rose and the reading shown on the compass is recorded on a deviation card. The airplane is then aligned at 30° intervals and each reading is recorded. If the airplane is to be flown at night, the lights are turned on and any significant changes in the readings are noted. If so, additional entries are made for use at night.

The accuracy of the compass can also be checked by comparing the compass reading with the known runway headings.

A deviation card, similar to figure 14-10, is mounted near the compass, showing the addition or subtraction required to correct for deviation on various headings, usually at intervals of 30°. For intermediate readings, the pilot should be able to interpolate mentally with sufficient accuracy. For example, if the pilot needed the correction for 195° and noted the correction for 180° to be 0° and for 210° to be +2°, it could be assumed that the correction for 195° would be +1°. The magnetic heading, when corrected for deviation, is known as compass heading.

FOR (MAGNETIC)..........	N	30	60	E	120	150
STEER (COMPASS).......	0	28	57	86	117	148
FOR (MAGNETIC)..........	S	210	240	W	300	330
STEER (COMPASS).......	180	212	243	274	303	332

Figure 14-10. Compass deviation card.

The following method is used by many pilots to determine compass heading: After the true course (TC) is measured, and wind correction applied resulting in a true heading (TH), the sequence TH ± variation (V) = MH ± deviation (D) = compass heading (CH) is followed to arrive at compass heading. [Figure 14-11]

EFFECT OF WIND

The preceding discussion explained how to measure a true course on the aeronautical chart and how to make corrections for variation and deviation, but one important factor has not been considered—wind. As discussed in the study of the atmosphere, wind is a mass of air moving over the surface of the Earth in a definite direction. When the wind is blowing from the north at 25 knots, it simply means that air is moving southward over the Earth's surface at the rate of 25 nautical miles (NM) in 1 hour.

Under these conditions, any inert object free from contact with the Earth will be carried 25 NM southward in 1 hour. This effect becomes apparent when such things as clouds, dust, and toy balloons are observed being blown along by the wind. Obviously, an airplane flying within the moving mass of air will be similarly affected. Even though the airplane does not float freely
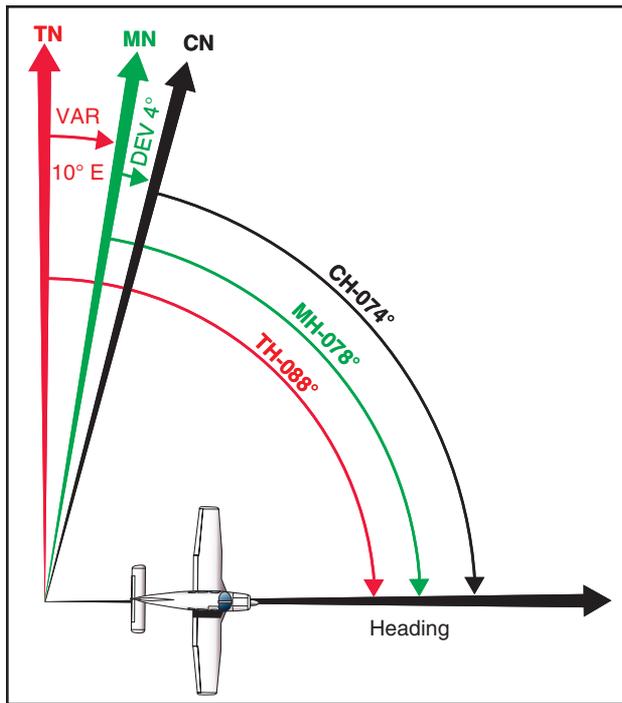

Figure 14-11. Relationship between true, magnetic, and compass headings for a particular instance.

with the wind, it moves through the air at the same time the air is moving over the ground, thus is affected by wind. Consequently, at the end of 1 hour of flight, the airplane will be in a position which results from a combination of these two motions:

• the movement of the air mass in reference to the ground, and

• the forward movement of the airplane through the air mass.

Actually, these two motions are independent. So far as the airplane's flight through the air is concerned, it makes no difference whether the mass of air through which the airplane is flying is moving or is stationary. A pilot flying in a 70-knot gale would be totally unaware of any wind (except for possible turbulence) unless the ground were observed. In reference to the ground, however, the airplane would appear to fly faster with a tailwind or slower with a headwind, or to drift right or left with a crosswind.

As shown in figure 14-12, an airplane flying eastward at an airspeed of 120 knots in still air, will have a groundspeed exactly the same—120 knots. If the mass of air is moving eastward at 20 knots, the airspeed of the airplane will not be affected, but the progress of the airplane over the ground will be 120 plus 20, or a groundspeed of 140 knots. On the other hand, if the mass of air is moving westward at 20 knots, the airspeed of the airplane still remains the same, but groundspeed becomes 120 minus 20 or 100 knots.
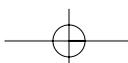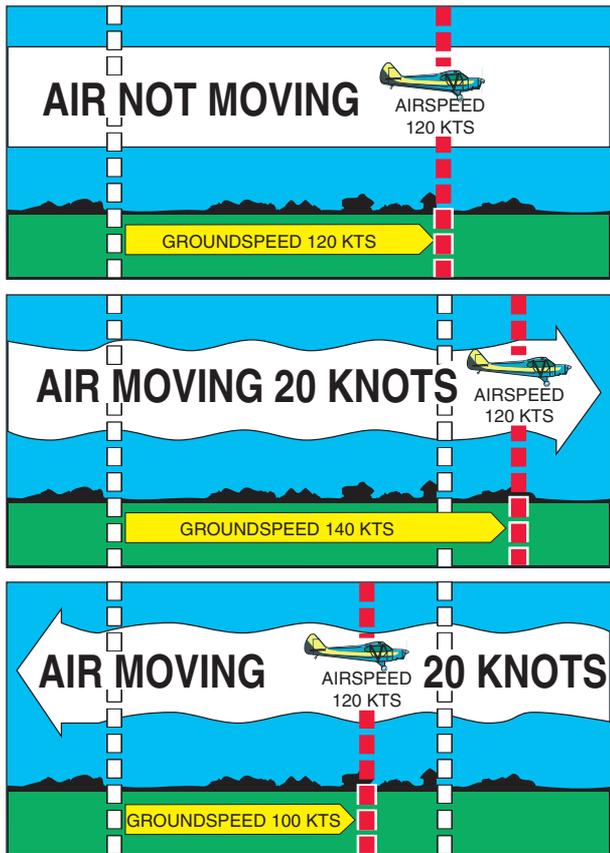
Figure 14-12. Motion of the air affects the speed with which airplanes move over the Earth's surface. Airspeed, the rate at which an airplane moves through the air, is not affected by air motion.

Assuming no correction is made for wind effect, if the airplane is heading eastward at 120 knots, and the air mass moving southward at 20 knots, the airplane at the end of 1 hour will be almost 120 miles east of its point of departure because of its progress through the air. It will be 20 miles south because of the motion of the air. Under these circumstances, the airspeed remains 120 knots, but the groundspeed is determined by combining the movement of the airplane with that of the air mass. Groundspeed can be measured as the distance from the point of departure to the position of the airplane at the end of 1 hour. The groundspeed can be computed by the time required to fly between two points a known distance apart. It also can be determined before flight by constructing a wind triangle, which will be explained later in this chapter. [Figure 14-13]
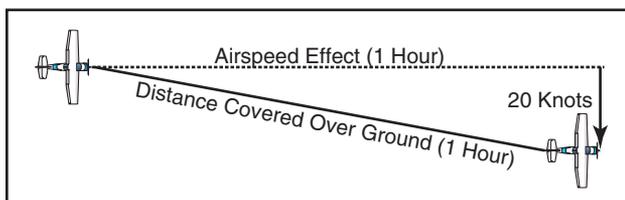

Figure 14-13. Airplane flightpath resulting from its airspeed and direction, and the windspeed and direction.

The direction in which the plane is pointing as it flies is heading. Its actual path over the ground, which is a combination of the motion of the airplane and the motion of the air, is track. The angle between the heading and the track is drift angle. If the airplane's heading coincides with the true course and the wind is blowing from the left, the track will not coincide with the true course. The wind will drift the airplane to the right, so the track will fall to the right of the desired course or true course. [Figure 14-14]
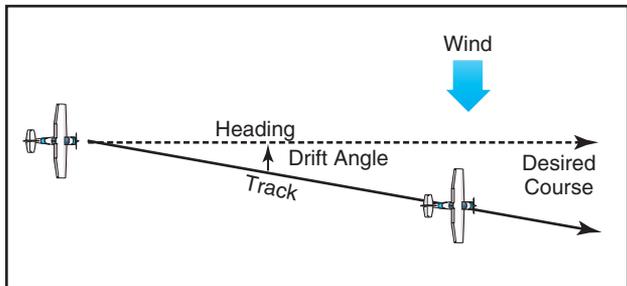

Figure 14-14. Effects of wind drift on maintaining desired course.

By determining the amount of drift, the pilot can counteract the effect of the wind and make the track of the airplane coincide with the desired course. If the mass of air is moving across the course from the left, the airplane will drift to the right, and a correction must be made by heading the airplane sufficiently to the left to offset this drift. To state in another way, if the wind is from the left, the correction will be made by pointing the airplane to the left a certain number of degrees, therefore correcting for wind drift. This is wind correction angle and is expressed in terms of degrees right or left of the true course. [Figure 14-15]
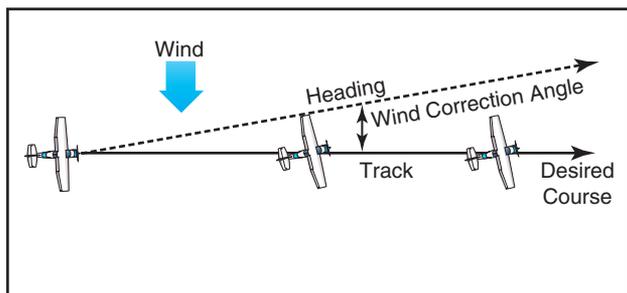

Figure 14-15. Establishing a wind correction angle that will counteract wind drift and maintain the desired course.

To summarize:

- **COURSE**—is the intended path of an airplane over the ground; or the direction of a line drawn on a chart representing the intended airplane path, expressed as the angle measured from a specific reference datum clockwise from 0° through 360° to the line.
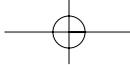
- **HEADING**—is the direction in which the nose of the airplane points during flight.

- **TRACK**—is the actual path made over the ground in flight. (If proper correction has been made for the wind, track and course will be identical.)

- **DRIFT ANGLE**—is the angle between heading and track.

- **WIND CORRECTION ANGLE**—is correction applied to the course to establish a heading so that track will coincide with course.

- **AIRSPEED**—is the rate of the airplane's progress through the air.

- **GROUNDSPEED**—is the rate of the airplane's in-flight progress over the ground.

BASIC CALCULATIONS
Before a cross-country flight, a pilot should make common calculations for time, speed, and distance, and the amount of fuel required.

CONVERTING MINUTES TO EQUIVALENT HOURS
It frequently is necessary to convert minutes into equivalent hours when solving speed, time, and distance problems. To convert minutes to hours, divide by 60 (60 minutes = 1 hour). Thus, 30 minutes 30/60 = 0.5 hour. To convert hours to minutes, multiply by 60. Thus, 0.75 hour equals 0.75 x 60 = 45 minutes.

Time T = D/GS
To find the **time** (T) in flight, divide the **distance** (D) by the **groundspeed** (GS). The time to fly 210 nautical miles at a groundspeed of 140 knots is 210 divided by 140, or 1.5 hours. (The 0.5 hour multiplied by 60 minutes equals 30 minutes.) Answer: 1:30.

Distance D = GS X T
To find the distance flown in a given time, multiply groundspeed by time. The distance flown in 1 hour 45 minutes at a groundspeed of 120 knots is 120 x 1.75, or 210 nautical miles.

Groundspeed GS = D/T
To find the groundspeed, divide the distance flown by the time required. If an airplane flies 270 nautical miles in 3 hours, the groundspeed is 270 divided by 3 = 90 knots.

CONVERTING KNOTS TO MILES PER HOUR
Another conversion is that of changing knots to miles per hour. The aviation industry is using knots more frequently than miles per hour, but it might be well to

discuss the conversion for those who do use miles per hour when working with speed problems. The National Weather Service reports both surface winds and winds aloft in knots. However, airspeed indicators in some airplanes are calibrated in miles per hour (although many are now calibrated in both miles per hour and knots). Pilots, therefore, should learn to convert windspeeds in knots to miles per hour.

A knot is 1 nautical mile per hour. Because there are 6,076.1 feet in a nautical mile and 5,280 feet in a statute mile, the conversion factor is 1.15. To convert knots to miles per hour, multiply knots by 1.15. For example: a windspeed of 20 knots is equivalent to 23 miles per hour.

Most flight computers or electronic calculators have a means of making this conversion. Another quick method of conversion is to use the scales of nautical miles and statute miles at the bottom of aeronautical charts.

FUEL CONSUMPTION
Airplane fuel consumption is computed in gallons per hour. Consequently, to determine the fuel required for a given flight, the time required for the flight must be known. Time in flight multiplied by rate of consumption gives the quantity of fuel required. For example, a flight of 400 NM at a groundspeed of 100 knots requires 4 hours. If the plane consumes 5 gallons an hour, the total consumption will be 4 x 5, or 20 gallons.

The rate of fuel consumption depends on many factors: condition of the engine, propeller pitch, propeller r.p.m., richness of the mixture, and particularly the percentage of horsepower used for flight at cruising speed. The pilot should know the approximate consumption rate from cruise performance charts, or from experience. In addition to the amount of fuel required for the flight, there should be sufficient fuel for reserve.

FLIGHT COMPUTERS
Up to this point, only mathematical formulas have been used to determine such items as time, distance, speed, and fuel consumption. In reality, most pilots will use a mechanical or electronic flight computer. These devices can compute numerous problems associated with flight planning and navigation. The mechanical or electronic computer will have an instruction book and most likely sample problems so the pilot can become familiar with its functions and operation. [Figure 14-16]

PLOTTER
Another aid in flight planning is a plotter, which is a protractor and ruler. The pilot can use this when determining true course and measuring distance. Most plotters have a ruler which measures in both