1. The nucleus of \(^{14}\text{C}\), the \(A=14\) isotope of Carbon \((Z=6)\), is made up of
   a) eight protons and six neutrons.
   b) six protons and eight electrons.
   c) fourteen protons.
   d) six protons and eight neutrons.
   e) six protons and six neutrons.

2. In a fission reactor, about 0.1% of the mass of the fissionable fuel is converted into energy. How many kilograms of \(^{235}\text{U}\) are needed to provide the annual thermal energy input required in the reactor core of a 33%-efficient, 1000 MW electric plant?
   a) 350 kg
   b) 1.060 kg
   c) 1.06 kg
   d) \(3.18 \times 10^9\) kg
   e) \(3.18 \times 10^{10}\) kg

3. One way that a \(^{235}\text{U}\) nucleus can fission in the core of a thermal fission reactor is
   \[ n + ^{235}\text{U} \rightarrow ^{141}\text{Ba} + ^{91}\text{Kr} + 5n \]
   Using the masses in amu below, how much energy is released in this example of fission?
   \( ^{235}\text{U} = 235.0439; n = 1.008665; ^{141}\text{Ba} = 140.9141; ^{91}\text{Kr} = 89.9198 \)
   a) 0.175 MeV
   b) 175 MeV
   c) 163 MeV
   d) 2.2 MeV
   e) 200 MeV

4. Consider a boiling water reactor (BWR) where 1000 kcal of input heat energy at 285°C produce 400 kcal of waste heat at 100°C and 600 kcal of electrical energy. Concerning this BWR one can say:
   a) \(\eta_{\text{max}}\) of the BWR is 65%, and its efficiency is 40%.
   b) the situation is impossible.
   c) the efficiency of the BWR is 33%.
   d) the maximum efficiency of the BWR is 60%.
   e) the efficiency of the BWR is 60% and \(\eta_{\text{max}}\) is 65%.

5. Which of the following comments about moderators in nuclear reactors is true?
   a) Nuclear reactors in Canada use heavy water as their moderator.
   b) Moderators are usually coated with a cladding of stainless steel or zircaloy.
   c) Moderators are used principally to absorb neutrons.
   d) Moderators are usually fabricated of cadmium and boron, which slow down neutrons.
   e) The moderator used in the Soviet reactors at Chernobyl is light water.
6. We have discussed a number of radioactive nuclei. For each of the following nuclei indicate whether it is a fission fragment, a fissionable fuel, or neither.

\[ ^{238}\text{U}, \quad ^{137}\text{Cs}, \quad ^{90}\text{Sr}, \quad ^{239}\text{Pu}, \quad ^{14}\text{C} \]

a) [fuel, fragment, fragment, neither, neither]
b) [neither, fragment, fragment, fuel, neither]
c) [fuel, fragment, neither, fuel, neither]
d) [fuel, fragment, fragment, fuel, fragment]
e) [neither, fuel, fuel, fragment, neither]

7. In the course of normal operation, a thermal fission reactor releases 1 mrem/year of Tritium \(^{3}\text{H}\). If the half-life of Tritium is 12.5 years, how long will it take for the amount of released Tritium to decay to the level of 0.25 mrem/year?

a) 1 year
b) 25 years
c) 12.5 years
d) 37.5 years
e) 50 years

8. From our discussion of the Chernobyl Reactor disaster of 1986, which of the following is mainly responsible for the disaster?

a) The use of graphite instead of water to moderate neutrons.
b) Electrical power failure in Soviet grid system near Kiev.
c) Fundamental reactor design flaw in control rod design.
d) Pump failure in reactor coolant system.
e) Operators carrying out forbidden procedures.

9. Based on data from Hiroshima, the number of cancer deaths is about 1 cancer death per 5,000 person-rem's of exposure. Using this rate, how many additional cancer deaths would you expect from the Chernobyl accident where 100,000,000 people were exposed to an average of 0.5 Rem additional radiation?

a) 4,000 deaths
b) 1,000 deaths
c) 4,000,000,000 deaths
d) 400,000 deaths
e) 10,000 deaths

10. Hot objects emit thermal radiation. The operating temperature of the reactor core of the HTGR at Ft. Saint Uran in Colorado is 500°C. A distribution of wavelengths of electromagnetic radiation is emitted. What is the most likely wavelength to be emitted? [Hint: the visible spectrum extends from red light at 0.7 x 10^-6 m to violet at 0.4 x 10^-8 m.]

a) ultraviolet
b) x-ray
c) infrared
d) red
e) violet
11. Yellow light has a frequency of $5.4 \times 10^{14}$ Hz. How much energy does each photon of yellow light carry?
   a) $2.4 \times 10^{-11}$ eV
   b) 0.22 eV
   c) $3.6 \times 10^{-19}$ eV
   d) 2.2 eV
   e) $4.1 \times 10^{-15}$ eV

12. How hot must the filament in a 100 watt light bulb be in order for it to radiate a thermal energy spectrum whose wavelength at the maximum corresponds to that of yellow light?
   a) 273 °K
   b) 520 °K
   c) 5200 °K
   d) 540 °K
   e) 5200 °C

13. We often drink coffee from a "hot" cup made of styrofoam, a material with a thermal conductivity, $k$, of 0.01 watts/m°C. What is the heat loss through the sides and bottom of a styrofoam cup when it has boiling water (T=100°C) inside and room temperature air (T=20°C) outside. Styrofoam cups are 3mm thick (0.011m) and have a total surface area of 0.01 m². [Hint: use $Q/\text{time} = (k)(A)(\Delta T)/L$]
   a) 27,000 watts
   b) 2,700,000 watts
   c) 0.027 watts
   d) 2.7 watts
   e) 270 watts

14. From a table of average Degree-Days (DD), one finds for Indianapolis in March (31 days), 177 Degree-Days. What is the average temperature in March in Indianapolis?
   a) 52.3°F
   b) 55.3°F
   c) 59.3°F
   d) 65.0°F
   e) 47.3°F

15. Your Bloomington apartment has 30 ft² of single-pane glass windows, with a R value of 1.0 ft²·°F·hr per Btu. How much heat do you lose through your windows for each one Degree-Day in winter? [Hint: use $Q/\text{time} = (A)(\Delta T)/R$]
   a) 1.08 x 10² Btu
   b) 720 Btu
   c) 3600 Btu
   d) 1.25 Btu
   e) 30 Btu
16. A rule-of-thumb for solar collectors states that the break-even cost for a 30%-efficient collector is about $20/ft^2. For how many seconds would 1.0 ft\(^2\) of this 30%-efficient collector have to operate to collect and deliver $1 worth of energy. Use a solar flux of 15 W/ft\(^2\) and an energy cost of $1.00 for 10\(^6\) Joules of energy.

a) 0.66 x 10\(^6\) sec  
b) 2.2 x 10\(^6\) sec  
c) 4.44 x 10\(^6\) sec  
d) 1.11 x 10\(^6\) sec  
e) 1.33 x 10\(^6\) sec

17. A P125 student decides to cover the flat roof of his electric car with photovoltaic cells. At present, amorphous (polycrystalline) Silicon solar cells have a ratio of output electric energy to incident solar energy of approximately

a) 0.15  
b) 0.30  
c) 0.55  
d) 0.99  
e) 0.01

18. Standing at the top of the small dam at the end of Lake Monroe, we estimated that the water was flowing through the dam at about 5 m/sec and was falling a distance of 8 meters. If an 80%-efficient hydropower plant were installed, how many households could such a dam supply with electricity?

[Assume that an average household uses 1000 watts of power.]

a) 31 households  
b) 310 households  
c) 3,100 households  
d) 31,000 households  
e) less than one household

19. One of our own students is making a study of geothermal energy. She wishes to know which one of the following statements concerning geothermal energy is Incorrect.

a) Geothermal power production is accompanied by several kinds of pollution including noise pollution and air pollution.  
b) The specific heat of rock is less than that of water.  
c) At present, in the US, geothermal energy is only used for electricity generation.  
d) Dry steam sources of geothermal energy are rare in the US.  
e) At present the US produces less than 10 Gigawatts of electric power from Geothermal sources.

20. A local contractor has invented an OTEC device which he installs in his swimming pool. The temperature at the surface of his pool is 30°C while the temperature at the bottom of the pool is 25°C. In actual operation he finds that for every 1001 Joules of heat delivered to the cool water at the bottom, his device must take in 1001 Joules of heat at the top. The operating efficiency of this OTEC device is:

a) .00165  
b) .167  
c) .833  
d) .999  
e) .001

Answers: d c e b a; b b e c e; d c d c b; b a b c e