FREE-RESPONSE EXPLANATIONS

Question 1

(a) 3 points maximum

(i) 1 point

Restatement: Number of cubic feet of natural gas required to heat the house for the winter.

$$4{,}000 \text{ } \cancel{\text{square feet}} \times \frac{100{,}000 \text{ Btus}}{1 \text{ } \cancel{\text{square foot}}} = \mathbf{400{,}000{,}000 \text{ Btus}}$$

(ii) 1 point

Restatement: Cost of heating the home for one winter using natural gas.

$$400{,}000{,}000 \text{ } \cancel{\text{Btus}} \times \frac{1 \text{ } \cancel{\text{cubic foot natural gas}}}{1{,}000 \text{ } \cancel{\text{Btus}}} \times \frac{\$5.00}{1{,}000 \text{ } \cancel{\text{cubic feet}}} = \mathbf{\$2{,}000}$$

(iii) 1 point

Restatement: Cost of heating the home for one winter using electricity.

$$400{,}000{,}000 \text{ } \cancel{\text{Btus}} \times \frac{1 \text{ } \cancel{\text{kWh}}}{10{,}000 \text{ } \cancel{\text{Btus}}} \times \frac{\$50}{500 \text{ } \cancel{\text{kWh}}} = \mathbf{\$4{,}000}$$

NOTE:

1. If you do NOT show calculations, no points are awarded.
2. No penalty assessed if you do not show units. However, you risk setting up the problem incorrectly if you do not show units so that they cancel properly.
3. If your setup is correct but you make an arithmetic error, no penalty is assessed.

NOTE: For Parts (b) and (c), there are no points for just listing ideas. Each idea MUST be explained. The following are ideas that you could use to write your paragraph(s). Take these ideas, and create an outline of the order in which you wish to answer them. You do NOT need to use all ideas. Before you begin, decide on the format of how you wish to answer your question (pros versus cons, chart format with explanations within the chart, compare and contrast, etc.).

(b) 4 points maximum

(i) (1 point definition) In active solar heating applications, heat from the sun is collected, stored, and used primarily for domestic hot water and space heating. The reason the system is called active is because pumps and fans are used to transfer the captured heat to an area where it can be stored or used. The main components of an active solar system are the collectors, the collector controls, the storage tank, and the distribution system.

PRACTICE EXAM 2

Active Solar System (1 point) Choose ideas from the list below:

- Active liquid solar systems heat water or an antifreeze solution in a collector. Liquid solar collectors are most appropriate for central heating. Flat-plate collectors are the most common. In the collector, a heat transfer fluid such as a water or antifreeze absorbs the solar heat. At the appropriate time, a controller operates a circulating pump to move the fluid through the collector. The heated liquid flows to either a storage tank or a heat exchanger for immediate use.
- Air collectors produce heat earlier and later in the day than liquid systems. Therefore, air systems may produce more usable energy over a heating season than a liquid system of the same size. Solar air collectors have a black metal plate for absorbing heat, which in turn heats air in the collector. A fan then blows this heated air into the house. Air collectors can be installed on a roof or on a south-facing exterior wall. These systems are easier and less expensive to install than a central heating system. They do not have a dedicated storage system or extensive ductwork. The floors, walls, and furniture will absorb some of the solar heat, which will help keep the room warm for a few hours after sunset. Masonry walls and tile floors will also provide more thermal mass and thus provide heat for longer periods. A well-insulated house will make a solar room air heater more efficient.

(ii) (1 point definition) In passive solar building design, windows, walls, and floors are made to collect, store, and distribute solar energy in the form of heat in the winter and reject solar heat in the summer. This is called passive solar design or climatic design because, unlike active solar heating systems, it doesn't involve the use of mechanical and electrical devices. The key to designing a passive solar building is to best take advantage of the local climate. Elements to be considered include window placement and glazing type, thermal insulation, thermal mass, and shading.

Passive Solar System (1 point definition) Choose ideas from the list below:

- There are two basic approaches to passive solar systems. First, direct gain—solar energy is transmitted through south-facing windows. Works best when the south window area is double-glazed and the building has considerable thermal mass in the form of concrete floors and masonry walls. Second, indirect gain in which a storage mass collects and stores heat directly from the sun and then transfers the heat to the living space(s).

(iii) Choose ONE idea from the list below: (1 point)

Advantages

- Reduces the use of fossil fuels and their emission of greenhouse gases.
- Solar energy is a renewable energy resource.
- The financial costs of solar systems are falling as technology develops.
- Fossil fuels, being a nonrenewable energy source, are running out. As they become more scarce, prices will rise, making solar energy more cost effective in the future.
- Suitable for remote areas that are not connected to energy grids or pipelines.
- Zero risk of indoor pollution such as carbon monoxide.

Disadvantages

- Higher initial cost of equipment than conventional heating systems.
- Clouds may reduce effectiveness.
- A solar energy installation requires a large area for the system to be efficient in providing a source of electricity. This may be a disadvantage in areas where space is short, or expensive.
- The location of solar panels can affect performance, due to possible obstructions from the surrounding buildings or landscape.

(c) 3 points maximum

(i) (1 point definition): A green building focuses on a whole-system approach, including energy conservation, resource-efficient building techniques and materials, indoor air quality, water conservation, and designs that minimize waste while utilizing recycled materials. Green buildings are a product of a good design that minimizes a building's energy needs while reducing construction and maintenance costs over the life cycle of a building.

(ii) (2 points) Choose any TWO ideas from the following:

- Solar collectors for space heating.
- Solar collectors for water heating.
- Photovoltaics to supply electrical energy.
- Hybrid systems that incorporate more than one power source such as wind and solar.
- Use of energy efficient (Energy Star) appliances.
- Products made from environmentally sustainable materials.
- Products that do not contain toxins (ex: PVC pipes, ozone-depleting chemicals, formaldehyde in plywood, paints and stains with VOCs).
- Products that reduce the environmental impact on building operations (ex: new energy saving thermostats, newer landscape irrigation systems that only activate based on soil moisture content).
- Products that remove or warn of indoor pollution hazards (ex: carbon monoxide detectors, air filtration systems, water purifying systems).
- Homes that meet or exceed insulation requirements.
- Green landscaping—landscaping that provides shade during the summer and allows sunlight to warm the house during winter and the use of plants that do not require large amounts of water.

Question 2

(a) Define "aquafarming" (1 point)

Aquafarming is the commercial farming of freshwater and saltwater fish, mollusks, crustaceans, and aquatic plants. Also known as aquaculture, it involves cultivating aquatic populations under controlled conditions.

(i) Describe TWO advantages of aquafarming over traditional wild harvesting. (2 points)

In aquaculture, the life cycle of organisms occurs under controlled conditions. Advantages of having control over the life cycle of organisms include: (1) more intensive farming is possible, which often results in higher yields and greater profits; (2) more uniformity in the product since environmental conditions are controlled and managed, which results in less waste and higher profits; (3) predator control; (4) the ability to accelerate growth and maturation by controlling the climate, especially on farms located in more temperate zones; and (5) most traditional expenses and variables inherent to wild harvesting (the costs of boats, crews, nets, weather conditions, searching for areas with enough of the species that can be captured to be profitable, etc.) are minimized or eliminated.

(ii) Describe TWO negative environmental impacts of aquafarming. (2 points)

Fish waste is organic and composed of nutrients necessary in all components of aquatic food webs. Aquaculture often produces much higher-than-normal fish waste concentrations, as the habitat is confined. The waste collects on the ocean bottom, damaging or eliminating bottom-dwelling life. Waste can also decrease dissolved oxygen levels in the water column, putting further pressure on other organisms. Waste products from aquafarming are often discharged untreated directly into the surrounding aquatic environment and frequently contain antibiotics and pesticides.

Growers often supply their animals with antibiotics to prevent disease, which can accelerate the evolution of bacterial resistance.

Other acceptable answers include:

- *Fish can escape from coastal pens, where they can interbreed with their wild counterparts, diluting wild genetic stocks.*
- *Escaped fish can become invasive, outcompeting native species.*
- *Aquaculture is becoming a significant threat to coastal systems; e.g., about 20% of mangrove forests worldwide have been destroyed since 1980, partly due to shrimp farming.*

(b) Describe TWO methods that can be employed in aquaculture to lessen the environmental impact. (2 points)

Onshore recirculating aquaculture facilities using polyculture techniques and properly sited facilities (e.g., offshore areas with strong currents) can minimize the negative environmental effects.

Other acceptable methods include:

- *Formulate coastal aquaculture development and management plans.*
- *Formulate integrated coastal zone management plans.*
- *Assess the capacity of the local ecosystem to sustain aquaculture development with minimal ecological change, and establish a permit system based on the local ecosystem's capacity for aquafarming.*
- *Establish guidelines governing the use of wetlands and mangrove forests.*
- *Establish guidelines for the use of bioactive compounds (pesticides, hormones, pharmaceuticals, herbicides, etc.)*
- *Assess and evaluate the true consequences of transfers and introduction of exotic organisms.*
- *Regulate discharges from land-based aquaculture through the enforcement of effluent standards.*
- *Establish quality control measures for aquaculture products.*
- *Apply incentives and deterrents to reduce environmental degradation from aquaculture activities.*
- *Monitor water quality using established protocols for any signs of ecological change.*

(c) How is raising and harvesting kelp and bivalve mollusks a more sustainable method of aquafarming than raising and harvesting higher trophic order fish such as salmon? (1 point)

Raising seaweed and filter-feeding bivalve mollusks, such as oysters, clams, mussels, and scallops, has a very low impact on the environment and may even be environmentally restorative, as these filter-feeders filter pollutants and excessive nutrients from the water, often improving water quality. Kelp extract nutrients such as inorganic nitrogen and phosphorus directly from the water, while filter-feeding mollusks can extract nutrients as they feed on particulates such as phytoplankton and detritus.

(d) The newspaper announcement claims that aquafarming is the answer to world hunger. Give TWO examples of how this statement may be contrary to environmental sustainability. (2 points)

Salmon farming currently involves a high demand for wild forage fish for feed, as well as their by-products—fish meal and fish oil. As carnivores high on the food chain, salmon require a lot of protein, and farmed salmon consume more protein than they produce; e.g., each pound of farmed salmon requires up to 6 pounds (2 kg) of wild fish. About 75% of the world's monitored fisheries are already near to or have exceeded their maximum sustainable yield. The industrial-scale extraction of wild forage fish for salmon farming also impacts the survivability of the wild predator fish that rely on them for food.

Question 3

(a) Describe the role and importance of stratospheric ozone to life on Earth. (1 point)

The ozone (O_3) layer, located in the lower portion of the stratosphere, absorbs up to 99% of the sun's high-frequency ultraviolet radiation, which is damaging to life on Earth. About 90% of the atmospheric ozone resides in a layer approximately 6–30 miles (10–50 km) above the Earth's surface, in the region of the atmosphere known as the stratosphere. This stratospheric ozone is commonly referred to as the "ozone layer." The remaining ozone is in the lower region of the atmosphere, the troposphere, which extends from the Earth's surface up to about 6 miles (10 km). Stratospheric ozone plays a beneficial role by absorbing most of the biologically damaging ultraviolet sunlight (UVB and UC) before it reaches the Earth's surface. The absorption of ultraviolet radiation by ozone in this zone creates a source of heat in the stratosphere that increases with altitude. Ozone thus plays a key role in the temperature structure of the Earth's atmosphere. Without the filtering action of the ozone layer, more of the sun's UVB and UVC radiation would penetrate the atmosphere and reach the Earth's surface.

(b) Suggest ONE possible reason for the appearance of the hole in the ozone layer, which was first observed in the 1980s. (1 point)

Scientific evidence has shown that human-produced chemicals are most likely responsible for the observed depletion of the ozone layer. CFCs (chlorofluorocarbons) were the first mass-produced chemical compounds shown to destroy ozone. CFCs were primarily used in refrigeration and air-conditioning (e.g., Freon) and in the dry cleaning industry (e.g., carbon tetrachloride). Later, halocarbons, chemical compounds similar to CFCs but which contain bromine, were also shown to destroy ozone molecules. Halocarbons were used in foam blowing, soil fumigants and pesticides (e.g., methyl bromide), fire retardants and extinguishers, and as a solvent in producing circuit boards (e.g., methyl chloroform).

(c) Ultraviolet (UV) radiation occurs in three forms, known as UVA, UVB, and UVC.

(i) Describe at least ONE characteristic of EACH form of ultraviolet radiation. (3 points)

The three types of UV radiation are classified according to their wavelength. They differ in their biological activity and the extent to which they can penetrate the skin; i.e., the shorter the wavelength, the more harmful the UV radiation. However, shorter wavelength UV radiation is less able to penetrate the skin. Short-wavelength UVC is the most damaging type of UV radiation. However, it is completely filtered by the atmosphere and does not reach the Earth's surface. Medium-wavelength UVB is very biologically active but cannot penetrate beyond the superficial skin layers. Most solar UVB is filtered by the atmosphere. The relatively long-wavelength UVA accounts for approximately 95% of the UV radiation reaching the Earth's surface.

(ii) Describe the effects that increased UV radiation would have on:

(a) Human health (1 point)

Changes in the skin's DNA due to UVA and UVB rays can cause serious, long-term skin damage. UVA and UVB radiation can penetrate into the deeper layers of the skin and is responsible for the immediate tanning effect. Furthermore, it also contributes to skin aging and wrinkling, and recent studies suggest that it may also enhance the development of skin cancers. One effect of UV exposure is that it advances the signs of aging. Premature wrinkling is common in people who have been exposed to the sun over long periods of time, as are age spots and uneven complexions. UV radiation can also cause cataracts and weaken the immune system.

(b) Terrestrial ecosystems (1 point)

Excessive exposure to UV radiation can cause cancers in animals and damage their eyesight. Increase UV exposure can harm DNA and proteins, and affect organisms in their developmental stages. These direct effects may lead to indirect effects, such as decreased primary productivity, changes in biodiversity, decreased nitrogen uptake by microorganisms, and reduced capacity for oceans to fix carbon dioxide. Research on the effects of increased UVB exposure in higher trophic levels has shown reduced reproductive capacity, growth, and survival rates. Experiments on certain food crops (e.g., rice and soybeans) have shown lower crop yields when exposed to higher levels of UVB radiation. The plants minimize their exposure to increased UV radiation by limiting the surface area of their foliage, which in turn impairs growth.

(c) Marine ecosystems (1 point)

Phytoplankton, which are located at the base of the aquatic food pyramid, account for approximately 30% of the world's intake of animal protein. Phytoplankton productivity is restricted to the upper layer of the water, where sufficient light is available. A small increase in UVB exposure brought about by less stratospheric ozone could significantly reduce the size of plankton populations, affecting the environment in several ways: (1) with less organic matter in the upper layers of the water, UV radiation can penetrate deeper into the water and affect more complex plants and animals living there; (2) UV radiation directly damages animals during their early development; (3) pollution of the water by toxic substances may synergistically magnify the adverse effects of UV radiation, working its way up the food chain; (4) less plankton means less food for the animals that prey on them and a reduction in fish stocks already depleted by overfishing; (5) decreased bacterial and plankton activity may lead to an increase in dissolved organic matter in ocean waters, as assimilation of dissolved organic matter is reduced. Cyanobacteria, organisms important in nitrogen fixation, are also at risk. Cyanobacteria transform dissolved nitrogen in ocean water to nitrates and other forms that are accessible by higher plants; (6) a decrease in phytoplankton growth reduces the uptake of carbon dioxide by the oceans, thus leaving more CO_2 in the atmospheric reservoir. Increased atmospheric CO_2 has implications for global warming; and (7) decreased amounts of plankton causes a decrease in the amount of dimethyl sulfide (DMS) they release, an important source of cloud condensation nuclei.

(d) Identify and describe ONE alternative to ozone-destroying chemical compounds. (1 point)

Compounds containing C-H bonds (HCFCs) have been designed to replace chlorofluorocarbons. These compounds are more reactive and less likely to survive long enough in the atmosphere to reach the stratosphere, where they would affect the ozone layer. While less damaging than CFCs, HCFCs also have a significant negative impact on the ozone layer. HCFCs are also being phased out.

(e) Identify and briefly describe ONE international treaty that addresses the release of chemical compounds that destroy stratospheric ozone. (1 point)

The 1987 Montreal Protocol on Substances that Deplete the Ozone Layer was an international treaty designed to protect the ozone layer by phasing out the production of a number of substances, especially chlorofluorocarbons (CFCs), believed to be responsible for ozone depletion. Stratospheric ozone depletion can be expected to continue (but at a slower pace) because of CFCs used by nations that have not banned them, and because of gases that are already in the stratosphere. CFCs have a very long atmospheric lifetime, ranging from 50 to more than 100 years, so the complete recovery of the ozone layer is expected to require several lifetimes.

Question 4

(a) (i) 2 points maximum (1 point for each correct event)

Restatement: Two possible events that have occurred within the last 100 years that can account for the increase in human life span.

Since 1900, the average life span of persons living in the United States has increased by more than 30 years, with most of this gain attributable to advances in public health. The three advances in public health that have had the greatest impact on world health and human life span have been the availability of clean water, improvements in sanitation, and the development of vaccines.

(ii) 1 point maximum (1 point for a correct and accurate description of one event listed above)

Restatement: Describe how public sanitation increased average human life span.

At the turn of the 20th century, it was a common practice to dispose of garbage, industrial wastes, and raw sewage by dumping them into waterways. Few municipalities treated wastewater because it was widely believed that running water purified itself. Typhoid, dysentery, and diarrhea were the most common waterborne diseases and were also the third leading cause of death in the United States at that time. As a result of disinfection of public drinking water and improved sanitation methods, the major waterborne diseases have all but ceased to exist in the United States. Worldwide, the median reduction in deaths from water-related diseases is approximately 70% among people with access to potable water and proper sanitation. Yet waterborne diseases continue to be major killers in less-developed countries, causing half of all deaths of children in poor countries.

(b) (i) 1 point maximum (1 point for a correct explanation of how malaria is transmitted)

Restatement: How malaria is transmitted through the human population.

Malaria is naturally transmitted by the bite of a female *Anopheles* mosquito. When this species of mosquito bites an infected person, a small amount of blood is taken, which contains malaria parasites (*Plasmodium*). These parasites develop within the mosquito, and about one week later, when the mosquito takes its next blood meal, the parasites are injected with the mosquito's saliva into the person being bitten. After a period of between two weeks and several months (occasionally years) in the human liver, the malaria parasites start to multiply within red blood cells, causing symptoms that include fever and headache. In severe cases, the disease worsens, leading to coma and death.

(ii) 4 points maximum (1 point for each correct environmental factor, maximum of 2 points; 1 point for each correct explanation of how each factor influenced the increase of the disease, maximum of 2 points)

Restatement: Two environmental factors that contribute to the emergence of malaria and how those factors influence the increase in the incidence of the disease.

Environmental factors that can contribute to the emergence of malaria include:

1. A decrease in the population of mosquito predators, which can increase the mosquito population and the rate of transmission.

2. Genetic resistance to pesticides, which can also increase the mosquito population and the rate of transmission.
3. Changes in the climate (e.g., global warming), which can increase the number of suitable habitats, resulting in increased rates of transmission.
4. Changes in the current habitats (e.g., agriculture, logging), which can increase the number of breeding sites.
5. An increase in the population density, which allows for a greater opportunity for transmission.
6. The emergence of *Plasmodia* strains that are resistant to anti-malarial drugs, which can then lead to an increase in the incidence and transmission of malaria.

(iii) 2 points maximum (1 point for a correct description of biological control and 1 point for a correct method for controlling the spread of malaria)

Restatement: Description of biological control and an example of one biological control method used for controlling the spread of the disease.

Biological control is the reduction of pest populations by natural enemies and typically involves an active human role. It is a method of controlling pests that relies on predation, parasitism, or other natural mechanisms and can be an important component of integrated pest management programs. Effective biocontrol agents that can be used to decrease the incidence of malaria include predatory fish that feed on mosquito larvae; other insects, such as dragonfly nymphs, that consume mosquito larvae in the breeding waters; adult dragonflies that eat adult mosquitoes; other mosquito species that prey on the *Anopheles* mosquito; predatory crustaceans; birds; bats; lizards; and frogs. Microbial pathogens that can be used to target and control *Anopheles* mosquitoes include viruses, bacteria, fungi, protozoa, nematodes, and microsporidia. Dead spores of varieties of the natural soil bacterium Bt (*Bacillus thuringiensis*) can be used to interfere with the digestive systems of *Anopheles* larvae and can be dispersed by hand or dropped by air over large areas.