NPRE 402
Nuclear Power Engineering
Fall 2020

Online Temporary Coverage and access during Covid-19 Pandemic

1. Please read the assigned-reading lecture-notes chapters.
2. Then answer the corresponding written assignment,
3. For questions about the assignments, please access the teaching assistants by email:
https://www.mragheb.com/NPRE%20402%20ME%20405%20Nuclear%20Power%20Engineering/talist.htm
4. Submit the corresponding written assignment through email to https://compass2g.illinois.edu
5. Please use either the Word or pdf formats
6. In case of internet "rationing" (e. g. to health and government authorities) or collapse through overload, the submitted assignments and the already-taken tests will be used in assessing the final grade.

Regrettably, some 3,278 colleges and universities across the USA have been impacted by the Covid-19 pandemic, with many temporarily closing their campuses and switching to online classes, affecting more than 22 million students.
To all and everyone we wish good health and well-being.

Number	Date Assigned	Due Date	Description
1	8/24	9/9	**Reading assignment** NEW **Preface** **Written Assignment** On the Kardashev Scale, identify the power needs in Watts for Type I, II and III civilizations. What is the current position of human civilization on that scale? In how many years is Humanity expected to achieve a Type I status? Define the Quad unit of energy in terms of BTUs and Joules. Use the 2019 Sankey diagram to calculate the end use efficiencies of the following energy sectors: 1. Residential, 2. Commercial, 3. Industrial, 4. Transportation. What is the percentage share of nuclear energy in: a) The primary energy supply, b) Electrical energy generation?
2	8/26	9/9	**Reading assignment** NEW **Preface** **Written Assignment** Construct a diagram showing the different components of the future smart electrical grid from the perspective of the vision of the Internet of Things (IoT). Access the Table of the Nuclides data warehouse and mine for the following data for the naturally occurring isotopes of the given elements of interest in nuclear power generation: a) Natural abundances in atomic percent (a/o), b) Atomic mass in atomic mass units (amu). 1. Uranium,

			2. Thorium, 3. Lithium, 4. Carbon, 5. Hydrogen, 6. Lead, 7. Calcium, 8. Beryllium, 9. Boron, 10. Sodium.
3	8/28	9/9	**Reading assignment** NEW **1. First Human Made Reactor and Birth of Nuclear Age** **Written Assignment** 1. Calculate the speed in [m/s] of a kT moderated "thermal neutron" with an energy of 0.025 eV. 2. Calculate the speed of a fission unmoderated "fast neutron" with an energy of 2.0 MeV. 3. Calculate the speed of a fusion unmoderated "fast neutron" with an energy of 14.06 MeV. Consider the kinetic energy as non-relativistic; $E = \frac{1}{2}mv^2$.
4	8/31	9/9	**Reading assignment** NEW **1. First Human Made Reactor and Birth of Nuclear Age** **Written Assignment** Use the mass to energy conversion equation to calculate: **1.** The energy release in ergs and MeV in the annihilation process of a positron and an electron. **2.** The energy release in ergs and MeV in the annihilation process of a proton and an antiproton.
5	9/2	9/9	**Reading assignment** NEW **1. First Human Made Reactor and Birth of Nuclear Age** **Written Assignment** If a single fission reaction produces about 180 MeV of energy, use Avogadro's law to calculate the number of grams of the fissile elements: 1. U^{235} 2. Pu^{239} 3. U^{233} 4. Np^{237} that would release 1 kT of TNT equivalent of energy. Assume that all the energy release is available, except for the energy carried away by the antineutrinos, as well as the delayed fission products beta particles and gamma rays, which is not fully recoverable. Hint: Use Avogadro's law to estimate the number of nuclei in a given weight of the fissile material: $N[nuclei] = \frac{g[gm]}{M[amu]} A_v, \quad A_v = 0.6 \times 10^{24} [\frac{nuclei}{mole}]$
6	9/4	9/11	**Reading Assignment** NEW **2. German Nuclear Program** NEW **3. Japanese Nuclear Weapons Program** NEW **4. Nuclear World** **Written Assignment** Compare the critical masses for a reflected and a non-reflected core of 1. U^{235} 2. Pu^{239}

<table>
<tr><td></td><td></td><td></td><td>For the Crossroads Baker nuclear test, list:
1. Yield in kT of TNT equivalent.
2. Date of test,
3. Purpose of test,
4. Result of test.</td></tr>
<tr><td>-</td><td>9/7</td><td>-</td><td>Labor day, no class</td></tr>
<tr><td>7</td><td>9/9</td><td>9/16</td><td>Reading Assignment
  4. Nuclear Processes, The Strong Force
Written Assignment
Apply conservation of charge and nucleons to balance the following nuclear reactions:
1. $_1D^2 + _1T^3 \rightarrow _0n^1 + ?$ (DT fusion reaction)
2. $_1D^2 + _1D^2 \rightarrow _1H^1 + ?$ (Proton branch of the DD fusion reaction)
3. $_1D^2 + _1D^2 \rightarrow _0n^1 + ?$ (Neutron branch of the DD fusion reaction)
4. $_1D^2 + _2He^3 \rightarrow _2He^4 + ?$ (Aneutronic or neutronless DHe^3 reaction).
5. $_0n^1 + _3Li^6 \rightarrow ?+?$ (tritium breeding reaction)
6. $_0n^1 + _3Li^7 \rightarrow _0n^1 + ?+?$ (tritium breeding reaction)
7. $_1T^3 + _1T^3 \rightarrow 2\,_0n^1+?$ (neutron multiplier reaction)
8. $_0n^1+_5B^{10} \rightarrow _2He^4+?$ (neutron absorption reaction)</td></tr>
<tr><td>8</td><td>9/11</td><td>9/18</td><td>Apply conservation of momentum and energy to calculate the Q values and the kinetic energies of the product nuclei from the following binary reactions:
1. $_1D^2 + _1T^3 \rightarrow _0n^1 + ?$ (DT fusion reaction)
2. $_1D^2 + _1D^2 \rightarrow _1H1 + ?$ (Proton branch of the DD fusion reaction)
3. $_1D^2 + _1D^2 \rightarrow _0n^1 + ?$ (Neutron branch of the DD fusion reaction)
4. $_1D^2 + _2He^3 \rightarrow _2He^4 + ?$ (Aneutronic or neutronless DHe^3 reaction).

Calculate the Q values or energy releases in MeV from the following nuclear fission reactions:
1. $_0n^1 + _{92}U^{235} \rightarrow 3\ _0n^1 + _{53}I^{137} + _{39}Y^{96}$
2. $_0n^1 + _{92}U^{235} \rightarrow 3\ _0n^1 + _{54}Xe^{136} + _{38}Sr^{97}$

Fill out the table describing the Cosmological Inventory of matter and energy.
<table>
<tr><th>Component</th><th>Percent</th><th>Properties</th></tr>
<tr><td>Dark energy
Expanding universe</td><td>-</td><td>-</td></tr>
<tr><td>Dark matter
Gravitational effect on galaxies</td><td>-</td><td>-</td></tr>
<tr><td>Luminous matter:
Stars and luminous gas
Radiation</td><td>-</td><td>-</td></tr>
</table></td></tr>
</table>

			Other nonluminous components: Intergalactic gas Neutrinos Supermassive black holes	-	-
9	9/14	9/21	**Reading Assignment** NEW **4. Nuclear World** **Written Assignment** An ICBM has an average speed of 18,566 miles/hour. Calculate its Mach Number M, considering that the speed of sound is 761.2 miles per hour. What do the following nuclear-related acronyms stand for? ICBM, ABM, MIRV, kT, MT, NPT, MAD, TNT, SALT Balance the Catalyzed DD fusion reaction: $_1D^2 + {}_1D^2 \rightarrow {}_1?+ {}_1H^1 + 4.03\ MeV$ $_1D^2 + {}_1D^2 \rightarrow ?+ {}_0n^1 + 3.27\ MeV$ $_1D^2 + {}_1T^3 \rightarrow ?+ {}_0n^1 + 17.6\ MeV$ $_1D^2 + {}_2He^3 \rightarrow ?+ {}_1H^1 + 18.3\ MeV$ $---------- $ $6\,{}_1D^2 \rightarrow ?+?+?+?\,MeV$		
10	9/16	9/23	**Reading Assignment** NEW **4. Nuclear World** **Written Assignment** Briefly describe in a short paragraph each of: 1. The Doomsday clock, 2. The six components of Russia's revived arms race, 3. Near-miss handling by Soviet Lieutenant Colonel Stanislav Petrov, 4. The Broken Arrow mishap near Goldsboro, North Carolina, 5. Plowshare Program, 6. Nuclear False alarm over Hawaii, 2018, 7. Electro Magnetic Pulse, EMP effects. 8. Nuclear football and biscuit, 9. Nuclear Non-Proliferation Treaty, NPT, 10. International Atomic Energy Agency, IAEA, 11. Treaty on the Prohibition of Nuclear Weapons.		
11	9/18	9/25	**Reading Assignment** NEW **1. Radioactive Transformations Theory, The Weak Force** **Written Assignment** Prove that the heuristic and the differential calculus forms of the law of radioactive decay are equivalent.		

			Calculate the activity of 1 gm of the radium isotope Ra^{226} in Becquerels and Curies. Discuss the relationship to the Curie (Ci) unit of activity. Complete the following nuclear reactions occurring when radioactive materials such as radium are placed in a sealed container of air. Small amounts of hydrogen, which does not exist in ordinary air, would appear. $_{88}Ra^{226} \rightarrow {}_{86}Rn^{222} + ?$ $?+ {}_{7}N^{14} \rightarrow {}_{1}H^{1} + ?$ $\_\_\_\_\_$ $_{88}Ra^{226} + {}_{7}N^{14} \rightarrow {}_{1}H^{1} + ?+ ?$ Complete the following reaction leading to the production of Carbon^{14}, that exists in all living creatures, with a half-life of 5,730 years as an ongoing nuclear transformation from the neutrons originating from cosmic rays bombarding Nitrogen^{14} in the Earth's atmosphere: $_{0}n^{1} + ? \rightarrow ?+ {}_{6}C^{14}$ $_{6}C^{14} \rightarrow ?+ {}_{7}N^{14}$ $---------$ $_{0}n^{1} \rightarrow ?+ ?$ The production of carbon^{14} with a half-life of 5,730 years is an ongoing nuclear transformation from the neutrons originating from cosmic rays bombarding nitrogen14 in the Earth's atmosphere: Carbon exists as $C^{14}O_2$ and is inhaled by all fauna and flora. Because only living plants continue to incorporate C^{14}, and stop incorporating it after death, it is possible to determine the age of organic archaeological artifacts by measuring the activity of the carbon^{14} present. Two grams of carbon from a piece of wood found in an ancient temple are analyzed and found to have an activity of 20 disintegrations per minute (dpm). Estimate the approximate age of the wood, if it is assumed that the current equilibrium specific activity of C^{14} in carbon has been constant at 13.56 disintegrations per minute per gram.
12	9/21	9/28	**Reading Assignment** NEW **1. Radioactive Transformations Theory, The Weak Force** NEW **9. Gamma and X rays Detection** **Written Assignment** Show a sketch of the electronic circuit of a Geiger-Mûller radiation detector. Tritium, an isotope of hydrogen used in fusion systems and a nanotechnology and Micro Electro Mechanical Systems (MEMS) power source devices, decays through the following reaction: $_{1}T^{3} \rightarrow {}_{-1}e^{0} + \_\_\_\_\_$ Using the law of radioactive decay calculate the fraction of the tritium isotope $(N_0\text{-}N(t))/N_0$ decaying into the He^3 isotope. The half-life of tritium is 12.33 years. 1. Within 1 year. 2. Within 12.33 years. 3. Within 24.66 years. Radon^{222} as a daughter in the decay chain of uranium is gaseous at room temperature. It is an inert or noble gas that does not interact chemically in the

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<tr><td></td><td></td><td></td><td>body. However it decays into Pb^{210} which attaches itself to vegetation such as tobacco leaves as a solid and subsequently decays into Po^{210} which emits an energetic alpha particle with 5.3 MeV of energy. The inhalation of these two isotopes in the particulate matter of cigarettes smoke delivers to the average smoker a radiation dose equivalent or dose equivalent of 8 rems (radiation equivalent man) per year to the basal cells of the bronchial tissue. The “cancer dose” is the total radiation dose that if spread through a population would cause one additional cancer death and is considered to be approximately 2,000 rems. Calculate the ensuing radiological risk in units of cancer deaths per year in a population of one million smokers.</td></tr>
<tr><td>13</td><td>9/23</td><td>9/30</td><td>Reading Assignment
2. Food Preservation by Radiation
3. Terrestrial Radioactivity and Geothermal Energy
Written Assignment
For the following radiological quantities, fill out the table showing the corresponding units and their abbreviations.
<table><tr><td>Radiological quantity</td><td>Conventional System Unit</td><td>SI System Unit</td></tr><tr><td>Absorbed dose</td><td></td><td></td></tr><tr><td>Activity</td><td></td><td></td></tr></table>
Calculate the ratio of heat convection in rocks to that of incident solar radiation.
Compare the result to the ratio of energy available in photosynthesis, storage in plants, and fossil fuels to the incident solar radiation.
Discuss the implication concerning geothermal energy, bioenergy and fossil fuel sources.
Hint: Use the data in Table 2 on the Earth’s power flows in the notes.</td></tr>
<tr><td>14</td><td>9/25</td><td>10/2</td><td></td></tr>
<tr><td>15</td><td>9/28</td><td>10/2</td><td></td></tr>
<tr><td>16</td><td>9/30</td><td>10/2</td><td></td></tr>
<tr><td>17</td><td>10/2</td><td>10/2
First
Midterm</td><td></td></tr>
<tr><td>18</td><td>10/5</td><td>10/12</td><td></td></tr>
</table>

Assignments Policy

Assignments will be turned in at the beginning of the class period, one week from the day they are assigned.
They need to be submitted earlier when tests are scheduled.
The first five minutes of the class period will be devoted for turning in, and returning graded assignments.
Late assignments will be assigned only a partial grade. Please try to submit them on time since once the assignments are graded and returned to the class, late assignments cannot be accepted any more.
If you are having difficulties with an assignment, you are encouraged to seek help from the teaching assistants (TAs) during their office hours. Questions may be e-mailed to the TA's, but face-to-face interaction is more beneficial.

Although you are encouraged to consult with each other if you are having difficulties, you are kindly expected to submit work that shows your individual effort. Please do not submit a copy of another person's work as your own. Copies of other people's assignments are not conducive to learning, and are unacceptable.
For further information, please read the detailed assignments guidelines.