P125 Energy in the 21st Century

HOMEWORK ASSIGNMENT #13

(Due 8:00 pm, Wednesday, April 20, 2005)
(except for P5-9-18, due 8:00 pm, Friday, April 29, 2005)

I. Introduction: 1 point

In this homework assignment we complete our discussion of a Plan for our Future Use of Energy.

Our plan for the transition period considers the relative merits of coal, thermal fission, and solar energy sources for electrical energy generation and local heating and cooling. For the long-term plan, diversification and flexibility are the key words, vigorously pursuing both research on new technologies and engineering of small pilot plants. Only coal, nuclear and solar sources have long enough lifetimes.

During this week we use a portion of your P125 time to continue work on your research paper (HW#14).

The essay question for HW#13 involves providing your title, a list of references, and a one-page outline of your paper. Some of the questions (Q5-Q6) and problems (P5-9, P8) on this assignment are for review and are assigned in preparation for the Third Test (to be held 8:00-10:00 pm, Thursday, May 5).

II. Questions: 6 points

Q1. The main advantages of each energy source under consideration for the transition period are:

- _______ cost and _______ abundant for coal, _______ pollution and _______ CO₂
  for thermal fission, and a _______ energy source and _______ CO₂ for solar.

Q2. Two new designs for thermal fission reactors of a second generation are:

- _______ Light Water Reactors with gravity feed of core cooling and _______ Reactors (HTGR) with better safety and performance.

Q3. Uranium resources are limited. Two nuclear alternatives for the long-term future are:

- _______ Fission Reactor, which breeds new ²³⁹Pu fuel from existing ²³⁸U and _______ Fusion Reactor, whose energy source is from D+D or D+T fusion.

Q4. One of the goals of advanced technologies with coal is to develop cleaner ways to use our vast coal reserves. In coal _______, the synthetic coal gas (syngas) produced may have a lower sulfur content than the original solid coal. In coal _______, further distillation leads to a synthetic liquid fraction (synoil) that has a higher energy content.

Q5. Units tell us whether it's energy or power. Label the following units as units of Energy (E) or Power (P) by entering the appropriate letter in each blank.

  - _____ Joule, _____ MW, _____ kilowatt-hour, _____ kg-m/s², _____ kcal/s, _____ kg-m²/s³.

Q6. Label the following energy sources or strategies as short-term (S), transition period (T), or long-term (L) according to the time-scale of our "Energy Plan for the Future" where their presence is most important by entering the appropriate letter in each blank.

  - ____ conservation, ____ fusion, ____ thermal fission, ____ solar electric.

III. Problems: 8 points

P1. The temperature of the core of the Super Phoenix fast-breeder reactor is 627°C and the condenser temperature is 27°C. For 1000 kcal of energy input at 627°C, the work out is 400 kcal. The real efficiency = _______ % and the maximum efficiency = _______.

P2. Suppose 25% of the coal used annually in the US (see Priest, Table 3.1) is to be converted to synthetic natural gas (SNG). The SNG yield from coal is 10,000 ft³ SNG per ton of coal. The amount of SNG converted = _______ ft³ SNG. As a result of this conversion, the percentage increase in the US annual natural gas consumption = _______ %.

(over)
P3. The fusion of deuterium and tritium via the D + T reaction

\[ ^1\text{H} + ^3\text{H} \rightarrow ^4\text{He} + ^1\text{n} + \text{energy} \]

is one of the D + T fusion reactions that leads to a large energy release. The masses in amu are \( m_d = 2.014012 \), \( m_t = 3.0166066 \), \( m_n = 4.002603 \), \( m_H = 1.008665 \). The amount of mass converted to energy, \( \Delta m = [2m_{\text{nuc}} - 2m_{\text{det}}] \), is \( \quad \text{amu} \)
and the energy released in this fusion reaction is \( \quad \text{MeV} \).

P4. High grade oil shale has an oil content of 25 gal/ton of ore. A gallon of oil has an energy content of 1.45 \( \times \) 10^8 joules and 1 ton = 910 kg. The energy density of the oil shale is \( \quad \text{J/kg or W-hr/kg} \). If the oil shale is located at a depth of 100 meters, the ratio of its oil energy content to the work that must be done against gravity to raise it to the surface (i.e., work = \( \Delta FE = \text{mgh} = \quad \text{m}^2 \).

P5. A pumped-water storage reservoir at an elevation of 300 meters above an electric generating plant must be able to produce 25% of the 24-hour energy output of the 1000 MW plant. The 24-hour output of the plant is \( \quad \text{joules} \). If the efficiency of the pumped-storage plant is 80%, the required volume of the reservoir is \( \quad \text{m}^3 \).

P6. In 1970, the electrical energy usage was growing exponentially at a rate of 7% per year. This corresponds to a doubling time = \( \quad \text{years} \). Suppose this rate of growth suddenly drops to a rate of 3.5% per year or a new doubling time = \( \quad \text{years} \). Forty years later, in 2010, the ratio of the old projected energy usage to the new reduced projected energy usage = \( \quad \).

P7. For January (31 days), Bloomington has a heating load of 1000 degree-days (DD). The average outdoor temperature for this period = \( \quad \)°F. Suppose your house has a thermal conductance of 15,000 Btu/DD. With the thermostat set to 65°F, the amount of thermal energy lost for the month of January = \( \quad \) Btu. The amount of thermal energy saved for the month of January by lowering the thermostat to 55°F = \( \quad \) Btu.

P8. Each 24-hour day, 1.0 m\(^3\) of soil produces 20 grams of food that is 10% carbohydrates. 1.0 kilogram of carbohydrates is equivalent to 4000 kcal. The area that must be planted to provide carbohydrates for an athlete who needs 3000 kcal/day = \( \quad \text{m}^2 \).

IV. Essay Question: 10 points

Instructions: Type your response to the Essay Question in the window provided. Your answer to the Essay Question should begin with a title describing its content and it should be about 300 words or 5 paragraphs in length. You can work on this essay in more than one sitting, but please be sure to SAVE the contents of your window often!

Essay Question:
For Homework #14, due on Monday, April 25, your assignment is to write a short research paper on a topic concerned with energy, an energy-related technology, or US energy policy.

For Homework #13, please provide me with:
I. Your Name and the Title of your research paper,
II. List of References (that you will be using),
III. Outline of your research paper (one-page, single-spaced).

Please include these three items in your response to the essay question this week.