

Physics 100 - February 16, 2009

①

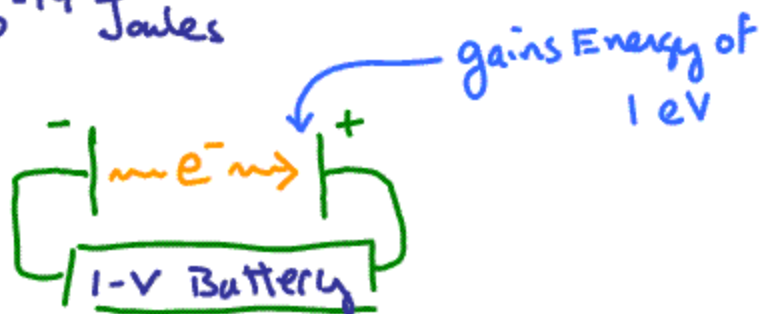
You should be able to find the accompanying audio file (mp3 format) on the class website

Last Time

Joule $\equiv$ mks metric unit of energy
meter-kilogram-second
good for "normal" things

eV $\equiv$ electron-volt Energy of electron accelerated by a 1-volt battery
good for atomic and subatomic things

$$1 \text{ eV} = 1.6 \times 10^{-19} \text{ Joules}$$



(2)

units of
energy commonly
used in physics of
atoms and particles

eV	
keV	Thousand of eV
MeV	Millions of eV
GeV	Billion of eV
TeV	Thousands of Billion eV

Energy + Mass
related by

$$E = mc^2$$

eV

$$\text{Mass of particle} \sim \frac{eV}{c^2}$$

$$0.511 \text{ MeV}/c^2 = \text{electron mass}$$

Common to ignore the c^2 and refer to
masses in terms of eV or MeV

Last Time

Do ripple
TANK
Applet

Maxwell's equations
interference
diffraction
Refraction
dispersion
⋮

light is
a wave!

3



Planck

Blackbody
Radiation

light comes in
little packets
with
energy
 $E = h\nu$



Einstein

Photoelectric
effect

1905

light is a
particle!

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AS STRANGE AS IT SEEMS ...

light has both wave and
particle properties



wave

$$v = \lambda \nu$$

particle

$$E = h \nu$$

The "packet" w/ energy
called the "photon"

↑ Gilbert Lewis, 1926

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mid-1920's

de Broglie hypothesized matter can have wave characteristics with a wavelength given by

So-called
de Broglie Wavelength

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

(4)

From special relativity

$$E = \sqrt{p^2 c^2 + m^2 c^4}$$

(A)

Form of "E=mc²" when particle moving

For photon, m=0

(B)

$$E = pc \text{ or } p = \frac{E}{c}$$

(C)

From Blackbody + PhotoElectric

$$E = h\nu$$

(D)

$$\nu = \frac{c}{\lambda}$$

(E)

$$E = \frac{hc}{\lambda}$$

(F)

$$\frac{h}{\lambda} = \frac{E}{c}$$

$$\lambda = \frac{h}{p} \text{ for photon}$$

(G)

de Broglie: Perhaps
Also true for
Particle with Mass

⑥

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

baseball at 92 mph
/
mass 142 g ↑ 41 m/s

$$p \text{ of baseball} = mv$$

$$p = 5.7 \text{ kg m/s}$$

$$\lambda_{\substack{92 \text{ mph} \\ \text{baseball}}} = \frac{\overset{h}{\downarrow} 6.6 \times 10^{-34} \text{ J}\cdot\text{s}}{5.7 \text{ kg m/s}}$$

$$\lambda = 1. \times 10^{-34} \text{ m}$$

incredibly small wavelength — not
noticeable to us.

(7)

1 eV electron

energy of $\underline{1.6 \times 10^{-19} \text{ J}}$

(A)

$$= \frac{1}{2} m v^2 \rightarrow v = 596 \text{ m/s}$$

$$p = (9 \times 10^{-31} \text{ kg}) (596) = 5 \times 10^{-28} \text{ kg m/s}$$

$$\lambda_{e^-} = \frac{6.6 \times 10^{-34}}{5 \times 10^{-28}} = 1.3 \times 10^{-6} \text{ m}$$

$$\sim 1 \mu\text{m}$$

Electron Microscope
 can use electron waves
 to image very small objects
 because electron wavelength
 is smaller than wavelength
 of visible light

$\lambda = \frac{h}{p}$
 higher Energy
 of $p \rightarrow$ smaller λ
 of electron

Not so incredibly small
 careful experiments can see
 wave effects like diffraction
 and interference
 of electrons

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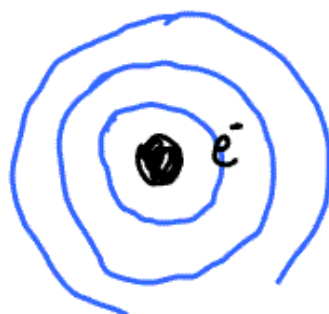
Niels Bohr

(1885 - 1962) (Denmark)

1922 Nobel Prize in Physics

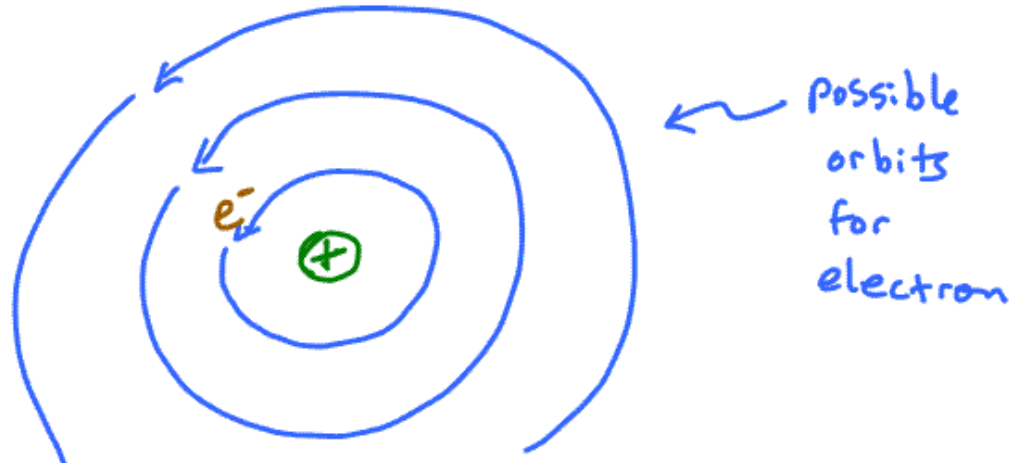
Atomic (planetary) model with fixed orbits

nicely motivated by de Broglie's matter waves in 1924

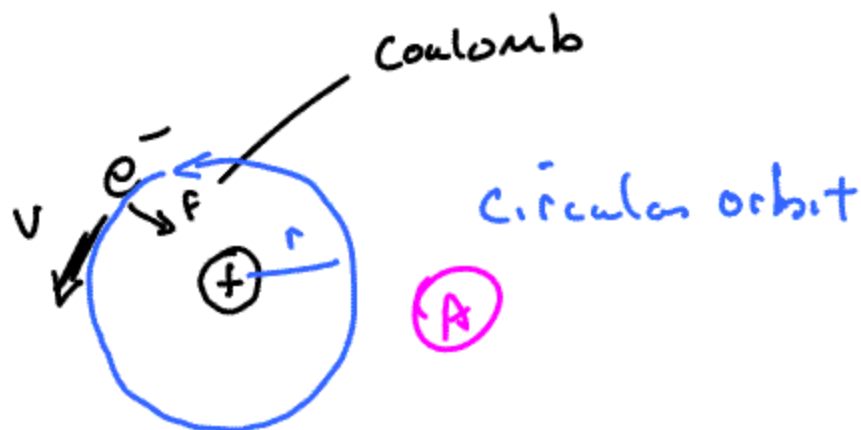


Bohr model of the atom

- Positive Nucleus
- electrons orbit in circles
- only particular "discrete" orbits allowed
 - ↑ known as quantization
- electric (Coulomb) force holds electron on circle as it orbits ... attracts electron toward Nucleus

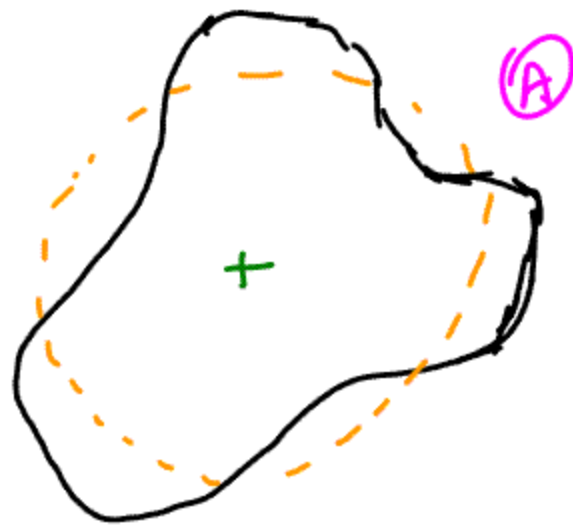


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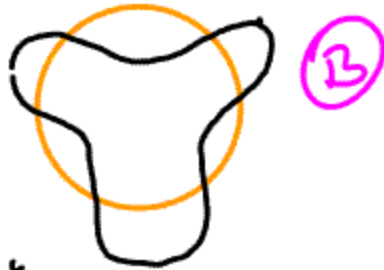
Recall "STANDING Waves" on a string demo. Waves travel down string and reflect. Waves travel down string and interfere w/ reflected waves travelling back

only get "resonance" or stable system when wave and reflected wave interfere constructively



Imagine attaching
one end of
string to the other
in a circle

STABLE WAVE



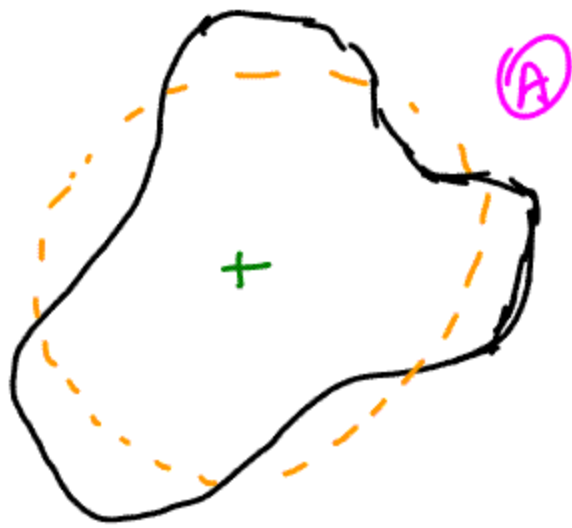
UNSTABLE WAVE



If electron is a wave in Bohr
Model circular orbit, Electron
can only exist in orbits where
the electron wave interferes
constructively with itself as
you go around the circle.

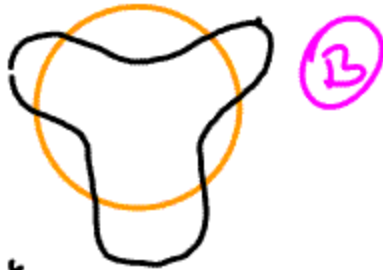
⇒ only particular circumferences
and circle sizes (radii)
will work

Leads to quantization



Imagine attaching one end of string to the other in a circle

STABLE WAVE



UNSTABLE WAVE



If electron is a wave in Bohr Model circular orbit, Electron can only exist in orbits where the electron wave interferes constructively with itself as you go around the circle.

⇒ only particular circumferences and circle sizes (radii) will work

Leads to quantization

$$F_{\text{center}} = \frac{m v^2}{R}$$

Condition for
Circular Motion



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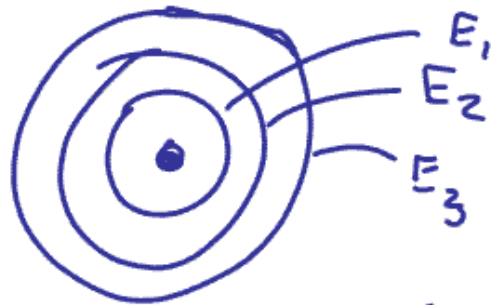
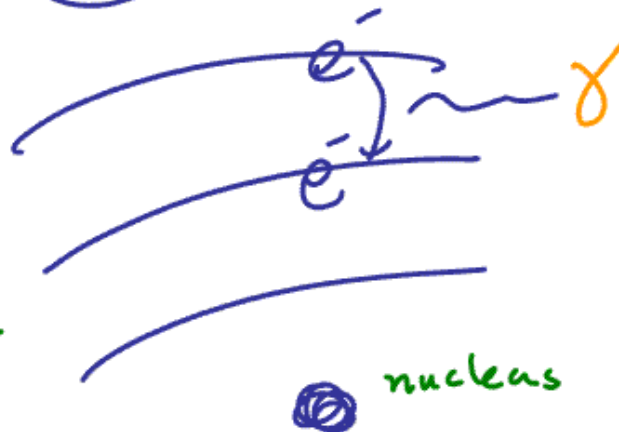
quantized orbits lead to
quantized electron
energies

light absorbed and
emitted as electron
jumps from one orbit w/
fixed energy

to
another.

→ leads to
discrete
Atomic
spectra

given $R \rightarrow$ fixed energy



$$E = E_3 - E_2$$

