ENVIRONMENTAL SCIENCE

SECTION II

Time—90 minutes

4 Questions

Directions: Answer all four questions, which are weighted equally; the suggested time is about 22 minutes for answering each question. Write all your answers on the pages following the questions in this booklet, NOT on the green insert. Where calculations are required, clearly show how you arrived at your answer. Where explanation or discussion is required, support your answers with relevant information and/or specific examples.

1. A large, coal-fired electric power plant produces 12 million kilowatt-hours of electricity each day. Assume that an input of 10,000 BTU's of heat is required to produce an output of 1 kilowatt-hour of electricity.

   (a) Showing all steps in your calculations, determine the number of

   (i) BTU's of heat needed to generate the electricity produced by the power plant each day,

   (ii) pounds of coal consumed by the power plant each day, assuming that one pound of coal yields 5,000 BTU's of heat,

   (iii) pounds of sulfur released by the power plant each day, assuming that the coal contains one percent sulfur by weight.

   (b) The Environmental Protection Agency (EPA) standard for power plants such as this one is that no more than 1.2 pounds of sulfur be emitted per million BTU's of heat generated. Using the results in part (a), determine whether the power plant meets the EPA standard.

   (c) Describe two ways by which a fuel-burning electric power plant can reduce its sulfur emissions.

   (d) Discuss why sulfur emissions from coal-fired power plants are considered an environmental problem and describe one negative effect on an ecosystem that has been associated with sulfur emissions.

GO ON TO THE NEXT PAGE.

Question 1 Scoring Guide

(a) 3 POINTS MAXIMUM

1 point earned each for i, ii, and iii for correct setup and answer (units not required in answer)
1 point deducted if proper units not included within calculation in i and ii

Several different styles of equations earn credit. Some examples are:

i. $\dfrac{1.2 \times 10^{7}\ \cancel{\text{kWH}}}{\text{day}} \times \dfrac{1.0 \times 10^{4}\ \text{BTUs}}{\cancel{\text{kWH}}} = 1.2 \times 10^{11}\ \text{BTUs/day}$

$1.2 \times 10^{7}\ \cancel{\text{kWH}} \times \dfrac{1.0 \times 10^{4}\ \text{BTUs}}{\cancel{\text{kWH}}} = 1.2 \times 10^{11}\ \text{BTUs/day}$

$\dfrac{1.0 \times 10^{4}\ \text{BTUs}}{1\ \text{kWH}} = \dfrac{x}{1.2 \times 10^{7}\ \text{kWH}}\ ;\quad x = 1.2 \times 10^{11}\ \text{BTUs/day}$

$12{,}000{,}000\ \text{kWH} \times 10{,}000\ \text{BTU/kWH} = 120{,}000{,}000{,}000\ \text{BTUs/day}$

ii. $\dfrac{1.2 \times 10^{11}\ \cancel{\text{BTUs}}}{\text{day}} \times \dfrac{1\ \text{lb coal}}{5.0 \times 10^{3}\ \cancel{\text{BTUs}}} = 2.4 \times 10^{7}\ \text{lbs coal/day}$

$\underline{1.2 \times 10^{11}\ \cancel{\text{BTUs}}} \times \dfrac{1\ \text{lb coal}}{5.0 \times 10^{3}\ \cancel{\text{BTUs}}} = 2.4 \times 10^{7}\ \text{lbs coal/day}$

$\dfrac{1\ \text{lb coal}}{5.0 \times 10^{3}\ \text{BTUs}} = \dfrac{x}{1.2 \times 10^{11}\ \text{BTUs}}\ ;\quad x = 2.4 \times 10^{7}\ \text{lbs coal/day}$

$120{,}000{,}000{,}000\ \text{BTUs/day} \div 5{,}000\ \text{BTUs/lb coal} = 24{,}000{,}000\ \text{lbs coal/day}$

iii. $\dfrac{2.4 \times 10^{7}\ \cancel{\text{lbs coal}}}{\text{day}} \times \dfrac{0.01\ \text{lb sulfur}}{1\ \cancel{\text{lb coal}}} = 2.4 \times 10^{5}\ \text{lbs sulfur/day}$

$2.4 \times 10^{7}\ \text{lbs coal} \times \dfrac{0.01\ \text{lb sulfur}}{1\ \text{lb coal}} = 2.4 \times 10^{5}\ \text{lbs sulfur/day}$

$\dfrac{1\ \text{lb sulfur}}{100\ \text{lbs coal}} = \dfrac{x}{2.4 \times 10^{7}\ \text{lbs coal}}\ ;\quad x = 2.4 \times 10^{5}\ \text{lbs sulfur/day}$

$24{,}000{,}000\ \text{lbs of coal/day} \times 1\%\ \text{sulfur} = 240{,}000\ \text{lbs of sulfur/day}$

(b) 2 POINTS MAXIMUM

1 point earned for an appropriate method that shows how the conclusion was reached (units of measurement not required)

$$\frac{1.2 \times 10^{11}\ \cancel{\text{BTUs}}}{\text{day}} \times \frac{1.2\ \text{lbs}}{1.0 \times 10^{6}\ \cancel{\text{BTUs}}} = 1.44 \times 10^{5}\ \text{lbs sulfur/day maximum allowable release}$$

$$120{,}000{,}000{,}000\ \cancel{\text{BTUs}} \times \frac{1.2\ \text{lbs}}{1{,}000{,}000\ \cancel{\text{BTUs}}} = 144{,}000\ \text{lbs sulfur/day maximum allowable release}$$

$$\frac{2.4 \times 10^{5}\ \text{lbs sulfur}}{1.2 \times 10^{11}\ \cancel{\text{BTUs}}} \times \frac{1.0 \times 10^{6}\ \cancel{\text{BTUs}}}{1\ \text{million BTUs}} = 2\ \text{lbs sulfur/million BTUs actually released}$$

$$\frac{2.4 \times 10^{5}\ \text{lbs sulfur}}{1.2 \times 10^{11}\ \text{BTUs}} = \frac{x}{1.0 \times 10^{6}\ \text{BTUs}}\ ; \quad x = 2\ \text{lbs sulfur per million BTUs}$$

$$1{,}000{,}000\ \cancel{\text{BTUs}} \times \frac{1\ \text{lb coal}}{5{,}000\ \cancel{\text{BTUs}}} = 200\ \text{lbs coal}$$

$$200\ \cancel{\text{lbs coal}} \times \frac{1\ \text{lb sulfur}}{100\ \cancel{\text{lbs coal}}} = 2\ \text{lbs sulfur/million BTUs}$$

1 point earned for reaching a conclusion that is consistent with the method used to compare the permissible sulfur level with the sulfur level determined in (a) iii or with the 1.2 lbs permitted by the EPA. (Conclusions that are incorrect due to mathematical errors, but are based on valid calculations, earn the point.)

The power plant is NOT in compliance, because it releases

- 2 lbs of sulfur per million BTUs instead of the 1.2 lbs per million BTUs as the EPA allows

<u>OR</u>

- 2.4×10^{5} lbs of sulfur/day when the limit is 1.44×10^{5} lbs/day

(b) Scientific Information (4 POINT MAXIMUM)

i. Environmental benefits (1 point for each piece of scientific information with a 2 POINT MAXIMUM – no credit earned for economic statements)
ii. Environmental costs (1 point for each piece of scientific information with a 2 POINT MAXIMUM – no credit earned for economic statements or any negative variation of a statement from part i)

From the following list of pieces of scientific information that might be needed to evaluate the environmental benefits and costs of recycling newspapers, four different items should be included in the answer, two of which should clearly be identified as benefits and two as costs. No credit is earned for a negative or opposite variation of any statement given as a previous answer.

- Amount of energy required to recycle *vs*. the use of virgin materials or the reuse of newspapers
- Amount of water used to recycle *vs*. the use of virgin material or the reuse of newspapers
- Number of trees harvested for virgin materials *vs*. number of trees harvested for recycled material
- Volume of newspapers in landfills
- Time required for newspaper to decompose
- Effect of timber harvesting on soil erosion or water quality
- Effect of pollution from paper reprocessing *vs*. processing or the reuse of newspapers on air quality
- Effect of pollution from paper reprocessing *vs*. processing or the reuse of newspapers on water quality
- Effect of timber harvesting on habitats/ecosystems/biodiversity
- Effect of recycling plant construction on habitats/ecosystems/biodiversity
- Volume of newspapers required to support a recycling plant
- Amount of virgin material required to strengthen recycled fibers
- Amount and types of toxic waste produced from reprocessing (de-inking and bleaching) *vs*. processing (inking) or reusing newspapers.
- Effect of newspapers on leachate in landfills

(c) Recommendation and Two Reasons**-** 1 point for each reason (2 POINT MAXIMUM)
Aluminum:

- Non-renewable resource as opposed to trees which are a renewable resource
- There is a greater demand for recycled aluminum than recycled paper
- Reduces U.S. dependence on other countries for virgin aluminum (bauxite)
- Monetary return for aluminum is greater than that for newspapers ($800 per ton of aluminum *vs*. $160 per ton of newspaper – 1996. Some states have passed legislation that requires a monetary deposit on aluminum cans.)
- Cost of baling and organizing newspapers is greater than aluminum
- Negative effects of mining are greater than the negative effects of timber harvest*****
- Newspapers are more likely to be reused
- As more newspapers become available on the internet, fewer people may purchase paper copies, thereby reducing the supply of newspapers to be recycled
- Paper can be made from the fibers of rapidly growing plants other than trees
- Recycling aluminum is more energy efficient than recycling newspapers
- Some states have banned aluminum cans from disposal in landfills but not newspapers
- Newspapers are biodegradable, whereas aluminum is not
- Aluminum can be recycled more times than newspaper without significant effect on quality