

This is an open book exam. You have eighty (80) minutes to complete it.

1. Download the pdf with the midterm questions: <http://courses.physics.illinois.edu/phys280/sp2020/secure/assignments/midterm/Exam/20p280-midterm.pdf>
2. Download the Excel worksheet for answers: <http://courses.physics.illinois.edu/phys280/sp2020/secure/assignments/midterm/Exam/mid-term-answers.xlsx>
3. Enter your **first name, name, netID**, writing Lab Section and Writing Lab TA Name in the **proper fields in the Excel worksheet term-answer.xlsx**.
4. At the end of the exam (**not before 3.10pm**) **upload your mid-term-answer.xlsx** via the usual assignment upload, <https://my.physics.illinois.edu/courses/upload/>. This is the same upload that you have been using for the essays. The assignment name is "Midterm March 26 2020".
5. In case there are problems, enter 280-ZOOM meeting <https://illinois.zoom.us/j/656685782> for support.
6. **This Exam Booklet is Version A.**

Before starting work, check to make sure that your pdf file is complete. You should have 17 numbered pages.

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Please note we will be using Turnitin to check your essays for possible plagiarism (including copying from previous or current students in the class).

Exam Grading Policy—

The exam consists of 73 questions, composed of 4 types of questions.

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. → in mid-term-answers.xlsc enter your letter choice A or B or ...
- (b) If you mark *two* answers, one of which is the correct answer, you earn **3** points. → in mid-term-answers.xlsc enter your choice of two letters, eg. AC ...
- (c) If you mark *three* answers, one of which is the correct answer, you earn **2** points. → in mid-term-answers.xlsc enter your choice of three letters, eg. ABD ...
- (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. → in mid-term-answers.xlsc enter your letter choice A or B or ...
- If you mark *two* answers, one of which is the correct answer, you earn **2** points. → in mid-term-answers.xlsc enter your choice of two letters, eg. AC ...
- (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) A nuclide that fissions only with neutrons of sufficient energy is:
 - A. Fissile
 - B. Fissionable, but not fissile
 - C. Fertile

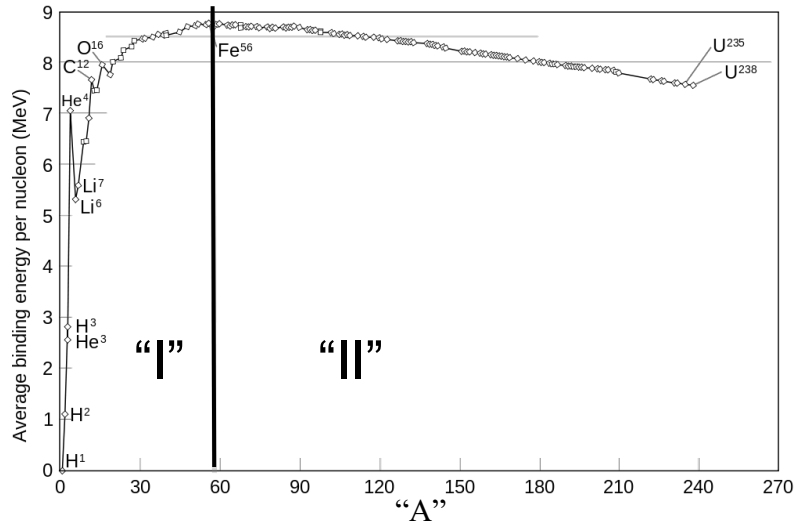
- 3) What isotope of plutonium is most common in nature?
 - A. Pu-238
 - B. Pu-239
 - C. Pu-241
 - D. None of the above isotopes are found in nature

- 4) The nuclide ${}^{241}_{95}\text{Am}$ has...
 - A. 241 neutrons and 95 protons
 - B. 95 neutrons 146 protons
 - C. 95 neutrons and 241 protons
 - D. 146 neutrons and 95 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 7-9.



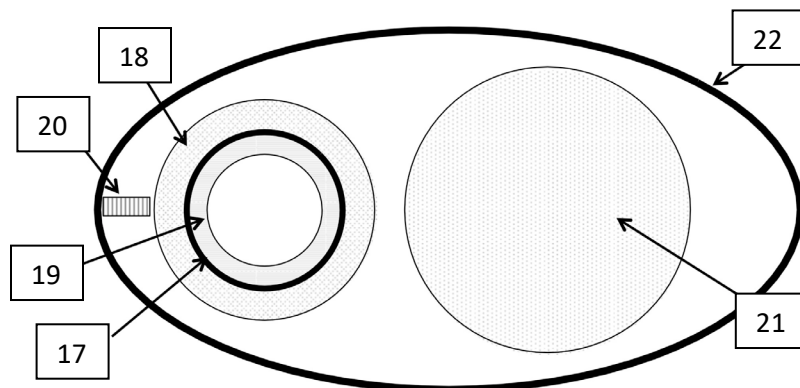
- 7) Which of the following isotopes has the most stable nucleus?
- He^4
 - O^{16}
 - Fe^{56}
 - U^{235}
- 8) The region of the binding energy graph where **FUSION** can occur is...
- region "I" at small values of A
 - region "II" at large values of A
 - regions "I" and "II"
 - binding energy is not related to fusion
- 9) The region of the binding energy graph where **FISSION** can occur is...
- region "I" at small values of A
 - region "II" at large values of A
 - regions "I" and "II"
 - binding energy is not related to fission
- 10) What determines the chemical properties of an atom?
- Number of protons
 - Number of neutrons
 - Number of protons and neutrons combined

B. Nuclear weapons

- 11) Which statement most accurately describes how a supercritical assembly is formed in a gun-type weapon?
- A HEU bullet is fired into a hollow HEU cylinder
 - Two cylindrical HEU bullets are simultaneously fired at one another
 - A hollow HEU cylinder is fired onto a HEU target
 - A HEU sphere is compressed using conventional explosives

- 12) 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
- 13) Only Pu-239 can be used to create an implosion-type nuclear weapon.
- A. True
 - B. False
- 14) 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
- 15) 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 16-22. The items in the diagram are labeled with the relevant questions number:



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

Questions 17-22 (Corresponding to items identified in diagram above) Match the weapon components identified by numbers in the figure above, 17-22, 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. Depleted uranium shell
- AB. Fusion packet

- 23) 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

- 24) The spread of nuclear weapons to previously non-nuclear-weapon states is sometimes referred to as "horizontal" _____.
- A. Risk
 - B. Deterrence Failure
 - C. Proliferation
 - D. Arms Race
 - E. Expansion
- 25) Which nuclear weapons-capable state is NOT part of the Nonproliferation Treaty (NPT)?
- A. China
 - B. France
 - C. United Kingdom
 - D. Pakistan
 - E. United States

- 26) Which of the following is NOT true about India's K-4 ballistic missile?
- A. It is nuclear-capable.
 - B. It is an intermediate-range (range ~3,500) ballistic missile.
 - C. It is launched from a submarine.
 - D. Its primary target will be short-range targets like Karachi, Pakistan.
 - E. All of the above
- 27) The United States has accused Russia of violating limitations established by the 1987 INF treaty with their newly developed Novator 9M729 cruise missile. What does INF stand for?
- A. Intensive Non-Fissile Treaty
 - B. Intermediate-Range Nuclear Forces Treaty
 - C. Implosion Nuclear Forces Treaty
 - D. Intensive New Freedom Treaty
 - E. Independent Nuclear Forces Treaty
- 28) What makes the US' new W76-2 warhead (the US' first low-yield Trident nuclear warhead) a dangerous step towards nuclear war?
- A. Having tactical weapons may shift the primary use of nuclear weapons away from deterrence to a way to win regional wars.
 - B. Its yield of 5 kilotons is one of the largest payloads deployed by the US.
 - C. This warhead is no different than any other weapons in the US' arsenal, and it is unlikely to cause any changes in the US' nuclear strategy.
 - D. They would be highly effective in all out nuclear wars.
 - E. Russia has no low-yield weapons, and this weapon gives the US a distinct technological advantage.
- 29) Why has Washington issued waivers for Russian, Chinese, and European companies to continue working on Iranian nuclear sites?
- A. The US is backing down on its pressure towards the Iranian regime.
 - B. The presence of foreign nationals makes it more difficult for Iran to develop nuclear weapons.
 - C. These companies paid billions of dollars to the US in order to remain in Iran.
 - D. Washington has not provided any waivers to its sanctions on Iran.
 - E. Iran threatened to conduct airstrikes on more US bases if the US didn't issue these waivers.

- 30) What happened to Amir Rahimpour, who Iran accused of being a spy for the CIA and giving information about the Iranian nuclear program?
- A. The CIA claimed diplomatic immunity and brought Rahimpour back to the US.
 - B. He was sentenced to 5 years in an Iranian prison.
 - C. Iran is continuing to hold him with no contact with lawyers or family.
 - D. The top Iranian court confirmed his death sentence.
 - E. Iran convinced him to serve as a double agent, and he is now in an American prison.
- 31) How many years are left in the New START treaty?
- A. 1 year
 - B. 5 years
 - C. 10 years
 - D. Indefinite
 - E. 15 years
- 32) In the US' first Minuteman III missile launch of 2020, what new design was being tested with the missile test, if any?
- A. It was testing a new chemically explosive fuze.
 - B. It was a routine test with no new developments.
 - C. The US claims that it was a political message towards Russia after the INF treaty failed.
 - D. This design tested a new nuclear warhead and detonated it in the atmosphere.
- 33) What is the reason President Trump has given for allowing the New START's expiration date to draw nearer with no intention of renewal?
- A. Russia violated New START limitations.
 - B. START inspections allow Russia to know too much about the US' forces.
 - C. New START provides the US with no strategic benefit.
 - D. President Trump is vigorously advocating for a new arms race, which New START prevents.
 - E. President Trump would like to extend the treaty to include China as well.
- 34) Who is currently the only nuclear-armed state in the EU?
- A. Germany
 - B. Russia
 - C. United Kingdom
 - D. France
 - E. Poland

D. Nuclear weapon delivery methods

- 35) The Chinese Silkworm cruise missile 180 miles range. 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.
- 36) 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.
- 37) 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.
- 38) 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
- 39) This Soviet missile design, based on the German V2, is the basis for many other missiles.
- A. "November Rain" / N-12
 - B. "Scud" / R-11
 - C. "Big Ivan" / BM-2
 - D. "Hammer" / USSR-2

- 40) 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
- 41) 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
- 42) 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

- 43) In which of the following test environments did the United States discover the effects of the electromagnetic pulse (EMP) following a nuclear explosion?
- A. Air and surface bursts
 - B. Underwater bursts
 - C. Bursts in space
 - D. High-altitude bursts
- 44) Deep underground nuclear tests can be detected through the monitoring of:
- [Mark all correct answers]**
- A. Detection of low frequency acoustic signals
 - B. Irregular seismic activity
 - C. The development of cracks in the Earth's surface
 - D. The release of radioactive noble gases
 - E. Deep underground tests cannot be detected

- 45) What is the expected change in global surface temperatures that would be produced if the weapons in the current strategic arsenals of the United States and Russia exploded?
- A. +3 to +4 C
 - B. 0 to +2 C
 - C. -2 to 0 C
 - D. -3 to -4 C
 - E. -9 to -7 C
- 46) A nuclear attack on a country would lift soot into the atmosphere, screening the sunlight and changing surface temperatures on Earth. How long would it take for half of the soot to fall out of the atmosphere?
- A. 10 years
 - B. 5 years
 - C. 1 year
 - D. 1 month
- 47) Which of the following effects of a 1 MT nuclear air burst would be felt first 5 miles away?
- A. Residual nuclear radiation (fallout)
 - B. Electromagnetic pulse (EMP)
 - C. Blast
 - D. Thermal radiation
- 48) Which of the following effects of a 1 MT nuclear air burst contains the most energy many seconds after detonation?
- A. Residual nuclear radiation (fallout)
 - B. Electromagnetic pulse (EMP)
 - C. Blast
 - D. Thermal radiation
- 49) The seriousness of burn injuries due to the thermal radiation emitted from a nuclear burst depends on:
- [Mark all correct answers]**
- A. Yield
 - B. Weapon design
 - C. Clothing worn by person
 - D. Presence of nearby radio towers
 - E. Weather conditions

50) Fill in the blank: In a transparent atmosphere, the radiation flux (radiation passing through a unit area) due to a nuclear explosion scales roughly as _____, where D is the slant range.

- A. $1/D$
- B. $1/D^2$
- C. $\exp(-D)$
- D. $-D$

51) Choose the correct sequence of events for an atmospheric nuclear explosion.

- A. Fireball formation > blast wave formation > mushroom cloud formation
- B. Mushroom cloud formation > fireball formation > blast wave formation
- C. Fireball formation > mushroom cloud formation > blast wave formation
- D. Blast wave formation > fireball formation > mushroom cloud formation

52) Which of the following is not true about a nuclear explosion after 1 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 the center of the Sun)

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

[Mark all correct answers]

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

F. Terrorism and its characteristics

54) What type of nuclear weapon design would be easiest for a terrorist group to construct?

- A. Levitated-pit implosion
- B. Implosion
- C. Gun Type
- D. Two-point hollow-pit implosion

- 55) Which of the below is NOT one of the standard phases in the response to terrorism of a society without previous experience with terrorism?
- A. Polarization of politics
 - B. Demonstration of resolve by adopting draconian responses that largely go unchallenged by the public
 - C. Societal lack of concern regarding the seriousness of the threat
 - D. Reasoned reflection on the nature of the threat and measured and efficient response
- 56) What is the definition of terrorism?
- A. Using a weapon of mass destruction on a large population center.
 - B. Deliberately and violently targeting civilians for political purposes.
 - C. The murder of three or more people.
 - D. Any violent act that incites fear or terror in the public.
- 57) Mark all TRUE statements about terrorism.
- A. The point of terrorism is not to defeat the enemy but to send a message.
 - B. The goals the group is fighting for must be considered morally unjustified.
 - C. Terrorism is a relatively new phenomenon.
 - D. The act and the victims of terrorism typically have symbolic significance.
- 58) Has a country ever lost a nuclear weapon?
- A. Yes
 - B. No
 - C. We don't know
- 59) Mark all true answers. Terrorists usually seek to _____
- A. Achieve military victory over their enemy.
 - B. Cause their enemy to overreact.
 - C. Cause enough psychological and economic damage to compel their enemy to change course.
- 60) According to Richardson, terrorists act with 3 immediate objectives (the "3 Rs") in mind, what are they?
- A. Revenge, Renown, Reaction
 - B. Revenge, Retribution, Reaction
 - C. Righteousness, Rage, Redemption
 - D. Relevance, Renown, Reconciliation

- 61) True or False: Smuggling of nuclear materials is relatively difficult to stop.
- A. True
 - B. False
- 62) What's the best way for the government to reduce the threat of nuclear terrorism?
- A. Increase the legal penalties for terrorism
 - B. Increase investment in counter-terrorism forces
 - C. Increase investment in local police stations, fire departments and emergency medical services
 - D. Improve nuclear security
- 63) 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. 60%
 - B. 25%
 - C. 6%
 - D. 2%
- 64) In the 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 detector was not powerful enough to detect the bomb
 - B. The border guard did not know how to properly use the device
 - C. The bomb was shielded by a material like lead
 - D. Fissile material in warheads are not detectable by portable radiation detectors

G. Nuclear materials

- 65) Enrichment of uranium is an important process for nuclear power as well as nuclear weapons. Enrichment percentages of uranium are commonly stated in reference to which isotope?
- A. U-233
 - B. U-234
 - C. U-235
 - D. U-236
 - E. U-238

- 66) Fill in the blank: Tritium and Deuterium are important nuclear materials because _____.
- A. They are fissile.
 - B. They are used as initiator in fission weapons.
 - C. A thermonuclear weapon cannot be made without them.
 - D. Are used in nuclear reactors for the purpose of creating ${}_{94}^{239}\text{Pu}$.
 - E. All of the above
- 67) What R values (multiplication factors) correspond to “subcritical”, “critical” and “supercritical” configurations of nuclear materials?
- A. Subcritical: $R = -0.5$ Critical: $R = 0$ Supercritical: $R = 0.5$
 - B. Subcritical: $R < 1$ Critical: $R = 1$ Supercritical: $R > 1$
 - C. Subcritical: $R = 0$ Critical: $R = 1$ Supercritical: $R > 1$
 - D. Subcritical: $R = 0$ Critical: $R = 0.5$ Supercritical: $R = 1$
 - E. None of the above because R is only related to critical masses
- 68) Which statements are correct with regards to HEU and Pu?
- A. HEU and plutonium can both be used in gun-type weapons
 - B. Pu can be used in gun-type weapons only while HEU cannot
 - C. HEU can be used in implosion and gun type weapons
 - D. HEU isotopes tend to cause preinitiation due to high rate of spontaneous neutron emission
 - E. In general, Pu isotopes have a lower rate of heat generation than HEU and are a lower radiological hazard which make them not ideal for weapons
- 69) What properties are important for evaluating the effectiveness of 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
- 70) 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

- 71) ${}_{94}^{239}\text{Pu}$ 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. β^- decay: ${}_{93}^{239}\text{Np} \rightarrow {}_{94}^{239}\text{Pu} + e^- + \nu_e$
- B. β^+ decay: ${}_{93}^{239}\text{Np} \rightarrow {}_{94}^{239}\text{Pu} + e^+ + \nu_e$
- C. α decay: ${}_{96}^{243}\text{Cm} \rightarrow {}_{94}^{239}\text{Pu} + \alpha$
- D. ${}_{94}^{239}\text{Pu}$ Cannot be made in nuclear reactors
- 72) 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

H. Essay Question – 45 points (Limit Answer to one page on the next sheet)

Oppenheimer and the Manhattan Project

August 6th and 9th of this year marks 75 years since the first nuclear weapons were dropped on Hiroshima and Nagasaki. Due to the historical significance of this day, the editor of *The New York Times* has asked you, one of his journalists, to write a brief article on the Manhattan Project, J. Robert Oppenheimer, and the bombs. Your editor feels that many Americans do not know much about the project or the bombs dropped on Japan. In your column, please include responses to the following questions:



- What is the Manhattan Project? Who is J. Robert Oppenheimer?
- What kind of technological hurdles did J. Robert Oppenheimer face when developing the bombs?
- What was the significance of this project in relation to the war effort?
- What were the names of the bombs dropped on Japan? What kind of weapons design(s) were they?

Type your answer to the essay question in the text box in mid-term-answers.xlsx, save and upload through the server

Check to make sure you bubbled in all your answers.