GROUND LESSON 3

LESSON OBJECTIVE:

During this lesson the student will be introduced to basic aerodynamics to gain an understanding of the principles of helicopter flight.

LESSON CONTENT:

A. The four forces

-Lift

-Weight

-Thrust

-Drag

B. Airfoils

-Symmetrical vs. Asymmetrical

-Leading edge

-Trailing edge

-Chord line

-Relative wind

-Angle of attack

-Bernoulli's Principle

-Tip path plane

C. Factors affecting lift and drag

-Surface area

-Angle of attack

-Velocity of airflow

-Air density

-Blade stall

D. The three axes

-Longitudinal/Roll

-Lateral/Pitch

-Vertical/ Yaw

E. Torque

-Newton's third law of motion

-Tail rotor thrust

-Controlling torque

F. Rotor systems

-Fully articulated

-Semi-rigid

-Rigid

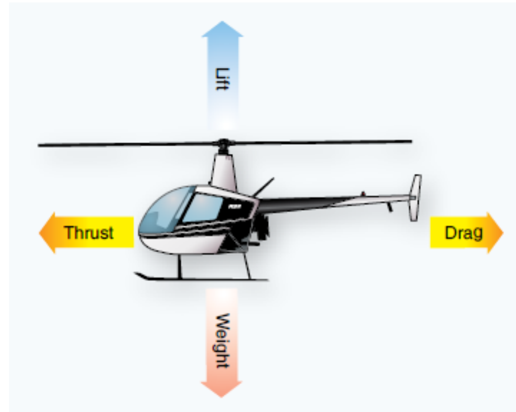
G. Vibrations

-Resonance; sympathetic, ground resonance
-Low frequency vibrations
-Medium frequency vibrations
-High frequency vibrations

COMPLETION STANDARDS:

This lesson is complete when, by oral examination, the student displays an understanding of the material presented. Recommended study material for this lesson: Basic Helicopter Handbook chapters 1, 2, 5 and 9, and Helicopter Pilot Manual chapter 1.

3.1 THE FOUR FORCES(2-5)



LIFT

- The upward force
- Created by the effect of the airflow as it passes around an airfoil
- Acts at right angles to the airflow

WEIGHT

- Opposes lift
- Caused by the downward pull of gravity

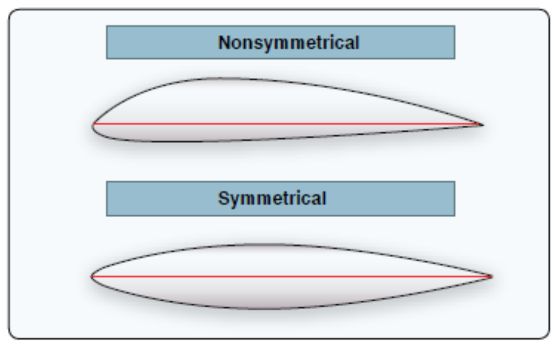
THRUST

- The force that propels the helicopter through the air

DRAG

- Opposes thrust
- Retarding force created by the movement of an object through the air
- Acts in line with airflow

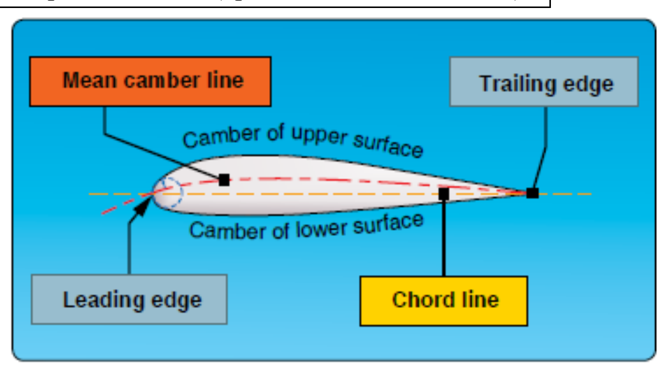
3.2. AIRFOILS



SYMMETRICAL VS. ASYMETRICAL

- Symmetrical = both sides of airfoil are equal
- Asymmetrical = both sides are different, the camber

Symmetrical Airfoil	Asymmetrical Airfoil(Cambered)
Upper and lower camber same size	Upper and lower camber different
Produces no lift at zero AOA	Produce useful lift at zero AOA.
Cheap	Expensive
Light, Strong shape	Heavy, Requires strong structure
Stable center of pressure	Center of pressure moves(up to 20% of the chord line)



Leading edge

—the front edge of an airfoil.

Trailing edge

—the rearmost edge of an airfoil

Chord line

—a straight line intersecting leading and trailing edges of the airfoil.

Relative wind

—defined as the airflow relative to an airfoil and is created by movement of an airfoil through the air.

Center of pressure

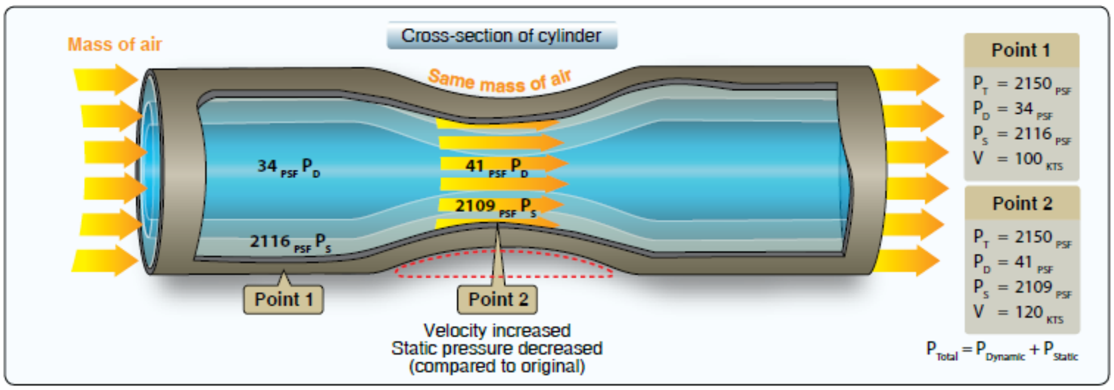
—Point on the chord line where most aerodynamic forces are said occur.

Angle of attack(AOA)

—the angle measured between the resultant relative wind and chord line.

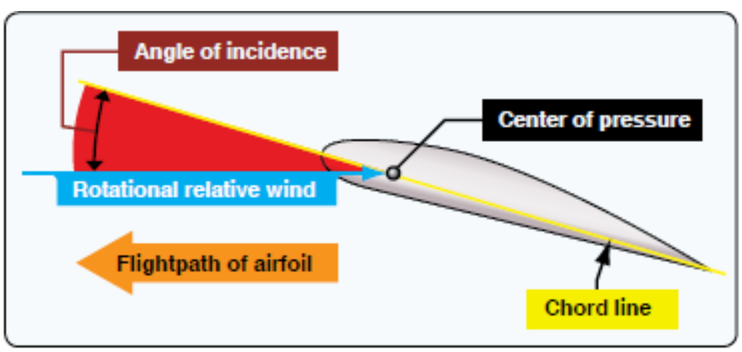
BERNOULLI’S PRINCIPLE

- When velocity increases, pressure decreases
- Airflow on the upper surface of an airfoil has to travel further and therefore speeds up
- As the air speeds up, pressure decreases
- High pressure goes towards low pressure which results in lift



TIP PATH PLANE(Rotational Relative Wind)

Tip path plane = plane of rotation



3.3. FACTORS AFFECTING LIFT AND DRAG

LIFT FORMULA

$Lift = C_L \times ½ \rho v^2 \times S$

C_L = coefficient of lift, angle of attack (collective)

½ ρ = Air density

v^2 = Velocity of relative wind (RPM, throttle)

S = Air foil surface area (bigger is better)

(what we can control?)

DRAG FORMULA

Drag = $C_d \times \frac{1}{2} \rho v^2 \times A$

C_d = coefficient of drag, angle of attack (collective)

½ ρ = Air density

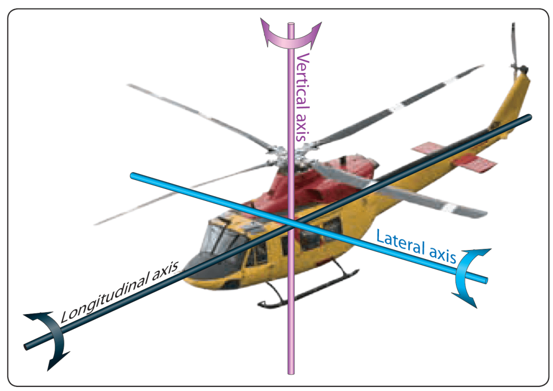
v^2 = Velocity of relative wind (RPM, throttle)

A = Air foil surface area (bigger is better)

BLADE STALL

- Results for exceeding the critical angle of attack
- The airflow gets separated from the upper chamber
- No lift production
- Once the blade stalls, there is no recovery
- R22 about 15° AoA. (SN-24)
- Called "critical angle of attack"

3.4 THE THREE AXES



Longitudinal

Roll – "Long" axis, from nose to tail.

Left/Right Cyclic

Lateral

Pitch – nose up and down.

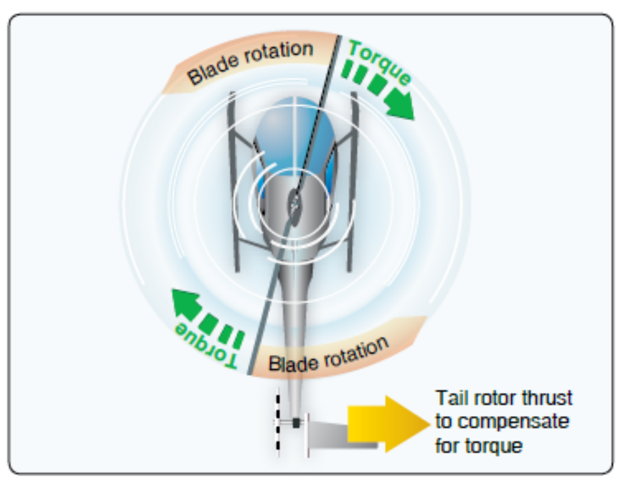
For/Aft Cyclic

Vertical

Yaw – Nose left and Right

Left/Right Peddles

3.5 TORQUE



Newton's third law of motion

– For every action there is an equal and opposite reaction.

① Engine turns blades Counter Clockwise in American built helicopters, torque is produced Clockwise… equal and opposite reaction

②Turning main rotor causes fuselage to turn in opposite direction

③Anti-torque – Tail rotor produces force to counteract this force

Tail rotor thrust

Produce opposite direction to the torque to compensate

Controlling torque

Use paddles to control AOA of the tail rotor, according to the lift formula the thrust will change.

3.6 ROTOR SYSTEMS

Provides lift and Thrust (directional control)

3 major types of rotor systems (classified by how they move at the rotor hub)

 Fully articulated

- Flap, feather, lead and lag (independently from each other)
- Usually consists of three or more blades most complex

Semi-rigid – R22

- Feather, flap as a unit (teetering hinge)
- usually 2 blades

Rigid

- Feather, forces absorbed through bending
- very simple, low maintenance, very expensive.

3.7 VIBRATIONS

Resonance

GROUND RESONANSE

- Applies only to fully articulated rotor systems
- A hard impact with ground sends a "shock" up the rotor system and moves the blades out of phase because of the lead/lag system
- Cannot occur in flight, must be in contact with ground
- Can flip the helicopter over or self-destruct in seconds
- If within normal rotor rpm – pick the helicopter up and the rotor system will reload it self
- If low rotor rpm – roll off throttle and lower collective full down

(Helicopter self destruction)

SYMPATHETIC RESONANSE

- Avoid certain rotor rpm, this is the lower yellow range in tachometer 60-70% R22
- Tail rotor and main rotor frequencies work with each other
- Can create violent vibrations and lead to structural damage

LOW FREQUENCY

- Usually from main rotor
- Can be felt through the controls, airframe, or both
- Can be vertical , horizontal or a combination
- Rotor blades can be out of track, out of balance, damaged blades, worn bearings

MEDIUM FREQUENCY

- Usually from tail rotor
- Can usually be felt through the pedals, if no hydraulics installed
- Any imbalance from the tail rotor is very harmful

HIGH FREQUENCY

- Usually from engine, some cases tail rotor
- If it’s the engine you may feel it in your back
- Spark plug fouling, incorrect magneto timing, carb ice, incorrect fuel/air mixture
- In the R22, the tail rotor and engine operate at about the same RPM, therefore the vibrations would be of high frequency and about the same on both sources.
    - Tail rotor rpm is higher than engine

Resource

Helicopter flying handbook (FAA=H-8083-21A)

- Chapter 01: Introduction to the helicopter
- Chapter 02: Aerodynamics of flight
- Chapter 11: Helicopter emergencies and hazards