HEADQUARTERS, DEPARTMENT OF THE ARMY

FEBRUARY 1975
# FIXED WING FLIGHT

## Chapter 1. GENERAL

<table>
<thead>
<tr>
<th>Section</th>
<th>Paragraph</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1-1.1-4</td>
<td>1-1</td>
</tr>
</tbody>
</table>

## Chapter 2. PRINCIPLES OF AIRFOILS AND FORCES ACTING ON AN AIRCRAFT IN FLIGHT

<table>
<thead>
<tr>
<th>Section</th>
<th>Paragraph</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.</td>
<td>2-1-2-3</td>
<td>2-1</td>
</tr>
<tr>
<td>II.</td>
<td>2-4-2-6</td>
<td>2-3</td>
</tr>
<tr>
<td>III.</td>
<td>2-7-2-9</td>
<td>2-4</td>
</tr>
</tbody>
</table>

## Chapter 3. FLIGHT CONTROLS AND PRINCIPLES OF FLIGHT

<table>
<thead>
<tr>
<th>Section</th>
<th>Paragraph</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.</td>
<td>3-1-3-2</td>
<td>3-1</td>
</tr>
<tr>
<td>II.</td>
<td>3-3-3-5</td>
<td>3-3</td>
</tr>
</tbody>
</table>

## Chapter 4. AIRCRAFT AND PROPELLER PERFORMANCE

<table>
<thead>
<tr>
<th>Section</th>
<th>Paragraph</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.</td>
<td>4-1-4-4</td>
<td>4-1</td>
</tr>
<tr>
<td>II.</td>
<td>4-5-4-7</td>
<td>4-2</td>
</tr>
</tbody>
</table>

## Chapter 5. AIRPLANE CLASSIFICATION, CONSTRUCTION, AND STABILITY

<table>
<thead>
<tr>
<th>Section</th>
<th>Paragraph</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.</td>
<td>5-1-5-9</td>
<td>5-1</td>
</tr>
<tr>
<td>II.</td>
<td>5-10,5-11</td>
<td>5-5</td>
</tr>
</tbody>
</table>

## Chapter 6. PRIMARY FLIGHT MANEUVERS

<table>
<thead>
<tr>
<th>Section</th>
<th>Paragraph</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.</td>
<td>6-1-6-3</td>
<td>6-1</td>
</tr>
<tr>
<td>II.</td>
<td>6-4-6-7</td>
<td>6-3</td>
</tr>
<tr>
<td>III.</td>
<td>6-8-6-12</td>
<td>6-5</td>
</tr>
<tr>
<td>IV.</td>
<td>6-13-6-17</td>
<td>6-9</td>
</tr>
<tr>
<td>V.</td>
<td>6-18-6-20</td>
<td>6-11</td>
</tr>
<tr>
<td>VI.</td>
<td>6-21-6-24</td>
<td>6-12</td>
</tr>
<tr>
<td>VII.</td>
<td>6-25-6-30</td>
<td>6-14</td>
</tr>
</tbody>
</table>

## Chapter 7. INTERMEDIATE FLIGHT MANEUVERS

<table>
<thead>
<tr>
<th>Section</th>
<th>Paragraph</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.</td>
<td>7-1-7-2</td>
<td>7-1</td>
</tr>
<tr>
<td>II.</td>
<td>7-3-7-6</td>
<td>7-2</td>
</tr>
<tr>
<td>III.</td>
<td>7-7-7-9</td>
<td>7-3</td>
</tr>
<tr>
<td>IV.</td>
<td>7-10-7-13</td>
<td>7-4</td>
</tr>
</tbody>
</table>

## Chapter 8. ADVANCED FLIGHT MANEUVERS

<table>
<thead>
<tr>
<th>Section</th>
<th>Paragraph</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.</td>
<td>8-1-8-2</td>
<td>8-1</td>
</tr>
<tr>
<td>II.</td>
<td>8-3-8-6</td>
<td>8-1</td>
</tr>
</tbody>
</table>

## Chapter 9. TWIN-ENGINE AIRPLANE

|         | 9-1-9-7   | 9-1  |

## Chapter 10. TACTICAL FLIGHT TRAINING

<table>
<thead>
<tr>
<th>Section</th>
<th>Paragraph</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.</td>
<td>10-1-10-4</td>
<td>10-1</td>
</tr>
<tr>
<td>II.</td>
<td>10-5-10-8</td>
<td>10-4</td>
</tr>
<tr>
<td>III.</td>
<td>10-9-10-14</td>
<td>10-7</td>
</tr>
</tbody>
</table>

## Appendix

### A. REFERENCES

|         | A-1 |

### B. BASIC PHYSICAL LAWS APPLICABLE TO AERODYNAMICS

|         | B-1 |

### C. CARE AND USE OF THE PARACHUTE

|         | C-1 |

## GLOSSARY

|         | Glossary-1 |

## INDEX

|         | Index-1 |

*This manual supersedes FM 1-50, 10 July 1973.*
1-1. Purpose
This manual explains the principles and techniques of fixed wing flight. It serves as a reference for the—

a. Fixed wing aviator student during the primary and advanced stages of training.

b. Ground instructor and instructor pilot for presenting instruction.

c. Check pilot for the flight evaluation of the student’s fundamental knowledge of fixed wing flight.

d. Rated aviator when undergoing Methods of Instruction (MOI) training and aircraft qualification training.

e. Unit commander for unit training when conducting specialized training.

1-2. Scope

a. Chapters 1 through 5 explain basic airplane aerodynamics and flight techniques. Chapters 6 through 8 cover the mechanics of flight maneuvers, providing the experienced aviator a basis for checking his proficiency. Chapter 9 explains major flight characteristics of a twin-engine airplane, and chapter 10 explains advanced methods of flying an airplane to accomplish the Army aviation mission. Basic physical laws applicable to aerodynamics are covered in appendix B. A glossary lists and defines specialized terms used in this manual.

b. Information in this manual is general and applicable, in part, to all airplanes. Specific flight procedures and practices for individual airplanes are found in the applicable operator’s manual. Additional references are given in appendix A.

1-3. High Threat Environment

a. The high threat environment is a combat environment in which the enemy employs in quantity some combination of automatic weapon (AW), antiaircraft artillery (AAA), surface-to-air missiles (SAM), and airborne interceptors (AI) to establish air defense over a portion of territory he holds and into friendly airspace contiguous to that territory. These weapons are directed by radar, infrared, visual, optical, or electro-optical means. They may be supplemented by a variety of electronic warfare methods to include jamming and deception. Air defense doctrine and equipment of potential enemies in existence and anticipated is directed toward complete denial of the airspace above the front, including adjacent enemy airspace, to any and all hostile aircraft.

b. Enemy doctrine incorporates mechanized air
defense artillery weapons within the maneuver elements during both offensive and defensive operations. The capability of these weapons to engage airborne targets while maneuvering affords the enemy force a greater degree of air defense protection. Additionally, the enemy's highly sophisticated air defense weapons (missiles) are track mounted, giving them the capability for rapid and frequent displacement. The mobility of these air defense weapons enables the enemy force commander to employ these weapons with his maneuver elements, thus providing an air defense umbrella to protect his ground forces during both defensive and offensive operations.

On future battlefields, the potential enemy may employ attack, scout, and utility helicopters. The attack helicopters may possess both automatic weapons and air-to-air armament systems equipped with heat-seeking missiles. Because this enemy capability is a threat to tactical aviation operations, Army aviators must be trained in detection avoidance techniques and air to air combat.

1-4. Recommended Changes

Users of this publication are encouraged to submit recommended changes and comments to improve the publication. Comments should be keyed to the specific page, paragraph and line of the text in which the change is recommended. Reasons will be provided for each comment to insure understanding and complete evaluation. Comments should be prepared using DA Form 2028 (Recommended Changes to Publications and Blank Forms) and forwarded direct to Commander, United States Army Aviation Center, ATTN: ATZQ-D-TL, Fort Rucker, Alabama 36360.
Section 1. PRINCIPLES OF AERODYNAMICS

2-1. Aerodynamics
Aerodynamics is that branch of dynamics that concerns the motion of air and other gases or the forces acting on objects in motion through the air (gases). In effect, aerodynamics is concerned with—the object (the airplane), the movement (the relative wind), and the air (the atmosphere).

2-2. Bernoulli's Theorem
The scientist Bernoulli discovered that the total energy of a system remains unchanged (constant). If one element of the energy system increases, another element decreases to counterbalance it; thus, when the energy of motion increases, the energy of pressure decreases. This theorem readily is seen by use of a venturi tube (fig 2-1). If the same amount of air that enters the tube is also going to leave it, then the velocity of the air must increase while passing the neck of the venturi (as shown in green in fig 2-1). As the velocity increases, the air has less time in which to push against the sides of the tube, thereby exerting less pressure. Since there is no change of velocity of the air about the open end of the tube, there is no change in pressure. The differential pressure on the ends of the tubes attached to the venturi causes the fluid to move toward the end of the tube that has the least pressure.
2-3. Design of an Airfoil
The upper and lower surfaces of an airfoil will normally differ in total length, the upper surface being the longer. Air passing over the upper surface can be compared to the lower half of a venturi tube (fig 2-2). This air must increase its velocity since it has a greater distance to travel; therefore, pressure on top of the airfoil is decreased. Air passing under the bottom of the airfoil has less distance to travel, so the velocity of the air is not as great as over the top; therefore, more pressure is present on the lower surface. Also, the lower surface in normal flight moves at an angle to the relative wind, causing the wind (or air) to strike the surface and produce some impact pressure. The reduced pressure above and increased pressure beneath the airfoil produces the "resultant aerodynamic force."

Figure 2-1. Venturi tube.

Figure 2-2. Comparison of airfoil and venturi tube.
Section II. FORCES ACTING ON AN AIRCRAFT IN FLIGHT

2-4. Lift and Weight

a. Lift. Lift, illustrated in green in figure 2-3, is a component of the total aerodynamic force on an airfoil and acts perpendicular to the relative wind. This force acts straight up from the center of lift, which is the mean of all centers of pressure. The magnitude of lift varies proportionately with airspeed, air density, shape and size of the airfoil, and (within a limited range) angle of attack. In straight and level flight, it is equal and opposite the weight component.

b. Weight. Weight, illustrated in green in figure 2-3, is the force exerted by an airplane from the pull of gravity. It acts on an airplane through the center of gravity, and its direction is straight down toward the center of the earth. The magnitude of this force changes only with a change in gross weight.

2-5. Thrust and Drag

a. Thrust. Thrust, illustrated in green in figure 2-3, is the force that drives an airplane forward through the air. It is produced by a rotating propeller, jet engine, or other propulsive device.

b. Drag. Drag, illustrated in green in figure 2-3, is the force produced by the resistance of the air on an object passing through it. In unaccelerated flight, it is equal and opposite to thrust. Total drag may be divided into two main types—induced and parasite.

(1) Induced drag is that part of the drag induced by the airflow about the lifting surfaces.

(2) Parasite drag is that part of the drag created by the entire airplane, excluding induced drag. It is caused by protrusions (e.g., hinges and landing gear), rough surfaces of the airplane, and the impact of air on the frontal surfaces of the airplane.

2-6. Centrifugal Force

Centrifugal force (CF) is produced by an object moving in a curved path (green circle in fig 2-4). The force acts toward the outside of the circle or turn. It acts on an airplane during all turns, regardless of the plane of the turn.

![Diagram of Forces and their centers in flight.](image)

![Diagram of Normal Turn and Dive Recovery.](image)
2-7. Equations
Important factors influencing lift and drag are the shape and area of the airfoil, angle of attack, air density, and airspeed. A change in any of these factors affects the relationship of lift and drag. This is best seen through use of the following equations:

a. Lift Equation.
\[ L = C_L \frac{\rho}{2} S V^2 \]
- \( L \) = lift in pounds
- \( C_L \) = coefficient of lift (pure number)
- \( \rho \) = density of the air in slugs per cubic foot (29.92 inches Hg = 0.002378 slugs per cubic foot)
- \( S \) = total wing area in square feet
- \( V \) = airspeed in feet per second

b. Drag Equation.
\[ D = C_D \frac{\rho}{2} S V^2 \]
- \( D \) = drag in pounds
- \( C_D \) = coefficient of drag (pure number)
- \( \rho \) = density of the air in slugs per cubic foot
- \( S \) = total wing area in square feet
- \( V \) = airspeed in feet per second

Note. \( C_L \) and \( C_D \) are pure numbers (dimensionless) and are indicative of the efficiency of an airfoil. They are determined from wind tunnel tests and their values vary with different types of airfoils and different angles of attack.

2-8. Effect of Airfoil Shape and Angle of Attack
a. Two design factors that affect the coefficients of lift and drag of an airfoil are the shape and the angle of attack.

b. As the length of the upper camber is increased (by manufacturers design or by the use of flaps), lift is increased to a certain point. If the length is further increased, the airflow will separate from the airfoil, causing a loss of lift.

c. As the angle of attack changes, the distance the air must travel changes (and therefore, the speed), causing a change in differential pressure or lift as shown by green arrows in figure 2-5.

Note. As the lift is increased, so is the drag. Therefore, the airfoil is designed to produce the most lift and the least drag within normal speed ranges. (Figure 2-6 shows how lift and drag increase with the angle of attack. The third line (L/D) shows how the lift/drag ratio varies with different angles of attack.)
2-9. Effect of Air Density, Wing Area, and Airspeed

a. Air Density. Density is the weight of an object per unit volume and differs from pressure in that pressure is force per unit area. Density is directly affected by temperature, pressure, and humidity. Since density affects lift—temperature, pressure, and humidity also affect lift. Any change in temperature, humidity, or pressure will cause density to change. To sustain level flight when these changes occur, the pilot must change either the angle of attack or the airspeed to maintain sufficient lift.

b. Sufficient/Constant Lift. To maintain sufficient/constant lift, see table 2-1.

c. Wing Area. Wing area affects lift and drag directly. If two wings have the same proportion and airfoil sections, a wing with an area of 200 square feet will lift twice as much at the same angle of attack and airspeed as a wing with an area of 100 square feet.

d. Airspeed. In the lift formula, lift varies as the square of velocity. Therefore, an airplane traveling at 200 knots has four times as much lift as one traveling at 100 knots so long as other factors remain constant. If airspeed is changed, then some other factor must be inversely changed to maintain the same lift. The only other factor a pilot can control is the angle of attack (para 2-8c). For a given airspeed and weight, there is only one angle of attack that will maintain level flight.

<table>
<thead>
<tr>
<th>Table 2-1. Maintaining Lift</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
</tr>
<tr>
<td>Increase</td>
</tr>
<tr>
<td>Decrease</td>
</tr>
<tr>
<td>Increase</td>
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<tr>
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</tr>
</tbody>
</table>
CHAPTER 3
FLIGHT CONTROLS AND PRINCIPLES OF FLIGHT

FOR POWER OFF OPERATIONS, THERE IS ONE AIRSPEED (FOR A GIVEN WEIGHT) THAT WILL GIVE THE BEST NO WIND GLIDE DISTANCE.

Section I. FLIGHT CONTROLS

3-1. General
Each flight control change affects the attitude of the aircraft and controls movement about an axis. Airplanes have three axes (as illustrated in green in fig 3-1) about which they rotate and three flight controls to effect rotation about these axes.

3-2. Operation of Controls
For desired control, the pilot should use controlled pressures instead of abrupt control movements. All controls should be coordinated while flying. The following controls are discussed separately here only for clarity:

a. The elevator controls the rotation about the lateral axis. This is called pitch. When forward pressure is applied to the elevator control (shown in green in A, fig 3-2), the elevator moves downward, causing the tail to move upward and the nose downward. When back pressure is applied to the elevator control (shown in green in B, fig 3-2), the elevator moves upward, causing the tail to move downward and the nose upward.

b. The rudder controls the rotation about the vertical axis. This is called yaw. When pressure is applied to the left rudder pedal, the rudder moves to the left (shown in green in A, fig 3-3), causing the tail to move to the right and the nose to move to the left. When pressure is applied to the right rudder pedal, the rudder moves to the...
right (shown in green in B, fig 3-3), causing the tail to move to the left and the nose to the right.

c. The ailerons control the rotation about the longitudinal axis of the airplane. This is called roll. When right pressure is applied to the aileron control (shown in green in A, fig 3-4), the right aileron moves up as shown in green in A, figure 3-4, causing a loss of lift on that wing. At the same time, the left aileron moves down, causing an increase of lift on that wing. These aileron movements make the airplane roll to the right. When left pressure is applied to the aileron control (shown in green in B, fig 3-4), the left aileron moves up as shown in green in B, figure 3-4, causing a loss of lift on that wing; the right aileron moves down, causing an increase of lift on that wing. This makes the airplane roll to the left.
3-3. Climbing Flight

a. The forces acting on an airplane in a climb (fig 3-5) differ somewhat from those in straight and level flight. In the climb, lift acts perpendicularly to the flightpath, so that it does not entirely support the weight of the airplane. Weight acts in a vertical direction, and drag acts in opposition to the flightpath. Thus, thrust must overcome drag and some of the airplane weight.

b. The rate of climb (altitude gained in a given time) does not vary with the wind. However, the angle of ascent (angle between the flightpath and the ground) does vary with the wind for the same rate of climb. Therefore, two airplanes climbing at the same rate, one upwind and one downwind, will gain the same amount of altitude in a given time but will have different angles of ascent. Figure 3-6 shows the relative climb angle under various wind conditions.
3-4. Turning Flight

a. Turning flight is accomplished by changing lift from the vertical (A, fig 3-7) toward the horizontal. This produces centrifugal force, which (para 2-6) tends to move an object toward the outside of a turn. The resultant of weight and
Centrifugal force is outward and downward. This must be overcome by lift or the airplane will lose altitude (B, fig 3-7). Lift has a vertical and horizontal component in the turn. The resultant of these components must equal the resultant of weight and centrifugal force for a level turn. At this time, the vertical component of lift is equal to weight and the horizontal component is equal to the centrifugal force (C, fig 3-7).

b. The resultant of weight and centrifugal force produces an increased load factor on an airplane. Load factor is the total load imposed on an object divided by the weight of the object, and is measured in G units. The centrifugal force produced by a turn adds to the total load on the airplane, thereby increasing its load factor. The load factor in a turn is affected by angle of bank (shown by black line in fig 3-8). Airspeed does not affect it because, for a given angle of bank, the rate of turn decreases with an increase in airspeed, resulting in no change of centrifugal force. In a coordinated level turn with a 60° bank, the load factor for any airplane is 2 G's, regardless of airspeed. Since stalling speed varies in direct proportion to the square root of the load factor, an airplane with a normal stalling speed of 50 mph (43.5 knots) will stall at 70 mph in a 60° bank. It must be remembered that load factors do not cause stalls. Stalls occur when the pilot increases his angle of attack to compensate for additional requirements. (The square root of 2 G's is 1.41 G's. This factor multiplied by the stalling speed of 50 mph equals 70.50 mph (61 knots)—the new stalling speed.)

3-5. Gliding Flight

a. When the engine fails, the airplane does not drop straight down. Because the center of gravity is forward of the center of lift, the airplane will tend to nose over when power is removed. As the nose lowers, the weight component begins to provide thrust. In doing so, it will maintain airspeed, which creates lift. Although lift is then acting perpendicular to the flightpath, it still has a vertical component. When the vertical component equals the weight component, the rate of descent and airspeed are stabilized and the airplane is in a constant glide. The thrust resultant of weight and lift then equals drag, and the vertical component of lift equals weight (illustrated in green in fig 3-9).

b. If the vertical lift component should become less than weight, the airplane will increase its angle of descent, causing an increase in airspeed and a resulting increase in lift. This will cause the vertical lift component to increase, and the glide will again stabilize, though at a steeper angle than normal. If elevator control back pressure is applied, an increase in angle of attack will result, causing a corresponding increase in lift and drag and a momentary decrease in angle of descent. Airspeed will begin to dissipate, causing lift to decrease until it becomes equal to weight. The glide will again stabilize, but at an angle steeper than normal because the lift-drag ratio has changed.

c. Glides can be divided into three types—normal, slow, and fast (fig 3-10).

(1) The normal glide (often called "best" glide) gives the greatest forward distance for a given loss of altitude. There is one indicated airspeed for a maximum glide distance at a given weight. Any deviation from this airspeed will result in a shorter glide distance per foot of altitude loss. The airspeed for maximum glide distance decreases with weight decrease and vice versa. The maximum glide ratio is the maximum lift to drag ratio for the airplane in the glide condition and is independent of weight; i.e., the airspeed must vary with a weight change, but the glide distance will remain constant.
(2) A slow glide is one at an airspeed slower than a normal glide. The resultant angle will be steeper than that of a normal glide.

(3) A fast glide is one at an airspeed faster than a normal glide. The resultant angle will be steeper than that of a normal glide.

VERTICAL COMPONENT OF LIFT

RESULTANT EFFECT OF LIFT AND DRAG IS EQUAL TO AND OPPOSITE TO THE RESULTANT EFFECT OF WEIGHT AND THRUST.

Figure 3-9. Forces in gliding flight.

Figure 3-10. Glide.
CHAPTER 4
AIRCRAFT AND PROPELLER PERFORMANCE

Section 1. AIRCRAFT PERFORMANCE

4-1. General
Performance characteristics of an airplane include factors such as range, endurance, rate of climb, ceiling, and various airspeeds. A general knowledge of how these factors may vary is important to the aviator.

4-2. Effect of Air Density on Performance
a. One of the most consistent and definite influences on aircraft performance is air density. Because atmospheric pressure decreases with altitude (about 1 inch Hg per 1,000 ft), the air becomes thinner (thereby less dense) and changes overall performance. It is desirable to learn to think of the aircraft in terms of its power required and power available. If the engine is not supercharged, the power available will lower as the altitude increases. That is, as the aircraft climbs the air becomes thinner and the density of the air decreases. This affects the combustion processes in the cylinders and the power produced by the engine drops off. If the engine is equipped with a supercharger, it acts as a pump to pack more air into the cylinders, thus producing conditions that are near that of sea level flight and increasing the power output by the engine to its normal sea level rating up to an altitude equivalent to the design capability of the supercharger. The air density affects the length of the takeoff. The takeoff run at 5,000 feet is approximately double the length of the takeoff at sea level. The indicated airspeed on landing at a landing area at 5,000 feet is the same as at sea level. Due to the reduced air density, the true airspeed is more and the length of the rollout after touchdown is greater. The approach angle is more shallow at a landing area at 5,000 feet than at sea level when maintaining this same indicated airspeed.

b. The power requirement varies as the cube of the airspeed for a specific air density; to double the airspeed at a given altitude requires eight times the horsepower along with the associated increase in fuel consumption. However, air density at 36,000 feet is about one-fourth of sea level air density. Therefore, due to less resistance,
the true airspeed at this altitude can be double sea level true airspeed with the same power requirement for both altitudes. Yet, as air density decreases, so does available horsepower and lift. Also, adverse wind factors may counteract the advantage gained by the decreased drag at higher altitudes. Nevertheless, the effects of density on speed and range and the advantage of high altitude flight within the airplane’s capability should be apparent.

4-3. Forces Affecting Performance
Of the basic forces acting on an airplane (lift, weight, thrust, and drag), the most common variation is in its weight. An increase in weight, for instance, requires a corresponding increase in lift to carry the extra weight. This requires additional thrust and/or angle of attack, which produces more drag. The net result is less range for a given speed or less speed for a given power.

Simultaneously, the operational ceiling of the airplane is lowered due to requirements for increased lift, and rate of climb is decreased because of reduced reserve power.

4-4. Cruise Control
Cruise control is the scientific operation of an airplane engine and propeller setting to obtain maximum efficiency commensurate with the requirements of the mission. Factors which affect the efficiency of the airplane engine are power settings/manifold pressure/torque, rpm, fuel mixture, and fuel and air mixture temperature. Cruise control definitely affects the range and endurance of an airplane and provides economy for the amount of fuel used during the flight and in overall engine wear. For recommended cruise power setting, refer to the appropriate operator’s manual.

Section II. PROPELLER PERFORMANCE

4-5. Propeller Design
The propeller is considered an airfoil because it creates a useful aerodynamic reaction when moved through the air. It receives its power from the engine, which causes the propeller to rotate and create propeller lift (commonly called thrust).

a. Like all airfoils, the propeller must be designed to withstand various stresses caused by the forces acting on it. Centrifugal force acts on the propeller constantly during use as pointed out by green arrow in figure 4-1. This is caused by the rotation which tends to pull on the propeller from the hub toward the ends. The strength of this force varies directly with the proportionate square of rotational speed. Lift, derived from the rotation, also produces a force on the propeller which tends to bend it. If the bending stress on the propeller is too great, it would start “fluttering,” setting up vibrations that could cause it to disintegrate.

b. At a constant rotational speed, the tip of the propeller travels at a considerably higher speed than the section nearest the hub. Therefore, in an attempt to provide symmetrical loading, the propeller is twisted in design to decrease the pitch angle from hub to tip. This causes the amount of lift produced along the propeller blade to remain nearly constant from the hub to the tip (fig 4-2).

c. When there is no forward movement of the airplane, the relative wind for the propeller is determined by the propeller’s direction and speed of rotation. As the airplane moves forward, the relative wind will change, decreasing the angle of attack. All airfoils have one angle of attack which is operationally most efficient. By using a propeller on which the pitch angle can be varied as the airspeed varies, propeller efficiency can be maintained at its peak most of the time. Many types of propellers permit this. However, smaller
aircraft normally use a fixed-pitch propeller—its pitch cannot be changed, but the angle of attack changes with each change in forward or rotational speed (airspeed or rpm).

d. Propellers of smaller aircraft usually are attached to the engine crankshaft. It is not always possible to have engine and propeller rotational speeds the same. An engine must be able to attain given rpm to reach maximum horsepower. This might cause the peripheral (tip) speed of a propeller to be too great. To compensate for this, some propellers are geared to the engines to achieve good propeller efficiency and high engine horsepower. This results in the propeller rpm being lower than the engine rpm.

e. In order to provide high propeller efficiency through a wide range of operations, the propeller blade must be controllable. The most convenient means of controlling the propeller is the provision of a constant speed governing apparatus (constant speed propeller). The constant speed governing feature is favorable from the standpoint of engine operation in that engine output and efficiency is positively controlled and governed. The governing of the engine-propeller combination will allow efficient operation throughout a wide range of power and speed. Practically all Army airplanes employ this governing feature.

f. Propellers on most multiengine airplanes can be feathered: the mean blade angle can be turned parallel to the direction of flight. Thus, if an engine becomes inoperative, the pilot can reduce drag on the aircraft by feathering the propeller of the inoperative engine, consequently increasing stability, controllability, and available range.

g. Reversible-pitch propellers can be adjusted to change the angle of attack so that the propeller provides a thrust or reverse action when on the ground. They generally are used on larger multiengine airplanes. This characteristic is especially helpful to shorten the ground landing roll; it also may be used to maneuver the airplane on the ground.

h. The length/number of propeller blades (propeller surface area) is determined by the maximum horsepower which must be absorbed from the engine. If the blade length is limited because of tip speed or ground clearance requirements, then the propeller must be designed with more blades to increase the surface of the propeller.

4-6. Propeller Torque Reaction

a. During takeoff, the design characteristic of the aircraft will not compensate for torque. As a result, the tendency of the aircraft is to yaw to the left. The degree of yaw can be controlled by the application of power. A small continuous application of power will result in very little yawing action; whereas, a rapid application of power will result in a more severe yawing action.

b. Torque reaction of a clockwise turning propeller (as the pilot views it from the cockpit) causes a counter-clockwise rolling tendency as depicted in green in figure 4-3. (Newton's Third Law—for every action there is an equal and opposite reaction.) For straight and level flight, torque reaction is compensated for by engineering design features and the tendency to roll left is minimized.

4-7. Other Propeller Forces

a. The slipstream (prop wash) flows behind the propeller in a corkscrew motion. With low forward speed and high propeller speed, the corkscrew
ROTATING SLIPSTREAM STRIKES LEFT SIDE OF FIN AND RUDDER

PLANE TENDS TO YAW

RIGHT RUDDER NEEDED TO MAINTAIN STRAIGHT FLIGHT AT SLOWER AIRSPEEDS

SLIPSTREAM \ RELATIVE WIND

THE OFFSET FIN IS DESIGNED SO THAT THE ANGLE OF ATTACK OF THE FIN IS ZERO (THE FORCES BALANCE) AT CRUISE

Figure 4-4. Correcting for yaw.

A

AT 90° TO RELATIVE WIND

B

90°

RELATIVE WIND

C

GREATER THAN 90° TO RELATIVE WIND

Figure 4-5. Asymmetric disk loading effects.
motion is tight and will strike the left side of the vertical tail surface, thereby pushing the tail to the right. As forward speed increases, the corkscrew motion elongates until its effect is slight at normal cruise (compensated for by offsetting the vertical stabilizer, changing wing angle of incidence, or other design features).

b. Asymmetrical loading of the propeller (P factor) causes an airplane to have a tendency to yaw to the left as illustrated by green rudders in figure 4-4. When the airplane is in a relatively high angle of attack (slow flight, climb, takeoff roll on tailwheel of aircraft), the plane of propeller rotation is at an angle greater than 90° to the relative wind as shown by green broken line in figure 4-5.

c. The descending blade (right side as seen from the cockpit) has a higher angle of attack than the ascending blade and consequently greater thrust, which results in a tendency to yaw left. The procedure to compensate for P factor is to add right rudder or right rudder trim.
CHAPTER 5
AIRPLANE CLASSIFICATION, CONSTRUCTION, AND STABILITY

WEIGHT AND BALANCE AFFECT PERFORMANCE

Section 1. CLASSIFICATION AND CONSTRUCTION

5-1. Methods of Classifying Airplanes
Airplanes may be classified by distinguishable features of the wing, powerplant, and landing gear, and by their purpose.

a. Wing. The number, location, and design of the wing helps classify an airplane. There may be one, two, or more wings, although most of today's airplanes are of single-wing construction. The high-wing airplane has the wing attached to the top of the fuselage; the mid-wing, at or near the center of the fuselage; and the low-wing, at the bottom of the fuselage. The wing may have the normal straight-edge design; the swept-wing design, where both the leading and trailing edges are at an angle to the longitudinal axis; or delta wing design, where the leading edge is swept back and the trailing edge forms the rear of the airplane.

b. Powerplant. An airplane may be referred to by the type of powerplant used, such as reciprocating, gas turbine, or jet. The reciprocating engine always drives a propeller, which may further aid in classification. Aircraft equipped with a turbine engine drives a propeller and is referred to as a turboprop or a turbojet.

c. Landing Gear. There are several different types of landing gear. For landplanes, they may be either retractable or fixed. Conventional landing gear has two main wheels (one on each side of the fuselage) and a tailwheel. Tricycle gear has two main wheels, one on each side of the fuselage, and a nosewheel. Seaplanes use floats or the hull for water operations. Amphibian airplanes are equipped for both land and water operations.

d. Purpose. The purpose for which an airplane is designed or used will also help classify it. This classification may be observation, cargo, utility, or trainer. Other classifications of military aircraft are not applicable to Army fixed wing airplanes.

5-2. Stresses
a. Structural units of an airplane are designed to withstand various stresses while in flight and on the ground. The five types of stress are
5-1. Compression, tension, bending, torsion, and shear (fig 5-1).

(1) Compression is the stress which tends to compress, or push together, a structural part. Sitting on a chair subjects the legs of the chair to compression stress.

(2) Tension is the stress pulling at opposite ends of a structural part. Movement of the controls by the pilot causes tension on the control cables.

(3) Bending is the stress applied to a structural unit (or beam) at other than the supporting points. It is a combination of compression and tension. When bent, one side of the beam is pushed together and the other side is stretched.

(4) Torsion is the stress which tends to twist a structural unit. Torsion is exerted on the propeller shaft by the engine turning the shaft and the propeller resisting the turning force.

(5) Shear is the stress which tends to cut an object into two portions by a sliding action. When two pieces of metal fastened together by rivets slide across each other in opposite directions, shear is the stress that cuts the rivets.

b. Stresses seldom act singly, but in combinations of two or more types. All five stresses may be acting on an aircraft at the same time. However, any one point cannot have more than four stresses acting on it simultaneously, since tension and compression cannot act on the same point at the same time. Any distortion of a body as a result of applied stress is called strain.

5-3. Acceleration Stresses

a. Dynamic Loads. In addition to the stress placed upon an airplane by normal flight, it must be designed to withstand stresses caused by acceleration and resulting centrifugal force. These additional stresses are called dynamic loads and are measured in terms of load factors (G units). They may be caused by moving the aircraft in a curved path such as loops, snap rolls, turns, and pullouts from dives. If improperly done, such maneuvers may cause a greater dynamic load than the structure of the airplane can withstand, causing structural damage or failure.

b. Design Load Factor (in G units): The maximum load which may be placed on an aircraft without sustaining any structural damage. Ultimate load factor (in G units): The load at which damage will be sustained to primary aircraft structures. (Exceeding the design load without reaching the ultimate load will cause damage, and will reduce the ultimate load to some factor less than its original value.)

5-4. Structural Units

The principal structural units of an airplane are the fuselage, wings, control surfaces, and landing gear. Each has a specific function and when considered collectively are called airframe or aircraft structure.

a. The fuselage is the main body of an airplane to which the other structural units are fastened. It will contain the crew and cargo, except external stores, and on single engine airplanes usually will contain the powerplant. The three main types of fuselage construction are truss, monocoque, and semimonocoque.

(1) The truss type is mostly used on fabric-covered airplanes. The most common truss is the Warren-type, which consists of a rigid framework made of beams, struts, and bars welded together to form triangles. Its main advantage is that members are subjected only to tension or compression stresses.

(2) A true monocoque construction consists of only the shell, with no internal bracing to help carry stresses (as in a tin can). Consequently, it requires heavy metal for the shell and is not too desirable because of the weight factor.

(3) The semimonocoque type (a modified monocoque) is more suitable for military use. It uses rings, bulkheads, and stringers inside the shell to help give shape and carry stress, e.g., as a tin can with bracing inside. The shell (or stressed skin) is fastened to the internal members and can be of lightweight metal. Since stresses are divided between skin and internal bracing, vital or critical points are for the most part eliminated.

b. The wing provides the lifting force that makes an airplane fly and supports the weight of the airplane during flight. Its design is dependent on the size, weight, purpose, and desired speed for flight and takeoff of the airplane. There are two general types of wing construction internally and externally braced—called cantilever and semicantilever. Each type may be covered with cloth or stressed skin. Stressed-skin wings distribute the load over more of the wing area and, thereby, can carry more load or stress.
without failing. Most military airplanes are constructed with stressed-skin wings.

c. Control surfaces (manual, mechanical, hydraulic, or electrical) are supplementary airfoil sections which the pilot uses to control the flight of the airplane. Primary control surfaces are the ailerons and elevators shown in green in figure 5-2, and the rudder shown in green in figure 5-2; they are constructed on the same principle as an airfoil and are normally covered with metal. The ailerons are attached by hinges to the outer panels of the trailing edge of the wings. Secondary control surfaces are trim tabs, balance tabs, and servo tabs; these are attached to the primary control surfaces and may be used to trim the airplane in flight or reduce the force required to move primary control surfaces. The elevators and rudder are part of the empennage, which is the entire tail group. In addition to elevators and rudder, the empennage contains the stabilizers. These normally are fixed surfaces, one vertical and one horizontal. The vertical stabilizer is used to help maintain directional stability; the rudder is attached to the stabilizer by a hinge at the trailing edge. The horizontal stabilizer may or may not be fixed. It helps to maintain longitudinal stability and, if movable, is used for trimming the airplane longitudinally. The elevators are attached by a hinge to the trailing edge of the horizontal stabilizer. The ailerons are attached to the trailing edge of the wing.

d. The landing gear consists of wheels, shock absorbers, and possibly a retracting mechanism. Most small airplanes have fixed gear; however, larger, faster airplanes usually have retractable landing gear, which cuts down on overall drag and stress while in flight.

5-5. High Lift Devices

Only one angle of attack for a given speed will maintain a constant altitude. Flying too slowly results in an excessive angle of attack and eventual stalling. The minimum (or stalling) speed for the average airplane is about 1/3 to 2/5 of the maximum level flight speed. A high landing speed requires a shallow gliding angle and a long runway to dissipate the excessive speed. Because of these disadvantages, the modern airplane is equipped with high lift devices. These devices are incorporated into the wing structure; they increase the angle of glide and allow airplanes to land at a slower airspeed.

a. Variations in wing area, while aerodynamically sound, entail structural difficulties. The rigidity of the wing must not be impaired, the necessary additional weight of the operating mechanism must not be excessive, the strength of the wing must be maintained, and the shape of the section cannot be detrimentally affected by the variation.

b. The factor most commonly changed is lift. It may be altered by changing the camber of the airfoil while in flight. This is accomplished by lowering the flaps.

5-6. Flaps

The flap is the portion of the wing that can be
changed from the cockpit to increase lift and drag. This improves the lift of the wing by increasing the camber, and also acts as an airbrake, since it creates more drag. In doing so, it allows a more rapid descent at a given airspeed. When using flaps, the landing speed is slower and the approach angle is steeper.

a. Types of Flaps. The common types of airplane flaps in use today are the simple flap, the split flap, Fowler flap, and the slotted flap as shown in green in figure 5-3. Though they differ in operation, their design and construction generally parallel that of the airfoil.

![Simple Flap](image1)
![Split Flap](image2)
![Slotted Flap](image3)
![Fowler Flap](image4)

Figure 5-3. Flaps.

(1) **Simple flap.** The simple flap is a movable continuation of the trailing edge of the wing. It is similar to the aileron, except that it moves only downward, and at the same time and angle as its companion flap on the other wing. When lowered, the simple flap increases camber of the wing and thus increases airfoil lift for a given angle of attack. However, the simple flap not only increases lift but also increases drag. This increase of drag permits a steeper glide without a corresponding increase in gliding speed.

(2) **Split flap.** The split flap consists of a flat, movable section beneath the trailing edge of the wing. When in use, it is lowered in the same manner as the simple flap, but the upper surface of the trailing edge remains in a fixed position. Its main purpose is to create drag.

(3) **Fowler flap.** The Fowler flap not only increases the effective angle of attack by increasing the camber but also increases the wing area. The flap moves both down and backwards, sliding out from its mounting beneath the trailing edge. Usually it is designed to form a small slot between the trailing edge of the wing and the leading edge of the flap (extended) to help decrease burbling at high angles of attack.

(4) **Slotted flap.** Placing slots in the flaps will permit a combination of camber change and smoother flow.

b. Use of Flaps. Airplanes usually are designed so that an increase in flap deflection produces a nose down movement that rotates the nose of the airplane downward away from a stall position. Since flaps increase drag, this nosedown movement is necessary to prevent deceleration. However, some elevator control adjustment or trim may be required to stabilize the airplane at the required airspeed. Unless flight controls are used to prevent it, the opposite effect (pitchup) occurs when retracting flaps.

(1) **Flaps should never be lowered at excessive speeds, because great stresses are produced by the sudden change in the effective angle of attack and result in structural damage.**

(2) **Flaps should never be retracted suddenly at low airspeeds, as this causes sudden loss of lift and an increase in stalling speed.**

5-7. Type of Slot Arrangements

There are two types of slot arrangements—fixed and movable. The fixed type is built into the wing, a few inches back of the leading edge. The movable type is designed into the leading edge of the wing and, in normal flight, is a part of the wing. As airspeed decreases, it may be extended from the wing either manually or automatically as shown in green in figure 5-4 to form the slot.

![Slotted Wing](image5)

Figure 5-4. Slotted wing.

5-8. Effect of Slots

**Burble** (turbulence) is caused by eddies of air over the top surface of the wing. If the eddies can be reduced, the burble point will not occur until a higher angle of attack is reached. To reduce these eddies, some wings have a slot near the leading edge of the wing. At high angles of attack, the air passes through the slot and smooths the airflow over the wing, thus delaying the stall. To make the ailerons more effective near the burble point when they are most needed, slots are commonly installed near the outer end of the wing in front of the ailerons. Two of the greatest advantages of slots are reduced stalling airspeed and prolonged aileron control during a stall.

5-9. Slats

Slats provide the same function as slots by directing airflow along the top surface of the wing at high angles of attack. Slats are thin, curved,
venetian-blind-type devices which are fitted forward of the leading edge of the wing to provide airflow direction without changing the airfoil camber or surface area.

Section II. STABILITY

5-10. Types of Stability
Design and construction of the airplane primarily determine its stability; however, the manner of distribution of added weight (cargo, etc.) is critical.

a. Positive stability, often referred to as stability, causes the airplane to return to its original attitude when disturbed by an outside force. It may further be divided into static and dynamic stability.

b. Neutral stability causes an airplane to maintain its attitude in flight. However, if the attitude is changed by an outside force, the airplane will tend to maintain the new attitude until again disturbed by an outside force.

c. Negative stability (instability) tends to change an airplane from normal to abnormal flight. It constantly works against the pilot.

d. Static stability tends to return an airplane to its original position when its course is disturbed.

e. Dynamic stability is the motion of an airplane that results when it is disturbed. If an oscillation steadily decreases in amplitude, the airplane is dynamically stable; but if the oscillation steadily increases in amplitude, the airplane is dynamically unstable (fig 5-5).

f. Military aircraft incorporate positive dynamic stability, and therefore positive static condition of the aircraft.

5-11. Stability About the Axes
Airplane stability is accomplished by controlling movement about its three axes (fig 3-1). Certain features incorporated in the design of an airplane give it stability about its longitudinal, lateral, and vertical axes.

a. Longitudinal stability makes an airplane stable about its lateral axis. Without this stability, the airplane would tend to climb or dive. Longitudinal stability is achieved by designing the airplane with the center of gravity forward of the center of wing lift. This alone would cause the airplane to nose down. However, the horizontal stabilizer has a negative angle of attack which affords negative lift to the tail, thereby counterbalancing nose-heaviness. If airspeed decreases, negative lift on the tail decreases, allowing it to rise and the nose to lower. This results in an increase in airspeed. As speed increases, the negative lift on the horizontal stabilizer increases, depressing the tail. If, through improper loading, the center of gravity is moved beyond the allowable limits, this stability is lost.

b. Lateral stability makes an airplane stable about its longitudinal axis. It prevents constant rolling of the airplane. Lateral stability is most commonly achieved by dihedral (designing the wing tips higher than the wing roots). As one wing drops, the dihedral causes the lowered wing to have more lift than the raised wing. This increase in lift tends to return the wing to its original position. Lateral stability is also achieved by keel effect. The fuselage of the airplane reacts to air like a keel of a ship to water. By placing the center of gravity low in the fuselage, any rolling tendency is dampened by the weight pulling downward.

c. Directional stability makes an airplane stable about its vertical axis. It tends to prevent an airplane from yawing (turning). Sweepback of the wings (the leading edge tapers back until the tip is to the rear of the root) provides some directional stability. However, the most important influence on directional stability is the slipstream action on the sides of the fuselage and the vertical stabilizer. Since a greater side area of the fuselage is behind rather than ahead of the center of gravity, the airplane pivots about its center of gravity and weathervanes into the wind on the ground.
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<tr>
<th>STATIC STABILITY</th>
<th>DYNAMIC STABILITY</th>
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<tr>
<td><strong>Positive Static Stability</strong> exists when an aircraft resists displacement/has a tendency to return to its original attitude</td>
<td><strong>Positive Dynamic Stability</strong> exists when the oscillations of an aircraft decrease in returning to its original attitude</td>
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<td><strong>Neutral Dynamic Stability</strong> exists when the aircraft oscillations remain the same in attempting to return to its original attitude</td>
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<td><strong>Neutral Static Stability</strong> exists when an aircraft has no tendency either to return or diverge from its original attitude</td>
<td><strong>Negative Dynamic Stability</strong> exists when the oscillations become greater in the aircraft's attempt to return to its original attitude</td>
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<td><img src="image" alt="Neutral Dynamic Stability" /></td>
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<td><strong>Negative Static Stability</strong> exists when an aircraft tends to move away from its original attitude</td>
<td><strong>No Dynamic Properties</strong>—aircraft remains offset with no tendency to return to original position</td>
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*Figure 5-5. Dynamic and static stability.*
CHAPTER 6
PRIMARY FLIGHT MANEUVERS

Section I. TAXIING

6-1. General
Taxiing is the controlled movement of an airplane across the ground under its own power, except movement that is incident to takeoff and landing. The taxiing speed is normally that of a brisk walk; however, the existing taxiing area and other conditions may alter that speed. Throttle, assisted sparingly and only when necessary by brakes, is used to attain and maintain desired taxiing speed. The steerable tailwheel or nosewheel, rudder, and brakes are used for directional control.

6-2. Use of Throttle and Flight Controls

a. The amount of power required to start the initial roll is considerably greater than that for normal taxiing speed. Power should be applied slowly, and, as soon as the airplane starts to move, the brakes should be tested for proper functioning. After the taxiing roll is underway, a constant power setting is desirable; however, if turns are made, throttle adjustments for varying wind effects may be required to maintain proper taxiing speed. In conventional gear airplanes, S-turning may be required to improve the pilot's view of the taxiing area. However, when in confined areas, the S-turn may be impossible and ground guides may be necessary.

b. Wind has a definite effect on the airplane while on the ground. It tends to retard or increase speed, as well as turn the airplane. If the pilot makes improper use of controls, a light airplane taxiing in a strong wind can be damaged.

(1) When taxiing a conventional gear airplane into a direct headwind (A, fig 6-1), the elevator control should be held back in order to raise the elevators and exert downward force on the tail to hold it on the ground. For a tricycle gear airplane in the same situation (A, fig 6-1), the elevator and aileron controls are held in a neutral position to give a neutral elevator and aileron condition. If the wind is quartering off the nose, the elevator and aileron controls are positioned so as to use the elevators and ailerons effectively to help keep the airplane upright. To
do this in a conventional gear airplane, the controls are held back and toward the windward wing. For a tricycle gear airplane, the elevator control is positioned to give a neutral elevator setting. The aileron control is held in the direction of the windward wing to give an up-aileron position (B, C, fig 6-1). In this position, the aileron on the windward wing moves up, spoiling lift, while simultaneously the aileron on the leeward wing lowers and creates more lift on that wing. This also creates more drag and helps counteract weathervaning tendencies.
(2) When taxiing a conventional gear airplane and a T-41 with a tailwind (D, fig 6-1), the elevator control is moved to lower the elevators allowing the wind to exert a downward force on the tail; the ailerons are held in a neutral position. If the wind is quartering off the tail (E, F, fig 6-1), the elevator control is held forward and the aileron control toward the leeward wing. The downward deflected aileron helps prevent weathervaning tendencies. For a tricycle gear airplane with a tailwind, except T-41, (D, fig 6-1), the elevator control is moved aft to raise the elevators, and the ailerons are held in a neutral position. If the wind is quartering off the tail of a tricycle gear airplane (E, F, fig 6-1), the elevator control is held aft and the aileron control toward the leeward wing.

(3) Elevator position should never be held with force while taxiing in a tailwind. The propeller slipstream or taxiing speed may be strong enough to offset the tailwind; if so, the elevator has to be moved up to hold the tail down (conventional gear). When this condition exists, slight downward/upward position of the elevator normally is desirable to allow for wind gusts. Less throttle is required to taxi with a tailwind because the wind helps to move the airplane. Brakes are used as necessary to prevent excessive speed.

6-3. Taxiing Precautions
Most taxiing accidents can be eliminated by observing a few rules:

a. The aircraft must be kept under constant control.
b. When possible, S-turns (conventional gear) should be used to afford maximum visibility of the taxiing area.
c. Speed must be commensurate with the taxiing area and pilot proficiency.
d. Sharp turns should not be attempted at excessive speeds.
e. In confined areas, wingmen or ground signalmen should be used, or aircraft should be moved by hand.
f. At night, extra precautions must be taken.
g. When in doubt about the area, a thorough ground reconnaissance should be made prior to taxiing the airplane.
h. Controls should be positioned according to wind direction and windspeed.
i. Wing-walkers should be used when wind-speed is excessive or when directional control is likely to be too difficult or dangerous.
j. When applying brakes to stop forward movement, application of pressure should be smooth and continuous rather than rapid or abrupt.

Section II. TAKEOFFS

6-4. General
Actual flight begins with the takeoff. As the throttle is advanced to start the roll down the active runway, the takeoff begins; it continues until the airplane becomes positively airborne. Mastery of the takeoff is a basic requirement of flying.

6-5. Normal Takeoff
The normal takeoff (fig 6-2) is made directly into the wind, or as directly as the runway will allow.

In this manner, the airplane becomes airborne with shorter ground roll.

a. After clearance for takeoff is received from the tower, the airplane is taxied onto the active runway and aligned with the centerline. Insure the nose or tailwheel is aligned (centered). Advance power smoothly to takeoff setting and utilize rudder to maintain directional control. Use of brakes will be minimal.
b. As the airplane accelerates and directional
control is positive, elevator position should be neutralized. Approaching the recommended takeoff speed, adjust aircraft pitch with elevator to the proper attitude for liftoff. Conventional gear aircraft will lift off at an attitude near three point (tailwheel 2-3" off surface). Tricycle aircraft generally lift off in a slight nose up attitude dependent on configuration. As the aircraft becomes airborne, adjust pitch attitude to attain recommended climb speed and set climb power. Takeoff power should not be reduced until a safe altitude is reached. Perform takeoff check and continue the climbout aligned with the runway heading until a turn is required. Trim the aircraft.

6-6. Effect of wind
Takeoff depends upon the wings deriving sufficient lift to overcome the weight of the airplane. By taking off into the wind, the airplane has an airspeed equal to the headwind component before the takeoff is started. Therefore, less ground roll is required to become airborne (A, fig 6-3). Since airspeed to be attained, resulting in a longer ground roll and the need for a longer runway. Runway length requirement increases approximately 20 percent per 1,000-foot increase in altitude (fig 6-4).

Figure 6-3. Effect of wind on takeoff.
Section III. FUNDAMENTALS OF FLIGHT

6-8. General
There are four fundamental flight maneuvers—straight and level, climbs, glides, and turns. Mastery of these fundamental maneuvers is one of the prime requisites for pilot proficiency, since any other flight maneuver is a combination of two or more of these.

6-9. Straight and Level
a. Perhaps the most difficult maneuver is straight and level flight since the pilot has to maintain a constant heading and altitude. Many factors affect the flight attitude of an airplane and continual small corrections are required.

b. In flight, the airplane must be kept steady with relationship to the horizon and its lateral, longitudinal, and vertical axes. These axes are three imaginary lines that are perpendicular to each other and pass through the center of gravity of the airplane. The airplane rolls about the longitudinal (nose-to-tail) axis, pitches about the lateral (side-to-side) axis, and yaws about the vertical (up-and-down) axis. The pilot uses reference points or instruments in the airplane to detect movement about these axes.

c. The longitudinal (or pitch) reference point for level flight is usually some portion of the nose, cowling, or even a bolt on the windshield. This reference point may not rest directly in line with the horizon in level flight, but if the variation from the horizon is clearly established in the pilot’s mind, it will serve that purpose. A relative increase of distance between the eye and the reference point permits easier and quicker notice of changed relationship between the point and the horizon. When this reference point falls below the desired relationship, back pressure on the elevator control may be required to return to straight and level flight; or, if this point rises above the established relationship, forward elevator control pressure is required. With variations of attitude caused by changes in atmosphere and power, and center of gravity, the pilot has to change the reference point or the relationship to fit the new level-flight attitude.

d. Lateral level flight is established by equalizing the distance between each wingtip and the horizon, and is controlled by the ailerons.

e. Checking the lateral axis for straight and level flight serves the additional purpose of verifying clearance of the area. This is an important safety habit for the pilot. Furthermore, the head motion eases pilot tension and lessens fixation of attention to a limited field of vision.

f. Straight flight is best achieved by establishing flight relationship with a section line,
road, fence line, or any ground reference point and the nose (longitudinal axis) of the airplane. The pilot uses ailerons and rudder to make corrections to maintain straight flight. As training becomes more advanced, direction can be determined by reference to the magnetic compass or the directional indicator.

- Cross checks with the turn/bank indicator should be made to insure that the airplane is in coordinated flight.

h. Trim tabs should be adjusted for all conditions of flight.

Note. A change to one of the three axes affects the others; therefore, additional control pressures are required for the other axes. However, in attempting to maintain straight and level flight, the aviator must not constantly alter flight controls. An airplane will roll and pitch with air turbulence, but if practicable, it should be allowed to level itself by inherent design stability. Pilot fatigue may result from constant control corrections.

6-10. Climbs

Climbs are used for ascent to a higher altitude. The type of climb that an Army aviator will most often use is normal, with other types of climbs limited to short duration only.

a. The normal climb is made at an angle, airspeed, and power which will give a desirable lift-drag ratio and adequate speed for engine cooling. Climb power settings are usually above cruise power settings. For airplanes with variable pitch propellers, rpm should be increased to climb setting prior to increasing manifold pressure/torque. The operator's manual should be referred to in determining the recommended climb airspeed, and power setting.

b. Normal climb attitude is entered from straight and level flight by the pilot applying back pressure to the elevator control. As the nose starts to rise, airspeed begins to dissipate, and power should be slowly and smoothly added to obtain climbing power and speed simultaneously. For reciprocating engine aircraft not equipped with a supercharger, continuous application of power will be required to maintain a constant setting as the aircraft climbs to higher altitudes. The aviator enters climb pitch attitude by relating reference points on the airplane to the horizon.

Note. Flight controls feel quite different to the pilot at the slower climbing airspeed, and they react to pilot pressures more slowly. In addition, airflow about the cockpit decreases in sound intensity, while engine noise increases.

c. Increased power and decreased speed result in a left turn or yaw during climb. To compensate, pressure on the right rudder pedal is required throughout the climb. If rudder trim is available by cockpit control, it should be used to relieve pedal pressure. If available, elevator trim should also be used to relieve elevator control pressure during the climb.

d. When the desired altitude is reached, the power will be adjusted to maintain the desired airspeed in level flight. This is best accomplished by starting to lower the nose of the airplane as the desired altitude is approached and by maintaining climb power. When altitude and cruising airspeed are reached, the level-off is completed by reducing power to normal cruise. When reducing power, first reduce manifold pressure/torque, then reduce rpm. Then the airplane should be retrimmed for straight and level flight at normal cruise.

6-11. Glides

The glide is used to descend to a lower altitude. The normal glide is a glide at an angle and airspeed permitting the greatest forward distance with a given loss of altitude. Refer to operator's manual to determine best glide airspeed.

a. To enter the glide from a straight and level flight, the aviator should reduce power to idle or required setting in a smooth motion. Maintain altitude until airspeed dissipates to normal glide airspeed for the particular airplane, then lower the nose to maintain that airspeed. With reduced power and airspeed, control pressures on both the elevator and rudder should be coordinated to maintain glide attitude. Without power, the airplane tends to turn to the right, and the left rudder pedal has to be used to counteract this tendency. As airspeed decreases, back pressure should be applied to the elevator control to keep the nose in level attitude. When gliding airspeed is reached, the aviator should reduce back pressure to lower the nose and to maintain gliding airspeed. Subsequent control pressures are applied only as necessary to maintain the gliding attitude. If available, trim is used to relieve pilot control pressures.

b. As in the climb, initial glide training requires reference points to maintain correct glide attitude until the ability to sense and feel the proper speed and attitude is developed.

c. The level-off from a normal glide should begin about 50 feet prior to reaching the desired altitude. At this time, the aviator should increase power slowly and smoothly to that desired. While maintaining straight and level flight, the airspeed will stabilize at an indication corresponding to the power setting. As power increases, he adjusts rudder or trim to maintain heading. After the airplane has stabilized in straight and level flight attitude, the aviator retrimms the airplane to relieve control pressures.
d. Wind affects a glide (fig 6-5) by varying ground track and distance covered. In a headwind, the glidepath will be steeper if the airspeed remains unchanged because the effective headwind will reduce the groundspeed of the airplane by the amount of that component. An airplane gliding at 60 knots into a headwind of 60 knots will have a groundspeed of zero and will make a vertical descent. By the same analysis, the same aircraft gliding with a 60-knot tailwind will have a groundspeed of approximately 120 knots and a proportionately shallower glidepath.

6-12. Turns

Turns are used to change the direction of the flightpath. Their three general classifications are shallow, medium, and steep.

a. Turns are made by inclining the airplane’s lateral axis toward the horizon by moving the aileron control as shown in green in figure 6-6. A difference of lift developed on each wing (fig 6-6) causes the airplane to bank. Actually the lift already being developed by the wing has been directed toward the desired side of turn. After the desired angle of bank is established, the ailerons should be returned to the neutral position. If the ailerons are not neutralized, the angle of bank and rate of turn will continue to increase.

b. Since drag increases with lift and the ailerons cause a difference in lift, an airplane being banked in one direction tends to yaw in the opposite direction. A slow deliberate movement of the elevator control in the direction of the turn will reduce the yawing tendency, but will considerably increase the time required to establish the bank.

c. Rudder is used to prevent yaw when entering or recovering from a bank; however, it is not used to turn the airplane. For example, if the aileron control is moved to the right, the pilot uses right rudder until the bank is established. The rudder pressure is then released and the rudder allowed to streamline (shown in green in A, fig 6-7). If bottom (inside) rudder pressure is held during the turn, the airplane will skid (shown in green in B, fig 6-7). If top (outside) rudder pressure is applied, the airplane will slip (shown in green in C, fig 6-7).

d. An airplane is correctly banked by coordinated use of ailerons and rudder. The relative use of these controls is determined by the characteristics of the particular airplane and the airspeed at which the maneuver is executed. After the airplane has been banked for a turn, the angle of bank should be held constant without skidding or slipping. This requires some adjustment of aileron, rudder, and elevator pressures, depending upon the characteristics of the airplane and its speed.
A. RUDDER STREAMLINED WITH TURN (NEUTRAL PRESSURE)

B. RUDDER INTO THE TURN, OR EXCESS TURN FOR DEGREE OF BANK—SKIDDING RESULTS.

C. OPPOSITE RUDDER, OR INSUFFICIENT TURN FOR BANK ENTERED—SLIPPING RESULTS.

Figure 6-7. Effect of rudder in turns.
Once a turn is started, the pilot begins to increase elevator control back pressure to maintain level flight. This increases the angle of attack and results in more lift, which compensates for the loss of vertical lift and for the additional weight caused by the centrifugal force of the turn (para 3-4). The amount of back pressure on the elevator control is in proportion to the steepness of the bank.

General rules cannot be set for determining, in advance, the exact amount of control pressures for a specified airplane; the pressures must be learned from actual practice.

The stalling speed of an airplane is increased in a turn because of the increase of aerodynamic load from centrifugal force. The increase of stalling speed is proportional to the square root of the load factor. Therefore, an airplane with a normal stalling speed of 60 knots will stall at 120 knots with a load factor of 4 G's (para 3-4 b).

Climbing turns generally are made with a shallow bank. With the shallow angle, the bank is not steep enough to cause the resultant of lift to drop appreciably. Normally, since airspeed is less than at normal cruise with power greater, torque tends to turn the airplane to the left. In airplanes without trim control, entry in a left climbing turn does not always require left rudder pedal; instead, a slight relaxation of pressure on the right rudder pedal will prevent skidding. In entering a right climbing turn, the pilot must increase rudder pressure beyond that of a straight climb.

Gliding turns generally should be limited to no more than a medium bank. However, if the situation requires a steeper bank, the aviator must remember that stalling speed increases as the bank increases.

Section IV. CONFIDENCE MANEUVERS

6-13. General
Most airplanes must actually be forced into a dangerous attitude, and even then, if permitted to do so, they usually will right themselves to normal flight attitude. Through practice of confidence maneuvers, the pilot gains knowledge of the airplane stability and maneuverability characteristics.

6-14. Slow flight
Slow flight serves two purposes. It teaches the beginning student that the airplane will fly with sufficient control at reduced airspeeds. For the experienced aviator, it serves as a review and coordination exercise for power approach techniques, as well as acting as a foundation for other flight activities.

a. Slow flight may be at any airspeed between normal cruise and stalling, but is usually flown about 10 knots above stalling airspeed. Pitch and power are used as necessary to control altitude.

b. Slow flight is entered by reducing power and letting the airspeed dissipate. Altitude is maintained by increasing elevator control back pressure as airspeed dissipates. When the desired airspeed is reached, required pitch and power are used to control altitude. Turns can then be executed, but the angle of bank should be very limited due to reduced airspeed. Slow flight should be practiced at various flap settings.

6-15. Stalls
An airplane will stall only when an excessive angle of attack is reached. The stall (fig 6-8) may occur at reduced airspeed or at any airspeed
following an abrupt change of attitude which causes a high load factor. When the stall occurs, the aviator must be able to recognize it as such and take proper corrective action. Practice stalls are, therefore, part of confidence maneuvers.

a. An airplane will stall at the same angle of attack without regard to pitch attitude (A, B, and C, fig 6-8). In a power-off stall (A, fig 6-8), reduce power to idle and enter a normal glide. The nose is raised approximately to the landing attitude, which is maintained until the stall occurs. At this time, the nose will drop below level flight attitude if aft pressure is released. Flying speed will be regained and the airplane will tend to assume a normal glide attitude. Throughout the stall sequence proper rudder and aileron coordination is imperative to prevent slipping or skids during recovery. If the aircraft stalls through left or right wing low, rudder application has been improper.

b. For the normal power-on stall (B, fig 6-8) power and resultant thrust require greater pitch attitude. Normally, a given pitch attitude is maintained until the stall occurs. As airspeed starts dissipating, the aviator should compensate left turn effect with right rudder and continue to increase aft pressure on the elevator control. As stall occurs and the nose starts dropping, with airspeed increasing, he should release right rudder pressure.

c. Initially, stall recovery should be effected in a positive manner by lowering the nose (decreasing angle of attack) and applying power to regain flying speed, then adjust flight controls to attain straight and level flight at cruise setting. A constant heading should be maintained throughout the recovery.

d. As proficiency in stall recognition and recovery develops, the aviator can complete the recovery with less loss of altitude. He should practice this until recovery can be made at the moment the stall occurs. As the airplane stalls, he should relax back pressure and smoothly apply full power to increase the thrust, and thereby help break the stall. However, since the aviator has minimum control (torque effects are great) and the airplane may enter unusual attitudes that are dangerous to the inexperienced aviator, this type of recovery should not be practiced until the aviator has developed some proficiency.

e. The airplane can stall in both gliding and climbing turns and these should therefore be practiced. Stall recovery is accomplished by lowering the nose to lessen the angle of attack. Then, the wings are leveled and the nose pulled back to level flight attitude. Power may be used to help execute recovery.

6-16. Spins
A high degree of proficiency is required to avoid an accidental or unintentional spin. Generally,
airplanes are designed to resist spinning. Yet, at minimum airspeed, spinning is possible by mishandling of the controls. It may occur so easily and smoothly that the inexperienced aviator detects the change only after spin entry. Little or no warning may precede this type of spin. Obviously, the ability to recover from a spin is essential to safe flying and it bolsters pilot morale and confidence.

a. Normally, the intentional spin is a maneuver in which the airplane descends in a helical path while in a stalled condition, rotating about its vertical and longitudinal axes. The nose will be pointing at some angle between horizontal and vertical, depending on the aircraft. It may be entered from either a power-on or power-off stall.

b. When the spin is entered (fig 6-9), proper pilot control to keep the airplane spinning consists of full rudder, full back elevator control, and neutral aileron control. Rudder is held toward the inside of the spin. If either rudder or elevator pressure is relaxed, the airplane normally tends to fly out of the spin.

c. Recovery from the spin is achieved by stopping the rotation and breaking the stall. Rotation is stopped by applying positive, opposite rudder. In most airplanes, the stall is broken by releasing back pressure, at which time the rudder is neutralized to avoid a skidding recovery. By slight back pressure on the stick, the airplane is eased out of the resulting dive and returned to straight and level flight. Power is added as airspeed returns to normal cruise. If the recovery from the dive is too abrupt, a secondary stall may occur, with recovery from it resulting in a further increase of airspeed and loss of altitude.

It is also possible to exceed design/ultimate load factor if the pullout from the dive is too abrupt.

6-17. Elementary Forced Landing

A forced landing may be caused by a number of emergency conditions—a partial loss of power or complete engine failure are two examples. Being constantly alert for such conditions, an aviator will be better able to meet the requirements presented by a forced landing. Through practice of simulated forced landings and associated emergency procedures, he learns to react to the situation quickly and with confidence.

a. Since glides usually are performed with little or no power, forced landings require considerable proficiency. Each forced landing, simulated or actual, has specific problems that may never again be duplicated; therefore, each requires thorough planning. The pilot must plan his landing pattern while retaining control of the airplane; thereafter, except to avoid certain disaster, he must follow the selected plan.

b. After power is reduced for a simulated forced landing, the pilot glides the airplane from the initial altitude until he can determine that the maneuver will or will not succeed. During the glide, the necessary emergency procedures must be performed to rectify the emergency condition. If it is determined that the forced landing must be continued, the airplane will be maneuvered to the desired landing area. The turn onto final approach can be modified to insure a safe altitude. The use of flaps during the glide will increase the angle of descent and shorten the ground roll. After determining the success of the simulated maneuver, the pilot should add power and the airplane will start climbing to a higher altitude.

Section V. COORDINATION EXERCISES

6-18. General

Coordination exercises vary in degree of difficulty, but together they develop and maintain proficiency in the coordinated use of flight controls. They should be practiced throughout an aviator’s career.

6-19. Banks Without Turns

a. The first of two elementary coordination exercises is that of a series of banks without letting the airplane turn, sometimes referred to as the “Dutch Roll” or control timing. Although the airplane does slip during the maneuver, the aviator develops a perceptual motor skill—the ability to perceive flight characteristics or faults and to respond instinctively with corrective action.

b. To perform this maneuver, a constant heading is maintained while the airplane is rolled back and forth from right to left banks without pause at the wings-level position. The maneuver is entered by applying either left or right aileron and rudder pedal in the desired direction of turn. As the degree of bank is reached, a reversal of the procedure is followed. Altitude is kept constant. The degree of bank may be increased progressively with skill in performance of the maneuver, or a specified degree of bank may be used. The rate at which control pressures are applied will affect the coordination of the
maneuver. Combining this maneuver with climbs and glides further develops pilot control touch, timing, and alertness.

6-20. Banks With Turns

a. The second elementary coordination exercise consists of a series of banks with turns. The bank is shallow at first, with the angle increased as proficiency develops. The airplane is allowed to turn while the pilot maintains continuous coordinated flight.

b. A reference line on the ground, normally a straight road or fence row, is chosen and the airplane flown above and in alinement with this ground line. The pilot starts the first turn in either direction and allows it to continue until the angle is approximately 45° of turn from the original heading, at which time a turn in the opposite direction is started and continued for 90° (45° from the original heading in the opposite direction).

c. The entry of the turn, or roll-in, should be smooth and steady until the desired degree of bank is attained. The change from one bank to one in the opposite direction is continuous, without pause at the wings-level position. The new turn is continued for 90° (45° from original heading in opposite direction). Altitude should be held constant, and all turns should be fully coordinated. The rollout from each turn must be lead to insure that the desired heading is not overshot.

Section VI. PRIMARY GROUND TRACK MANEUVERS

6-21. General

Much Army aviation flying is at low altitudes and requires frequent and often prolonged observations beyond the confines of the airplane cockpit. Therefore, the aviator must develop perceptual motor skills to such a degree that he reacts automatically and safely to flight requirements while keeping most of his attention on mission requirements.

6-22. Rectangular Course

The rectangular course is an elementary ground track maneuver, but even an experienced aviator may fail to fly a good rectangular course if he does not closely follow well-planned procedures.

a. An area approximately \( \frac{1}{2} \) mile square, or as close to this measure as terrain permits, with straight sides and well-defined corners is selected for the exercise. Usually the airplane is flown around this area at the established traffic pattern altitude, and away from and parallel to the sides of this area (fig 6-10) at a distance equal to the turn radius of the airplane in a medium bank. When flying crosswind, the airplane is crabbed as necessary to maintain a ground track parallel to the area sides. Each turn is started when the corner is reached, and executed so as to roll out of the turn when the corner is completed at the prescribed distance from the next side to be flown. The arc described over the ground during the turn should be equidistant from the corner at all times; together, all four turns should form a circle (fig 6-11). The bank varies on each turn, as necessary, to compensate for wind and maintain a constant-radius turn.

b. While flying the rectangular course, attention must be divided between outside alinements and control of the airplane. Ground
track should be parallel with the area sides and with altitude held constant. Roll-in and rollout of turns must be properly timed, and bank must be correctly varied to give a constant-radius turn regardless of wind direction. An aviator who thoroughly understands and is able to fly a good rectangular course has the foundation basis for flying the traffic pattern (para 6-25 through 6-30).

a. For the exercise, a straight road (or fence line) is selected which runs perpendicular to the wind, or as close to perpendicular as possible. The airplane initially is flown either into the wind or downwind to cross the road at right angles. As the road is crossed, the pilot starts a turn in either direction and continues it through 180°. The turn is timed so that the airplane crosses the road perpendicularly as the wing reaches level attitude during rollout. Then the pilot immediately starts a turn in the opposite direction and times it as in the first turn. The complete turn should make a semicircular ground pattern (fig 6-12). The speed of the airplane will determine the radius of the circle flown. Under no-wind conditions, a medium bank angle should provide the correct distance. Since bank can be controlled easier than groundspeed, it is necessary to vary the amount of bank in order to fly a semicircular ground track on each side of the road.

b. The greatest groundspeed is developed flying downwind and will require the steepest bank in the turn. Flying upwind, the opposite is true: the shallowest bank will be required in the turn.

c. Analysis of the maneuver through a complete turn will reveal that the bank begins slowly and is gradually increased throughout the initial 180° of turn. This is because groundspeed is constantly increasing. The rollout is quite fast; and, without hesitation, a new bank in the opposite direction is started with a fast roll-in to get the bank established. As this turn progresses, the amount of bank should gradually decrease since groundspeed decreases throughout the second 180° of turn. Altitude remains constant during the entire maneuver.

6-23. S-Turns Across a Road
Because wind affects ground track, proper timing of entry and exit of turns is a definite requirement for safe flying. Pilot perceptions during turns near the ground are different from those at higher altitude and can cause control errors which lead to the accidental spin. Therefore, benefits gained from the exercise of S-turning across a road are a vital part of pilot training.
6-24. Elementary 8's
The elementary 8 describes a path over the ground resembling the written number. Without wind, the maneuver is simple; with wind, the maneuver offers important training for the aviator developing perceptual motor skills and good subconscious flying habits. Figure 6-13 shows how wind affects the ground track at a constant rate of turn. There are many types of figure 8's, progressing from elementary to advanced maneuvering skills. Only one type will be described here—the elementary 8.

a. For this maneuver, select a crossroad or an intersection with one of the roads being as nearly perpendicular to the wind as possible. (Roads offer ready identification of flight position during the maneuver.) The figure 8 is flown so that two circles are tangent at the intersection and bisected by the road perpendicular to the wind (fig 6-14).

b. The maneuver normally is entered by flying into the wind over the intersection at the altitude prescribed for ground track maneuvers. As the intersection is crossed, a turn is started in either direction, with the bank varied so as to complete a circle as the intersection is again crossed. At this time, a second turn is started in opposite direction attention between flying and ground track since each turn involves 360° and a constantly changing bank.

c. The maneuver requires great division of pilot to the first to accomplish a circle on the opposite side of the road intersection. The radius of the circle flown will be determined by the speed of the airplane. Under no-wind conditions, a medium bank angle should provide the correct distance.

Figure 6-13. Effect of wind on a constant rate turn.

Section VII. TRAFFIC PATTERN

6-25. General
The traffic pattern is a method of expediting the flow of air traffic about an airfield with safety and regularity. It requires division of attention by the pilot between watching for other aircraft, attention to tower signals, and airplane control.

6-26. Description
The traffic pattern is a designated flightpath for landings and takeoffs at an airfield. Normally, this flightpath is of rectangular shape, the active runway forming one side, with all turns made to the left in forming the other three sides (fig 6-15).
Each side is referred to as a leg—takeoff, crosswind, downwind, base, and approach. The latter occurs after the last turn before landing and is called final approach. The normal pattern is flown 1,000 feet above the terrain. The first turn after takeoff may be started before reaching 1,000 feet, but should not be less than 500 feet or until the field boundary is crossed, whichever comes last. When other traffic is in the pattern, the takeoff leg may be extended to acquire adequate spacing between airplanes. The climb is continued to the designated altitude, and climb power is maintained until the airplane accelerates to the prescribed downwind airspeed. The turn from crosswind to downwind should be so executed as to place the airplane at the proper distance from the runway. Depending upon the airplane and the traffic pattern altitude, proximity to the runway may range from 1,000 to 5,000 feet, with 2,000 feet usually adequate.

6-27. Use

Entry into a traffic pattern is made by flying toward the field at a 45° angle to the downwind leg. This entry reveals the pilot’s intentions and affords excellent pilot visibility for checking the area for other aircraft in the pattern. As the downwind leg is reached just short of the field, the airplane is turned 45° to fly the downwind leg (fig 6-15).

6-28. Approach

The 180° side approach normally is used. It involves two turns of 90° each. On the downwind leg of the traffic pattern at a point opposite the point of intended landing, the pilot reduces power and establishes a descent. The turn to the base leg should be executed at an altitude that will insure that the turn to final is completed prior to crossing field boundary. The point of initiating the turn to final and the angle of bank is determined by the wind condition and the distance from touchdown.

6-29. Normal Landing

The landing is accomplished into the wind to effect a slower groundspeed at touchdown. The airplane attitude is changed from normal glide to landing attitude (fig 6-16). The rate of descent is decreased until the airplane flies parallel with the surface of the runway. This change of attitude and flightpath is called the roundout.

a. The roundout must be started and timed to attain a landing attitude, stall, and touchdown almost simultaneously. Application of elevator
NORMAL LANDING

1. LANDING MADE INTO THE WIND.

2. AIRPLANE ATTITUDE IS CHANGED FROM NORMAL GLIDE TO LANDING ATTITUDE.

3. THE RATE OF DESCENT IS DECREASED UNTIL THE AIRPLANE FLIES PARALLEL WITH THE SURFACE OF THE RUNWAY.

control back pressure increases pitch attitude and dissipates airspeed. Elevator control back pressure is continued smoothly, only with enough force to prevent the airplane from striking the ground prior to obtaining a landing attitude. At this time, the airplane should be only inches from the runway, and almost instantaneously making ground contact. Airplanes with conventional gear should be stalled simultaneously with ground contact.

b. Tricycle landing gear generally simplifies the landing; the touchdown should be made on the main gear. The nose wheel will be off the ground when the main gear touches. The location of the center of gravity forward of the two main wheels combines with the forward momentum of the airplane to help hold the airplane on the ground. It also tends to keep the airplane rolling in a straight path.

c. If the roundout is too fast, the airplane will "balloon," causing a gain of altitude. Since airspeed is dissipating, the airplane may stall at considerable height above the ground. If ballooning occurs, the pilot must compensate with a relaxing of back pressure to get the airplane back to the runway in a landing attitude before the stall occurs. This may require application of power to prevent a stall at an unsafe altitude; or, because of the lack of available landing space, the pilot may have to effect a go-around (para 6-30) for another approach.

d. If the roundout is too slow, the airplane will strike the ground while descending and either bounce back into the air, possibly damaging the landing gear, or crash. If the airplane touches the runway before reaching the desired landing attitude, with descent unchecked, it will ricochet off
the ground with results similar to ballooning. Recovery is effected with application of power.

e. The pilot must maintain directional control of the airplane after wheel contact with the runway. Ground steering is by means of rudder, steerable nose/tail wheel, and brakes. If available runway permits, the speed of the airplane is allowed to dissipate with normal ground friction and drag. Brakes are used if needed to help slow the airplane. If necessary, maximum braking can be used immediately after touchdown, gradually releasing brake pressure as speed decreases in order to prevent nosing over in conventional gear and exerting excessive weight on the nose gear in tricycle aircraft.

6-30. Go-Around Procedure

A go-around is a procedure for remaining airborne following a decision to discontinue an intended landing. Go-arounds are used when the control tower landing clearance is withheld, when for any reason the approach does not develop as planned, and as an extreme measure in recovering from a poor landing.

a. Go-arounds in a controlled traffic pattern are usually initiated upon instructions from the tower, and are limited to maintaining or regaining pattern altitude and spacing in accordance with local traffic rules. Alertness for other traffic is of prime importance.

b. The majority of go-arounds are initiated on the timely decision of the pilot, at any time prior to completion of the landing roll. Both the decision and the implementing action must be timely—a late start may result in failure to clear a barrier or an accidental stall in the climb.

c. Go-arounds frequently occur in limited or confined areas requiring an accurate awareness of airplane and pilot performance limitations. The problem is basically one of building up speed and altitude within the limitations imposed by available power; preoccupation with either factor will result in a loss of the other. Maximum performance requires a thorough familiarity with the airplane’s behavior under a variety of atmospheric conditions, flap configurations, and airspeed.

d. Generally, go-arounds are used to salvage a bounced, dropped in, or crabbed landing attempt. Such situations may involve directional control and stall recovery problems, which may consume considerable space before the climbout can be started. Serious structural damage is possible in any hard ground contact; it may be wiser to land rather than risk further flight in a weakened or uncontrollable airplane. There is no easy rule of thumb; each situation must be decided upon its merits.

e. Go-around techniques vary greatly with the airplane type, the proficiency of the pilot, and the situation in which he is placed. The following guidelines apply to the execution of the go-around:

(1) Decide—act without delay.
(2) Propeller control full forward.
(3) Smoothly advance power to desired setting.
(4) Lower the nose (a high angle of attack will further aggravate the condition).
(5) Retract flaps to climb position.
(6) Retract gear and flaps when safe airspeed is attained.
(7) Trim aircraft for climb attitude.
(8) Beware of a go-around with a disabled airplane. If this occurs, the situation will dictate the best procedure. Extent of the damage will govern whether to defer landing until a favorable area is reached. If control response is abnormal, a climb to a safe maneuvering altitude will permit detection of adverse landing characteristics while retaining the option to bail out. A call to the tower will bring expert advice and alert the crash crew.
CHAPTER 7
INTERMEDIATE FLIGHT MANEUVERS

Section I. INTERMEDIATE GROUND TRACK MANEUVERS

7-1. General
Pilot sensory perception of the airplane and trained reactions are continuing requirements on an Army aviator's skill. In this respect, ground track maneuvers must be practiced throughout an aviator's career.

7-2. Around Pylons
This maneuver primarily is designed to develop planning and sensory-type flying. Two pylons (identification points) are selected on a line perpendicular to the wind. The two pylons need not be identical, but both should be easily discernible. Trees, spires, fence corners, water tanks, etc., may be used for pylons. A symmetrical ground track is flown around the pylons while maintaining a constant altitude above the terrain. The ground track is in the shape of a figure 8; the two pylons are centered in the loops of the 8 (fig 7-1).

a. The maneuver is begun by flying downwind between the two pylons or by flying parallel to the pylons on the downwind side. After about 270° of turn, the airplane is rolled out into straight and level flight and flown between the two pylons, downwind, at about 45° to a line connecting the two pylons. As the plane approaches a point where a pylon becomes perpendicular to the flightpath, a turn is started around the second pylon. This turn is continued for approximately 270°, at which time the airplane is rolled out straight and level and flown between the pylons at about 45°, downwind, to a point where the first
pylon approaches the perpendicular to the flightpath. A turn is then started around the first pylon again. The amount of bank used in the turns varies as necessary to maintain a constant-radius circle about a pylon.

Section II. INTERMEDIATE AIR WORK

7-3. General
The maneuvers explained in this section serve a definite purpose in the career of the Army aviator in developing coordination between mind and body and providing knowledge which is helpful in everyday flying and flight emergencies.

7-4. Precision Turns—720°.
All turns should be made with precision. Turns of 90° or 180°, using shallow or medium banks, require good coordination for precision accomplishment. However, to continue a turn through 360° or 720° requires a higher degree of perfected coordination and more exact understanding of control functions. The requirement is still more pronounced if a steep bank is used.

a. A turn of 360° or 720° using a steep bank (generally 60°) is referred to as a power turn or a steep turn. Steep turns involve the use of all flight controls, generally including throttle to maintain necessary airspeed. Entry into a steep turn is like other turn entries, but it is continued until a steep bank has been established. As the bank progresses past that of medium, power is slightly increased to prevent any further reduction of airspeed. The turn is continued through 720° and rolled out on the original heading. Controls are coordinated from entry to completion of rollout to avoid slips or skids, with altitude constant.

b. Uncoordinated control pressures will show up quite readily in this maneuver. A definite increase of back pressure, in addition to increased power, is required to maintain altitude. Regaining lost altitude is a most common requirement. Excessive back pressure during the steep turn does not provide the desired gain in altitude and can result in accelerated stalls. The correct technique for altitude control requires that the bank be shallower while holding back pressure to raise the nose. A climb can be stopped, or nosedown pitch achieved, by increasing the bank while maintaining back pressure. The basic technique of adjusting pitch by changing bank, as developed during steep turn practice, is necessary to accomplish advanced oblique turning maneuvers such as chandelles and lazy eights. Precision rollout requires expert control touch. Back pressure must be released as the bank decreases, with coordinated aileron and rudder pressures. Power is reduced after normal cruising airspeed has been regained.

7-5. Spirals
A spiral is a gliding turn of 360° or more, usually at a steep bank. The two main types of spirals are the constant bank-and-speed spiral and the spiral about a point. Each type develops and helps maintain flying proficiency.

a. A constant bank-and-speed spiral helps develop control touch and coordination for power-off conditions. It is entered from a normal glide. After a steep bank is established, the spiral may be maintained for any desired number of turns. Rollout may be on a predetermined heading or altitude. Coordinated controls are used at all times during entry, spiral, and rollout, with airspeed constant. During the spiral, bank is constant.

b. In the spiral about a point the aviator selects a reference on the ground and flies the airplane to an advantageous position from which a circular ground track of about a 1000-foot radius can be entered. A normal glide is started and the airplane is banked as necessary to maintain desired ground track. Elementary-8 fundamentals are applied to this type spiral to accomplish the constant radius circle about the point. The flight controls are coordinated at all times and rollout may be on a predetermined heading or altitude. Because of ground orientation requirements the spiral about a point requires a greater division of attention than the constant bank-and-speed spiral.

7-6. Slips.
A slip is a combination of forward and sideward movement, the lateral axis being inclined and the sideward motion of the longitudinal axis being toward the lower side. Slips can be used for crosswind landings (para 7-9) and to dissipate
altitude without increasing forward speed. They are controlled by the aviator to make the airplane move sideways or to continue the initial flight-path over the ground, and may be used during a turn.

a. To establish a slip from a normal glide, the wing toward the desired direction of slip is lowered by use of ailerons. Opposite rudder is applied simultaneously to control the desired ground track, which may or may not require a change of heading. Normal gliding speed should be maintained during the slip. Due to the stress that is placed on the airplane, prolonged flight in this out-of-trim condition should be avoided.

b. Slips are extremely useful if the airplane has no flaps or if the flaps fail to function properly. Slips can be used to shorten the gliding distance and to increase the angle and rate of descent. Accuracy of landing also may be improved by use of a slip. The slip, however, is not normally used to increase approach angles in airplanes equipped with flaps.

Section III. CROSSWIND TECHNIQUE

7-7. General
It is impractical to build an airfield with sufficient runways to meet all wind conditions. When using small airfields with a limited number of runways or a strip with only one runway, proper crosswind technique must be employed.

7-8. Crosswind Takeoff

a. Proper application of controls during crosswind takeoff is necessary to maintain aircraft control. Should the airplane inadvertently become airborne from a wind gust, the pilot must maintain straight ground track by lowering the wing into the wind. In effect, the airplane is slipped into the wind only enough to offset wind drift. This results in a straight ground track parallel to the longitudinal axis and prevents a side stress on the gear if the airplane returns to the runway. After the airplane becomes positively airborne, the slip is removed and a crab is established to correct for drift and allow a faster rate of climb.

b. Use of ailerons is the same as when taxiing crosswind, with elevators used initially as in normal takeoff. Rudder is applied to maintain a straight ground roll. As the roll increases in speed, aileron pressure is decreased to prevent the upwind wing from dipping excessively at liftoff; the wing should, however, be allowed to lower sufficiently to compensate for the wind. The airplane should be held on the ground slightly longer than in a normal takeoff; this will assure its remaining airborne when it leaves the ground.

7-9. Crosswind Landing
Successful landings under crosswind conditions are largely dependent upon the aviator's ability to fly by sensory perceptions. The aviator must be able to recognize drift and make corrections. Crosswind capabilities differ with different airplanes, but corrective methods are identical. The two methods used are the wing-low and crab.

a. The wing-low method is a slip; it is accomplished by lowering the upwind wing into the wind just enough to compensate for drift (fig 7-2). The slip normally is established during the final approach. It is then maintained as necessary throughout the approach and roundout. The airplane will initially touch down on the upwind main wheel, and as speed decreases, it will settle onto the other main wheel.

b. The crab method (fig 7-3) is more difficult since better timing is needed during the roundout. The aviator maintains required crab for the wind condition throughout the final approach. Just prior to touchdown, he removes the crab and lines the airplane up with the runway. If the crab is not completely removed prior to touchdown, side loads will be imposed on the landing gear that may result in gear damage or loss of control. If the crab is removed too soon, the airplane will drift off course.

Figure 7-2. Crosswind landing—slip.
Section IV. ACCURACY LANDINGS

7-10. General
Perhaps the most demanding requirement of Army aviators is that of landing on a predetermined spot with precision, and doing it repeatedly. Proficiency in accuracy landings is mandatory as a training maneuver, and its value cannot be overemphasized for emergency landing proficiency.

7-11. Side and Overhead Approaches: 180°

a. The most commonly used approach in Army aviation is the 180° side approach (fig 7-4). Power is reduced on the downwind leg opposite the desired point of touchdown, and a glide is established for the remainder of the pattern. After power is reduced on the downwind leg, the length of the power-off approach of the downwind leg, the base leg, and the final approach should be approximately equal. However, if the downwind leg is too far from the field, the base leg must be closer in than normal. This approach, as all the others, requires accurate judgment of gliding distance for the existing wind and weather conditions.

b. The 180° overhead approach is initially more difficult to judge since it requires more turns. Power is reduced while flying downwind, directly over the point of touchdown (fig 7-5). The airplane is then turned 45° off the downwind track in either direction and this heading maintained until ready to turn onto a base leg. This turn is 135° and must be started soon enough to rollout on base leg with sufficient altitude to continue a normal approach without power. If the base leg is too close or too far from the field, the aviator must take supplementary action to accomplish the landing on the predetermined spot. This may require either an early or delayed turn onto final approach.

7-12. Overhead Approach: 360°
The 360° overhead approach is not often used for a normal landing. However, this approach is used by the aviator to maintain proficiency in glide judgment. The pattern for this approach is shown in figure 7-6. Flying in the same direction in which the landing is to be accomplished, power is reduced over the desired point of touchdown. A glide is then established for the remainder of the approach. The first turn is 135° in either direction and executed as power is reduced and the glide established. The remainder of the pattern is the same as the 180° overhead approach, the second turn being 135° to place the airplane on base leg. The base leg may then vary as necessary to...
compensate for error in judgment and to allow arrival at the point of touchdown.

7-13. Spiral Approach

The spiral approach normally is used only in the event of a forced landing. Its advantages are limited to particular situations; e.g., over swampy or wooded terrain with only one available landing area. The chance of probable error in judgment is lessened, since all maneuvering is done in the immediate vicinity of the landing area and touchdown point. The spiral, which usually is performed about the point of touchdown, can be broken off into a pattern for a normal approach from any position at the selected altitude. A steep spiral will result in a fast loss of altitude, while a shallow- or medium-banked spiral will lessen the rate of descent and give the pilot more time for continued planning and execution of the appropriate emergency procedures.

Figure 7-5. 180° overhead approach.

Figure 7-6. 360° overhead approach.
Section I. ADVANCED GROUND TRACK MANEUVERS

8-1. General
Successful completion of many Army aviation missions is directly dependent upon the aviator's ability to fly by sensory perceptions. Practice of air-ground visual perspectives helps develop this capability.

8-2. Steep 8's Around Pylons
The major principles of flying 8's around pylons (fig 7-1 and para 7-2) are the same, whether they are shallow or steep; the only difference is the amount of bank required. Steep 8's generally use a circle one-half the size of the normal 8. To lessen the amount of straight and level flight between pylons, distance between pylons can be reduced. Since the circle about the pylon is smaller, slight errors are more noticeable. Consequently, more attention must be given to the ground track. This requires a higher degree of sensory-type flying. Proper performance of this maneuver is dependent upon a reasonable degree of proficiency in the normal 8 around pylons.

Section II. ADVANCED AIR WORK

8-3. Chandelles
The chandelle is an advanced maneuver in which the airplane is flown at varying airspeed, power, bank, and pitch attitude. The maneuver normally involves airspeeds ranging from above normal cruise to just above stalling. The banks will vary with the available power of the individual airplane. The more power available, the less the bank requirement, and consequently, the greater the altitude gained. The chandelle involves a 180° change of direction; it consists of a portion of a loop in an oblique plane, followed by a climbing rollout.

a. A chandelle should not be started at an
airspeed above maneuvering speed. If normal cruising speed is approximately equal to but less than maneuvering speed, it can be started from straight-and-level flight. If normal cruising speed is less than maneuvering speed, the entry may be made from a flight descent to obtain approximate maneuvering speed. In those airplanes which cruise faster than maneuvering speed, it will be necessary to decrease the airspeed to maneuvering speed prior to entry (fig 8-1). The degree of bank will determine height of pattern, altitude gain, and power requirements. Airplanes with small power reserves must use correspondingly steeper banks than airplanes with greater reserve power. Banks too shallow for available power cause stalls due to excessive climb; banks too steep allow termination of the maneuver with excess speed. When proper bank has been established, it is held constant and back pressure is applied to start a climb. As the airplane starts the climb, it will turn and the bank will appear to steepen. Power is added as airspeed decreases in the climb. After turning 90° from the original heading, the acquired pitch attitude is held constant, and the bank is removed slowly so that, after turning another 90°, the wings are level and the airplane is in a nose-high attitude, with airspeed just above stalling.

b. At the halfway mark when the rollout is started, the power should be at maximum allowable power. After turning 180° and leveling the wings, the nose is lowered slowly for airspeed to build up to normal cruise without losing altitude. As airspeed increases, power is slowly reduced to prevent engine overspeeding. When normal cruising airspeed is reached, power must be further reduced to normal cruise. Coordination must be precise throughout the maneuver. Although the chandelle is often called an altitude-

Figure 8-1. Chandelle.

gaining maneuver, the overall net gain should not be a primary criterion for its performance. Loss of altitude during the initial dive, plus lack of required power in some airplanes, limits appreciable increase in altitude during the maneuver.

8-4. Lazy Eight
The lazy eight is an advanced coordination exercise. Unlike the chandelle, it is wholly a training exercise. For its execution, the airplane

8-2
is flown through a wide range of airspeeds and bank and pitch attitudes, with constantly varying control pressures. The lazy eight is unrelated to other 8's previously described because it does not describe a figure 8 over the ground, and ground track is irrelevant. The lazy eight (fig 8-2) is described by the projection of the longitudinal axis on the horizon and is apparent only to airplane occupants.

a. The lazy eight consists of two 180° turns in opposite directions, entering one from the other, with a symmetrical climb and dive during each turn. The only straight and level attitude during the maneuver is at the moment of passing from one turn to another.

b. To help achieve symmetrical loops in the two turns, a reference point is selected on the horizon 90° from the direction of flight (the cross in fig 8-2). During the maneuver, the lateral axis will appear to descend through the reference point as the turn is started, and the longitudinal reference will appear to descend through the ground reference point diagonally, at the 90° point of turn.

c. The maneuver is entered while flying crosswind at the established entry speed. A climb is started and a turn is begun toward the reference point. At this time, the inside wingtip (or lateral axis) will appear to pass down through the reference point. Bank is constantly increased through the first 90° of turn. After 45° of turn, the pitch attitude should start decreasing until the longitudinal axis is level after 90° of turn; the longitudinal reference on the airplane will then appear to pass through the ground reference point.

d. At this time a slow rollout is begun. The nose continues downward, entering a dive. As airspeed again builds and bank decreases, the nose will stop descending and start upward. As it passes through level flight, the wings should be level with the airplane flying 180° to the original heading.

e. Without pausing at level flight, a climbing turn is started in the same manner as in c above but using an opposite bank, and the same pattern is flown again. At the completion, the airplane will be on the same heading as when the maneuver started.

f. Throughout the maneuver, the airplane should be flown with precision. Continual small corrections usually will be required and should be made using control combinations to maintain coordination. Because of the requirement of constantly varying control pressures, practice of this maneuver develops control touch.

8-5. Precision Spins

Precision spins are essentially elementary spins, the entry and spin being executed in an identical manner. However, precision spins require better use of controls and spin orientation. The precision
spin normally requires recovery on a specific heading after a preselected number of turns, with minimum slipping and skidding during recovery.

8-6. Accidental Stalls and Spins
When an aviator fails (through preoccupation) to recognize an approaching stall in time to avert it, the resulting unintentional stall may lead to a spin. If the spin occurs near the ground, altitude may be insufficient for recovery, with the accidental stall ending in disaster.

a. Accidental stalls and spins may result from improperly executed steep turns, or from an increase in load factor and stalling speed due to an increase in bank (para 3-4). When close to stalling speed, slight application of rudder may cause an airplane to spin. If top (outside) rudder is applied, the airplane will spin opposite the direction of the turn (over-the-top); if bottom (inside) rudder is applied, it will spin in the direction of the turn (under-the-bottom).

b. Probably the most disastrous of all inadvertent spins occurs when turning into the approach leg of the traffic pattern. Being close to the ground, the aviator may be somewhat dubious of using a steep bank to accomplish the necessary rate of turn to align with the runway. He may try to tighten the turn with bottom rudder without increasing the bank. This will cause a skidding turn that leads to a violent under-the-bottom spin. Conversely, if outside rudder were used to decrease the rate of turn, a slip would result. If a stall occurred during this slip, an over-the-top spin could result. To accomplish a safe turn, airspeed must be kept well above stalling and the controls must be well coordinated at all times.

c. Accidental stalls and spins are not limited to turning situations; they may occur in any flight attitude.
CHAPTER 9
TWIN ENGINE AIRPLANES

9-1. General
Several types and models of twin-engine airplanes are now used in performing the training and the operational missions of Army aviation. This chapter primarily concerns the most prominent of those flight characteristics of twin-engine airplanes that require additional aviator knowledge and skill.

9-2. Asymmetric Thrust
Asymmetric thrust is the principal flight characteristic of multiengine airplanes that must be counteracted. To accomplish the desired stability during power changes, most single-engine airplanes have the engine positioned to allow the thrust line to pass through or near the center of gravity. In conventional twin-engine airplanes, only the resultant thrust of both engines will provide this stability. When both engines are not operating at equal power, unequal (asymmetric) thrust results and causes yaw (movement about the vertical axis). The rudder is used to prevent this movement. If yaw occurs, the airplane may also roll or bank and both rudder and aileron are required to regain level flight.

9-3. Minimum Single Engine Control Speed (Vmc)
When the critical engine (the left one of US airplanes) is inoperative and the other at takeoff power, maximum asymmetric thrust is created. When adequate airspeed is maintained, yaw can be prevented by rudder application. Below this airspeed, directional control can only be maintained by reducing power. This critical airspeed is identified for each airplane as the minimum control speed (Vmc). It is the minimum speed at which one engine can be rendered inoperative and straight flight continued with the remaining engine operating at takeoff or maximum available power. When the most critical engine is rendered inoperative and the airplane is in the most unfavorable flight configuration, Vmc assures the ability to stop a turn and maintain the new heading. Vmc applies only to the control of asymmetric thrust and does not assure that altitude can be maintained or climb accomplished.

9-4. Climbs
a. In addition to normal climbs, the airplane operator's manual establishes the best angle of
climb and the best rate of climb speeds. Climbing is by means of reserve power (the power available that is not required to maintain level flight). Under the most favorable circumstances with one engine shut down, a twin-engine airplane will not have an abundance of reserve power. Any change from the best rate and angle of climb will rapidly decrease climb performance. This means airspeed above, as well as below, the best single-engine climb speed.

b. To provide adequate power for single-engine climbs, drag should be reduced to a minimum by retracting the landing gear, positioning flaps at cruise, and feathering the propeller of the inoperative engine. The exact sequence of events is determined by the flight situation and the type of airplane. Single-engine climb speed is the most efficient single-engine operating speed. If altitude cannot be gained at this speed, climbing is not possible without obtaining more power or reducing drag or weight.

9-5. Level Flight

a. The operator's manual provides power settings and ceilings for both normal and single-engine cruise flight. The ability to maintain level flight with one engine inoperative is possible only below the single-engine absolute ceiling. This ceiling is based upon standard atmosphere, sea level conditions, with the inoperative engine at maximum continuous power, maximum gross weight, gear and flaps up, and the inoperative propeller feathered. Factors that reduce the ceiling are high density altitude or failure of the propeller to feather. Airspeed is also a factor; for example, the best single-engine rate of climb speed provides maximum efficiency.

b. An average power chart provides for cruise operation with 45 to 75 percent power. One engine alone may be required to operate above the recommended cruise range to supply the necessary power for continued flight. The loss of one engine creates an emergency, and flight should not be continued beyond the nearest suitable airfield. When operating with a single engine, trim controls usually are adequate to relieve control pressures. Some operator's manuals recommend a bank of no more than $5^\circ$ toward the operating engine during straight flight. Bank reduces the amount of rudder required to counter asymmetric thrust but results in a slip and reduced vertical component of lift. Thus, degree of bank should be confined to recommended amounts.

9-6. Descents

Usually, descent is performed at a specified power setting and airspeed that will retain minimum engine operating temperature and avoid plug fouling or engine loading. Descents made at idle power for prolonged periods should be avoided. One inch of manifold pressure for each 100 rpm is the general rule for descent power; for specific information, consult the engine power charts in the operator's manual. Due to the low power requirements involved, en route descents with one engine inoperative present no problems. However, descent for landing is more involved and requires some precaution to avoid undue hazard.

9-7. Approach and Landing

a. Approach speeds vary with airplane configuration and the type of approach. The operator's manual and pilot's checklist supply this information. When both engines are operating normally, no special technique or skill is required; however, performing the approach and landing with one engine inoperative demands more skill and judgment. When possible, normal patterns and speeds should be used for single-engine approaches. Speeds above $V_{mc}$ should be maintained during approach and landing or during go-around to preclude loss of directional control if high power settings are used.

b. If rudder trim has been used to counteract asymmetric thrust, retrim to neutral during the approach following power reduction.
CHAPTER 10
TACTICAL FLIGHT TRAINING

SHORTER LANDING FIELDS
REQUIRE MORE PRECISE TOUCHDOWN POINT.

Section I. SHORT FIELD AND ROAD STRIP TECHNIQUE

10-1. Power Approach

a. The power approach is used to accomplish touchdown accuracy and the shortest safe ground roll. The shortest safe ground roll is accomplished by maintaining the slowest speed during the approach that is required to provide a safe margin above stalling. This airspeed will vary with different airplanes, loads, and weather conditions (e.g. temperature, relative humidity, and density altitude). To assure minimum safe airspeed consistent with prevailing conditions, an appropriate pitch attitude should be established. This attitude is the highest pitch attitude which would sustain controlled flight with power removed, and commonly is referred to as “power approach” attitude. Use of attitude rather than airspeed allows the pilot to devote his attention outside the cockpit, yet provides for immediate recognition and correction of error on the glidepath. The angle of descent is controlled by the pitch attitude and the airspeed is controlled by the throttle or power lever.

b. There are many important factors to be considered by a pilot before landing in short, strange fields. Two of these are—

(1) Touchdown point. The touchdown point is the place on the ground selected by the pilot on which to land the airplane. It should provide maximum usable distance for the ground roll after landing. If barriers exist at the approach end of the landing area, the point of touchdown must be far enough away from the barriers to provide a safe approach angle over them.

(2) Go-around point. The go-around point is a point selected by the pilot from which either a safe landing roll or a safe go-around can be executed. Its location will vary from a position on final approach prior to the touchdown point to a place farther down the landing area beyond the touchdown point, depending upon the wind, barriers, and length of usable strip.

c. The power approach may be started from any position. Usually a normal glide is used until the airplane is on the required glidepath, then the power approach is started. If the approach is made to an open touchdown point, the pilot must visualize the proper glidepath and maintain it. If there is a barrier at the approach end of the landing area, the pilot can use the sight picture method to help visualize and maintain the
glidepath (A and B, fig 10-1). When operating in a high threat environment, the aircraft should be flown at a low altitude; therefore, the pilot must plan the approach before the landing site comes into view. The situation requires that the pilot slow the aircraft and employ slow flight techniques before arriving over the touchdown point.

**Figure 10-1. Barrier sight picture.**
d. The roundout is started at the same point as in a normal poweroff approach, but is executed more gradually since less change in pitch attitude and airspeed is required. Due to the slow speed at this point, a low, abrupt roundout should be avoided. It is started in sufficient time to simultaneously stop the descent, attain the landing attitude, and make ground contact at the touchdown point. To prevent the airplane from floating, power reduction is started simultaneously with roundout; but it should be slow enough to prevent early stalling. Normal crosswind technique is used as required. After touching down, brakes are applied as necessary. If severe breaking action is necessary, brake pressure should be applied immediately after touchdown.

10-2. Maximum Performance Takeoff

a. The maximum performance takeoff is designed for takeoffs from small, rough landing areas with minimum ground roll. Maximum permissible power is used. The throttle is advanced while holding the airplane in the takeoff position with brakes until maximum permissible power is reached. Ground roll begins by releasing the brakes; directional control is accomplished by use of the tailwheel or nosewheel and rudder. Further use of brakes is avoided except for emergencies.

b. The takeoff is made in a tail-low attitude. After leaving the ground, pitch attitude may be increased to achieve the maximum angle of climb for clearing a barrier. Once the barrier is cleared, a normal climb is assumed. If there is no barrier, normal climb is assumed after the airplane becomes airborne. Crosswind control is the same as in a normal takeoff. After becoming airborne, the slip is removed and a crab is established to maintain runway alinement.

10-3. Flight Reconnaissances

Since much of the flying required of Army aviation is from unprepared strips, some of which may have other uses, the aviator must be sure that the strip is in usable condition before attempting a landing. This is determined by means of a thorough reconnaissance, which is divided into two phases—high and low. To prevent disclosing the location of the strip, these reconnaissances must be made at minimum altitude commensurate with safe, accurate observations and with as few passes as possible.

a. High Reconnaissance. During the high reconnaissance, the strip is surveyed as accurately as possible, checking its length, slope, direction, obstacles (on the ends or sides), and available forced landing areas (for both landing and takeoff). After considering these facts the directions of landing and takeoff are tentatively selected, and tentative points of touchdown and go-around are chosen. The direction and area of flight for the low reconnaissance is also selected. If the strip is on a road, particular attention must be given to ditches, culverts, bridge and culvert abutments, power and telephone lines (either parallel to or crossing the strip), and road signs which a wing or strut might hit. Traffic on the road must also be considered. No particular flight pattern or altitude is prescribed for the high reconnaissance.

b. Low Reconnaissance. The low reconnaissance normally is made in the same direction as landing and takeoff. However, in all cases, the low reconnaissance will be made in the safest direction that allows suitable observation of the strip surface. The altitude (B, fig 10-2) and flightpath (A, fig 10-2) for the low reconnaissance is such that the pilot is able to see all of the strip. Altitude should provide a safe margin above the highest obstacle in the flightpath. Where to fly the low reconnaissance is governed by such factors as wind, forced landing areas, and obstacles. It is generally best to select a flightpath that will allow observation with a minimum of obstructions to vision at the lowest possible altitude. During the low reconnaissance, the surface of the strip is inspected for suitability of use (watching for holes, rocks, stumps, or anything else that may prove hazardous to a landing). If it is an area strip with more than one possible landing lane, only that portion of the area selected for the landing should be scanned; the remainder of the area can be better evaluated after landing. Discoveries during the low reconnaissance may necessitate changes to the original plan of landing. Newly discovered features must be analyzed, alternate possibilities weighed, and a sound decision made promptly in order to eliminate unnecessary flying about the selected landing site.
10-4. Ground Reconnaissance

A ground reconnaissance is performed to determine the operational capabilities of the strip, with primary emphasis on safety details. Taxiing on the strip is avoided, except under the direction of ground personnel or after completing a thorough ground inspection. During the ground reconnaissance, such details as length and width of usable strip, condition of the surface of the entire strip, location and type of barriers, and overall size for operational requirements must be considered to determine the feasibility of using the strip. If immediate takeoff is contemplated, wind direction is checked and takeoff direction confirmed. The best position for take-off is selected and the takeoff lane doublechecked for safety. Ground reconnaissance of road strips also includes checking ditches, culverts, lateral clearance, and turnaround areas.

Section II. NIGHT OPERATIONS

10-5. General

a. Operations in a high threat environment cannot be restricted to daylight periods only. Safe operations at night can be accomplished with adequate training and detailed pre-mission planning. However, night flying is physically more demanding and requires that greater emphasis be placed upon the physiological needs of the aviator to include rest, food, and physical exercise.

b. During the training phase, precautions should be undertaken to assure the psychological readiness of the aviator to cope with night flight. A positive training program should instill aviator confidence in his own ability to conduct night flight; motivate his interest so as to increase his flying skill; and eliminate distractions from the learning process. A positive approach to training for night operations will steadily increase the aviator’s learning rate.

c. In the forward areas, Army aircraft must be capable of landing and taking off with minimum lighting on the aircraft and on the ground. Therefore, training should be conducted using minimum lighting with training progressing from normal lighting to minimum lighting as the aviator increases his proficiency. When conducting this training, maximum use should be made of night vision devices.

d. Because potential enemies have sophisticated air defense weapons capable of detecting and engaging aircraft well beyond the
FEBA, fixed wing aircraft will be required to fly nearer the ground. An effective tactic to deny the enemy the ability to visually, optically, or electronically detect or locate the aircraft involves the employment of the aircraft in such a manner to utilize the terrain, vegetation, and manmade objects. This tactic is known as “terrain flying” and involves a constant awareness of the capabilities and relative position of the enemy weapons and detection means in relation to available masking, terrain features, and flight route. Of the flight techniques associated with terrain flight, only contour and low level are suitable for use by fixed wing aircraft in the high threat environment. Training should be conducted in these techniques, both with the unaided eye and with vision aids (AN/PVS-5 goggles).

10.6 Night Vision

a. To attain total night adaptation, the human eye requires about a 30 to 45-minute period of adaptation to darkness. This adaptation may be accelerated by remaining in a red-lighted area or by wearing redlensed goggles for a period of time prior to conducting a night flight. Once achieved, night vision should be carefully preserved; even a brief flash of bright light destroys the adaptation. If a pilot is exposed to a bright light, he should close one eye to preserve its dark adaptation. Cockpit lighting should be kept to a minimum; therefore, the pilot must have a thorough “blindfold” knowledge of the cockpit.

b. Because of the structure of the eye, central vision used during the daylight hours becomes less sensitive during the hours of darkness, resulting in a relative blind spot of 5° to 10° wide. For this reason, if an object is viewed directly at night, it may not be detected, and if detected, it will fade more rapidly. To compensate, the aviator must view objects by looking 10° above, below, or to the side in order to perceive the image. This technique is called off-center viewing.

c. Under certain conditions, the visual sense (which is normally the pilot’s most dependable sensation) can be adversely affected by vertigo, with possible loss of orientation.

d. Lack of oxygen is harmful to night perception. It is recommended that supplementary oxygen be used on night flights above 4,000 feet msl.

e. General physical condition affects night vision. Fatigue, excessive smoking or drinking, and poor eating habits reduce night vision capabilities.

f. Windshields and windows should be clean, clear, and free of scratches.

10.7. Airfield Lighting

a. In general, airfield lighting includes runway lighting, approach lighting, taxiway lighting, obstruction and hazard lighting, beacons, lighted wind direction indicators, and special signal lights. The colors and configurations have been generally standardized on an international scale, with no essential difference between fixed and temporary installations. The basic color code is as follows:

(1) Blue—taxiway lighting.
(2) Clear (white)—the sides of a usable landing area.
(3) Green—the ends of a usable landing area (threshold lights) and, when used with a beacon, a lighted, attended local airfield.
(4) Red—hazard, obstruction, and nonlandable area.
(5) Yellow—caution, and when used with a beacon, seaplane base.

b. Runway lighting is divided into two classes: (1) high intensity for IFR operation and (2) medium intensity for VFR operation. Taxiway lights may be supplemented by reflectors.

c. Approach lighting may be used on the primary approach of those airfields intended for instrument flying and all-weather operation. Approach lighting is used only at installations providing precision instrument approach facilities.

d. Special signal lights are used to convey instructions to aviators during radio silence. The following signal lighting is currently used at some military airfields and at civil airfields:

(1) Flashing lights to outline the wind indicator mean that the weather is below VFR minimums.

(2) A flashing amber light on top of the tower, adjoining building, or in the center of a segmented circle means that a clockwise flow of traffic is in effect.

e. Standard lighting (which may include use of floodlights) is used for initial night training. Such training is conducted on permanent airfields that provide an approach angle ratio of 50 to 1. Advanced night training is conducted on sod fields with expedient lighting arranged similar to Army Supplementary Airfield Lighting Set No. 24, as field configuration permits. Length of the lighted portion of the runway usually is restricted for training purposes, and usually a glide slope indicator is not used.

(1) Traffic is controlled either by radio or standard signal-light gun.

(2) Tactical night training may be ac-
accomplished with expedient lighting in areas considered operational but not meeting prescribed glide angle approach clearance. Theater-of-operations portable lighting systems (Set No. 6 and Supplementary Set No. 24) are explained in TM 5-330.

10-8. Night Flying Considerations

a. The pilot should be thoroughly familiar with the airplane, its lighting system, and emergency equipment. A red-filter flashlight should be carried within easy reach in case of lighting failure.

b. All position lights and the battery-generator system must be checked for correct operation. If improperly positioned or too bright, cockpit lights may interfere with outside vision by reflecting against the glass of the cabin enclosure. The position lights should be turned on prior to starting the engine and remain on during engine operation.

c. Night taxiing should be slow and executed with extreme care. Landing lights should be used for clearing and orientation only as necessary. Landing lights may blind other aviators as they are approaching to land. Taxi lights should be used instead of landing lights to reduce the amount of light being emitted.

d. Distance judgment at night is deceptive. For takeoff, the aircraft should be lined up carefully with the runway lights and normal takeoff techniques used. For takeoff from a field without runway lights, a light should be positioned at the upwind end of the field to provide the aviator a reference point for alignment and distance. Normal takeoff procedures should be used avoiding premature lift off or prolonged ground roll. Flight instruments should be cross-checked during initial climb to avoid disorientation until a safe altitude is reached and visual references become discernable.

(1) Due to the deception involved in estimating distance, altitude, and speed at night, the approach and landing require more caution than during daytime operations. The night traffic pattern is the same traffic pattern as used for the type of aircraft in day operations.

(2) If obstruction lights are available, the pilot may use them in conjunction with the threshold lights to establish a sight picture during landing approach.

(3) In the absence of obstruction lights, runway lights provide limited aid in judging the approach angle. If the terrain is level and the lights are spaced at a known interval, the problem is simple. Rolling terrain or nonstandard light spacing makes the angular reference unreliable. In such cases, the aviator can sometimes take advantage of other reference points in the vicinity of the approach area.

e. Landing lights may be used to aid in seeing unlighted obstructions, although their use may restrict vision during conditions of poor visibility caused by haze, smoke, etc., and their range may be insufficient for the aviator to perceive an obstruction in time to avoid it. The glide angle indicator light is the most accurate and reliable means of approach-angle indication; however, aviators are cautioned not to stare at this light as this can cause an illusion and loss of perspective.

f. Night landings can be accomplished using normal approach and landing techniques; however, even the most experienced aviator may error in depth perception. The standard procedure involves use of power during the landing flare to maintain minimum flying speed until touchdown. The initial approach may be with power, but care must be exercised to avoid an unsafe airspeed. The use of power is essential during dark field landings when ground surface is not visible. It is an effective safeguard against errors in judgment and perception even on lighted fields. The best night technique is to maintain speed above stalling with power until the wheels touch, thereby avoiding sole reliance on vision.

g. The fading or disappearance of an area of lights is usually a symptom of deteriorating weather. A halo-like glow at the wingtip position lights is an indication of decreasing visibility.

h. The rotating anticollision light (Grimes light) can induce flicker vertigo when reflected by the propeller disc or by hazy or smoky atmosphere; dizziness and nausea may result.

i. Disorientation happens to the best pilots. An orderly plan for reorientation, based on all the available aids, should be formulated in advance. Thorough knowledge of the area, availability and use of up-to-date navigation charts, use of radio navigation aids, and requesting assistance from ground radio stations and other aircraft may be used to reestablish orientation.

j. Fuel and engine gages must be checked regularly. Cockpit illumination should be kept low. A vigilant watch for other aircraft must be maintained.

k. High approaches seldom result in anything more serious than a go-around. Low approaches often fail to reach the runway.

l. Practice of landings and takeoffs under minimum lighting conditions increases proficiency in night flying operations.
Section III. EMPLOYMENT OF EVASIVE MANEUVERS

10-9. Threat and Survivability

a. The encounter of a sophisticated enemy air defense system constituting a high threat environment can be anticipated on future battlefields. This system will include weapons ranging from individual heat seeking antiaircraft weapons to radar controlled surface-to-air missiles. The component weapons of this system will be deployed in depth throughout the enemy area. The emplacement of the various weapons of the system will be arranged so that the fields of fire overlap. This overlapping of fields of fire will result in almost continuous coverage of the enemy area from the surface to an altitude of several thousand feet. Additionally, the emplacement of the various weapons will insure overlapping coverage of the battlefield from behind the friendly FEBA to the enemy rear areas by target acquisition equipment and visual observation.

b. When operating in a high threat environment as described above, survivability becomes a decisive factor in planning all aviation missions. Survivability in this type environment depends on avoiding detection and preventing tracking by electronic, visual, or optical means. These two requirements of survivability can best be met by fixed wing aircraft employing the tactic of terrain flight. (For a discussion of terrain flight, see para 10-5d.) Low level flight and contour flight are the only techniques of terrain flight suitable for use by fixed wing aircraft in a high threat environment. These techniques are discussed in paragraphs 10-10 through 10-12.

c. In addition to the threat posed by enemy activity on the FEBA, fixed wing aviators will encounter hazards caused by friendly ground forces—the primary users of the forward airspace. These hazards include direct and indirect fire, low level air defense systems, drones, other aircraft, nuclear fire, and communication wire.

10-10. Low Level Flight

Low level flight is conducted at a selected altitude at which detection or observation of an aircraft or the points from which and to which it is flying is avoided or minimized. The route is pre-selected and conforms generally to a straight line and a constant airspeed and indicated altitude. This method is best adapted to flights conducted over extended distances or periods of time.

10-11. Contour Flight

Contour flight is flight at low altitude conforming generally, and in close proximity, to the contours of the earth. This type flight takes advantage of available cover and concealment in order to avoid observation or detection of the aircraft and/or its points of departure and landing. It is characterized by a constant airspeed and a varying altitude as vegetation and obstacles dictate. In contour flight, the aviator must be constantly alert for obstructions. Precarious flight positions, such as abrupt pullups and excessively steep banks, should be avoided; and care must be taken not to lower a wing into ground obstructions, even in shallow banks. Although valleys offer good concealment from enemy observation, if the area is unfamiliar the aviator must assume that wires are strung between the hills. An identical assumption must be applied to any inviting gap between ground obstructions. Thorough flight planning should take into consideration possible obstructions along the route.

10-12. Contour Approach

Advantages gained from contour flight may be lost if a normal approach pattern is used in the landing. The contour approach is employed to offset this disadvantage. For this type of approach, a preplanned avenue of approach should be used taking advantage of available cover and concealment by the terrain along the approach path. The approach should be flown at normal contour airspeed until arriving in the near vicinity of the landing area, at which time the airspeed should be reduced to allow a landing without overflying the landing area. When the touchdown point is in sight, power should be further reduced and the approach made using the power required to maintain obstacle clearance. This technique takes advantage of low exposure time to enemy observation.

10-13. OV-1 Mohawk Airplane Operations in a High Threat Environment

a. Penetration Missions. When operating airplanes in a high threat environment, the flight from the base airfield to a point just prior to the target area should be flown at low level altitudes. As necessary, the aviator should increase his altitude to that required to accomplish the mission. After the mission has been accomplished, he should return to contour altitude and return to his home base by a different route from the one use enroute to mission site.

b. Non-penetration missions. The aircraft will standoff outside the enemy air threat envelope to accomplish SLAR imagery missions. To obtain
oblique photography of 30 or 60 degrees, it will be necessary to work in the vicinity of the FEBA. However, penetration may not be necessary.

10-14. Use of Aerial Maneuvers
If attacked by enemy aircraft or ground fire, the only effective evasive action for the Army airplane is for the pilot to make rapid changes in altitude and/or direction (e.g., climbs and steep diving turns) as altitude and airspeed permit. Caution must be exercised to avoid obstructions and a high speed stall during the pullout. A turn toward the attacking aircraft or missile will reduce the closure time and increase the rate of change of the attack angle of the attacking aircraft or missile and be an advantage for the slower Army airplane.
APPENDIX A
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APPENDIX B
BASIC PHYSICAL LAWS APPLICABLE TO AERODYNAMICS

Section I. PHYSICAL LAWS

B-1. General
An aviator does not need to know all physical laws related to aerodynamics as does an aeronautical engineer. He must, however, have some knowledge of these laws to understand aerodynamics as applied to his airplane and its control. This knowledge is best gained through application of basic laws to demonstrate how forces which affect the airplane or its various parts cause specific actions and reactions in flight.

B-2. Force, Pressure, Work, and Power

a. Force. Force is the effect of any action which changes the state of motion or position of a body; i.e., any action which tends to produce, retard, or oppose motion. A force has three characteristics—magnitude, direction, and point of application. It may be referred to as a push or a pull on a body that tends to produce motion or equilibrium. For example, an airplane in straight and level flight is acted on by the lift force of the wings opposed by the downward force of gravity and the thrust force of the engine opposed by the drag force of air resistance. When these forces are balanced, the airplane is in equilibrium and moves ahead at constant speed with no acceleration.

b. Pressure. Pressure is force per unit of area and usually is measured in pounds per square inch. For example, if the base of a suitcase has an area of 100 square inches and weighs 100 pounds, the pressure of the suitcase on the area will be 100 pounds divided by 100 square inches, or 1 pound per square inch.

\[ \text{Pressure} = \frac{\text{Total Force}}{\text{Area Acted Upon}}; \quad F = \frac{P}{A} \]

c. Work. Work is the exertion of a force over a given distance expressed in foot-pounds. The time required to do the work is not a consideration. For example, if a 50-pound weight is raised 10 feet, 500 foot-pounds of work has been accomplished.

\[ W = F \times D \]

Likewise, if a roller is placed under the weight so that only 15 pounds of force is required to move it along the floor, 150 foot-pounds of work is done in moving it a distance of 10 feet.

d. Power. Power is work accomplished in a given time, and is expressed in foot-pounds per second.

\[ \text{Power} = \frac{\text{Force} \times \text{Distance}}{\text{Time}} = \frac{\text{Work}}{\text{Time}} \]

Power is also equal to force times the velocity at which it moves. Horsepower is an arbitrary unit of power equal to 550 foot-pounds per second.

B-3. Energy
Energy is the ability to do work. It is measured in the same units as work and is of two types—potential and kinetic.

a. Potential Energy. Potential energy is that stored energy in a body which may be released to do work at some future time. Bodies containing potential energy are a suspended weight, water stored behind a dam, gasoline or a storage battery (chemical energy), and compressed air or other gas (pressure energy). A suspended weight of a 2,000-pound airplane at an altitude of 2,000 feet above the terrain contains 4,000,000 foot-pounds of potential energy.

\[ E = W \times D \]

b. Kinetic Energy. Kinetic energy is energy of motion and refers to the ability of a body in motion to do work on another body. If the 2,000-pound airplane in a above is moving at the rate of 160 feet per second, it also possesses 800,000 foot-pounds of kinetic energy due to its motion.

B-4. Speed and Velocity
Speed and velocity are frequently used interchangeably, but in aerodynamics they are distinguished. Speed is determined by distance traveled in an interval of time, regardless of direction. Velocity is speed in a certain stated direction; it is the amount of displacement of a body divided by the time required for this displacement.

B-5. Acceleration
Acceleration is the change in velocity per unit of time. It results from unbalanced forces acting on
a body. For example, the downward force of gravity acting on a ball falling in space accelerates it at a rate of about 32 feet per second (disregarding air friction).

B-6. Laws of Motion
Newton's three laws are inertia, acceleration, and action-reaction.

a. The first law (inertia) states that a body at rest will remain at rest, and a body in motion will remain in motion at the same speed and in the same direction until affected by some external force. Nothing in nature starts or stops without an outside force to bring about or prevent this motion. Hence, the force with which a body offers resistance to change is called the force of inertia.

b. The second law (acceleration) asserts that the force required to produce a change in motion of a body is directly proportional to its mass and the rate of change in its velocity. Acceleration may be due to an increase or a decrease in velocity, although deceleration is commonly used to indicate a decrease.

c. The third law (action-reaction) states that to every action there is an equal and opposite reaction. If an interaction occurs between two bodies, equal forces in opposite directions will be imparted to each body.

Section II. VECTORS

B-7. Vector and Scaler Quantities
A vector quantity is a graphic representation of a force and shows both the magnitude and direction of the force. Velocity is a vector quantity. It specifies a certain amount of speed in a certain direction. Speed is called a scalar quantity (point of a scale) since it represents only magnitude. When an object is being acted upon by two or more forces, the combined effect of these forces may be represented by the use of vectors. In representing a vector quantity, a directed line segment with an arrow at the end is used. The arrow indicates the direction in which the force is acting. The length of the line segment in relation to a given scale represents the magnitude of the vector. The vector, therefore, is drawn in relation to a reference line. The magnitude is drawn to whatever scale is most convenient to the specific problem (fig B-1).

Figure B-1. Vector diagram.
B-8. Vector Solutions

Individual force vectors are useful in analyzing conditions of flight. In the air, the chief concern is with the resultant, or combined effects, of the several component forces acting on an airplane. Three methods of solving for resultants are—

a. **Parallelogram.** A parallelogram contains two vectors, and lines are drawn parallel to these vectors to determine the resultant mean. When two tugboats are pushing a barge with equal force, the barge will move forward in a direction that is a mean to the direction of both tugboats (fig B-2).

![Figure B-2. Resultant by parallelogram.](image)

b. **Polygon Vector Solution.** When more than two forces are acting in different directions, the resultant may be found by using a polygon vector solution. In the solution shown in figure B-3, one force is acting at 090° with a force of 180 pounds; second force is acting at 045° with a force of 90 pounds; the third force is acting at an angle of 315° with a force of 120 pounds. To determine the resultant, draw the first vector from a point beginning at 0 (fig B-3) and follow it with the remaining vectors, consecutively. The resultant is drawn from the point of start (a) to the ending of the final vector (C).

![Figure B-3. Resultant by polygon.](image)

c. **Triangle of Vectors.**

(1) A triangle of vectors is a simplified and special form of a polygon vector solution which involves only two vectors and their resultant. It is the most commonly used vector solution in navigating.

(2) To form a triangle of vectors, draw two vectors and connect them with a resultant line of vector. In this way, calculations may be made for drift and groundspeed. In figure B-4, an aircraft is heading 078° with a true airspeed of 100 knots. Wind direction is from the northeast at 30 knots. By drawing a vector for each of these known velocities and drawing a connecting line between the ends, a resultant velocity is determined.

![Figure B-4. Resultant by triangulation.](image)
APPENDIX C
CARE AND USE OF THE PARACHUTE

C-1. Introduction
The aviator should be thoroughly familiar with the various items of flight equipment before he starts flying, especially those items that are provided for his safety. One of the most important is the parachute. Most of the personnel parachutes used by Army aviators are of the back (A, fig C-1) and chest (B and C, fig C-1) types, each of which has a 28-foot canopy. The airplane to be flown will dictate the type of parachute to be used; however, the back pack is the most common. Without a thorough knowledge of WHEN, WHY, and HOW to use the parachute, it will be of little value as an item of safety equipment.

C-2. Back-Pack Parachute
The back-pack parachute (fig C-2 and C-3) has five main components—

A - BACK PACK (COMPLETE)
B - CANOPY PACK (CHEST)
C - HARNESS AND PADDING (CHEST)

Figure C-1. Back and chest pack parachutes.
the pack. Without the pilot chute, canopy opening would be slow and the wearer's body might become entangled in the canopy and suspension lines, thereby fouling the chute and rendering it useless.

c. **Main Canopy.** A drag-producing fabric surface that is deployed to slow the descent to the ground; it is secured to the risers by suspension lines. The parachute canopy is of high grade silk, nylon, or pongee. An air vent is provided at the top of the canopy to help steady the parachute as it settles toward the earth. Without this vent, oscillations would be great and, for the most part, uncontrollable.

d. **Risers.** Fabric straps that are secured at one end to the canopy suspension lines and at the opposite end to the harness. Risers control the rate and direction of descent.

e. **Harness.** That part of the parachute that fits about the body. The harness is constructed principally from type XIII nylon webbing. It can be adjusted to the individual's body with straps, buckles, and fittings. Most of the metal used for the hardware is made from cadmium-plated chrome nickel steel or from polished stainless steel.

### C-3. Inspection

Each time the aviator receives a parachute, he should perform a routine inspection of it, just as he performs a preflight inspection of an airplane. This general inspection will indicate whether the chute is in proper condition for use. All visible components of the parachute which may be inspected without opening the pack are inspected, such as webbing, canvas, and hardware. The following checks will be as complete as possible:

a. **Date of repack must be noted.** Parachutes must be repacked at intervals of 120 days.

b. **External condition of the pack and harness assembly must be checked.** (Fig C-2 and C-3) for defects or deterioration, the stitching and webbing for damage, and the metal fittings for cracks or rust.

c. **Elasticity and attachment of pack opening bands must be checked.**

d. **Ripcord pin protector flap must be opened (Fig C-3) and ripcord pins checked for proper seating in the cones.** Also pins must be checked to insure that they are not bent or corroded.

e. **For back-pack parachutes, the harness webbing must be grasped at a point on the lift web just beyond the ripcord grip pocket and pulled against the weight of the pack assembly.** Check that pins are not withdrawn by excessive stretch or improper location of the ripcord.
housing; ripcord housing must be checked for dents or breakage.

f. The ripcord grip handle pocket should be checked to see that the grip is held securely and protruding enough to be readily accessible. Also check that removal of the grip is not obstructed by misplaced hand stitching.

g. The canopy release should be inspected for smooth operation and for damage.

h. Upon completion of the inspection, a checkmark should be made in the routine inspection column of the DA Form 10-42 (Army Parachute Log Record), complete the date column, and sign your last name along with your organization in columns provided in the log book. This form has been superseded by DA Form 3912; however, it should be used until the supply has been exhausted.

Note. If, as a result of these checks, conditions are found that indicate a need for repairs or a more thorough inspection, return the parachute to a parachute maintenance shop for complete repair and inspection, regardless of date of last repack.

C-4. Fitting

a. **Tightness of Harness Fit.** After determining that the parachute is serviceable, it should be fitted to the individual who will wear it. When all buckles are fastened, the harness should fit snugly in standing position (fig C-4).

![Figure C-4. Front view of individual wearing back-pack parachute.](image)

b. **Strap Adjustment.** For safety reasons, chest and leg straps should be adjusted properly. The chest strap should be snug to prevent the buckle from slapping the user in the face when the chute opens. The main lift web has a chest strap adjustment and a main sling adjustment (fig. C-4). The front of the harness webbing has main sling index numbers on it (fig C-4). Normally, these numbers can be used as a reference for harness adjustment; i.e., the smaller the number the taller the individual, and the larger the number the shorter the individual. However, if the diagonal back straps (fig C-2) have been adjusted abnormally before you receive the parachute they will also require adjusting. These straps are easily adjusted and permit the user to make a last minute, quick adjustment before bailout.

C-5. Bailout Precautions

Over good terrain, it may be as safe to execute a forced landing as to bail out. This is because of the maneuverability and short field performance of airplanes used in Army aviation. However, there will be times when it is safer to bail out, such as engine failure during night or weather flying, structural failure, or a major fire. If an emergency should develop requiring a bailout, the aviator should make the decision to do so and stick to it. After deciding to bail out, certain precautions should be taken to minimize the possibility of injury. Ability to take precautionary measures will vary, of course, with the time available for bailout and with the degree of flight control. If the airplane is not controllable, exit must be accomplished in the best way the situation will allow. The aviator tries to push himself clear of the airplane and to be sure he actually is clear before pulling the ripcord. The following precautions should be observed to the extent practicable:

a. Slow and trim the airplane as much as possible.

b. Tighten the parachute harness.

c. Disconnect the flight helmet cord.

d. Jettison the door.

e. Release safety belt and shoulder harness.

f. Dive outward and rearward, being careful to avoid catching the parachute pack on anything as you leave the cockpit.

g. When completely clear of the airplane, firmly pull the ripcord, being sure the cord clears the housing completely.

C-6. Opening Shock and Descent Precautions

A few precautions can be observed to lessen the opening shock and make the descent as uneventful as possible. These precautions are as follows:
a. Keep feet together and bend the head forward, putting chin hard on chest. This will prevent or lessen injuries which might be inflicted by the opening shock.

b. After the canopy has opened, look up at it. If any of the suspension lines are twisted or across

\[\text{the canopy, manipulate the lines by pulling in an effort to correct the fault.}\]

c. Slow oscillation during descent is quite normal. Observe drift as quickly as possible, then try to turn to face the direction of drift (fig C-5). It will then be possible to see the terrain that will be landed on.

d. It is possible to control the direction of descent to some extent by slipping the chute. To slip the chute, pull the risers on the left or right, as appropriate, to cause slipping in that direction. Slipping the chute should be employed only to miss trees, powerlines, or water—if the occasion allows. It should not be attempted near the ground.

e. Approximately 100 feet from the ground, determine direction of drift and slip in the opposite direction one time (into the wind). Lock the risers to chest and press elbows to sides. Keep head down, chin on chest, and eyes open. Keep feet and legs together, knees unlocked, and balls of the feet pointed slightly towards the ground. Maintain moderate tension in the legs since they must absorb a major portion of the landing shock.

f. Absorb the initial impact on the toes, and then start a fall to the side to allow the rest of the impact to be absorbed by the calf of the leg, thigh, hip, and shoulder. Keep the head down and tension on the neck throughout the fall to keep the head from snapping back and hitting the ground. If there is a high wind, activate the canopy release after contracting the ground to prevent being dragged across the ground. If the releases malfunction, try to get up and run around behind the canopy. If one release functions, the canopy will spill itself but it may drag the parachutist a short distance before it does.

g. If it is impossible to miss trees or foliage during descent, keep the feet and legs tight together, and cover the face with the arms before entering the trees (fig C-6). Be sure a safe descent to the ground can be made before slipping out of the harness.

h. If it is necessary to land in water, activate the canopy release upon touching the water; then start swimming upwind to prevent entanglement in canopy and suspension lines.

C-7. Parachute Care

An Army aviator has a parachute as a safety precaution. Without proper care, it ceases to provide the safety it should and can. Some points to observe in caring for a parachute are—

a. Never leave the parachute where it may be exposed to rain or dew.
b. Do not let the parachute come in contact with any acid, oil, gasoline, or other substance which might tend to weaken or rot the harness or canopy.

c. Do not leave the parachute on its back; lay it on its harness, to prevent bending the locking pins.

d. Handle the parachute carefully to prevent possible disarrangement of the pack which might keep it from opening properly.

e. If anything happens to the parachute which might cause a malfunction, report it promptly so that corrective action can be taken.

f. Treat the parachute with care and respect: it may save a life.

Figure C-6. Descent into trees.
GLOSSARY

aileron—A hinged control surface on the wing to aid in producing a bank or roll about the longitudinal axis.

aircraft—Any form of flying machine.

airfoil—A portion of an airplane which, when moved through the air, is capable of producing a useful aerodynamic reaction.

airplane—A mechanically driven, heavier than air, flying machine that derives its lift from a fixed wing.

airspeed—The speed of an aircraft in relation to the air through which it is passing.

altitude—The elevation of an aircraft above a given reference plane.

angle of attack—The acute angle between the chord of an airfoil and its direction of motion relative to the air.

attitude—The position of an aircraft considering the inclination of its axes in relation to the horizontal.

axis—The theoretical line extending through the center of gravity of an aircraft in each major plane: fore and aft, crosswise, and up and down. These are the longitudinal, lateral, and vertical axes.

bank—To tip or roll about the longitudinal axis of the airplane. Banks are essential to all properly executed turns.

buffeting—the beating effect of the disturbed airstream on an airplane's structure during flight.

camber—The distance in the curve of an airfoil section from its chord.

ceiling (aircraft)—The maximum altitude the aircraft is capable of obtaining under standard conditions.

center of gravity—The point within an aircraft through which, for balance purposes, the total force of gravity is considered to act.

chord—The longitudinal dimension of an airfoil section, measured from the leading to trailing edge.

controls—The devices used by a pilot in operating an aircraft.

control surfaces—Hinged airfoils exposed to the airflow which control the attitude of the airplane and which are actuated by use of the controls in the airplane.

coordination—The movement or use of two or more controls in their proper relationship to obtain the desired results.

cruise control—The procedure for the operation of an aircraft and its powerplants to obtain the maximum efficiency on extended flights.

dihedral—The upward inclination of a wing from center section toward the tip.

dive—A steep descent with or without power at a greater airspeed that normal to level flight.

drag—Force opposing the motion of the aircraft through the air.

drift—Angular deflection (due to wind) of an aircraft's horizontal direction of movement measured from heading to track.

element—In relation to formation flying, a 2- or 3-plane formation of aircraft.

elevator—A movable, horizontal control surface used to control the pitch of an airplane.

empennage—The entire tail group of an airplane, including the fixed and movable tail surfaces.

fin—A fixed airfoil which aids directional stability.

flap—An appendage to an airfoil (usually the wing) used for changing lift and/or drag characteristics.

flight—In relation to formation flying, a 2-, 3-, or 6-plane formation of aircraft.

flightpath—The path of the center of gravity of an airplane through the air.

fuselage—The body to which the wings, landing gear, and tail are attached.

glide—Sustained forward flight in which speed is maintained only by the loss of altitude.

glide angle—The acute angle between the horizontal and downward path along which an airplane descends.

go-around—A procedure for remaining airborne following a decision to discontinue an intended landing.

incidence, angle of—The angle between the mean chord of the wing and the longitudinal axis of the airplane.

induced drag—Drag produced indirectly by the effect of induced lift.

induced lift—Lift caused by the low pressure of the rapidly-flowing air over the top of an airfoil.

kinesthesia—The sense which detects and estimates motion without reference to vision or hearing.

landing—The act of terminating flight and bringing the airplane to rest.

landing gear—The structure which supports the weight of the airplane while at rest.
leading edge—The forward edge of any airfoil.
lift—The supporting force induced by the dynamic reaction of air against the airfoil.
lift component—A force acting on an airfoil, perpendicular to the direction of its motion through the air.
load—The forces acting on a structure. These may be static (as with gravity) or dynamic (as with centrifugal force), or a combination of static and dynamic.
load factor—The sum of the loads on a structure, including the static and dynamic loads, expressed in units of G, or one gravity.
longeron—The principal longitudinal structural member in a fuselage.
maneuver—Any planned motion of an aircraft in the air or on the ground.
monocoque—A type of aircraft construction in which the external skin constitutes the primary structure.
nosewheel—A turnable or steerable wheel mounted forward in tricycle-geared airplanes.
orientation—The act of fixing position or attitude by visual and other reference.
overshoot—To fly beyond a designated area or mark.
pilot—A person trained to operate the controls of an airplane in flight.
pitch (propeller)—The angle of propeller blades measured from the plane of rotation.
propeller—A device for producing thrust in a fluid, such as water or air.
pusher—An airplane in which the engine and propeller are mounted facing aft.
pylon—A prominent mark or point on the ground used as a fix in precision maneuvers.
relative wind—The motion of the air relative to the airfoil; it is parallel and opposite the flightpath.
roll—Movement around the longitudinal axis of an aircraft.
roundout—A change of aircraft attitude and flightpath from that used on final approach to that used for landing.
rudder—A hinged, vertical control surface used to control movement about the vertical axis.
rudder pedals—Controls within the airplane by means of which the rudder is actuated.
runway—A strip, either paved or improved, on which takeoffs and landings are effected.
skid—Rate of turn is greater than normal for degree of bank established.
slip—Rate of turn is less than normal for the degree of bank established.
slipstream—The current of air driven astern by the propeller.

spin—A prolonged stall in which an airplane rotates about its center of gravity while it descends, usually with its nose well down.
normal—A prolonged gliding turn during which at least a 360° change of direction is effected.
stability—The tendency of an airplane to return to the original flight condition without aid when disturbed.
stabilizer—The fixed airfoil of an aircraft used to increase stability; usually, the aft fixed horizontal surface to which the elevators are hinged. Some aircraft have been designed with a movable horizontal stabilizer.
stall—A condition of an airfoil in which it is at an angle of attack greater than the angle of attack of maximum lift.
tailwheel—A turnable or steerable wheel mounted at the aft end of the airframe.
taxi—To operate an airplane under its own power on the ground, except that movement incidental to actual takeoff and landing.
terminal velocity—The hypothetical maximum speed which could be obtained in a prolonged vertical dive.
thrust—The forward force on an airplane in the air provided by the engine acting through a propeller in conventional airplanes.
torque—Any turning or twisting force applied to the rolling force imposed on an airplane by the engine in turning the propeller.
trailing edge—The rearmost edge of an airfoil.
useful load—The difference, in pounds, between the empty weight and maximum authorized gross weight of an aircraft.
vector—A measurement which has both magnitude and direction.
venturi or venturi tube—A short tube having a large opening in the front and rear with a smaller diameter neck in between. The flow through the venturi causes a pressure drop in the smallest section, the amount of the drop being a function of the velocity of flow.
Vmc—Minimum control speed.
wash—Air which has been disturbed by the passage of an airfoil.
wash-in—Wing twist design with a greater angle of incidence at the wingtip than at the wing root.
washout—Wing twist design with a smaller angle of incidence at the wingtip than at the wing root.
weathervane—The tendency of an airplane on the ground to face into the wind.
wing—An airfoil which produces the major portion of the lift of an aircraft.
**wing root**—The end of the wing which joins the fuselage or opposite wing.

**wingtip**—The end of the wing farthest from the fuselage or cabin.

**yaw**—Movement about the vertical axis.

**zoom**—To climb for a short time at an angle greater than the angle of maximum climb, the airplane being carried by momentum.
# INDEX

<table>
<thead>
<tr>
<th>Paragraph</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceleration</td>
<td>B-5</td>
</tr>
<tr>
<td>Aerodynamics, definition</td>
<td>2-1</td>
</tr>
<tr>
<td>Ailerons</td>
<td>3-2c; 5-4c; 3-2.5-3</td>
</tr>
<tr>
<td>Aircraft performance:</td>
<td></td>
</tr>
<tr>
<td>Characteristics</td>
<td>4-1</td>
</tr>
<tr>
<td>Cruise control</td>
<td>4-4</td>
</tr>
<tr>
<td>Effect of air density</td>
<td>4-2</td>
</tr>
<tr>
<td>Air density</td>
<td>2-8.4-2</td>
</tr>
<tr>
<td>Airfoil:</td>
<td></td>
</tr>
<tr>
<td>Design</td>
<td>2-3</td>
</tr>
<tr>
<td>Shape</td>
<td>2-8a</td>
</tr>
<tr>
<td>Airframe</td>
<td>5-4</td>
</tr>
<tr>
<td>Angle of attack</td>
<td>2-8</td>
</tr>
<tr>
<td>Approaches:</td>
<td></td>
</tr>
<tr>
<td>Contour</td>
<td>10-11</td>
</tr>
<tr>
<td>Overhead: 360°</td>
<td>7-12</td>
</tr>
<tr>
<td>Power</td>
<td>10-1</td>
</tr>
<tr>
<td>Side and overhead: 180°</td>
<td>7-11</td>
</tr>
<tr>
<td>Spiral</td>
<td>7-13</td>
</tr>
<tr>
<td>Twin-engine</td>
<td>9-7</td>
</tr>
<tr>
<td>Asymmetric thrust</td>
<td>9-2</td>
</tr>
<tr>
<td>Axis:</td>
<td></td>
</tr>
<tr>
<td>Lateral</td>
<td>3-2a, 6-9</td>
</tr>
<tr>
<td>Longitudinal</td>
<td>3-2c, 6-9</td>
</tr>
<tr>
<td>Vertical</td>
<td>3-2b, 6-9</td>
</tr>
<tr>
<td>Bailout precautions</td>
<td>B-5</td>
</tr>
<tr>
<td>Banks</td>
<td>6-19,8-20</td>
</tr>
<tr>
<td>Bending</td>
<td>5-2a (3)</td>
</tr>
<tr>
<td>Bernoulli's theorem</td>
<td>2-2</td>
</tr>
<tr>
<td>Burble</td>
<td>5-8</td>
</tr>
<tr>
<td>Centrifugal force</td>
<td>2-6.3-4</td>
</tr>
<tr>
<td>Chandelle</td>
<td>8-3</td>
</tr>
<tr>
<td>Climbs:</td>
<td></td>
</tr>
<tr>
<td>Maximum performance</td>
<td>10-2</td>
</tr>
<tr>
<td>Normal</td>
<td>6-10b</td>
</tr>
<tr>
<td>Twin-engine</td>
<td>9-4</td>
</tr>
<tr>
<td>Compression</td>
<td>5-2a (1)</td>
</tr>
<tr>
<td>Coordination exercises</td>
<td>6-18,6.20</td>
</tr>
<tr>
<td>Crab method</td>
<td>7-9b</td>
</tr>
<tr>
<td>Crosswind techniques:</td>
<td></td>
</tr>
<tr>
<td>Landing</td>
<td>7-9</td>
</tr>
<tr>
<td>Takeoff</td>
<td>7-8</td>
</tr>
<tr>
<td>Design load factor</td>
<td>5-3b</td>
</tr>
<tr>
<td>Drag:</td>
<td></td>
</tr>
<tr>
<td>Definition</td>
<td>2-5b</td>
</tr>
<tr>
<td>Formula</td>
<td>2-7b</td>
</tr>
<tr>
<td>Induced</td>
<td>2-5b (1)</td>
</tr>
<tr>
<td>Parasite</td>
<td>2-5b (2)</td>
</tr>
<tr>
<td>Dynamic loads</td>
<td>5-3</td>
</tr>
<tr>
<td>Elevators</td>
<td>3-2a, 5-4c</td>
</tr>
<tr>
<td>Empennage</td>
<td>5-4c</td>
</tr>
<tr>
<td>Energy:</td>
<td></td>
</tr>
<tr>
<td>Definition</td>
<td>B-3</td>
</tr>
<tr>
<td>Kinetic</td>
<td>B-3b</td>
</tr>
<tr>
<td>Potential</td>
<td>B-3a</td>
</tr>
<tr>
<td>Equations:</td>
<td></td>
</tr>
<tr>
<td>Drag</td>
<td>2-7b</td>
</tr>
<tr>
<td>Lift</td>
<td>2-7a</td>
</tr>
<tr>
<td>Flaps:</td>
<td></td>
</tr>
<tr>
<td>Definition</td>
<td>5-6</td>
</tr>
<tr>
<td>For takeoff</td>
<td>6-5b</td>
</tr>
<tr>
<td>Types</td>
<td>5-6a</td>
</tr>
<tr>
<td>Use</td>
<td>5-6b</td>
</tr>
<tr>
<td>Flight:</td>
<td></td>
</tr>
<tr>
<td>Controls:</td>
<td></td>
</tr>
<tr>
<td>Ailerons</td>
<td>3-2c</td>
</tr>
<tr>
<td>Elevator</td>
<td>3-2a</td>
</tr>
<tr>
<td>Rudder</td>
<td>3-2b, 9-2,</td>
</tr>
<tr>
<td>Fundamentals:</td>
<td></td>
</tr>
<tr>
<td>Climbs</td>
<td>6-10</td>
</tr>
<tr>
<td>Glides</td>
<td>6-11</td>
</tr>
<tr>
<td>Straight and level</td>
<td>6-9</td>
</tr>
<tr>
<td>Turns</td>
<td>6-12</td>
</tr>
<tr>
<td>Principles:</td>
<td></td>
</tr>
<tr>
<td>Climbing</td>
<td>3-3</td>
</tr>
<tr>
<td>Gliding</td>
<td>3-5</td>
</tr>
<tr>
<td>Turning</td>
<td>3-4</td>
</tr>
<tr>
<td>Slow</td>
<td>6-14</td>
</tr>
<tr>
<td>Flying, contour</td>
<td>10-11,10-12</td>
</tr>
<tr>
<td>Fuselage</td>
<td>5-4a</td>
</tr>
<tr>
<td>G units</td>
<td>3-4b, 6-12g</td>
</tr>
<tr>
<td>Glides</td>
<td>3-5c, 6-11</td>
</tr>
<tr>
<td>Glossary</td>
<td>Glossary-1</td>
</tr>
<tr>
<td>Go-around</td>
<td>6-30,10-11b</td>
</tr>
<tr>
<td>High air defense threat</td>
<td></td>
</tr>
<tr>
<td>environment</td>
<td>1-3,10-9</td>
</tr>
<tr>
<td>Landing gear</td>
<td>5-1c, 5-4d</td>
</tr>
<tr>
<td>Landings:</td>
<td></td>
</tr>
<tr>
<td>Forced</td>
<td>6-17,7-10,</td>
</tr>
<tr>
<td>Normal</td>
<td>9-7</td>
</tr>
<tr>
<td>Laws, physical</td>
<td>B-1—B-6</td>
</tr>
<tr>
<td>Laws of motion</td>
<td>8-4</td>
</tr>
<tr>
<td>Lazy eights</td>
<td>8-4</td>
</tr>
<tr>
<td>Lift:</td>
<td></td>
</tr>
<tr>
<td>Components</td>
<td>3-4a</td>
</tr>
<tr>
<td>Definition</td>
<td>2-4a</td>
</tr>
<tr>
<td>Formula</td>
<td>2-7a</td>
</tr>
<tr>
<td>Maneuvers:</td>
<td></td>
</tr>
<tr>
<td>Chandelles</td>
<td>8-3</td>
</tr>
<tr>
<td>Evasive</td>
<td>10-8,10-14</td>
</tr>
<tr>
<td>Ground track, advanced:</td>
<td></td>
</tr>
<tr>
<td>Steep 8's around pylons</td>
<td>8-2</td>
</tr>
<tr>
<td>Ground track, intermediate:</td>
<td></td>
</tr>
<tr>
<td>8's around pylons</td>
<td>7-2</td>
</tr>
<tr>
<td>Ground track, primary:</td>
<td></td>
</tr>
<tr>
<td>Elementary 8's</td>
<td>6-24</td>
</tr>
<tr>
<td>Rectangular course</td>
<td>6-22</td>
</tr>
<tr>
<td>S-turns across a road</td>
<td>6-23</td>
</tr>
<tr>
<td>Lazy eight</td>
<td>8-4</td>
</tr>
<tr>
<td>Precision turns: 720°</td>
<td>7-4</td>
</tr>
<tr>
<td>Slips</td>
<td>7-6</td>
</tr>
<tr>
<td>Spins</td>
<td>6-16,8-5,</td>
</tr>
<tr>
<td>9-2</td>
<td>8-4</td>
</tr>
<tr>
<td>Spirals</td>
<td>7-5</td>
</tr>
<tr>
<td>Stalls</td>
<td>6-15,8-6</td>
</tr>
</tbody>
</table>

Index-1
Minimum control speed: 9-3,9-7a, 9-1,9-2
Monocoque: 5-4a, 5-2
Motion, laws:
  Acceleration (Newton's second law): B-2b, B-1
  Action-reaction (Newton's third law): B-2c, B-1
  Inertia (Newton's first law): B-2a, B-1
Night operations: 10-5–10-8, 10-4, 10-6
Parachute: App C, C-1
Pitch: 6-9b,c, 6-5
Power: B-2d, B-1
Powerplant: 5-1b, 5-1
Pressure: B-2b, B-1
Propeller:
  Design: 4-5, 4-2
  Fixed-pitch: 4-5c, 4-2
  Reversible pitch: 4-5f, 4-3
  Symmetrical loading: 4-5b, 4-2
  Torque effects: 4-6, 4-3
Reconnaissance:
  Ground: 10-4, 10-4
  High: 10-3a, 10-3
  Low: 10-3b, 10-3
References: App A, A-1
Roll: 3-2c, 3-2
Roundout: 6-29, 10-1d, 6-15, 10-3
Rudder: 3-2b, 5-4c, 3-1,5-3, 6-12c, 6-7
Shear: 5-2a, 5-1
Slips: 7-6, 7-9a, 7-2,7-3
Slipstream: 4-7b, 4-5
Slots: 5-7,5-8, 5-4
Spins: 6-16,8-5, 6-10,8-3, 8-6, 8-4
Spirals: 7-5, 7-2
Stability:
  Directional: 5-11c, 5-5
  Lateral: 5-11b, 5-5
  Longitudinal: 5-11a, 5-5
  Types: 5-10, 5-5
Stabilizers: 5-4c, 5-3
Stalls: 6-15,8-6, 6-9,8-4
Straight and level flight: 6-9, 6-5
Strain: 5-2b, 5-2
Stressed skin: 5-4a,b, 5-2
Stresses:
  Bending: 5-2a (3), 5-2
  Compression: 5-2a (1), 5-2
Stresses—Continued
  Shear: 5-2a (5), 5-2
  Tension: 5-2a (2), 5-2
  Torsion: 5-2a (4), 5-2

Table 2-1. Maintaining lift: 2-5
Takeoffs:
  Effect of altitude: 6-7, 6-4
  Effect of wind: 6-6, 6-4
  Maximum performance: 10-2, 10-3
  Normal: 6-5, 6-3
Taxing:
  Definition: 6-2a, 6-1
  Effect of wind: 6-2b, 6-1
  Precautions: 6-3, 6-5
  Use of throttle: 6-1,6-2, 6-1
Tension: 5-2a (2), 5-2
Throttle: 6-2, 6-1
Thrust: 2-4a, 4-5, 2-3,4-2
Torque effect on propeller: 4-6, 4-3
Torsion: 5-2a (4), 5-2
Touchdown point: 10-1b (1), 10-1
Traffic patterns:
  Approach: 6-28, 6-15
  Definition: 6-25, 6-14
  Description: 6-26, 6-14
  Use: 6-27, 6-15
Truss: 5-4a, 5-2
Turns:
  Climbing: 6-12h, 6-9
  Gliding: 6-12i, 6-9
  Precision: 7-4, 7-2
  Types: 6-12, 6-7
User comments: 1-4, 1-2
Vector:
  Quantities: B-7, B-2
  Solutions:
    Parallelogram: B-8a, B-3
    Polygon: B-8b, B-3
    Triangle of vectors: B-8c, B-3
Velocity: B-4, B-1
Venturi tube: 2-2,2-3, 2-1,2-2
Weight: 2-4b, 2-3
Wing:
  5-1a, 5-4b, 5-1,5-2
  2-9c, 2-5
  Wing-low method: 7-9, 7-3
  Work: B-2c, B-1
Yaw: 3-2b, 3-1
By Order of the Secretary of the Army:

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Chief of Staff.

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Major General, United States Army,
The Adjutant General.

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