I. Introduction: 1 point

In this homework assignment we will consider how we make use of energy in the fossil fuel era. We will examine the origins of electrical energy and consider the physical principles that govern its generation and use. Both the energy transformations that take place at electric power plants during the generation of electrical energy and the environmental impact of these power plants are relevant. Our consideration of thermal energy will lead us to a description of the energy conversion devices employed at an electric power plant to convert thermal energy to mechanical energy and the fundamental limits that physics places on their efficiencies.

II. Questions: 6 points

Q1. Compared to oil and coal, natural gas has several advantages as an energy source. They include: ________ burning, ________ cost, and ________ to transport.

Q2. Hubbert's model has been used to estimate the lifetimes of our US fossil fuel reserves. 100 years from now, for naturally-occurring fossil fuels, deposits of ________ will be very scarce, but there will still be an abundance of ________.

Q3. According to our Energy Flow Diagram for the US in 1980 (Figure 2 in UFAE): the efficiency of the electrical energy generation sector = ________% and the percentage of the input energy that is lost = ________%.

Q4. In the transmission of electrical energy with alternating currents (AC), transformers are electromagnetic devices used to step up or step down the AC ________.

Q5. The environmental impacts of emissions from a fossil-fuel electric power plant include: global warming which is linked to ________ gas from the combustion of coal and acid rain which arises from ________, oxides and ________.

Q6. Thermal energy is a measure of the ________ KE of the molecules of a substance? The 1st Law of Thermodynamics is an extension of the principle of conservation of ________ to include thermal energy and heat.

III. Problems: 9 points

P1. Priest's model of a fossil-fueled electrical plant gives energy conversion efficiencies for the following stages; (boiler, 88%), (turbine, 47%), and (generator, 99%). The overall efficiency of this plant is ________%.

P2. From 1935 to 1975, the electrical energy use in the US grew at a rate of 7% per year. The doubling time for electrical energy use during this period = ________ years. The growth factor for this forty-year period = ________ x ________ x ________ = ________.

P3. Suppose you left a 100 W light bulb on continuously for one month (30 days). The electrical energy consumed by the bulb = ________ kW.hr and at 7 cents per kW.hr the energy cost = ________.

P4. An electric toaster uses 1100 watts of electric power when it is connected to a standard household electrical outlet rated at 110 volts. The electric current = ________ amps and the resistance of the toaster = ________ ohms.

(over)
P5. A 1000 MW electric generating plant with 40% efficiency operates for a 24-hour period. The total electrical energy output = __________ joules and the thermal energy input from coal = __________ joules.

P6. The high-grade coal burned in the 1000 MW power plant is 80% Carbon and the energy released in burning 1 ton of high-grade coal is $2.40 \times 10^9$ joules. The number of tons of coal to produce this thermal energy input = __________ tons.

P7. 100 tons of high-grade coal (80% Carbon, 4% Sulfur and 16% incombustibles) are burned in the reaction $C + O_2 \rightarrow CO_2 + \text{energy}$. The number of tons of CO$_2$ produced = __________ tons.

P8. Suppose your body with a mass $m = 70 \text{ kg}$ is mostly water with a specific heat $C_{\text{H}_{2}\text{O}} = 1.0 \text{ kcal/kg}^\circ\text{C}$. The amount of heat energy ($Q$) required to raise your body temperature $\Delta T$ degrees is given by $Q = (m)(C_{\text{H}_{2}\text{O}})(\Delta T)$. The heat energy to raise your temperature from 98.6 $^\circ$F to 104 $^\circ$F = __________ kcal.

P9. A schematic diagram of an engine is shown on the right. This engine has a heat energy input ($Q_h$) of 1000 Btu at $T_H = 1000 ^\circ\text{K}$. It has output work ($W$) of 400 Btu and it gives up waste heat ($Q_c$) of 600 Btu at $T_c = 300 ^\circ\text{K}$. The actual efficiency = _______ %. The Carnot efficiency = _______ %.

IV. Essay Question: 9 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 each of the three stages (boiler, turbine, and generator) in the operation of a coal-fired, electric power plant, describe:
(a) the energy transformation that takes place,
(b) the efficiency of the energy conversion, and
(c) the emissions to the environment that occur.

Write a short critique of the operation of each stage of the plant indicating:
(a) how good the stage is,
(b) what improvements ought to be made to the stage, and
(d) what impact the improvements might have?

What will this do to the cost of electrical energy and what emissions will remain?