Nuclear Weapons (and Energy)

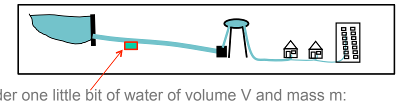
the how, the what … and why?

Reminders:
Ths: Nucl. Energy / Reactors
HW next Mond
Review next Tues
Exam Thurs

Phys 1010, Day 13:
Questions?
Finishing fluids/ Bernoulli
Nuclear Weapons Blmfld 16.1

Finish Bernoulli's Equation

$PV + \frac{1}{2} mv^2 + mgh = E_{total}$



Consider one little bit of water of volume V and mass m:

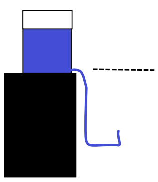
Replace $m = \rho V$ where ρ is the fluid density (ρ = mass/volume = 1000kg/m^3 for water)

$PV + \frac{1}{2} \rho V v^2 + \rho V g h = E_{total}$

$P + \frac{1}{2} \rho v^2 + \rho g h = E_{total}/V$ ($E_{total\ per\ unit\ volume}$)

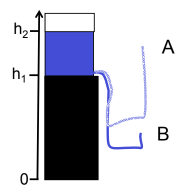
$E_{total\ per\ vol}$ is constant:
Know P, v and h at one point ⇒ can calculate these quantities at another

Here I have a tank of water with a hose connected to the bottom. When I take my finger off the hose, water (under pressure) will squirt into the air. Will the water go higher or lower than the opening in the tank (dashed line)?



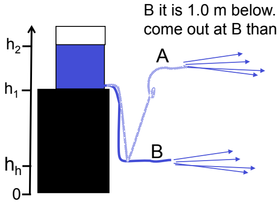
a. Higher
b. Right exactly to the dashed line
c. Lower
d. Impossible to predict
e. None of the above.

Here I have a tank of water with a hose connected to the bottom. When I take my finger off the hose, water (under pressure) will squirt into the air. I can hold the hose high (at A) or low (at B). From which location will the water squirt higher (relative to the ground)?



a. A, the higher location
b. B, the lower location
c. Water reaches the same height from both locations
d. Impossible to predict
e. None of the above.

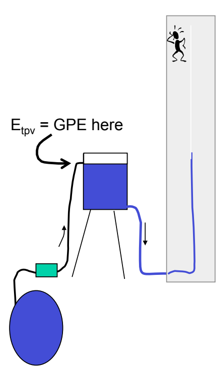
At A, the hose is 0.25 m below the water's surface. At B it is 1.0 m below. How much faster will the water come out at B than at A?



a. ¼ as fast at B as at A.
b. ½ as fast at B as at A
c. same speed
d. 2 times faster at B than at A
e. 4 times faster at B than at A

Hint how much lower from top (mgh) is B than A?

Water distribution in skyscrapers

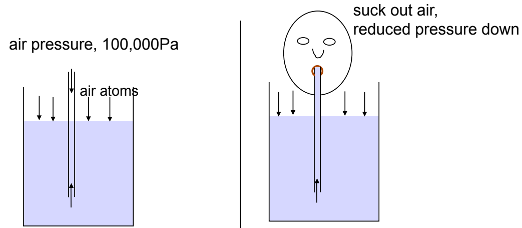


The skyscraper water problem:
- Less pressure on the higher floors,
- Water won't make it to the top floor….

How can you solve this problem?

- Put very high pressure pump at bottom (give water enough PPE at bottom)
- Use a series of pumps up the building
- Pump water to a tank on the roof, then you will always have pressure on the floors below.

Straws



- The pressures up and down balance….
  ⇒ So there is no flow through straw.

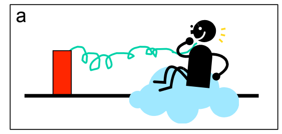
- The air pressure on water surface pushes the water up the straw.
- The maximum pressure difference inside/outside straw = 100,000 Pa = 1atm.
- The highest straw is 10 m (Beqn)

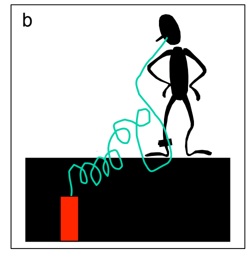
You suck on 30 foot straw.

a. sitting on floor
b. standing on desk

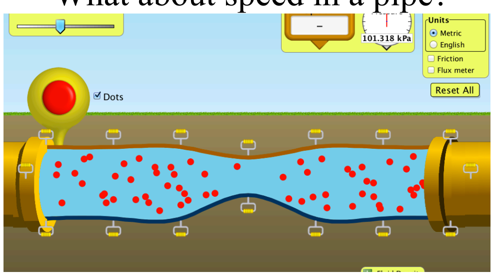
For you to suck up the red juice

a. will have to suck the same
b. will have to suck less hard from floor
c. suck less hard from desk





What about speed in a pipe?



$P + \frac{1}{2}\rho v^2 + \rho g h = E_{total}/V$ ($E_{total\ per\ unit\ volume}$)

http://phet.colorado.edu/en/simulation/fluid-pressure-and-flow

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Bernoulli's Equation in Real Life

Total Energy per volume $= P + \frac{1}{2}\rho v^2 + \rho g h$

- This is a good approximation but it cannot be perfectly correct
- What type of energy does it ignore?
  ⇒ Think about a narrow pipe.

- Does not consider energy going into thermal energy- from friction with walls etc.
- For example, for high speed flow in a narrow pipe, more water molecules bounce off walls, creating significant friction and energy loss as heat
- But for most water distribution systems, friction can be ignored Bernoulli works very well.

Nuclear Weapons…

- There will be a "reading quiz" on Thurs
- Keep to the schedule on the web:
- HW This week

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*Nuclear Weapons**

release of ENORMOUS amounts of energy stored in the nuclei at center of atoms.

I. "Atomic" bomb (actually "fission" bomb) *today*

a. how nuclei are held together, why so much energy involved.
b. how they come apart and release LOTS of energy.
   alpha decay, neutron-induced fission
c. how to make a whole bunch of them do it at once
   = LOTS x whole bunch= bomb

II. Radioactivity- what is it and why bad for living cells.
   half-life

III. Fusion bomb (*little nuclei stick together*).

** don't try this at home*

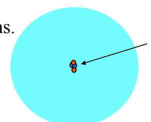
Recipe- how to make an atom:

Ingredients: 1 teaspoon protons
1 teaspoon neutrons
1 cup of electrons

- Proton (**positive charge**)
- Neutron (**no charge**)
- Electron (**negative charge**)

1. Mix protons and neutrons thoroughly.
2. Bake at 100 million degrees until sticks together to form solid dense nucleus (about .0000001 s).
3. Frost with lightly with fluffy layer of negative electrons.

4. *Chill before serving!*



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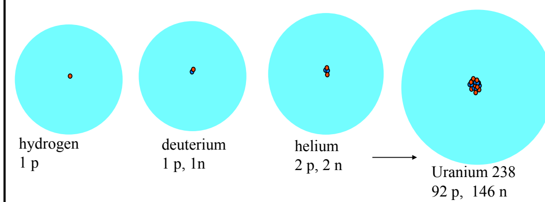
Each element has different number of protons.

Atom ingredients:
- Proton (**positive charge**) – charge = 1.6 x 10^{-19} Coulombs
  mass = 1.66 x 10^{-27} kg.
- Neutron (**no charge**) – no charge
  mass = 1.66 x 10^{-27} kg.
- Electron (**negative charge**) – charge = -1.6 x 10^{-19} Coulombs
  mass = 9.10 x 10^{-31} kg



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Oxygen has 8 protons, 8 neutrons:

Consider a nuclei with 7 protons, 7 neutrons (nitrogen atom)… what if we want to add another proton to make oxygen (8 protons):

What will we need to do to get proton stuck to nucleus:
a. just give it a little push so it will hit nucleus dead on and it will drift towards nucleus and stick.
b. the closer it gets, the harder you have to push, will take lots of work
c. you'll need to push really hard at first and then less as you get closer
d. you'll have to push the proton towards the nucleus with a fixed amount of force (constant force).

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Oxygen has 8 protons, 8 neutrons

Consider a nuclei with 7 protons, 7 neutrons… what if we want to add another proton to make oxygen:

Like charges repel:

Force on proton given by Coulomb's law (k = Coulomb's constant):

In general: Force = $\frac{\text{k x charge of object \#1 x charge of object \#2}}{(\text{distance between objects})^2}$

F = $\frac{\text{k x charge of nucleus in coulombs x charge of proton in coulombs}}{(\text{distance}_{\text{nucleus-proton}})^2}$

The smaller the distance the larger the force!

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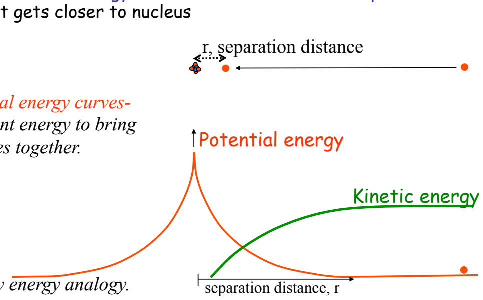
What if threw proton so starts out going towards nitrogen nucleus with a lot of speed (lots of kinetic energy)?
Starts with lots of kinetic energy →
Repelling force from nucleus slows down proton →
Proton's kinetic energy converted into electrostatic potential energy, as it gets closer to nucleus

Potential energy curves- represent energy to bring particles together.



Gravity energy analogy.
if at center, want to roll down hill/fly apart … lots of electrostatic potential energy

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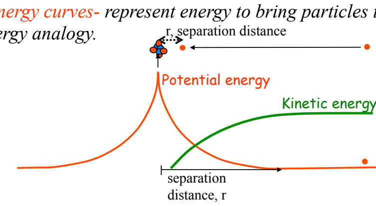
Potential energy curves- represent energy to bring particles together.
Gravity energy analogy.



Potential energy at separation distance of r = $\frac{\text{k x charge of 7 proton nucl. x charge of single proton}}{(\text{separation distance})}$

Charge of 1 proton = 1.6 x 10^{-19} Coulombs; Charge of 7 protons=11.2 x 10^{-19} C

So at 10^{-15} m away (~ radius of nucleus),
Potential energy = $\frac{8.99 \times 10^9 \text{ N m}^2/\text{C}^2 \times 11.2 \times 10^{-19} \text{ C} \times 1.6 \times 10^{-19} \text{ C}}{(10^{-15} \text{ m})}$
= 1.61 x 10^{-12} Joules = 10 million electron Volts.
(1 electron volt = energy gained by electron moving through 1 Volt diff.= 1.6 x 10^{-19} J)

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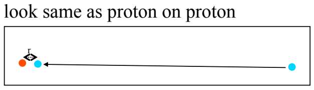
Potential energy curve (Energy vs. separation distance)
for bringing electron in to proton

a. This curve would be flat, not going up or down
b. look like bringing a proton into a proton except upside down so going down instead of up.
c. would look same as proton on proton



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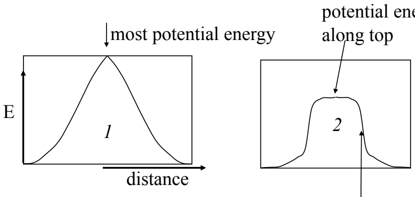
Analyzing shape of potential energy curves:



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How can a bunch of repulsive positively charged protons stick together?

Like hopper toy- really strong **nuclear force** between protons and neutrons overwhelms electrical force if *really* close together.

Spring legs- like electrical force, pushes over distance.
suction cup- like nuclear force, only strong when very close
like double sticky tape… only works if in close contact.

Nuclear force- Why like this?
Just different! That is the way nature is!

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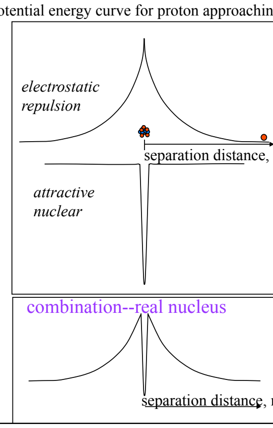
Potential energy curve for proton approaching nucleus



Energy scale gigantic compared to chemical energy.
Why? Simple coulomb's law.

$F = \frac{k\,(\text{charge of \#1})(\text{charge of \#2})}{r^2}$

Chemistry- forces between electrons and protons on distance scale of atomic size (> 10^{-10} m).

Nuclear forces- forces between protons on distance scale 10-100,000 times smaller.
10,000 times closer means forces **100,000,000 times bigger** because of $1/r^2$. Lots more potential energy stored!!!

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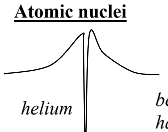
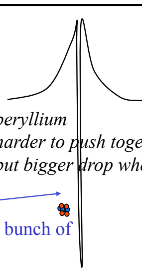
Atomic nuclei

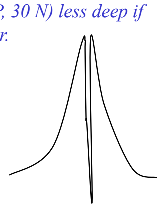


helium

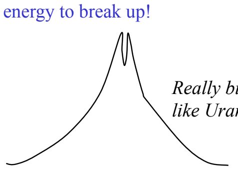


beryllium
harder to push together,
but bigger drop when do.

Gets deeper until iron
(26 P, 30 N) less deep if bigger.



Really stable:
Have to add a whole bunch of energy to break up!



Really big nucleus, >100 P, >100 N,
like Uranium or plutonium

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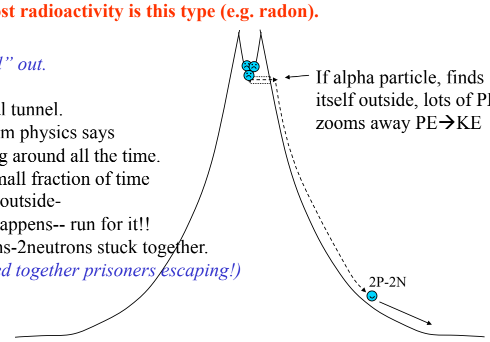
Nuclear decay- one kind of nucleus changes into another.
alpha decay, (beta decay), induced fission
a. alpha decay- alpha particle = 2p and 2n. They escape together. Most radioactivity is this type (e.g. radon).

"tunnel" out.

Not real tunnel.
Quantum physics says jumping around all the time.
Very small fraction of time appear outside-
when happens-- run for it!!
2protons-2neutrons stuck together.
(chained together prisoners escaping!)



If alpha particle, finds itself outside, lots of PE, zooms away PE→KE

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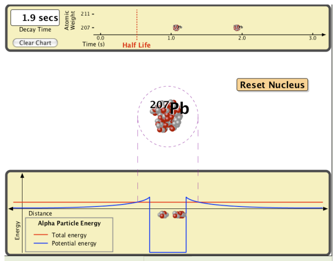
A useful simulation
alpha decay



http://phet.colorado.edu/simulations/sims.php?sim=Alpha_Decay

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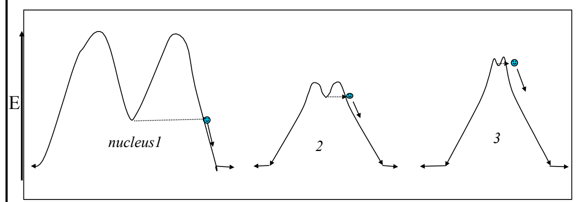
tunneling difficulty = width x depth of tunnel



How much energy released?
a. 1 most, 2 second, 3 least
b. 2 most, 1, 3 least
c. 3 most, 2, 1 least
d. 3 most, 1, 2 least

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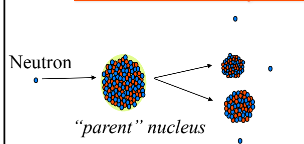
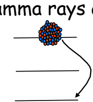
B. Radioactive decay-fission

Neutron Induced fission- key to atomic bombs



- *two smaller nuclei*
- *few extra free neutrons*
- ***LOTS OF ENERGY!!***
- *(+sometimes other bad stuff)*

"daughter" nuclei – come out in *excited* nuclear energy state
…. Give off gamma rays as drop to lower energy.



Jumps down in energy …
Gives off gamma ray…
VERY HIGH ENERGY PHOTON

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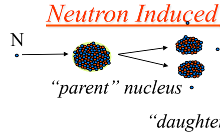
Neutron Induced fission- key to atomic bombs



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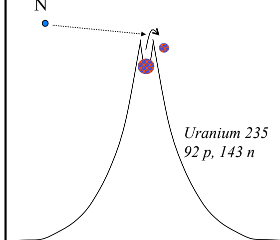

Neutron absorbed →
Excites U235 nucleus up above potential barrier →
Splits into two smaller nuclei…
which zoom apart due to electrostatic repulsion!

simulation

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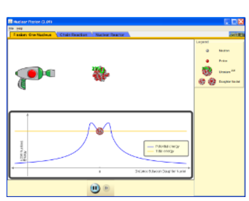
Another Sim
(because this is hard to do at home)



http://phet.colorado.edu/en/simulation/nuclear-fission

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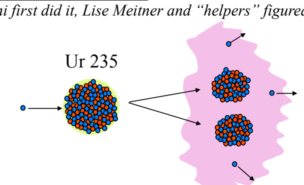
neutron induced fission
Fermi first did it, Lise Meitner and "helpers" figured out what was happening.



If don't get swallowed the 3 free neutrons can go induce more fission.

Chain reaction: neutrons making fission that makes more neutrons, that makes more fission that makes more neutrons, that makes more fission that makes more neutrons, that makes more fission that makes more neutrons, that makes more fission that makes more neutrons, that makes more

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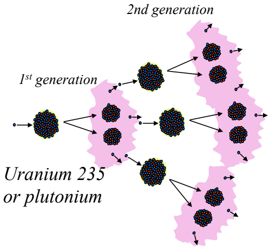
Fission Nuclear explosion
"atomic bomb"



Fission Nuclear explosion
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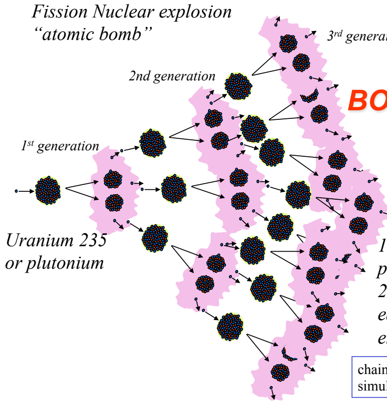
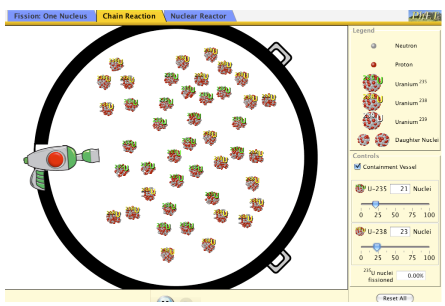


100 generations per microsecond!
*2 x 2 x 2 ….x2 fissions each with **LOTS** of energy.*

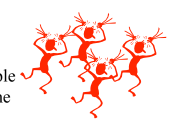
chain reaction simulation

A useful simulation

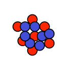


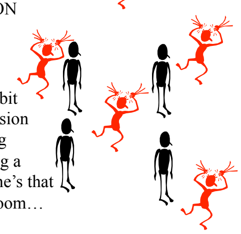
http://phet.colorado.edu/simulations/sims.php?sim=Nuclear_Fission

Stabilizing effect of neutrons in the nucleus … why do you need them?



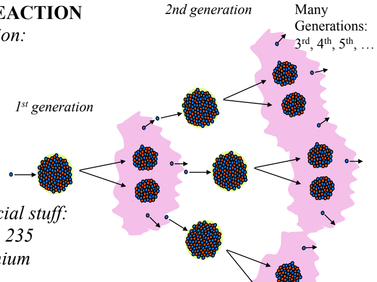
If only have big bunch of protons, proton repelling each other a whole bunch. Like putting a bunch of people who find each other repulsive in same room… UNSTABLE SITUATION



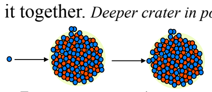


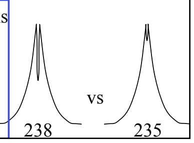
Add neutrons then space protons a bit away from each other, proton repulsion goes down a bit but still have strong nuclear binding forces. Like putting a bunch of neutral people between one's that find each other repulsive in same room… MORE STABLE SITUATION

BACK TO CHAIN REACTION
Fission Nuclear explosion:
"atomic bomb"

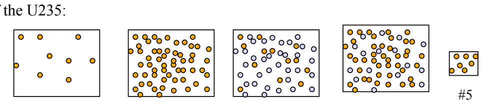


Why Ur 235 not 238? U 238 has 3 extra neutrons help hold it together. *Deeper crater in potential energy.*





U235 and U238 atoms are placed into a container, which are likely to result in a chain reaction (resulting in explosion) when a free neutron triggers fission of one of the U235:



a. #2 only
b. #1, #2, and #5
c. #2 and #4
d. #2, #3, and #4
e. #2, #4, and #5.

Lots of uranium in the ground… why not just blow up?