

**Question 3: Analyze an Environmental Problem
and Propose a Solution (Doing Calculations)****10 points**

A **Identify** an anthropogenic source of particulate matter, other than from motor vehicles. **Point 01**

Examples of acceptable responses may include the following:

- Coal/fossil fuel combustion
- Industrial exhaust
- Construction/demolition
- Waste incineration
- Mining
- Burning of biomass
- Anthropogenically caused wildfires
- Unpaved roads
- Agricultural fields

B One way to reduce pollutants associated with motor vehicles is to use a vapor recovery nozzle. **Describe** one way a vapor recovery nozzle is used to reduce atmospheric pollution. **Point 02**

Acceptable description point:

- It prevents fumes/vapors from escaping into the atmosphere when gassing/fueling (a motor vehicle).

C **Explain** how a decrease in the number of people commuting to work in their personal vehicles could lead to a reduction in acid rain. **Point 03**

Examples of acceptable responses may include the following:

- (A decrease in commuting) would result in lower nitrogen oxide/sulfur oxide emissions from cars/vehicles.
 - (A decrease in commuting) would lead to less nitric acid/sulfuric acid in the atmosphere.
-

D	Calculate the percent change in gas mileage between the gasoline-powered SUV and the hybrid SUV based on the data provided. Show your work. One point for the correct setup to calculate the percent change in gas mileage. Examples of acceptable responses may include the following: • $(36 \text{ mpg} - 22 \text{ mpg}) / 22 \text{ mpg} \times 100$ • $(36 - 22) / 22 \times 100$	Point 04
	One point for the correct calculation of the percent change in gas mileage. Examples of acceptable responses may include the following: • 63.6% increase • 63.6% • 63.6 • 64% • 64	Point 05
E	Calculate how many more miles the owner can drive in the hybrid SUV in the city than they could have driven in the gasoline-powered SUV. Show your work. One point for the correct setup to calculate how many more miles the hybrid SUV can drive than the gasoline-powered SUV. Examples of acceptable responses may include the following: • $(14 \text{ gallon} \times 36 \text{ mpg}) - (14 \text{ gallon} \times 22 \text{ mpg})$ • $(14 \times 36) - (14 \times 22)$ • $14 \times (36 - 22)$	Point 06
	One point for the correct calculation of how many more miles the hybrid SUV can drive than the gasoline-powered SUV. Examples of acceptable responses may include the following: • 196 • 200	Point 07
F	Propose a realistic solution that schools could implement to decrease energy use for heating and cooling, other than a reduction in the amount of time the school building is occupied. Examples of acceptable responses may include the following: • Implement green building design features • Open windows to reduce use of air conditioning • Use energy-efficient heating and cooling equipment • Adjust the thermostat to reduce use of heat and air conditioning • Install conservation landscaping	Point 08

G **Calculate** the energy use in the school building in kilowatts per year using LED light bulbs. **Point 09**

Show your work.

One point for the correct setup to calculate the energy use in the school building in kWh/year using LED light bulbs.

Examples of acceptable responses may include the following:

- $(2.8 \times 10^4 \text{ bulbs}) \times 0.0085 \text{ kilowatt} \times 2,340 \text{ hours}$
- $(2.8 \times 10^4) \times 0.0085 \times 2,340$

One point for the correct calculation of the energy use in the school building in kWh/year using LED light bulbs. **Point 10**

Examples of acceptable responses may include the following (if units are included in the response, kWh/year or kW/year are accepted):

- 556,920
 - 5.6×10^5
 - 5.6E5
-

Question 3: Analyze an Environmental Problem and Propose a Solution (Doing Calculations)

10 points

A **Identify** a type of surface mining the company could use to access the coal.

Point 01

Examples of acceptable responses may include the following:

- Strip mining
- Open pit
- Mountain top removal

B **Describe** an environmental problem associated with surface mining.

Point 02

Examples of acceptable responses may include the following:

- Removal of vegetation/soil/rock causes loss/destruction of habitat.
- (Surface mining) causes loss of habitat, which results in loss of biodiversity.
- Removal of vegetation can increase rates of erosion.
- (Surface mining) can lead to contamination of groundwater/surface water/waterways from runoff of sediments/pollutants.
- Removal of vegetation/soil/bedrock/parent material can release dust particles/methane.
- High energy/fossil fuel consumption is needed to operate equipment and leads to air pollution.

C **Describe** an environmental problem the town could experience as a result of the electricity generation at the coal-burning power plant.

Point 03

Examples of acceptable responses may include the following:

- Release of air pollutants/toxic metals/particulates/ NO_x / SO_x could lower air quality/result in respiratory problems.
- Release of air pollutants/sulfur dioxides/nitrogen oxides could cause acid rain.
- Greenhouse gas emissions/carbon dioxide/methane/water vapor could lead to altered precipitation/climate/weather/temperature patterns.

D **Propose** a realistic solution the local government could enact that would reduce the negative environmental consequences of using coal to generate electricity.

Point 04

Examples of acceptable responses may include the following:

- Require/incentivize the plant to install scrubbers/electrostatic precipitators.
- Incentivize the use of alternative energy sources/energy efficient appliances.
- Incentivize green building design/conservation landscaping/planting trees as carbon sinks.

E	Calculate how many pounds of coal would need to be burned to generate enough electricity to power a town with 11,000 houses for a year. Show your work. One point for the correct setup to calculate how many pounds of coal would be needed. Examples of acceptable responses may include the following: • $(11,000 \text{ houses} \times 10,640 \text{ kWh per house}) / 0.88 \text{ kWh per lb of coal}$ • $(11,000 \times 10,640) / 0.88$	Point 05
	One point for the correct calculation of how many pounds of coal would be needed. Examples of acceptable responses may include the following: • 133,000,000 • 1.33×10^8	Point 06
F	Calculate the percent change in bird species per hectare since the power plant was installed. Show your work. One point for the correct setup to calculate the percent change in bird species per hectare. Examples of acceptable responses may include the following: • $(6.0 \text{ species / ha} - 7.5 \text{ species / ha}) / 7.5 \text{ species / ha} \times 100$ • $(6.0 - 7.5) / 7.5 \times 100$	Point 07
	One point for the correct calculation of the percent change in bird species per hectare. Examples of acceptable responses may include the following: • -20% • 20% decrease • -20	Point 08
G	Assuming that the growth rate remains constant, calculate the year in which the population will reach 52,500. Show your work. One point for the correct setup to calculate the year the population will reach 52,500. Acceptable setup point: • $(70 / 5.38) + 2022$	Point 09
	One point for the correct calculation of the year the population will reach 52,500. Acceptable calculation point: • 2035	Point 10

Question 3: Analyze an Environmental Problem and Propose a Solution Doing Calculations**10 points**

-
- (a) **Describe** one environmental impact on marine ecosystems associated with extraction or transportation of crude oil. **1 point**

Accept one of the following:

- Marine life is harmed/killed by being coated/suffocated by oil from spills.
- Animals are harmed/killed by ingesting spilled oil.
- Oil slicks from spills can block sunlight from entering water and inhibit photosynthesis.
- Oil that washes up on beaches/in marshes/in estuaries damages habitat.
- Noise pollution disrupts marine animals' ability to communicate/mate/eat/evade prey.
- CO₂ from combustion of fuels in boats/equipment is absorbed by ocean and contributes to ocean acidification.

-
- (b) **Identify** an atmospheric pollutant released during the combustion of refined oil products. **1 point**

Accept one of the following:

- Carbon dioxide (CO₂)
- Nitrogen oxides (NO_x, NO, NO₂, N₂O)
- Sulfur oxides (SO_x, SO₂, SO₃)
- Particulate matter (PM)
- Carbon monoxide (CO)
- Volatile Organic Compounds (VOCs)

-
- (c) **Propose** a solution an individual can use to reduce their reliance on refined oil products for transportation. **1 point**

Accept one of the following:

- Ride a bike/scooter/skateboard or walk instead of driving.
 - Replace a gasoline/diesel powered car with a hybrid or electric vehicle.
 - Replace a gasoline/diesel powered car with one that utilizes alternative fuel (biodiesel, ethanol, hydrogen).
 - Buy/Drive a more fuel-efficient vehicle.
 - Work from home/telecommute to reduce miles driven.
 - Choose housing that is close to employment to reduce miles driven.
 - Take public transportation instead of driving.
 - Carpool instead of driving alone.
 - Combine trips to reduce miles driven.
-

(d) **Justify** the solution proposed in part (c) by providing a benefit to human health.

1 point

Accept one of the following:

Solution proposed in part (c)	Justification of solution with additional advantage
Replace a gasoline powered car with a hybrid or electric vehicle. Replace a gasoline/diesel powered car with one that utilizes an alternative fuel. Buy/Drive a more fuel-efficient vehicle. Work from home/telecommute to reduce miles driven. Choose housing that is close to employment to reduce miles driven. Take public transportation instead of driving. Carpool instead of driving alone. Combine trips to reduce miles driven.	• Fewer air pollutants (particulates, NO_x, VOCs, smog) leads to lower rates of ○ respiratory illness/problems such as asthma, COPD, lung cancer. ○ cardiovascular illness such as heart attacks. ○ eye irritation.
Ride bike/scooter/skateboard or walk instead of driving.	• Fewer air pollutants (particulates, NO_x, VOCs, smog) leads to lower rates of ○ respiratory illness/problems such as asthma, COPD, lung cancer. ○ cardiovascular illness such as heart attacks. ○ eye irritation. • Improved health/Decreased risk of disease/cardiovascular illness from more physical activity/exercise.

- (e) A deposit is estimated to contain 260 million metric tons of gold ore. **Calculate** the number of grams of gold that could be extracted from the deposit. **Show** your work. **1 point**

One point for the correct setup to calculate the number of grams of gold that could be extracted from the gold deposit:

Accept one of the following:

- $260 \text{ million metric tons} \times \frac{5 \text{ grams}}{1 \text{ metric ton}}$
- $260 \times 10^6 \text{ metric tons} \times 5 \text{ grams}$
- $5 \times 260,000,000$

One point for the correct calculation of the number of grams of gold that could be extracted from the gold deposit: **1 point**

Accept one of the following:

- 1,300,000,000
- 1.3×10^9

Total for part (e) 2 points

- (f) Assuming the price of gold is \$62.56 per gram, **calculate** the value of the gold that could be recovered from 1,000 metric tons of gold ore in the deposit. **Show** your work. **1 point**

One point for the correct setup to calculate the value of the gold that could be recovered:

Accept one of the following:

- $\frac{\$62.56}{1 \text{ gram}} \times 1,000 \text{ metric tons} \times \frac{5 \text{ grams}}{1 \text{ metric ton}}$
- $\$62.56 \times 1,000 \text{ metric tons} \times 5 \text{ grams}$
- $\frac{\$62.56}{\text{g}} \times \frac{5 \text{ g}}{\text{metric ton}} \times 1,000$
- $1,000 \times 5 \times \$62.56$

One point for the correct calculation of the value of gold that could be recovered: **1 point**

Accept one of the following:

- \$312,800
- 312,800 dollars

Total for part (f) 2 points

-
- (g) A typical cell phone contains 0.034 grams of gold. **Calculate** how many metric tons of gold ore would need to be mined to extract enough gold to manufacture 100,000 cell phones. **1 point**
Show your work.

One point for the correct setup to calculate the number of metric tons of gold ore that would need to be mined to manufacture 100,000 cell phones:

Accept one of the following:

- $\frac{0.034 \text{ grams}}{1 \text{ cell phone}} \times \frac{1 \text{ metric ton}}{5 \text{ grams}} \times 100,000 \text{ cell phones}$
- $\frac{0.034 \text{ grams}}{1 \text{ cell phone}} \times \frac{1 \text{ metric ton}}{5 \text{ grams}} \times 100,000$
- $0.034 \text{ grams} \times \frac{1 \text{ metric ton}}{5 \text{ grams}} \times 100,000$
- $\frac{0.034 \times 100,000}{5}$

One point for the correct calculation of the number of metric tons of gold ore that would need to be mined to manufacture 100,000 cell phones: **1 point**

- 680

Total for part (g) 2 points

Total for question 3 10 points

Question 3: Analyze an Environmental Problem and Propose a Solution Doing Calculations

10 points

- (a) **Identify** one negative human health effect linked to the exposure to pollutants resulting from the combustion of coal. **1 point**

Accept one of the following:

- Lung disease/respiratory diseases (asthma, COPD, bronchitis, lung cancer)
- Neurological damage
- Birth defects
- Heart disease
- Eye irritation/respiratory irritation/headaches

Total for part (a) 1 point

- (b) (i) **Describe** an environmental problem associated with coal ash waste disposal. **1 point**

Accept one of the following:

- Leaching from landfills/clay-lined pits
- Overflowing of coal ash into bodies of water
- Leaking and contamination of groundwater, soil, or nearby bodies of water
- Coal ash washing into bodies of water as a result of severe weather events
- Dry ash carrying into nearby bodies of water, increasing turbidity/decreasing photosynthesis

- (ii) A proposed solution is to dispose North Carolina's coal ash in clay-lined pits. **Justify** this solution by providing one advantage of using clay soil. **1 point**

- Clay is less permeable than unlined pits and can prevent the leaching of coal ash into soil/groundwater.

Total for part (b) 2 points

- (c) (i) **Calculate** the percent change in Charlotte's population from 2013 to 2019. **Show** your work. **1 point**

One point for the correct setup to calculate the percent change:

- $\frac{857,425 \text{ people} - 757,278 \text{ people}}{757,278 \text{ people}} \times 100$
- $\left(\frac{857,425 \text{ people}}{757,278 \text{ people}} - 1 \right) \times 100$

One point for the correct calculation of the percent change: **1 point**

Accept one of the following:

- 13%
- 13.22%
- 13.224602%

(ii)	Based on Charlotte's 2019 growth rate of 1.88%, calculate the year when the population of Charlotte will double, assuming the growth rate stays the same. Show your work.	1 point
One point for the correct setup to calculate the year the population of Charlotte will double:		
Doubling time = $\frac{70}{1.88} = 37 \text{ years} + 2019$		
One point for the correct calculation year the population of Charlotte will double:		1 point
2056		
(iii)	The average Charlotte resident uses 90 gallons of water per day. Calculate the gallons of water used by the population of Charlotte in the year 2018. Show your work.	1 point
One point for the correct setup to calculate the gallons of water used in 2018:		
$\frac{90 \text{ gallons of water}}{\text{person per day}} \times 841,611 \text{ people} \times 365 \text{ days}$		
One point for the correct calculation of the gallons of water used in 2018:		1 point
Accept one of the following:		
27,646,921,350 gallons 2.76×10^{10} gallons 2.8×10^{10} gallons 3×10^{10} gallons		
Total for part (c)		6 points
(d)	Drought periods are becoming more frequent in North Carolina, causing water resources to become more scarce. Describe one realistic action that citizens could take to reduce domestic outdoor water use.	1 point
Accept one of the following:		
- Plant drought resistant plant species/use artificial landscaping/use xeriscaping to reduce the need for irrigation. - Eliminate/reduce nonessential usage of water, such as washing of cars, power washing. - Reduce the use of sprinklers/irrigation by monitoring soil conditions, weather conditions or reducing frequency. - Collect rainwater or gray water for irrigation. - Water plants/lawn before sunrise/after sunset to limit evaporation. - Switch to drip irrigation to limit evaporation.		
Total for part (d)		1 point
Total for question 3		10 points

2019**AP[®]** **CollegeBoard**

AP[®] Environmental Science

Scoring Guidelines

2019 SCORING GUIDELINES**Question 1**

(a) Use the maps provided to answer the following questions.

(i) **Identify** the preferred nesting habitat for piping plovers.

(1 point for the correct identification of a preferred nesting habitat for piping plovers)

- Unvegetated sand
- Sandy areas/open sandy beaches
- Washovers

(ii) **Describe** the change in the number of piping plover nests in Assateague Island between 1999 and 2009.

(1 point for the correct description of the change in the number of piping plover nests)

- The number of nests decreased by almost half (43%).
- The number of nests decreased from 44 to 25.
- There were 19 more nests in 1999 than in 2009.

(iii) **Describe** one likely reason for the change in the number of piping plover nests between 1999 and 2009.

(1 point for the correct description of a likely reason for the change in the number of piping plover nests)

- The preferred habitat was reduced because of a decrease in unvegetated sandy areas.
- The preferred habitat was reduced because of an increase in the amount of vegetation/revegetation.

(b) Coastal species are affected by more than just natural events.

(i) Special beach restrictions can help piping plovers during nesting season. **Describe** one restriction that could reasonably be implemented to help prevent the destruction of plover nests by human actions.

(1 point for the correct description of a restriction that could reasonably be implemented to help prevent the destruction of plover nests by human activity)

- Post warning signs/fencing/barrier tape/boardwalks around the nesting area.
- Place wire enclosures/other barriers over active nests.
- Limit specified recreational activity on beaches with plover nests (prohibit kite flying, fireworks, etc.).
- Implement motor vehicle restrictions (limit times, size of vehicles, raking, etc.).
- Require pets to remain indoors or on leashes.

2019 SCORING GUIDELINES**Question 1 (continued)**

- (ii) In addition to providing habitat for piping plovers, barrier islands (and closely related landforms) are important for other reasons. **Explain** one way that these features help to preserve and protect the environment in coastal regions.

(1 point for the correct explanation of one way that features of barrier islands help to preserve and protect the environment in coastal regions)

- They block/buffer the wind and/or waves, which mitigate beach erosion.
- They reduce storm surge, which protect the interior coastline from flooding.
- They block/buffer the waves and create wetland ecosystems/pools, which serve as habitat for a variety of species (fish, turtles, migratory birds, etc.).
- They trap sediments/pollutants in wetland habitats/marsh grasses, which filter the water.

- (iii) **Identify** one human action that directly threatens coastal habitats and **describe** one impact on species, other than the piping plover, that use the habitat.

(2 points; 1 point for the correct identification of a human action that directly threatens coastal habitats and 1 point for the correct description of the impact of human activity on species that use the habitat)

Identify one human action that directly threatens coastal habitats	Describe one impact on species that use the habitat
Tourism/Recreation	• Beachgoers accidentally step on or crush nests of species on the beach. • Unleashed pets on beaches may cause stress and/or disrupt nesting, survival, etc. of coastal species. • Vehicles on beach can disrupt nesting, survival, etc. of coastal species habitat. • Beachgoers leave food/garbage that attracts predators/harbors pathogens of coastal species. • Sunscreen washes off and can be toxic to coral or other coastal marine organisms.
Coastal Development	• Development (commercial, residential, recreational) can lead to the loss of suitable habitats of coastal species. • Development near beach may increase noise pollution or light pollution, which disrupts nesting/migration/survival of coastal species. • Development near beach may provide food/garbage that attracts predators/harbors pathogens of coastal species.
Littering/Solid Waste Disposal	• Coastal species get tangled up in trash (plastic) on the beach or in coastal water. • Coastal species ingest trash, which fills or blocks respiratory/digestive tract.
Offshore Oil Drilling	• Spilled oil coats coastal marine organisms, impacting survival. • Spilled oil can be toxic if ingested by coastal marine species.
Commercial Fishing	• Dredging or trawling can destroy coral/habitat for bottom-dwelling organisms. • Overharvesting can dramatically decrease coastal populations of fish or shellfish. • Coastal species can unintentionally get trapped in fishing gear.

2019 SCORING GUIDELINES**Question 1 (continued)**

(c) **Identify** one economic impact on coastal communities that has resulted from rising sea levels.

(1 point for the correct identification of one economic impact on coastal communities that has resulted from rising sea levels)

- Decrease of tourist revenue
- Decrease of property value
- Increase in damage to property, land, or infrastructure requiring repair or replacement
- Increase in insurance costs
- Loss of agricultural land or aquaculture operations resulting in financial loss
- Loss of fish nurseries in wetland areas leading to less revenue for commercial fisheries
- Increase in jobs in infrastructure/construction to repair damaged structures and properties
- Increase in costs associated with preventative measures (building sea walls, raising building, etc.)

(d) **Describe** TWO methods that may be used locally to protect coastal communities from rising sea levels.

(2 points; 1 point for each correct description and method that may be used locally to protect coastal communities from rising sea levels)

- Raise structures to reduce or prevent water damage.
- Move/build structures back from the beach (setbacks) to reduce or prevent water damage.
- Install pumps to reduce flooding.
- Build structures, such as sea walls, to protect area from wave action/storm surge/flooding/erosion.
- Plant vegetation along appropriate shoreline to decrease erosion.
- Replenish sand to address problems from erosion or to increase width of beach.
- Build jetties/groins to act as a barrier from waves.

2019 SCORING GUIDELINES**Question 2**

As conventional sources of crude oil are depleted, unconventional sources such as oil sands (also known as tar sands) are being utilized. Oil sands contain bitumen, which can be processed into a synthetic crude oil. A region of boreal forest in Alberta, Canada, that covers a deposit of oil sands will be cut and removed during the process of bitumen extraction. It is estimated that the deposit contains 73 billion barrels of recoverable bitumen. The rate of extraction from the deposit will be approximately 1 million barrels of bitumen per day.

(a) **Identify** one ecological benefit, other than providing habitat, that is provided by forests.

(1 point for the correct identification of an ecological benefit provided by forests)

- Absorb carbon dioxide/produces oxygen (gas exchange)
- Maintain ecological and/or species diversity
- Provide food for organisms
- Moderate/regulate (local) climate
- Purify/filter water or air
- Reduce soil erosion
- Absorb/store/regulate water
- Help maintain stream temperature/stream flow
- Aid in nutrient cycling
- Aid in soil formation

(b) **Identify** one economic benefit that is provided by forests.

(1 point for the correct identification of an economic benefit provided by forests)

- Source of forest products (timber, medicine, nuts, crops such as shade-grown coffee, etc.)
- Tourism
- Jobs in recreation/tourism/forestry
- Reduction in air pollutants, which can
 - reduce health care costs
 - improve crop yields

(c) **Describe** TWO environmental consequences, other than those related to the loss of boreal forest habitat, that result from the extraction of bitumen or the transportation of synthetic oil to customers.

(2 points; 1 point for each correct description of an environmental consequence that results from the extraction of bitumen or the transport of synthetic oil to customers)

- Release of greenhouse gases/air pollutants such as NO_x from fossil fuel combustion that powers equipment/transportation/oil processing
- Release of air pollutants (NO_x, SO_x, or particulates) during mining operations or oil processing
- Storage and disposal of large amounts of solid/liquid mining waste, which can be toxic to organisms
- Pollution of surface water and/or groundwater from oil spills/leaks during transport
- Sediment pollution in surface water and/or groundwater from strip mining
- Disturbance from pipelines, such as habitat fragmentation, disruption of migratory routes, etc.
- Noise pollution from use of machinery during processing or transport
- Diversion/use of water from surface water and/or groundwater for processing oil

2019 SCORING GUIDELINES**Question 2 (continued)**

- (d) Assuming the above extraction rate, **calculate** how many days will be needed to extract the recoverable volume of bitumen from the oil sands.

(2 points; 1 point for the correct setup and 1 point for the correct answer)

$$7.3 \times 10^{10} \text{ barrels of bitumen} \times \frac{1 \text{ day}}{1.0 \times 10^6 \text{ barrels of bitumen}}$$

$$= 7.3 \times 10^4 \text{ days}$$

$$= 73,000 \text{ days}$$

(Note: Units are not required in the answer)

- (e) **Calculate** how many years will be needed to fully extract the recoverable volume of bitumen from the oil sands.

(2 points; 1 point for the correct setup and 1 point for the correct answer; incorrect answer from (d), used correctly, can still earn points in part (e))

$$7.3 \times 10^4 \text{ days} \times \frac{1 \text{ year}}{365 \text{ days}}$$

$$= 2 \times 10^2 \text{ years}$$

$$= 200 \text{ years}$$

(Note: Units are not required in the answer.)

- (f) Monthly production of synthetic crude oil is 30 million barrels. Producing one barrel of synthetic crude oil uses two barrels of heated freshwater. **Calculate** the number of barrels of freshwater needed each year to supply this demand.

(2 points; 1 point for the correct setup and 1 point for the correct answer)

$$\frac{3 \times 10^7 \text{ barrels of synthetic oil}}{1 \text{ month}} \times \frac{2 \text{ barrels of fresh water}}{1 \text{ barrel of synthetic oil}} \times \frac{12 \text{ months}}{1 \text{ year}}$$

$$= 7.2 \times 10^8 \text{ barrels of fresh water}$$

$$= 720,000,000 \text{ barrels of fresh water}$$

(Note: Units are not required in the answer)

2019 SCORING GUIDELINES

Question 3

The graph shows measurements of atmospheric levels of carbon dioxide (CO_2) at Mauna Loa Observatory, Hawaii, and the measurements of pH levels in the ocean nearby at Station ALOHA. Measurements of pH began in 1992.

(a) Use the graph above to answer the following questions.

(i) **Determine** the concentration of CO_2 (in ppm) recorded at Mauna Loa in 2005.

(1 point for identifying from the graph the correct value of concentration of CO_2 recorded at Mauna Loa in 2005)

380 ppm (+/-5 ppm)

(ii) **Determine** the pH recorded at Station ALOHA in 2005.

(1 point for identifying from the graph the correct value of pH recorded at Station ALOHA in 2005)

8.08 (+/- 0.02)

(b) Changes in atmospheric carbon dioxide affect Earth's oceans.

(i) **Predict** the effect of increased concentration of atmospheric CO_2 on the concentration of CO_2 in the ocean.

(1 point for correctly predicting the effect of an increase in concentration of CO_2 in the ocean)

- Oceanic CO_2 will increase.
- Dissolved oceanic CO_2 will increase.

(ii) Based on the data, **identify** the relationship in the concentration of atmospheric CO_2 and the pH of the ocean water.

(1 point for correctly identifying the relationship between the concentration of atmospheric CO_2 and the pH of ocean water based on data)

- As atmospheric CO_2 increases, pH decreases.
- As more CO_2 dissolves in the water, it becomes more acidic/less alkaline.
- As atmospheric CO_2 increases, H_3O^+ or H^+ ions increase.

(iii) **Provide** the complete chemical equation that represents the reaction between oceanic carbon dioxide (CO_2) and water (H_2O).

(1 point for the correct balanced chemical equation that represents the reaction between oceanic carbon dioxide and water)

- $\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3$ (carbon dioxide plus water produces carbonic acid)
- $\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}^+ + \text{HCO}_3^-$ (carbon dioxide plus water produces one hydrogen ion and one bicarbonate ion)
- $\text{CO}_2 + \text{H}_2\text{O} \rightarrow 2\text{H}^+ + \text{CO}_3^{2-}$ (carbon dioxide plus water produces two hydrogen ions and one carbonate ion)

2019 SCORING GUIDELINES**Question 3 (continued)**

- (iv) **Identify** the specific environmental problem that directly results from the decrease in pH of Earth's oceans.

(1 point for correctly identifying the specific environmental problem that directly results from the decrease in pH of Earth's oceans)

Ocean Acidification

- (c) Changes in pH in the world's oceans pose a risk to many marine organisms.

- (i) **Explain** why certain organisms, in particular those with calcium carbonate shells or exoskeletons, are threatened by the decreasing pH levels measured in seawater.

(2 points; 1 point for correctly explaining the impact of a decrease in pH on shells or exoskeletons and 1 point for an impact on survival of organisms)

Chemical impact on shell/coral formation	Impact on survival of organism
A decrease in pH levels could • Cause shells/exoskeletons to dissolve • Prevent the growth of new coral/shells • Prevent renewal/maintenance of existing coral/shells	Organisms, such as mollusks and coral, would be threatened with • Reduced fitness/decreased number of offspring • Increased predation risk • Increased threat of disease

2019 SCORING GUIDELINES**Question 3 (continued)**

- (ii) Other than threats posed by decreasing pH, **identify** an additional anthropogenic threat to the world's coral reef ecosystem and **describe** how the threat damages the coral reefs and coral reef ecosystems.

(2 points; 1 point for the correct identification of an additional anthropogenic threat to the world's coral reef ecosystem and 1 point for correctly linking a description of the identified threat to the damage to coral reefs and coral reef ecosystems)

Identify one additional anthropogenic threat to the world's coral reef ecosystems	Describe how the threat damages coral reefs and coral reef ecosystems
Increased ocean temperature	• Coral bleaching (loss of the algal symbiont) • Reduction of dissolved oxygen concentration
Recreational activities, such as watercraft, scuba, snorkeling, swimming, etc.	• Physical damage to/destruction of coral reefs
Fishing practices, such as bottom trawling, dynamite fishing, overfishing, etc.	• Physical damage to/destruction of coral reefs • Removal of key species disrupts the food web/causes a trophic cascade
Nutrient pollution (from agricultural runoff, wastewater treatment plants, etc.)	• Cultural eutrophication and eventual decrease in dissolved oxygen levels • Excessive algal growth reduces light penetration
Sediment pollution (from logging operations, mining, etc.)	• Increased turbidity/reduction in light penetration • Deposited sediments cover/smother coral reefs
Chemical pollution, such as oil spills, pesticide runoff, sunscreen, etc.	• Disruption of reproduction and growth cycles • Disruption of metabolic processes • Endocrine disruption/DNA damage • Reduction in light penetration
Plastic/solid waste pollution	• Physical damage to/destruction of members of the coral reef ecosystem • Reduction of light penetration
Introduction of invasive species (lionfish/turkey fish, Philippine mantis shrimp, etc.)	• Invasive species can outcompete native species

2019 SCORING GUIDELINES**Question 4**

One reason that people visit national parks is to view the scenery. Visibility at the four parks in the graph has been reduced over time so that by 2015 the visibility was an average of 70 miles less than the historical visibility. Regional air pollutant sources are commonly located over 100 miles away from national parks.

- (a) Based on the data provided in the graph, **identify** the national park that had the greatest loss of visibility as of 2015 when compared with the historical natural visibility.

(1 point for the correct identification of the national park that has had the greatest loss of visibility)

Sequoia National Park

- (b) Visibility in national parks can be affected by many different air pollutants.

- (i) **Identify** a primary air pollutant.

(1 point for the correct identification of a primary air pollutant)

- Carbon dioxide (CO_2)
- Carbon monoxide (CO)
- Nitrogen oxides (NO_x)
- Nitrous oxide (N_2O)
- Particulate Matter (PM)
- Sulfur dioxide (SO_2)
- Methane (CH_4)
- Volatile organic compounds (VOCs)

- (ii) **Describe** how a primary air pollutant becomes part of the atmosphere.

(1 point for the correct description of how a primary air pollutant becomes part of the atmosphere)

- Primary pollutants are released directly from a specific source, such as a smokestack, tailpipe, leaking pipelines, etc.
- Primary pollutants are released from the combustion of fossil fuels.
- Some pollutants (CO , PM) are a result of incomplete combustion of hydrocarbons.
- Some pollutants (methane, nitrous oxide, ammonia) are released directly from a biological source, such as cows, swamps, etc.

- (iii) **Identify** a secondary air pollutant.

(1 point for the correct identification of a secondary air pollutant)

- Ozone (O_3)
- Sulfuric acid (H_2SO_4)
- Sulfur trioxide (SO_3)
- Nitric acid (HNO_3)
- Peroxyacyl nitrates (PANs)
- Nitrogen dioxide (NO_2)
- Aldehydes

2019 SCORING GUIDELINES**Question 4 (continued)**

(iv) **Describe** how a secondary air pollutant is formed within the atmosphere.

(1 point for the correct description of how a secondary air pollutant is formed within the atmosphere)

- Secondary air pollutants are formed when primary pollutants react with other compounds.
- Ozone (O_3) forms when primary pollutants such as NO_x and VOCs react with oxygen in the presence of sunlight.
- Sulfuric acid forms when SO_x reacts with water.
- Nitric acid forms when NO_x reacts with water.

(c) In 1990 Great Smoky Mountains National Park had a visibility of 25 miles. Visibility data for 2015 can be determined from the graph above.

(i) **Calculate** the percentage of increase in visibility from 1990 to 2015.

(1 point for the correct calculation of the percentage of increase in visibility from 1990 to 2015. Students are not required to show work.)

$$80\% \text{ increase in visibility } \left(\frac{45 \text{ miles} - 25 \text{ miles}}{25 \text{ miles}} \times 100 = 80\% \right)$$

(ii) **Discuss** TWO specific actions that the state or federal government could take or encourage to further improve the visibility in Great Smoky Mountains National Park.

(2 points; 1 point for each correct and realistic discussion of a specific action the state or federal government could take or encourage to further improve the visibility in Great Smoky Mountains National Park)

- Require or offer incentives for utilities/corporations to reduce emissions by specific methods, such as cap-and-trade, pollution-prevention control devices, alternative energy sources, environmental standards on new equipment, etc.
- Limit vehicle traffic in the park through increased parking fees, free/required shuttles, HOV priority parking, etc.
- Enact stricter standards for emissions on motor vehicles.
- Offer incentives to switch from gasoline-powered vehicles to electric vehicles or natural-gas powered vehicles.
- Offer tax credits or subsidies to homeowners to increase the use of renewable energy sources.
- Limit incineration practices/prohibit campfires to reduce air pollutants.

2019 SCORING GUIDELINES**Question 4 (continued)**

(d) Excluding air pollution, **discuss** TWO additional ways national park ecosystems are being degraded by high levels of visitor use.

(2 points; 1 point for each correct discussion of an additional way national park ecosystems are being degraded by high levels of visitor use)

- Littering or inappropriate disposal of trash can negatively impact the health of wildlife.
- Littering or inappropriate disposal of trash can negatively impact water quality.
- Infrastructure construction/maintenance can result in habitat fragmentation.
- Driving or walking off road/path damages vegetation, increases erosion, or increases soil compaction.
- Noise pollution can adversely impact wildlife by disrupting mating, ranging, foraging, etc.
- Light pollution can adversely impact wildlife by disrupting mating, ranging, foraging, etc.
- Interactions with humans or pets adversely impacts wildlife by disrupting mating, ranging, foraging, etc.
- Visitors transporting nonnative species to the park results in an increase in invasive species.
- Camp fires from visitors can lead to wildfires.
- Removal of individual organisms for food, trophies, or human use can disrupt the food web.
- Water used for bathing and sanitation can lead to pollution of water resources.