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2007 SCORING GUIDELINES

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)

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

AP® ENVIRONMENTAL SCIENCE
2007 SCORING GUIDELINES

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:

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

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 each for describing two 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 each 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.)

Question 3 (continued)

(d) Identify TWO possible environmental consequences of climate change on the hydrology of the Colorado River system.

A total of 2 points can be earned, 1 for each correct response. The specific climate change must be paired with its effect on the hydrologic cycle. (Only the first two responses are scored.)

Specific Climate Change Phenomenon	Effect on Hydrologic Cycle
Warmer temperatures	• Reduced snow(pack) in (Rocky) Mountains • Increased evaporation from bodies of water • Increased evaporation from soil • Altered plant transpiration rates • Timing of snow/melt
Increased precipitation	• Increased surface water or groundwater inputs • Increased sedimentation in bodies of water • Increased aquifer recharge
Decreased precipitation	• Decreased surface water or groundwater inputs • Decreased sedimentation in bodies of water • Decreased aquifer recharge
Increased frequency or severity of storms	• Increased sedimentation • Increased flooding • Increased runoff volume

AP® ENVIRONMENTAL SCIENCE
2009 SCORING GUIDELINES

Question 3 (continued)

(e) In addition to impacts on the Colorado River system, climate change is impacting the hydrology of coastal ecosystems. Identify and describe TWO possible consequences of climate change on coastal ecosystems.

A total of two points can be earned, one for each correct response. A correct response both identifies a climate change phenomenon and describes how that change affects the coastal ecosystem. (Only the first two responses are scored.) A single phenomenon may be paired with two different effects on ecosystems.

Climate Change Consequence	Effect on Coastal Ecosystem
Rising sea levels	• Terrestrial ecosystems are inundated, affecting biota • Shallow aquatic systems become deepwater habitats • Saltwater intrusion of water table inland • Saltwater intrusion into rivers/estuaries/ wetlands
More frequent and/or severe storms	• Destruction of habitat • Increased mortality of coastal species
Warming/cooling of coastal waters	• Affects aquatic ecological tolerances or interactions • Disrupts spawning • Altered nutrient cycling dynamics • Reduced dissolved oxygen levels (in warmer water) • Increased dissolved oxygen levels (in colder water)
Increased or decreased rate of water cycling (change in precipitation or evaporation/ transpiration)	• Riparian habitats altered (scouring, temperature, etc.) due to new flow regime • Altered inputs of freshwater, sediments, nutrients
Atmospheric circulation (winds) change	• Air or ocean currents are changed (new patterns) • Affects aquatic ecological tolerances or interactions • Disrupts spawning • Altered nutrient cycling dynamics • Changes in dissolved oxygen levels
Increased carbon dioxide (CO_2) concentration in atmosphere	• Carbon dioxide dissolves in ocean, lowering pH (increasing acidity), which affects biota • Altered nutrient cycling dynamics

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Question 3

(a) Multiple dams have been erected along the Colorado River. Identify TWO benefits other than agriculture and recreation that people derive from that system of dams.

A total of 2 points can be earned, 1 for each correct response. (Only the first two responses are scored.)

- Hydroelectric power/affordable (inexpensive) electricity
- Flood control
- Storage of water for domestic/nonagricultural use; municipal water supply (must specify a nonagricultural use)
- Provision of/increase in navigable waterways
- Employment/stimulation of local economy (dam construction, maintenance, operation)
- Reduced air pollution as hydroelectric power replaces electrical generation from fossil fuels

(b) Discuss TWO potential environmental consequences of damming a major river.

A total of 2 points can be earned, 1 for each correct response. (Only the first two responses are scored.)

- Habitat alteration; displacement or death of native species (e.g., fish, plants, birds)
- Population decline of migratory fish (salmon, etc.) or disruption of fish migrations
- Risk of flood from catastrophic failure of dam
- Sedimentation behind dam
- Downstream ecosystems deprived of sediments, nutrients, or water
- Reduction in amount of agricultural land
- Reduction of available water because of increased evaporative loss
- Scouring of channel downstream from dam alters habitat or destabilizes banks
- Increased risk of diseases associated with reservoir (e.g., Aswan dam and schistosomiasis)
- Release of mercury or other toxins from flooded soils
- Accumulation of toxins behind dam
- Methane produced by biomass decomposing in lake
- Humans displaced/local inhabitants forced to move, due to inundation/lake formed behind dam

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2009 SCORING GUIDELINES

Question 3 (continued)

(c) Competition for access to Colorado River water has increased dramatically due to increased population size and intensive agricultural use. Describe TWO conservation strategies for reducing agricultural water consumption.

A total of 2 points can be earned, 1 for each correct response. (Only the first two responses are scored.)

Note: Correct answers must detail how agricultural water-use efficiency can be improved. Answers suggesting incentives or regulations to spur conservation are insufficient, unless they are linked to one of the strategies listed below.

- Employ microirrigation (drip irrigation; trickle irrigation)
- Choose crops that do not require irrigation in that climate
- Breed/select/develop crops for more efficient water use or drought tolerance
- Irrigate when evaporative loss is lower (e.g., at night)
- Level fields to improve delivery efficiency
- Carefully monitor soil moisture levels to reduce unnecessary irrigation
- Transport irrigation water in pipes or lined channels
- Direct sprinkler heads downward or place near soil
- Increase soil organic (matter) content
- Incorporate shelterbelts or windbreaks
- Use measures to reduce or slow runoff: contour planting, strip cropping, terracing, etc.
- Cover surface with mulch to reduce evaporative water loss
- Reduce meat consumption, because more water is used in animal production than in plant production

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