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Uses for the Examination

- Excelsior College, the test developer, recommends granting three (3) semester hours of lower-level undergraduate credit to students who receive a letter grade of C or higher on this examination.

- Other colleges and universities also recognize this exam as a basis for granting credit or advanced standing.

- Individual institutions set their own policies for the amount of credit awarded and the minimum acceptable grade.

Exam-takers who have applied to Excelsior College should ask their academic advisor where this exam fits within their degree program.

Exam-takers not enrolled in an Excelsior College degree program should check with the institution from which they wish to receive credit to determine whether credit will be granted and/or to find out the minimum grade required for credit. Those who intend to enroll at Excelsior College should ask an admissions counselor where this exam fits within their intended degree program.

Examination Length and Scoring

The examination consists of approximately 120 questions, most of which are multiple choice; for samples of all the item types on this exam, see the sample items in the back of this guide. Some items are unscored, pretest items. The pretest items are embedded throughout the exam and are indistinguishable from the scored items. You will have two (2) hours to complete the examination. Your score will be reported as a letter grade.

UExcel Exam Resources

Excelsior College Bookstore

The Excelsior College Bookstore offers recommended textbooks and other resources to help you prepare for UExcel exams.

The bookstore is available online at: www.excelsior.edu/bookstore

UExcel Practice Exams

The official UExcel practice exams are highly recommended as part of your study plan. Once you register for your UExcel exam, you are eligible to purchase the corresponding practice exam, which can be taken using any computer with a supported Web browser. Each practice exam includes two forms that you may take within a 180-day period.

Excelsior College Library

Enrolled Excelsior College students can access millions of authoritative resources online through the Excelsior College Library. Created through our partnership with the Sheridan Libraries of The Johns Hopkins University, the library provides access to journal articles, books, websites, databases, reference services, and many other resources. Special library
Preparing for UExcel Exams

How Long Will It Take Me to Study?

A UExcel exam enables you to show that you’ve learned material comparable to one or more 15-week college-level courses. As an independent learner, you should study and review as much as you would for a college course. For a 3-credit course in a subject they don’t know, most students would be expected to study nine hours per week for 15 weeks, for a total of 135 hours.

Study Tips

Become an active user of the resource materials. Aim for understanding rather than memorization. The more active you are when you study, the more likely you will be to retain, understand, and apply the information.

The following techniques are generally considered to be active learning:

- **preview or survey** each chapter
- **highlight or underline text** you believe is important
- **write questions or comments** in the margins
- **practice re-stating content** in your own words
- **relate what you are reading** to the chapter title, section headings, and other organizing elements of the textbook
- **find ways to engage** your eyes, your ears, and your muscles, as well as your brain, in your studies
- **study with a partner or a small group** (if you are an enrolled student, search for partners on MyExcelsior Community)
- **prepare your review notes** as flashcards or create recordings that you can use while commuting or exercising

When you feel confident that you understand a content area, review what you have learned. Take a second look at the material to evaluate your understanding. If you have a study partner, the two of you can review by explaining the content to each other or writing test questions for each other to answer. Review questions from textbook chapters may be helpful for partner or individual study, as well.
Using UExcel Practice Exams

We recommend taking the first form of the practice exam when you begin studying, to see how much you already know. After taking the first practice exam, check your performance on each question and find out why your answer was right or wrong. This feedback will help you improve your knowledge of the subject and identify areas of weakness that you should address before taking the exam. Take the second form of the practice exam after you have finished studying. Analyze your results to identify the areas that you still need to review.

Although there is no guarantee, our research suggests that students who do well on the practice exams are more likely to pass the actual exam than those who do not do well (or do not take advantage of this opportunity).

About Test Preparation Services

Preparation for UExcel® exams and Excelsior College® Examinations, though based on independent study, is supported by Excelsior College with a comprehensive set of exam learning resources and services designed to help you succeed. These learning resources are prepared by Excelsior College so you can be assured that they are current and cover the content you are expected to master for the exams. These resources, and your desire to learn, are usually all that you will need to succeed.

There are test-preparation companies that will offer to help you study for our examinations. Some may imply a relationship with Excelsior College and/or make claims that their products and services are all that you need to prepare for our examinations.

Excelsior College is not affiliated with any test preparation firm and does not endorse the products or services of these companies. No test preparation vendor is authorized to provide admissions counseling or academic advising services, or to collect any payments, on behalf of Excelsior College. Excelsior College does not send authorized representatives to a student’s home nor does it review the materials provided by test preparation companies for content or compatibility with Excelsior College examinations.

To help you become a well-informed consumer, we suggest that before you make any purchase decision regarding study materials provided by organizations other than Excelsior College, you consider the points outlined on our website at www.excelsior.edu/testprep.

Preparing for This Exam

Prior Knowledge

No prior knowledge of weather and climate is assumed.

Using the Content Outline

Each content area in the outline includes (1) the recommended minimum hours of study to devote to that content area and (2) the most important sections of the recommended resources for that area. These annotations are not intended to be comprehensive. You may need to refer to other chapters in the recommended textbooks. Chapter numbers and titles may differ in other editions.

This content outline contains examples of the types of information you should study. Although these examples are numerous, do not assume that everything on the exam will come from these examples. Conversely, do not expect that every detail you study will appear on the exam. Any exam is only a broad sample of all the questions that could be asked about the subject matter.

Using the Sample Questions and Rationales

Each content guide provides sample questions to illustrate those typically found on the exam. These questions are intended to give you an idea of the level of knowledge expected and the way questions are typically phrased. The sample questions do not sample the entire content of the exam and are not intended to serve as an entire practice test.
Recommended Resources for the UExcel Exam in Weather & Climate

The study materials listed below are recommended by Excelsior College as the most appropriate resources to help you study for the examination. For information on ordering from the Excelsior College Bookstore, see page 1 of this guide. You may also find resource materials in college libraries. Public libraries may have some of the textbooks or may be able to obtain them through an interlibrary loan program.

You should allow sufficient time to obtain resources and to study before taking the exam.

Textbooks
The following textbook was used by the examination development committee to verify all questions on the exam. These study materials may be purchased from the Excelsior College Bookstore.

www.excelsior.edu/bookstore


Open Educational Resources
Many colleges and universities have free versions of their courses available through iTunes U.

Atmosphere, Ocean and Environmental Change, from Open Yale Courses

Exploring the science of climate, from The Open University

Geography 121 Weather and Climate, from the University of Wisconsin, Oshkosh

Reducing Textbook Costs
Many students know it is less expensive to buy a used textbook, and buying a previous edition is also an option. The Excelsior College bookstore includes a buyback feature and a used book marketplace, as well as the ability to rent digital versions of textbooks for as long as students need them. Students are encouraged to explore these and the many other opportunities available online to help defray textbook costs.
**General Description of the Examination**

The UExcel Weather and Climate examination is based on material typically taught in a one-semester lower-level course in weather and climate. The content of the examination corresponds to course offerings such as Weather and Climate I, Introduction to Atmospheric Science, Introduction to Weather and Climate, and Introduction to Meteorology.

The examination measures comprehension of college-level meteorology and atmospheric science skills and concepts. In particular, it measures knowledge and understanding of the following major themes: observing, analyzing, describing, and diagramming the basics of major atmospheric processes including, energy, pressure, wind, precipitation, air masses, fronts, storm systems, and basic climate and weather patterns, and understanding the physical processes and mechanisms underlying weather and climate behaviors and phenomena.

No prior knowledge of weather and climate is required before beginning study for this exam.

**Learning Outcomes**

After you have successfully worked your way through the recommended study materials, you should be able to demonstrate the following learning outcomes:

1. Observe, analyze, describe, and diagram the basics of major atmospheric processes including energy, pressure, wind, precipitation, air masses, fronts, storm systems, and basic climate and weather patterns.

2. Explain the physical processes and mechanisms underlying weather and climate behaviors and phenomena.

3. Perform basic calculations pertinent to these processes and mechanisms (energy, pressure, wind, precipitation, air masses, fronts, weather and climate patterns, and storm systems).

4. Describe and diagram how these processes and mechanisms (energy, pressure, wind, precipitation, air masses, fronts, weather and climate patterns, and storm systems) are linked in a weather and climate system.

5. Describe the impacts of weather and climate on human activity and the impacts of human activity on weather and climate.
Content Outline

The content outline describes the various areas of the test, similar to the way a syllabus outlines a course. To fully prepare requires self-direction and discipline. Study involves careful reading, reflection, and systematic review.

The major content areas on the Weather & Climate examination, the percent of the examination, and the hours to devote to each content area are listed below.

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<tr>
<th>Content Area</th>
<th>Percent of the Examination</th>
<th>Hours of Study</th>
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<td>I. Characteristics and Behaviors of the Atmosphere</td>
<td>30%</td>
<td>41</td>
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<tr>
<td>II. Hydrologic Cycle and the Atmosphere, Weather, and Climate</td>
<td>20%</td>
<td>27</td>
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<tr>
<td>III. Forms of Weather</td>
<td>20%</td>
<td>27</td>
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<tr>
<td>IV. Human Factors</td>
<td>15%</td>
<td>20</td>
</tr>
<tr>
<td>V. Climate</td>
<td>15%</td>
<td>21</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
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</table>

NOTE: Occasionally, examples will be listed for a content topic to help clarify that topic. However, the content of the examination is not limited to the specific examples given.

I. Characteristics and Behaviors of the Atmosphere

30 PERCENT OF EXAM   | 41 HOURS OF STUDY

Ch. 1, Composition and Structure of the Atmosphere
Ch. 2, Solar Radiation and the Seasons
Ch. 3, Energy Balance and Temperature
Ch. 4, Atmospheric Pressure and Wind
Appendix A, Units of Measurement and Conversions
Appendix C, Weather Map Symbols
Appendix D, Weather Extremes

A. Energy and matter

1. Definitions
   a. Weather
   b. Climate
   c. Atmosphere
2. Characteristics of the atmosphere
   a. Composition
      1) Permanent gases
      2) Variable gases
      3) Aerosols
   b. Vertical Structure
      1) Density
      2) Pressure
      3) Electrical properties
      4) Temperature
      5) Humidity
   c. Observations
      1) History
      2) Air
3) Land
4) Sea
5) Remote sensing

B. Solar radiation
1. Energy
   a. Types
      1) Kinetic
      2) Potential
2. Characteristics of radiation
   a. Intensity and wavelength
      1) Stefan-Boltzmann Law
      2) Wien’s Law
3. The solar constant
   a. The inverse square law
   b. Variations
4. Earth’s seasons
   a. Earth’s revolution and rotation
   b. Climate
5. Solar radiation transfer
   a. Absorption
   b. Reflection
   c. Scattering
      1) Rayleigh scattering
      2) Mie scattering
      3) Nonselective scattering
6. Energy transfer processes
   a. Surface-atmosphere radiation exchange
   b. Conduction
   c. Convection
      1) Free convection
      2) Forced convection
   d. Sensible heat
   e. Latent heat
   f. Advection
   g. Net radiation and global temperature
   h. Latitudinal variations
7. The greenhouse effect
   a. Climate
   b. Human interactions and responses
8. Temperature
   a. Influences on temperature
      1) Latitude
      2) Altitude and elevation
      3) Atmospheric circulation patterns
      4) Contrasts between land and water
      5) Warm and cold ocean currents
      6) Local conditions
   b. Daily and annual temperature patterns
      1) Daytime heating and nighttime cooling
      2) Effects of cloud cover and wind
   c. Measurement of temperature
   d. Temperature means and ranges
   e. Useful temperature measures
   f. Thermodynamic diagrams and vertical temperature profiles
   g. Observed patterns by seasons and climates

C. Atmospheric pressure and wind
1. Pressure
   a. The concept of pressure
      1) Dalton’s Law
   b. Vertical and horizontal changes in pressure
   c. The equation of state (ideal gas law)
   d. Measuring pressure
      1) Barometers and barometric pressure
      2) Pressure as a force
   e. The distribution of pressure
      1) Pressure gradients
a) Horizontal pressure gradient
b) Vertical pressure gradient
2) Hydrostatic equilibrium

2. Wind
a. Forces affecting the speed and direction
   1) The Coriolis effect
   2) Friction
b. Wind in the upper atmosphere
   1) Geostrophic flow
   2) Gradient flow
   3) Supergeostrophic and subgeostrophic flow
c. Near-surface winds
d. Anticyclones, cyclones, troughs, and ridges
e. Measuring wind

D. Units of measurement and conversion, weather map symbols, and observations

II. Hydrologic Cycle and the Atmosphere, Weather, and Climate

20 PERCENT OF EXAM | 27 HOURS OF STUDY

Ch. 5, Atmospheric Moisture
Ch. 6, Cloud Development and Forms
Ch. 7, Precipitation Processes

A. Atmospheric moisture
   1. The hydrologic cycle
   2. Water vapor and liquid water
      a. Evaporation and condensation
   3. Measures of water vapor content
      a. Vapor pressure
      b. Absolute humidity
      c. Specific humidity
      d. Mixing ratio
      e. Relative humidity
      f. Dew point
   4. Measuring humidity
   5. Distribution of water vapor
   6. Processes that cause saturation
   7. Saturation
      a. Processes
      b. Factors
         1) Condensation nuclei
         2) Ice nuclei
   8. Diabatic and adiabatic processes
      a. Diabatic processes
         1) Second law of thermodynamics
      b. Adiabatic processes
         1) First law of thermodynamics
         2) Adiabatic lapse rates
      c. Lapse rates
         1) Standard atmosphere
         2) Environmental lapse rate (ELR)
         3) Dry adiabatic lapse rate (DALR)
         4) Moist adiabatic lapse rate (MALR)
   9. Forms of condensation
      a. Dew
      b. Frost
      c. Fog
         1) Typology
         2) Distribution
   10. Formation and dissipation of cloud droplets
   11. High humidity and human discomfort
   12. Atmospheric moisture and climate variability

B. Cloud development and forms
   1. Mechanisms that lift air
      a. Orographic uplift
      b. Frontal lifting
      c. Convergence
      d. Localized convection
2. Static stability and the environmental lapse rate
   a. Absolutely unstable air
   b. Absolutely stable air
   c. Conditionally unstable air
   d. Static and potential instability
3. Factors influencing the environmental lapse rate (ELR)
   a. Heating or cooling of the lower atmosphere
   b. Advection of cold and warm air at different levels
   c. Advection of an air mass with a different ELR
4. Limitations on the lifting of unstable air
5. Extremely stable air: inversions
6. Cloud types
   a. High clouds
   b. Middle clouds
   c. Low clouds
   d. Clouds with vertical development
   e. Unusual clouds
7. Cloud coverage, observation, and climate
C. Precipitation process
   1. Growth and cloud droplets
      a. Growth by condensation
      b. Growth in warm clouds
         1) Collision
         2) Coalescence
      c. Growth in cool and cold clouds
         1) Bergeron process
         2) Rimming and aggregation
   2. Distribution and forms of precipitation
      a. Snow
         1) North American distribution
         2) Local/regional and climate variations
      b. Rain
   c. Graupel and hail
   d. Sleet
   e. Freezing rain
3. Measuring precipitation
   a. Rain gauges
   b. Snow measurement
4. Cloud seeding and human impacts

III. Forms of Weather

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<td>Ch. 11, Lightning, Thunder, and Tornadoes</td>
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<td>Ch. 12, Tropical Storms and Hurricanes</td>
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A. Distribution and movement of air
   1. Atmospheric circulation and pressure distributions
      a. The concept of scale and observation
      b. The single-cell model of general circulation
      c. The three-cell model of general circulation
         1) The Hadley cell
         2) The Ferrel and Polar cells
      d. Semi-permanent pressure cells
      e. The upper troposphere
         1) Westerly winds
         2) The polar front and jet streams
         3) Troughs and ridges
         4) Rossby waves
      f. The oceans
         1) Ocean currents
         2) Upwelling
      g. Major wind systems
1) Monsoons
2) Foehn, Chinook, and Santa Ana winds
3) Katabatic winds
4) Sea and land breezes
5) Valley and mountain breezes

h. Air-sea interactions in weather and climate
1) El Niño, La Niña, and the Walker circulation
2) Pacific decadal oscillation
3) Arctic oscillation and North Atlantic oscillation

2. Air masses and fronts
a. Formation of air masses
1) Source regions
2) Continental polar (cP) and continental arctic (cA) air masses
3) Maritime polar (mP) air masses
4) Continental tropical (cT) air masses
5) Maritime tropical (mT) air masses
b. Fronts
1) Cold fronts
2) Warm fronts
3) Stationary fronts
4) Occluded fronts
5) Drylines

B. Disturbances
1. Midlatitude cyclones
a. Polar front theory
b. The life cycle of a midlatitude cyclone
1) Cyclogenesis
2) Mature cyclones
3) Occlusion
4) Movement and weather conditions
5) Seasonal and climatological frequencies and characteristics
c. Processes of the middle and upper troposphere
1) Rossby waves and vorticity
d. Surface fronts and upper-level patterns
1) Cold fronts and the formation of upper-level troughs
2) Interaction of surface and upper-level conditions
e. Flow patterns and large-scale weather
1) Steering of midlatitude cyclones
2) Migration of surface cyclones relative to Rossby waves

f. Anticyclones

2. Lightning, thunder, and tornadoes
a. Processes of lightning formation
1) Charge separation
2) Runaway discharges
3) Leaders, strokes, and flashes
4) Types of lightning
5) Thunder
b. Thunderstorms: air mass, multicell, and supercell
1) Air mass thunderstorms
   a) Cumulus stage
   b) Mature stage
   c) Dissipative stage
2) Multicell and supercell storms
   a) Mesoscale convective complexes
   b) Squall line thunderstorms
   c) Supercell storms
3) Downbursts, derechos, microbursts, and haboobs
c. Geographic and temporal distribution of thunderstorms
d. Tornadoes
   1) Tornado characteristics and dimensions
   2) Tornado formation
   3) Occurrence of tornadoes
   4) Tornado damage
   5) Watches and warnings
   6) Tornado outbreaks
   7) Waterspouts
3. Tropical storms and hurricanes
   a. Hurricane characteristics
   b. Hurricane structure
      1) The eye and the eye wall
   c. Stages in hurricane formation
      1) Tropical disturbances
      2) Tropical depression and tropical storms
      3) Hurricanes
      4) Conditions for hurricane formation
   d. Hurricane movement and dissipation
      1) Hurricane paths
      2) Effect of landfall
      3) Wind
      4) Heavy rain
      5) Tornadoes
      6) Storm surges
   e. Hurricane forecasts and advisories
      1) Hurricane watches and warnings
      2) Hurricane intensity scale

IV. Human Factors

15 PERCENT OF EXAM | 20 HOURS OF STUDY

Appendix: Numerical Forecast Models, located at the end of Ch. 13, Weather Forecasting and Analysis

Ch. 14, Human Effects on the Atmosphere

A. Weather forecasting and analysis
   1. Forecasting methods
   2. Types of forecasting
   3. Assessing and verifying forecasts
   4. Data acquisition and dissemination
   5. Forecast procedures and products
      a. Phases in numerical modeling
         1) Analysis phase
         2) Prediction phase
         3) Postprocessing phase
      b. Medium-range forecasts
      c. Long-range forecasts and seasonal outlooks
   6. Weather maps and images
      a. Surface maps
      b. Upper-level maps
      c. Satellite images
      d. Radar images
      e. Thermodynamic diagrams

B. Human effects on the weather and climate
   1. Atmospheric pollutants
      a. Particles
      b. Carbon dioxide
      c. Sulfur compounds
      d. Nitrogen oxides (NOx)
      e. Volatile organic compounds (hydrocarbons)
      f. Photochemical smog
   2. Atmospheric conditions and air pollution
   3. Urban heat islands
V. Climate

15 PERCENT OF EXAM | 21 HOURS OF STUDY

Ch. 15, Earth's Climates
Ch. 16, Climate Changes: Past and Future

A. Earth's climates

1. The Koeppen system
2. Tropical climates
   a. Tropical wet (Af)
   b. Monsoonal (Am)
   c. Tropical wet and dry (Aw)
3. Dry climates
   a. Subtropical deserts (BWh)
   b. Subtropical steppe (BSh)
   c. Midlatitude deserts (BWk)
   d. Midlatitude steppe (BSk)
4. Mild midlatitude climates
   a. Mediterranean (Csa, Csb)
   b. Humid subtropical (Cfa, Cwa)
   c. Marine west coast (Cfb, Cfc)
5. Severe midlatitude climates
   a. Humid continental (Dfa, Dfb, Dwa, Dwb)
   b. Subarctic (Dfc, Dfd, Dwc, Dwd)
6. Polar climates
   a. Tundra (ET)
   b. Ice cap (EF)
7. Highland climates (H)

B. Climate variability and change

1. Defining climate change
2. Methods for determining past climates
   a. Oceanic deposits
   b. Ice cores
   c. Remnant landforms
   d. Past vegetation
3. Temporal and spatial scales of climate change
4. Past climates
   a. Warm intervals and ice ages
   b. The current ice age
   c. The last glacial maximum
   d. The Holocene
   e. The last century
5. Factors involved in climate change
   a. Variations in solar output
   b. Changes in Earth's orbit
      1) Eccentricity
      2) Obliquity
      3) Precession
   c. Changes in land configuration and surface characteristics
   d. Changes in atmospheric turbidity
      1) Tropospheric aerosols
      2) Stratospheric aerosols
   e. Changes in radiation-absorbing gases
      1) Mechanism of greenhouse warming
      2) Recent changes in greenhouse gases
   f. Feedback mechanisms
      1) Ice-albedo feedback
      2) Water-vapor and cloud feedbacks
      3) Atmosphere-ocean interactions
      4) Atmosphere-biota interactions
6. General circulation models
   a. Identifying the causes of climate change
   b. Projecting climate change
Sample Questions

The sample questions give you an idea of the level of knowledge expected in the exam and how questions are typically phrased. They are not representative of the entire content of the exam and are not intended to serve as a practice test.

Rationales for the questions can be found on pages 16–19 of this guide. In that section, the correct answer is identified and each answer is explained. The number in parentheses at the beginning of each rationale refers to the corresponding section of the content outline. For any questions you answer incorrectly, return to that section of the content outline for further study.

You will be provided with an erasable white board to use during your exam. During your exam, a basic 8-function calculator will also be available on your computer. The calculator button is in the top left hand corner of the page as each question is presented. A typical calculator is printed at the back of this content guide.

1. Which atmospheric layer contains the most mass?
   1) troposphere
   2) mesosphere
   3) stratosphere
   4) thermosphere

2. Which graph correctly shows the relationship between altitude (Km) and atmospheric pressure in a stable climate?
   1) Figure A
   2) Figure B
   3) Figure C
   4) Figure D

3. Which energy source drives Earth’s atmosphere to create weather and climate?
   1) the difference in heat energy across latitudes
   2) Earth’s geothermal energy source at its core
   3) solar radiation and its variations across latitudes
   4) electromagnetic radiation absorbed by Earth’s surface

4. Which pair of compounds or elements found in the atmosphere is most effective in the absorption of long wavelength radiation or heat energy?
   1) nitrogen and oxygen
   2) carbon dioxide and nitrogen
   3) carbon dioxide and water
   4) water and nitrogen
5. Which property of an air parcel will remain unchanged when pressure and temperature change?
   1) relative humidity
   2) density ratio
   3) mixing ratio
   4) dew point

6. What is the relative humidity of air that has a mixing ratio of 6 grams of water vapor per kilogram of dry air and a saturation mixing ratio of 8 grams of water vapor per kilogram of dry air?
   1) 20%
   2) 33%
   3) 60%
   4) 75%

7. What does the dew point measure?
   1) the temperature in a region
   2) the level of pollen in the atmosphere
   3) the amount of water in the atmosphere
   4) the temperature at which water vapor condenses

8. What process is defined by no loss or gain of heat?
   1) Bergeron process
   2) isothermal process
   3) adiabatic process
   4) Bessemer process

9. What is the most common mechanism for cloud formation in the atmosphere?
   1) upward movement of moist air
   2) mixing of moist air with cold air
   3) injection of condensation nuclei into moist air
   4) radiational cooling of moist air

10. What is the static stability of the atmosphere if the environmental lapse rate is negative?
    1) potentially stable
    2) absolutely stable
    3) conditionally unstable
    4) absolutely unstable

11. Which processes cause precipitation in the midlatitudes?
    1) convection and conduction
    2) collision and coalescence
    3) Bergeron process and drag
    4) riming and aggregation

12. In the winter, sleet and freezing rain are found along which fronts?
    1) cold fronts
    2) stationary fronts
    3) warm fronts
    4) occluded fronts

13. Which symbol is used to represent an occluded front?

   FRONTAL SYMBOLS USED ON WEATHER MAPS
   SYMBOL
   A. [Symbol]
   B. [Symbol]
   C. [Symbol]
   D. [Symbol]

   1) A
   2) B
   3) C
   4) D

14. Which way does the wind move in the center of a low pressure system in the Northern hemisphere?
    1) clockwise
    2) counterclockwise
    3) stationary
    4) vertical
15. How are primary and secondary pollutants classified?
   1) Primary pollutants are released into the air and secondary pollutants result from chemical reactions between primary pollutants and the surrounding atmosphere.
   2) Primary pollutants are similar to secondary pollutants in composition but have larger particulate matter.
   3) Natural occurrences of volcanic eruptions are considered as primary pollutants whereas secondary pollutants are manmade.
   4) Primary pollutants are found in urban areas whereas secondary pollutants are generated in rural areas from large farms.

16. Which forms of pollution affect the cardiovascular system’s ability to circulate oxygen to the rest of the body?
   1) acid deposition
   2) nitric oxides
   3) particulate matter
   4) carbon monoxide

17. Which two atmospheric pollutants, in the presence of sunlight, are responsible for producing photochemical smog?
   1) carbon dioxide and sulfur dioxide
   2) ozone and peroxyacetyl nitrate (PAN)
   3) volatile organic compounds (VOCs) and nitrogen oxides (NOx)
   4) smoke and fog

18. In the midlatitudes, when can the greatest amount of acid precipitation occur?
   1) during heavy rains
   2) during the formation of fog
   3) during springtime snow melt
   4) at any time, as acid precipitation is constant

19. What major factors contribute to the magnitude of a heat island effect?
   1) the size of the urban area
   2) the size and density of the urban area
   3) the density of the urban area
   4) the location and size of the urban area

20. What is the annual precipitation pattern of a monsoonal (Am) climate?
   1) wet all year
   2) wet summer and dry winter
   3) dry summer and wet winter
   4) wet spring and fall, dry winter and summer
SECTION FOUR

Rationales

1. (IA2a)
   *1) The troposphere is where 99.9% of the atmosphere lies.
   2) The mesosphere makes up most of the .1% of the atmosphere that remains after the troposphere is accounted for.
   3) The stratosphere is the uppermost layer of the atmosphere.
   4) The thermosphere is the hottest and least dense layer.

2. (IA2b)
   1) Figure A would not represent altitude or pressure in a stable climate. It could be similar to a weather front.
   2) Figure B is incorrect in that pressure is caused by gravitational attraction of the atmosphere to the Earth. Pressure is greater closer to the earth than 100 km above it.
   3) Figure C may look correct, but the axis labels are reversed.
   *4) Figure D is correct in labels and line function (inverse square).

3. (IB3)
   1) See 3).
   2) The convection that occurs from the heat rising from Earth’s core is believed to be the driving force for plate tectonics.
   *3) Differences in temperature cause high and low pressure areas, but the source of these differences is the Sun’s energy heating the land and oceans differently. The different rates by which these land masses absorb and reflect the sun’s energy and the rotation of the earth cause climate patterns to form and create various forms of weather.
   4) The energy emitted by the Sun is transferred to Earth as electromagnetic radiation which contributes energy for the movement of the atmosphere, growth of plants, and evaporation of water, among other things.

4. (IB5)
   1) Although nitrogen and oxygen are permanent gases in the atmosphere, they are not the most effective in absorbing heat energy.
   2) Carbon dioxide is a greenhouse gas, but nitrogen is not.
   *3) Carbon dioxide and water are considered to be two of the compounds that absorb heat energy and contribute to the greenhouse effect.
   4) Water absorbs heat energy effectively, but nitrogen is not considered to be a greenhouse gas.

*correct answer
5. (IIA3d)
1) Relative humidity increases as temperature decreases.
2) Density increases with increase in pressure and decreases with increase in temperature.
*3) Mixing ratio is a measure of air composition that does not change with variations in only pressure or only temperature.
4) Dew point changes when pressure changes, because changing pressure also changes the ambient water vapor pressure.

6. (IIA3e)
1) $8 - 6 = 2$ (x 10% to be in usual range of values). Relative humidity is a ratio, not a difference.
2) $(8/6 - 1) \times 100\% = 33\%$. The ratio is inverted and subtracting 1 is needed to get less than 100%.
3) 6 is just the value of the mixing ratio (x 10% to be in the usual range of values).
*4) $6/8 \times 100\% = 75\%$.

7. (IIA3f)
1) The average temperature in a region would be an isotherm.
2) Pollen index is the average level of pollen in the atmosphere.
3) Relative humidity is the percentage of water in the atmosphere.
*4) The average temperature at which water vapor condenses is the general definition for the term dew point.

8. (IIA8b)
1) This is a cold cloud precipitation process.
2) In this process, temperature does not change, but heat may be exchanged.
*3) An adiabatic process is a process with no heat added to or removed from a substance.
4) This is a process for making steel.

9. (IIB1)
*1) Uplift of moist air to saturation is the most common way to form clouds.
2) Mixing can form clouds but that happens less commonly than by uplift.
3) For CN injection to cause cloud formation, air would need to be very clean and already supersaturated by another mechanism. If the air is unsaturated, adding CN may form a haze, but not a cloud.
4) Radiational cooling is more common as a means of forming fog. Effects of vertical motion are more important to cloud formation in the atmosphere.

10. (IIB2b)
1) This is not a classification of static stability, but is similar in wording to potential instability (convective instability) which is another type of stability.
*2 Negative lapse rate means temperature increases with altitude (an inversion).
3) This applies to a lapse rate between the dry and saturated adiabatic lapse rate (both positive values).
4) This applies to a lapse rate greater than the dry adiabatic lapse rate of 10 K/km.

11. (IIC1b)
1) Convection and conduction processes are related to energy transfer.
*2) Collision and coalescence are defined as the main processes for which raindrops form in clouds.
3) The Bergeron process is associated with cold cloud fronts and drag is the resistance that air exerts on water as it falls.
4) Rimming and aggregation processes are associated with cold cloud formation.

*correct answer
12. (IIIA2d)
1) Cold fronts can produce precipitation in the form of rain and snow, but the structure of the front where the colder air is below the warm air does not set conditions for sleet or freezing rain.
2) Stable fronts do not produce precipitation.
3) Warm fronts position a warm layer of air below the colder, more dense air above. This causes precipitation (ice) to melt and then partially freeze on its way to earth.
4) Occluded fronts cause clouds, but not freezing rain.

13. (IIIA2b)
1) Figure A represents a warm front.
2) Figure B represents a cold front.
3) Figure C represents a stationary front.
4) Figure D represents an occluded front.

14. (IIIB1e)
1) Low pressure regions produce counterclockwise movement of the wind.
2) Low pressure regions produce counterclockwise movement of the wind.
3) Cold and warm fronts by nature have horizontal and vertical wind associated with them.
4) Although fronts can have vertical air movement, low pressure areas produce a counterclockwise motion.

15. (IVB1)
1) Primary and secondary pollutants are defined by this statement.
2) Although particles can be found in primary pollutants and can be classified by size, this may or may not interact with other pollutants to produce secondary pollutants.
3) Volcanic eruptions do produce primary pollutants that can react with other substances in the atmosphere to produce secondary pollutants. Primary pollutants are occur both naturally and by human causes.
4) Pollutants, whether primary or secondary, are not limited to any one population center. Both urban and farm areas produce primary and secondary pollutants.

16. (IVB1)
1) With acid deposition, breathing may become irritated, but this does not primarily affect the body's ability to circulate oxygen.
2) Nitric oxides will produce acid precipitation and can interact to produce secondary pollutants, but these do not primarily affect the cardiovascular system.
3) Particulate matter can be an irritant and can cause health problems, but it is not directly related to the cardiovascular system or the body's ability to circulate oxygen.
4) CO attaches to the iron molecule of red blood cells and stops the body from releasing the carbon dioxide molecules contained in the cells. Without the transfer of carbon dioxide from the cells so it can receive the oxygen molecule, death can happen.

17. (IVB1e)
1) Carbon dioxide does not contribute to smog and sulfur dioxide is a pollutant that causes classical, not photochemical, smog.
2) Ozone and PAN are products of the photochemical reactions.
3) The oxidation of VOCs in the presence of NOx and sunlight produces the components of photochemical smog.
4) The term smog derives from combining smoke + fog, but this refers to classical (London or sulfurous) smog. The word smog was later applied to describe the poor air quality in Los Angeles, even though the cause of the “smog” was quite different.
18. (IVB2)
1) Acid precipitation is found in rainfall, but can vary greatly by region and wind patterns.
2) Fog can be a source of acid precipitation, but tends to be a temporary condition and may have little effect in the region.
*3) During the spring when the snow accumulated during winter melts and enters the streams, lakes, and rivers, it causes a large spike in acid concentrations. Over the winter months acid precipitation accumulates in snowbound regions and the overall concentration of acid occurs. The sudden melting releases larger amounts of stored acid in the snow.
4) See 3).

19. (IVB3)
1) The size of the urban area is a partial answer. Population density is also an important factor contributing to the magnitude of a heat island.
*2) The size of the city and population density determine the amount of heat retained, based on structures, concrete, the number of people, and how they consume energy and release it into the atmosphere.
3) Population density is a partial answer. The size of the urban area is also an important factor.
4) Location is one factor, but population density and size contribute more to the magnitude of a heat island effect.

20. (VA2b)
1) This would be typical of a humid continental climate.
*2) Monsoonal circulation produces moist on-shore flow in summer and dry off-shore flow during winter.
3) This is a reversed pattern from monsoonal circulation.
4) The monsoonal dry/wet precipitation cycle is annual, not semiannual.
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Weather & Climate Exam
Development Committee

Thomas R. Morin, MEd
(Plymouth State University)
Atmospheric Science and Chemistry, Plymouth State
University, retired

Paul J. Croft, PhD
(Rutgers University, Meteorology and Horticulture)
Earth Science (Meteorology) Program, School of
Environmental & Life Sciences, Kean University;
Meteorologist

Robert G. Keesee, PhD
(University of Colorado, Physical Chemistry)
Atmospheric and Environmental Sciences, University
at Albany (SUNY)