

1. Notices

Notices

- M. Sherwin & K. Bird *American Prometheus* (bio of J.R. Oppenheimer) Pulitzer!

- Thursday 4:30

Tufts is having a panel on the Iran situation.

"Target: Iran? Teach-In"

sponsored by TCOWI

What is the reality and what are the myths behind Iran's nuclear program?

What are the real motives of the Bush administration?

What would a US attack mean for Iranians?

Gary Goldstein will be speaking about the nuclear issue. Modhumita Roy will talk about nuclear weapons in South Asia. Two or three grad students from the Middle East will be connecting to political issues. Given the heating up of the rhetoric and the Seymour Hersh article in the New Yorker about the build-up to war, this is an urgent issue for all of us.

- **What are the big ideas of the course?**

- Modern physics has effected how our contemporary world works
- Modern physics gives an understanding of how nature works (at many levels)

5/10/2006

Physics 6 - G.R. Goldstein - Spr. 03
- Spring 06 - G.R. Goldstein

1

(c) 2006, Gary R. Goldstein, Ph.D.

2. More details

More details

- 10 nsec for 1 generation (1 nsec = 1 nanosec = 10^{-9} sec)
- With neutron speed 10^7 m/s that is over
 $d=10^7$ m/s $\times 10^{-8}$ sec = 10^{-1} m = 10 cm or 4 inches
- ~1 microsec for 80 gens
or ~10 kT bomb
with critical mass ~10Kg
- See copy of part of chapter on assembling the bomb

Models of U235 -> Hiroshima
"little boy"
and Pu239 bombs->Nagasaki
"fat man"



Source: <http://www.luxi.gov.kit.gov/monishow/fat%20man.html>

5/25/2006

Physics 6 - Spring 06 - G.R. Goldstein

2

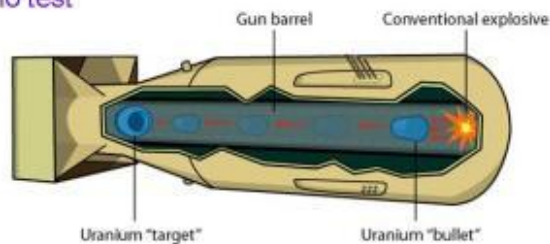
(c) 2006, Gary R. Goldstein, Ph.D.

3.

“Little boy”

“Little boy”

- Little boy ^{235}U
- Critical mass must be assembled in less time than spontaneous fission & minimize n loss
 - Sphere to minimize critical mass
 - Gun type trigger
 - Sure thing - no test



Source: http://en.wikipedia.org/wiki/Little_boy

5/25/2006

Physics 6 - Spring 06 - G.R. Goldstein

3

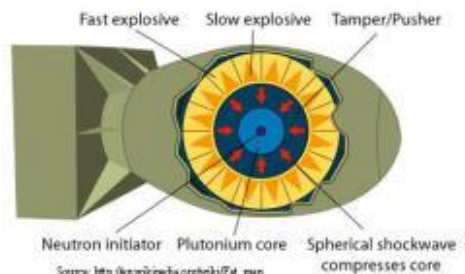
(c) 2006, Gary R. Goldstein, Ph.D.

4.

Fat man

Fat man

- Fat man ^{239}Pu from reactors (Hanford)
 - $n + {}_{92}^{238}\text{U} \rightarrow {}_{92}^{239}\text{U} \rightarrow {}_{93}^{239}\text{Np} + e + \nu$
 - ${}_{93}^{239}\text{Np} \rightarrow {}_{94}^{239}\text{Pu} + e + \nu$
- ^{239}Pu much faster spontaneous fission than ^{235}U
- Needs faster assembly to avoid fizzle
 - Implosion of sphere - subcritical with components
 - Compress to criticality, initiator, until internal P exceeds compression (80th gen) then disassembles
 - Very delicate technology needed testing



Source: http://en.wikipedia.org/wiki/Fat_man

5/25/2006

Physics 6 - Spring 06 - G.R. Goldstein

4

(c) 2006, Gary R. Goldstein, Ph.D.

5. Lecture 21: A-bombs and Effects: Slide 5

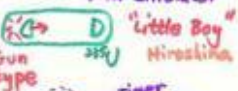
Fission Material


1. ^{235}U 0.7% vs ^{238}U 99.3%
fast fission vs *n absorption & slow fission* → ^{239}Pu

Enrichment to > 90% ^{235}U
Gaseous Diffusion (Oak Ridge) → Towers using gravity to separate minute amounts
 1st: Mining, Refining, Gasifying *goldbricks* → Recent switch to centrifuges (India, Pakistan, ...?)

2. ^{239}Pu *faster fission*
 1st: N. Reactor with 90% ^{235}U → Pu, (Hanford) → More sustainable production (Seaborg resigned)
 Removal, Chemical Separation

Triggering - Rapid Assembly of Critical Mass + n Initiator

1.  "Little Boy" *easy construction (no tests)* ⇒ ~14 kilotons (≈14,000 tons TNT) vs. ~20 Kg Uranium
 Gun type ^{235}U Hiroshima

2.  *very delicate construction (Alamogordo - Trinity Test)* ⇒ 21 kilotons ~ 100,000 - 200,000 deaths
 Implosion ^{239}Pu "Fat Man" Nagasaki

5/10/2006

Physics 6 - G.R. Goldstein - Spr.03Physics 6
 - Spring 06 - G.R. Goldstein

5

(c) 2006, Gary R. Goldstein, Ph.D.

6. Radiation and other effects

Radiation and other effects

- Blast - pressure & shock waves
 - Structures collapse & overpressure compresses objects
 - Debris propelled
 - Fatalities - crushes, collapses, collides - in seconds
- Burn - temperature of sun expanding outward
 - Expanding fireball
 - Burning structures & firestorms - fatalities over hours
- Radiation
 - alpha, beta, gamma & neutrons
 - Each has its own characteristics
 - Immediate: γ ~ seconds → radiation sickness
 - Intermediate: radionuclides ~ days
 - Fallout: radionuclides ~ weeks

All yield long term genetic damage, birth defects

5/10/2006

Physics 6 - G.R. Goldstein - Spr.03Physics 6
 - Spring 06 - G.R. Goldstein

6

(c) 2006, Gary R. Goldstein, Ph.D.

7. Nuclear decays

Nuclear decays

- α : $(Z,A) \rightarrow (Z-2,A-4) + {}_2^4\text{He}$
 - Strong or nuclear glue and quantum tunneling
- β : $(Z,A) \rightarrow (Z+1,A) + e^-$ also have $(Z-1,A) + e^+$
 - Weak and based on $n \rightarrow p + e^- + \bar{\nu}$ (*anti-neutrino*)
- γ : $(Z,A)^* \rightarrow (Z,A) + \gamma$
 - EM quantum transition
- N: $(Z,A) \rightarrow (Z,A-1) + n$
- Each with characteristic decay time and energy release (Q value)

5/10/2006

Physics 6 - G.R. Goldstein - Spr.03
- Spring 06 - G.R. Goldstein

7

(c) 2006, Gary R. Goldstein, Ph.D.

8. Radioactivity

Radioactivity

- All decays occur randomly - probability distribution characteristic of nuclide and decay products
- Activity = rate of decrease in time = $\underline{A}(t)$
- \underline{A} in units of Curies
 - 1 Curie = 3.7×10^{10} disintegrations/sec
 - or Becquerels (Bq) SI units
- $\underline{A} \propto N(t)$ (each decay is independent of others)
- How does $N(t)$ change in time?

5/10/2006

Physics 6 - G.R. Goldstein - Spr.03
- Spring 06 - G.R. Goldstein

8

(c) 2006, Gary R. Goldstein, Ph.D.

9. Exponential decay

Exponential decay

- $t_{1/2}$ is the half-life
- If N_0 at time 0, $N_0/2$ at $t_{1/2}$
 $N_0/4$ at $2 t_{1/2}$ $N_0/8$ at $3 t_{1/2}$ $N_0/16$ at $4 t_{1/2}$
or $N_0/2^n$ at time $n t_{1/2}$
- Exponential decay law for many phenomena, especially QM decays (and heat transfer)

$$N(t) = N_0 2^{-\left[\frac{t}{t_{1/2}}\right]} = N_0 e^{-\left(\frac{0.69 t}{t_{1/2}}\right)}$$

$$\text{Activity (Bq)} = \frac{0.69}{t_{1/2}} N(t) \quad \text{with } t \text{ in sec}$$

5/10/2006

Physics 6 - G.R. Goldstein - Spr.03
- Spring 06 - G.R. Goldstein

9

(c) 2006, Gary R. Goldstein, Ph.D.

10. Decay examples

Decay examples

NUCLEUS	ATOMIC WEIGHT	HALF LIFE	DECAY PRODUCTS
• Ra	226	1602 years	alpha, gamma (4%)
• C	14	5730 years	beta
• Sr	90	28 years	beta
• ³ H	3	12.3 yr	beta
• I	131	8 days	beta, gamma
• Cs	137	30 yr	beta, gamma
• Rn	222	3.8 days	alpha, gamma (0.1%)
• U	238	4.50 x 10 ⁹ yr	alpha, gamma (23%)
• U	235	7.0 x 10 ⁸ yr	alpha, gamma
• Pu	239	24,400 yr	alpha

5/10/2006

Physics 6 - G.R. Goldstein - Spr.03
- Spring 06 - G.R. Goldstein

10

(c) 2006, Gary R. Goldstein, Ph.D.