associated with cold fronts are narrow with showers, and in extreme cases are associated with severe weather. Lifting along the warm front is more gradual, thus clouds tend to be more horizontal in development and are known as stratiform type, e.g. nimbostratus, altostratus, etc. This lifting is sometimes referred to as **over-running**, where warmer air overruns the cooler air that is at the surface. Generally this type of lifting results in an expansive shield of clouds and precipitation extending well ahead of the warm front. It is typical to see cloud characteristics of an approaching warm front 24-48 hours before arrival, while the narrower cold front clouds frequently become apparent only a few hours or less before arrival.

Because air mass characteristics usually are quite different across a strong front, many criteria are used to locate the position of potential weather fronts on a weather map. Some of these indicators are: (1) **marked shifts in wind direction**, (2) **sharp temperature changes over a relatively short distance**, (3) **distinct changes in dew point temperatures**, (4) **changes in surface pressure**, (5) **presence of clouds and precipitation**. A front may be associated with all or some of the criteria above.

Air mass motion, thus frontal motion, is strongly influenced by large-scale surface high and low pressure regions that extend over many states. These pressure systems are related to atmospheric winds aloft. Where air aloft is forced toward the surface, a **high pressure** system results with surface circulation that is **clockwise** in the northern hemisphere. The centers of these regions are denoted by a large H on the surface weather map. If the movement of winds aloft are such that air is lifted away from the surface, a **low pressure** system results with a surface circulation that is **counter-clockwise** in the northern hemisphere. (For locations in the southern hemisphere, the circulations are reversed.) The centers of these low pressure systems are denoted by a large L on the surface weather map. As these high and low pressure systems move eastward across the country, their circulation patterns cause warm, moist air to move northward, while at the same time, cause cold, drier air to move southward. This sets the stage for the clash of air masses that results in frontal development. The drawing below shows an ideal mid-latitude low pressure system along the northeast coast, with its associated fronts.

Frequently the warm and cold front meet at the center of the low pressure system. For most locations in the United States, the cold front ushers in cP air that will move southeastward, replacing mT air moving northeastward behind the warm front. The scalloped lines indicate the cloud/precipitation shield commonly associated with these fronts.

(Notice the difference in comparative extent of the cloud shield for the different fronts.) Regions influenced by high pressure are usually characterized by fair weather and are rarely associated with any significant fronts.

Because the results of severe weather can be so devastating, it is important for meteorologists to identify air masses and track their motion. The analysis of weather satellite photography has been of immense importance in this endeavor. Weather generated along fronts can greatly affect our daily lives. Heavy snow or rain can delay travel while severe weather can cause property damage and loss of life. Even such minor concerns as knowing if one should water the lawn or if an umbrella is needed are all influenced by air masses and their associated weather fronts. Many of us may have vivid memories of devastating floods, the blizzard we were caught in, the tragedy of a tornado experience, the graduation that was rained out, or the fabulous weather that accompanied the vacation trip. These memories may be bitter or sweet, but the effects of air masses and weather fronts will always be a part of our lives.

**QUESTIONS:**

1. Complete the following parts a - d of this question based on air mass characteristics.

   a. For vertical mixing and radiative exchange to produce some measure of equilibrium between the surface and the overlying air mass, the air mass must remain over its **source** region for **several** days.

   b. Based on **moisture characteristics only**, the two possible types of air masses are (name and letter):

   \[C(\text{continental}) \quad m(\text{maritime})\]

   c. Based on **temperature characteristics only**, the four possible types of air masses are (name and letter):

   \[P(\text{Polar}) \quad T(\text{Tropical}) \quad E(\text{Equatorial}) \quad P(\text{Polar})\]

   d. Using the appropriate two letter code, the most **unstable** air masses would be designated as **mT** while the most **stable** air masses would be designated as **cP**.

2. For the following parts, a - h, you may need to consult an atlas. Each region refers to a possible source region. Indicate the most likely two letter code for air masses developing over the indicated regions. Remember, you will need to consider if the region is a high or low latitude land or ocean environment when determining your answer.
a. Antarctica  [CA]
b. North Africa  [CT]
c. Equatorial Pacific Ocean  [mE]
d. Central Australia  [CT]
e. Northern Canada (winter)  [CA/cP]
f. Central Atlantic (between Africa and South America)  [mT]
g. Ocean between Antarctica and Southern Africa  [mp]
h. Arctic Ocean  [mp/cA (ice)]

3. The sketch below shows the various directions from which air masses may influence the United Kingdom. Complete parts a and b of this question.

a. Write the names of the countries, in their locations, on the sketch. United Kingdom, Ireland, Iceland, Norway, Sweden, Finland, Denmark, Spain, France, Italy and Germany.

b. At the beginning of each arrow indicate the most likely two letter air mass code. If more than one type of air mass is likely, indicate in which season it is most likely to occur.

4. The sketch at the top of the next column shows a strong high pressure system centered over the central United States during the early spring. Complete parts a - c of this question.

a. Indicate the average large scale air flow pattern (winds) around this system, by marking the wind flow with arrows on this sketch.

b. The location of regions A and B are shown on this sketch. Based on the large scale influence of the winds associated with this high pressure system, indicate the most likely air mass influencing each region using the two letter code. Region A  [CP]  Region B  [mP/c1]. Explain your reasoning.

Assuming this high pressure system moves eastward and its center is well off the east coast in 4 days, write a simplified general regional weather forecast for region A over the next 5 days, emphasizing the expected temperature/moisture changes.

Days 1-2: cool, dry, nw winds
Days 4-5: warm, humid, se winds

5. The station model is a circle where weather observations are indicated in coded form for a particular reporting station. Analyzing the weather data provided by numerous stations allows one to detect potential fronts, air mass characteristics and movement, and the general state of the atmosphere. The information provided by the station model is the basis for the generation of surface weather maps with the typical high and low pressure systems we have come to recognize. Although the actual station circle data bank of information can be quite sophisticated, we will consider a far simpler version for this question. The station circle in this investigation will only include information on current surface temperature, dew point temperature, surface winds and percentage of cloud cover. Complete parts a - d of this question.
a. Measuring wind speed and direction provides information on the movement of air masses in the region. The direction of the wind is indicated by the "wind pole". The "wind pole" projects from the edge of the station circle and points in the direction the wind is **coming from**, as shown in the example below. Four station circles (1 - 4) with wind poles are shown. Below each indicate the compass direction of the winds at each station.

```
NW
W
SW
S
NE
E
```

b. Attached to the "top" of the wind pole and pointing in a clockwise direction around the station circle are "wind barbs". Wind barbs indicate the wind speed as shown in the example below. Together the wind pole and wind barbs comprise the "wind flag". Four station circles (1 - 4) with wind flags are shown. Below each indicate the wind direction and wind speed for each station.

**EXAMPLES (Wind Speed in knots)**

<table>
<thead>
<tr>
<th>1-2</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
</tr>
</thead>
<tbody>
<tr>
<td>(3-7)</td>
<td>(8-12)</td>
<td>(13-17)</td>
<td>(18-22)</td>
<td>(23-27)</td>
<td></td>
</tr>
</tbody>
</table>

```
NE 20kt NE 10kt SW 15kt NW 15kt
```

c. The number at the upper left of the surface station circle is the surface air temperature, usually given in °F (United States). The number at the lower left is the dew point temperature in °F, and is a measure of the water vapor content of the air. High dew point temperatures mean high water vapor content. Four station circles (1 - 4) are shown at the top of the next column. Decode the first two station circles and list the temperature and dew point below each station circle. Listed below the last two station circles are the current conditions. Complete these last two station circles based on this data.

```
1
18

2
-2
```

<table>
<thead>
<tr>
<th>Air Temp.</th>
<th>Dew Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>82°F</td>
<td>68°F</td>
</tr>
<tr>
<td>18°F</td>
<td>-2°F</td>
</tr>
</tbody>
</table>

```
3

4
```

<table>
<thead>
<tr>
<th>Air Temp.</th>
<th>Dew Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>51°F</td>
<td>48°F</td>
</tr>
<tr>
<td>65°F</td>
<td>37°F</td>
</tr>
</tbody>
</table>

```
Dew Point: 48°F
Air Temp.: 51°F
```

```
Dew Point: 37°F
Air Temp.: 65°F
```

d. The percentage of cloud cover, in simplified coded form, is shown by the examples below. Based on this, completely decode the first four station circles and write the information below the respective station circle. For the remaining two, complete each station circle using the current associated weather conditions.

**EXAMPLES (% Cloud Cover)**

<table>
<thead>
<tr>
<th>CLEAR</th>
<th>25% (20-30%)</th>
<th>50% (40-60%)</th>
<th>75% (70-80%)</th>
<th>100% (90-100%)</th>
</tr>
</thead>
</table>

```
1
2
3
4
```

T°: 44°F 58°F 84°F 78°F 10°F
T°: 20°F 52°F 7° 62°F
Wind NW 10kt M 50kt NE 5kt
Sky: CLEAR 100% SC 60% 25%

```
1
2
3
4
```

Winds: West at 4 kt NE at 16 kt
Cloud Cover: 22% 60%
Temp.: 53°F 49°F
Dew Point: 36°F 44°F

6. On the sketches a - c at the top of the next page, indicate the most likely location of a surface front based on the **single weather characteristic** (air temperature, dew point temperature or wind) indicated with the station circles in each sketch. Draw a solid line indicating the likely location of a surface front. **DO NOT** attempt to determine the type of front.
7. Sketches A and B below show northern hemisphere station circles for the same region, several hours apart. The existing weather conditions at each reporting station, for the given time, is indicated. Note that the three digit number located to the upper right of the station model represents the surface pressure in coded form. **DO NOT consider these values in determining frontal location for this question.** Complete parts a - f of this question.

a. For each sketch draw in light pencil, the probable location of a surface front.

b. Draw an arrow across the center of the front, for each time, indicating its probable direction of movement.

c. This front is a (warm, cold) front. Explain.

d. Appropriately color-code the front in both sketches.

e. Based on the associated distance scale and time indicated, calculate the approximate speed of this front in miles per hour and indicate its compass direction of movement. (Recall: Speed = Distance/Time)

   Speed 30 mph. Direction East

   (20 - 40 mph is acceptable)

f. The station circle below is the eastern most station circle on sketch B above. Indicate what the likely predicted weather conditions for this station will be at 4 p.m. **tomorrow**, by appropriately completing the station circle. Encode this station circle for predicted sky conditions, air temperature, dew point temperature and wind speed/direction.

   ![Station Circle Diagram]

FOR QUESTIONS 8 - 10 USE THE INSERT PROVIDED.

8. Figure B (insert) shows a typical weather system and its associated fronts. Station model information is provided at various locations. Use this information to answer problems a - h.

a. Which air mass is most likely dominating the weather in South Dakota? Explain.
b. Where is the likely **source region** for this air mass? **Canada**

c. Which air mass is most likely dominating the weather in Illinois? Explain.
   **Southerly winds**

d. Where is the likely **source region** for this air mass?
   **Gulf of Mexico**

e. Draw a large blue arrow indicating the movement of the colder air mass.

f. Draw a large red arrow indicating the movement of the warmer air mass.

g. Assuming this weather system is moving NE, circle the change expected in temperature, dew point temperature, and wind direction in central Missouri after frontal passage.
   
   Temperature: (Increase/Decrease)
   Dew point temperature: (Increase/Decrease)
   Wind shift from **SW** to **NW**

h. Circle the change expected in temperature, dew point temperature, and wind direction in northern Michigan after frontal passage.
   
   Temperature: (Increase/Decrease)
   Dew point temperature: (Increase/Decrease)
   Wind shift from **E** to **S**

**9.** Figure D (insert) shows a map of the United States with official weather observation stations denoted by a three letter code, e.g. Boston, MA (BOS). To determine frontal locations on a weather map, extensive data is collected at many observation stations and plotted around the station identifier circle. For this question, the station circles will reflect more limited data than is actually used by the National Weather Service in generating surface weather maps. Using the data provided below, complete parts a - h.

   Where: T - temperature (°F)
   TD - dew point temperature (°F)
   WD - wind direction
   WS - wind speed (knots)

<table>
<thead>
<tr>
<th>STATION</th>
<th>T</th>
<th>TD</th>
<th>WD</th>
<th>WS</th>
<th>STATION</th>
<th>T</th>
<th>TD</th>
<th>WD</th>
<th>WS</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOS</td>
<td>53</td>
<td>50</td>
<td>E</td>
<td>20</td>
<td>BUF</td>
<td>50</td>
<td>48</td>
<td>E</td>
<td>15</td>
</tr>
<tr>
<td>NYC</td>
<td>55</td>
<td>50</td>
<td>E</td>
<td>15</td>
<td>PHL</td>
<td>55</td>
<td>55</td>
<td>E</td>
<td>20</td>
</tr>
<tr>
<td>DCA</td>
<td>60</td>
<td>60</td>
<td>E</td>
<td>20</td>
<td>PTV</td>
<td>59</td>
<td>56</td>
<td>E</td>
<td>15</td>
</tr>
<tr>
<td>CMH</td>
<td>59</td>
<td>55</td>
<td>NE</td>
<td>15</td>
<td>ROA</td>
<td>83</td>
<td>70</td>
<td>SW</td>
<td>10</td>
</tr>
<tr>
<td>CLT</td>
<td>86</td>
<td>71</td>
<td>SW</td>
<td>10</td>
<td>ATL</td>
<td>90</td>
<td>73</td>
<td>SW</td>
<td>5</td>
</tr>
<tr>
<td>LOU</td>
<td>85</td>
<td>71</td>
<td>S</td>
<td>10</td>
<td>BNA</td>
<td>87</td>
<td>72</td>
<td>S</td>
<td>5</td>
</tr>
<tr>
<td>BHM</td>
<td>92</td>
<td>73</td>
<td>SW</td>
<td>10</td>
<td>JAN</td>
<td>92</td>
<td>73</td>
<td>SW</td>
<td>10</td>
</tr>
<tr>
<td>LIT</td>
<td>88</td>
<td>72</td>
<td>S</td>
<td>15</td>
<td>STL</td>
<td>83</td>
<td>69</td>
<td>SE</td>
<td>10</td>
</tr>
<tr>
<td>IND</td>
<td>53</td>
<td>52</td>
<td>E</td>
<td>10</td>
<td>ORD</td>
<td>50</td>
<td>50</td>
<td>E</td>
<td>20</td>
</tr>
<tr>
<td>DSM</td>
<td>49</td>
<td>42</td>
<td>NE</td>
<td>20</td>
<td>OMA</td>
<td>45</td>
<td>39</td>
<td>N</td>
<td>20</td>
</tr>
<tr>
<td>MCI</td>
<td>50</td>
<td>45</td>
<td>NW</td>
<td>25</td>
<td>DEN</td>
<td>49</td>
<td>35</td>
<td>NW</td>
<td>15</td>
</tr>
<tr>
<td>DDC</td>
<td>49</td>
<td>35</td>
<td>NW</td>
<td>25</td>
<td>FTW</td>
<td>59</td>
<td>39</td>
<td>W</td>
<td>15</td>
</tr>
<tr>
<td>SAT</td>
<td>62</td>
<td>42</td>
<td>W</td>
<td>10</td>
<td>ABQ</td>
<td>53</td>
<td>32</td>
<td>NW</td>
<td>10</td>
</tr>
</tbody>
</table>

i. On Figure D (insert), plot the data for each location on its station circle. You may need to make the circles somewhat larger in each case.

b. Place a large red "L" in the center of Missouri. This denotes the location of the low pressure center.

c. Locate the cold front and, using the correct designation, mark it in **blue**.

d. Locate the warm front and, using the correct designation, mark it in **red**.

e. Draw a large red arrow indicating the average motion of the warm air and a large blue arrow indicating the average motion of the cold air.

f. Outline broad regions on this map where eP, mP, and mT air appear to be dominating the weather, and write the appropriate two letter code inside each outlined region.

g. Would Little Rock, AR (LIT) experience steady rain or thundershowers? Explain.
   **T-showers, cold fronts produce cumulonimbus clouds**

h. Would Washington, D.C. (DCA) experience steady rain or thundershowers? Explain.
   **Rain, warm fronts produce nimbostratus clouds**

**10.** Figure C (insert) shows a satellite image of a well developed storm system as indicated by the classic comma-shape cloud arrangement. Use this figure to answer question a - f.

a. Assume the low pressure center is over Lake Huron. Mark it with a large red "L".

b. Draw the likely position of a cold front (blue) and the likely position of a warm front (red) on the satellite picture.

c. Which general types of clouds are along the cold front? Explain.

d. Which general types of clouds are along the warm front? Explain.

e. Shade in yellow the regions where light to moderate steady rain might be falling.

f. Shade in green the regions where heavier showers and thunderstorms may be occurring.

**11.** Fronts separate air masses of distinct characteristics, therefore after frontal passage, there
can be significant changes in the weather such as temperature, dew point temperature, wind direction, etc. For the following problems, assume that the fronts are strong, that is there will be dramatic weather changes. Also, assume that cP air will be ushered into the region by the cold front, while mT air will be ushered into the region by the warm front. Complete parts a - d.

Where: T — temperature
TD — dew point temperature
WD — wind direction
PT — pressure tendency
WX — current weather
SH — showers
SP — steady precipitation
* — normally clear

a. Circle the correct choices in the table below.

<table>
<thead>
<tr>
<th></th>
<th>BEFORE COLD FRONT</th>
<th>AFTER COLD FRONT</th>
<th>BEFORE WARM FRONT</th>
<th>AFTER WARM FRONT</th>
</tr>
</thead>
<tbody>
<tr>
<td>T:</td>
<td>warm, cold</td>
<td>warm, cold</td>
<td>warm, cold</td>
<td>warm, cold</td>
</tr>
<tr>
<td>TD:</td>
<td>high, low</td>
<td>high, low</td>
<td>high, low</td>
<td>high, low</td>
</tr>
<tr>
<td>WD:</td>
<td>NW, SW</td>
<td>NW, SW</td>
<td>ESE, ESE</td>
<td></td>
</tr>
<tr>
<td>PT:</td>
<td>rise, fall</td>
<td>rise, fall</td>
<td>rise, fall</td>
<td>rise, fall</td>
</tr>
<tr>
<td>WX:</td>
<td>SH, SP</td>
<td>*</td>
<td>SH, SP</td>
<td>*</td>
</tr>
</tbody>
</table>

b. It can be generalized that the wind across a cold front changes from **NW** to **NE**, and winds across a warm front change from **E** to **SE**.

c. Pressure always **falls** as a weather front approaches.

d. After a frontal passage, the weather normally **improves**.

12. There are other smaller-scale fronts that may cause significant weather such as sea-breeze fronts and dry-line circumstances. A sea-breeze front, usually occurring in the late afternoon, is very similar to a cold front and is denoted by the same frontal symbol. Cooler ocean air flows inland and lifts the warm air that is over land. Sea-breeze fronts, common in Florida, can usually be located by noticing a drop in temperature along the coastline. The dry-line, common in Texas and Oklahoma, is a boundary separating cT air originating in Mexico from mT air moving inland from the Gulf of Mexico. The dry-line, denoted by a dashed line, is usually located by analyzing dew points and orienting the front along the 55°F dewpoint isoline. The isoline must connect points of equal value. Use the following maps of Florida and Texas to complete parts a - f.

a. On the map of Florida draw the sea-breeze front and mark it in **blue**.

b. Shade in **green** a region where thunderstorms may be located.

c. Sea-breeze fronts don’t occur at night. Explain?

   **not enough warm air to cause rising air above land and is cooling off.**

d. On the map of Texas label a region of cT air and label a region of mT air.

e. Mark the dry-line, which is the 55°F dew point isoline, with a dashed **black** line. (The dry-line is usually located in a position where it separates air with dew points $< 55^\circ F$ to the west and dew points $> 55^\circ F$ to the east.)

f. Which side of the dry-line front will thunderstorms be present? Explain.

   **EAST: WARM, HUMID AIR RISES TO FORM T-STORMS.**