

**Physics/Global Studies 280**  
**Nuclear Weapons, Nuclear War, and Arms Control**

**Final Examination**

**2012 May 4**

Full Name \_\_\_\_\_

UIUC ID No. \_\_\_\_\_ Lab No. \_\_\_\_\_

- This is a closed book examination—you are not to consult any materials other than the exam itself, or any person. Giving or receiving unauthorized help is a violation of the University's rules on academic integrity.
- You have the full exam period (180 minutes) to complete this examination.
- Answer all the questions on all 20 topics. Each topic counts 20 points.
- The point value of each question within a topic is indicated by a boldface number in square brackets, e.g., [2].
- Write your answers in the spaces provided below each question. *Do not submit any additional pages.* If you need more room, write on the back of the preceding page.
- To receive full credit for definitions, give numbers where relevant.
- Questions with multiple possible answers will be scored using right minus wrong scoring.

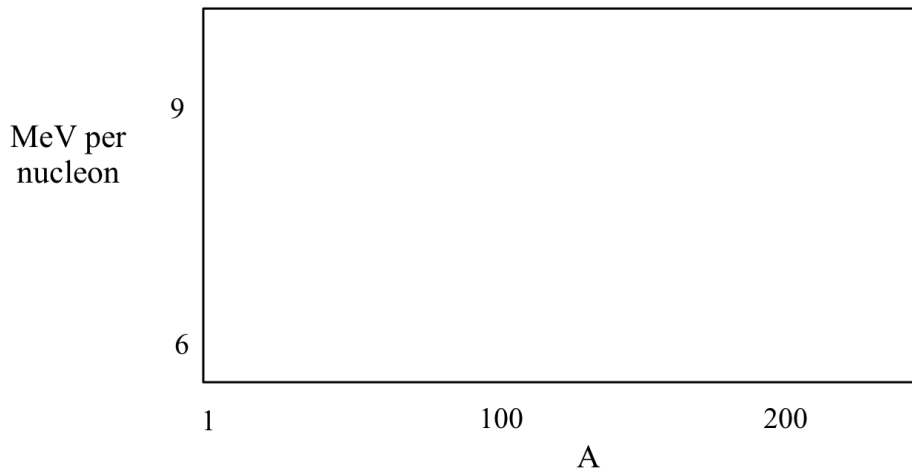
**Scores**

1. _____[20]	6. _____[20]	11. _____[20]	16. _____[20]
2. _____[20]	7. _____[20]	12. _____[20]	17. _____[20]
3. _____[20]	8. _____[20]	13. _____[20]	18. _____[20]
4. _____[20]	9. _____[20]	14. _____[20]	19. _____[20]
5. _____[20]	10. _____[20]	15. _____[20]	20. _____[20]

Total \_\_\_\_\_[400]

**1. Nuclear physics and nuclear weapons – I [20]**

- (a) In the panel below, sketch the curve of binding energy per nucleon from
- $A=1$
- to
- $A=240$
- . [2]



- (b) Label on the panel above the approximate range(s) of
- $A$
- where
- fission*
- can occur. [2]

- (c) Label on the panel above the approximate range(s) of
- $A$
- where
- fusion*
- can occur. [2]

- (d) Match the type of nuclide listed on the left with the property listed on the right: [6]

fissile	fissioned only by a neutron with sufficient energy
fissionable but not fissile	becomes fissile by absorbing a neutron
fertile	fissioned by a neutron with any energy

- (e) What isotope of uranium is most common in nature? [1]

- (f) What naturally-occurring isotope of uranium is fissile? [1]

- (g) Are all fissile nuclides nuclear-explosive nuclides? [1]

Yes	No
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- (h) Are there any nuclear-explosive nuclides that are
- not*
- fissile? [1]

Yes	No
-----	----

- (i) What type of nuclear weapon design would be easiest for a terrorist group to construct? [2]

- (j) What type of nuclear explosive material would the group need to make this design work? [2]

**2. Nuclear physics and nuclear weapons – II [20]**

- (a) Define the following materials in terms of the percentages of U-235 they contain: [6]
- i. low-enriched-uranium (LEU) —
  - ii. highly-enriched uranium (HEU) —
  - iii. weapons-grade uranium —
- (b) What is the currently preferred technology for producing weapons-grade uranium? [2]
- (c) The minimum amount of weapons-grade uranium needed to make a nuclear bomb is about the same size as a [2]
- pea            marble            baseball            softball            big beach ball
- (d) Define the following materials in terms of the percentage of Pu-239 they contain: [4]
- i. reactor-grade plutonium —
  - ii. weapons-grade plutonium —
- (e) What are the two main steps involved in producing weapons-grade plutonium? [4]
- i.
  - ii.
- (f) The minimum amount of weapons-grade plutonium needed to make a nuclear bomb is about the same size as a [2]
- pea            marble            baseball            softball            big beach ball

**3. Effects of nuclear explosions [20]**

(a) The explosive energy of a given mass of nuclear-explosive material is about how many times greater than the energy of an equal mass of conventional high explosives? [2]

100 times      1,000 times      10,000 times      100,000 times      1 million times

(b) The fundamental limit to the yield of a modern, two-stage nuclear weapon is about [2]

100 kilotons      500 kilotons      1 Megaton      10 Megatons      there is none

(c) If exploded in a city, a “small”(10-kiloton) nuclear device would: [4]

i. destroy about how many square kilometers?

1                              30                              300

ii. kill about how many people?

1,000              30,000              100,000              1,000,000

(d) If exploded in a city, a “large” (1-megaton) nuclear weapon would: [4]

i. destroy about how many square kilometers?

1                              30                              300

ii. kill about how many people?

1,000              30,000              100,000              1,000,000

(e) A nuclear attack on a country would loft soot into the upper atmosphere, screening sunlight and reducing surface temperatures around the Earth. About how long would it take for half the soot to fall out of the atmosphere? [2]

1 week              1 month              6 months              1 year              5 years

(f) The atmospheric effects of the regional nuclear war between India and Pakistan discussed in class would likely reduce the length of the growing season in the U.S. Midwest by [2]

1%–2%              10%–15%              30%–40%              70%–80%

(g) The atmospheric effects of the limited nuclear war between the United States and Russia discussed in class would reduce the surface temperature in the U.S. Midwest by about [2]

1 C                              5 C                              8 C

(h) The atmospheric effects of the limited nuclear war between the United States and Russia discussed in class would reduce the length of the growing season in the U.S. Midwest by [2]

1%–2%              10%–15%              30%–40%              70%–80%

**4. Nuclear terrorism [20]**

(a) Complete the following definition: [4]

In Physics 280, terrorism is defined as

(b) Define the following types of terrorism: [3]

i. State terrorism

ii. State-sponsored terrorism

ii. War terrorism

(c) Richardson argues that a “lethal cocktail” of three factors produces terrorism. List them. [3]

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- 
- 

(d) Richardson argues that although the long-term goals of terrorists differ, almost all terrorists share three short-term goals. List them. [3]

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- 
- 

(e) List the three basic terrorist pathways to a nuclear bomb discussed in Ferguson’s book *Preventing Catastrophic Nuclear Terrorism* and in the lecture-discussions: [3]

- 
- 
- 

(f) Graham Allison and other nuclear terrorism experts argue that we must insist on “Three No’s” to prevent nuclear terrorism. List them. [3]

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- 
- 

(g) State in one sentence the most effective way to prevent terrorists from getting a nuclear bomb. [1]

**5. Nuclear weapon delivery methods – I [20]**

(a) Decode the following initializations and list the ranges that define these missile types. **[8]**

i. IRBM —

ii. ICBM —

iii. MRBM —

iv. SRBM —

(b) For each category of nuclear delivery system listed below, name the nuclear-weapon states that have deployed it. Scores will be computed by taking right minus wrong answers. **[12]**

i. Bombers —

ii. ICBMs —

iii. SLBMs —

**6. Nuclear weapon delivery methods – II [20]**

(a) List in order the three main phases in the flight of an ICBM. [6]

i.

ii.

iii.

(b) Can a nuclear-armed cruise missile be recalled after it has been launched? [2]

Yes

No

(c) Can a nuclear-armed ballistic missile be recalled after it has been launched? [2]

Yes

No

(d) Is there any physical barrier to prevent the crew of a U.S. submarine carrying nuclear-armed long-range ballistic missiles from launching them without Presidential authority? [2]

Yes

No

Answer the following two questions in a phrase or a sentence, as appropriate.

(e) List two methods for delivering nuclear weapons that are among those the U.S. intelligence community assesses are most likely to be used to attack the territory of the United States. [4]

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•

(f) The most recent U.S. National Intelligence Estimate of the ballistic missile threat to the United States gives several reasons why an attacker is likely to prefer one of the methods asked for in part (e) over other methods. List two of these reasons. [4]

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**7. Nuclear arsenals – I [20]**

List (a) *all countries* that are currently thought to have nuclear weapons, (b) the *year* each first created a nuclear explosion (if it is publicly known), and (c) the *total number* of weapons each country now has.

<i>Country</i>	<i>Year of first explosion</i>	<i>Approximate number of weapons</i>
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How many nuclear weapons of all kinds are there in the world today?



**8. Nuclear arsenals – II [20]**

- (a) About how many tons of highly enriched uranium (HEU) are there in the world? [2]
- (b) This quantity of HEU is enough to make about how many nuclear weapons? [2]
- (c) How many *operational strategic* nuclear weapons does Russia currently have? [2]
- (d) How many *operational strategic* nuclear weapons does the United States currently have? [2]
- (e) How many *tactical* nuclear weapons does Russia currently have in its arsenal? [2]
- (f) How many *tactical* nuclear weapons does the United States currently have in Europe? [2]
- (g) During the next decade, U.S. spending on nuclear weapons and nuclear weapon delivery systems is planned to [2]  
decrease substantially      remain about the same      increase substantially
- (h) Is it possible to make a functioning nuclear weapon using reactor-grade plutonium? [1]  
Yes      No
- (i) How did India obtain the fissile material it used in its first nuclear explosive device? [1]
- (j) Which country gave Pakistan detailed plans for a nuclear weapon? [2]
- (k) Which country gave ballistic missiles and ballistic missile technology to Pakistan in return for Pakistan's assistance in developing nuclear weapons? [2]

**9. India's and Pakistan's nuclear and missile programs [20]**

- (a) What fissile material is used in most of India's nuclear weapons? [2]
- (b) Which NPT Nuclear Weapon State has recently begun supplying fissile material and nuclear technology to India, despite the fact that this is not permitted by the NPT? [2]
- (c) What nuclear delivery method would India most likely use if it attacked Pakistan? [2]
- (d) What fissile material is used in most of Pakistan's nuclear weapons? [2]
- (e) How did Pakistan first obtain the technology to produce this fissile material? [2]
- (f) What nuclear delivery method would Pakistan most likely use if it attacked India? [2]
- (g) What is the name of the Pakistani scientist who sold nuclear weapon designs and fissile material production technology to a vast black market? [2]
- (h) Name three countries to which Pakistan sold technology for producing nuclear explosive material and blueprints for nuclear weapons. [6]
- - 
  -

**10. North Korea's nuclear and missile programs [20]**

(a) Circle the year(s) in which North Korea attempted to launch a three-stage rocket: [5]

1998                  2003                  2006                  2009                  2012

(b) How many of these attempted launches were successful? [2]

(c) What is the range in km of the longest-range missile North Korea has successfully tested? [2]

(d) Could this missile reach any part of the United States? [1]

Yes    No

(e) North Korea is currently thought to have enough plutonium to make about how many nuclear weapons? [2]

1 or 2                  5 or 6                  5–10                  15–20                  30–40

(f) Circle the year(s) in which North Korea tested a nuclear weapon: [5]

2001                  2003                  2006                  2009                  2012

(g) In 2010, several U.S. scientists (including Siegfried Hecker) were allowed to tour nuclear installations in North Korea. What two new facilities were shown to these scientists? [2]

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(h) North Korea is thought to have made what fundamental change in its nuclear program? [1]

**11. Iran's nuclear and missile programs [20]**

- (a) What fissile material is Iran currently seeking to produce? [2]
- (b) What technology is Iran currently using to produce this fissile material? [2]
- (c) From what country did Iran obtain this fissile-material production technology? [2]
- (d) Why does Iran say it needs uranium enriched to 20% U-235? [2]
- (e) Other things being equal, the effort to go from 20% U-235 to weapons-grade uranium is [2]  
much less than                      about the same as                      much greater than  
the effort needed to go from natural uranium to 20% U-235.
- (f) The 2007 National Intelligence Estimate concluded that Iran's nuclear weapons program [2]  
has been suspended                      is continuing                      is accelerating
- (g) Which two countries have played an especially important role in helping Iran develop its ballistic missiles? [4]
- -
- (h) What is the range in km of the longest-range ballistic missile Iran has successfully tested? [2]
- (i) Could this missile reach any part of the United States? [2]  
Yes    No

**12. U.S. anti-ballistic-missile efforts – I [20]**

(a) In what decade did the United States begin spending on anti-ballistic-missile programs? [2]

(b) About how much, in 2012 dollars, has the United States spent on missile defenses so far? [2]

(c) In what year did the United States first declare a missile defense system “operational”? [2]

(d) How long was that system operational before it was shut down forever? [2]

(e) Have any of the systems the U.S. has tested or deployed been shown to be effective under battlefield conditions? [2]

Yes

No

(f) President Reagan called on scientists to render nuclear weapons.... [4]

• and •

(g) Which “Star Wars” missile interceptor idea was itself a large thermonuclear weapon? [2]

(h) List two then-existing Soviet delivery systems not addressed by the “Star Wars” program. [2]

• •

(i) Did any “Star Wars” technologies contribute significantly to later ABM programs? [2]

Yes

No

**13. U.S. anti-ballistic-missile efforts – II [20]**

(a) What are the three “Nitze Criteria” an anti-ballistic missile system must satisfy in order for deployment to make sense? [6]

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- 
- 

(b) Initial reports that the Patriot defense system was highly successful during the 1991 Gulf War played a key role in efforts to restart a U.S. program to defend against ICBMs. In the end, how many intercepts of Iraqi short-range missiles were well-documented? [2]

0                      1                      3                      12                      73

(c) Why did the Republicans in Congress request in 1995 a National Intelligence Estimate (NIE) on the ballistic missile threat to the United States? [2]

(d) Why did many Republicans in Congress object to this NIE? [2]

(e) What action did these Republicans in Congress take in response to this NIE? [2]

(f) In what way did the 1998 Rumsfeld Commission change intelligence estimates? [2]

(g) Why did Donald Rumsfeld say “God bless Kim Jong-Il” in the fall of 1998? [2]

(h) Tests of the U.S.-based midcourse system have been highly scripted and unrealistic. Even so, the percentage of tests that have been declared successful is only (circle the right answer) [2]

0%                      10%                      50%                      80%                      90%

**14. U.S. anti-ballistic-missile efforts – III [20]**

(a) List two countermeasures that could be used to defeat any midcourse-intercept system. [4]

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- 

(b) The difficulty of midcourse-intercept led to interest in intercept while the missile's rocket motors are burning ("boost-phase intercept"). List two important challenges faced by boost-phase intercept systems. [2]

- 
- 

(c) Money has been spent on many programs for boost-phase intercept. Have any of these programs been successful? [2]

Yes

No

(d) List the two countries that are supposed to host ground-based interceptors for Obama's European-based midcourse defense system. [4]

- 
- 

(e) Obama's European-based midcourse defense system will initially rely primarily on [2]

Ground-based interceptor rockets

Ship-based interceptor rockets

Ship-based lasers

Airborne lasers

(f) The first phase of Obama's European midcourse missile defense system became operational in what year? [1]

(g) Obama's proposed European midcourse missile defense system calls for how many ship-based interceptor missiles by 2018? [2]

50

100

200

300

500

(h) Obama's proposed European midcourse missile defense system is supposed to have some capability against intercontinental-range missiles in what year? [1]

(i) Why have the Russians objected to NATO's planned deployment of this system? [2]

**15. Nuclear arms control – I [20]**

- (a) According to International Law, a State that has signed a treaty must comply with it even if the State has not ratified the treaty. [2]

Yes

No

- (b) What year was the Limited Test Ban Treaty opened for signature? [1]

- (c) What was banned by the Limited Test Ban Treaty? [2]

- (d) What threat did the Limited Test Ban Treaty eliminate? [2]

- (e) Did the Limited Test Ban Treaty have any significant impact on the nuclear arms race? [2]

- (f) Horizontal proliferation is defined as [2]

- (g) Vertical proliferation is defined as [2]

- (h) List the two different countries that have waged preventive wars because of concern about another country's supposed nuclear weapons program and name all countries attacked. [5]

- attacked                    •                    and                    •
- attacked

- (i) Were these wars legal under International Law? [2]

Yes

No



**16. Nuclear arms control – II [20]**

(a) How many weapons were in the global nuclear arsenal when it reached its maximum? [2]

(b) What year did the global nuclear arsenal reach its maximum? [2]

(c) What year was the nuclear Non-Proliferation Treaty (NPT) opened for signature? [1]

(d) List the five States that are recognized as nuclear-weapon States by the NPT. [5]

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- 
- 
- 
- 

(e) List the four States that are thought to have nuclear weapons but either never signed the Nuclear Nonproliferation Treaty or later withdrew from it. [4]

- 
- 
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- 

(f) The five nuclear-weapon states-parties to the NPT agreed to do what two things? [4]

- 
- 

(g) The non-nuclear-weapon states-parties to the NPT agreed not to do what? [2]

**17. Nuclear arms control – III [20]**

(a) List the four states that once had nuclear weapons but gave them up. [4]

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- 
- 
- 

(b) State in one sentence why Israel has not publicly acknowledged having nuclear weapons. [2]

(c) What year was the Anti-Ballistic Missile Treaty signed? [2]

(d) Which countries signed the Anti-Ballistic Missile Treaty? [2]

(e) What was the purpose of the Anti-Ballistic Missile Treaty? [2]

(f) Is the Anti-Ballistic Missile Treaty still in force? [2]

Yes

No

(g) President's Reagan and Gorbachev almost reached an historic arms control agreement in 1986 at Reyjavik [6]

i. What was the nature of the agreement they *almost* reached?

ii. What ultimately prevented them from reaching an agreement?

**18. Nuclear Arms Control – IV [20]**

(a) What year was the CTBT opened for signature? [1]

(b) Has the United States signed the CTBT? [1]                      Yes                      No

(c) Has the United States ratified the CTBT? [1]                      Yes                      No

(d) Is the United States currently bound by the CTBT? [1]                      Yes                      No

(e) In order to enter into force, the CTBT must be ratified by certain specific States. List four of these states that have not yet ratified the treaty: [4]

- 
- 
- 
- 

(f) List three CTBT verification technologies that have now been deployed worldwide: [3]

- 
- 
- 

(g) The March 30, 2012 U.S. National Academy of Sciences report on the CTBT says: [3]

i. The United States no longer needs to conduct nuclear tests                      Yes                      No

ii. Renewed nuclear testing would reduce U.S. security                      Yes                      No

iii. Entry into force would significantly deter testing by others                      Yes                      No

(h) Nuclear weapons have been banned entirely from which of the following regions: [5]

Africa                      Antarctica                      Latin America                      South Pacific                      Southeast Asia

(i) Which category of nuclear weapons has never been addressed by an arms control treaty? [1]

**19. Nuclear arms control – V [20]**

- (a) What year was the Intermediate-Range Nuclear Forces Treaty signed? [1]
- (b) Which countries are states-parties to the INF treaty? [2]
- (c) What is the range interval (in km) of the missiles restricted by the INF treaty? [1]
- (d) How many of these missiles was each party to the INF treaty allowed? [1]
- (e) What year was the Strategic Arms Reduction Treaty (START) signed? [1]
- (f) Is the START Treaty still in force? [1]
- Yes                                  No
- (g) What year was the New Strategic Arms Reduction Treaty (New START) *signed*? [1]
- (h) Which countries have ratified the New START treaty? [2]
- (i) Which category of weapons is restricted by the New START treaty? [1]
- (j) How many of these weapons is each party to New START allowed in 2018? [1]
- (k) Which of the following U.S. officials and world leaders advocate reducing the number of nuclear weapons in the world to zero. (Circle them.) [8]

Jimmy Carter

Ronald Reagan

Barack Obama

Mikhail Gorbachev

Tony Blair

Robert McNamara

George Schulz

Henry Kissinger

**20. Current events [20]**

- (a) North Korea recently attempted to launch a satellite into space, but failed. [8]
- i. In which direction was the rocket launched?
  - ii. What was unique about this launch?
  - iii. Why was this space launch attempt condemned by the United Nations?
  - iv. What provocative action might North Korea take to compensate for this failure?
- (b) What major change is North Korea thought to be making in its nuclear weapon program? [2]
- (c) India recently tested a nuclear-capable ballistic missile that can reach Beijing. [2]
- |     |    |
|-----|----|
| Yes | No |
|-----|----|
- (d) What important meeting took place in Seoul, South Korea, in April, 2012? [2]
- (e) What was one important recommendation made at the Seoul meeting? [2]
- (f) What activity began in April in Istanbul, between Iran and the P5+1 (the five permanent members of the UN Security Council plus Germany)? [2]
- (g) According to news reports, South Africa is considering resuming what activity? [2]