Nuclear Weapons (and Energy)

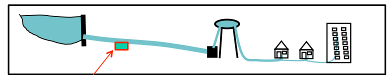
the how, the what … and why?

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

Reminders:
Ths: Nucl. Energy / Reactors
HW next Monday- email Paige&me!
Review next Tues
Exam Thurs

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)

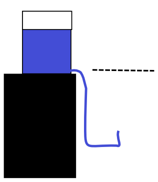
$PV + \frac{1}{2} \rho V v^2 + \rho V g h = E_{total}$

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

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

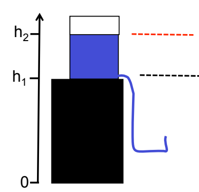
---

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. 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.

Think conservation of total energy per volume

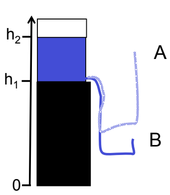
At top of tank: $E_{tpv} = \rho g h_2$

Water squirts out of hose and reaches highest point of flight:

$P = 0$, $v = 0$, height $= h_{top}$
$E_{tpv} = \rho g h_{top}$

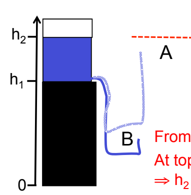
E_{tpv} the same everywhere
$\Rightarrow h_2 = h_{top}$

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.

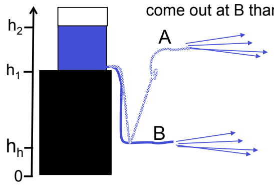
Here I have a tank of water with a hose connected to the bottom. When I take my finger off the hose, water (under pressure) will squirt into the air. I can hold the hose high (at A) or low (at B). From which location will the water squirt higher (relative to the ground)?



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

From previous question: $E_{tpv} = \rho g h_2$
At top of flight (after leaving hose) $E_{tpv} = \rho g h_{top}$ (all GPE)
$\Rightarrow h_2 = h_{top}$
The height of the hose end doesn't come into it
At A, water leaves hose slower, but starts higher
At B, water leaves hose faster, but starts lower
$\Rightarrow$Reach same max height
(Note: Friction may reduce h_{top} slightly below h_2)

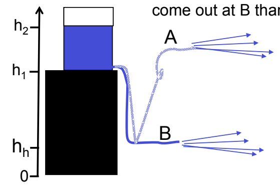
At A, the hose is 0.25 m below the water's surface. At B it is 1.0 m below. How much faster will the water come out at B than at A?



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?

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

$E_{tpv} = P + \frac{1}{2} \rho v^2 + \rho g h$

Consider water at surface of tank: $E_{tpv} = \rho g h_2$

Consider water leaving hose at height h_h : $E_{tpv} = \rho g h_h + \frac{1}{2} \rho v^2$

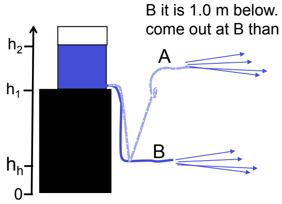
$\Rightarrow \rho g h_2 = \rho g h_h + 1/2 \rho v^2$

$\Rightarrow v^2 = 2g(h_2 - h_h)$

$\Rightarrow v \propto$ sqrt(drop from surface to hose)

If drop increases by factor of 4, v increases by factor of sqrt(4) = 2

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

Quick route:
- Think: This is all about conservation of energy
- PPE not involved

$\Rightarrow$ GPE lost per vol = KE gained per vol

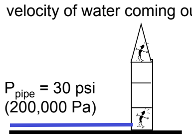
$\rho g h_{drop} = \frac{1}{2} \rho v^2$

$\Rightarrow v = \text{sqrt}(2 g h_{drop})$ as before

Where does the shower work best?

In the house below, water pressure on the 1st floor is 30 psi. What is the velocity of water coming out of the shower on the 1st floor?

P_{pipe} = 30 psi
(200,000 Pa)



a. 2 m/s,
b. 5 m/s,
c. 20 m/s,
d. 100 m/s,
e. 414 m/s

$P + \frac{1}{2} \rho v^2 + \rho g h = E_{tpv}$

Does h change on first floor?

$E_{tpv\ INSIDE} = E_{tpv\ OUTSIDE}$

ignore v inside pipe.

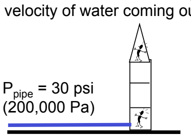
P (inside shower) $= \frac{1}{2} \rho v^2$

$\rho = 1000\ kg/m^3$

Where does the shower work best?

In the house below, water pressure on the 1st floor is 30 psi. What is the velocity of water coming out of the shower on the 1st floor?

P_{pipe} = 30 psi
(200,000 Pa)



a. 2 m/s,
b. 5 m/s,
c. 20 m/s,
d. 100 m/s,
e. 414 m/s

$P + \frac{1}{2} \rho v^2 + \rho g h = E_{tpv}$

Inside pipe: $P = P_{pipe}$, $v \approx 0$, set $h = 0$

$\Rightarrow E_{tpv} = P_{pipe}$

Just outside showerhead: $P = 0$, $h = 0$, $v = v_{shower}$

$\Rightarrow E_{tpv} = \frac{1}{2} \rho v_{shower}^2$

$P_{pipe} = \frac{1}{2} \rho v_{shower}^2$

$v_{shower} = \text{sqrt}(2P_{pipe}/\rho)$

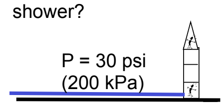
$= \text{sqrt}(2 \times 200{,}000/1000)$

$= 20 m/s$

Where does the shower work best?

Now in this same house, the 3rd floor shower is 10 m higher. What's the velocity of water at the 3rd floor shower?

P = 30 psi
(200 kPa)



a. 2 m/s, b. 5 m/s, c. 15 m/s, d. 20 m/s, e. 50 m/s

$P + \frac{1}{2} \rho v^2 + \rho g h = E_{tpv}$

Inside pipe on first floor: $P = P_{pipe}$, $v \approx 0$, set $h = 0$

$\Rightarrow E_{tpv} = P_{pipe}$

Just outside showerhead on 3rd floor: $P = 0$, $h = h_3 = 10m$, $v = v_{shower}$

$\Rightarrow E_{tpv} = \frac{1}{2} \rho v_{shower}^2 + \rho g h_3$

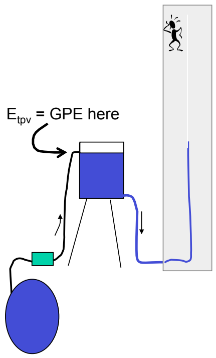
$P_{pipe} = \frac{1}{2} \rho v_{shower}^2 + \rho g h_3$

$\frac{1}{2} \rho v_{shower}^2 = P_{pipe} - \rho g h_3$

$v_{shower} = \text{sqrt}(2(P_{pipe} - \rho g h_3)/\rho)$

$= \text{sqrt}(2(200000 - 1000*9.8*10)/1000) = 14 m/s$

Water distribution in skyscrapers



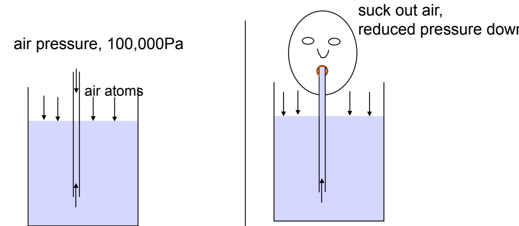
The skyscraper water problem:

- 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.

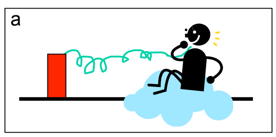
Straws



- The pressures up and down balance….

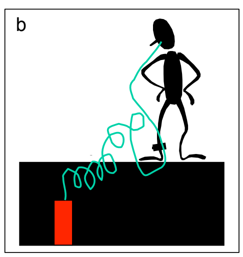
⇒ So there is no flow through straw.

- 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)



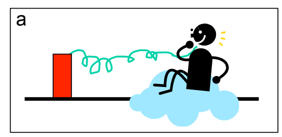
You suck on 30 foot straw.

a. sitting on floor
b. standing on desk



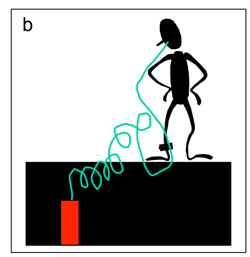
For you to suck up the red juice

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



You suck on 30 foot straw.

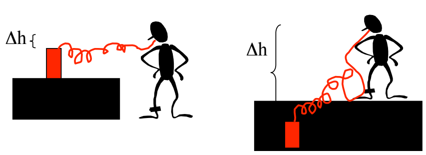
a. sitting on floor
b. standing on desk



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

b. suck less from floor



work = Fd= change in energy =mg(Δh),
Fd also = pressure (F/area) x volume (area x height).
So, bigger pressure needed.

LIKE RAMP, more distance up needs more work.

How can you figure this out using Bernoulli's equation?

Straw height and Bernoulli's Eqn.

(Go through on own)

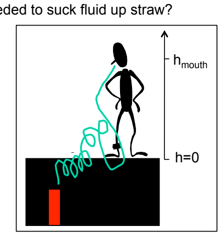
$P + \rho gh = E_{tpv}$ (KE term ~ 0 v is close to 0)

How to apply this to figure out what pressure is needed to suck fluid up straw?

Bottom of straw: P = 1atm, h = 0 (define)
E_{tpv} = 1atm (100,000Pa)

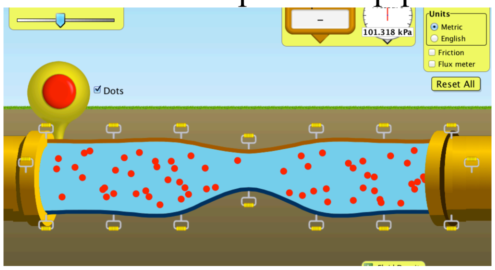
Top of straw: $P = 1\text{atm} - \Delta P_{suck}$, $h = h_{mouth}$
$E_{tpv} = (1\text{atm} - \Delta P_{suck}) + \rho g(h_{mouth})$

⇒ $1\text{atm} = (1\text{atm} - \Delta P_{suck}) + \rho g(h_{mouth})$
⇒ $\Delta P_{suck} = \rho g h_{mouth}$
⇒ The higher you stand the harder it is to suck fluid up the straw



Notice how P = 1 atm canceled from both sides. Always does so it's easiest to always just use P as difference from 1 atmosphere.
i.e. set zero of pressure at 1atm

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

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

*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*).

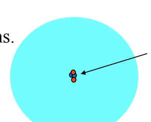
* *don't try this at home*

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**)

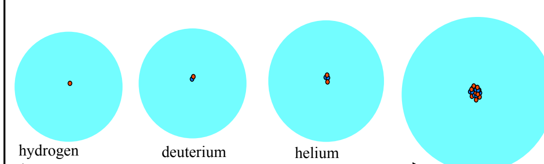
1. Mix protons and neutrons thoroughly.
2. Bake at 100 million degrees until sticks together to form solid dense nucleus (about .0000001 s).
3. Frost with lightly with fluffy layer of negative electrons.
4. *Chill before serving!*



atom size:
Radius of nucleus is 10,000 times smaller than nucleus-electron distance

Each element has different number of protons.

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



hydrogen 1 p
deuterium 1 p, 1n
helium 2 p, 2 n
Uranium 238 92 p, 146 n

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).

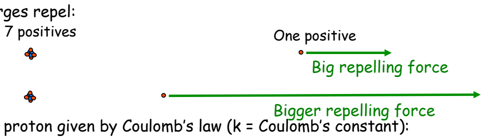
25

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:

What will we need to do to get proton stuck to nucleus:
b. the closer it gets, the harder you have to push, will take lots of work ... Lots of energy

Like charges repel:



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

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

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

The smaller the distance the larger the force!

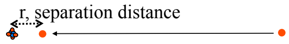
26

What if threw proton so starts out going towards nitrogen nucleus with a lot of speed (lots of kinetic energy)?

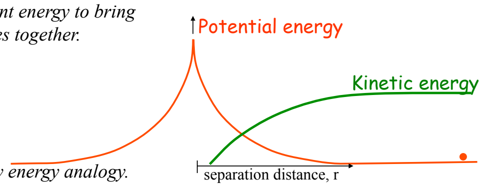
Starts with lots of kinetic energy →

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.

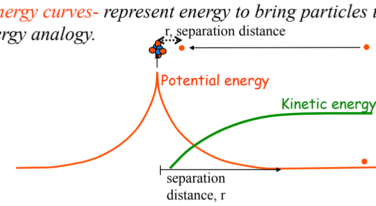


Gravity energy analogy.

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

27

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



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

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

So at 10^{-15} m away (~ radius of nucleus),

Potential energy = $\frac{8.99 \times 10^9 \text{ N m}^2/\text{C}^2 \times 11.2 \times 10^{-19} \text{ C} \times 1.6 \times 10^{-19} \text{ C}}{(10^{-15} \text{ m})}$

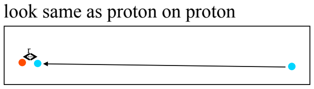
= 1.61×10^{-12} Joules = 10 million electron Volts.

(1 electron volt = energy gained by electron moving through 1 Volt diff.= 1.6×10^{-19} J)

28

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

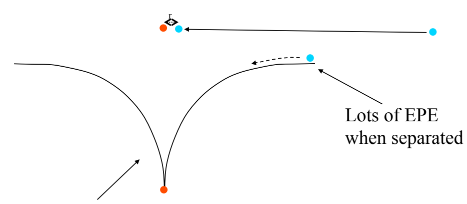


29

---

potential energy curve for bringing electron in to proton

b. look like proton on proton except upside down so going down.

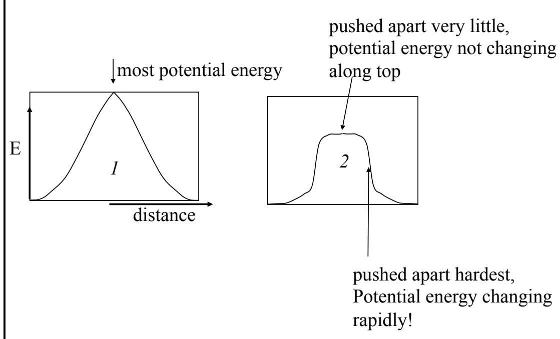


Electron and proton get pulled together,
curve tells us that must *add* energy to separate electron and proton.
electron wants to roll into center as close as possible.

What about a neutron? No electrostatic repulsion!

30

Analyzing shape of potential energy curves:



31

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

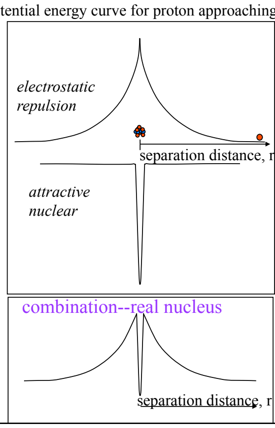
Like hopper toy- really strong **nuclear force** between protons and neutrons overwhelms electrical force if ***really*** close together.

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!

32

Potential energy curve for proton approaching nucleus



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

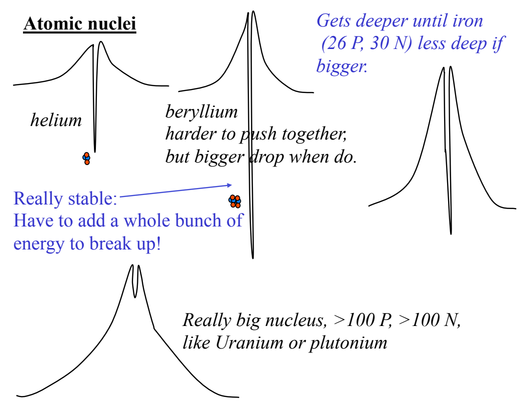
$$F = \frac{k\ (\text{charge of \#1})(\text{charge of \#2})}{r^2}$$

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!!!

33

Atomic nuclei



34

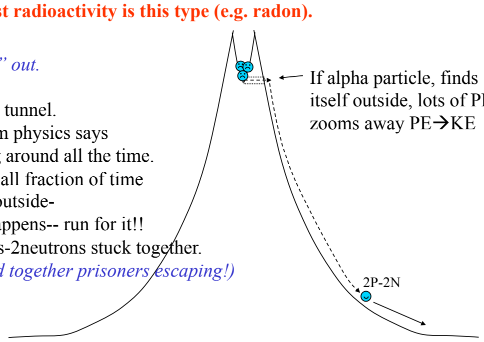
Nuclear decay- one kind of nucleus changes into another.
alpha decay, (beta decay), induced fission

A. alpha decay- alpha particle = 2p and 2n. They escape together. Most radioactivity is this type (e.g. radon).

"tunnel" out.

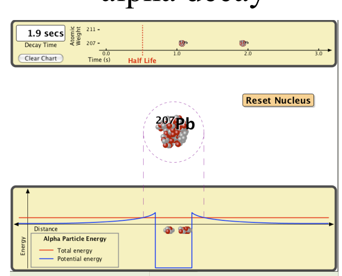
Not real tunnel.
Quantum physics says jumping around all the time.
Very small fraction of time appear outside-
when happens-- run for it!!
2protons-2neutrons stuck together.
(chained together prisoners escaping!)

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



35

A useful simulation alpha decay



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

36