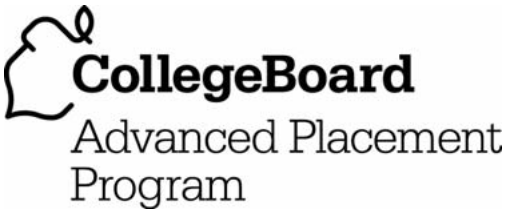

AP® Environmental Science
2007 Scoring Guidelines

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AP® ENVIRONMENTAL SCIENCE
2007 SCORING GUIDELINES

Question 1

Read the Fremont Examiner article below and answer the questions that follow.

(a) Identify ONE component of the sewage that is targeted for removal by primary treatment and ONE component of the sewage that is targeted for removal by secondary treatment. (2 points—1 point for each)

Primary treatment removal	Secondary treatment removal
Any relatively large (macroscopic) solid material (e.g. rocks, gravel, sand, solid human or animal waste, twigs, cans, etc)	Dissolved/suspended organic materials such as human waste products, soaps, detergents, food waste, pathogens (e.g., *E. coli*)
Fats, oil, or grease (FOG)	Phosphates, Nitrates

(b) For EACH of the pollutants that you identified in part (a), describe how the pollutant is removed in the treatment process. (2 points—1 point for each)

PRIMARY TREATMENT

Pollutant	Removal mechanism
All large objects such as rags, sticks, condoms, cans, tampons, fruit, etc.	Description of a physical process for removing solids from the liquid component (grid filtration, screening, sieving, nets, filters, etc.)
Sand, grit, fecal material	A settling tank; incoming wastewater is slowed so sand, grit, small rocks, fecal material can settle out (also called a detritor or sand catcher)
Fats, oil, or grease	Allowed to float to the top of the wastewater, where it can be mechanically skimmed off

SECONDARY TREATMENT

Pollutant	Removal mechanism
Any dissolved/suspended organic substance	1) Effluent is brought in contact with oxygen and aerobic microorganisms that break down/consume the organic matter 2) Anaerobic microbial digester 3) Secondary sedimentation and floc removal
Pathogens (bacteria, *E. coli*, etc.)	Disinfection (chlorine, ozone, UV, etc.)
Phosphate	Lime, alum, aluminum sulfate, iron chloride, iron sulfate, biological removal
Nitrates/Ammonia	Denitrifying bacteria (anaerobic microbial digester)

AP® ENVIRONMENTAL SCIENCE
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Question 1 (continued)

(c) Explain how sewage treatment plants create the solid waste problem that Dr. Goodwin mentioned in the article. (1 point)

Particulates and other substances removed from wastewater during primary and secondary treatment create a significant amount of solid material which must then be disposed of elsewhere.

(d) Two common methods of disposing of solid waste from sewage treatment plants are transporting it to a landfill or spreading it onto agricultural lands. Describe an environmental problem associated with EACH of these methods. (2 points)

Landfill Problems	Agricultural Problems
Takes up a considerable amount of landfill space (resulting in expansion or new development of landfills) Potential groundwater contamination (toxins, contaminants, heavy metals, leachates) Greenhouse gases, such as methane, produced during anaerobic decomposition can escape into the atmosphere and contribute to global warming Environmental effects associated with transportation of solid waste	Human/animal health problems associated with bacterial wastes contaminating food/feed crops Potential groundwater/soil/plant contamination (toxins, contaminants, heavy metals, leachates) Incorporation of toxins/heavy metals into the food chain Field runoff resulting in surface water contamination (eutrophication/oxygen depletion of surface waters due to wastes high in nitrogen or phosphorus)

(e) The final step in sewage treatment is disinfection. Identify ONE pollutant that is targeted during disinfection and identify ONE commonly used method of disinfection. (2 points—1 point for identifying a pollutant and 1 point for identifying a method of disinfection)

Pollutants: Pathogenic contaminants:

- *E. coli* bacteria
- Coliform bacteria
- *Giardia*
- Pathogens
- Microorganisms/bacteria
- Cholera
- Viruses

Question 1 (continued)

Method of disinfection (pollutant and disinfection method do NOT need to be linked)**:**

- chlorine or ozone (or other oxidizing chemicals such as bromine, iodine or hydrogen peroxide, bleach/sodium hypochlorite, chloramines)
- ultraviolet radiation (UV)
- microfiltration (using ceramic filters)
- lime treatment
- electron beam radiation

(f) Identify ONE United States federal law that requires monitoring the quality of the treated sewage that is discharged into the Fremont River. (1 point for specifically identifying a U.S. federal law)

- (Federal) Water and Pollution Control Act (1956)
- National Environmental Policy Act (1969)
- (Federal) Water Pollution Control Act (1972), (1977), (1987)—"Clean Water Act" accepted
- (Federal) Safe Drinking Water Act (1974)—amended in 1996 to include protection of drinking water sources

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Question 2

The Cobb family of Fremont is looking at ways to decrease their home water and energy usage. Their current electric hot-water heater raises the water temperature to 140°F, which requires 0.20 kWh/gallon at a cost of $0.10/kWh. Each person in the family of four showers once a day for an average of 10 minutes per shower. The shower has a flow rate of 5.0 gallons per minute.

(a) Calculate the following. Be sure to show all your work and include units with your answers.

(i) The total amount of water that the family uses per year for taking showers (2 points—1 point for correct set-up and 1 point for correct answer with units)

10 minutes/day x 5 gallons/minute x 365 days/year x 4 (people) = 73,000 gallons/year
(73,000 gallons also acceptable due to usage defined as per year)

(ii) The annual cost of the electricity for the family showers, assuming that 2.5 gallons per minute of the water used is from the hot-water heater (2 points—1 point for correct set-up and 1 point for correct answer with units)

73,000 gallons/year ÷ 2 = 36,500 gallons of hot water per year

36,500 gallons/year x 0.20 kWh/gallon x $0.10/kWh = $730/year
($730 also acceptable due to cost defined as per annum)

(b) The family is considering replacing their current hot-water heater with a new energy-efficient hot-water heater that costs $1,000 and uses half the energy that their current hot-water heater uses. How many days would it take for the new hot-water heater to recover the $1,000 initial cost? (2 points—1 point for correct set-up and 1 point for correct answer with units)

Old bill for electricity = $730/year = $2/day ($730/yr ÷ 365day/year = $2/day)

New bill for electricity = $730 ÷ 2 = $365/year
$365/yr ÷ 365 day/year = $1/day = new cost per day

Old cost = $2/day, new cost = $1/day
Savings old – new = $1/day
Days to pay off initial cost = cost ÷ $saved/day = $1,000 ÷ $1/day = 1,000 days
(1,000 also acceptable due to days stated in the question)

With the old heater they were spending $2/day for hot water for showers; with the new heater they would spend $1/day for hot water for showers. Therefore, the savings is $1/day, and they would recover the $1,000 cost of the new hot-water heater in 1,000 days.

Savings calculation alone:
0.2kWh/gallon ÷ 2 = 0.10kWh/gallon saved
0.10kWh/gallon x 2.5 gallons/minute x 10 minutes/person x 4 people x $0.10/kWh = $1/day
$1,000 ÷ $1/day = 1,000 days

Another way of looking at it:
The new hot-water heater would mean a savings of $365 per year. $1,000 ÷ $365/year = 2.74 years
2.74 years x 365 days/year ≈ 1,000 days (1,000 also acceptable due to days given in problem)

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Question 2 (continued)

(c) Describe TWO practical measures that the family could take that would reduce their overall water use at home. (2 points total—1 point for each measure)

Valid answers to this question include:

Reduce the length of daily showers
Shower less frequently
Install low-flow shower heads and/or toilets
Make sure all water leaks are fixed
Don't let water run while brushing teeth
Run the dishwasher or washing machine only when fully loaded
Use a water-efficient appliance
Hand washing dishes uses less water then running a dishwasher
Use of paper plates and plastic silverware; not using the dishwasher
Use plants outside that require little watering/only water on alternate days/use drip irrigation systems/moisture sensing sprinklers
Sweeping driveway/sidewalks versus washing with water
Don't let water run while washing the car
Wash the car less frequently
Use a car wash
Reuse of water—gray water, bucket in shower to later water plants, rain barrel, etc.

(d) Describe TWO conservation measures (other than reducing hot water use) that the family could take to reduce the total amount of energy that they use at home. (2 points—1 point for each measure)

Valid answers to this question include:

Turn off electric appliances when no one is in the room
Turn off lights in daylight hours
Replace incandescent light bulbs with fluorescents
Increase insulation
Set thermostat to higher temperatures in the summer and lower temperatures in the winter
Use an automatic thermostat that lowers/raises temperatures when no one is in the house
Replace appliances with energy-efficient appliances
Caulk and/or weather-strip exterior doors and windows
Replace single-pane windows with double-pane or other more energy-efficient windows
Open windows/run fans rather than running air-conditioning
Use sweaters/blankets rather than running heater
Reduce usage by not using appliances—hand wash vs. dishwasher
Unplug appliances when not in use.
Line dry clothing instead of using dryer
Lower thermostat of water heater
Add insulation blanket to the hot water heater
Purchase more energy-efficient water heater
Use of passive solar with description

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Question 3

In the mid 1970s, Sherwood Rowland and Mario Molina predicted a thinning of the stratospheric ozone layer over Antarctica. The thinning was confirmed in the late twentieth century and has continued into the twenty-first century.

(a) Identify the class of chemical compounds that is primarily responsible for the thinning of the stratospheric ozone layer and describe TWO major uses for which these chemicals were manufactured. (3 points)

*1 point for identifying a **class** of compounds—CFCs, halocarbons*
1 point each for describing two major uses
If students do not correctly identify a class of chemical, they cannot earn points for describing use.

Chlorofluorocarbons (CFCs)
- Coolant/refrigerant/air conditioners/refrigerators
- Aerosol or propellant
- Foam-blowing plastics/insulation (Styrofoam)
- Solvents/cleaners (e.g., methyl chloroform, carbon tetrachloride)

Halocarbons/Halons
- Fire retardant (fire extinguishers)
- Soil fumigant/pesticide (e.g., methyl bromide)
- Solvents
- Foam-blowing insulation

(b) Describe how the chemical compounds that you identified in part (a) destroy stratospheric ozone molecules. You may include chemical equations as part of your answer. (3 points)

Answer must link to chemical compounds identified in part (a)
- Description of how CFCs are broken down by UV radiation resulting in the release of halogen atoms—chlorine/bromine/fluorine
- Description of the process by which the halogen atoms prevent the formation of O_3 by sequestering atomic O to form halogen oxides, which is necessary for the formation of O_3
- Description of how the halogen breaks down O_3 into $O + O_2$, thereby reducing O_3 levels
- Description of how halogen is released to catalyze further reactions

Students can also earn points for demonstrating understanding of ozone depleting chemicals
- Description of how the stability of CFCs and/or halocarbons allow them to reach the stratosphere/no reservoir for CFCs in nature/chemicals are persistent
- Stratospheric clouds and/or ice crystals tend to enhance the reactions that break down O_3 / polar vortex which concentrates clouds and ice over the Antarctic

Reactions:

$CCl_3F + UV \rightarrow Cl + CCl_2F$
$Cl + O_3 \rightarrow ClO + O_2$
$ClO + O \rightarrow Cl + O_2$

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Question 3 (continued)

(c) Identify the major environmental consequence of the depletion of stratospheric ozone and describe TWO effects on ecosystems and/or human health that can result. (3 points)

1 point for identifying the major environmental consequence of depletion as an increase in UV (specifically UVB) reaching the earth's surface
1 point <u>each</u> for describing <u>two</u> effects of the identified consequence [increased UV] on ecosystems and/or human health (consequence [increased UV] must be identified to earn these points)

Human Health	Ecosystems
• Sunburn (if not linked to skin cancer) • Skin cancer in humans • Eye damage (cataracts) • Damage/reduction in efficiency of human immune system • Possible synergistic effects with various other air pollutants	• Reduction of primary productivity in oceans • Disruption of food chains • Direct damage to fish/amphibians/mammals • Widespread effects on major food crops (beans, wheat, rice, corn) • Decreased plant productivity

Students do not earn points for simply reiterating that increased UV causes damage to ecosystems and/or human health as stated in the question.

(d) Ozone formed at ground level is a harmful pollutant. Describe TWO effects that ground-level ozone can have on ecosystems and/or human health. (2 points)

1 point for <u>each</u> description of an effect that tropospheric ozone can have on ecosystems and/or human health

Human Health	Ecosystems
• Respiratory irritant (lung problem/irritation) • Coughing • Throat irritation • Pain, burning, or discomfort in the chest • Shortness of breath/tightness in chest • Eye irritant • Mucous membrane irritant • Aggravation of asthma/emphysema/chronic bronchitis • Increased susceptibility to lung infections (pneumonia and bronchitis) • Suppression of the immune system • Lung scarring/fibrosis • Impaired development of lungs in young children	• Chlorosis, bleaching, stippling, and spotting of leaves • Crop damage resulting in decreased yields • Kills leaf tissue at high concentrations • Stresses plants, possibly making them more susceptible to other diseases • Decreased photosynthesis due to reduced effective solar radiation to plants • As a greenhouse gas, ozone leads to global warming; this, in turn, results in environmental damage (e.g., disruptions of food chains, increased extinction resulting from climatic changes that may exceed an organism's range of tolerance, etc.)

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Question 4

Some scientists estimate that by 2025 over 60 percent of the global human population will live in urban areas. Urban residents experience a variety of problems related to the physical environment.

(a) Describe how the temperature of urban areas like Atlanta, Philadelphia, and Chicago differs from that of surrounding rural areas. (1 point)

Temperatures in urban areas tend to be **higher** than those in rural areas. (This temperature difference, called the "urban heat island effect," is typically larger during the nighttime hours.)

(b) Identify and describe TWO differences between urban and surrounding rural areas that contribute to the temperature difference between them. (4 points)

1 point each for stating two possible differences. 1 point for describing each stated difference. The description must match the given difference.

Possible Differences	Possible Descriptions
More: • asphalt • concrete • buildings, etc. Fewer/less: • trees • vegetation*	• Change in surface composition causes overall urban albedo (reflectivity) to decrease. The resulting increase in energy emission causes the temperature to rise. • The absorption of additional solar radiation by surfaces causes the temperature to increase due to increased energy emission by the surfaces. • Reduces the natural cooling effects of shading and evaporation of water from soil and leaves (may be regional) • Buildings may intercept outgoing infrared radiation emitted by the earth's surface. The absorption and scattering of this radiation reduces the rate of energy loss and leads to elevated urban temperatures.
More: • cars • factories/industry • machinery that use combustion	• Heat is a by-product of combustion.
Tall buildings/narrow streets	• Trap warm air between them or may reduce airflow • May reduce cooling by convection
More people	• Require housing, air conditioning, factories that all produce heat as a by-product

*In the Southwest increased vegetation leads to increased urban temperatures. The transpiration introduces more water vapor that may trap heat.

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Question 4 (continued)

(c) Urban areas typically have levels of air pollution that are significantly higher than those found in surrounding rural areas. Identify a characteristic of the urban microclimate that leads to higher levels of air pollution and describe how that characteristic contributes to the increase. (2 points)

1 point is awarded for identifying the characteristic, and 1 point is awarded for describing how it contributes to increased air pollution.

Possible Characteristic	Possible Description (must be specific)
(Increased combustion) due to large numbers of: • automobiles • burning garbage • factories • airplanes • or other urban machinery	• Increased temperature along with ozone precursors (e.g., NO_x, VOCs) increase ground level ozone • Increase in particulates (ash or soot) from incomplete combustion • Nitrogen oxides react with oxygen to form nitrogen dioxide (a foul-smelling brown gas). Also may combine with water vapor and other pollutants to produce smog • Other pollutants include sulfur oxides, lead, CO, and NO_x
Industrial processes	• Petroleum refineries produce hydrocarbon and particulates. • The volatile fumes from dry cleaners contribute to photochemical smog. • Bakeries and dry cleaners release hydrocarbons, which are converted with sunlight and other gasses to form ozone.
Urban development	• Increase in particulates from exposed soil
Tall buildings	• Trap pollutions or limit airflow, which will limit diffusion of pollutions
Less vegetation	• Less filtering/absorption of particulates, or pollutants such as CO, SO_x, NO_x, and ozone
Urban heat island effect	• Ozone formation due to photochemical reactions from precursors

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Question 4 (continued)

(d) Identify and describe TWO actions that local governments in urban areas could take to reduce outdoor air pollution. (2 points)

1 point is awarded for each acceptable action with an outcome attached that reduces outdoor air pollution.

Possible Action	Possible Outcome (Valid **description** that supports the action)
• Incentives/taxes -subsidize • Laws/regulations -CAFE standards, zoning, limits/bans, fines • Direct action - build mass transit, build bike paths, HOV lanes, plant vegetation, convert to less-polluting practice • Education - promote, suggest, encourage	• Reduced number/use of motor vehicles • Reduced emissions (tailpipe/industrial, etc.) • Improved fuel efficiency • Reduced particulates or other specific pollutants • Reduced fossil fuel use

(e) Identify and describe TWO ways in which the local hydrologic cycle of urban areas differs from that of nearby rural areas. (2 points)

1 point is awarded for each acceptable way with a complete thought attached.

Possible Ways
Manmade urban surfaces (e.g., asphalt, concrete, rooftops) absorb little water when compared with rural areas with more vegetation. This can result in: • Greater runoff in urban areas/decreased infiltration • Increased flooding during heavy rainfall events • Rapid discharge of water from storm drains directly into bodies of water • Reduced water evaporation from the soil into the atmosphere • Increased stream flow (peak flow, etc.) • Alteration of evapotranspiration rates Urban heat island effect causes daytime convection/rainfall to be more vigorous over urban areas.