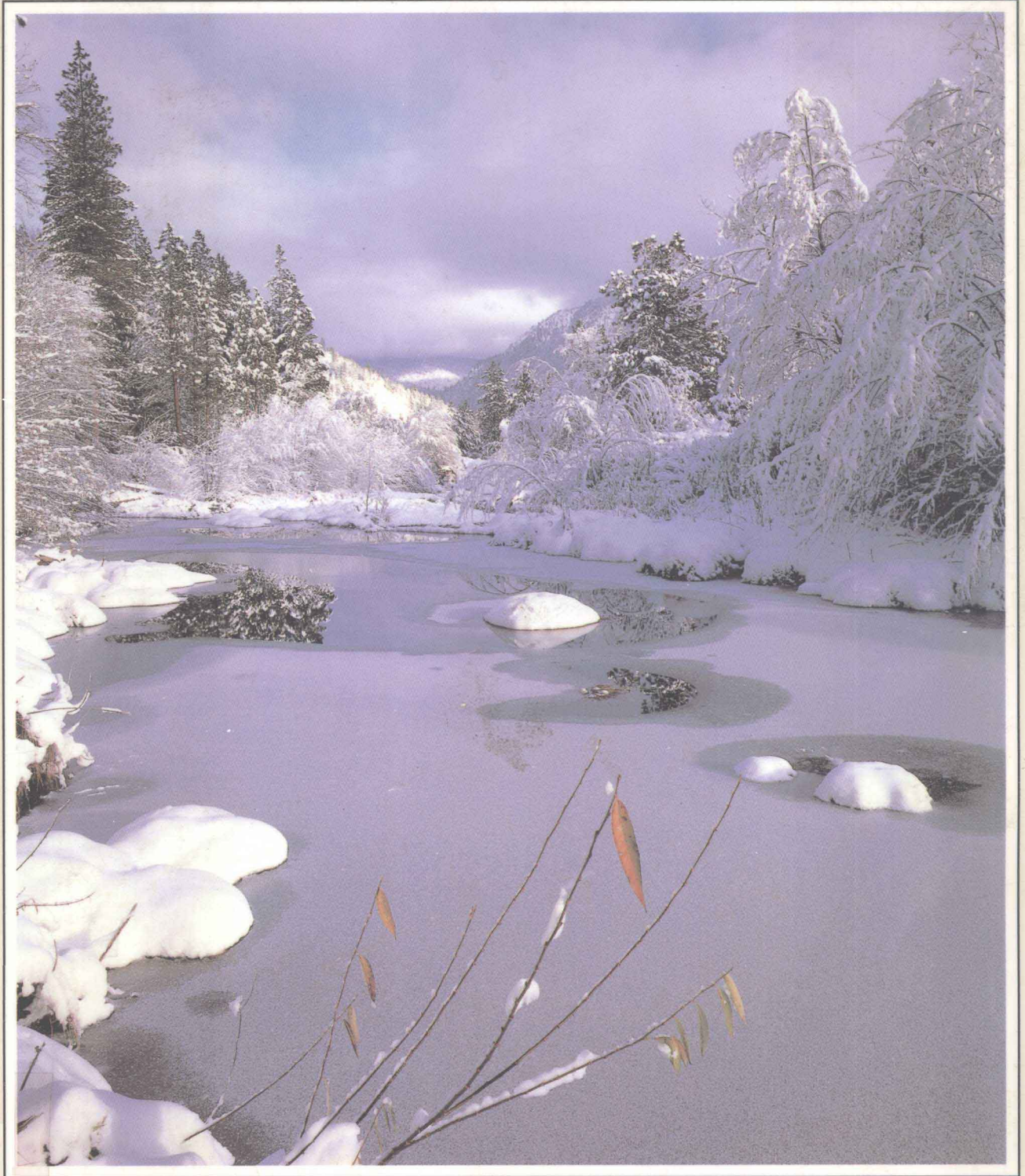


C. DONALD AHRENS



WORKBOOK/STUDY GUIDE TO ACCOMPANY

# METEOROLOGY TODAY

AN INTRODUCTION TO WEATHER, CLIMATE, AND THE ENVIRONMENT

FOURTH EDITION

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# **METEOROLOGY TODAY**

**AN INTRODUCTION TO WEATHER, CLIMATE, AND THE ENVIRONMENT**  
FOURTH EDITION

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**C. DONALD AHRENS**

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## PREFACE

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This workbook/study guide has been developed as a tool to help you learn the information in the textbook, *Meteorology Today*, 4th Edition. Meteorology is a complex subject; understanding weather and climate means mastering many new terms, concepts and ideas. It is my hope that with the aid of this workbook/study guide, learning about the weather around you will be a positive and enjoyable experience.

The workbook/study guide is organized so that each chapter begins with a brief *summary* of the information presented in the corresponding textbook chapter. This is followed by a list of the chapter's *important concepts*. Continuing through the workbook/study guide you will find *matching*, *fill-in-the-blank*, *multiple choice*, *true-false* and *problem type* questions. I feel the best way to answer these questions is to first carefully read the chapter in your textbook, then begin answering the questions in the study guide. If you find that you are having difficulty with a certain concept, return to your textbook and reread the section dealing with that particular topic. When answering the true-false questions it is important that you know why an answer is false, not just that it is. After you have finished answering the questions, turn to the end of the workbook/study guide chapter for the correct answers.

Toward the end of each chapter is a list of *additional readings*. They provide a closer look at certain issues and subjects associated with the topics covered in the chapter. Most are found in journals that are available in university and college libraries. I have also listed a few books that may be helpful.

The study of the science of meteorology is fascinating and often exciting. It is my hope that through your text, this study guide, and the information you gain in class you will come to a special appreciation of the dynamics of the atmosphere around you.

### ACKNOWLEDGMENTS

Special thanks to the many people who helped with the preparation of this workbook/study guide: To Joe Medeiros for his talented and creative illustrations; to Laurie Rydelius, Nancy Newsom and Kay Behrens for carefully reading the manuscript; to Martin Arthur for his layout and production; and to Suzy Ahrens whose input into this project has been invaluable. A special note of gratitude goes to Steve Schonebaum for his professional concern, editing, and assistance.

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## INTRODUCTION: THE EARTH AND ITS ATMOSPHERE

Chapter One is a rather brief introductory chapter that provides you with a broad overview of the earth and its atmosphere. The first part of the chapter focuses on the earth as a planet. Here we see that the earth is one of nine planets, with a unique atmosphere comprised of nitrogen and oxygen with small amounts of other gases. Then comes an overview of the earth's atmosphere. Here we get a glimpse of several topics that will be covered more completely in later chapters, such as storm systems, weather maps, and satellite photographs. Keep in mind that the material in this section is mainly introductory in nature. It is designed to familiarize you with the atmosphere and some of the processes that take place within it. The last section briefly details the many ways weather and climate influence our lives, from how we feel on a windy day to the type of clothing we should purchase for the coming season.

### Some important concepts of this chapter:

1. The atmosphere of Earth is mainly nitrogen and oxygen, while the atmospheres of its closest neighbors, Venus and Mars, are mainly carbon dioxide.
2. The earth's atmosphere contains storms of all sizes, ranging from huge middle latitude cyclonic storms that may extend for thousands of kilometers, to the much smaller tornado that is typically less than one kilometer wide.
3. The wind direction is the direction from which the wind is blowing. A north wind blows from the north.
4. In the Northern Hemisphere, at the surface the wind blows clockwise and outward around an area of high pressure, and counterclockwise and inward around an area of low pressure.
5. Weather is the condition of the atmosphere at any particular time and place. Climate is the accumulation of daily and seasonal weather events that occur over a given period of time.



## SELF-TESTS

## ■ MATCH THE FOLLOWING

- |          |  |                                   |
|----------|--|-----------------------------------|
| <u>g</u> | 1. Another name for a high pressure area   | a. hurricane                      |
| <u>j</u> | 2. The planet with a strong greenhouse effect, whose surface temperature averages 480°C (900°F)      | b. wind                           |
| <u>a</u> | 3. A storm of tropical origin with winds in excess of 64 knots (74 mi/hr)                            | c. thunderstorm                   |
| <u>i</u> | ④. An elongated region of low atmospheric pressure   | d. Earth                          |
| <u>d</u> | 5. Planet whose atmosphere is mainly nitrogen and oxygen   | e. tornado                        |
| <u>l</u> | ⑥. Another name for an extratropical cyclone   | f. gravity                        |
| <u>c</u> | 7. A towering cloud (or cluster of clouds) accompanied by thunder, lightning, and strong gusty winds | g. anticyclone                    |
| <u>c</u> | 8. A relatively small, rotating funnel that extends downward from the base of a thunderstorm         | h. meteorology                    |
| <u>a</u> | 9. The study of the atmosphere and its phenomena   | i. trough                         |
| <u>k</u> | ⑩. On a weather map, this zone marks sharp changes in temperature, humidity, and wind direction.     | j. Venus                          |
| <u>f</u> | 11. It holds a planet's atmosphere close to its surface  | k. front                          |
| <u>b</u> | 12. The horizontal movement of air   | l. middle latitude cyclonic storm |

■ **FILL IN THE BLANK**

1. The primary source of energy for the earth's atmosphere is the \_\_\_\_\_.
2. The gas primarily responsible for the greenhouse effect on Venus is \_\_\_\_\_.
3. Where cold surface air is replacing warm surface air, the boundary separating the different bodies of air is termed a \_\_\_\_\_.
4. A molecule is a combination of two or more \_\_\_\_\_.
5. An elongated region of high pressure is called a \_\_\_\_\_.
6. Where warm surface air is replacing cold surface air, the boundary separating the different bodies of air is called a \_\_\_\_\_.
7. Horizontal differences in air pressure produce \_\_\_\_\_.

■ **MULTIPLE CHOICE**

1. The largest storm in our atmosphere, in terms of actual size (diameter) is the:
  - a. thunderstorm
  - b. hurricane
  - ☒ c. middle latitude cyclonic storm
  - d. tornado
2. If you are standing north of a smoke stack and smoke from the stack is drifting over your head, the wind direction would be:
  - a. north
  - ☒ b. south
3. In the Northern Hemisphere, surface winds tend to blow this way around an area of *surface low pressure*.
  - a. clockwise and inward
  - b. clockwise and outward
  - ☒ c. counterclockwise and inward
  - d. counterclockwise and outward
4. Which of the following statements relates to weather rather than climate?
  - ☒ a. Outside it is sunny and hot.
  - b. The winters here are cold and wet.
  - c. Thunderstorms are prevalent during July.
  - d. Our lowest temperature ever, was  $-20^{\circ}\text{C}$  ( $-4^{\circ}\text{F}$ ).
  - e. The average temperature during March is  $15^{\circ}\text{C}$  ( $59^{\circ}\text{F}$ ).





5. Of these four storms, the smallest in terms of actual size (diameter) is:

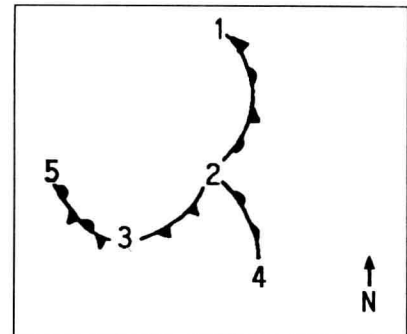
- a. thunderstorm
- b. hurricane
- c. middle latitude cyclonic storm
- d. tornado

6. Which below is *not* considered a weather element?

- a. air pressure
- b. air temperature
- c. clouds
- d. wind
- e. air density

7. In the adjacent weather map, a cold front is located between numbers \_\_\_\_\_ and \_\_\_\_\_ while a warm front is between numbers \_\_\_\_\_ and \_\_\_\_\_.

- a. 1 and 2; 2 and 4
- b. 1 and 2; 2 and 3
- c. 2 and 3; 3 and 5
- d. 2 and 3; 2 and 4
- e. 2 and 4; 1 and 2



Surface Weather Map

■ TRUE - FALSE

  T  

1. A north wind blows from the north and a south wind blows from the south.

2. The most abundant gas in the earth's atmosphere by volume is carbon dioxide.

  T  

3. In the Northern Hemisphere, surface winds tend to blow clockwise and outward around an area of high pressure.

4. Generally, weather in the middle latitudes moves from east to west.

  T  

5. Normally, large areas of high pressure tend to be accompanied by fair weather.

## ■ ADDITIONAL READINGS

“Saturn: Weather Under the Rings” by Alan Dyer, *Weatherwise*, Vol. 44, No. 3 (June 1991), p. 19.

“Venus: Weather like Hell” by Alan Dyer, *Weatherwise*, Vol. 44, No. 2 (April 1991), p. 10.

“From Gods to Satellites” by John Farrand, Jr., *Weatherwise*, Vol. 44, No. 2 (April 1991), p. 30.

“To Understand the Atmosphere” by Henry Lansford, *Weatherwise*, Vol. 38, No. 4 (August 1985), p. 184.

“Weather, Climate and You” by H. E. Landsberg, *Weatherwise*, Vol. 39, No. 5 (October 1986), p. 248.

“The Climate of Mars” by Robert M. Haberle, *Scientific American*, Vol. 254, No. 5 (May 1986), p. 54.

“Weather, Climate and the Economy” by Patrick Hughes, *Weatherwise*, Vol. 35, No. 2 (April 1982), p. 60.

**ANSWERS****■ MATCHING**

- |      |      |      |       |
|------|------|------|-------|
| 1. g | 4. i | 7. c | 10. k |
| 2. j | 5. d | 8. e | 11. f |
| 3. a | 6. l | 9. h | 12. b |

**■ FILL IN THE BLANKS**

- |                                      |               |
|--------------------------------------|---------------|
| 1. sun                               | 5. ridge      |
| 2. carbon dioxide (CO <sub>2</sub> ) | 6. warm front |
| 3. cold front                        | 7. wind       |
| 4. atoms                             |               |

**■ MULTIPLE CHOICE**

- |      |      |      |      |
|------|------|------|------|
| 1. c | 3. c | 5. d | 7. d |
| 2. b | 4. a | 6. e |      |

**■ TRUE - FALSE**

- |      |      |      |
|------|------|------|
| 1. T | 3. T | 5. T |
| 2. F | 4. F |      |

## THE EARTH'S ATMOSPHERE: ORIGIN, COMPOSITION, AND STRUCTURE

Chapter Two describes the earth's atmosphere in more detail. It begins by presenting a possible theory as to how the earth's atmosphere may have evolved. This discussion leads to the examination of the various constituents found in today's atmosphere, including the different greenhouse gases and the major atmospheric pollutants. The next section describes the different phases of water, as well as how water is transported and circulated within our atmosphere. This is followed by a section that investigates the behavior of air. Here we consider important relationships between air temperature, pressure, and density. We also examine temperature scales and learn how barometers work. The last section describes how atmospheric temperature varies with height and how this temperature profile can be divided into layers. Here we see that stratospheric ozone is being depleted by a number of complex chemical reactions and that an ozone hole has actually formed over the continent of Antarctica.

### Some important concepts of this chapter:

1. In a volume of air near the earth's surface, nitrogen occupies about 78 percent and oxygen about 21 percent.
2. The primary greenhouse gases in the earth's atmosphere include: water vapor ( $\text{H}_2\text{O}$ ), carbon dioxide ( $\text{CO}_2$ ), methane ( $\text{CH}_4$ ), nitrous oxide ( $\text{N}_2\text{O}$ ), and chlorofluorocarbons (CFCs).
3. Water is the only substance in our atmosphere that is found naturally as a liquid (water), as a gas (water vapor), and as a solid (ice).
4. The temperature of a substance is a measure of the average speed of its molecules.
5. Atmospheric pressure is a measure of the total weight of air above any point.
6. At the same temperature and at the same level, warm humid air is less dense than warm dry air.
7. Rising air expands and cools, while sinking air is compressed and warms.
8. At the same level in the atmosphere (same air pressure), a parcel of cold air will be more dense than a parcel of warm air.
9. A measured increase in air temperature with height is called an *inversion*, while the rate at which the air temperature decreases with height is called the *lapse rate*.
10. The majority of ozone in our atmosphere is found in the stratosphere, the layer above the troposphere.

## SELF TESTS

## ■ MATCH THE FOLLOWING

- |          |  |                                   |
|----------|--|-----------------------------------|
| <u>j</u> | 1. Weather element that <i>always</i> decreases with increasing height                             | <del>a.</del> temperature         |
| <u>c</u> | 2. The change of state of water vapor into a liquid  | <del>b.</del> expansion           |
| <u>b</u> | 3. The process which causes rising air to cool   | <del>c.</del> ozone               |
| <u>f</u> | 4. A barometer that contains no liquid   | <del>d.</del> altimeter           |
| <u>i</u> | 5. Instrument that measures temperature, pressure and humidity at levels above the earth's surface | <del>e.</del> condensation        |
| <u>g</u> | 6. The most abundant greenhouse gas in the earth's atmosphere                                      | <del>f.</del> troposphere         |
| <u>k</u> | 7. The unit of pressure most commonly found on a surface weather map                               | <del>g.</del> outgassing          |
| <u>e</u> | 8. Gas that strongly absorbs ultraviolet radiation in the stratosphere                             | <del>h.</del> Celsius             |
| <u>a</u> | 9. A measure of the average speed of air molecules   | <del>i.</del> radiosonde          |
| <u>n</u> | 10. A condition caused by a lack of oxygen to the brain  | <del>j.</del> pressure            |
| <u>g</u> | 11. The outpouring of gases from the earth's hot interior  | <del>k.</del> millibar            |
| <u>m</u> | 12. Greenhouse gas used as a refrigerant and as a solvent  | <del>l.</del> aneroid             |
| <u>o</u> | 13. The change of state of ice into vapor  | <del>m.</del> chlorofluorocarbons |
| <u>h</u> | 14. A temperature scale where 0° represents freezing and 100° boiling                              | <del>n.</del> hypoxia             |
| <u>f</u> | 15. Layer of the atmosphere that contains almost all the weather                                   | <del>o.</del> sublimation         |
| <u>r</u> | 16. Temperature scale that begins at absolute zero   | <del>p.</del> lapse rate          |
| <u>d</u> | 17. Instrument that measures pressure and indicates altitude                                       | <del>q.</del> water vapor         |
| <u>p</u> | 18. The average decrease in air temperature with increasing height above the surface               | <del>r.</del> Kelvin              |

**■ FILL IN THE BLANK**

1. The gas that shows the most variation from place to place and from time to time in the lower atmosphere is \_\_\_\_\_.
2. The mass of air in a given volume describes the air's \_\_\_\_\_.
3. Most of the ozone in the atmosphere is found in the atmospheric layer called the \_\_\_\_\_.
4. The circulation of water within the atmosphere is called the \_\_\_\_\_ cycle.
5. What percent does each of the following gases occupy in a volume of air near the earth's surface?  
nitrogen \_\_\_\_\_%  
oxygen \_\_\_\_\_%  
water vapor \_\_\_\_\_%  
carbon dioxide \_\_\_\_\_%
6. A recording aneroid barometer can also be called a \_\_\_\_\_.
7. Thermal (atmospheric) tides cause a daily (diurnal) rise and fall in what weather element at the earth's surface? \_\_\_\_\_
8. When chlorofluorocarbons (CFCs) are subjected to ultraviolet radiation from the sun, \_\_\_\_\_ is released, a gas which rapidly destroys ozone.
9. Energy of motion is also known as \_\_\_\_\_.
10. Most of the earth's water is believed to have originally come from \_\_\_\_\_.
11. A temperature of 300 K is equal to \_\_\_\_\_ degrees Celsius.
12. The process of water changing from a liquid to a vapor is called \_\_\_\_\_.
13. An invisible balloon-like body of air is called a \_\_\_\_\_.
14. The hottest atmospheric layer is the \_\_\_\_\_.
15. The only substance near the earth's surface that is found naturally in the atmosphere as a solid, a liquid, and a gas is \_\_\_\_\_.
16. At sea level, the average or standard value of atmospheric pressure is \_\_\_\_\_ millibars and \_\_\_\_\_ inches of mercury.



17. A measured increase in air temperature with increasing height is called an \_\_\_\_\_.
18. The \_\_\_\_\_ temperature scale sets the freezing of pure water at 32°.
19. The electrified region of the upper atmosphere is called the \_\_\_\_\_.
20. The average decrease in air temperature with increasing height in the lower atmosphere is about \_\_\_\_\_°C per 1000 meters, or \_\_\_\_\_°F per 1000 feet.
21. The atmospheric layer in which we live is called the \_\_\_\_\_.
22. The primary ingredient of photochemical smog is \_\_\_\_\_.

### ■ MULTIPLE CHOICE

1. Which below is *not* a process by which CO<sub>2</sub> enters the atmosphere?
- volcanic eruptions
  - decay of vegetation
  - evaporation
  - burning of fossil fuels
2. The process by which water changes from a vapor to a solid is called:
- evaporation
  - condensation
  - transpiration
  - deposition
3. The *primary* source of oxygen for the earth's atmosphere during the past half billion years or so appears to be:
- volcanic eruptions
  - photosynthesis
  - photodissociation
  - exhalation of animal life
  - transpiration
4. The "ozone hole" is observed in this atmospheric layer:
- thermosphere
  - mesosphere
  - troposphere
  - stratosphere
  - ionosphere

5. Air density normally:
- increases with increasing height
  - ☒ decreases with increasing height
  - remains constant with increasing height
6. In the thermosphere the temperature can exceed  $1000^{\circ}\text{C}$  ( $1800^{\circ}\text{F}$ ), yet a person's exposed hand might not "feel" hot, primarily because:
- the molecules are not moving rapidly at that elevation
  - there is no energy associated with the air molecules in the upper atmosphere
  - ☒ the air density of the atmosphere is low, so few molecules would collide with a person's hand
  - the air pressure is extremely low in the thermosphere
  - you lose all sense of feeling at those elevations
- ☒ 7. The so-called "ozone hole" is observed above:
- the continent of North America
  - the continent of Asia
  - the equator
  - the continent of Australia
  - ☒ the continent of Antarctica
8. Which below is *not* considered a greenhouse gas?
- carbon dioxide ( $\text{CO}_2$ )
  - methane ( $\text{CH}_4$ )
  - water vapor ( $\text{H}_2\text{O}$ )
  - nitrous oxide ( $\text{N}_2\text{O}$ )
  - ☒ oxygen ( $\text{O}_2$ )
9. A force exerted on a unit area describes air \_\_\_\_\_.
- density
  - temperature
  - ☒ pressure
10. As the average speed of air molecules decreases, the temperature of the air \_\_\_\_\_.
- increases
  - ☒ decreases
  - does not change

11. When the surface air pressure increases, the height of a column of mercury in a barometer will:
- also increase
  - decrease
  - show no change
12. Which of the following relationships best describes the gas law?
- pressure is proportional to density times temperature
  - temperature is proportional to density times pressure
  - density is proportional to pressure times temperature

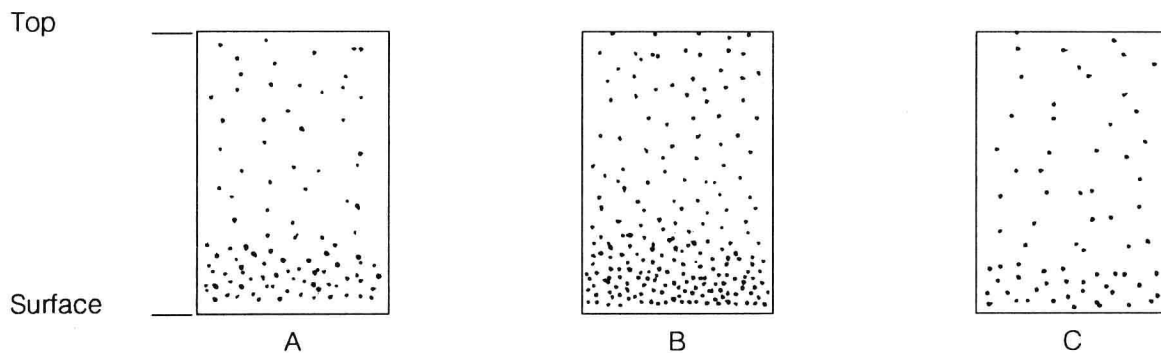


Figure 1

13. In Figure 1, if the air temperature is the same in each column, which column has the highest surface air pressure? (Each dot represents billions of air molecules.)
- column A
  - column B
  - column C

■ TRUE - FALSE

1. Over the last 100 years, the concentration of CO<sub>2</sub> in the earth's atmosphere has been increasing.
2. Chlorofluorocarbons enter the atmosphere mainly through the decay of vegetation.
3. All other factors being equal, increasing wind speed enhances evaporation.
4. A degree Fahrenheit is larger than a degree Celsius.
5. Near the earth's surface at the same temperature and level in the atmosphere, warm humid air is less dense than warm dry air.