2004-2

West Fremont is a community consisting of 3,000 homes. A small coal-burning power plant currently supplies electricity for the town. The capacity of the power plant is 12 megawatts (MW) and the average household consumes 8,000 kilowatt hours (kWh) of electrical energy each year. The price paid to the electric utility by West Fremont residents for this energy is $0.10 per kWh. The town leaders are considering a plan, the West Fremont Wind Project (WFWP), to generate their own electricity using 10 wind turbines that would be located on the wooded ridges surrounding the town. Each wind turbine would have a capacity of 1.2 MW and each would cost the town $3 million to purchase, finance, and operate for 25 years.

(a) Assuming that the existing power plant can operate at full capacity for 8,000 hrs/yr, how many kWh of electricity can be produced by the plant in a year?

(b) At the current rate of electrical energy use per household, how many kWh of electrical energy does the community consume in one year?

(c) Compare your answers in (a) and (b) and explain why you would or would not expect the numbers to be the same.

(d) Assuming that the electrical energy needs of the community do not change during the 25-year lifetime of the wind turbines, what would be the cost to the community of the electricity supplied by the WFWP over 25 years? Express your answer in dollars/kWh.

(e) Identify and explain TWO environmental benefits to West Fremont of switching from coal to wind power and TWO environmental costs to West Fremont of switching from coal to wind power.

Between 1950 and 2000, global meat production increased from 52 billion kilograms to 240 billion kilograms. During this period, the global human population increased from 2.6 billion to 6.0 billion.

(a) Calculate the per capita meat production in 1950 and in 2000.

(b) Use the values from part (a) to calculate the change in global per capita meat production during this 50-year period as a percentage of the 1950 value.

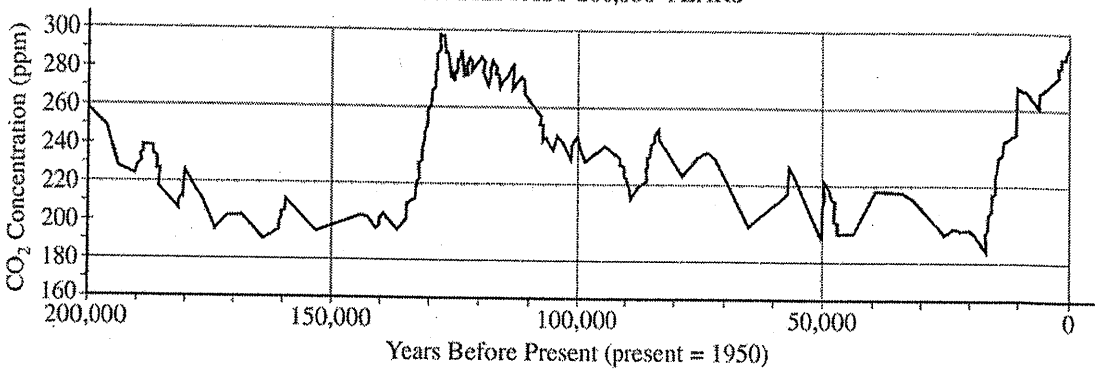
(c) Discuss why it is more efficient to produce grain for human consumption than to produce meat for human consumption. In your answer, consider both land use and energy use.

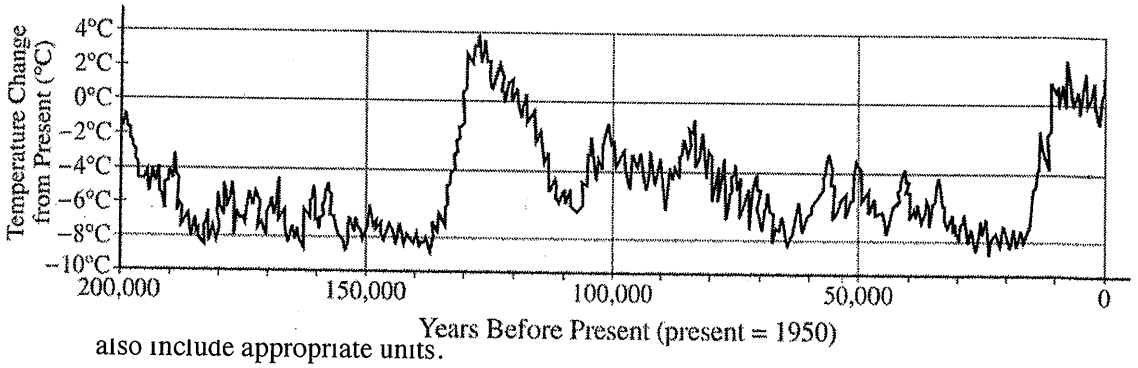
(d) Describe TWO environmental consequences of the increase in the production of meat for human consumption.

(e) Identify and explain one potential advantage and one potential disadvantage for human health of a diet that contains very little meat.

According to atmospheric temperature and CO_2 concentration records derived from Antarctic ice cores, Earth's climate has undergone significant changes over the past 200,000 years. Two graphs are shown below. The upper graph shows the variation in atmospheric CO_2 concentration, and the lower graph shows the variation in air temperature. Both graphs cover the same time period from approximately 200,000 years ago up until the year 1950, which is represented as year 0 on the graphs.

TEMPERATURE AND CO_2 CONCENTRATION IN THE ATMOSPHERE OVER THE PAST 200,000 YEARS





also include appropriate units.

(i) Determine the net change in atmospheric CO_2 concentration between 140,000 years ago and 125,000 years ago.

(ii) Calculate the ratio of the change in mean global temperature to the change in atmospheric CO_2 concentration between 140,000 years ago and 125,000 years ago.

(iii) Scientists predict that between 1950 and 2050, the atmospheric CO_2 concentration will increase by 200 ppm. Predict the change in mean global temperature between 1950 and 2050 using the ratio that you calculated in part (ii).

(iv) Describe one major assumption that was necessary to make the prediction in part (iii) above. Discuss the validity of the assumption.

(b) Identify and describe TWO major causes for the predicted 200 ppm increase in atmospheric CO_2 concentration between 1950 and 2050.

(c) Identify TWO gases other than CO_2 that contribute to the anthropogenic increase in mean global temperature. For each gas, describe a major human activity that leads to its release.

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

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

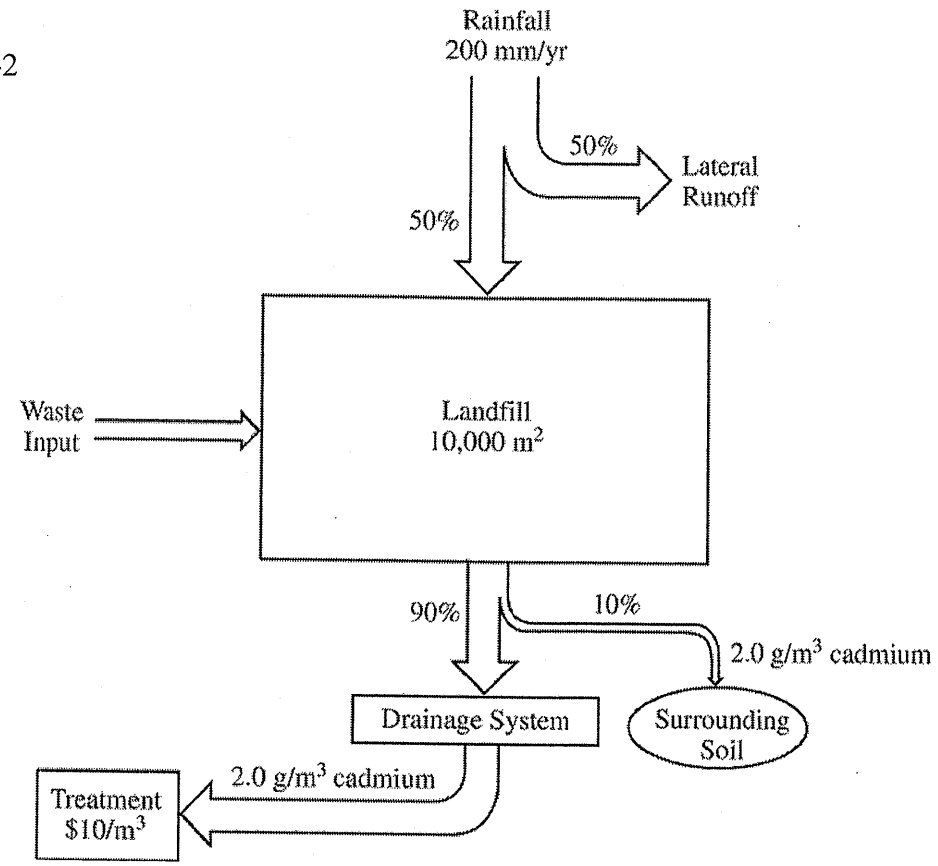
(i) The total amount of water that the family uses per year for taking showers

(ii) The annual cost of the electricity for the family showers, assuming that 2.5 gallons per minute of the water used is from the hot-water heater

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

(c) Describe TWO practical measures that the family could take that would reduce their overall water use at home.

(d) Describe TWO conservation measures (other than reducing hot water use) that the family could take to reduce the total amount of energy that they use at home.



The city of Fremont operates a municipal solid-waste landfill. As represented in the diagram above, the annual precipitation in Fremont is 200 mm/year: 50 percent of this water infiltrates through the landfill cover soil into the waste, and 50 percent drains off the landfill. A drainage system withdraws 90 percent of the leachate generated within the landfill for treatment. The rest of the leachate travels through the bottom liner of the landfill into the surrounding soil. Most of the cadmium disposed of in the landfill remains in the landfill; the leachate withdrawn from the landfill by the drainage system has an average cadmium concentration of 2.0 g/m3. Pumped to a treatment station, the leachate is treated at a cost of $10/m3.

(a) Calculate the volume, in m3, of each of the following:

(i) The water infiltrated through the landfill per year

(ii) The leachate that is treated per year

(b) Given that the cadmium concentration in the water draining from the landfill is 2.0 g/m3, calculate the mass, in kg, of cadmium that is released into the surrounding soil per year.

(c) What is the annual cost of treating the leachate from the drainage system?

(d) Discuss TWO viable methods for reducing the amount of cadmium entering the municipal waste input.

(e) Explain a shortcoming of ONE of the methods that you identified in part (d).

Anaerobic methane digesters have been used for many years to reduce energy costs on farms throughout Europe and on some large farms in the United States. The digesters operate by using anaerobic bacteria to break down animal waste. During the process, which typically uses a tank heated to about 100°F (38ÁC) to speed the reactions, raw manure is broken down and methane is produced. The methane can then be used to generate electricity or produce heat.

For a certain dairy farm with 500 cows, the cost of installing a digester is approximately $400,000. Assume that the farm uses 800,000 kilowatt-hours (kWh) of electricity each year at a cost of $0.10 per kWh. The waste from a single cow can produce 3.0 kWh of electricity each day.

(a) Describe the steps by which methane produced in the digester can be used to generate electricity.

(b) Discuss TWO environmental benefits that may result from the installation of an anaerobic methane digester.

(c) Assuming that the cost of electricity remains constant and the farmer starts using the manure from the cows in an anaerobic digester to produce electricity on the farm, calculate:

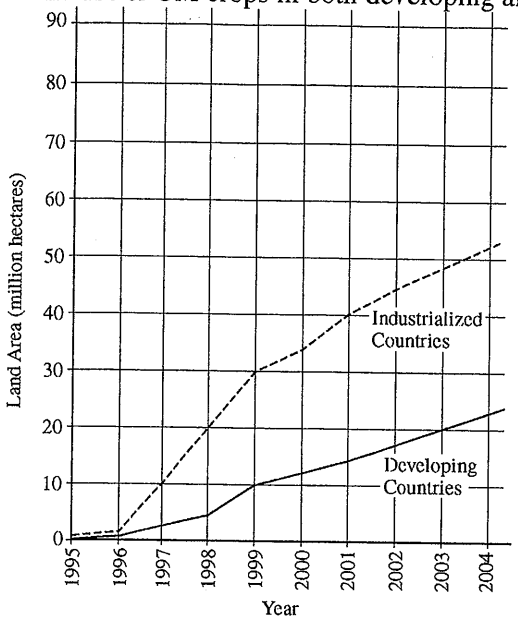
(i) The number of kWh of electricity that can be produced in one year

(ii) The amount of money the farmer can save in one year, NOT counting the installation cost of the digester. (You may round your answer to the nearest $1,000.)

(iii) The amount of time, in years, that it will take to recover the cost of installing an anaerobic digester on the farm. (You may round your answer to the nearest whole number of years.)

(d) Calculate the minimum number of cows the farm would need to produce 800,000 kWh of electricity per year.

The major issues in modern agriculture include the use of genetically modified (GM) crops and the implementation of sustainable agricultural practices. The following graph shows the increase in the use of GM crops in both developing and industrialized countries from 1995 to 2004.



(a) Reply to the following questions based on the data in the graph above.

(i) Calculate the increase in the area of land used for growing GM crops in developing countries from 1999 to 2003. Express your answer as a percentage of the 1999 value.

(ii) Calculate the annual rate of increase in land area used for growing GM crops in industrialized countries from 1997 to 1999.

(iii) Using the rate you calculated in part (ii), project the area of land that would have been expected to be used for GM crops in industrialized countries in 2004.

(iv) Identify one likely cause for the difference between the projected land area for GM crops in industrialized countries in 2004 and the actual land area for GM crops in industrialized countries in 2004.

(b) Describe one environmental advantage and one environmental disadvantage of using GM crops.

(c) Describe one economic advantage and one economic disadvantage of using GM crops.

(d) A healthy soil ecosystem is of primary importance in sustainable agriculture. Describe TWO viable agricultural practices that farmers can use to maintain or improve soil quality.

(e) Identify and describe one environmental advantage and one economic advantage of consuming locally grown produce.

Termites are social insects that are essential decomposers in tropical rain forest ecosystems. Termites may account for up to 95 percent of insect biomass in tropical rain forests. Termites consume vast amounts of dead and decomposing plant material, thanks to the work of mutualistic cellulose-digesting microorganisms that inhabit their guts. In addition to their roles as important decomposers, termites digest plant materials and directly contribute to carbon dioxide and methane emissions into the atmosphere. It is likely that, like many insect species, termites and their symbionts may be sensitive to changes in their microclimate caused by global climate change, especially with regard to temperature and humidity.

		Relative Humidity		
		50%	70%	90%
Temperature	20°C	0.04	0.05	0.05
	25°C	0.05	0.07	0.10
	30°C	0.12	0.13	0.27
	35°C	0.09	0.13	0.15
	40°C	0.00	0.00	0.00

(a) Respond to the following using the data in the table above, which gives the rate of wood consumption by termites, in mg per day per termite, under various temperature and relative humidity conditions. Under optimal conditions, the emission rate of methane by termites is approximately 70 kilograms of CH4 per year per 1,000 termites.

(i) According to the data, what are the optimal temperature and relative humidity for termite activity?

(ii) Given a density of 4.5×107 termites per hectare and optimal conditions, calculate the annual amount of methane emitted, in kilograms, by the termites inhabiting a 2,000-hectare tropical rain forest.

(iii) Suppose the temperature increases to 35°C and the relative humidity decreases to 50 percent. Using the data provided, determine the amount of methane, in kilograms, that would be emitted by the termites in the 2,000-hectare tropical rain forest.

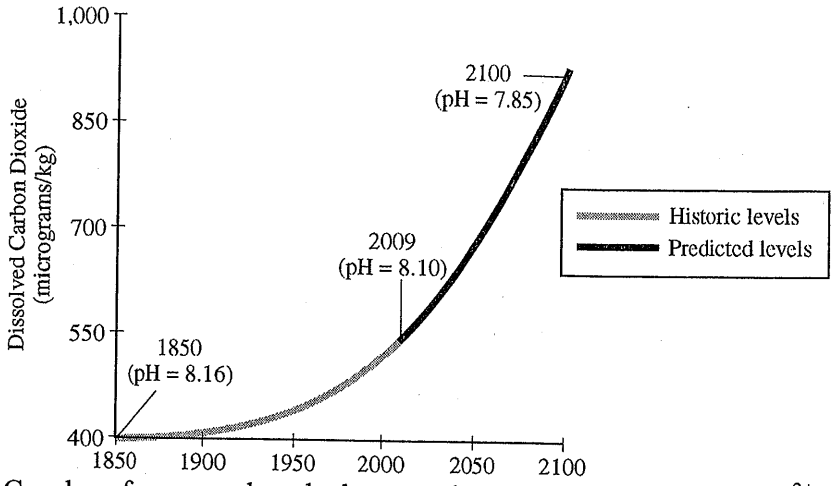
(iv) Explain why the population size of termites is also affected by temperature and humidity.

(b) It has been observed that soon after a tropical rain forest is cleared, termite density increases to an estimated 6.8×10^7 termites per hectare. Thereafter, the termite population size decreases dramatically.

(i) What is the most likely reason that the density of the termites increases when a tropical rain forest iscleared?

(ii) Why do the termite populations eventually decrease dramatically?

(c) Describe one way, other than changes in termite activity, that tropical rain forest destruction contributes to anthropogenic climate change.



Coral reefs are produced when corals acquire calcium ions (Ca^{2+}) and carbonate ions ($CO3^{2-}$) from seawater and deposit solid $CaCO_3$ to form their exoskeletons. Scientists are concerned that relatively rapid decreases in ocean water pH will hinder the deposition of $CaCO_3$. The graph above shows the amount of CO_2 dissolved in ocean water and ocean water pH (shown in parentheses) since 1850 and the predicted changes through 2100.

(a) Explain how an increase in the amount of dissolved CO_2 in ocean water results in a decrease in the pH of ocean water.

(b) Explain why the movement of carbon into the ocean has been increasing since 1850.

(c) In order to model the effects of ocean acidification on coral reefs, some simplifying assumptions can be made. Use the assumptions in the table below to perform the calculations that follow.

Assume that the total global area of corals growing in reefs is 2.5×10^{11} m^2.
Assume that corals grow only vertically and that the average vertical growth rate of corals is 3 mm/year.
Assume that the average density of $CaCO^3$ in corals is 2×10^3 kg/m^3.

(i) Calculate the current annual global increase in volume, in m^3, of $CaCO_3$ in coral reefs. Show all steps in your calculation.

(ii) Calculate the current annual global increase in mass, in kg, of $CaCO_3$ in coral reefs. Show all steps in your calculation.

(iii) Because of ocean acidification, it is expected that in 2050 the mass of $CaCO_3$ deposited annually in coral reefs will be 20 percent less than is deposited currently. Calculate how much less $CaCO_3$, in kg, is expected to be deposited in 2050 than would be deposited if ocean water pH were to remain at its current value.

(d) Identify and describe one likely negative environmental impact of the loss of coral reefs.

(e) Identify one environmental problem (other than one due to ocean acidification or loss of coral reefs) that affects marine ecosystems on a global scale.

The Fremont School District uses oil to heat school buildings. Go Green! is a new project the district will implement. The superintendent has declared that the district will dedicate itself to reducing its carbon footprint. In addition to taking serious energy-conservation measures, the district is planning to help offset its carbon dioxide emissions by raising money to help conserve a portion of a large tract of forest land adjacent to the high school campus.

(a) Describe one alternative energy source that would reduce the carbon footprint of the school district. Discuss one environmental benefit (other than reduced CO_2 emissions) and one environmental drawback of using the alternative source instead of fuel oil.

(b) Identify TWO ecological benefits provided by intact forest ecosystems (other than reducing CO_2 levels in the atmosphere).

(c) Use the assumptions below to answer the questions that follow. For each calculation, show all work.

The biomass of the forest increases at an annual rate of 2.7×10^5 kg/ha.
The forest biomass is 50 percent carbon by mass.
Each year the district uses 3.0×10^5 gallons of fuel oil for heating and hot water.
10 kg of CO_2 is produced when 1 gallon of fuel oil is burned.
1.0 kg of CO_2 contains 0.27 kg of carbon.
The cost of putting 1 ha of the forest into conservancy is $12,000.

(i) Calculate the mass of carbon, in kg, that is accumulated and stored in 1.0 ha of forest in one year.

(ii) Calculate the mass of carbon, in kg, that is emitted by the school as a result of its fuel-oil consumption in one year.

(iii) Calculate the number of hectares of forest the school district needs to conserve in order to offset the carbon released in one year by the school burning its fuel oil.

(iv) Calculate the amount of money the school district must raise for the conservation project.

2013-2

Battery electric vehicles (BEVs) have been introduced to consumers as an alternative way to reduce the environmental effects caused by use of internal-combustion engine (ICE) vehicles. A comparison of both vehicle types can help determine whether the use of BEVs would be beneficial in the future. Where calculations are required, please show your work.

(a) **Identify** THREE strategies that the federal government could implement to encourage the use of BEVs.

(b) Assume that the fuel efficiency of the ICE vehicle is 25 miles per gallon (mpg) and that gasoline costs $3.75 per gallon (gal). **Calculate** the cost of gasoline per mile.

(c) The charger supplies energy to the BEV battery at an average rate of 4.0 kilowatts (kW) and fully charges the BEV battery in 7.0 hours. The car will run for 100 miles on a full charge. The cost of electricity is $0.11 per kilowatt-hour (kWh).

i. **Calculate** the cost of the electricity to fully charge the battery. Assume that the battery is not charged to begin with.

ii. **Calculate** the cost of electricity per mile to drive the BEV.

When it is driven 100 miles, the ICE vehicle contributes 72.8 pounds (lb) of CO_2 from the burning of the gasoline. The drilling, refining, and transportation costs of getting the gasoline to the gas station add an additional 17.7 lb of CO_2 per 100 miles. The BEV does not emit any CO_2 itself, but the extraction, transportation, and combustion of the coal that produced the electricity at the power plant add 63.6 lb of CO_2 for the same 100 miles.

(d) **Calculate** the difference in the amount of CO_2 that would enter the atmosphere if both cars were driven 100 miles.

(e) **Describe** TWO economic impacts (excluding costs related to climate change resulting from CO_2 emissions or the cost of gasoline at the pump) that result from an increased number of BEVs on the road.

2014-2

Like many communities, Fremont has a combined sewer system that collects both sewage and storm water. When storm water runs into storm drains that connect to the city's sanitary sewer system, the storm water and sewage flow together to the Fremont Wastewater Treatment Plant (FWTP). During a major storm event, however, the combined volume of storm water and sewage may exceed the plant's capacity, and the overflow bypasses the FWTP. The untreated overflow is discharged into Fremont Creek along with the treated waste.

Recently parts of Fremont received 5 cm of rain in 60 minutes. The storm caused widespread flooding in the northeast section of town. Especially hard hit was the Shoppes at Fremont shopping center.

Use the data from the table below to answer the questions that follow. Show all calculations.

Fremont Water Data
The shopping center's parking lot is 200 meters long and 100 meters wide.
Fremont has an area of 10 km^2.
Impervious surfaces cover 20 percent of Fremont's area.
The FWTP typically treats 5000 m^3 of domestic sewage per day
The FWTP has the capacity to treat 10 000 m^3 of combined sewage and storm water per day.

(a) **Identify** TWO specific pollutants in storm-water runoff that degrade the quality of surface water.

(b) **Calculate** the volume of water (in m^3) that runs off the Shoppes at Fremont parking lot after a 5 cm rainfall event. Assume that all the water that falls on the parking lot runs off.

(c) **Calculate** the volume of storm-water runoff (in m^3) generated in all of Fremont by the 5 cm rainfall event. Assume that only the impervious surfaces generate runoff.

(d) Assume that all the runoff that you calculated in part (c) is captured by the storm sewers in one day.

Calculate the volume of untreated water (in m^3) that bypasses the plant as a result of the storm. (Note that the plant still receives 5000 m^3 of domestic sewage per day.)

(e) **Describe** TWO ways that the volume of storm-water runoff can be reduced.

(f) **Describe** one environmental problem (other than pollution from runoff and from untreated sewage) that results from having extensive paved areas.

2. Approximately 30 million mobile devices were sold in 1998 in the United States. The number sold increased to 180 million devices in 2007.

   (a) **Calculate** the percent increase of mobile device sales from 1998 to 2007.

   (b) Each mobile device sold in 2007 contained an average of 0.03 gram of gold. **Calculate** the number of grams of gold that were used in the production of the mobile devices sold in 2007.

   (c) Assume that the average mass of each mobile device was 0.1 kilogram. The United States Environmental Protection Agency estimates that about 10 percent of the mobile devices sold in 2007 were recycled. **Calculate** the mass (in kilograms) of the mobile devices sold in 2007 that were not recycled.

   (d) Discarded mobile devices become part of the electronic waste stream (e-waste). Mercury is often present in e-waste. **Identify** one negative human health effect, other than death, associated with exposure to mercury.

   (e) Improper disposal of e-waste has harmed human health and caused environmental damage in developing countries.

      (i) **State** TWO reasons why large quantities of e-waste from the United States are shipped to developing countries rather than being recycled in the United States.

      (ii) Retailers or manufacturers could take specific steps to dramatically reduce the amount of e-waste. **Describe** a realistic change in current practices that would accomplish this.

2. 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 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) 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.

(i) **Calculate** the weight (in tons) of rock waste produced globally each year when iron ore is converted to pig iron.

(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.

(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.

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.

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

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

(c) **Describe** TWO environmental problems that are associated with abandoned coal mine sites.

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

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