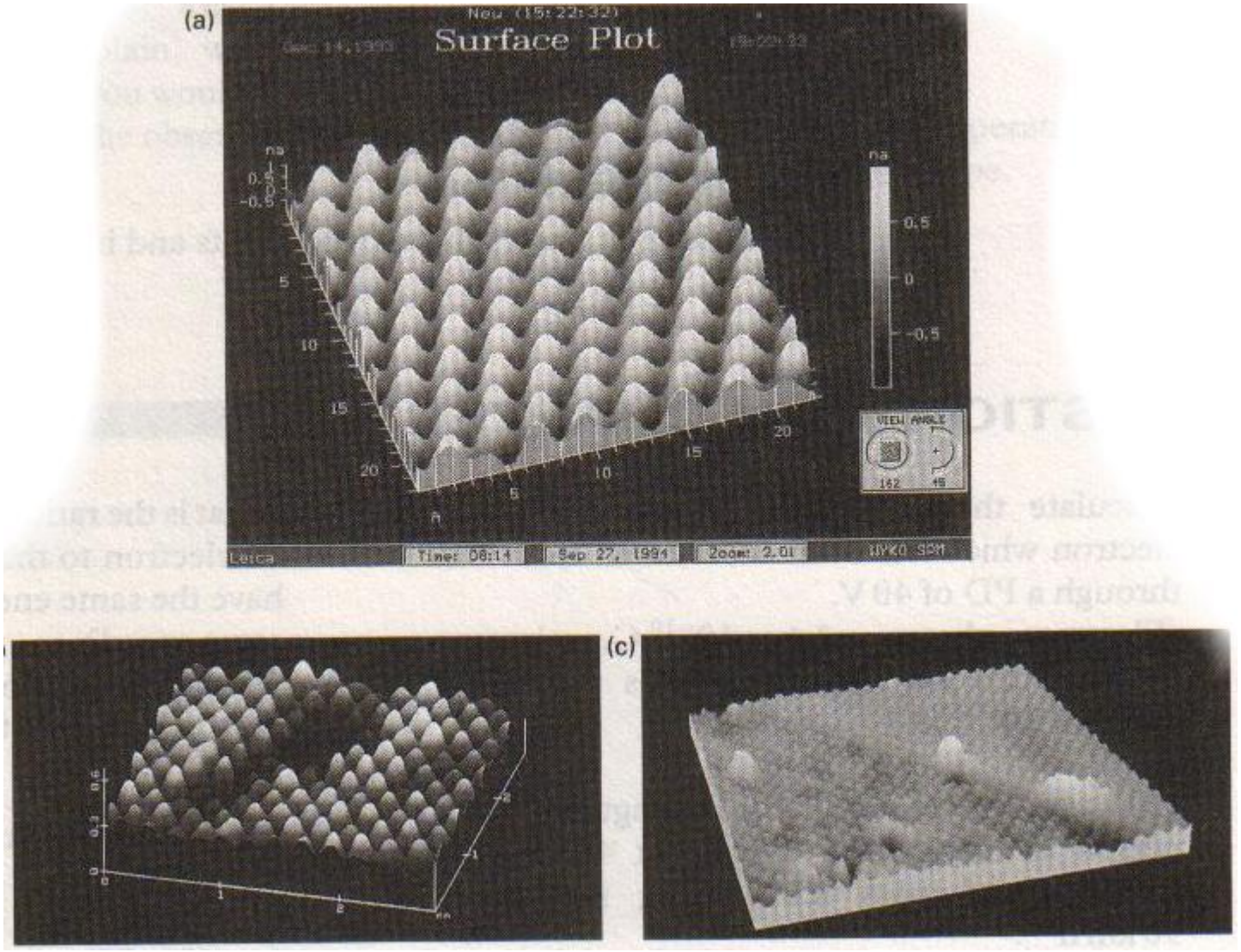
Tunnelling

If the electron can be treated as a wave then it has a small, but finite, probability of passing through a barrier which has a greater PE than the electron.



- Scanning tunnelling microscope uses this principle.
- A conducting probe with a sharp tip (often one atom thick) is positioned 0.1-1nm above the surface of a conducing sample.
- When a suitable pd is applied, 1V, between the tip and the surface some electrons will tunnel through the PE barrier.
- These will cause a small current to flow which is an exponential function of the width of the barrier.
- If the sample is scanned keeping this current constant the tip will follow the surface contour. The lateral resolution can be 0.2nm, good enough to resolve individual atoms.




(a)
Surface Plot
nm
0.5
0
-0.5
5
10
15
20
nm
VIEW ANGLE
162
45
Leica
Time: 08:14
Sep 27, 1994
Zoom: 2.0x
(c)

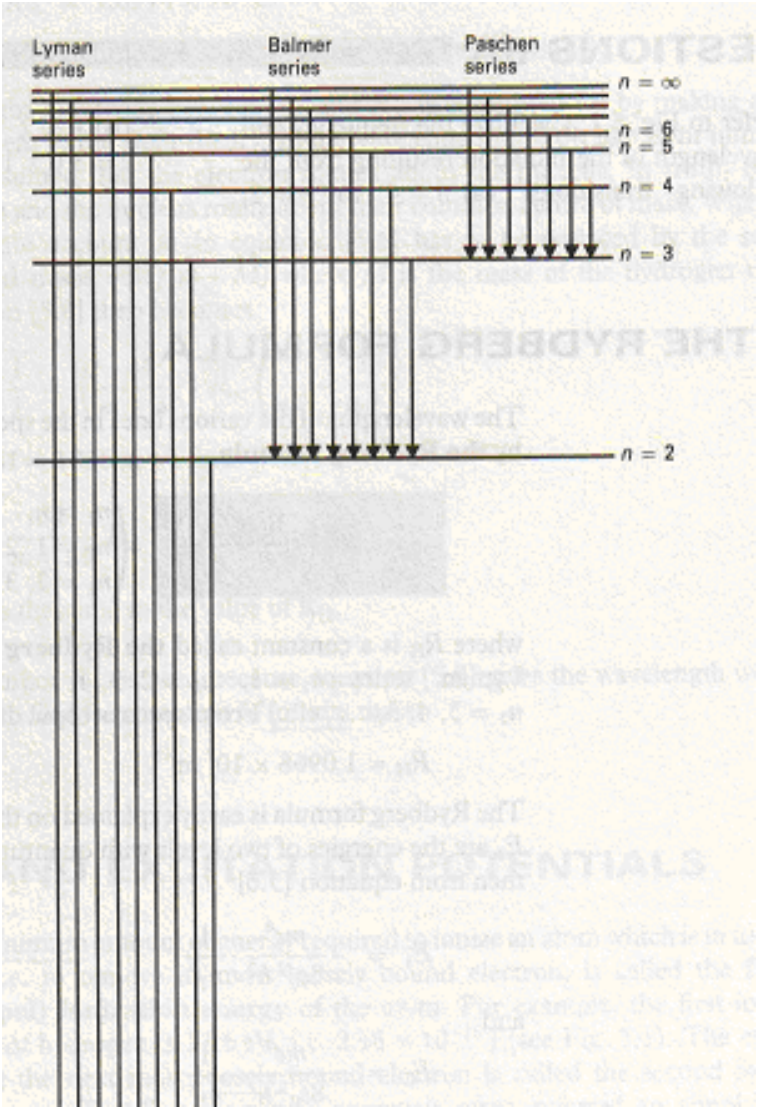
Atomic energy levels

- Rutherford model. Accelerating Electrons orbit and radiate energy continuously. Hence orbit collapses
- Bohr model --Quantised angular momentum
- Now wave Mechanics electron clouds
- Energy Levels

$$E = -\frac{me^4}{8\varepsilon_0^2 h^2}.\frac{1}{n^2}, (n = 1,2,3...)$$

- Only quantised amounts of energy are absorbed or emmited. $E_2 - E_1 = hf$

This leads to Line spectra. Eg in the hydrogen atom


Lyman series
Balmer series
Paschen series
n = ∞
n = 6
n = 5
n = 4
n = 3
n = 2

Lasers; Stimulated emission

Population inversion (eg by Radio frequency in the He-Ne Laser) causes a greater probability of stimulated emission.