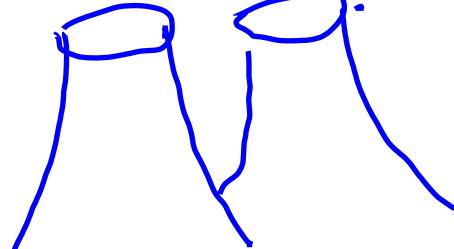


What do you think of when
you talk about nuclear
technology?

3 clouds radioactive?



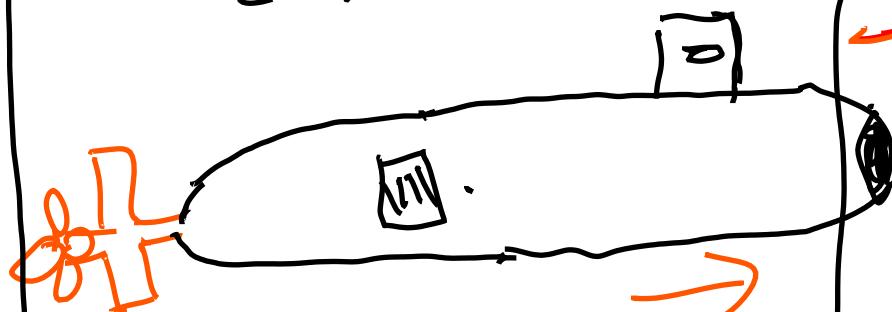
Picture 1



Picture 2

- Gen Y
- Red Alert 2
 - Yuri's Range
 - C & C
 - ↳ Generals
 - ↳ Tiberium Wars

Cold War



Picture 3

- Starcraft II
- Dune Part II
 - ↳ Atomics

))))

Sonar

What's in the cold war?

- Nuclear tests

↳ USA

↳ Castle Bravo

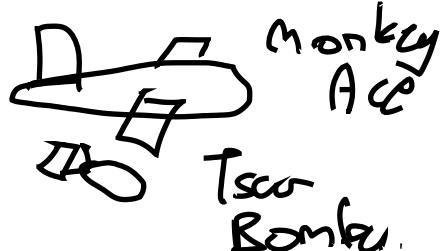
↳ Ivy Mike

↳ ~~Operation~~ Baker (Bikini Atoll)

↳ Russia

↳ Tsar Bomba.

Bloons TDB.



↳ China

↳ India

↳ France

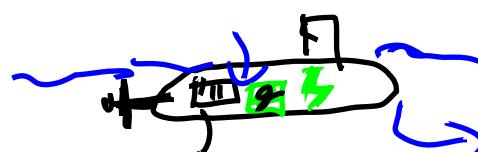
↳ UK.

Submarines

↳ reactors

↳ mobile missile sites (SLBMs)

U-boats.



Petrol/Diesel

above
water
speed >

Underwater
speed.

Nuclear Submarine mias.

U-571

↳ Hunt for the Red October

↳ Crimson Tide

Pop culture

- Nuclear is dangerous

- Nuclear → scary

- Nuclear is exotic

Nuclear accidents.

↳ Three Mile Island

↳ Chernobyl

↳ Fukushima Daiichi?

↳ check spelling

Nuclear safety.

For next lecture

① Accidents + pop culture

↳ BBC's Chernobyl.

② Nuclear security & cold war
arms race

③ Outline of technical stuff.

Cold War

1945

2x atomic bombs
plane

1945 - 1949 " US → major nuclear power

1949

USSR → explodes 1st atomic bomb.



Counter-value
drop bombs on
cities

Counter-force

drop bombs to
kill opponents nuclear
capability



Red Alert
Red Alert 2



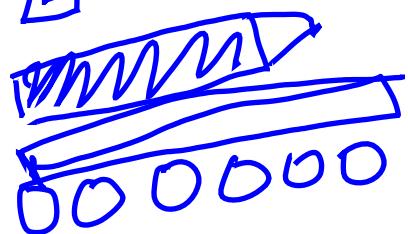
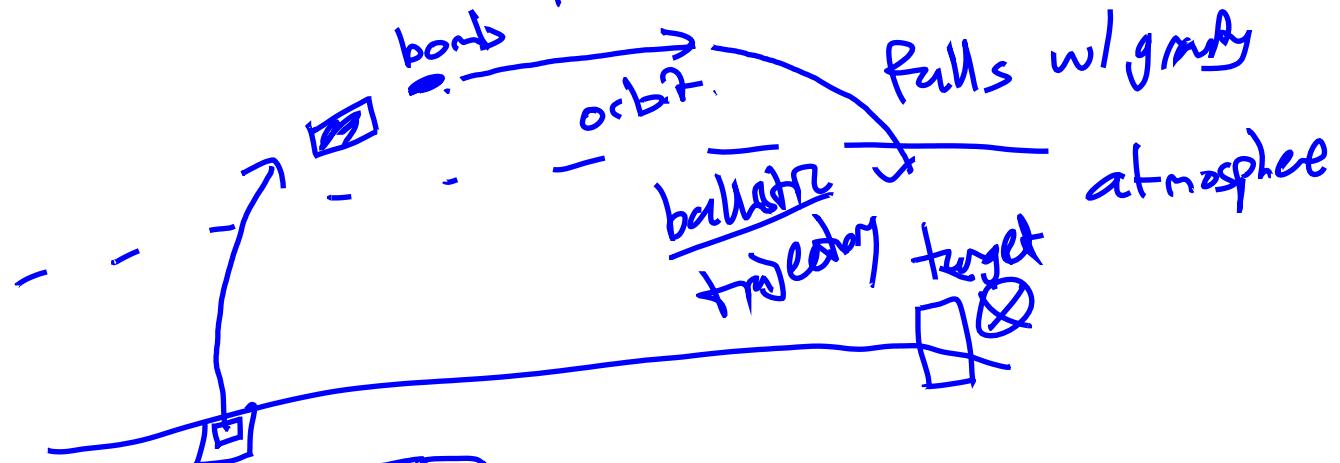
ICBMs



Intercontinental

Ballistic
missile

(ICBMs)



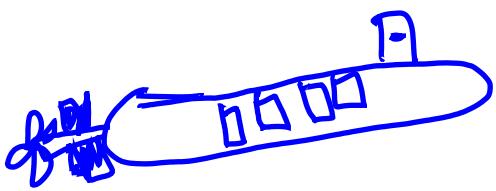
- SR 71 blackbird
- U2

mobile ICBM

nuclear
deterrence

mutually
assured
destruction

MAP



Submarine launched
ballistic missiles
(SLBMs)

accuracy \rightarrow a

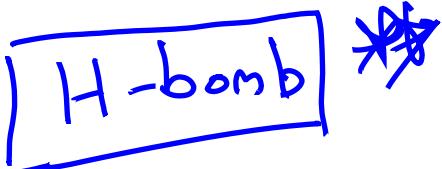
~~big~~ problem

for SLBMs.

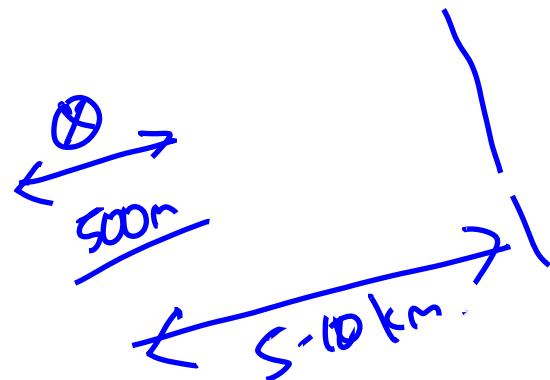
① stay underwater very long



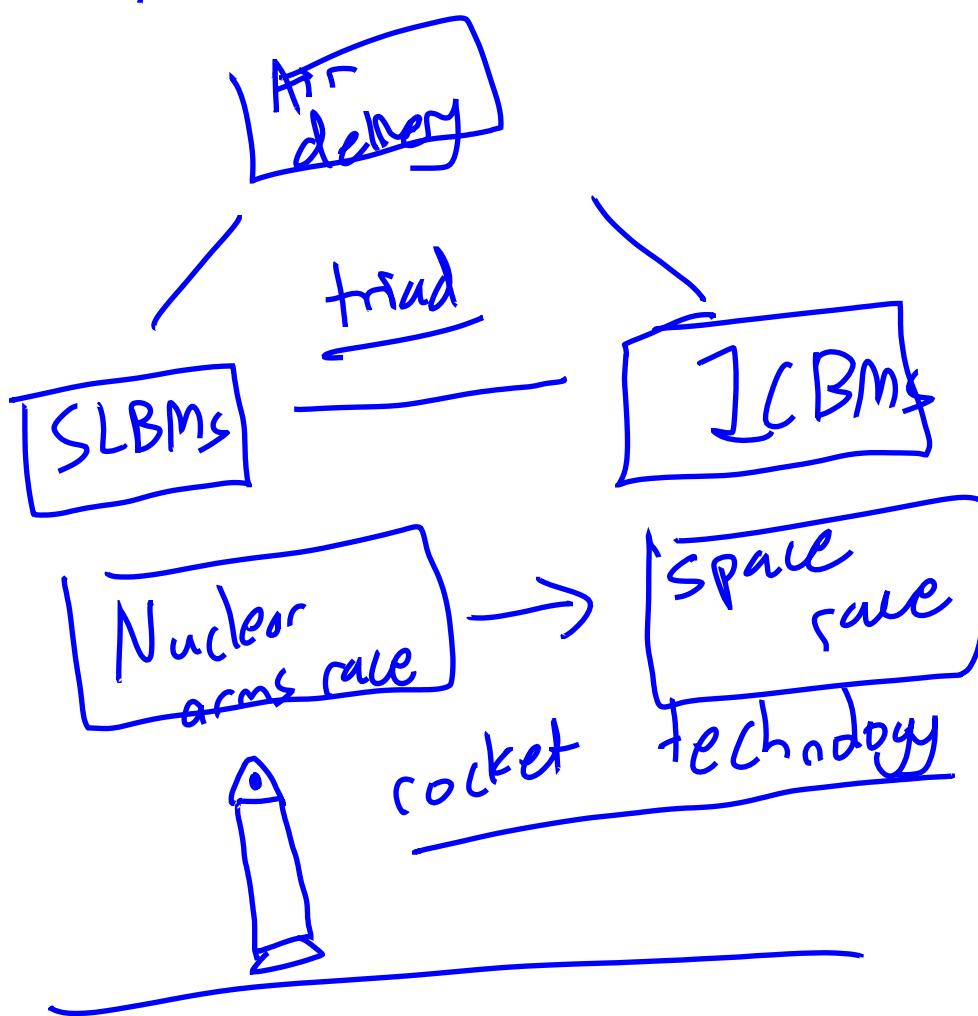
② Big big explosions,
much bigger than Hiroshima.



↑
tech.



nuclear triad.



- GPS
- Lunar explorations
- Communications networks → SpaceX
- Telescopes → Hubble space telescope
- Advanced science & technology

Lecture 3

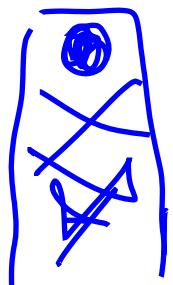
Manhattan project.

1942

* Oppenheimer
cooked

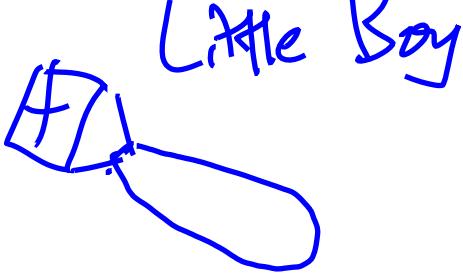
Nazi Germany

trinity



Pu-239

New Mexico



Little Boy

Hiroshima
Bomb

U-235



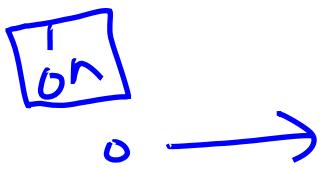
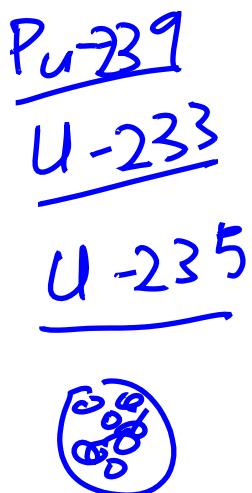
Fat man

Nagasaki

Pu-239

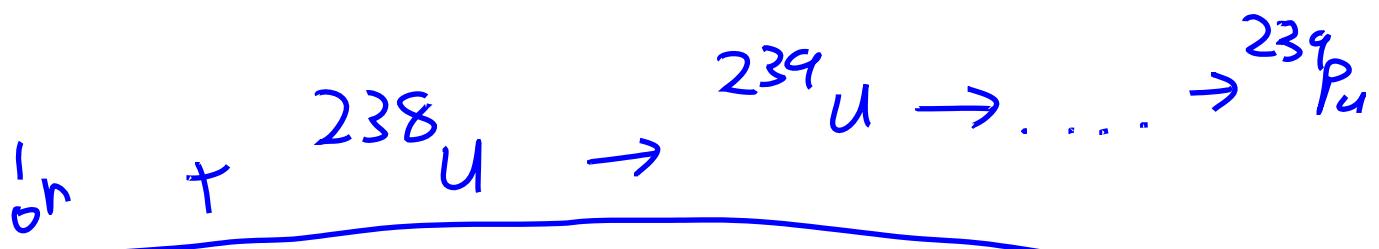
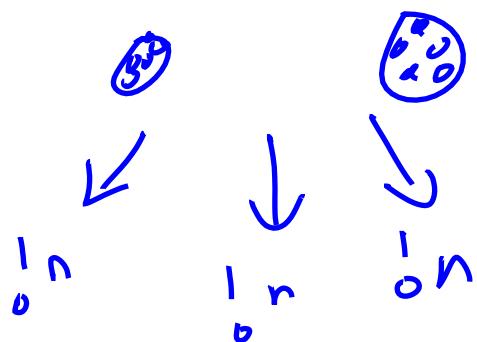
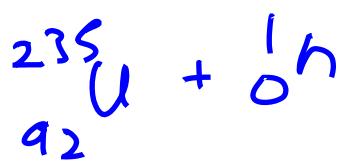
Concepts w/ as little mathematics as possible

Physics



↓ fission

A (total no. of neutrons + protons)
 $\frac{235}{92} U$
Z (proton number)



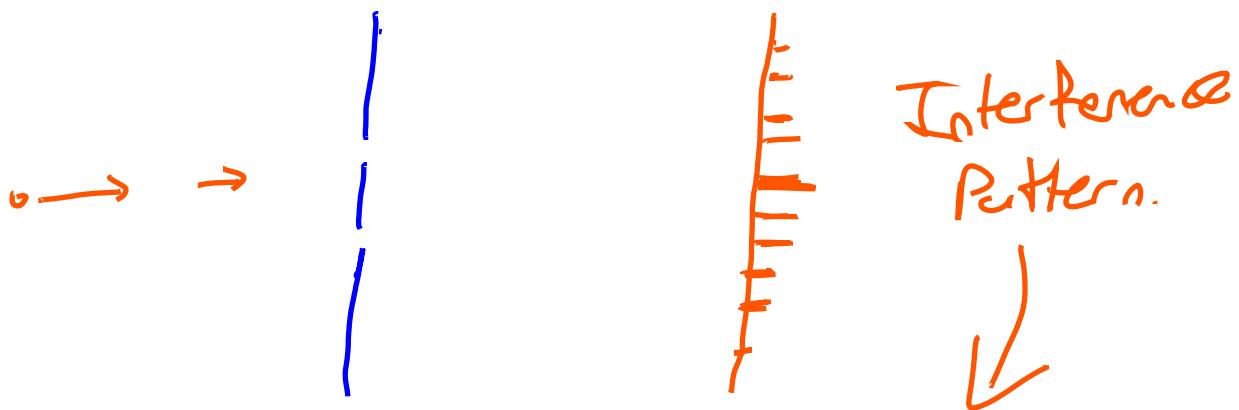
Quantum Physics

key Idea of Quantum Physics.

matter (protons, neutrons, electrons)

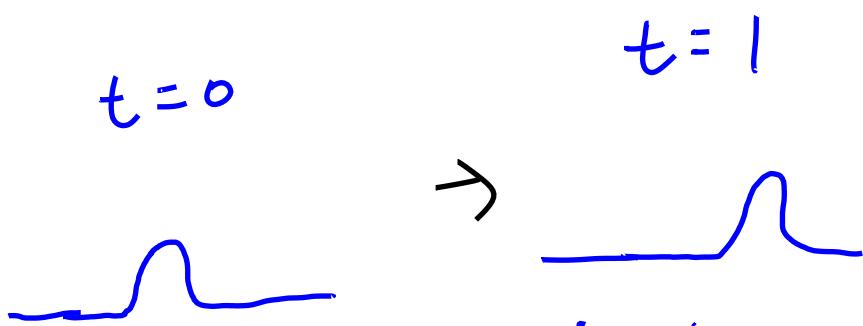
• particle "billiard balls."
— wave

Young's Double slit experiment.



Light \rightarrow electromagnetic wave

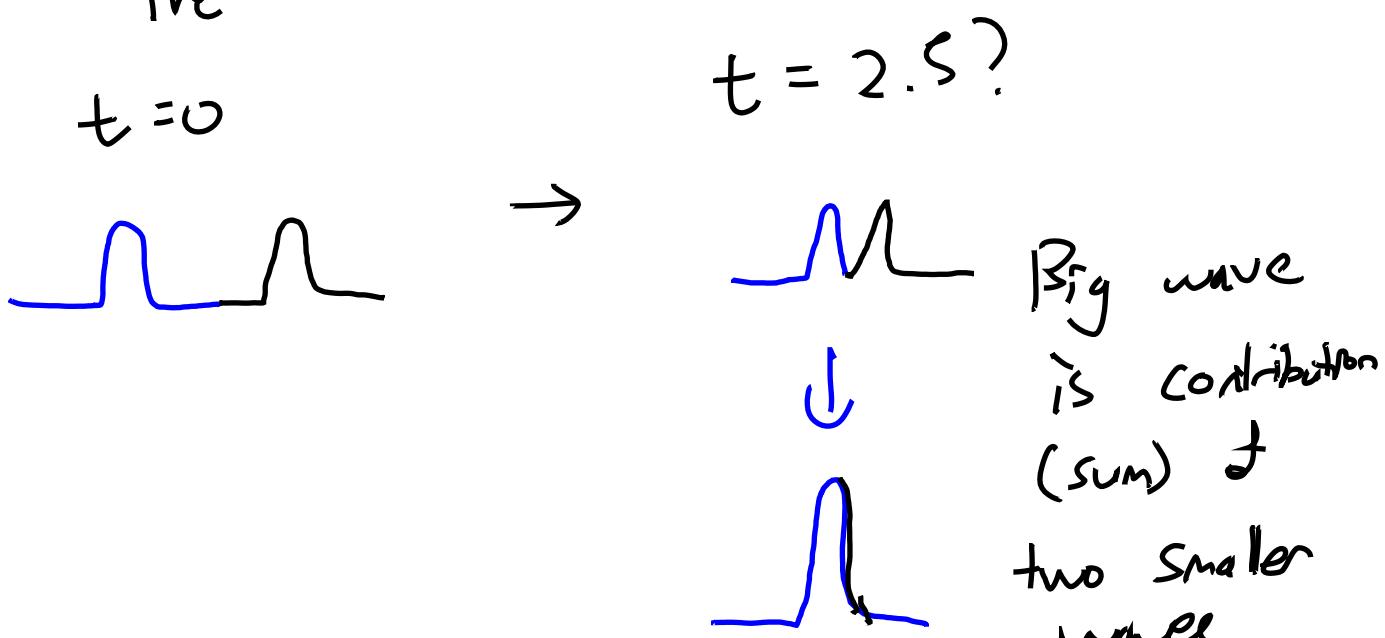
Waves & Superposition



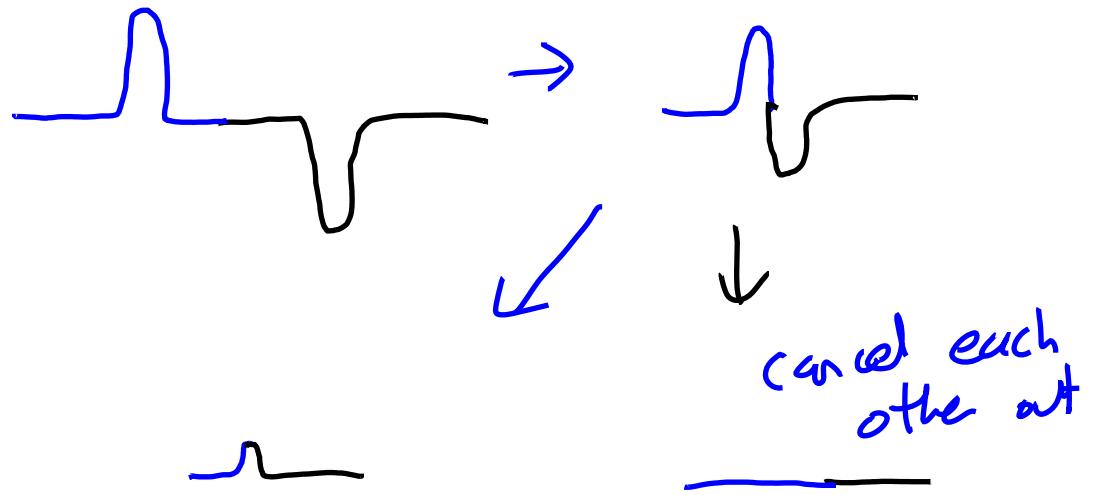
wave is traveling
to the right.



wave is traveling to
the left

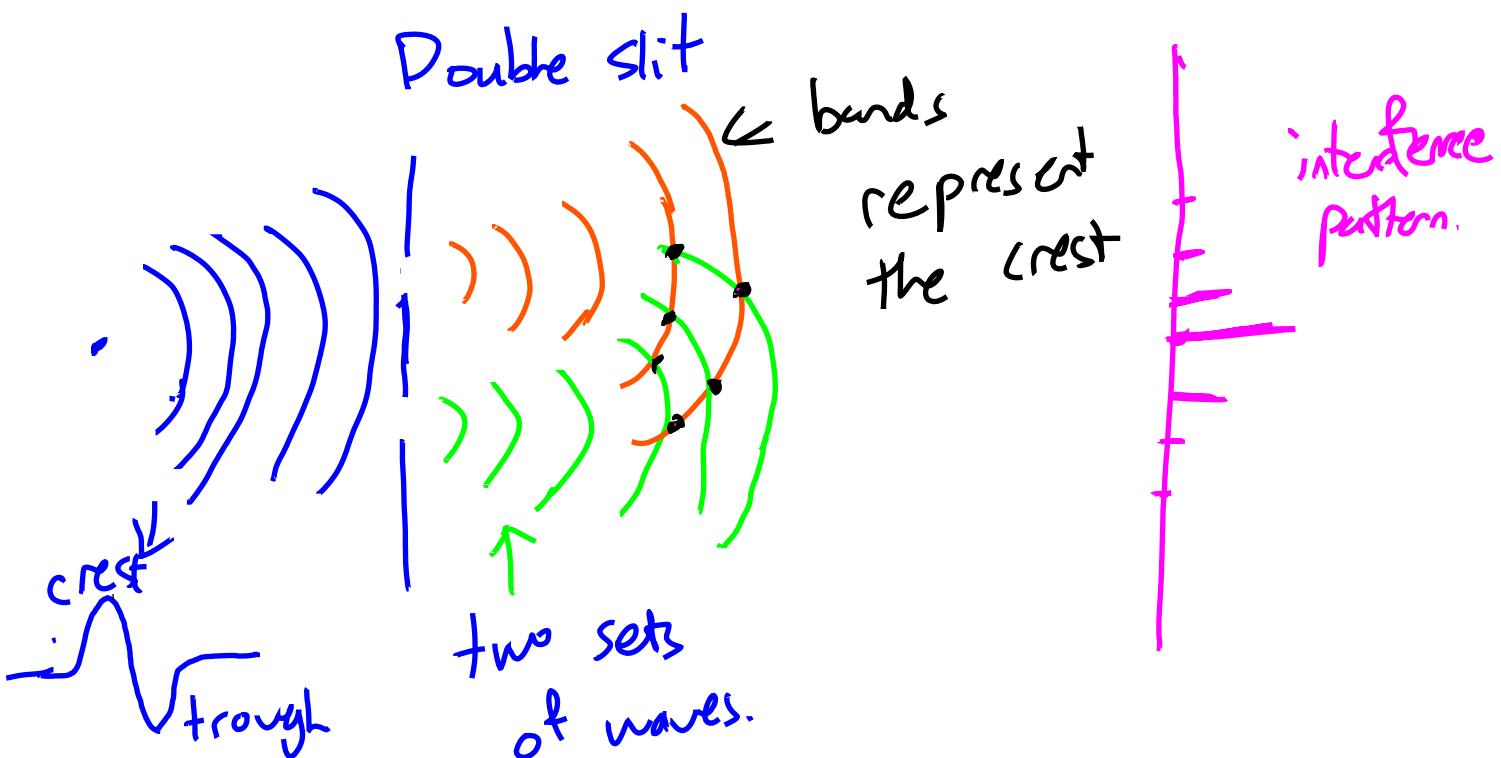


Basic idea of superposition →



① when waves build on each other → constructive interference

② when waves cancel each other out → destructive interference.



Lecture 4

Lot's of things in nuclear physics
can be explained by waves.

Consequences of wave behaviour

- electrons in atoms have discrete energy levels
- protons & neutrons in the nucleus have discrete energy levels



in quantum physics, the act of observation changes the experimental

results

Discrete Energy levels

wave behaviour \rightarrow discrete energy levels.

standing waves.

wave on water



"free"

I make the wave "not free"

make the ends "stuck"



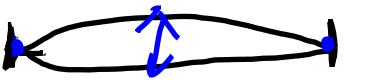
wave bounces back & forth &

interferes with itself.

Guitar string



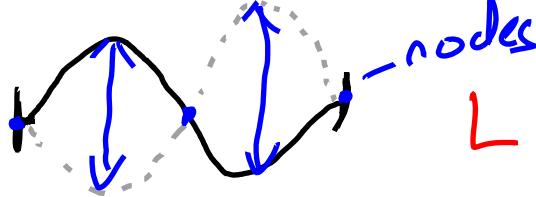
$$n = \underline{\underline{1}}$$



$$2L$$

You can have
a certain number
of peaks &
troughs.

$$n = \underline{\underline{2}}$$



$$L$$

$$n = \underline{\underline{3}}$$

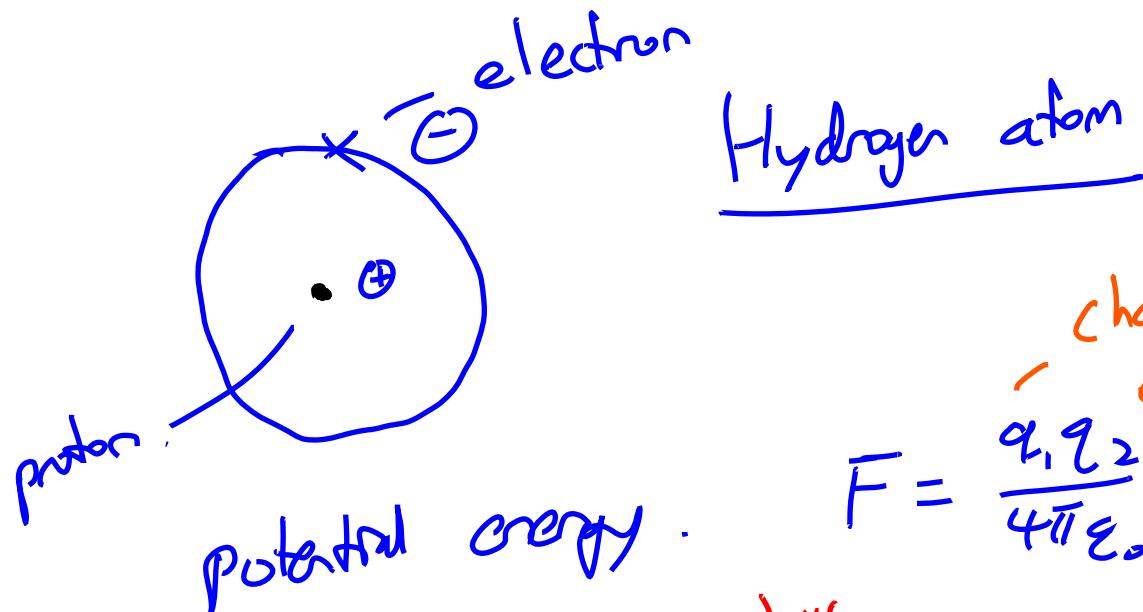


$$\xleftarrow{L}$$

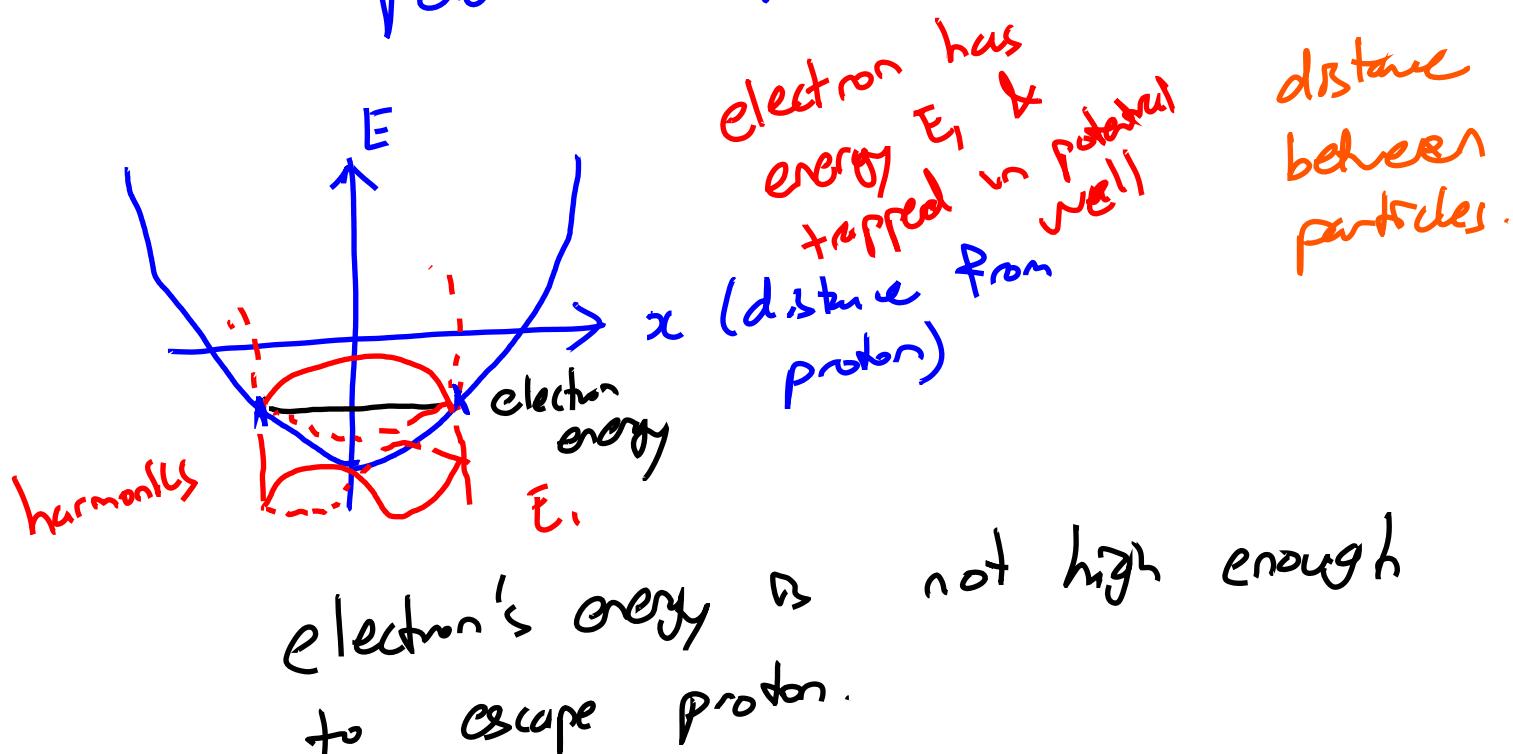
You can store energy at
different frequencies.

$$V = f\lambda$$

The frequencies (wavelengths) where you can store energy is fixed.



$$F = \frac{q_1 q_2}{4\pi \epsilon_0 r^2} = \text{charge of each particle}$$



① Electrons behave as waves

② movement of electron waves is

Standing electron

restricted as electron energy < walls.
potential energy req'd to escape.

↳ Standing waves consequence

- ① frequency / wavelength is restricted ✓
 - ② Energy is correlated to frequency
 - ③ Energy levels are therefore ✓
restricted.
-

What is the of electrons is also
the of the nucleus.

- ① protons/neutrons behave as waves
- ② movement of proton/neutron waves restricted by attractive forces in nucleus \rightarrow strong nuclear force

↳ give rise to fixed energy levels with ē nucleus.

Energy is "quantized"

↳ fixed energy levels.

If you are interested in the math.

Go read up:

- Schrodinger's equation

- Wave function

$$\boxed{\psi(x)}$$

ψ = "psi"

↳ "probability waves"

$$|\psi(x)|^2$$

↳ $\psi(x) \times \psi^*(x) \Rightarrow \underline{\text{probability}}$

Lecture 5

Schrodinger's equation

↳ implications

① Guitar string analogy

↳ Infinite square well.

↳ 1D

↳ "free field" is infinite

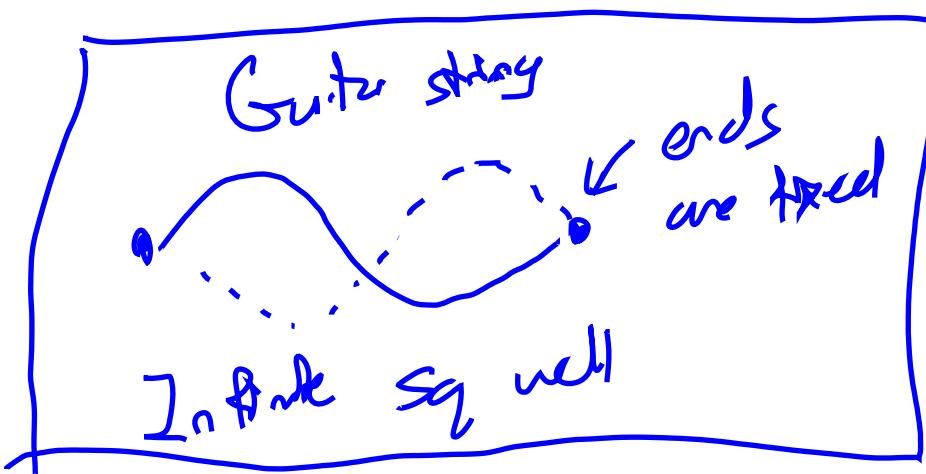
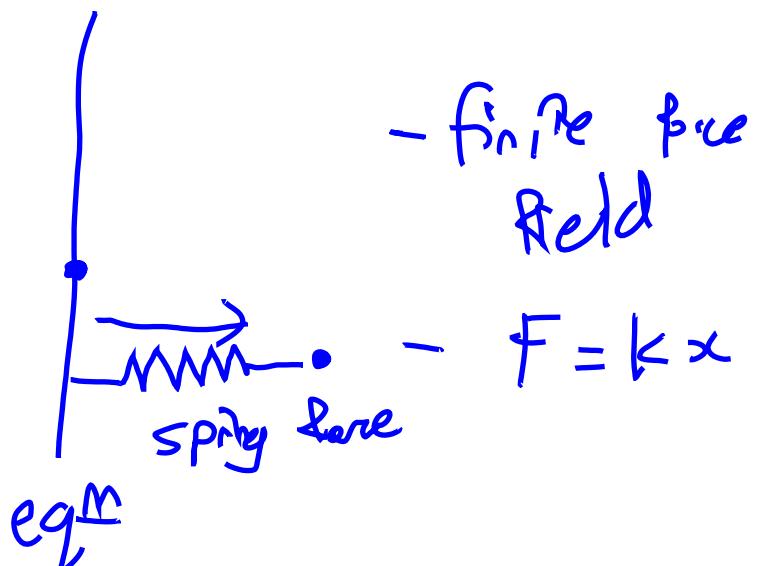
In real life, force fields
are finite

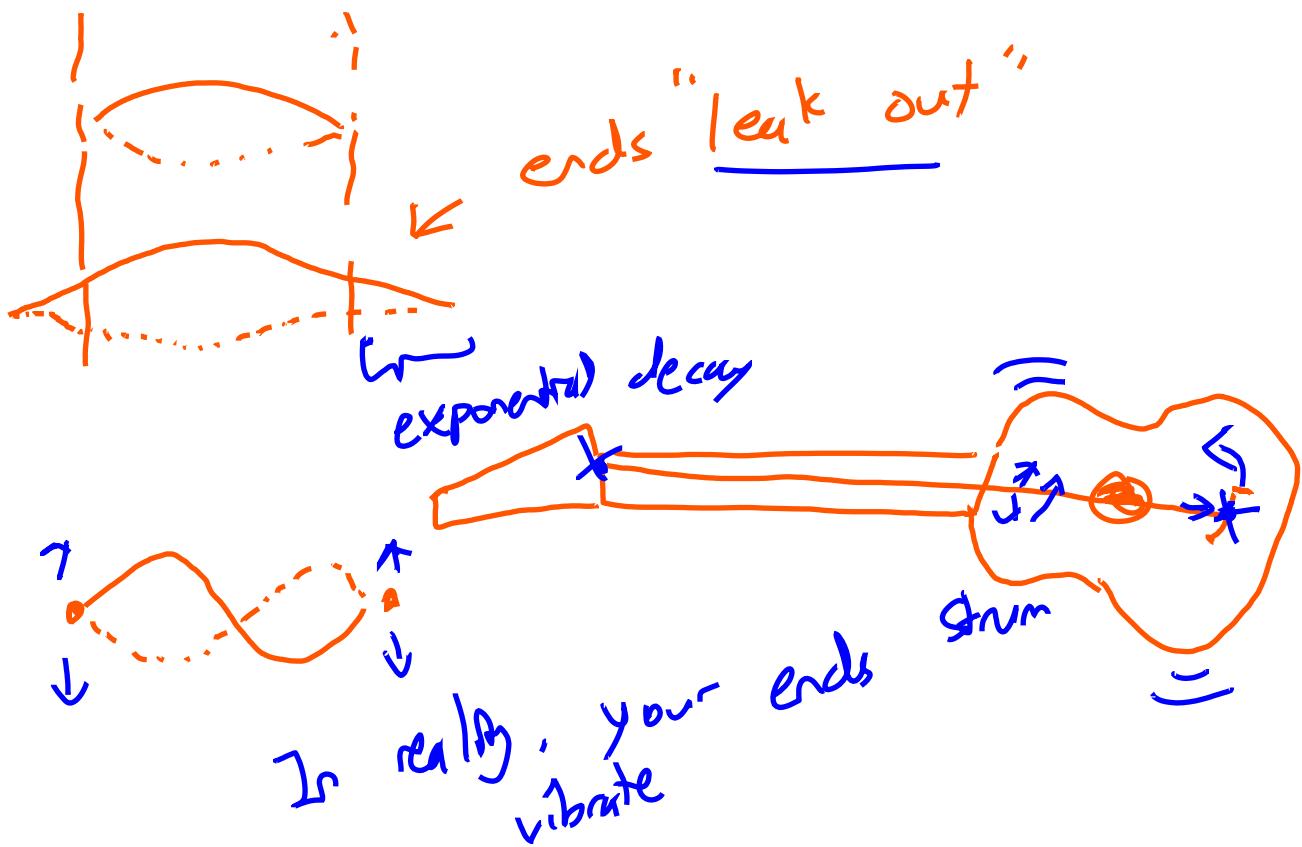
② Finite force fields

↳ 1D

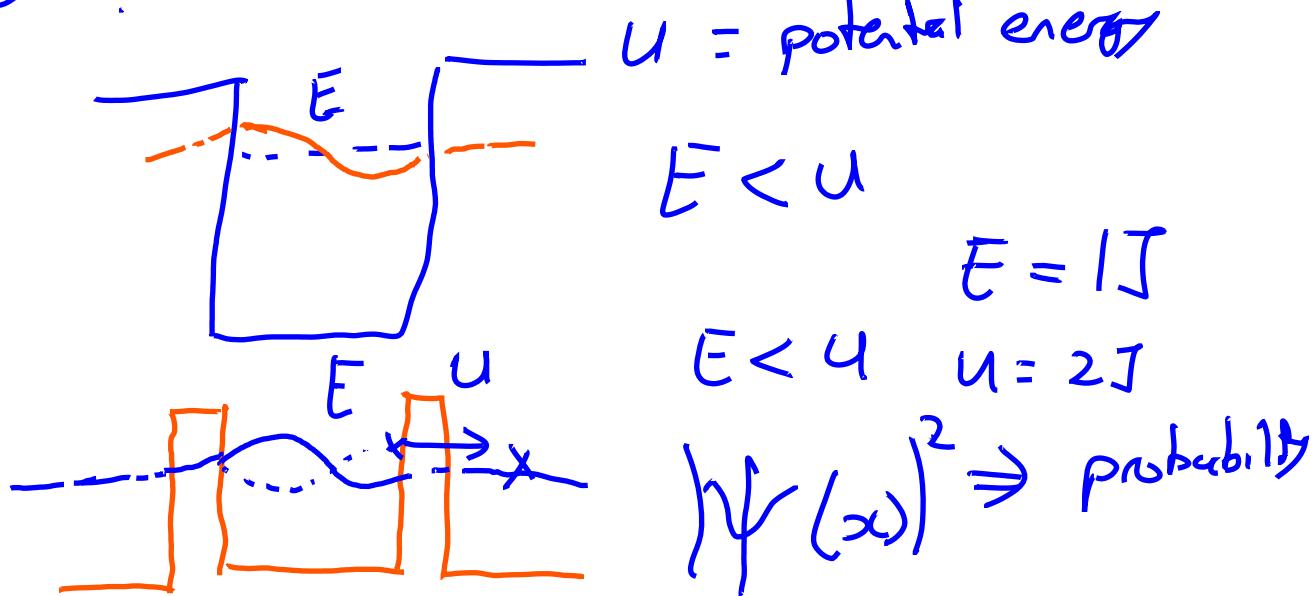
↳ finite force field,
finite well

↳ simple harmonic oscillator





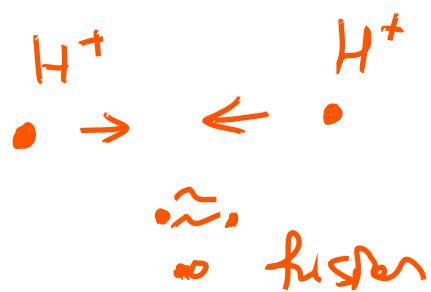
what do waves "leaking out"
mean?



particles leak through barrier

∴ Quantum Tunneling

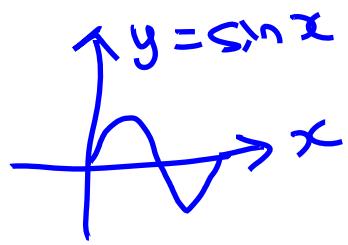
- ↳ Alpha decay
- ↳ Fusion process in the sun.



Lecture 6

In previous discussion, we
talked about 1D waves
 sine & cosine waves,

or exponentials



reality : 1D geometry is not
representative of an atom
or nucleus, we need

3D version.

Force fields are spherical in

nature : $F \propto \frac{1}{4\pi\epsilon_0 r^2}$ ← sphere surf
are
 $= 4\pi r^2$

need a
↳ spherical version of
the sine wave

Spherical harmonics

↳ 3D spherical version of sine waves

↳ explored in hydrogen atom

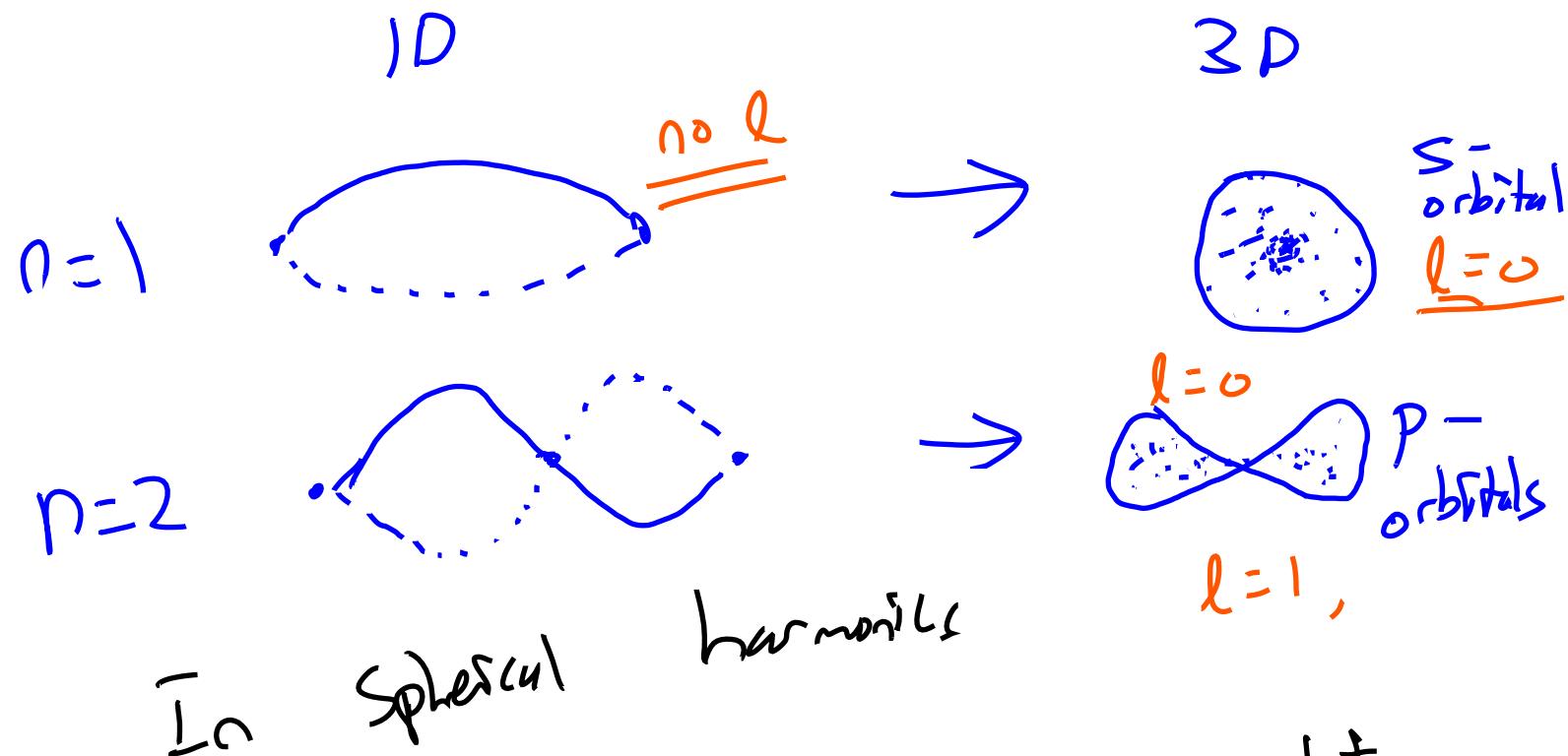


3D matter wave
electron 'cloud'

↳ implications of spherical harmonics

↳ angular momentum becomes important (l)

↳ angular momentum projection no. becomes important (m)



↳ n, l, m become important
in electrons

↳ same applies to the nucleus.
protons & neutrons

↳ strong nuclear force is
responsible for force field
rather than electric.

Summary: Implications of Schrödinger's equation

① Infinite Sq well

↳ discrete energy levels

② Finite well (Simple harmonic oscillator)

↳ Quantum Tunneling

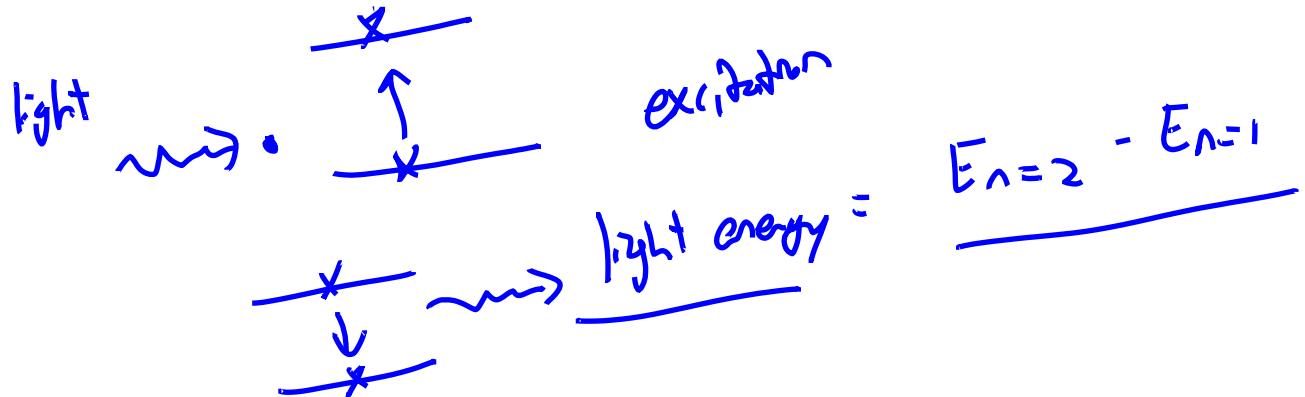
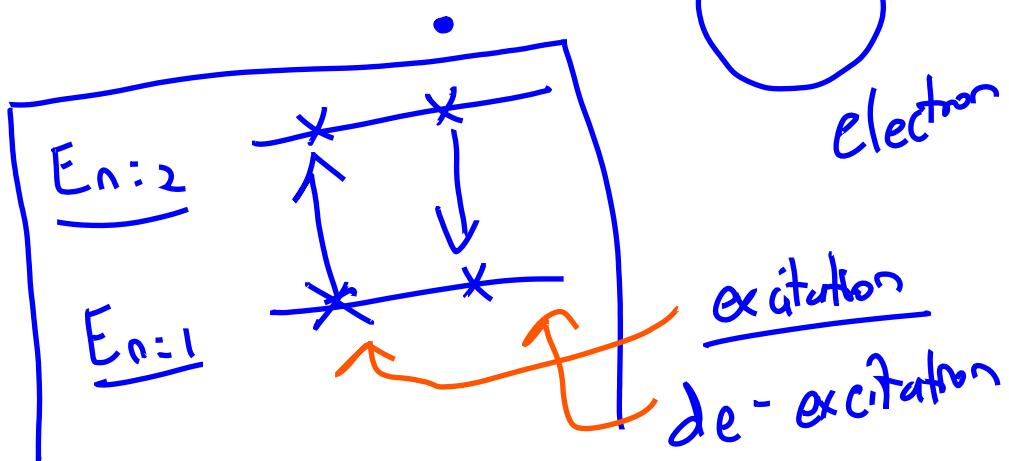
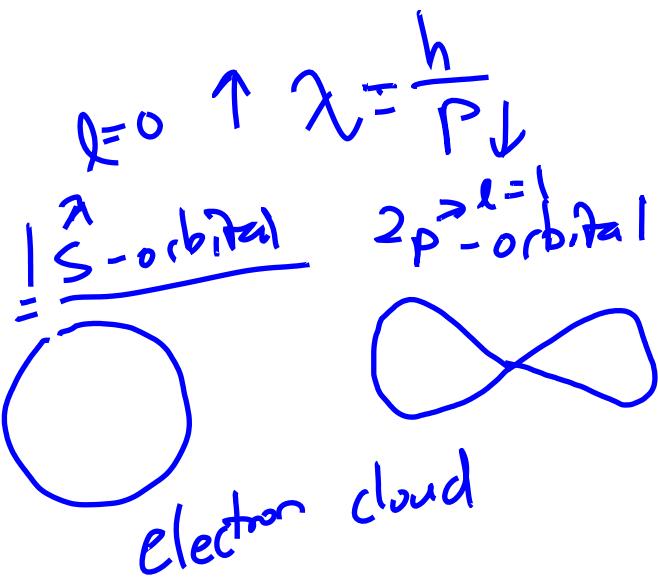
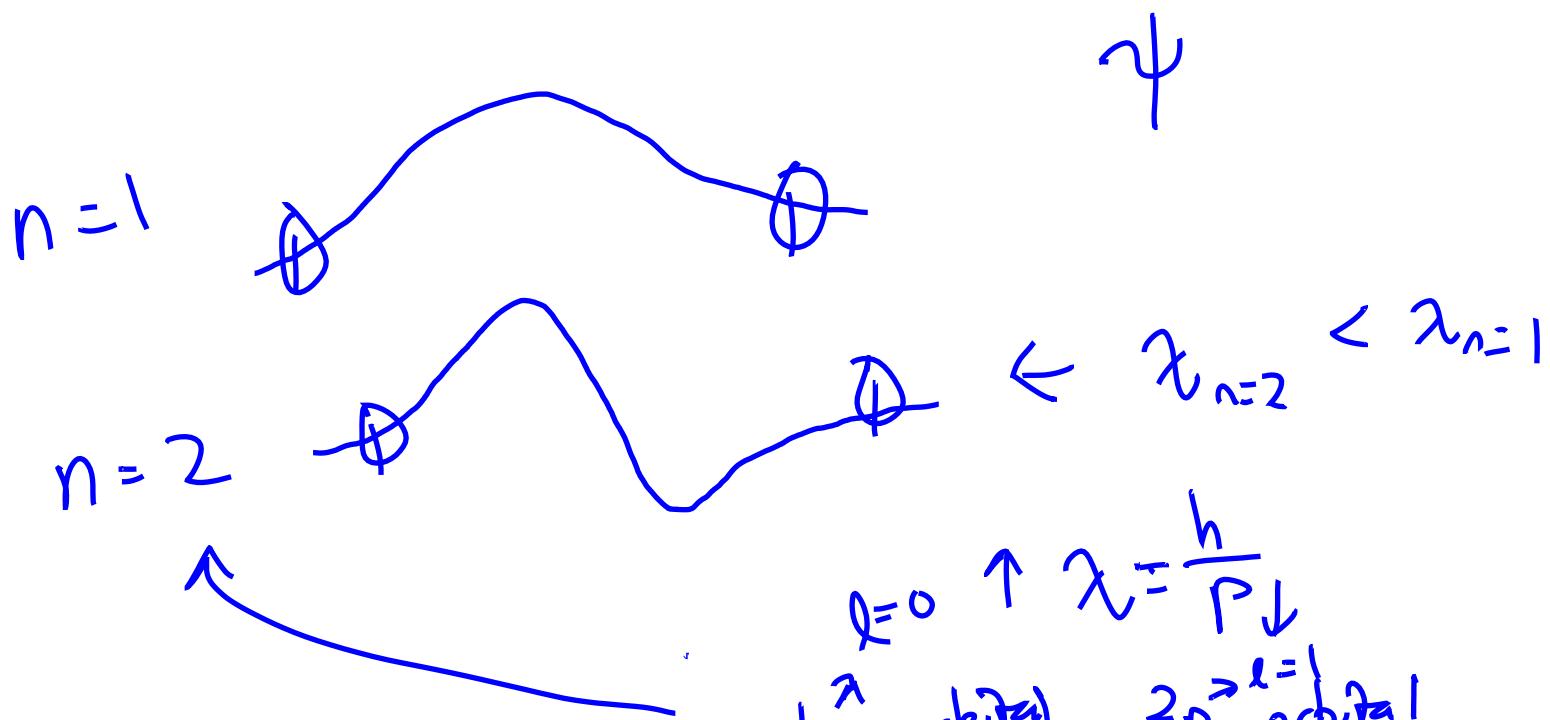
③ $1D \rightarrow 3D$ spherical harmony

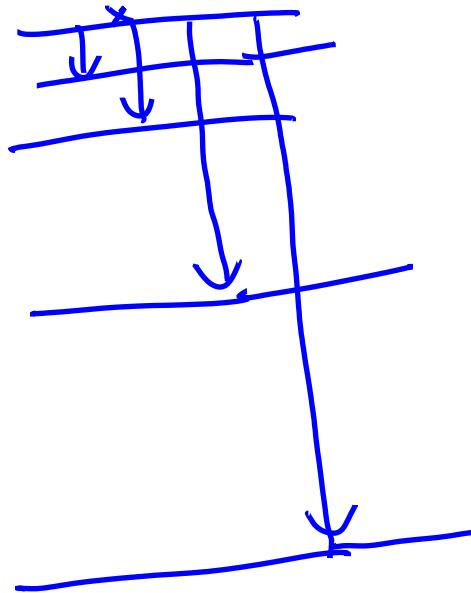
↳ l (angular momentum) becomes important

↳ m (angular momentum projector)

becomes important

Lecture 7





emitted light
from excited
Hydrogen atom
will have fixed
energy

fixed energy → fixed wavelength.

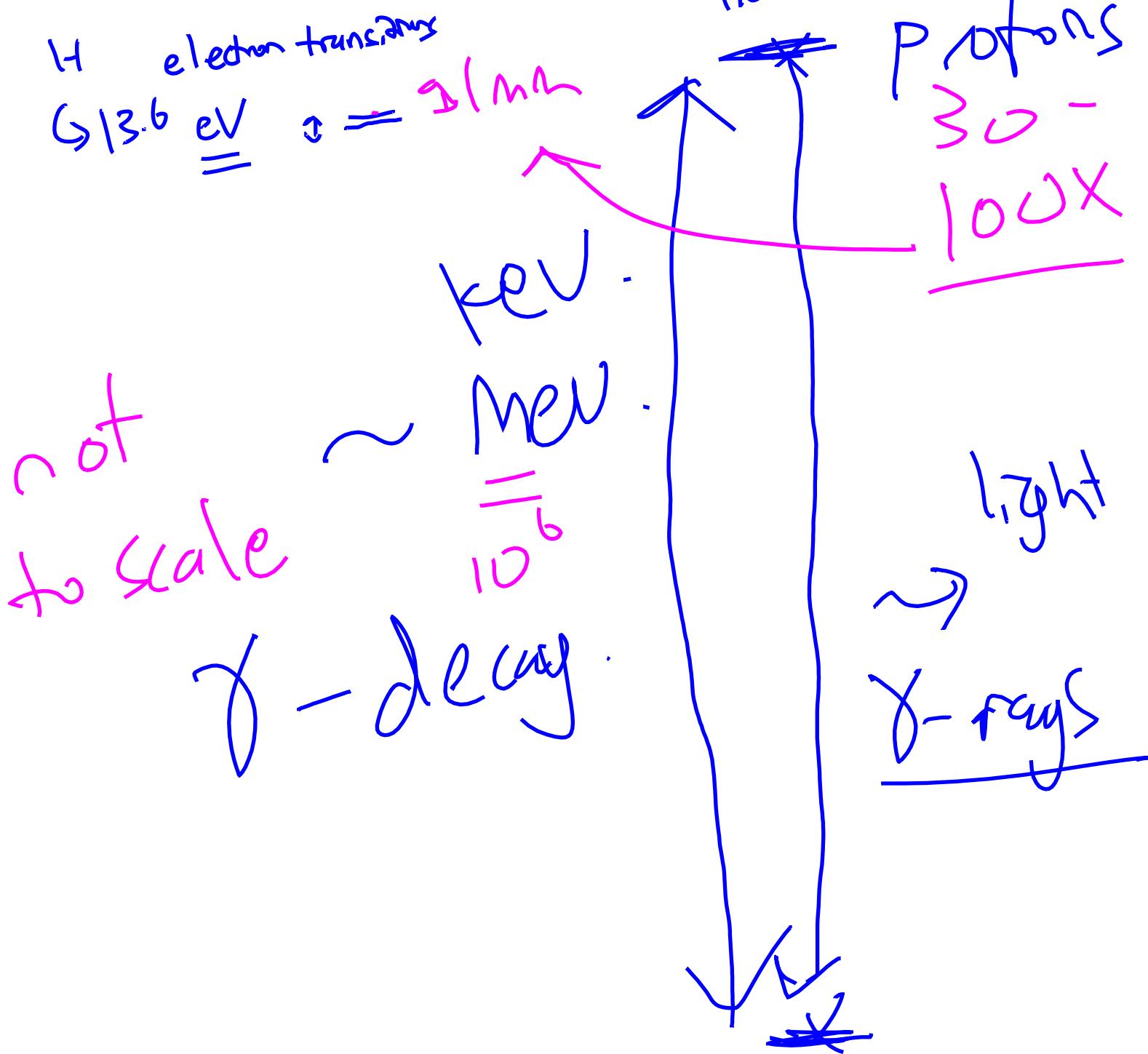
characteristic spectrum that
Hydrogen atom will have
when de-exciting

Different atoms have diff electric field
(force fields) → Energy level is diff

→ Wavelength/spectra is different.

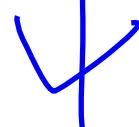
In the nucleus, strong nuclear force
is several orders of magnitude stronger
such that the energy level difference
is about ~ 1 million times more.

$$1 \text{ eV} = 1.602 \times 10^{-19} \text{ J}$$



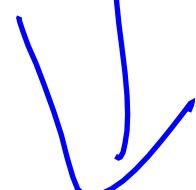
how many pages will we
need to draw this to
scale?

$$100 \times \underline{10,000} \text{ page}$$
$$10^2 \times 10^4$$



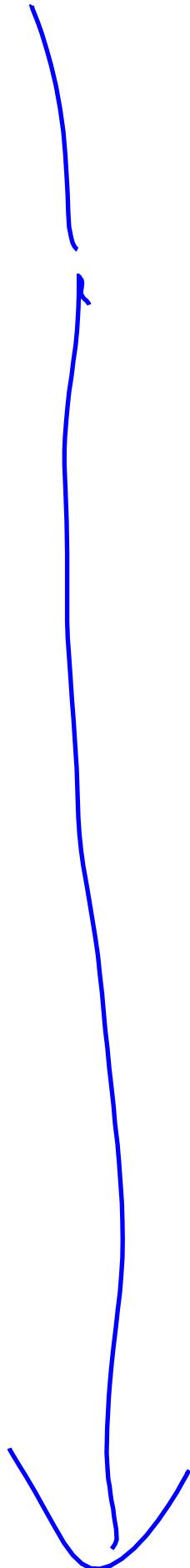
nuclear energy \rightarrow

1 million lines
more dense than
electron energy

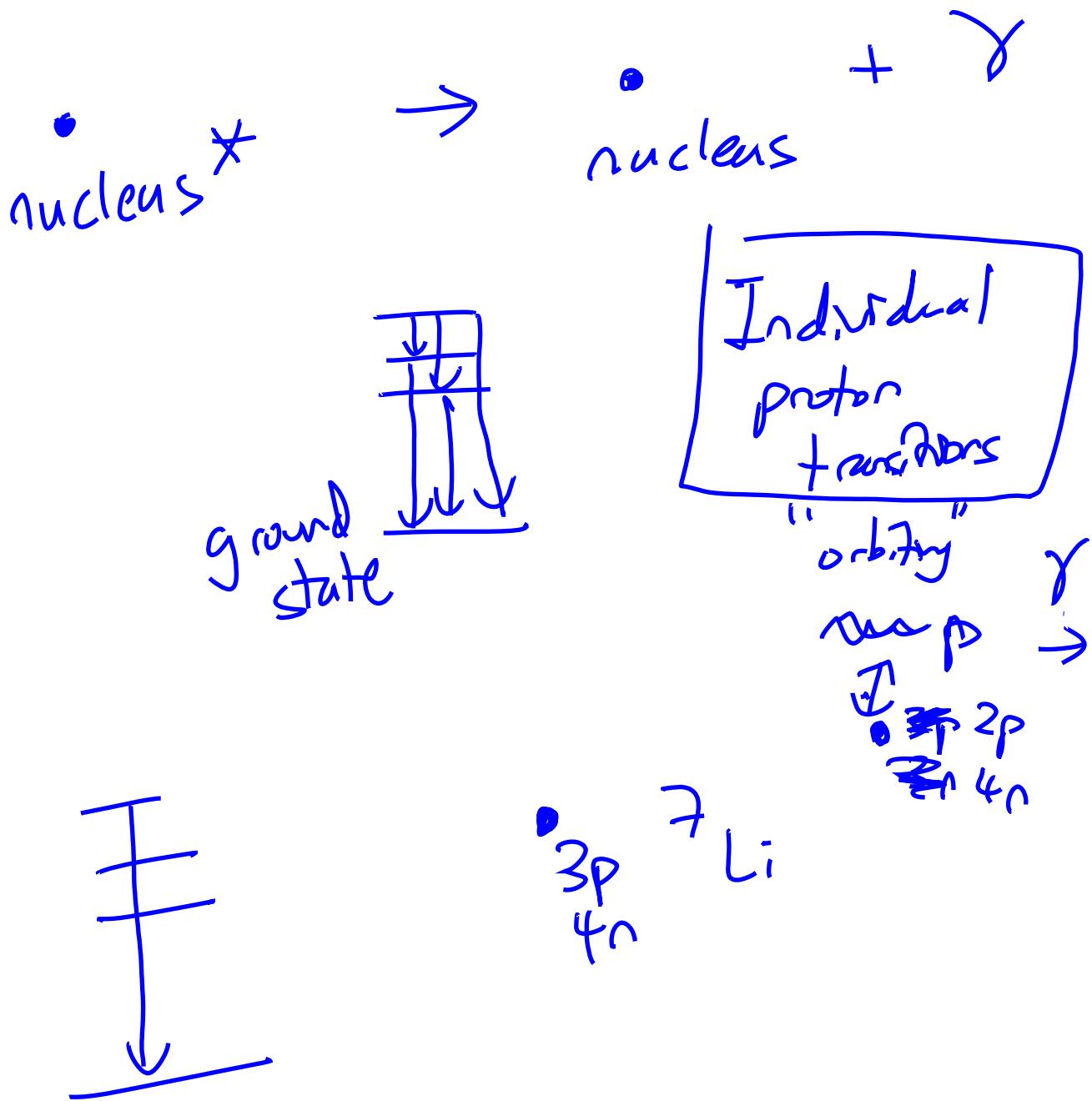


↓
chemical bonds
↳ fusion fuel
↳ battery

Nuclear energy ↗
super dense.



Lecture 8



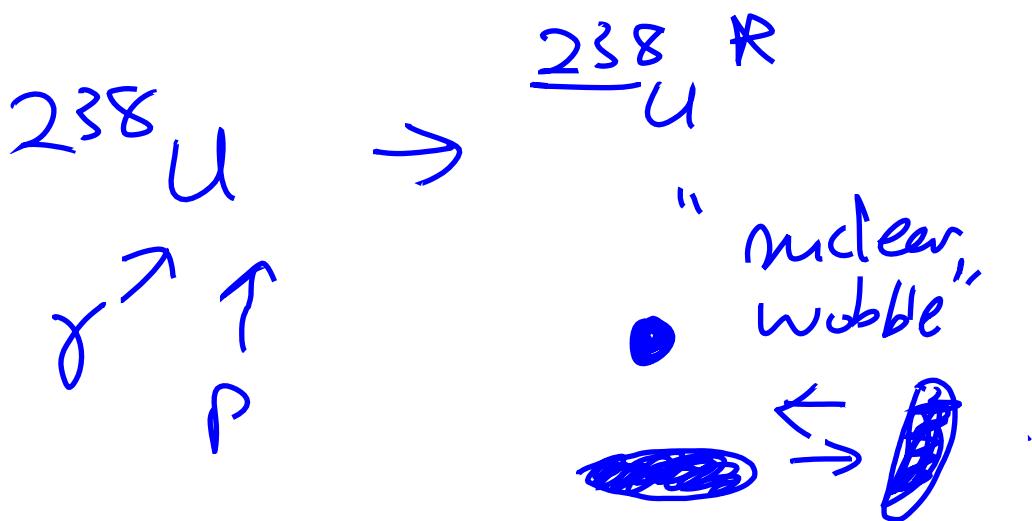
Main ways for nuclei to have Excited states (Gamma decay)

(1)

- Individual protons excited

(2)

collective motion.



"liquid drop"

"shaking"

→ "spinning"

particle
Individual "excited" states
energy > collective
vibration excited
state

E_{single}
 E_{ground}

collective is usually
motion for large nuclei

$E_{\text{collective}}$
 E_{grand}
low keV range

How do nuclei get excited?

① Photon absorption

② inelastic collision.

$$\boxed{\frac{1}{2} m v_1^2}$$

v_2

$$P_1 \rightarrow$$

$$\frac{P_2}{\text{rest}}$$

$$P_L$$

$$\boxed{\frac{1}{2} m v_1^2}$$

$$\frac{P_1}{\text{rest}}$$

- momentum conserved

- kinetic energy conserved

"no fraction"
elastic collision

inelastic collision \rightarrow "fraction"

$$\boxed{kE_1}$$

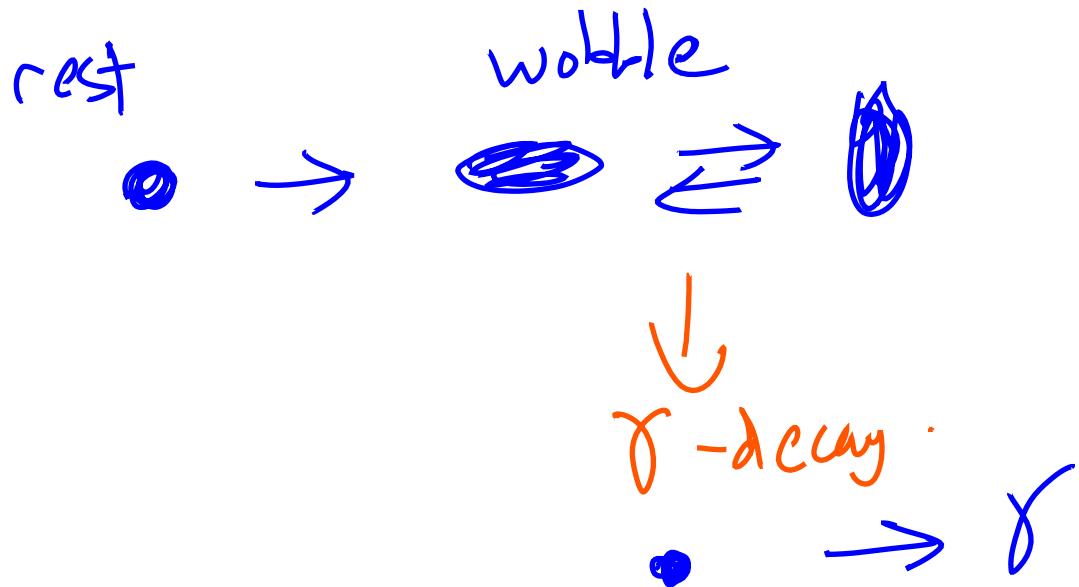
$$\xrightarrow{n}$$

$$kE_2$$

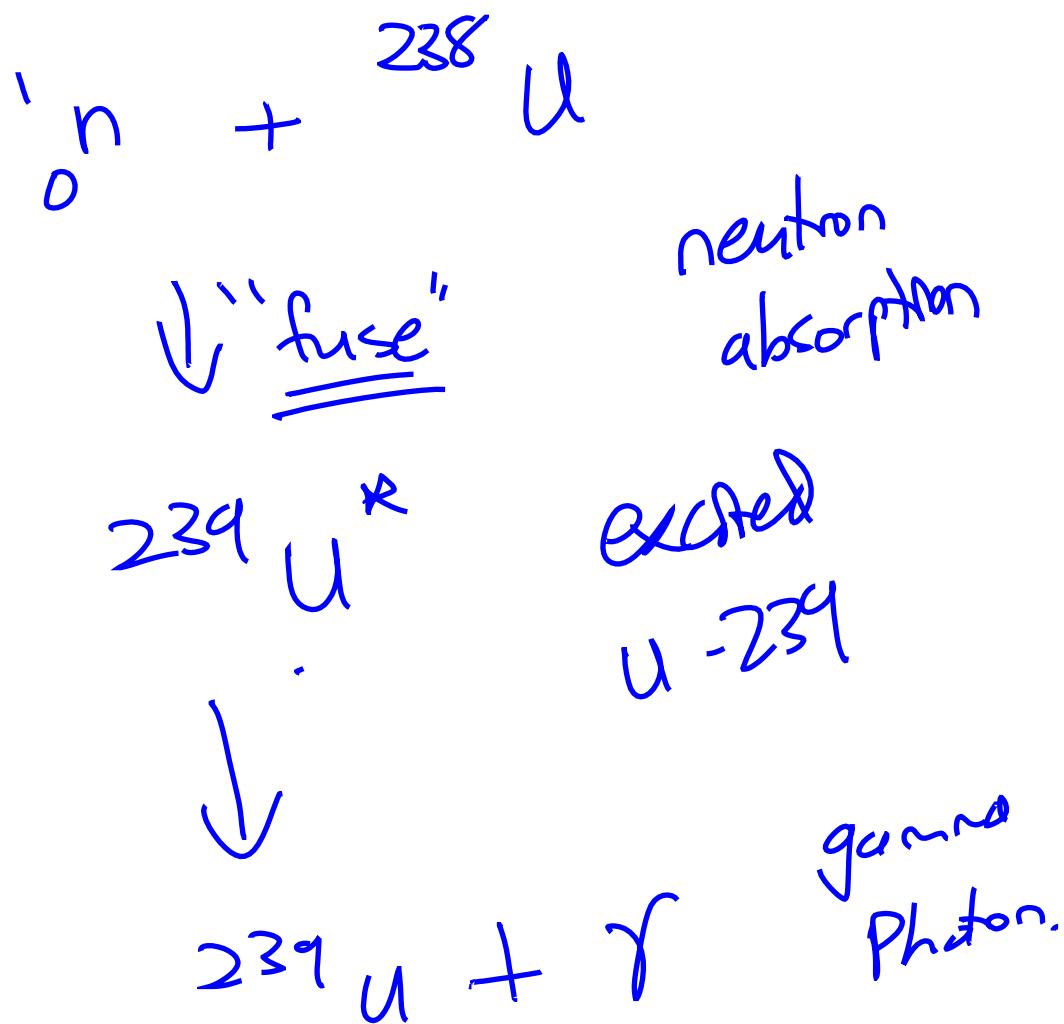
$$^{238}\text{U} \rightarrow kE_3$$

$$kE_1 > \underline{kE_2 + kE_3}$$

Where did the energy go?



③ nuclear reactions

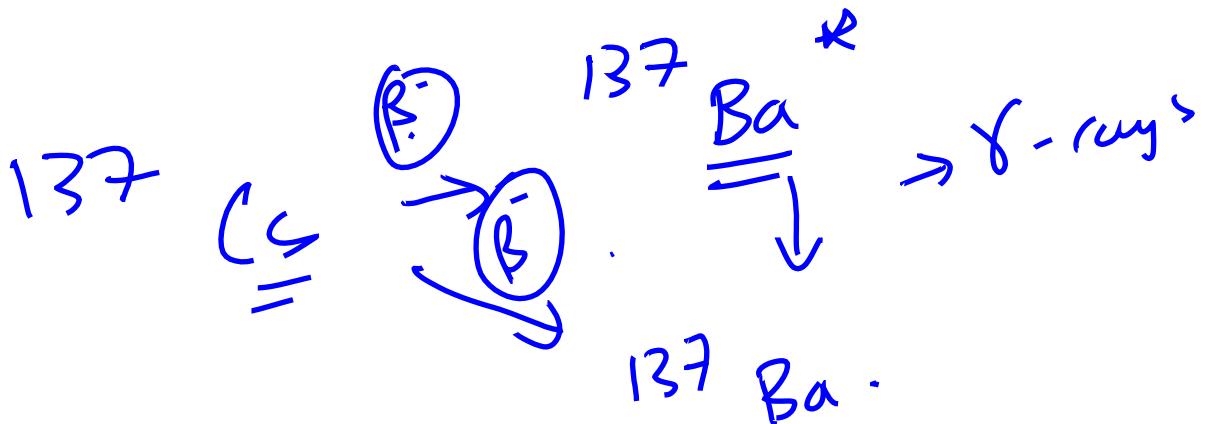
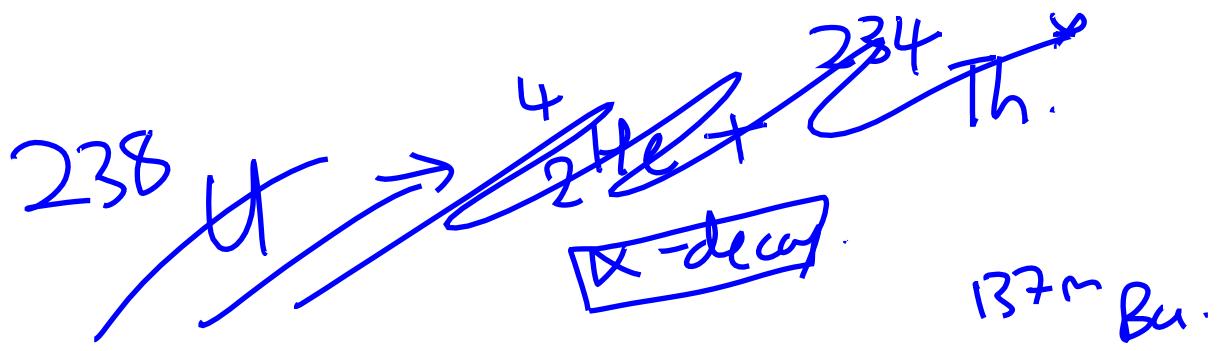
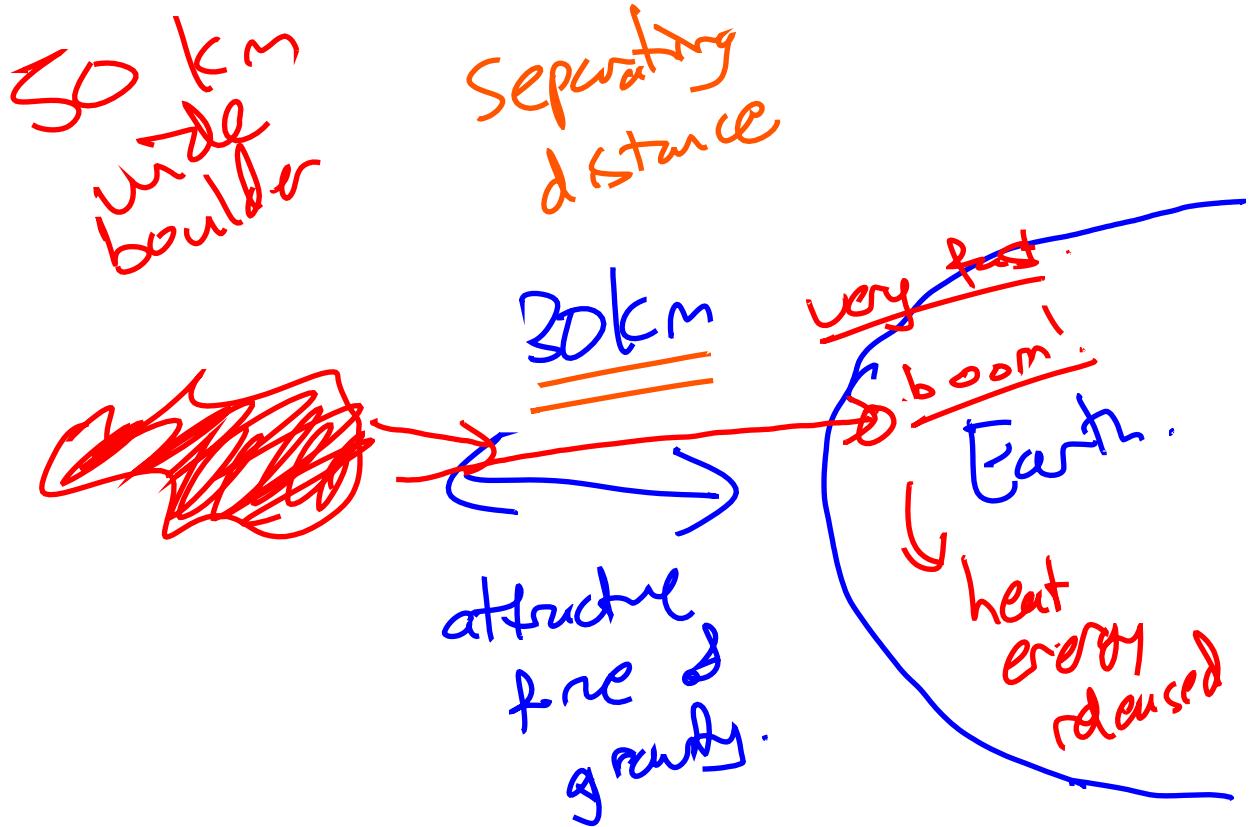


(n, γ) reactions \rightarrow important

Why did neutron absorption result in excited state?

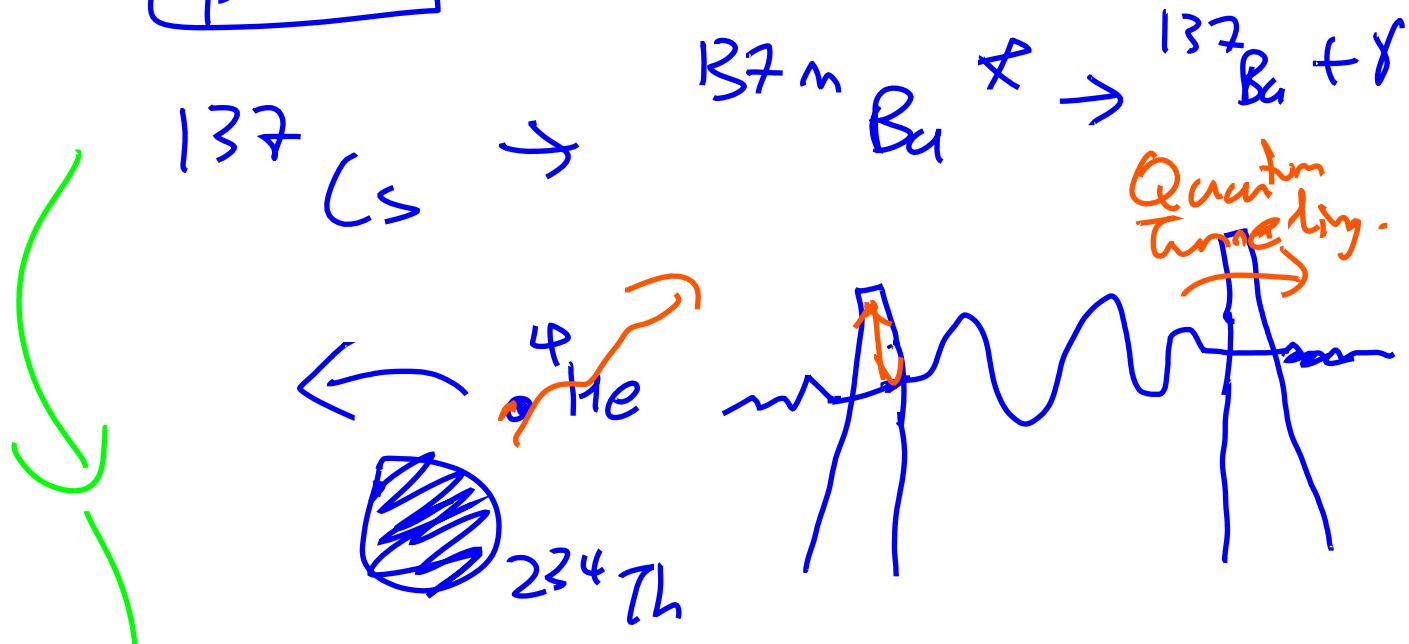
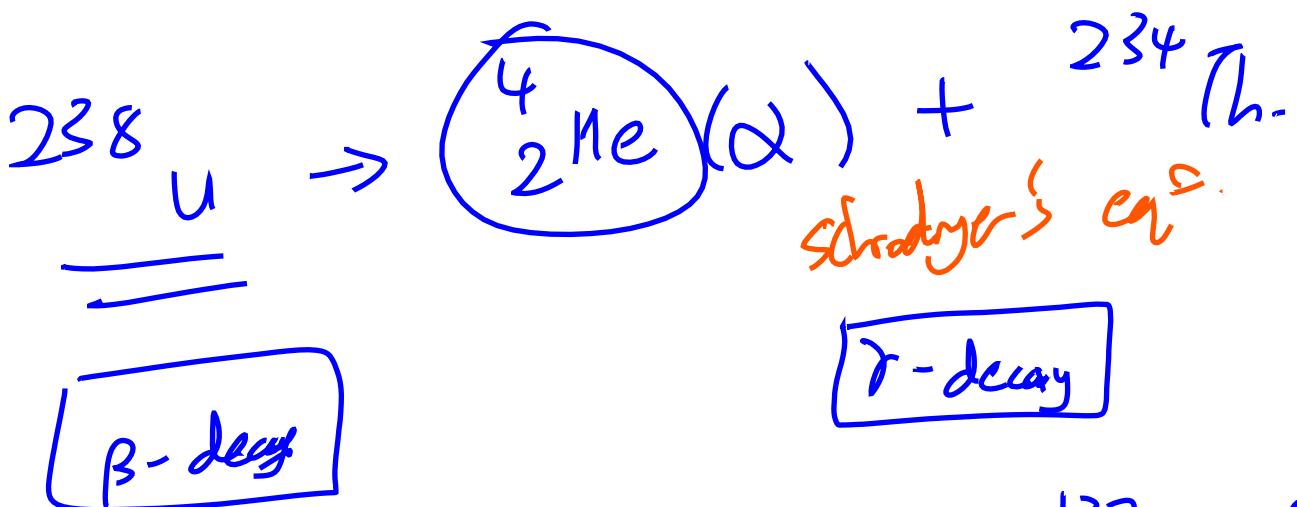
↙ binds Jan to forces.
strong force. \rightarrow attractive.
nuclear \leftrightarrow 
 $^{238}_{\text{U}}$

attractive force +
separating distance



α -decay.

Schrodinger's eq:



Beta decay is special

↳ relies on weak nuclear force.

