

AIM 2: How does heat energy travel?

HW

- Read “How Does Heat Energy Travel?” p190-195
- Do all questions on Part A&B-1 on p195-198

Heat is a form of energy because it can do work.

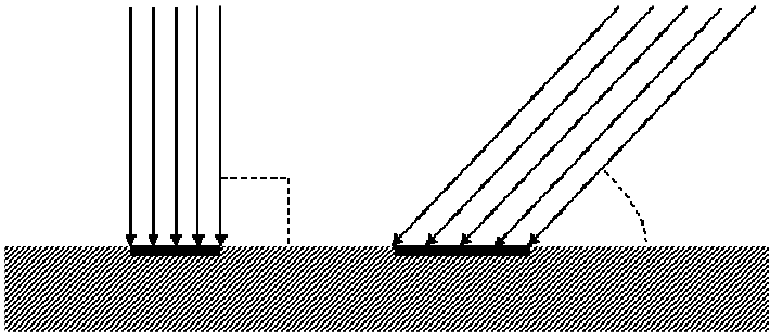
Heat energy travels in three ways

- **Conduction** is the flow of heat energy when a hot substance comes into contact with a cooler substance. Heat flows from hot to cold.
Ex: If you touch a hot object, you can feel the heat.
- **Radiation** is the flow of heat energy as electromagnetic waves travel through a vacuum such as outer space.
Ex: The Sun radiates its energy through space.
- **Convection** is the flow of heat energy due to density currents.
Ex: Convection cells driving Plate tectonics, wind, ocean currents...

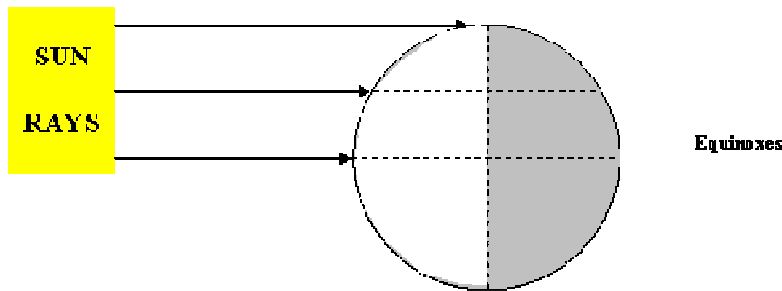
The sun's electromagnetic energy that reaches the earth is called insolation.

The intensity of insolation depends on several factors

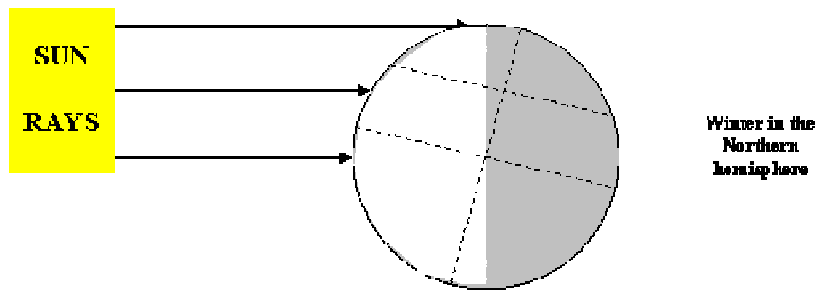
- **The angle of insolation**
It is a measure of the angle between sun rays and surface, as the angle increases the intensity of insolation also.



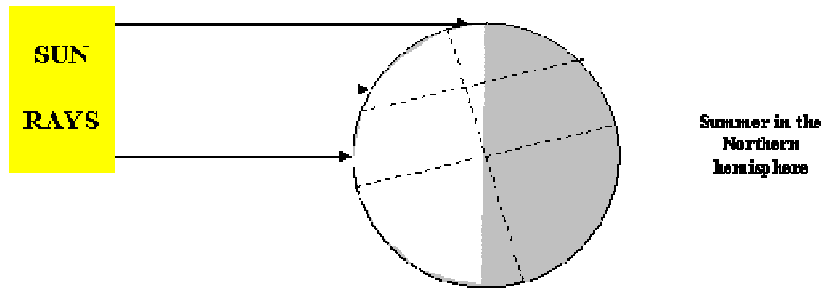
- **Angle of insolation** differs with latitude and seasons.
 - Somewhere in the tropics (between $23\frac{1}{2}^{\circ}\text{N}$ and $23\frac{1}{2}^{\circ}\text{S}$) the angle of insolation is 90° at noon each day.



- In New York state, the lowest angle of insolation is reached at the winter solstice (about Dec. 21)



- In New York state, the highest angle of insolation is reached at the summer solstice (about June 21)



- **The duration of insolation**

It is the length of time that the sun appears in the sky.

The duration of insolation varies greatly with latitude and time of the year. At any location on Earth, the total time the sun is above the horizon is six months of the year.

Ex:

- In NY State, the greatest duration of insolation occurs June 21 (15 hours of sunlight and 9 hours of darkness)
- At the North Pole six months of sunlight are followed by six months of darkness.
- At the equator 12 hours of sunlight are followed by 12 hours of darkness each day.

Earth absorbs most of the sunlight that falls on it. Absorption can differ for several reasons.

- **Specific heat**

A material with low specific heat such as land (granite) absorbs heat quickly and releases it quickly.

A material with high specific heat such water absorbs heat slowly and releases it slowly.

- **Color**

Dark-colored objects are better absorber and radiator of energy than light-colored objects.

- **Texture**

Rough objects are better absorber and radiator of energy than smooth objects.

- **Angle of insolation**

Low-angle insolation decreases absorption.

Insolation is reflected for several reasons

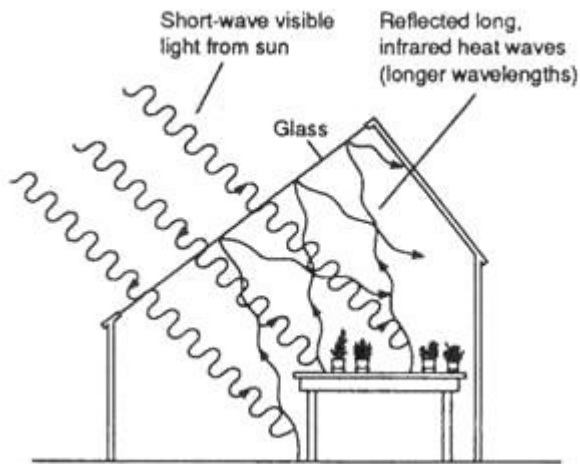
- Clouds reflect roughly half of the light falling on them.
- Earth's surface reflects light. Reflection is greater when:
 - The angle of insolation is low.
 - The land is light in color or covered by snow or ice.

Insolation is also scattered

Tiny solid particles such as dust, pollen and water droplets scatter insolation therefore less insolation reaches Earth's surface.

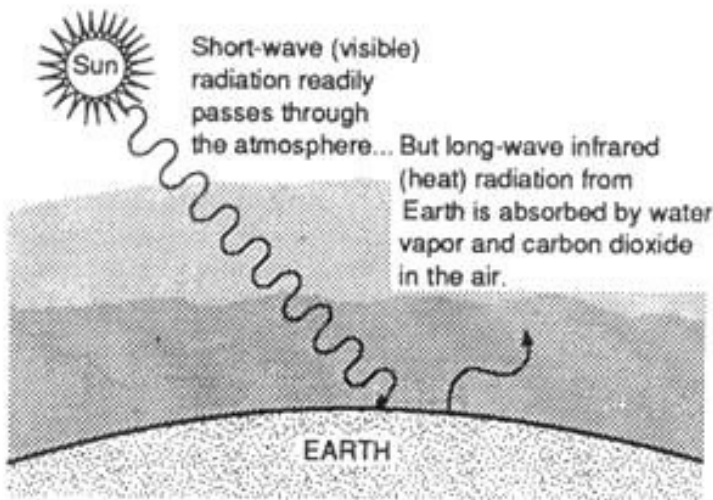
The greenhouse effect

- **In a greenhouse**



1. Short visible wavelengths pass through the glass and are absorbed by materials.
2. Materials give off heat (infrared) which are longer than visible wavelengths.
3. Infrared cannot pass through glass so they are reflected and stay inside the greenhouse and temperature increases.

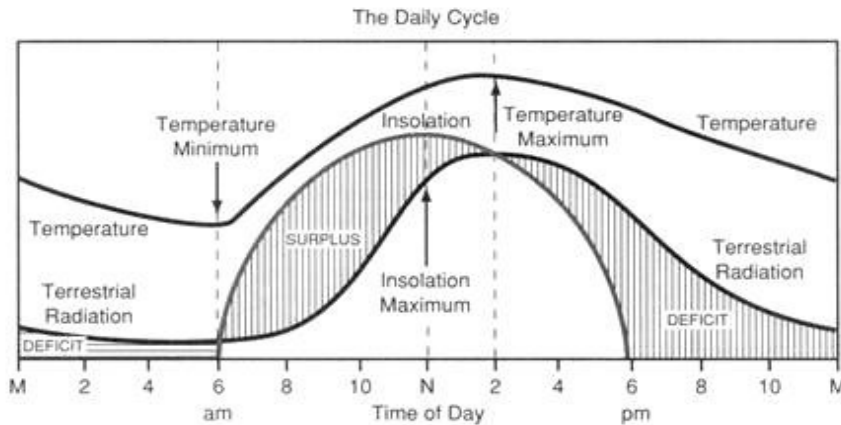
- **In the atmosphere**



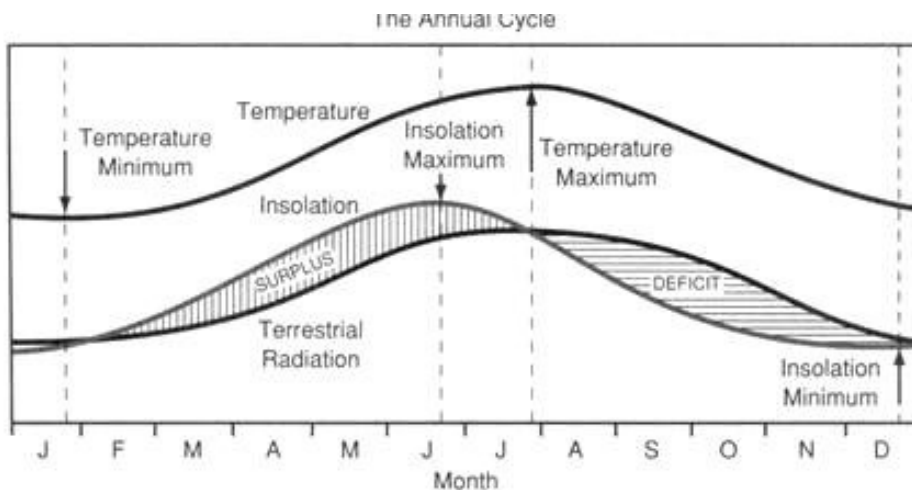
1. Short visible wavelengths pass through the atmosphere and are absorbed by materials.
2. Materials give off heat as infrared which are longer than visible wavelengths.
3. Infrared are absorbed by gases (greenhouse gases) such as carbon dioxide and water vapor and temperature of the atmosphere increases.

Without the greenhouse effect, the temperature of our planet would be too cold for most forms of life.

The insolation-temperature lag



During the day the maximum insolation is reached at noon time but the maximum temperature is reached later.



During the year the maximum temperatures are about one month after the maximum insolation (June 21).

TEST YOUR UNDERSTANDING

6/07

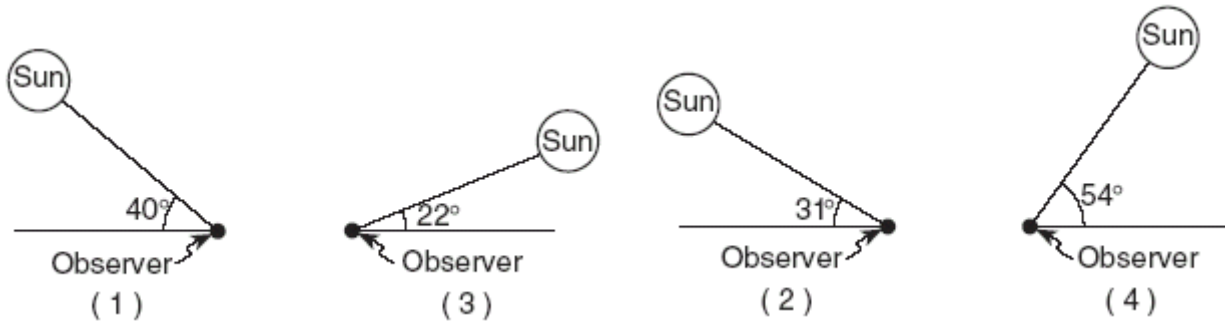
- 4 The average temperature at Earth's equator is higher than the average temperature at Earth's South Pole because the South Pole (1) receives less intense insolation (2) receives more infrared radiation (3) has less land area (4) has more cloud cover
- 6 Which type of electromagnetic energy has the longest wavelength?
 (1) infrared radiation (2) radio wave radiation (3) ultraviolet radiation (4) x-ray radiation
- 28 The diagram below shows four surfaces of equal area that absorb insolation.



Which letter represents the surface that most likely absorbs the greatest amount of insolation? (1) A (2) B (3) C (4) D

1/07

33 In which diagram is the observer experiencing the greatest intensity of insolation?

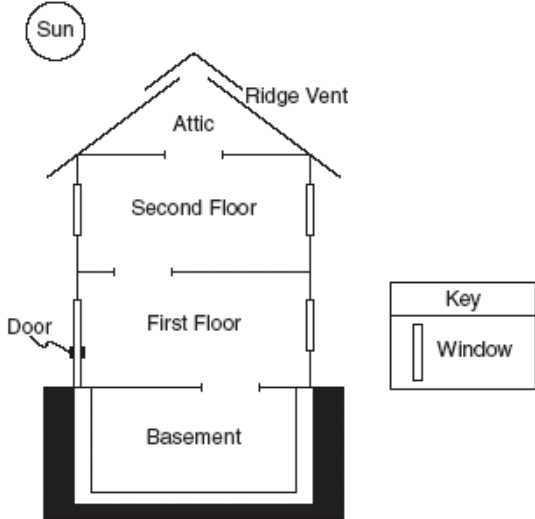


8/06

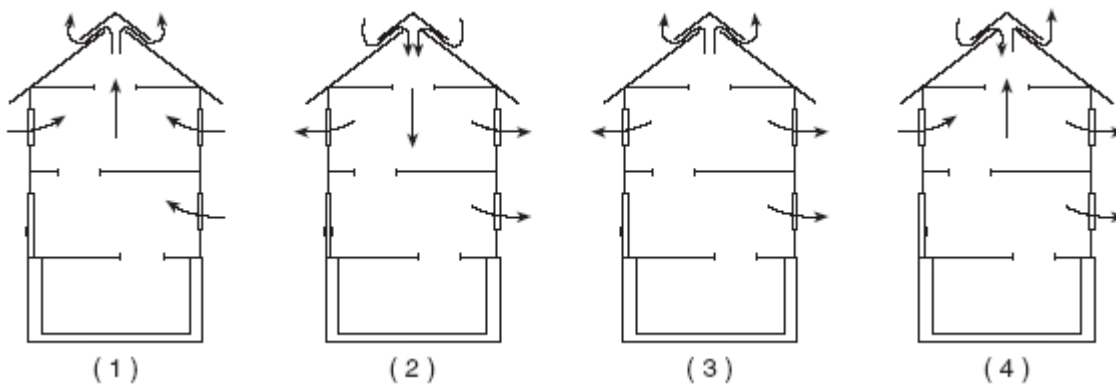
24 Which two gases have been added to Earth's atmosphere in large amounts and are believed to have increased global warming by absorbing infrared radiation?

- (1) neon and argon
- (2) chlorine and nitrogen
- (3) hydrogen and helium
- (4) methane and carbon dioxide

27 The cross section of a house is shown below. Open stairways allow air to move from one floor to another. The ridge vent is an opening in the roof that allows air to move in or out of the attic.



During a windless summer day, the air inside this house is warmed by the Sun. In which cross section do the arrows show the most likely air movement when the windows are opened?



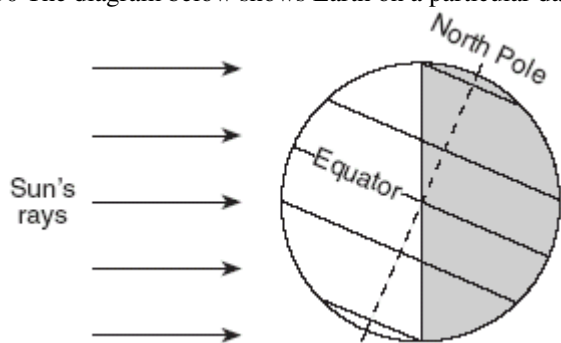
28 The ozone layer helps life on Earth because ozone

- (1) modifies the normal El Niño weather pattern
- (2) reflects insolation from the Sun
- (3) absorbs damaging ultraviolet radiation from the Sun
- (4) deflects winds from a straight line to a curved path

29 Under identical conditions, which surface will reflect the greatest amount of insolation?

- (1) a basaltic sand beach
- (2) a pine tree forest
- (3) a glacial ice sheet
- (4) a blacktop parking lot

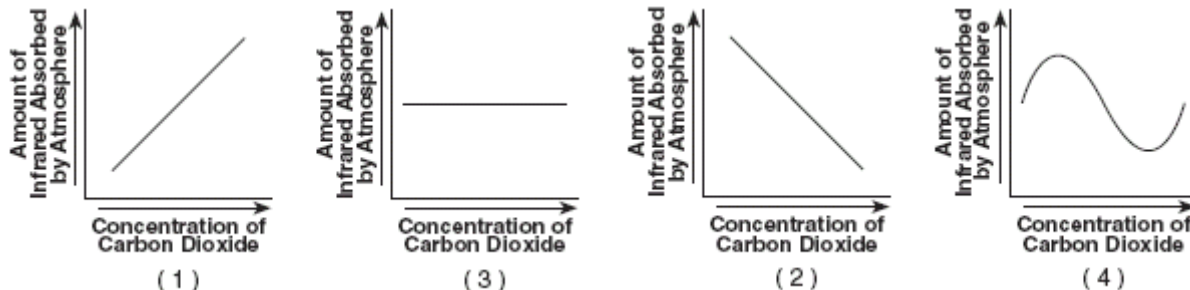
30 The diagram below shows Earth on a particular day in its orbit around the Sun. The dashed line represents Earth's axis.



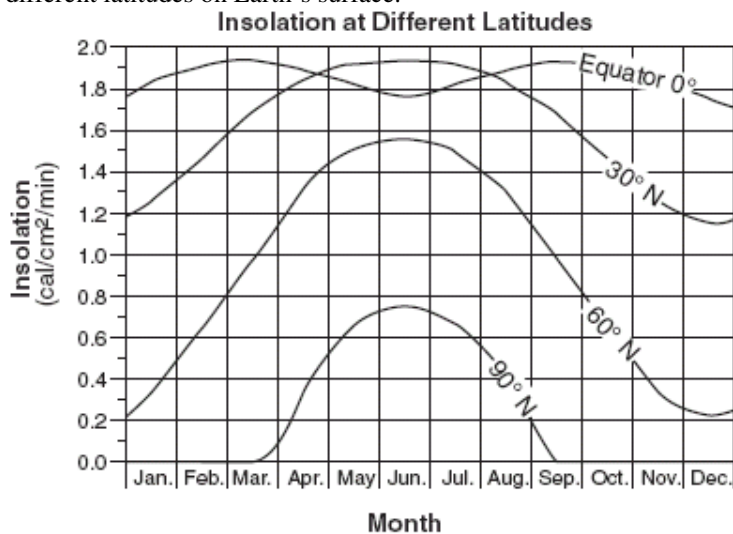
Which date is represented by the diagram? (1) March 21 (2) June 21 (3) September 23 (4) December 21

6/06

17 Which graph best shows the relationship between the concentration of carbon dioxide in Earth's atmosphere and the amount of infrared radiation absorbed by the atmosphere?



Base your answers to questions 47 through 49 on the graph below, which shows the amount of insolation during one year at four different latitudes on Earth's surface.



47 This graph shows that insolation varies with

- (1) latitude and time of day (2) latitude and time of year (3) longitude and time of day (4) longitude and time of year

48 Why is less insolation received at the equator in June than in March or September?

- (1) The daylight period is longest at the equator in June. (2) Winds blow insolation away from the equator in June.
 (3) The Sun's vertical rays are north of the equator in June. (4) Thick clouds block the Sun's vertical rays at the equator in June.

49 Why is insolation 0 cal/cm²/min from October through February at 90° N?

- (1) Snowfields reflect sunlight during that time.
 (2) Dust in the atmosphere blocks sunlight during that time.
 (3) The Sun is continually below the horizon during that time.
 (4) Intense cold prevents insolation from being absorbed during that time.

1/06

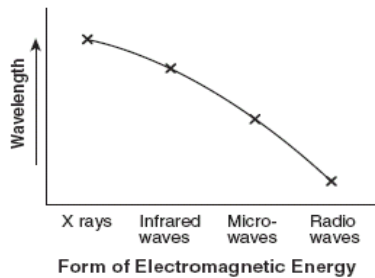
10 Which set of surface soil conditions on a hillside would result in the most infiltration of rainfall?

- (1) gentle slope, saturated soil, no vegetation (2) gentle slope, unsaturated soil, vegetation
 (3) steep slope, saturated soil, vegetation (4) steep slope, unsaturated soil, no vegetation

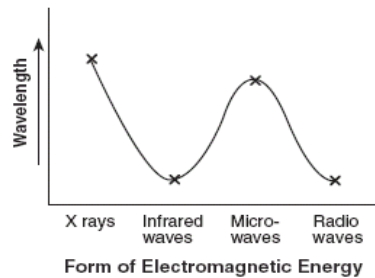
29 Which component of Earth's atmosphere is classified as a greenhouse gas?

- (1) oxygen (2) carbon dioxide (3) helium (4) hydrogen

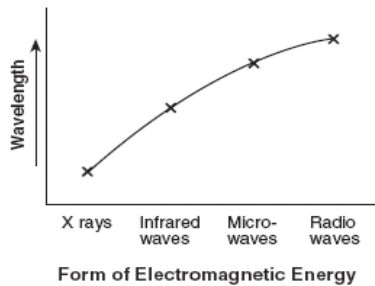
33 Which graph best represents the relative wavelengths of the different forms of electromagnetic energy?



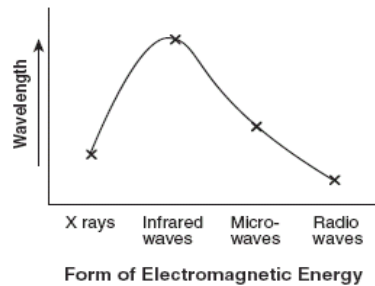
(1)



(3)



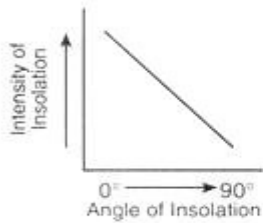
(2)



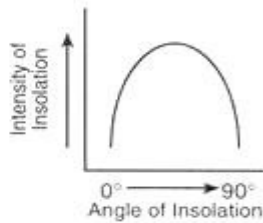
(4)

1/04

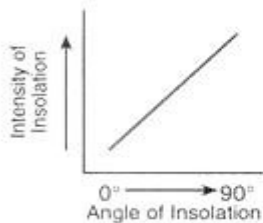
6 Which graph best represents the relationship between the angle of insolation and the intensity of insolation?



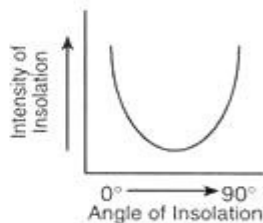
(1)



(3)



(2)

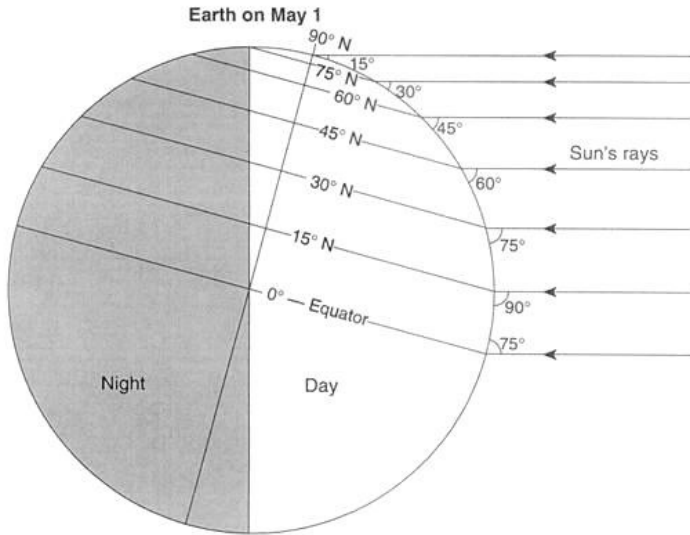


(4)

7 A square meter of surface of which of these natural areas would most likely absorb the most insolation during a clear day?

- (1) a fast-moving river (2) a dark-green forest (3) a beach with white sand (4) a snow-covered field

Base your answers to questions 36 and 37 on the diagram below, which shows the angle of the Sun's noontime rays received at different Earth latitudes on May 1.



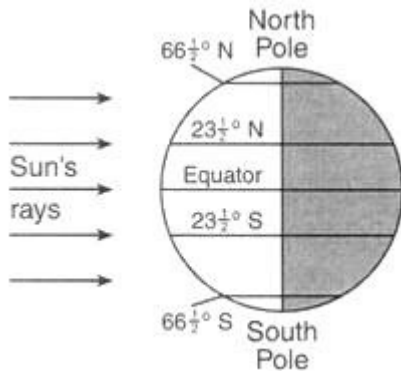
- 36 Which changes can be expected to occur at 45° N over the next 30 days?
- (1) The duration of insolation will decrease and the temperature will decrease.
 - (2) The duration of insolation will decrease and the temperature will increase.
 - (3) The duration of insolation will increase and the temperature will decrease.
 - (4) The duration of insolation will increase and the temperature will increase.

8/03

2 A person in New York State worked outdoors in sunlight for several hours on a day in July. Which type of clothing should the person have worn to absorb the least electromagnetic radiation?

- (1) dark colored with a rough surface
- (2) dark colored with a smooth surface
- (3) light colored with a rough surface
- (4) light colored with a smooth surface

4 The diagram below represents Earth at a specific position in its orbit as viewed from space. The shaded area represents nighttime. North



Which Earth latitude receives the greatest intensity of insolation when Earth is at the position shown in the diagram?

- (1) 0°
- (2) 23 1/2° N
- (3) 66° N
- (4) 90° N

9 The table below shows the duration of insolation (hours of daylight) measured by four observers, W, X, Y, and Z, at four different Earth latitudes on both March 21 and June 21. There were clear skies at all four latitudes on both days.

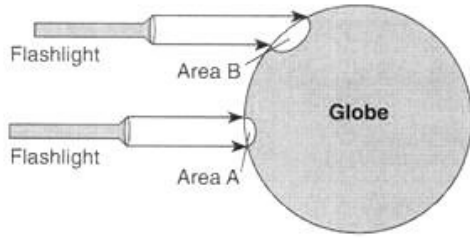
Observer	Duration of Insolation March 21	Duration of Insolation June 21
W	12 hr	0 hr
X	12 hr	12 hr
Y	12 hr	18 hr
Z	12 hr	24 hr

Which observer was located at the Equator? (1) W (2) X (3) Y (4) Z

17 At an altitude of 95 miles above Earth's surface, nearly 100% of the incoming energy from the Sun can be detected. At 55 miles above Earth's surface, most incoming x-ray radiation and some incoming ultraviolet radiation can no longer be detected. This missing radiation was most likely

- (1) absorbed in the thermosphere
- (2) absorbed in the mesosphere
- (3) reflected by the stratosphere
- (4) reflected by the troposphere

20 The diagram below shows a classroom demonstration. Two identical flashlights were placed in the positions shown and they illuminated areas of varying size, A and B, on a classroom globe. Thermometers were then placed at the center of each illuminated area to measure the rate of temperature increase. Readings were taken over a period of 30 minutes.



Students most likely observed that the temperature of area A increased at a

- (1) slower rate than the temperature of area B because area A received rays that were less concentrated
- (2) slower rate than the temperature of area B because area A received rays that were more slanted
- (3) faster rate than the temperature of area B because area A received rays that were more perpendicular to the surface
- (4) faster rate than the temperature of area B because area A received rays with less total energy

Base your answers to questions 71 through 74 on the reading passage below and on your knowledge of Earth science.

Greenhouse Effect

The warming of Earth's surface and lower atmosphere tends to intensify with an increase in atmospheric carbon dioxide. The atmosphere allows a large percentage of the visible light rays from the Sun to reach Earth's surface. Some of this energy is reradiated by Earth's surface in the form of long-wave infrared radiation. Much of this infrared radiation warms the atmosphere when it is absorbed by molecules of carbon dioxide and water vapor. A similar warming effect is produced by the glass of a greenhouse, which allows sunlight in the visible range to enter, but prevents infrared radiation from leaving the greenhouse.

The absorption of infrared radiation causes Earth's surface and the lowest layer of Earth's atmosphere to warm to a higher temperature than would otherwise be the case. Without this "greenhouse" warming, Earth's average surface temperature could be as low as -73°C. The oceans would freeze under such conditions.

Many scientists believe that modern industrialization and the burning of fossil fuels (coal, oil, and natural gas) have increased the amount of atmospheric carbon dioxide. This increase may result in an intensified greenhouse effect on Earth causing significant alterations in climate patterns in the future. Scientists estimate that average global temperatures could increase by as much as 5 °C by the middle of the 21st century.

71 The lowest layer of Earth's atmosphere has undergone a large increase in temperature due to the presence of greenhouse gases. State the name of this temperature- zone layer.

72 State a possible wavelength, in centimeters, of infrared radiation.

73 Explain why most scientists believe an increase in the greenhouse effect will cause sea levels to rise.

74 State one possible change humans could make to significantly reduce the amount of greenhouse gases added to the atmosphere each year.

6/03

3 Which of these characteristics identify an Earth surface that is likely to be the best absorber of insolation?

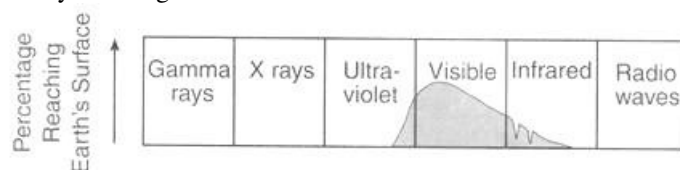
- (1) light colored and smooth
- (2) light colored and rough
- (3) dark colored and smooth
- (4) dark colored and rough

8 A gradual increase in atmospheric carbon dioxide would warm Earth's atmosphere because carbon dioxide is a

- (1) poor reflector of ultraviolet radiation
- (2) good reflector of ultraviolet radiation
- (3) poor absorber of infrared radiation
- (4) good absorber of infrared radiation

1/03

6 The diagram below shows the types of electromagnetic energy given off by the Sun. The shaded part of the diagram shows the approximate amount of each type actually reaching Earth's surface.



Which conclusion is best supported by the diagram?

- (1) All types of electromagnetic energy reach Earth's surface.
- (2) Gamma rays and x rays make up the greatest amount of electromagnetic energy reaching Earth's surface.
- (3) Visible light makes up the greatest amount of electromagnetic energy reaching Earth's surface.
- (4) Ultraviolet and infrared radiation make up the greatest amount of electromagnetic energy reaching Earth's surface.

8/02

15 Which two gases in Earth's atmosphere are believed by scientists to be greenhouse gases that are major contributors to global warming?

- (1) carbon dioxide and methane (2) oxygen and nitrogen (3) hydrogen and helium (4) ozone and chlorine

16 The average temperature at Earth's North Pole is colder than the average temperature at the Equator because the Equator

- (1) receives less ultraviolet radiation (2) receives more intense insolation (3) has more cloud cover (4) has a thicker atmosphere

6/02

10 An increase in which gas would cause the most greenhouse warming of Earth's atmosphere?

- (1) nitrogen (2) oxygen (3) carbon dioxide (4) hydrogen

13 Which characteristics of a building material would provide the most energy-absorbing exterior covering for a house?

- (1) dark colored and smooth textured (2) dark colored and rough textured
(3) light colored and smooth textured (4) light colored and rough textured

17 In which list are the forms of electromagnetic energy arranged in order from longest to shortest wavelengths?

- (1) gamma rays, x rays, ultraviolet rays, visible light (2) radio waves, infrared rays, visible light, ultraviolet rays
(3) x rays, infrared rays, blue light, gamma rays (4) infrared rays, radio waves, blue light, red light

1/02

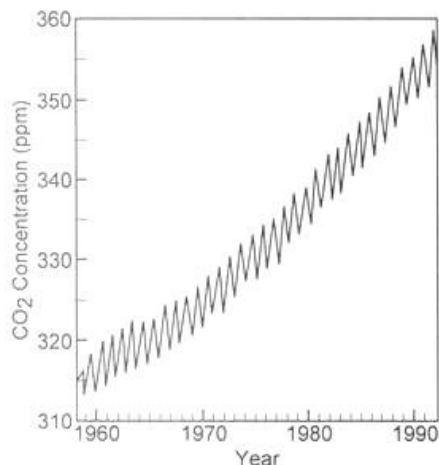
11 Energy is transferred from the Sun to Earth mainly by

- (1) molecular collisions (2) density currents (3) electromagnetic waves (4) red shifts

14 Compared to dull and rough rock surfaces, shiny and smooth rock surfaces are most likely to cause sunlight to be

- (1) reflected (2) refracted (3) scattered (4) absorbed

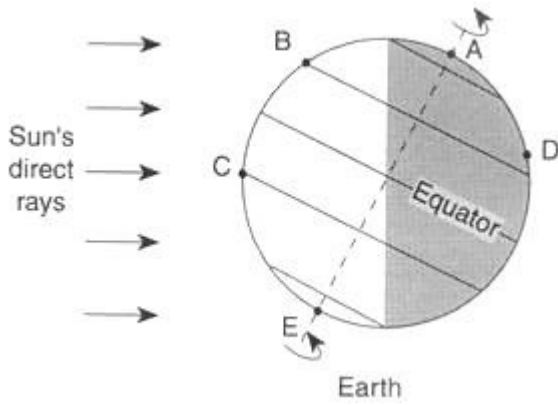
19 The graph below shows the change in carbon dioxide concentration in parts per million (ppm) in Earth's atmosphere from 1960 to 1990.



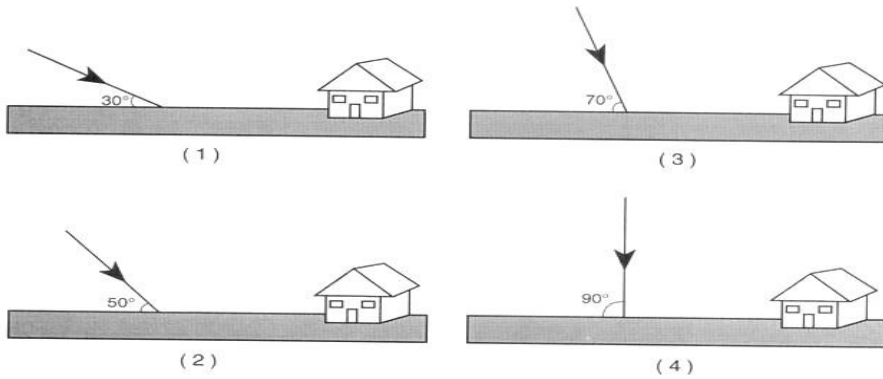
The most likely cause of the overall change in the level of carbon dioxide from 1960 to 1990 is an increase in the

- (1) number of violent storms (2) number of volcanic eruptions (3) use of nuclear power (4) use of fossil fuels

Base your answers to questions 48 through 50 on the diagram below, which shows the tilt of Earth on its axis in relation to the Sun on one particular day. Points A through E are locations on Earth's surface. Point D is located 'in New York State. The dashed line represents Earth's axis.



48 Which diagram best represents the angle of the Sun's rays received at location C at noon on this day?



49 What is the latitude of location A? (1) 0° (2) $23\frac{1}{2}^\circ$ (3) $63\frac{1}{2}^\circ$ (4) 90° N

50 On this day, which location has the greatest number of hours of daylight? (1) E (2) B (3) C (4) D

7 What is the basic difference between ultraviolet, visible, and infrared radiation?
 (1) half-life (2) temperature (3) wavelength (4) wave velocity

6/01

16 Ozone is concentrated in Earth's atmosphere at an altitude of 20 to 35 kilometers. Which atmospheric layer contains the greatest concentration of ozone? (1) mesosphere (2) thermosphere (3) troposphere (4) stratosphere

24 During which process does heat transfer occur because of density differences?
 (1) conduction (2) convection (3) radiation (4) reflection