Past-paper walk-through

Fossil Fuels ▪ 6.5

eXercise

Questions in this set

- 2026 Q2
- 2025 Set 2 Q3
- 2024 Set 1 Q3
- 2023 Set 1 Q3
- 2022 Set 1 Q2
- 2021 Set 2 Q3
- 2019 Q2
- 2018 Q1
- 2016 Q2

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 2

2026 ▪ Q2

The following information applies to parts A, B, C, D, E, F, and G.

The following graph shows the number of quadrillion British thermal units (BTUs) that were consumed in the United States using five different energy sources from 1950 to 2020.

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Question 2

- Petroleum (thick dotted): starts around 14 in 1950, rises steadily to a peak near 38 around 1978, dips to about 30 around 1983, rises again with fluctuations to a peak near 40 around 2005, declines to about 34 around 2012, rises slightly then drops sharply to about 33 by 2020.
- Natural gas (dashed): starts around 6 in 1950, rises to about 22 by 1970, dips slightly through the 1970s-80s to about 18, rises again through the 1990s-2000s to about 23 around 2000-2010, then rises sharply after 2010 to about 32 by 2020.
- Coal (thin solid): starts around 13 in 1950, dips to about 9 by 1960, rises gradually with fluctuations to about 23 by the early 2000s, stays around 20-22 through the 2000s, then declines sharply after 2010 to about 9 by 2020.

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- Nuclear (thick solid): near 0 from 1950 to about 1970, rises steadily from the 1970s to about 8 by 2000, continues rising slightly to about 8-9 through 2010-2020.
- Renewables (thin dotted): near 0-1 from 1950 to 1970, rises slowly with fluctuations to about 6 by 2000, rises gradually to about 8-9 by 2020, converging with Nuclear near the end.]

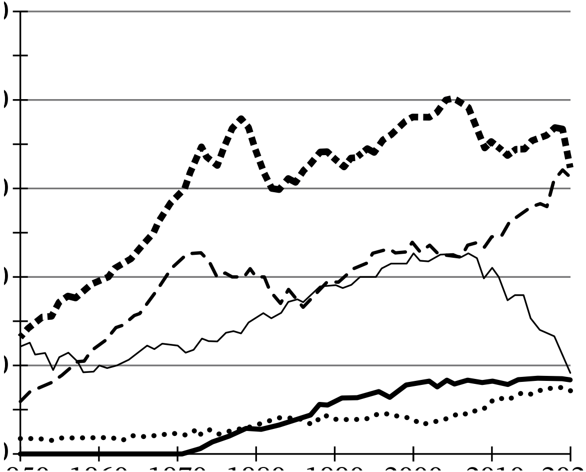
The following information applies to parts H and I.

Researchers studied an aquatic ecosystem near an area of land that had been converted to agricultural use. They reported an increase in nutrients, such as nitrates and phosphates, in the water.

2. Respond to parts A, B, C, D, E, F, G, H, and I, and all subparts.

(a) Identify one renewable energy source that is used to generate electricity.

Question 2



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2026 ▪ Q2

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The following information applies to parts H and I.
Researchers studied an aquatic ecosystem near an area of land that had been converted to agricultural use. They reported an increase in nutrients, such as nitrates and phosphates, in the water.

2. Respond to parts A, B, C, D, E, F, G, H, and I, and all subparts.

(b) Based on the data in the graph, **identify** the energy source that had the highest consumption in 2010.

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Researchers studied an aquatic ecosystem near an area of land that had been converted to agricultural use. They reported an increase in nutrients, such as nitrates and phosphates, in the water.

2. Respond to parts A, B, C, D, E, F, G, H, and I, and all subparts.

(c) Based on the data in the graph, **describe** the pattern in the energy consumption from coal in the United States from 1960 to 2020.

Question 2

2026 ▪ Q2

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2. Respond to parts A, B, C, D, E, F, G, H, and I, and all subparts.

(d) Based on the data in the graph and your knowledge of energy consumption, **explain** one likely reason why the use of coal for energy changed between 2010 and 2020.

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2. Respond to parts A, B, C, D, E, F, G, H, and I, and all subparts.

(e) Explain how fossil fuels are used to generate electricity.

Question 2

2026 ▪ Q2

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2. Respond to parts A, B, C, D, E, F, G, H, and I, and all subparts.

(f) In addition to fossil fuels, nuclear power can be used to generate electricity.

Identify one negative impact associated with nuclear energy.

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2026 ▪ Q2

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2. Respond to parts A, B, C, D, E, F, G, H, and I, and all subparts.

(g) Fossil fuel combustion leads to ocean warming. **Describe** one environmental problem other than coral bleaching that is associated with warming oceans.

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2. Respond to parts A, B, C, D, E, F, G, H, and I, and all subparts.

(h) Explain how an increase in nutrients, such as nitrates and phosphates, can negatively affect an aquatic ecosystem.

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2. Respond to parts A, B, C, D, E, F, G, H, and I, and all subparts.

(ii) Propose a realistic solution that would reduce nutrient pollution of waterways, while still allowing cultivation of crops.

(iii) Justify the solution proposed in part **I** (i) by explaining one potential advantage other than reducing nutrient runoff.

Question 3

2025 Set 2 ▪ Q3

The local government of a newly built town has contracted with an electrical company to provide energy to the town. The company generates electricity primarily through the burning of coal and has built a new power plant for the town. A nearby deposit of coal was discovered close to the surface. To access the coal, the company decides to remove the overburden and vegetation over the deposit.

Respond to parts A, B, C, D, E, F, and G.

(a) Identify a type of surface mining the company could use to access the coal.

Question 3

2025 Set 2 ▪ Q3

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Respond to parts A, B, C, D, E, F, and G.

(b) Describe an environmental problem associated with surface mining.

Question 3

2025 Set 2 ▪ Q3

The local government of a newly built town has contracted with an electrical company to provide energy to the town. The company generates electricity primarily through the burning of coal and has built a new power plant for the town. A nearby deposit of coal was discovered close to the surface. To access the coal, the company decides to remove the overburden and vegetation over the deposit.

Respond to parts A, B, C, D, E, F, and G.

(c) The town is located downwind of the new coal-burning power plant.

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

Question 3

2025 Set 2 ▪ Q3

The local government of a newly built town has contracted with an electrical company to provide energy to the town. The company generates electricity primarily through the burning of coal and has built a new power plant for the town. A nearby deposit of coal was discovered close to the surface. To access the coal, the company decides to remove the overburden and vegetation over the deposit.

Respond to parts A, B, C, D, E, F, and G.

(d) The local government is concerned about the environmental consequences of using coal to generate electricity for the town.

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

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2025 Set 2 ▪ Q3

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Respond to parts A, B, C, D, E, F, and G.

(e) Burning one pound of coal produces an average of 0.88 kilowatt-hours (kWh) of electricity. An average household in the United States uses 1.064×10^4 kWh of electricity each year.

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.

Question 3

2025 Set 2 ▪ Q3

The local government of a newly built town has contracted with an electrical company to provide energy to the town. The company generates electricity primarily through the burning of coal and has built a new power plant for the town. A nearby deposit of coal was discovered close to the surface. To access the coal, the company decides to remove the overburden and vegetation over the deposit.

Respond to parts A, B, C, D, E, F, and G.

(f) Researchers are concerned about the impact of noise pollution on songbirds in a forest near the power plant. Since the power plant was installed, bird species richness has declined from 7.5 species per hectare to 6.0 species per hectare.

Calculate the percent change in bird species per hectare since the power plant was installed. **Show** your work.

Question 3

2025 Set 2 ▪ Q3

The local government of a newly built town has contracted with an electrical company to provide energy to the town. The company generates electricity primarily through the burning of coal and has built a new power plant for the town. A nearby deposit of coal was discovered close to the surface. To access the coal, the company decides to remove the overburden and vegetation over the deposit.

Respond to parts A, B, C, D, E, F, and G.

(g) The town has been growing since it was built and had a growth rate of 5.38% in 2022, with a population of 26,250.

Assuming that the growth rate remains constant, **calculate** the year in which the population will reach 52,500. **Show** your work.

Solution 3

(a)

Mark scheme

- A type of surface mining the company could use to access the coal: strip mining, open pit mining, or mountaintop removal. 1 point for naming any one valid surface-mining type.

Solution 3

(b)

Mark scheme

- An environmental problem associated with surface mining: removal of vegetation/soil/rock causes loss/destruction of habitat (and resulting loss of biodiversity); removal of vegetation can increase erosion rates; surface mining can contaminate groundwater/surface water/waterways via runoff of sediments/pollutants; removal of vegetation/soil/bedrock/parent material can release dust particles/methane; or high energy/fossil fuel consumption to operate equipment leads to air pollution. 1 point for any one valid problem.

Solution 3

(c)

Mark scheme

- An environmental problem the downwind town could experience from the power plant's electricity generation: release of air pollutants/toxic metals/particulates/NOx/SOx could lower air quality and cause respiratory problems; release of sulfur dioxides/nitrogen oxides could cause acid rain; or greenhouse gas emissions (carbon dioxide/methane/water vapor) could alter precipitation/climate/weather/temperature patterns. 1 point for any one valid problem.

Solution 3

(d)

Mark scheme

- A realistic solution the local government could enact: require/incentivize the plant to install scrubbers/electrostatic precipitators; incentivize the use of alternative energy sources/energy-efficient appliances; or incentivize green building design/conservation landscaping/planting trees as carbon sinks. 1 point for any one valid, realistic solution.

Solution 3

(e) Mark scheme

- Setup (1 point): pounds of coal needed $=$ (11,000 houses x 10,640 kWh per house) / 0.88 kWh per lb of coal, i.e. $\dfrac{11{,}000 \times 10{,}640}{0.88}$, using the given household usage of 1.064×10^4 kWh/year and the given 0.88 kWh generated per pound of coal burned. Calculation (1 point): approximately 133,000,000 lb of coal (i.e. 1.33×10^8 lb). Award 1 point for the correct setup (total kWh needed for the town divided by kWh generated per lb of coal) and 1 point for the correct final numeric value (accept equivalent or reasonably rounded answers).

Solution 3

(f)

Mark scheme

- Setup (1 point): percent change = (6.0 species/ha - 7.5 species/ha) / 7.5 species/ha x 100, i.e. $\frac{6.0-7.5}{7.5} \times 100$. Calculation (1 point): -20

Solution 3

(g)

Mark scheme

- Setup (1 point): since the target population of 52,500 is double the 2022 population of 26,250, use the Rule of 70 to estimate doubling time and add it to the starting year: $\left(\frac{70}{5.38}\right) + 2022$. Calculation (1 point): 2035 (doubling time of about 13 years added to 2022). Award 1 point for the correct setup (70 divided by the percent growth rate, plus the starting year) and 1 point for the correct final year (accept 2035 or a value from a reasonably equivalent growth calculation).

Question 3

2024 Set 1 ▪ Q3

Earth's climate has changed over time by the addition of greenhouse gasses to the atmosphere. One approach to mitigate climate change is the use of nuclear power, rather than coal-burning power plants, for electricity generation.

(a) Identify a fuel used in a nuclear power plant.

Question 3

2024 Set 1 ▪ Q3

Earth's climate has changed over time by the addition of greenhouse gasses to the atmosphere. One approach to mitigate climate change is the use of nuclear power, rather than coal-burning power plants, for electricity generation.

(b) Describe a negative environmental impact on nearby bodies of water that is caused by using water for cooling in nuclear power plants.

Question 3

2024 Set 1 ▪ Q3

Earth's climate has changed over time by the addition of greenhouse gasses to the atmosphere. One approach to mitigate climate change is the use of nuclear power, rather than coal-burning power plants, for electricity generation.

(c) In 2021, 4.1×10^{12} kilowatt hours (kWh) of commercial electricity was generated in the United States. Nuclear power accounted for 18.9
Another approach to reduce greenhouse gas emissions is to switch from coal-burning power plants to natural gas power plants.

Question 3

2024 Set 1 ▪ Q3

Earth's climate has changed over time by the addition of greenhouse gasses to the atmosphere. One approach to mitigate climate change is the use of nuclear power, rather than coal-burning power plants, for electricity generation.

(d) In addition to reducing greenhouse gas emissions, **describe** how switching from coal-burning power plants to natural gas power plants will improve air quality.

Researchers have proposed large-scale tree planting as a solution to reduce the effects of fossil fuel combustion on global climate change.

Question 3

2024 Set 1 ▪ Q3

Earth's climate has changed over time by the addition of greenhouse gasses to the atmosphere. One approach to mitigate climate change is the use of nuclear power, rather than coal-burning power plants, for electricity generation.

(e) Justify the proposed solution by explaining an additional advantage, other than the reduction of atmospheric greenhouse gases.

Question 3

2024 Set 1 ▪ Q3

Earth's climate has changed over time by the addition of greenhouse gasses to the atmosphere. One approach to mitigate climate change is the use of nuclear power, rather than coal-burning power plants, for electricity generation.

(f) 7.4×10^7 cubic meters of natural gas were extracted from a large deposit in 2020. An average of 4.76 kWh of electricity can be generated from each cubic meter of natural gas combusted. In 2020, an average home consumed 10,715 kWh of electricity. **Calculate** how many homes could have been provided with electricity by natural gas extracted from the large deposit in 2020. **Show** your work.

Question 3

2024 Set 1 ▪ Q3

Earth's climate has changed over time by the addition of greenhouse gasses to the atmosphere. One approach to mitigate climate change is the use of nuclear power, rather than coal-burning power plants, for electricity generation.

(g) In 2021, 8.99×10^{11} kWh of electricity was generated through the combustion of coal. One kilogram of carbon dioxide is produced per kWh of electricity generated by combusting coal, while 0.42 kilograms of carbon dioxide is produced by combusting natural gas. **Calculate** how much less carbon dioxide would have been produced in 2021 if all coal-burning power plants were replaced with natural gas-burning power plants. **Show** your work.

Solution 3

(a)

Mark scheme

- A fuel used in a nuclear power plant: Uranium (U-235) or Plutonium.

Solution 3

(b)

Mark scheme

- Using water for cooling in nuclear power plants causes thermal pollution: discharged water raises the temperature of nearby bodies of water outside organisms' range of tolerance and/or decreases dissolved oxygen; organisms can also be wounded or killed at the water intake; and water loss through evaporation can decrease stream flow/volume.

Solution 3

(c)

Mark scheme

- Calculate electricity generated by nuclear power in the US in 2021 (2 points: 1 for setup, 1 for the answer). Setup: (4.1×10^12 kWh) $\times$ 18.9% $=$ (4.1×10^12) $\times$ 0.189. Calculation: 4.1×10^12 $\times$ 0.189 $=$ 7.749×10^11 kWh $\approx$ 774,900,000,000 kWh (accept 7.75×10^11 or 7.7×10^11 kWh).

Solution 3

(d)

Mark scheme

- Switching from coal-burning to natural gas power plants improves air quality because burning natural gas produces less NOx, SOx, ash, particulates, toxic metals, and smog compared to burning coal.

Solution 3

(e)

Mark scheme

- An additional advantage of large-scale tree planting beyond reducing atmospheric greenhouse gases: provides forest habitat/increases biodiversity/diversifies niches; creates jobs (planting, recreation, wood harvesting); creates a more aesthetically pleasing environment/enhances cultural ecosystem services; decreases soil loss/erosion/sedimentation in waterways; provides shade/decreases ambient temperature; or slows water runoff/reduces flooding.

Solution 3

(f)

Mark scheme

- Calculate how many homes could be powered by the natural gas extracted (2 points: 1 for setup, 1 for the answer). Setup: (7.4×10^7 m^3) × (4.76 kWh / 1 m^3) × (1 home / 10,715 kWh). Calculation: 7.4×10^7 × 4.76 / 10,715 ≈ 32,874 homes (accept 32,873 or ≈33,000).

Solution 3

(g)

Mark scheme

- Calculate how much less CO_2 would be produced if all coal plants were replaced by natural gas plants in 2021 (2 points: 1 for setup, 1 for the answer). Setup: difference in emission rate $\times$ total kWh from coal $=$ (1.0 kg CO_2/kWh $-$ 0.42 kg CO_2/kWh) $\times$ ($8.99\times10\hat{}11$ kWh); equivalently compute CO_2 from coal ($8.99\times10\hat{}11$ kWh $\times$ 1.0 kg/kWh $=$ $8.99\times10\hat{}11$ kg) minus CO_2 if that electricity were from natural gas ($8.99\times10\hat{}11$ kWh $\times$ 0.42 kg/kWh $=$ $3.776\times10\hat{}11$ kg). Calculation: $0.58 \times 8.99\times10\hat{}11 = 5.2142\times10\hat{}11$ kg $\approx$ 521 billion kg (accept 521,420,000,000 kg, $5.21\times10\hat{}11$ kg, or $5.2\times10\hat{}11$ kg).

Question 3

2023 Set 1 ▪ Q3

3. Crude oil is extracted, transported, and refined for various uses by humans.

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

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

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

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

Other natural resources, such as gold and silver, are also extracted. These resources can be used to make components for the electronics humans use. One metric ton of gold ore contains 5.0 grams of gold.

(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.

Question 3

(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.

(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. **Show** your work.

Begin your response to this question at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number.

STOP

END OF EXAM

Solution 3

(a)

Mark scheme

- Any one environmental impact: 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; or CO2 from combustion of fuels in boats/equipment is absorbed by the ocean and contributes to ocean acidification.

Solution 3

(b)

Mark scheme

- Any one atmospheric pollutant: carbon dioxide (CO_2); nitrogen oxides (NO_x, NO, NO_2, N_2O); sulfur oxides (SO_x, SO_2, SO_3); particulate matter (PM); carbon monoxide (CO); or volatile organic compounds (VOCs).

Solution 3

(c)

Mark scheme

- Any one solution: 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 close to employment to reduce miles driven; take public transportation instead of driving; carpool instead of driving alone; or combine trips to reduce miles driven.

Solution 3

(d)

Mark scheme

- Fewer air pollutants (particulates, NOx, VOCs, smog) from the proposed solution lead to lower rates of respiratory illness/problems (such as asthma, COPD, lung cancer), lower rates of cardiovascular illness (such as heart attacks), and less eye irritation. If the solution proposed in (c) was active transport (biking/walking/scootering), an additional acceptable justification is improved health/decreased risk of disease/cardiovascular illness from more physical activity/exercise.

Solution 3

(e)

Mark scheme

- Setup (1 point): 260×10^6 metric tons$\times \dfrac{5 \text{ grams}}{1 \text{ metric ton}}$ (equivalently $5 \times 260{,}000{,}000$). Calculation (1 point): $260{,}000{,}000 \times 5 = 1{,}300{,}000{,}000$ grams of gold (i.e. 1.3×10^9 g). Award 1 point for the correct dimensional setup and 1 point for the correct final numeric answer (1,300,000,000 g or 1.3 x $10^9 g$).

Solution 3

(f)

Mark scheme

- Setup (1 point): $\dfrac{\$62.56}{1 \text{ gram}} \times 1{,}000 \text{ metric tons} \times \dfrac{5 \text{ grams}}{1 \text{ metric ton}}$ (equivalently $1{,}000 \times 5 \times \$62.56$). Calculation (1 point): $1{,}000 \times 5 \times 62.56 = 312{,}800$, so the gold recovered from 1,000 metric tons of ore is worth \$312,800. Award 1 point for the correct setup and 1 point for the correct final numeric answer (\$312,800).

Solution 3

(g) Mark scheme

- Setup (1 point): $\dfrac{0.034 \text{ grams}}{1 \text{ cell phone}} \times \dfrac{1 \text{ metric ton}}{5 \text{ grams}} \times 100{,}000$ cell phones (equivalently $\dfrac{0.034 \times 100{,}000}{5}$). Calculation (1 point): $\dfrac{0.034 \times 100{,}000}{5} = \dfrac{3{,}400}{5} = 680$ metric tons of gold ore. Award 1 point for the correct setup and 1 point for the correct final numeric answer (680 metric tons).

Question 2

2022 Set 1 ▪ Q2

Developments in advanced hydraulic fracturing (fracking) technologies have allowed the total oil and gas production in the United States to increase rapidly.
[Scatter graph titled “METHANE CONCENTRATION IN DRINKING WATER WELLS IN PENNSYLVANIA.” Y-axis: “Methane Concentration in Well Water (mg/L),” scale 0 to 70 in increments of 10. X-axis: “Distance to Nearest Fracking Well (m),” scale 0 to 6,000 in increments of 1,000. A horizontal reference line is drawn at y = 10 mg/L, with an upward arrow above it labeled “Hazardous concentrations, mitigation required” and a downward arrow below it labeled “No mitigation required.” Data points (labeled “Well water sample” in the legend, shown as filled circles) are heavily concentrated at small distances (roughly 0–500 m) with methane concentrations ranging widely from near 0 up to about 64 mg/L (points near approximately 64, 60, 53, 52, 51, 42, 34, 33, 29, 24, 20, and several points below 10 clustered near x = 0–300 m). A few points

Question 2

appear farther out: around $x \approx$ 1,300–1,500 m with $y \approx$ 13–17 mg/L, and isolated lower points scattered out to about $x =$ 3,600 m ($y \approx 6$), $x =$ 3,700 m ($y \approx 3$), and $x =$ 4,300 m ($y \approx 1$), with most points beyond about $x =$ 1,000 m sitting at or near $y = 0$, extending out to about $x =$ 5,700 m.]

(a)(i) The graph shows the methane concentration in drinking water from home wells and the distance to the nearest fracking well in Pennsylvania. Based on the data in the graph, **identify** the highest methane concentration found in well water in Pennsylvania.

(a)(ii) Based on the data in the graph, **describe** the relationship between the concentration of methane in well water and the distance to a fracking well.

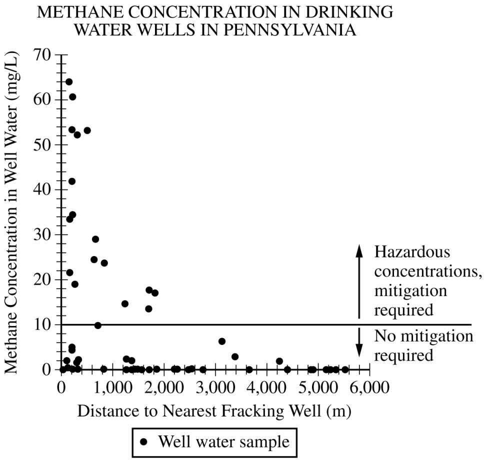
(a)(iii) Based on the data in the graph, **identify** the minimum safe distance that a new water well should be located from an existing fracking well.

(a)(iv) Explain how fracking fluid is used to access oil and natural gas in sedimentary rock, such as shale, during the fracking process.

Question 2

(a)(v) Identify one negative geologic effect in an area where hydraulic fracturing (fracking) occurs.

Question 2



METHANE CONCENTRATION IN DRINKING WATER WELLS IN PENNSYLVANIA
Methane Concentration in Well Water (mg/L)
70
60
50
40
30
20
10
0
0
1,000
2,000
3,000
4,000
5,000
6,000
Distance to Nearest Fracking Well (m)
Hazardous concentrations, mitigation required
No mitigation required
Well water sample

Question 2

2022 Set 1 ▪ Q2

Developments in advanced hydraulic fracturing (fracking) technologies have allowed the total oil and gas production in the United States to increase rapidly.

[Scatter graph titled "METHANE CONCENTRATION IN DRINKING WATER WELLS IN PENNSYLVANIA." Y-axis: "Methane Concentration in Well Water (mg/L)," scale 0 to 70 in increments of 10. X-axis: "Distance to Nearest Fracking Well (m)," scale 0 to 6,000 in increments of 1,000. A horizontal reference line is drawn at y = 10 mg/L, with an upward arrow above it labeled "Hazardous concentrations, mitigation required" and a downward arrow below it labeled "No mitigation required." Data points (labeled "Well water sample" in the legend, shown as filled circles) are heavily concentrated at small distances (roughly 0–500 m) with methane concentrations ranging widely from near 0 up to about 64 mg/L (points near approximately 64, 60, 53, 52, 51, 42, 34, 33, 29, 24, 20, and several points below 10 clustered near x = 0–300 m). A few points appear farther out: around x ≈ 1,300–1,500 m with y ≈

Question 2

13–17 mg/L, and isolated lower points scattered out to about $x = 3{,}600$ m ($y \approx 6$), $x = 3{,}700$ m ($y \approx 3$), and $x = 4{,}300$ m ($y \approx 1$), with most points beyond about $x = 1{,}000$ m sitting at or near $y = 0$, extending out to about $x = 5{,}700$ m.]

(b)(i) The volume of water used for oil and gas extraction is 28 times greater than it was fifteen years ago. Much of the water used for oil and gas extraction comes from groundwater sources in arid or semiarid regions. This increased use of water for fracking may mean that less water is available for local use. The use of groundwater for fracking is an example of individuals using a shared resource for their own self-interest. **Identify** the environmental concept illustrated by this example of overuse of a shared resource.

(b)(ii) **Describe** one environmental problem that may result from increased use of groundwater for fracking in arid or semiarid regions.

Question 2

(b)(iii) Describe how overuse of coastal groundwater supplies can result in water that is unsuitable for human consumption.

Question 2

2022 Set 1 ▪ Q2

Developments in advanced hydraulic fracturing (fracking) technologies have allowed the total oil and gas production in the United States to increase rapidly.

[Scatter graph titled "METHANE CONCENTRATION IN DRINKING WATER WELLS IN PENNSYLVANIA." Y-axis: "Methane Concentration in Well Water (mg/L)," scale 0 to 70 in increments of 10. X-axis: "Distance to Nearest Fracking Well (m)," scale 0 to 6,000 in increments of 1,000. A horizontal reference line is drawn at y = 10 mg/L, with an upward arrow above it labeled "Hazardous concentrations, mitigation required" and a downward arrow below it labeled "No mitigation required." Data points (labeled "Well water sample" in the legend, shown as filled circles) are heavily concentrated at small distances (roughly 0–500 m) with methane concentrations ranging widely from near 0 up to about 64 mg/L (points near approximately 64, 60, 53, 52, 51, 42, 34, 33, 29, 24, 20, and several points below 10 clustered near x = 0–300 m). A few points appear farther out: around x ≈ 1,300–1,500 m with y ≈

Question 2

13–17 mg/L, and isolated lower points scattered out to about $x = 3{,}600$ m ($y \approx 6$), $x = 3{,}700$ m ($y \approx 3$), and $x = 4{,}300$ m ($y \approx 1$), with most points beyond about $x = 1{,}000$ m sitting at or near $y = 0$, extending out to about $x = 5{,}700$ m.]

(c)(i) In addition to water quality issues caused by fossil fuel extraction, air quality can also be negatively affected by combustion of oil and natural gas. **Make a claim** for a realistic governmental action to improve air quality by reducing consumption of oil.

(c)(ii) Justify the action proposed in part (c)(i) by stating a potential environmental advantage of that action, other than slowing global climate change.

Solution 2

(a)(i)

Mark scheme

- The highest methane concentration found in well water in Pennsylvania is 64 mg/L.

(a)(ii)

Mark scheme

- Methane concentration in well water decreases as distance from the fracking well increases — an inverse/nonlinear, negative relationship between the two variables.

Solution 2

(a)(iii)

Mark scheme

- Any value between 1,800 and 2,200 meters is an acceptable minimum safe distance for a new water well from an existing fracking well.

Solution 2

(a)(iv)

Mark scheme

- Fracking fluid is injected/pumped into the well under high pressure, opening fissures in the shale/sedimentary rock and releasing the oil and natural gas; sand grains suspended in the fluid prop open the newly formed cracks/fractures so the oil and gas can flow up the well.

(a)(v)

Mark scheme

- One negative geologic effect of fracking: earthquakes/increased seismic activity, or ground subsidence/sinkholes.

Solution 2

(b)(i)

Mark scheme

- The environmental concept illustrated is the Tragedy of the Commons.

Solution 2

(b)(ii)

Mark scheme

- One environmental problem from increased groundwater use for fracking in arid/semiarid regions: loss of habitat/productivity in spring-fed ecosystems as springs dry up; loss of habitat/productivity or degraded water quality in streams and estuaries fed by groundwater discharge; soil erosion as vegetation dies due to a lowered water table and roots no longer hold soil; or desertification resulting from a lowered water table.

Solution 2

(b)(iii)

Mark scheme

- Overuse of coastal groundwater lowers the water table, allowing ocean water to flow into the aquifer (saltwater intrusion), contaminating it with saltwater and making it unfit for human consumption.

Solution 2

(c)(i)

Mark scheme

- A realistic governmental action to improve air quality by reducing oil consumption, e.g.: increase fuel economy standards for motor vehicles; invest in renewable energy resources; use tax incentives to encourage hybrid/electric vehicle sales; subsidize public transportation/walking/cycling projects; create tax incentives for work-from-home options; or increase the gasoline tax/reduce oil subsidies.

Solution 2

(c)(ii)

Mark scheme

- Justification must state a benefit (other than slowing climate change) tied to the action named in (c)(i) — e.g. decreased oil/fuel consumption leads to reduced particulates, surface ozone/photochemical smog, or acid rain; decreased oil consumption leads to fewer oil spills and decreased groundwater depletion/contamination from fracking/drilling; or decreased oil consumption leads to less disruption to wildlife/habitats (fragmentation, noise pollution) from drilling operations.

Question 3

2021 Set 2 ▪ Q3

Approximately 350 coal-fired power plants in the United States are older than the 30-year anticipated life-span for a coal generator. One problem with these aging power plants is that many lack the necessary modern air pollution controls. Additionally, there are concerns about rising fuel costs, so many utility companies are planning to retire coal-fired plants and build new natural-gas power plants.

(a) Describe why coal is considered a nonrenewable energy source.

Question 3

2021 Set 2 ▪ Q3

Approximately 350 coal-fired power plants in the United States are older than the 30-year anticipated life-span for a coal generator. One problem with these aging power plants is that many lack the necessary modern air pollution controls. Additionally, there are concerns about rising fuel costs, so many utility companies are planning to retire coal-fired plants and build new natural-gas power plants.

(b) Describe one potential environmental advantage of replacing a coal-fired power plant with a natural-gas power plant.

Question 3

2021 Set 2 ▪ Q3

Approximately 350 coal-fired power plants in the United States are older than the 30-year anticipated life-span for a coal generator. One problem with these aging power plants is that many lack the necessary modern air pollution controls. Additionally, there are concerns about rising fuel costs, so many utility companies are planning to retire coal-fired plants and build new natural-gas power plants.

(c) Describe one economic advantage of using natural gas, rather than coal, in producing electricity.

Question 3

2021 Set 2 ▪ Q3

Approximately 350 coal-fired power plants in the United States are older than the 30-year anticipated life-span for a coal generator. One problem with these aging power plants is that many lack the necessary modern air pollution controls. Additionally, there are concerns about rising fuel costs, so many utility companies are planning to retire coal-fired plants and build new natural-gas power plants.

(d) When natural gas is used to heat homes, it can produce carbon monoxide gas, which can lead to carbon monoxide poisoning in humans. Propose a solution to reduce the incidence of carbon monoxide poisoning in humans.

Particulate matter is another common pollutant in emissions from vehicles, coal-fired power plants, and various other sources. One size of particulates, $PM_{2.5}$, presents a particular risk to human health.

Question 3

ATMOSPHERIC CONCENTRATION OF PARTICULATE MATTER IN 1990 AND 2016

Year	Average Annual Atmospheric Concentration of $PM_{2.5}$ ($\mu g/m^3$)
1990	85
2016	188

Question 3

2021 Set 2 ▪ Q3

Approximately 350 coal-fired power plants in the United States are older than the 30-year anticipated life-span for a coal generator. One problem with these aging power plants is that many lack the necessary modern air pollution controls. Additionally, there are concerns about rising fuel costs, so many utility companies are planning to retire coal-fired plants and build new natural-gas power plants.

(e) Calculate the percent change in the average annual $PM_{2.5}$ concentration in the air from 1990 to 2016. Show your work.

Question 3

2021 Set 2 ▪ Q3

Approximately 350 coal-fired power plants in the United States are older than the 30-year anticipated life-span for a coal generator. One problem with these aging power plants is that many lack the necessary modern air pollution controls. Additionally, there are concerns about rising fuel costs, so many utility companies are planning to retire coal-fired plants and build new natural-gas power plants.

(f) Trees can remove $PM_{2.5}$ from the atmosphere when particulates settle on the leaves and are subsequently washed onto soil by rain. The average annual removal of $PM_{2.5}$ is 2.3 kilograms per hectare. Calculate the decrease in $PM_{2.5}$ removal in kilograms if logging reduced a forested area from 50,000 hectares to 43,000 hectares. Show your work.

Question 3

2021 Set 2 ▪ Q3

Approximately 350 coal-fired power plants in the United States are older than the 30-year anticipated life-span for a coal generator. One problem with these aging power plants is that many lack the necessary modern air pollution controls. Additionally, there are concerns about rising fuel costs, so many utility companies are planning to retire coal-fired plants and build new natural-gas power plants.

(g) Research has shown that hospital admissions for cardiovascular problems increase 1

Solution 3

(a)

Mark scheme

- Coal is considered nonrenewable because it exists in a fixed/finite/limited amount – its natural formation rate is far slower than the rate at which it is consumed/combusted.

Solution 3

(b)

Mark scheme

- One environmental advantage of replacing a coal-fired plant with a natural-gas plant: natural gas combustion emits fewer greenhouse gases/less CO2; does not emit mercury/lead/cadmium/uranium; emits less NOx/SOx, reducing acid precipitation; produces less/no particulate matter/soot/smog; requires less habitat destruction/fossil-fuel use to transport than coal; avoids habitat destruction from impoundment of coal ash or coal slurry; or avoids the habitat destruction of strip mining/mountaintop removal used to extract coal.

Solution 3

(c) Mark scheme

- One economic advantage of natural gas over coal in producing electricity: pipeline transport of natural gas costs less than rail transport of coal; natural gas (methane) harvested from decomposition (landfills, wastewater treatment plants, biodigesters) costs less than coal; fewer health-related costs are linked to burning natural gas than coal; fewer pollution controls are needed for a natural-gas plant, lowering operating/construction/permitting costs; lower combustion-residue disposal costs than coal-burning plants; or natural-gas plants are more efficient (more electricity output per unit energy input), leading to lower fuel costs.

Solution 3

(d) Mark scheme

- A solution to reduce carbon monoxide poisoning: install/use/replace/update carbon monoxide detectors/alarms/sensors (or replace their batteries); perform regular maintenance on natural-gas furnaces so minimal carbon monoxide is produced and combustion products are properly vented/exhausted; create laws/regulations mandating carbon monoxide detectors in all homes; use PSAs, billboards, or other methods to educate the public about carbon monoxide poisoning; or change the home heating system to a method that does not involve combustion of a fuel that could produce carbon monoxide.

Solution 3

(e)

Mark scheme

- Percent change = [(188 micrograms/m^3 - 85 micrograms/m^3) / 85 micrograms/m^3] x 100 ~= 121% (accept 120% or 121.2%). One point for the correct setup (must include units and multiplication by 100 to yield a true percentage: (188-85)/85 x 100); one point for the correct numeric result (121%, 120%, or 121.2%).

Solution 3

(f)

Mark scheme

- Decrease in PM2.5 removal = (50,000 ha - 43,000 ha) x 2.3 kg/ha = 7,000 ha x 2.3 kg/ha = 16,100 kg (accept 16,000 kg). Equivalently: 50,000 ha x 2.3 kg/ha = 115,000 kg; 43,000 ha x 2.3 kg/ha = 98,900 kg; 115,000 kg - 98,900 kg = 16,100 kg. One point for the correct setup (must include units); one point for the correct numeric result (16,100 kg or 16,000 kg).

Solution 3

(g)

Mark scheme

- Increase in admissions = (0.23/0.10) x 0.01 x 7,390 admissions, equivalently (23%/10%) x 1% x 7,390 admissions ~= 169-170 more admissions (accept 169 or 170). One point for the correct setup; one point for the correct numeric result.

Question 2

2019 ▪ Q2

As conventional sources of crude oil are depleted, unconventional sources such as oil sands (also known as tar sands) are being utilized. Oils 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.

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

Question 2

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

Solution 2

(a)

Mark scheme

- One ecological benefit, other than providing habitat, provided by forests, e.g.: absorb carbon dioxide/produce 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. Full credit for any one valid benefit.

Solution 2

(b)

Mark scheme

- One economic benefit provided by forests, e.g.: 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 or improve crop yields. Full credit for any one valid benefit.

Solution 2

(c) Mark scheme

- Describe TWO environmental consequences, other than those related to loss of boreal forest habitat, that result from bitumen extraction or transport of synthetic oil, 1 point per correct distinct consequence (max 2), e.g.: release of greenhouse gases/air pollutants such as NO_x from fossil fuel combustion powering 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 or disruption of

Solution 2

migratory routes; noise pollution from use of machinery during processing or transport; diversion/use of water from surface water and/or groundwater for processing oil.

Solution 2

(d)

Mark scheme

- Setup: 7.3×10^{10} barrels of bitumen $\times \dfrac{1 \text{ day}}{1.0 \times 10^{6} \text{ barrels of bitumen}} = 7.3 \times 10^{4}$ days $= 73{,}000$ days. 1 point for the correct dimensional-analysis setup, 1 point for the correct numeric answer (73,000 days). Units are not required in the final answer.

Solution 2

(e)

Mark scheme

- Setup: 7.3×10^4 days $\times \dfrac{1 \text{ year}}{365 \text{ days}} = 2 \times 10^2$ years $= 200$ years. 1 point for correct setup, 1 point for the correct answer (200 years). An incorrect numeric answer carried over from part (d), if used correctly here, can still earn both points. Units are not required.

Solution 2

(f) Mark scheme

- Setup: $\frac{3 \times 10^7 \text{ barrels of synthetic oil}}{1 \text{ month}} \times \frac{2 \text{ barrels of fresh water}}{1 \text{ barrel of synthetic oil}} \times \frac{12 \text{ months}}{1 \text{ year}} =$ 7.2×10^8 barrels of fresh water $= 720{,}000{,}000$ barrels of fresh water per year. 1 point for correct setup, 1 point for the correct numeric answer. Units are not required.

Question 1

2018 ▪ Q1

Read the following article from the *Fremont Daily Times* and answer the questions that follow.

[Newspaper article, masthead “Fremont Daily Times”, dated May 1, 2018, headline “GREEN IS THE NEW SCHOOL COLOR AT FREMONT HIGH SCHOOL!”]

A group of students from Fremont High School addressed the city council last night and proposed that one of the existing buildings at Fremont High School, which was built in 1970, be renovated to take advantage of recent advances in green technology. Currently the heat for the school is provided by fossil fuel combustion. The students said that the redesigned building would reduce the school’s carbon footprint, which is a measure of the amount of carbon dioxide and other carbon compounds released by various human activities. Incorporating specific features that conserve energy and utilize renewable energy sources can help reduce the carbon footprint.

Question 1

Councilperson Gail Fassler praised the idea, saying that the project could conserve local water resources, reduce the need for consuming new resources, and act as a "shining beacon" of sustainability for the greater Fremont community. Fassler suggested the project could even incorporate a living green roof as an additional sustainable feature. The council approved the initial site planning request and urged students to report back when the project was under way.

(a)(i) Define carbon footprint.

(a)(ii) Identify one way the school's heating system is likely adding to the school's carbon footprint.

(a)(iii) Describe one realistic way to reduce the contribution of the heating system to the school's carbon footprint.

(b) Identify TWO environmental benefits of a living green roof, such as that suggested by Councilperson Fassler.

Question 1

(c) Describe TWO practices the cafeteria's food service could use to decrease the environmental impacts of Fremont High School.
(d) Discuss TWO benefits of using native plants for landscaping at Fremont High School.
(e) During the renovation, the carpeting must be replaced. Discuss one environmental benefit of using flooring made of plant material, such as cork or bamboo, instead of carpet made of synthetic fibers.

Question 1

Fremont Daily Times May 1, 2018

GREEN IS THE NEW SCHOOL COLOR AT FREMONT HIGH SCHOOL!

A group of students from Fremont High School addressed the city council last night and proposed that one of the existing buildings at Fremont High School, which was built in 1970, be renovated to take advantage of recent advances in green technology. Currently the heat for the school is provided by fossil fuel combustion. The students said that the redesigned building would reduce the school's carbon footprint, which is a measure of the amount of carbon dioxide and other carbon compounds released by various human activities. Incorporating specific features that conserve energy and utilize renewable energy sources can help reduce the carbon footprint.

Councilperson Gail Fassler praised the idea, saying that the project could conserve local water resources, reduce the need for consuming new resources, and act as a "shining beacon" of sustainability for the greater Fremont community. Fassler suggested the project could even incorporate a living green roof as an additional sustainable feature. The council approved the initial site planning request and urged students to report back when the project was under way.

Solution 1

(a)(i)

Mark scheme

- 1 point for a correct definition of carbon footprint. Carbon footprint = the amount of carbon dioxide and/or other carbon compounds released to the environment by a product, process, or activity (a measurement of the amount of carbon released by human activities).

Solution 1

(a)(ii)

Mark scheme

- 1 point for correctly identifying a way the heating system adds to the carbon footprint. Accept: the burning/combustion of fossil fuels releases carbon dioxide; OR incomplete combustion of fossil fuels releases carbon monoxide.

Solution 1

(a)(iii)

Mark scheme

- 1 point for a correct description of a realistic way to reduce the heating system's contribution. Accept any one of: switch to renewables (solar, wind) or a more efficient fossil fuel (natural gas, propane) or a provider using nuclear energy; decrease the thermostat/program it to lower energy use at certain times; purchase carbon-offset credits through environmental agencies; increase insulation or other efficiency/design methods (green roof, double-paned glass, south-facing windows for passive solar heating, change air filters, etc.).

Solution 1

(b)

Mark scheme

- 2 points, 1 point per correct identification of an environmental benefit of a green roof (up to 2). Accept any two of: insulation/reduced fossil fuel use for heating and/or cooling; habitat for wildlife/plants, increases biodiversity; area to grow crops/local food production; reduction in urban heat islands; photosynthesis/carbon capture/CO2 storage/oxygen release; stormwater treatment/runoff reduction; filters particulates, VOCs, O3 from air.

Solution 1

(c) Mark scheme

- 2 points, 1 point per correct description of a practice that decreases the school's environmental impact (up to 2). Accept any two of: offer more vegetarian options/serve fewer animal products; use locally sourced food to reduce transportation; grow food at school; compost food waste; donate leftover food; use energy-friendly practices (LED lighting, more cold-cut sandwiches) to reduce energy use; purchase bulk packaged items; use recyclable containers/avoid disposable straws-trays; install a water fountain/stop selling single-serving bottled water; use reusable take-out containers/offer credit for reuse; allow students to choose appropriate portions to reduce food waste; purchase organic foods to reduce pesticide use; use gray water to irrigate landscaping.

Solution 1

(d)

Mark scheme

- 2 points, 1 point per correct discussion of a benefit of native plants (up to 2). Accept any two of: native plants need less pesticide/fertilizer/irrigation water because they are adapted to the local environment; increase biodiversity by providing native habitat; support native food webs/food production; reduce land available for invasive species to establish/spread; save the school money by needing less water/fertilizer/pesticide/upkeep.

Solution 1

(e) Mark scheme

- 1 point for a correct discussion of a benefit of plant-based flooring (e.g. cork, bamboo) over synthetic carpet. Accept any one of: plant-based material is more easily compostable/biodegradable/reusable, unlike carpet; it comes from a renewable resource, making it more sustainable than carpet; it is a carbon sink/reservoir (growing the plant material removes CO2 from the atmosphere), unlike carpet; it requires fewer fossil fuels/toxic chemicals to produce than synthetic carpet fibers; it produces fewer indoor pollutants (off-gassed VOCs/toxins) than carpet; it harbors fewer pathogenic vectors/diseases/allergens (fleas, ticks, dust mites, mold spores) than carpet; when cultivated it provides habitat for native species.

Question 2

2016 ▪ Q2

Iron ores are rocks from which metallic iron can be extracted for steel production. This process involves several steps. Iron ore is first mined and then turned into pig iron in a blast furnace, and some rock waste such as silicon dioxide (SiO_2) is separated out. In the final step, the pig iron is refined into steel using a process that includes reacting the molten pig iron with oxygen to remove impurities.

(a)(i) Use the data below to respond to the following. For each calculation, show all your work.

Global Iron and Steel Data
1.6 billion tons of iron ore are used yearly to make pig iron.
1.2 billion tons of pig iron are produced each year.
Iron ore reserves are estimated to be 800 billion tons.
95% of iron ore that is mined is used in steel production.

Question 2

Calculate the weight (in tons) of rock waste produced globally each year when iron ore is converted to pig iron.
(a)(ii) Calculate the weight (in tons) of pig iron that could be produced if all of the estimated global iron ore reserves were used for pig iron production.
(a)(iii) Calculate the weight (in tons) of the current global iron ore reserves that would be used to make steel if the current trends continue.

Question 2

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Question 2

2016 ▪ Q2

Iron ores are rocks from which metallic iron can be extracted for steel production. This process involves several steps. Iron ore is first mined and then turned into pig iron in a blast furnace, and some rock waste such as silicon dioxide (SiO_2) is separated out. In the final step, the pig iron is refined into steel using a process that includes reacting the molten pig iron with oxygen to remove impurities.

(b) Both iron ore and coal are mined for use in the manufacture of steel. It is estimated that for every ton of steel recycled, 1.25 fewer tons of iron ore and 0.7 fewer tons of coal must be mined. About 80 million tons of steel are recycled each year in North America.

Calculate the weight (in tons) of coal that is conserved each year in North America by recycling steel.

Question 2

2016 ▪ Q2

Iron ores are rocks from which metallic iron can be extracted for steel production. This process involves several steps. Iron ore is first mined and then turned into pig iron in a blast furnace, and some rock waste such as silicon dioxide (SiO_2) is separated out. In the final step, the pig iron is refined into steel using a process that includes reacting the molten pig iron with oxygen to remove impurities.

(c) Before the year 1900, most mining companies abandoned surface and subsurface coal mine sites once the resource was depleted.

Describe TWO environmental problems that are associated with abandoned coal mine sites.

Question 2

2016 ▪ Q2

Iron ores are rocks from which metallic iron can be extracted for steel production. This process involves several steps. Iron ore is first mined and then turned into pig iron in a blast furnace, and some rock waste such as silicon dioxide (SiO_2) is separated out. In the final step, the pig iron is refined into steel using a process that includes reacting the molten pig iron with oxygen to remove impurities.

(d) Describe one method that can be used to mitigate one of the problems you identified in part (c).

Question 2

2016 ▪ Q2

Iron ores are rocks from which metallic iron can be extracted for steel production. This process involves several steps. Iron ore is first mined and then turned into pig iron in a blast furnace, and some rock waste such as silicon dioxide (SiO_2) is separated out. In the final step, the pig iron is refined into steel using a process that includes reacting the molten pig iron with oxygen to remove impurities.

(e) Discuss one reason why surface coal mining is generally less expensive than subsurface mining.

Solution 2

(a)(i)

Mark scheme

- 1 point for the correct answer with work shown: 1.6 billion tons iron ore − 1.2 billion tons pig iron = 0.4 billion tons ($4 \times 10\hat{}8$ tons) of rock waste produced per year.

Solution 2

(a)(ii)

Mark scheme

- 2 points: 1 point for the correct setup and 1 point for the correct answer. Setup: (1.2 billion tons pig iron / 1.6 billion tons iron ore) $\times$ 800 billion tons iron ore reserves. Answer: 600 billion tons (6.0 $\times$ 10^11 tons) of pig iron could be produced from all estimated reserves.

Solution 2

(a)(iii)

Mark scheme

- 1 point for the correct answer with work shown: 0.95×800 billion tons iron ore $=$ 760 billion tons ($7.6 \times 10\hat{}11$ tons) of iron ore reserves would be used to make steel if current trends (95% of mined ore used in steel) continue.

Solution 2

(b)

Mark scheme

- 1 point for the correct answer with work shown: 0.7 fewer tons coal per ton steel recycled $\times$ 80 million tons steel recycled per year $=$ 56 million tons (5.6 $\times$ 10^7 tons) of coal conserved each year in North America.

Solution 2

(c)

Mark scheme

- 2 points: 1 point for each of TWO described environmental problems associated with abandoned coal mine sites — only the first two given earn credit. Acceptable: subsidence/sinkholes as shafts collapse; habitat destruction/slow recovery; stream/water quality degradation; acid mine drainage; heavy metal runoff; tailings altering landscape and drainage patterns; increased soil erosion; particulate/dust pollution; animals falling into open shafts; methane release; underground fires that are difficult to extinguish.

Solution 2

(d)

Mark scheme

- 1 point for a correct mitigation method tied to one of the problems in (c): plant trees/other vegetation to restore cover and reduce erosion; fill in or fence off abandoned shafts to stop subsidence/reduce access; prevent acid mine drainage and leaching using retaining ponds, berms, or other BMPs; treat acid mine drainage with limestone; return tailings to excavation sites; recontour the land; or place gravel on the surface to reduce wind erosion.

Solution 2

(e)

Mark scheme

- 2 points for correctly identifying a reason linked with a discussion of why surface mining is generally less expensive than subsurface mining. Acceptable — wages: fewer workers needed above ground, and workers are paid less for above-ground work; healthcare: lower workman's compensation and insurance costs; safety: increased below-ground likelihood of severe accidents, death, or black lung disease (avoided in surface mining); legal costs: fewer lawsuits from injuries, accidents, or rescues.