

Last Name: \_\_\_\_\_ First Name \_\_\_\_\_ Network-ID \_\_\_\_\_

Writing Lab Section: \_\_\_\_\_ Writing Lab TA Name: \_\_\_\_\_

**Turn off your cell phone and put it out of sight.**

**Calculators cannot be used.**

**This is a closed book exam. You have eighty (80) minutes to complete it.**

1. Use a #2 pencil. Do not use a mechanical pencil or pen. Darken each circle completely, but stay within the boundary. If you decide to change an answer, erase vigorously; the scanner sometimes registers incompletely erased marks as intended answers; this can adversely affect your grade. Light marks or marks extending outside the circle may be read improperly by the scanner. Be especially careful that your mark covers the **center** of its circle.
2. **This Exam Booklet is Version A.** Mark the **A** circle in the **TEST FORM** box near the middle of your answer sheet. **DO THIS NOW!**
3. Print your **NETWORK ID** in the designated spaces at the *right* side of the answer sheet, starting in the left most column, then **mark the corresponding circle** below each character. If there is a letter "o" in your NetID, be sure to mark the "o" circle and not the circle for the digit zero. If and only if there is a hyphen "-" in your NetID, mark the hyphen circle at the bottom of the column. When you have finished marking the circles corresponding to your NetID, check particularly that you have not marked two circles in any one of the columns.
4. Print **YOUR LAST NAME** in the designated spaces at the *left* side of the answer sheet, then mark the corresponding circle below each letter. Do the same for your **FIRST NAME INITIAL**.
5. Do not write in or mark the circles in any of the other boxes (STUDENT NUMBER, DATE, SECTION, SCORES, SPECIAL CODE).
6. Sign your name (**DO NOT PRINT**) on the **STUDENT SIGNATURE line**.
7. On the **SECTION line**, print your **Writing Lab Section**. You need not fill in the **COURSE** or **INSTRUCTOR** lines.

*Before starting work, check to make sure that your test booklet is complete. You should have **18 numbered pages**.*

**Academic Integrity—Giving assistance to or receiving assistance from another student or using unauthorized materials during a University Examination can be grounds for disciplinary action, up to and including dismissal from the University.**

*Exam Grading Policy—*

The exam consists of 62 questions, worth a total of **291** points, composed of 4 types of questions and an essay.

**Rules for partial credit**

**Note: there will be no partial credit for problems with multiple correct answers. These problems are marked and all correct answers need to be marked correctly on the answer sheet in order to obtain credit.**

**MC5:** *multiple-choice-five-answer questions, each worth 6 points.*

**Partial credit will be granted as follows.**

- (a) If you mark only one answer and it is the correct answer, you earn **6** points.
- (b) If you mark *two* answers, one of which is the correct answer, you earn **3** points.
- (c) If you mark *three* answers, one of which is the correct answer, you earn **2** points.
- (d) If you mark no answers or the wrong answer, or more than *three*, you earn **0** points.

**MC4:** *multiple-choice-four-answer questions, each worth 4 points.*

**Partial credit will be granted as follows.**

- (a) If you mark only one answer and it is the correct answer, you earn **4** points.
- (b) If you mark *two* answers, one of which is the correct answer, you earn **2** points.
- (c) If you mark a wrong answer or no answers or more than two, you earn **0** points.

**MC3:** *multiple-choice-three-answer questions, each worth 3 points.*

**No partial credit.**

- (a) If you mark only one answer and it is the correct answer, you earn **3** points.
- (b) If you mark a wrong answer or no answers, you earn **0** points.

**MC2:** *multiple-choice-two-answer questions, each worth 2 points.*

**No partial credit.**

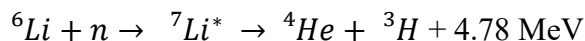
- (a) If you mark only one answer and it is the correct answer, you earn **2** points.
- (b) If you mark the wrong answer or neither answer, you earn **0** points

**A. Nuclear Physics**

- 1) Order the given fundamental forces by their relative strength (STRONGEST to WEAKEST):

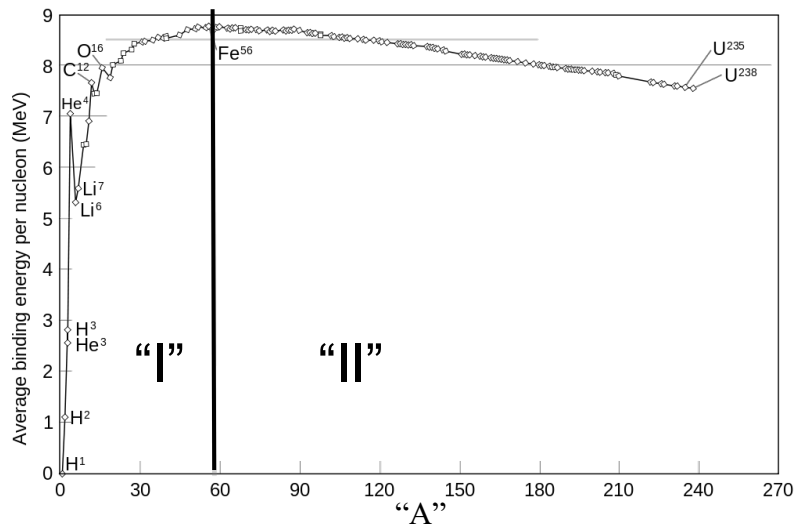
Electromagnetic (EM), Strong (S), Gravitational (G)

- A. EM, S, G
  - B. S, G, EM
  - C. G, S, EM
  - D. S, EM, G
- 2) Lithium-6 is used as part of the fusion packet for a thermonuclear weapon. Which product of the reaction is most important for the fusion reaction involving deuterium?



- A.  ${}^7\text{Li}^*$
  - B.  ${}^4\text{He}$
  - C.  ${}^3\text{H}$
  - D. 4.78 MeV
- 3) What isotope of uranium is most common in nature?
- A. U-235
  - B. U-238
  - C. U-233
  - D. U-239
- 4) The nuclide  ${}^{137}_{55}\text{Cs}$  has...
- A. 137 neutrons and 55 protons
  - B. 55 neutrons 82 protons
  - C. 55 neutrons and 137 protons
  - D. 82 neutrons and 55 protons
- 5) What isotope is formed if U-238 absorbs a neutron then undergoes double beta-decay?
- A. Pu-239
  - B. U-235
  - C. Pu-238
  - D. U-239
- 6) Nuclear binding energies compared to chemical binding energies are larger by a factor
- A. 100
  - B. 1,000
  - C. 100,000
  - D. 1,000,000

Use the graph of binding energies to answer questions 7-8.



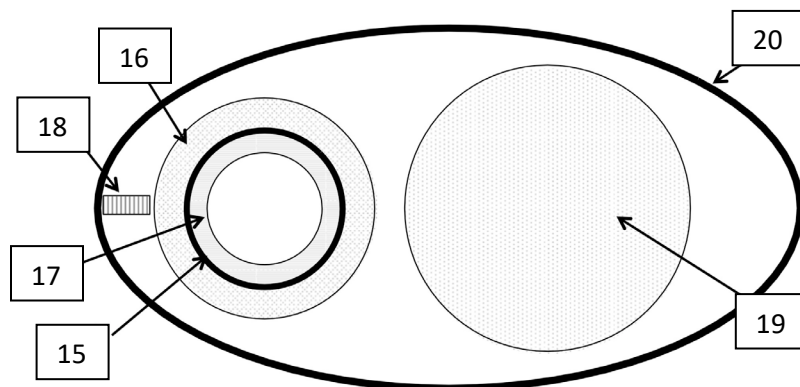
- 7) The region of the binding energy graph where **FUSION** can occur is...
- A. region "I" at small values of A      C. regions "I" and "II"  
 B. region "II" at large values of A      D. binding energy is not related to fusion
- 8) The region of the binding energy graph where **FISSION** can occur is...
- A. region "I" at small values of A      C. regions "I" and "II"  
 B. region "II" at large values of A      D. binding energy is not related to fission

### B. Nuclear weapons

- 9) Which statement most accurately describes how a supercritical assembly is formed in a gun-type weapon?
- A. A HEU bullet is fired into a hollow HEU cylinder  
 B. Two cylindrical HEU bullets are simultaneously fired at one another  
 C. A hollow HEU cylinder is fired onto a HEU target  
 D. A HEU sphere is compressed using conventional explosives
- 10) For potential weapon makers with limited relevant knowledge and technical skills, the gun-type design using HEU is advantageous because...
- [mark all correct answers]**
- A. The design and implementation is simpler than the implosion type  
 B. Less HEU is needed than weapons-grade plutonium  
 C. HEU has negligible heat generation  
 D. HEU has weak radioactivity  
 E. HEU can be chemically extracted from nuclear waste

- 11) Only Pu-239 can be used to create an implosion-type nuclear weapon.
- A. True
  - B. False
- 12) What is one reason reactor-grade plutonium complicates weapons-design?
- A. Reactor-grade plutonium is heavier because of the larger mixture of plutonium isotopes making it difficult to move
  - B. Pre-initiation is relatively low, preventing full yield
  - C. Pu-240 has a high rate of spontaneous fission, creating background neutrons
- 13) Assembly in an implosion-type weapon takes
- A. A fraction of a millisecond
  - B. Several milliseconds
  - C. One second

Use the diagram below to answer questions 14-20.



- 14) What device does the above diagram depict?
- A. Thermonuclear Weapon
  - B. Implosion Weapon
  - C. Gun-Type Weapon

**Questions 15-20** Match the weapon components identified by numbers in the figure above, 15-20, with the correct answer keys, A-E and AB, provided in the list below. The key “AB” requires you to bubble both answers A and B. [2 points each]

- A. Neutron-emitting initiator
- B. High-explosive lens assembly
- C. Tamper/reflector
- D. Hollow “pit”
- E. DU (depleted uranium) shell
- AB. Fusion packet

21) What is the theoretical maximum yield of the weapon shown in the above diagram?

- A. 100 kiloton
- B. 1 Megaton
- C. 100 Megatons
- D. None exists

### C. Current events and reading assignments

22) The Non-Proliferation Treaty (NPT) recognizes as legitimate the nuclear arsenals of the following states [**mark all correct answers**]:

- A. France
- B. India
- C. China
- D. Israel
- E. Russia

23) Which of the following is **NOT** true about “A Different Kind of Complex: The Future of U.S. Nuclear Weapons and the Nuclear Weapons Enterprise” by Richard Garwin:

- A. The author argues that improving the security of highly enriched uranium and plutonium against theft and detonation should be an essential pillar of the Reliable Replacement Warhead (RRW) program.
- B. The author argues that the US should increase its nuclear warheads in case of a potential attack from other nuclear powers and/or non-state actors.
- C. The author argues that the US should play a leading role in preventing nuclear proliferation by committing to eliminate nuclear explosive tests and reduce nuclear weapons and weapons-usable materials.

- 24) *The Day After Midnight* discusses the casualties and economic damage that would likely result from different types of attacks in a confrontation between the United States and the Soviet Union. Regardless of the scenario, which pattern did the authors expect to see?
- A. The Soviet Union would suffer more economic damage but a lower number of casualties.
  - B. The Soviet Union would suffer less economic damage and a lower number of casualties.
  - C. The Soviet Union would suffer more economic damage and a higher number of casualties.
  - D. The Soviet Union would suffer less economic damage but a higher number of casualties.
- 25) According to "The Hidden Travels of the Bomb," why have so few nations developed nuclear weapons?
- A. Mastering the technology to design and build a bomb is prohibitively difficult.
  - B. Very few states ever considered nuclear weapons to be a useful addition to their military arsenal.
  - C. No states have been able to develop sufficient technology for enrichment, production, and weapon design without help from another state that already had nuclear weapons.
  - D. No nuclear states were willing to divulge information about their nuclear programs, so each potential nuclear state had to work through the science of enrichment, production, and weapon design on their own.
- 26) Which of the following statements explains the current developments regarding Iran's nuclear weapons program best?
- A. Iran pulled out of the Joint Comprehensive Plan of Action (Iran's deal with major nuclear powers) upon the US withdrawal from the deal.
  - B. Iran is implementing its commitments under the Joint Comprehensive Plan of Action (Iran's deal with major nuclear powers) despite the US pulled out of the deal.
  - C. Iran is violating the rules of the Joint Comprehensive Plan of Action (Iran's deal with major nuclear powers) despite the US fulfilling its commitments.
  - D. Iran is trying to renegotiate the rules of the Joint Comprehensive Plan of Action with major nuclear powers to be able to develop its nuclear program further.

- 27) Which of the following statements explains the current developments regarding the relationship between the US and Russia on nuclear weapons?
- A. Both the US and Russia suspended their Intermediate-range Nuclear Forces (INF) Treaty and started testing nuclear-capable missiles.
  - B. The US keeps its commitments to Russia under the Intermediate-range Nuclear Forces (INF) Treaty while Russia has violated the INF Treaty.
  - C. Russia keeps its commitments to the US under the Intermediate-range Nuclear Forces (INF) Treaty while the US has violated the INF Treaty.
- 28) Which of the following statements explains the current developments regarding the relationship between the US and North Korea on nuclear weapons?
- A. The US and North Korea agreed on the general terms of a nuclear deal but are still negotiating on some conditions.
  - B. The 2019 North Korea–United States Hanoi Summit on nuclear weapons broke down, and the Trump administration threatened North Korea with starting a nuclear war.
  - C. The 2019 North Korea–United States Hanoi Summit on nuclear weapons broke down, and the Trump administration threatened North Korea with new sanctions.
  - D. The US and North Korea agreed on a nuclear deal during the 2019 Hanoi Summit.
- 29) Which of the following statements explains the current developments regarding the relationship between Germany and the US on nuclear weapons?
- A. Germany is reconsidering the nuclear-sharing agreement which allows the US to use German warplanes to launch nuclear weapons.
  - B. The US withdrew from its nuclear-sharing agreement with Germany and is considering to implement sanctions on Germany.
  - C. The US wants to strengthen the terms of the nuclear-sharing agreement which allows the US to use German warplanes to launch nuclear weapons.
  - D. Germany pulled out of the nuclear-sharing agreement which allows the US to use German warplanes to launch nuclear weapons.

#### **D. Nuclear weapon delivery methods**

- 30) The Chinese Silkworm cruise missile has a range of 180 miles. What does this range suggest?
- A. The Chinese have not succeeded of designing an accurate weapon with a longer range.
  - B. The Chinese perceive an enemy navy as a significant threat and this range is sufficient to destroy an enemy carrier group.
  - C. Designed after the Sino-Soviet Split, 180 miles is the distance between the silos in Altay, China and the Soviet Severnaya Satellite Station.
  - D. Chinese nuclear weapons are too heavy and limit the range of all Chinese missiles.



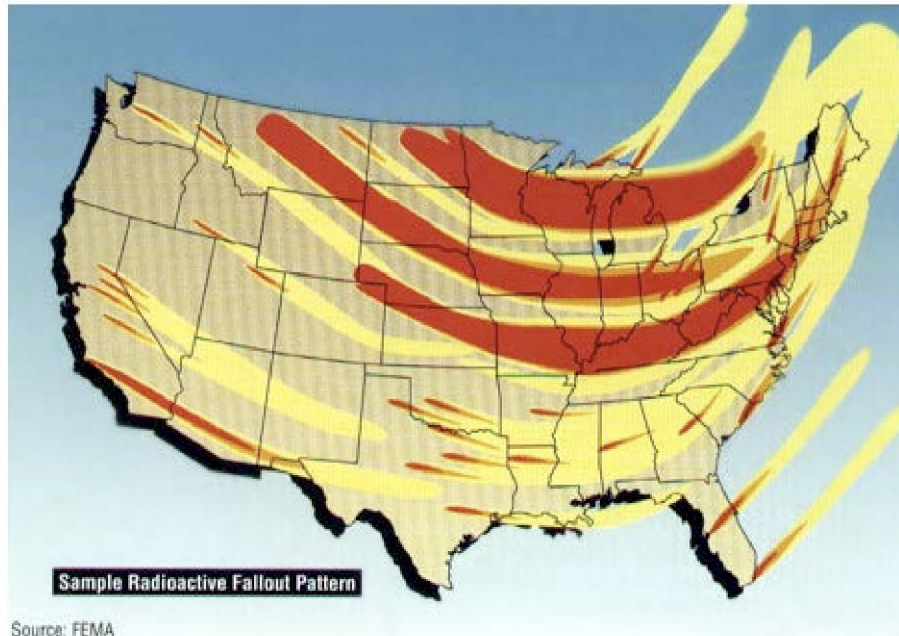
- 31) What is the primary difference between a hot and cold launch for a missile?
- A. A hot launch refers to procedures used to launch missiles in warm climates like Guam, whereas cold launches are used for Alaskan silos.
  - B. A hot launch occurs from a moving vehicle like an airplane or submarine, while a cold launch occurs from a stationary location like a silo.
  - C. A hot launch requires rocket engines to start within a silo, while a cold launch is initiated by a high-pressure ejection, and then activation of engines.
  - D. A hot launch is initiated by a high-pressure ejection, and then activation of engines, while a cold launch requires rocket engines to start within a silo.
- 32) The Special Atomic Demolition Munition is a small (less than 1kt), man-portable nuclear device designed to be used by US Army engineers in the event of a Soviet invasion of Europe. In this scenario, which of these would be effective uses of this delivery system?  
**[Mark all correct answers]**
- A. Knocking out strategic choke points such as bridges or tunnels to slow the Soviet advance.
  - B. Destroying Soviet cities as part of a nuclear retaliation by NATO.
  - C. Destroying power plants as part of a scorched-earth policy.
  - D. Battlefield use in support of troops against superior conventional forces.
- 33) What nation deploys its entire nuclear arsenal in the form of submarine-launched ballistic missiles?
- A. France
  - B. Russia
  - C. The United States
  - D. The United Kingdom
  - E. Japan
- 34) This Soviet missile design, based on the German V2, is the basis for many other nation's missiles.
- A. "November Rain" / N-12
  - B. "Scud" / R-11
  - C. "Big Ivan" / BM-2
  - D. "Hammer" / USSR-2

- 35) What bomber was converted to be incapable of delivering nuclear weapons as part of the START Treaty?
- A. B-1B
  - B. B-2
  - C. B-52
  - D. Tu-95
  - E. Tu-160
- 36) What is the correct order of missiles from shortest range to longest range?
- A. SRBM, IRBM, ICBM
  - B. ICBM, IRBM, SRBM
  - C. IRBM, ICBM, SRBM
- 37) What technological advance made cruise missiles militarily useful?
- A. Smaller and lighter nuclear warheads
  - B. Efficient turbofan engines
  - C. Highly capable miniaturized computers
  - D. GPS and TERCOM
  - E. All of the above

### E. Nuclear Explosions

- 38) A nuclear attack on a country would lift soot into the atmosphere, screening the sunlight and reducing surface temperatures on Earth. How long would it take for half of the soot to fall out of the atmosphere?
- A. 5 months
  - B. 1 year
  - C. 5 years
  - D. 100 years
- 39) Deep underground nuclear tests can be detected through the monitoring of:  
**[Mark all correct answers]**
- A. The release of radioactive noble gases
  - B. Irregular seismic activity
  - C. The development of cracks in the Earth's surface
  - D. Deep underground nuclear tests cannot be detected
  - E. Detection of low frequency acoustic signals
- 40) Which of the following is **not** true about a nuclear explosion after *one microsecond*?
- A. Essentially all of the energy has been liberated
  - B. Vaporized weapon debris has moved only ~1 meter
  - C. The majority of the energy is contained in the blast wave
  - D. Temperature of the debris is  $\sim 10^7$  C (approximately the temperature at center of Sun)

Questions 41-42 refer to the map below:



- 41) Using the above map, where should the U.S. have placed its missile silos to minimize the effects from residual nuclear radiation for its citizens?
- A. Northeastern U.S. (Vermont, New Hampshire, Maine)
  - B. Central U.S. (South Dakota, Nebraska, Kansas)
  - C. Southern U.S. (Arkansas, Louisiana, Mississippi)
  - D. Northwestern U.S. (Washington, Oregon, Idaho)
- 42) Using the above map, where in the U.S. should one live to reduce the health effects of fallout in the case of a nuclear attack?
- A. Northeast U.S.
  - B. Southeast U.S.
  - C. Northwest U.S.
  - D. Southwest U.S.
- 43) According to Toon, Robock, and Turco, the indirect effects of a nuclear war would be more important than the direct effects.
- A. True
  - B. False
- 44) In which of the following test environments did the United States discover the effects of the EMP (Electromagnetic Pulse) following a nuclear explosion?
- A. Explosions underground
  - B. Explosions at high altitudes
  - C. Underwater bursts
  - D. Air and surface bursts

45) Which of the following statements are correct for a 100 kT explosion?

**[mark all correct answers]**

- A. Surface burst produces greater fallout than an airburst
- B. The fireball touches the ground unless HOB > 3000ft
- C. For underground bursts, seismic waves caused by the explosion can be detected even at large distances
- D. If tested at a sufficient depth, an underground nuclear weapon test can be carried out undetected
- E. For a fully contained (no venting) underground nuclear explosion, no radioactivity (except noble gases) is released

#### **F. Terrorism and its characteristics**

46) Has a country ever lost a nuclear weapon?

- A. Yes
- B. No
- C. We don't know

47) Which of the following is known to contain radioactive isotopes and trigger radiological false alarms by less advanced portal monitors?

- A. Lithium-ion batteries
- B. Cat litter
- C. Fire extinguishers
- D. Canned tuna

48) Which European nation does not have weapons-usable nuclear materials?

- A. Italy
- B. Scotland
- C. Switzerland
- D. Spain

49) Which of the following is NOT a defining characteristic of terrorism?

- A. The act must be violent or threaten violence
- B. The violence must be against civilians
- C. The individual victims must be randomly chosen
- D. The violence must be deliberate
- E. The violence must have a political purpose

- 50) Which of the following could be used to create an implosion-type bomb?
- A. 5 kg of HEU
  - B. 5 kg of Spent Fuel from Clinton Power Station
  - C. 5 kg of Pu
  - D. 5 kg of Natural Uranium
- 51) Smuggling a nuclear device through a shipping container is often mentioned as a viable tactic for terrorist groups. What percentage of shipping containers are inspected carefully that enter the United States?
- A. 2%
  - B. 6%
  - C. 25%
  - D. 60%
- 52) Which of the following is not one of the “lethal triple cocktail” of factors that Richardson argues leads to terrorism?
- A. Extreme poverty
  - B. A disaffected individual
  - C. A legitimizing ideology
  - D. An enabling community
- 53) In the award-winning docudrama “Last Best Chance” shown in class, although the border guard scanned the cargo with a radiation detector, he failed to detect the nuclear bomb. Why?
- A. The nuclear bomb was likely shielded by a material like lead
  - B. The detector was not powerful enough to detect the nuclear bomb
  - C. The border guard did not know how to properly use the device
  - D. Fissile material in warheads are not detectable by portable radiation detector

### G. Nuclear materials

- 54) What neutron multiplication factor (  $R$  ) is required for the nuclear material configuration to be considered critical?
- A.  $R < 0$
  - B.  $R = 0$
  - C.  $0 < R < 1$
  - D.  $R = 1$
  - E.  $R > 1$

- 55) Identify the two most common fissile isotopes used for making fission weapons
- A. U-235 and Pu-239
  - B. Th-232 and Pu-239
  - C. U-238 and Pu-239
  - D. U-238 and Pu-240
  - E. U-235 and Pu-238
- 56) All techniques for enriching uranium depend on
- A. The mass difference between uranium isotopes
  - B. The binding energy per nuclear difference between uranium isotopes
  - C. How different uranium isotopes behave in a magnetic field
  - D. How different uranium isotopes behave in an electric field
  - E. How different uranium isotopes behave chemically
- 57) Which would not influence the amount of nuclear explosive material needed to assemble a critical mass?
- A. Geometry of the NEM
  - B. Purity of the nuclear explosive isotope in the NEM
  - C. Presence of an additional redundant neutron initiator
  - D. Presence of a neutron reflector surrounding the NEM
  - E. Density of the NEM
- 58) Nuclear reactors require nuclides that are fissionable
- A. True because fissionable nuclides can be fissioned by neutrons of any energy and are needed in order for a sustainable fission chain reaction to occur
  - B. True because fissionable nuclides cause fission which is all that is needed for a simplistic fission bomb
  - C. False because fissile nuclides sustain a steady chain reaction in a nuclear reactor by being able to be fissioned by neutrons of any energy level
- 59) What properties are important for evaluating the use of isotopes as NEM for the purposes of nuclear weapons?
- A. Heat from radioactive decay
  - B. Radiation damage from radioactive decay
  - C. Neutrons from spontaneous fission
  - D. A&B
  - E. All of the above

- 60) Uranium enrichment levels need to be \_\_\_\_, \_\_\_\_, and \_\_\_\_ in order to be classified as LEU, weapons-usable HEU, and weapons-grade HEU respectively:
- A. <80%, between 80% and 93%, >93%
  - B. <20%, between 20% and 80%, >80%
  - C. Between 20% and 80%, between 80% and 93%, >93%
  - D. None of the above; uranium does not need to be enriched for a nuclear weapon
- 61)  ${}_{94}^{239}\text{Pu}$  can be made within nuclear reactors if irradiation is brief enough to not produce too much “high burn-up” plutonium. What is the reaction that produces  ${}_{94}^{239}\text{Pu}$ ?
- A.  $\beta^-$  decay:  ${}_{93}^{239}\text{Np} \rightarrow {}_{94}^{239}\text{Pu} + e^- + \nu_e$
  - B.  $\beta^+$  decay:  ${}_{93}^{239}\text{Np} \rightarrow {}_{94}^{239}\text{Pu} + e^+ + \nu_e$
  - C.  $\alpha$  decay:  ${}_{96}^{243}\text{Cm} \rightarrow {}_{94}^{239}\text{Pu} + \alpha$
  - D.  ${}_{94}^{239}\text{Pu}$  Cannot be made in nuclear reactors

**H. Essay Question – 45 points of 291 (Limit Answer to two pages on the next two sheet)**

62) An abandoned soviet lighthouse in Siberia was recently found vandalized. Along with copper and other valuable scrap, the radioisotope thermoelectric generator (RTG) used to power this remote station is gone. The RTG contains a strontium-90 source whose heat it converts to electricity. Strontium-90 is known for its high-energy gamma emission. Officials are worried the perpetrators might have been looking for more than scrap metal.



<http://englishrussia.com/2009/01/06/abandoned-russian-polar-nuclear-lighthouses/>

The missing RTG was discovered just days from the start of a large meeting of world leaders in a major Russian city.

- a. Analyze the potential threat resulting from this source to the meeting: can the missing isotope be used to build a weapon to attack the meeting given the time frame? If an attack would occur, what would be the impact on the meeting, the city and its citizens?
- b. Given the vast size of the metropolitan area, describe a strategy to search for the stolen source and searching for members of the group that have carried out the theft and may be preparing to attack the meeting.
- c. Given the nature of the threat propose a security plan that could protect the meeting successfully. Will it be possible to guarantee security both for the meeting and the wider metropolitan area?



Written Answer to question 62 – limit hand written answer to space on this page and the next page. Note it is important to write your name and writing lab – this page will be separated from the exam for grading:

Name:

Your Writing Lab:

**Check to make sure you bubbled in all your answers.  
Did you bubble in your name, exam version and network-ID?**

Name:

Your Writing Lab:

**Check to make sure you bubbled in all your answers.  
Did you bubble in your name, exam version and network-ID?**