Physics 180

Nuclear Weapons, Nuclear War, and Arms Control

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Midterm Examination Answers
1997 March 10

Name _____

ID No. _____

- This is a closed book examination of 50 minutes duration.
- Answer all 5 questions. All count equally (20 points each).
- Write your answers in the space provided on these pages. If you need more room, write on the back of the page. For full credit on definitions, give numbers where appropriate.

SCORES

1. 20
2. 20
3. 20
4. 20
5. 20

TOTAL 100

1. Nuclear physics

Define *nuclear fission*. [5 points]

Nuclear fission is the breakup of a heavy nucleus, such as uranium, into two medium-weight nuclei. Fission is usually accompanied by emission of a few neutrons and γ-rays.

Define *fissile nuclide* and name two. [5 points]

A fissile nuclide has some probability of being fissioned by a neutron of any energy. [A non-fissile but fissionable nuclide can only be caused to fission by neutrons with energies above the fission threshold energy.] Three fissile nuclides relevant to the course are U-233, U-235, and Pu-239. [Full credit given for listing any two of these nuclides.]

Define *critical mass*. Explain the difference between an assembly that is *prompt critical* and one that is *delayed critical*. What is the prompt critical mass of a bare sphere of 100% Pu-239? [5 points]

A critical mass is the smallest mass of an element that can sustain a neutron chain reaction. An assembly that is prompt critical can sustain a neutron chain reaction using only the ~ 99.3% of neutrons that are emitted promptly when a nucleus fissions. An assembly that is delayed critical is subcritical when only prompt neutrons are counted but is critical when the delayed neutrons that are later emitted from the fission fragments (~ 0.007% of the total) are counted. The critical mass of a bare sphere of Pu-239 is about 10 kg (22 lb).

What is the difference between reactor-grade and weapon-grade plutonium? Can a weapon made of reactor-grade plutonium be made to explode? [5 points]

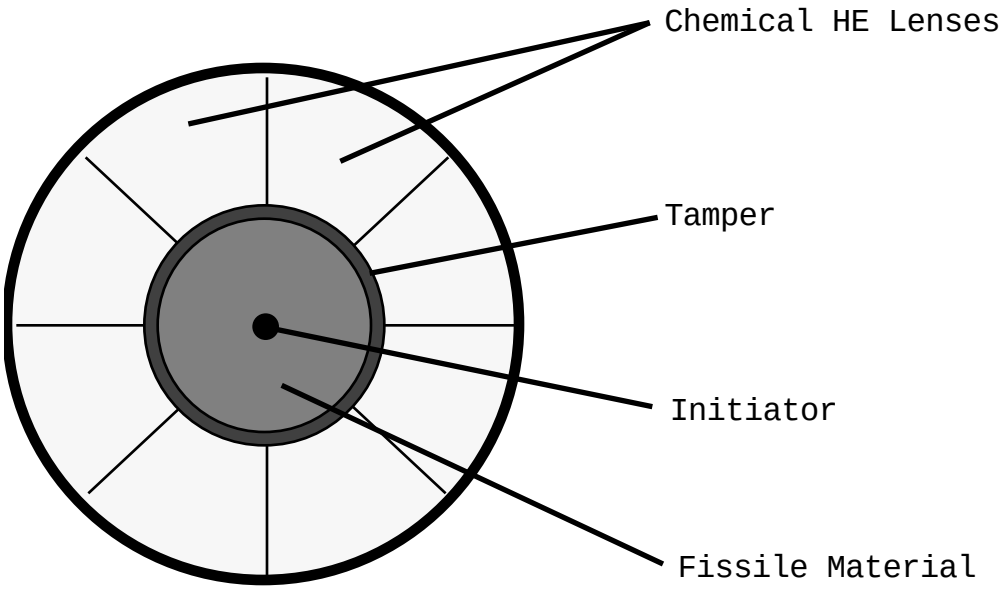
Reactor-grade [high burn-up] plutonium contains more of the isotopes Pu-240, Pu-241, and Pu-242 than does weapon-grade plutonium. [Full credit given for listing Pu-240 alone.] Yes, reactor-grade plutonium can be made to explode.

2. Fission Weapons

a) Shown here is a schematic diagram of an unboosted, implosion-type fission weapon. Indicate on the diagram the locations of the following key components:

- Initiator
- Chemical high explosive lenses
- Weapon-grade fissile material
- Tamper

[8 points]



b) Describe briefly the roles of each of these four components. [12 points]

Initiator: Provides neutrons at the instant of maximum compression to assure that the chain reaction will be initiated then.

Chemical high explosive lenses: Create a focused shock wave that compresses the fissile material, causing it to go critical.

Weapon-grade fissile material: Provides energy and further neutrons when fission reaction is started by the initiator. The nuclear 'fuel' of the weapon.

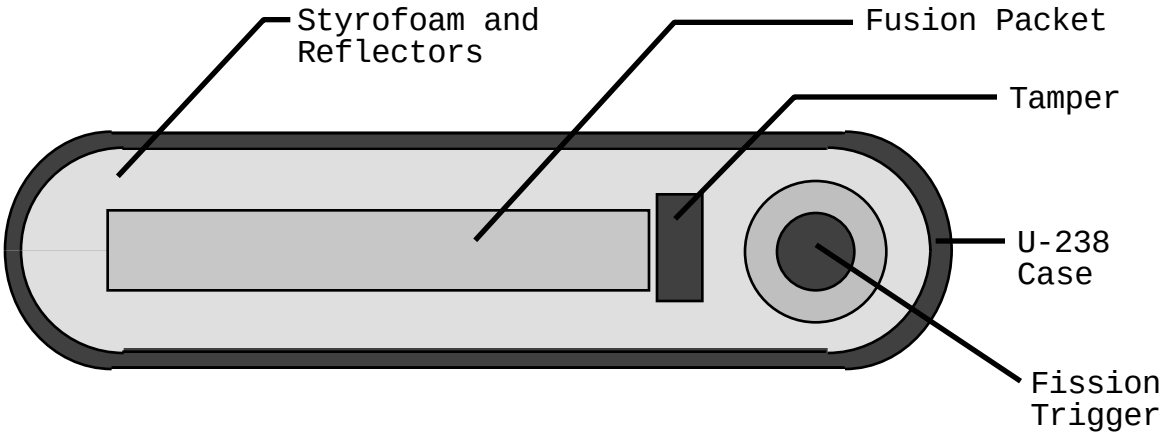
Tamper: Reflects neutrons back into the fissile material and helps (by its inertia) to keep the fissile material together, thus increasing the percentage of the material that fissions.

3. Thermonuclear Weapons

a) Shown here is a schematic diagram of a standard thermonuclear weapon. Indicate on the diagram the locations of the following key components:

- ^{6}LiD fusion packet
- U-238 case
- Fission trigger
- Tamper
- Styrofoam and reflectors

[10 points]



b) Describe briefly the roles of each of these five components. [10 points]

^{6}LiD fusion packet: The thermonuclear 'fuel' of the weapon. When exposed to neutrons, the ^{6}Li acts as a 'catalyst', providing more neutrons and tritium to fuse with the deuterium (D), releasing energy.

U-238 case: Has two purposes: holds the weapon together, increasing the yield of the fusion packet; fissions when exposed to the intense neutron flux from the fusion reactions, adding to the fission yield of the weapon.

Fission trigger: Provides the X- and γ-rays that compress and heat the fusion packet, causing the thermonuclear reaction to go.

Tamper: Slows propagation of the debris and shock wave from the fission trigger into the fusion packet, allowing the fusion reaction to proceed for some time before the fusion packet is disrupted.

Styrofoam and reflectors: Styrofoam holds the fusion packet in place and, when exposed to the X- and γ-rays from the fission trigger, creates a high-pressure plasma that helps to compress the fusion packet. Reflectors direct X- and γ-rays onto the surface of the fusion packet.

4. ICBMs

6. a) List the four phases in the flight of a MIRVed ICBM and indicate the approximate duration of each in minutes. [8 points]

	PHASE	DURATION (MINUTES)
i)	Boost	1-5
ii)	Post-boost [or bus]	5
iii)	Midcourse	20
iv)	Terminal	0.5-1

b) What is the approximate flight time in minutes for U.S. ICBMs to typical targets in the Soviet Union? If one was launched in error, could the U.S. do anything to prevent its warheads from exploding? [4 points]

30 minutes. No.

c) Define the terms *circular error probable* (CEP) and *bias* as used in discussions of ICBM warhead accuracy. [8 points]

CEP: The radius of a circle that encloses half (and only half) of the impact points of the RVs.

Bias: The distance between the aimpoint and the center of the distribution of RV impact points.

5. Acronyms

Translate *and briefly explain* the following acronyms: [4 points each]

ICBM—Intercontinental ballistic missile: A missile capable of striking targets at intercontinental distances, usually defined as distances of 5500 km or more.

MIRV—Multiple independently-targetable reentry vehicle: Configuration of a ballistic missile payload to carry multiple reentry vehicles, each of which can be aimed at a different target.

SSBN—Nuclear-powered submarine carrying ballistic missiles.

ALCM—Air-launched cruise missile. An air-breathing, [turbofan-powered] missile that can be launched from an airplane [usually a bomber]. [A cruise missile may be armed with a conventional (chemical) warhead or nuclear warhead.]

C^3I—Communications, command, control, and intelligence. The human and hardware components of the nuclear attack warning system and the nuclear strike command and control system.