UNITED STATES MARINE CORPS

LESSON PLAN

VECTORS

INTRODUCTION:

1. Gain Attention. There is a C-12 aircraft on descent about to lad at your air station; the pilot is calling your metro frequency, requesting the current crosswind component. What do you do?

2. Overview. This period of instruction provides a fundamental understanding of vectors and vectors operations. It also relates vector operations to daily meteorological operations.

3. Introduce Learning Objectives.

a. Terminal Learning Objective. With the aid of references, explain the difference between scalar and vector quantities, how to compute vector operations with the given formulas and how to use the resultant meteorologically.

b. Enabling Learning Objective(s). Without the aid of references, complete the following:

(1) Briefly describe scalar and vector quantities and give examples.

(2) Briefly describe the different vector operations:

(a) Vector addition and its meteorological uses.

(b) Vector subtraction and its meteorological uses.

(3) Determine vector components graphically.

(4) Briefly describe the common terms used in vector components.

4. Method/Media. This period of instruction will be taught using the lecture method with aid of QMMCBT-001 “Introduction to the Dynamics of the Atmosphere”.

5. Evaluation. You will be evaluated on how to use vector operations and given scenarios and expected to determine the type of vector operation necessary and how to compute the correct answer.

TRANSITION. There are many occasions when we find ourselves using vectors without even knowing it, such as setting crosswind advisories, determing vertical turbulence, and wind shear conditions. Vector addition and subtraction are the stepping-stones to vector computation.

BODY:

1. Scalar and Vector Quantities.

a. A "quantity" is something that one can measure. When measuring an object to determine its weight or distance to a location, the quantity that is represented are numbers such as 35 or 55 that are followed by a unit. For example, 35 pounds (lbs), would describe how much something weighs, 55 miles (mi) would describe how far it is to the airport, these are all quantities that have only size. A quantity that has only size or magnitude (no direction) is defined as a scalar quantity. Your weight is a scalar quantity.

"What is my Max?"

Figure 1 - Scalar quantity.

b. Some quantities have both speed and direction, such as velocity. *Velocity* is defined as a change in position expressed in terms of speed and direction. Any quantity that has both magnitude and direction is a *vector quantity*. In weather vectors can be represented graphically or mathematically.

c. On a surface Metar observation, a vector represents the winds. It gives both direction and magnitude, in this case it is 030 degrees and at 12 knots.

METAR KNYG 141555Z 03012KT 5SM -RA BR SCT003 BKN005 OVC008 02/00 A2992 RMK SLP134 P0010 T00220000

Figure 2 – Example of vector quantity.

(1) Representing vectors (2-dimensions).

a. Mathematically. Vectors are represented mathematically as 27008KT, where 270 is the direction towards travel, and 08 is the rate of travel.

b. Graphically. Arrows represent vectors. The length of the arrow represents the magnitude and the orientation of the arrow indicates the direction. It is plotted on a coordinate system to insure all vectors are represented in the same scale and correct orientation.

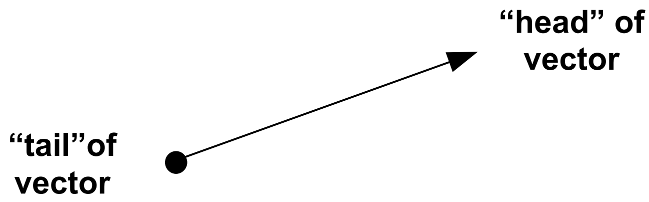

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Figure 3 - Anatomy of a vector.

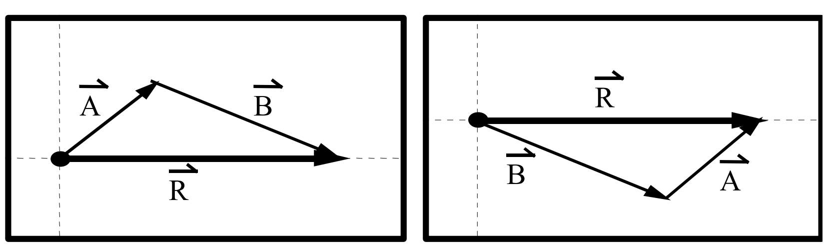
c. Axis. An axis is one of two perpendicular lines used to define the coordinate system. For our examples, one axis runs west to east and the other south to north. Vectors are plotted toward the direction given based on compass directions.

d. Origin . The intersection of the two axes. The end point of the vector is plotted at the origin. ***NOTE:*** When representing vectors numerically, the magnitude and the direction are explicitly stated. (i.e., the car is moving toward 360° at 70 mph.)

TRANSITION. Now that you have a background on vectors and that different types, we will learn exactly why they are so crucial to meteorologists. In this section we will cover the meteorological uses and how to perform vector addition as well as subtraction.

2. Vector operations.

a. Vector addition. The sum of two vectors, A and B, is a vector R that is obtained by placing the initial point of B on the final point of A, and then drawing a line from the initial point of A to the final point of B, as illustrated in Figure 4.



$\vec{A} + \vec{B} = \vec{R}$ $\vec{B} + \vec{A} = \vec{R}$

Figure 4 - *Vector addition.*

(1) Graphical method "Head to tail method".

Step 1. Construct x, y coordinate system.

Step 2. Select a scale & plot vector "**A**" to scale.

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Step 3. Plot vector **"B"** to scale, with proper orientation using another coordinate system on the head of vector **"A"**.

Step 4. Draw resultant vector **"R"** from origin of **"A"** to the head of last vector being added **"B"**.

Note: The order of addition makes no difference:
(Ex. A + B = B + A = R)

(2) Meteorological uses. There are several different things we use vector addition for meteorologically. One example would be ***Resultant of Forces***. The direction of a parcel's movement will be in the direction found by the vector sum of all of the forces acting on the parcel. The magnitude of the change in the parcel movement is proportional to the magnitude of the resultant. A way to understand this use is to think about the Coriolis force. You are heading north in the northern hemisphere, and Coriolis force is pushing you to the right, so between your heading and the coriolis force, you have a new direction.

(3) Meteorological uses. Average wind for a layer. The number of levels added to compute the average wind for a layer divides the magnitude, or speed, of the resultant wind. $(v_1 + v_2)/2$ = Average Wind e.g., the average wind for the layer from 700 mb to 500 mb would be: $(v_{500}+v_{700})/2$. DO NOT DIVIDE THE DIRECTION.

(4) When adding more than two vectors together, follow the same principle, just ensure that the resultant vector is drawn from the tail of the first vector to the head of the last vector added. Order of addition does not matter.

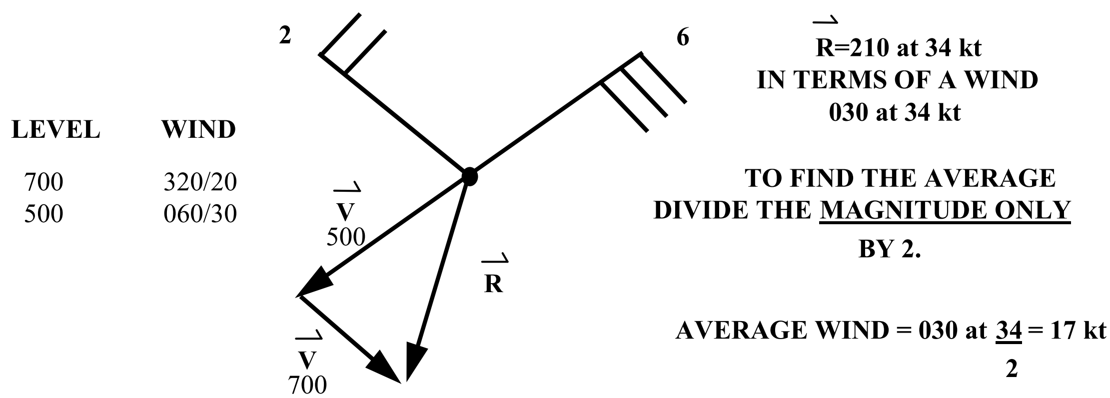

Figure 5 - Average winds for a layer.

b. Vector Subtraction. Subtract one vector from another graphically, draw the first vector, and then draw the second vector with its tail at the tail of the first. The difference vector is drawn from the head of the vector with the minus sign to the head of the vector that is being subtracted from.

(1) Graphical method "tail-to-tail" method.

Step 1. Construct x, y coordinate system.

Step 2. Select scale & draw both **"A"** & **"B"** to scale with both tails at the origin of coordinate system.

Step 3. For **A-B**, Draw resultant **"R"** from the head of the vector being subtracted **"B"** to the head of the vector being subtracted from **"A"**.

Note: THE ORDER DOES MAKE A DIFFERENCE: A-B does not equal **B-A** (The magnitudes of **R** would be the same, but direction would be 180° out.) **R** = **A** - **B**, draw the line to make certain of the direction of the resultant, **R**.

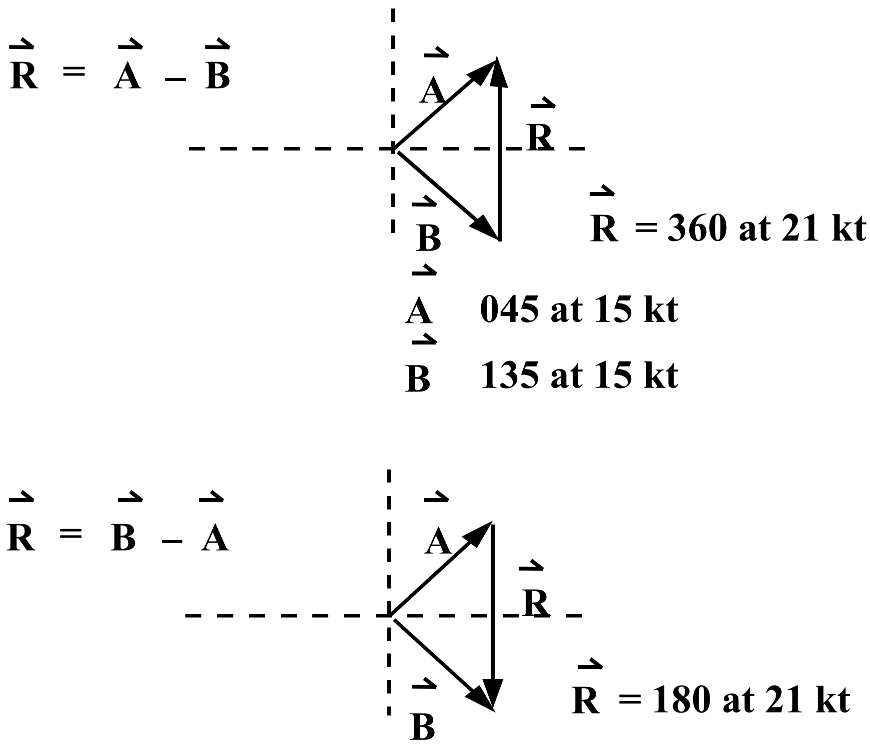

Figure 6 - Vector subtraction.

(3) Meteorological uses.

(a) Wind shear. Wind shear is the abrupt change of wind speed and/or direction, in the vertical or horizontal.

(b) Cirrus blow-off. Movement of cirrus blow off = (wind flow aloft minus cell movement). Cirrus starts at the origin and is blown off by the upper-level wind flow, vector "A". During the same time, the thunderstorm moves along vector "B". From the viewpoint of the thunderstorm (or as seen from a satellite), it appears that CI has blown off in direction "R".

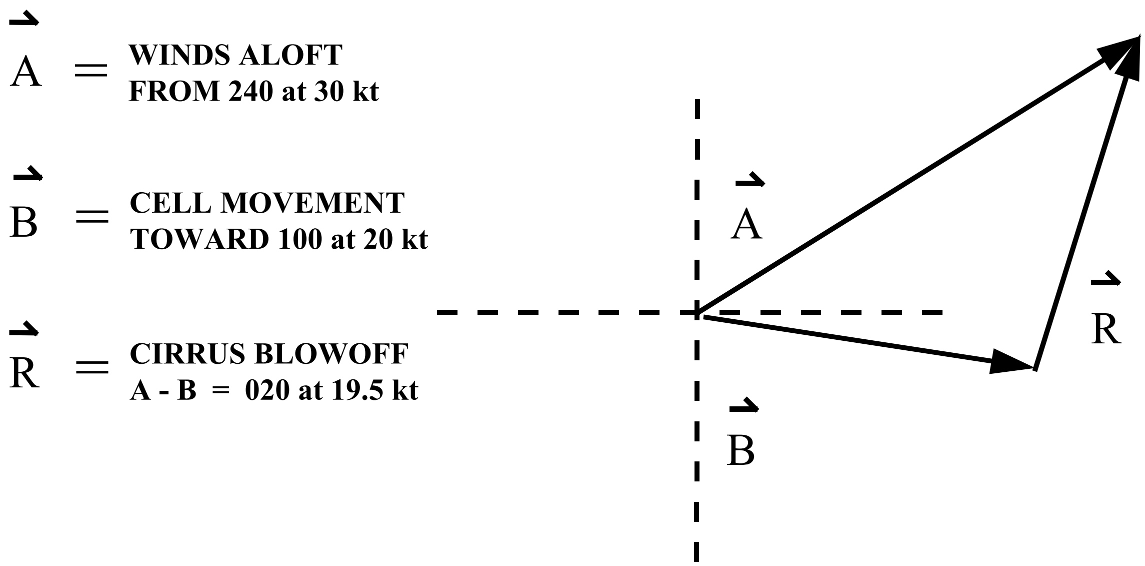

Figure 7 - Cirrus Blow-Off.

<u>TRANSITION</u>. Vector addition and subtraction are the underlying stepping-stones for vector operations. However there maybe at times where one will be required to graphically depict a vector.

3. <u>Computing Components of Vectors</u>.

a. Component. The portion of a vector along a given coordinate direction. Note: The sum of the components yields the vector.

b. Determining vectors components graphically.

Step 1. Draw a navigational coordinate system.

Step 2. Determine plotting scale.

Step 3. Plot vector from origin (usually you are given a wind, which you must convert to a vector).

Step 4. Drop a line from the head of the vector perpendicular to each axis.

Step 5. Determine the magnitude of each component (measure it).

Step 6. Determine the direction of each component.

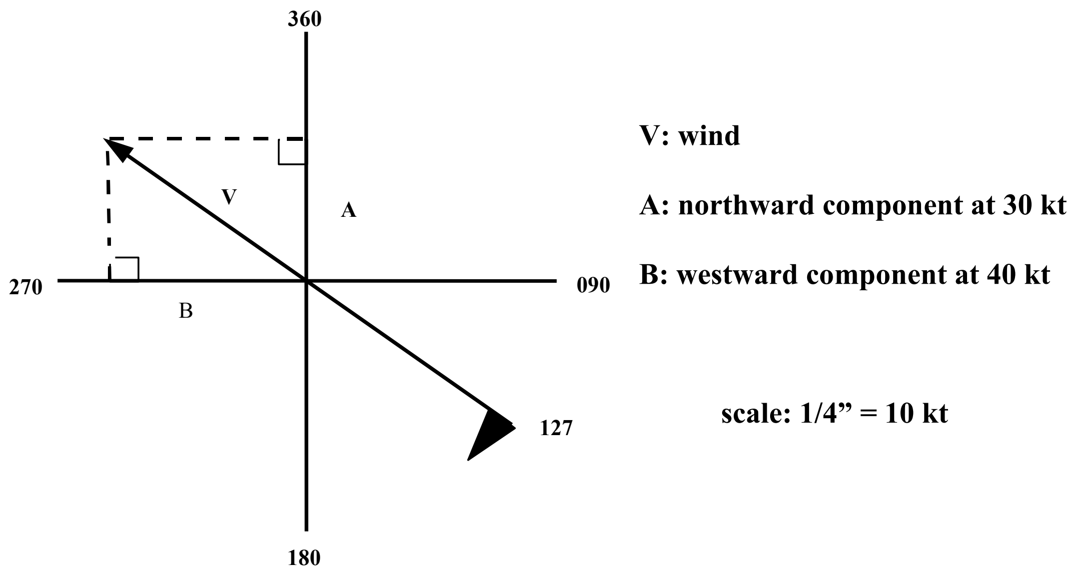

Figure 8 - Computing vector components.

TRANSITION. There are several common aviation terms that are operations of vectors that you do not realize, below are a few.

4. Commonly Used Terms in Using Vector Components.

a. Air speed. The speed at which an aircraft is flying relative to speed of the air.

b. Ground speed. The speed at which an aircraft is flying over (or relative to) the ground.

c. Head wind. This is a component of the wind vector that is parallel to the aircraft's direction of motion, opposes the aircraft's motion, and will result in a decreased ground speed.

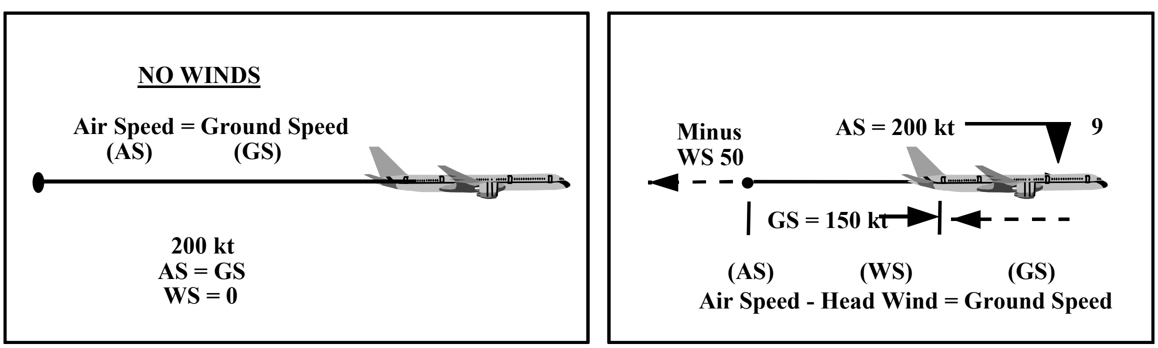

Figure 10 - Aircraft with no wind and aircraft with a headwind.

d. Tail wind. This is a component of the wind vector that is parallel to the aircraft's direction of motion, assists the aircraft's motion, and will result in an increased ground speed.

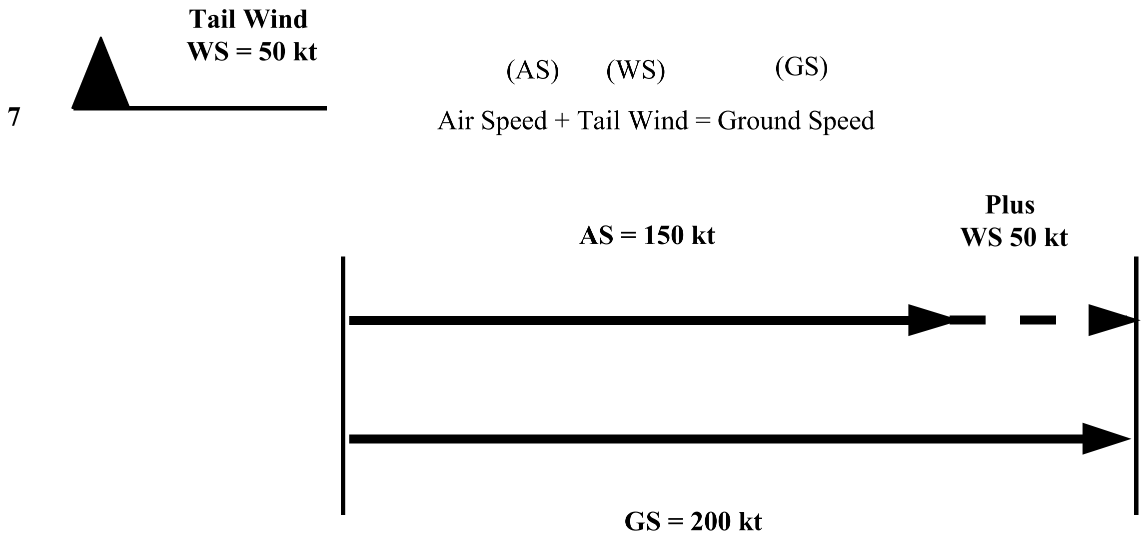

Figure 10 - Aircraft with a tail wind.

e. Crosswind. This wind component is perpendicular to an aircraft's flight path. It will require a change in the aircraft's heading in order to maintain the desired course. (Note! To determine headwind or tailwind and crosswind, use the steps for determining vector components graphically. Remember to convert the wind to a vector!

f. Runway crosswind. This wind component is perpendicular to an aircraft's flight path during its take off or landing on the runway. It may require a change in the aircraft's heading or make flight operations on the runway unsafe.

OPPORTUNITY FOR QUESTIONS:

1. Questions from the Class. At this time are there any questions from the class that pertain to any of the material just covered?

2. Questions to the Class. At this time there are no questions for the class.

SUMMARY: You have learned the difference between vector and scalar quantities. Have proficiently computed vector operations. In doing so have learned how important vectors are to forecasting as well as aviation safety.

INSTRUCTOR NOTE. GIVE THE STUDENTS A CHANCE TO ASK AS MANY QUESTIONS POSSIBLE, PLACE THEM ON A TEN-MINUTE BREAK.

REFERENCE:

NAVEDTRA 14010 Aerographer’s Mate 1&C.

“https://wwwnt.cnet.navy.mil/nttu/ag_links/ag_links2002/index.html”

Ahrens, Donald C. Meteorology Today. 4th Edition. West Publishing Company, 1991.

Physics Department, University of Guelph. Vectors. "http://www.physics.uoguelph.ca/tutorials/vectors/vectors.html"