CHAPTER 19: DETAILED THEORETICAL KNOWLEDGE SYLLABUS AND LEARNING OBJECTIVES
Subject – 082 – Principles of Flight (H)
See Appendix 1 to JAR-FCL 1.470 and JAR-FCL 2.470

**Note concerning the amendments dated August 2008, September and October 2008:**

**The following changes have been introduced:**

| | |
|---|---|
| **August 2008:** | **Addition at the end of paragraph 8 of the Introduction (see page 7)** |
| | **Addition at the end of paragraph 9 of the Introduction (see page 7)** |
| | **Changes to 082 02 01 02 (see page 14)** |
| | **Changes to 082 07 03 03 (see page 33)** |
| | **Changes to 082 08 01 01 (see page 33)** |
| **September 2008:** | **Correction to Introduction, paragraph 9.** |
| **October 2008:** | **Correction to 082 05 02 02. the sixth LO** |

## INTRODUCTION

### 1. VOCABULARY OF MECHANICS

**Speed** is a scalar quantity, it has only magnitude.

**Velocity** is a vector quantity having magnitude and direction.

The velocity (speed) of a point of the aerofoil in the rotation around its axis is the “linear” or “tangential” velocity (speed).

The rotational velocity (speed) of a body around an axis is an angular velocity (speed) expressed in revolutions per min (RPM), or degrees per second, or radians per second (rad/s).

**Density** is the mass of the fluid per unit volume , in SI units $kg/m^3$. (we mention this because in translation density is not the French ‘densité’ or the Dutch ‘densiteit’)

### 2. AERONAUTICAL DEFINITIONS

The <u>blade</u> is the aerofoil between a root radius and the tip radius (R) attached to the hub with hinges or flexible elements.

The intersection between the blade and a plane perpendicular to the longitudinal axis (spanwise axis or feathering axis) is the blade <u>section</u>. The section is at a distance (radius r) of the hub centre or shaft axis.

CHAPTER 19: DETAILED THEORETICAL KNOWLEDGE SYLLABUS AND LEARNING OBJECTIVES
Subject – 082 – Principles of Flight (H)
See Appendix 1 to JAR-FCL 1.470 and JAR-FCL 2.470

The section is characterised by a contour, a leading and trailing edge, a chord line, a chord (symbol c), a camber line, the maximum thickness or depth, the thickness to chord ratio, an upper and lower surface. (Strictly speaking there are no upper and lower surfaces of a section, but upper and lower curves; the word surface is nevertheless used).

The blade element is a spanwise piece of the blade. A blade element has a spanwise dimension of any length (usually an elementary spanwise length). The blade element has elemental upper and lower surfaces.

The aerodynamic forces on the blade element produce a lift, a drag and a pitching moment.

The centre of pressure is a point on the chord where the resultant of all aerodynamic forces acts and consequently the point about which the pitching moment is zero.

The planform of the blade is the shape of the blade as seen from above.

The pitch angle of a section is the angle between the chord line and a reference plane. (The reference planes will be defined later in this text)

The blade is without twist when the pitch angle is constant from root to tip.

The blade is twisted when the pitch angle of the sections varies in function of the radius (the chord lines are not parallel). If the pitch angle decreases towards the tip, the blade has wash-out.

$V_\infty$ undisturbed, free-stream or upstream airflow velocity (vector), the aerofoil or body is considered at rest.

The vectorsum of the undisturbed upstream velocity $V_\infty$ and the induced velocity $V_i$ is designated: the relative velocity.

In the helicopter theory we use the following definitions for angle of attack, lift and drag (which are different from these used in the classical aerodynamics):

- The angle between the relative velocity and the chordline is **the angle of attack** $\alpha$ or **AoA** called effective angle of attack in classical aerodynamics. (The geometric angle of attack is the angle between the undisturbed upstream velocity and the chord line.)

- The lift is the component of the aerodynamic force on a blade element perpendicular to the **relative** velocity.

- The profile drag is the component of the aerodynamic force on a blade element parallel to the **relative** velocity.

The **profile** drag is produced by the pressure forces and by skin friction forces that act on the surface of the blade element, aerofoil and/or body.

The component of the drag force due to the pressure forces is the **pressure** or **form** drag.

The component of the drag due to the shear forces over the aerofoil is termed **skin friction** drag.

The sum of the **pressure drag** and the **skin friction drag** is the **profile** drag.

**3. HELICOPTER CHARACTERISTICS**

The disc loading is by definition the mass M or weight W of the helicopter divided by the area of the disc, area defined by the blade tip-radius R.

The disc loading is $(M/\pi R^2)$ or $(W/\pi R^2)$

The blade loading is by definition the mass (weight) divided by the plan surface of the blades.

The surface of one rectangular blade ( the chord c is constant) is considered as the (chord x tipradius R.). When the blade is tapered (chord is not constant) we define an equivalent chord, in first approximation this can be taken as the geometric mean chord.

The blade loading is (M/bcR) or (W/bcR) , b is the number of blades.

Rotor Solidity : The ratio of the total blade area to the disc area

**4. PLANES , AXES , REFERENCE SYSTEMS of the ROTOR**

**PLANES and AXES**

- Shaft axis: the axis of the rotor shaft (mast).

- Hub plane: plane perpendicular to the shaft axis through the centre of the hub.

- Tip path plane: the plane traced out by the blade tips . This plane is also the no-flapping plane.

- Virtual rotation axis: axis through the centre of the hub and perpendicular to the tip path plane and thus the axis of the cone defined by the blade movement. Another name for this axis is the no-flapping axis.

- The rotor disc plane is another name for the tip path plane.

- The rotor disc is the disc traced out by the blade tips in the tip path plane.

- The plane of rotation is the plane parallel to the tip path plane through the hub centre or traced out by any point of the blade.

- No-feathering plane: is also called the control plane. This is the reference plane relative to which the blade pitch has no variation during the revolution or 1/rev variation. The control plane is parallel to the swash plate in the simple feathering mechanism (no flap-feathering coupling).

- Control axis or axis of no-feathering. Axis through the hub centre and perpendicular to the no-feathering or control plane.

- The azimuthal angle of the blade is the angle in the rotor disc plane between the rear direction of the helicoptervelocity and the blade in the rotation sense of the rotor. (advancing blade is at 90°, retreating blade is at 270°)

## 5. REFERENCE SYSTEMS (sometimes called frames)

There are three different reference systems in which the movement of the blades can be studied or observed:

- The tip path plane with the virtual rotation axis: The observer in this system observes no flapping , only cyclic feathering

- The no-feathering plane (or control plane) with the control axis: The observer in this system observes no feathering , only cyclic flapping

- The hub plane and shaft axis: The observer in this system observes both cyclic flapping and cyclic feathering

CHAPTER 19: DETAILED THEORETICAL KNOWLEDGE SYLLABUS AND LEARNING OBJECTIVES
Subject – 082 – Principles of Flight (H)
See Appendix 1 to JAR-FCL 1.470 and JAR-FCL 2.470

**6. ANGLES of the BLADES, INDUCED VELOCITY**

- Pitch angle of a blade section: the angle between the chord line of the section and the hub plane (the reference plane), also called the local pitch angle.

- Pitch angle of the blade : The pitch angle of the section at 75% of the tip radius

- Flapping angle : The angle between the longitudinal axis of the blade and the hub plane

- Coning angle : the angle between the longitudinal axis of the blade and the tip path plane

The induced velocity is the velocity induced at the rotor disc (about 10 m/s for a classical helicopter in the hover). The slipstream velocity continues to increase downstream of the rotor. In hover out of ground effect the velocity in the ultimate wake is equal to two times the induced velocity.

**Aerodynamic forces on the BLADES and the ROTOR.**

The airflow around the blade element produces an aerodynamic force resolved in two components; lift and drag. The elemental lift is perpendicular to the relative air velocity and the elemental drag is parallel to the relative air velocity.

The elemental aerodynamic force is also resolved in an elemental thrust perpendicular to the tip path plane (or plane of rotation) and a elemental drag force parallel to the tip path plane ( in the plane of rotation). This drag force is the result of the profile drag and the induced drag.

The angle between the lift vector and the thrust vector is very small thus the magnitudes of these two vectors are taken as equal.

The sum of all the elemental thrusts from the blade root to the tip is the blade thrust :$T_{blade}$

The sum of all the blade thrusts is the **rotor thrust** (some call it total rotor thrust, total is superfluous), acting through the centre of the hub and perpendicular to the tip path plane thus coincident with the virtual rotation axis.

The result of the elemental induced drag forces on all the blade elements (of all blades) is a resistant torque on the shaft which leads to the induced power on the rotor.

The result of all the elemental profile drags is a resistant torque (moment) on the shaft and a resistant force. The component (of this force) acting in the centre of the hub, opposite to the helicopter velocity is the rotor profile drag, symbol H. The power required to overcome both torque and drag H is the rotor profile power.

## 7. TYPES OF ROTOR HUBS

There are basically four types of rotor hubs in use:

1. Teetering rotor or seesaw rotor: The two blades are connected together ( like a beam), the hinge is on the shaft axis. A variation is the gimballed hub, the blades and the hub are attached to the rotor shaft by means of a gimbal or universal joint

2. Fully articulated rotor: The rotor has more than two blades. Each blade has a flapping hinge, a lead-lag hinge and a feathering bearing.

3. Hingeless rotor: There are no flap and lead-lag hinges, which are replaced by flexible elements at the root of the blades which allows the flapping and the lead-lag movements. The feathering bearing allows the feathering of the blade.

4. Bearingless rotor: There are no hinges or bearings. The flapping and lead-lag are obtained by flexing the flexible elements and the feathering by twisting the element.

Two remarks:

1. Hinge offset and equivalent hinge offset.
   The hinge offset is the distance between the shaft axis and the axis of the hinge. In the hingeless and bearingless rotor we define an equivalent hinge offset.

2. Elastoremic hinges
   This bearing consists of alternate layers of elastomer and metal. The elasticity in the elastomer allows the movements of flapping, lead-lag and feathering.

## 8. DRAG and POWERS

The induced power is the power necessary to induce velocities at the rotor disc. In hover in still air the induced power is minimum when the induced velocities are constant over the rotor disc. This requires a blade twist with wash-out.

The rotor profile drag H results from the component opposite to the helicopter velocity of the result of all the elemental profile drags on the blade elements of all the blades.
The power resulting from the elemental profile drags is the rotor profile power or the profile-drag power, (sum of the powers to overcome the resistant torque and the resistant drag H).

CHAPTER 19: DETAILED THEORETICAL KNOWLEDGE SYLLABUS AND LEARNING OBJECTIVES
Subject – 082 – Principles of Flight (H)
See Appendix 1 to JAR-FCL 1.470 and JAR-FCL 2.470

The parasite drag is the drag on the helicopter fuselage including the drag of the rotor hub and all external equipment as wheels, winch, etc. The tail rotor drag is also included in the parasite drag. The power to overcome this drag is the parasite power.

In the level flight at constant speed the main rotor induced power, the rotor profile power and the parasite power are summed to give the total power required to drive the main rotor notation: $P_{tot\ MR}$

The tail rotor induced power and the tail rotor profile power are summed to give the power required to drive the tail rotor.

The power required to drive the auxiliary services such as oil pumps and electrical generators is the accessory or ancillary power.. The power to overcome the mechanical friction in the transmissions is included in the accessory power.

The total power required in level flight at constant speed is the sum of the total power for the main rotor, the power for the tail rotor and the accessory power.

In the low speed region the required total power in level and straight flight diminishes as the speed increases., this phenomenom is called "translational lift".

The term limited power means that the total required power to hover OGE greater is than the available engine power.

**9. PHASE ANGLE IN FLAPPING MOVEMENT OF THE BLADE**

The forward cyclic movement tilts the rotor disc forward (in the direction of the helicopter velocity) through the application of cyclic pitch with a maximum/minimum pitch laterally.
The flapping response is approximately 90° out of phase with the applied cyclic pitch
(it can be about 10° less than 90° for articulated and hingeless rotors).

The pitch mechanisme consist of the swashplate, the pitch link attached to the swashplate and the pitch horn attached to the blade (usually at the front of the blade).

The advance angle is the azimuthal angle between the point of attachement of the pitch link to the swashplate and the longitudinal axis of the blade to which it relates.

~~The value of the advance angle is dependent on the value of the phase angle and the geometry of the pitch link and pitch horn~~

CHAPTER 19: DETAILED THEORETICAL KNOWLEDGE SYLLABUS AND LEARNING OBJECTIVES
Subject – 082 – Principles of Flight (H)
See Appendix 1 to JAR-FCL 1.470 and JAR-FCL 2.470

## 10. AXES THROUGH THE CENTRE OF THE HELICOPTER

Longitudinal axis or roll axis. Straight line through the centre of gravity of the helicopter from the nose to the tail about which the helicopter can roll left or right

Lateral axis, transverse axis or pitch axis: Straight line through the centre of gravity of the helicopter about which the helicopter can pitch its nose up or down. (This axis is also perpendicular to the reference plane of the aircraft).

Normal axis or yaw axis. Straight line perpendicular to the plane defined by the longitudinal and lateral axes and about which the helicopter can yaw.

Aircraft reference plane: The plane with respect to which a sub-set of the components that constitutes the major part of the aircraft is symmetrically disposed in the port and starboard sense.

CHAPTER 19: DETAILED THEORETICAL KNOWLEDGE SYLLABUS AND LEARNING OBJECTIVES
Subject – 082 – Principles of Flight (H)
See Appendix 1 to JAR-FCL 1.470 and JAR-FCL 2.470

| **Syllabus reference** | **Syllabus details and associated Learning Objectives** | *Aeroplane* | | *Helicopter* | | | *IR* |
|---|---|---|---|---|---|---|---|
| | | ATPL | CPL | ATPL /IR | ATPL | CPL | |
| **082 00 00 00** | **PRINCIPLES OF FLIGHT – HELICOPTER** | | | | | | |
| **082 01 00 00** | **SUBSONIC AERODYNAMICS** | | | | | | |
| **082 01 01 00** | **Basic concepts, laws and definitions** | | | | | | |
| **082 01 01 01** | **SI Units and conversion of units** | | | | | | |
| LO | List the fundamental units in SI system: mass (kg), length (m) , time (s) | | | x | x | x | |
| LO | Show and apply the tables of conversion of units | | | x | x | x | |
| LO | English units to SI units and vice-versa | | | x | x | x | |
| LO | The units of the physical quantities should be mentioned when these are introduced | | | x | x | x | |
| **082 01 01 02** | **Definitions and basic concepts about air** | | | | | | |
| LO | Describe the air temperature and pressure in function of the height | | | x | x | x | |
| LO | Use the table of International Standard Atmosphere | | | x | x | x | |
| LO | Define the air density, explain the relationship between density, pressure and | | | x | x | x | |
| LO | Explain the influence of the moisture content on the density | | | x | x | x | |
| LO | Define pressure altitude, density altitude | | | x | x | x | |
| **082 01 01 03** | **Newton's Laws** | | | | | | |
| LO | Describe Newton's second law: force equal product of mass and acceleration | | | x | x | x | |
| LO | Mass and weight , units | | | x | x | x | |
| LO | Describe the other form of the second law ; equation of momentum and impulse | | | x | x | x | |
| LO | Describe Newton's third law : action and reaction , force and torque | | | x | x | x | |

CHAPTER 19: DETAILED THEORETICAL KNOWLEDGE SYLLABUS AND LEARNING OBJECTIVES
Subject – 082 – Principles of Flight (H)
See Appendix 1 to JAR-FCL 1.470 and JAR-FCL 2.470

| **Syllabus reference** | **Syllabus details and associated Learning Objectives** | *Aeroplane* | | *Helicopter* | | | *IR* |
|---|---|---|---|---|---|---|---|
| | | ATPL | CPL | ATPL /IR | ATPL | CPL | |
| **082 01 01 04** | **Basic concepts about airflow** | | | | | | |
| LO | Describe steady and unsteady airflows | | | x | x | x | |
| LO | Define streamline and streamtube | | | x | x | x | |
| LO | Equation of continuity or mass conservation | | | x | x | x | |
| LO | Mass flow rate through a streamtube section and a pipe | | | x | x | x | |
| LO | Describe the relation between the external force on a streamtube and pipe and the momentum variation of the airflow | | | x | x | x | |
| LO | State Bernoulli's equation in a non-viscous airflow, use this equation to explain and define static pressure, dynamic pressure, total pressure. | | | x | x | x | |
| LO | Define the stagnation point in a flow round an aerofoil and explain the pressure obtained in the stagnation point | | | x | x | x | |
| LO | Describe the pitot system and explain the measurement of the airspeed, (no compressibility effects) | | | x | x | x | |
| LO | Define TAS, IAS, CAS | | | x | x | x | |
| LO | Define a two-dimensional airflow and an aerofoil of infinite span. Explain the difference between two- and three-dimensional airflow | | | x | x | x | |
| LO | Explain that a fluid (air) is characterised by viscosity | | | x | x | x | |
| LO | Describe the airflow over a flat surface of a plate and explain the tangential friction between air and surface and the development of a boundary layer | | | x | x | x | |
| LO | Define the laminar boundary layer, the turbulent boundary layer and the transition from laminar to turbulent. Show the influence of the roughness of the surface on the position of the transition point | | | x | x | x | |
| **082 01 02 00** | **Two-dimensional airflow** | | | | | | |
| **082 01 02 01** | **Aerofoil section geometry** | | | | | | |

CHAPTER 19: DETAILED THEORETICAL KNOWLEDGE SYLLABUS AND LEARNING OBJECTIVES
Subject – 082 – Principles of Flight (H)
See Appendix 1 to JAR-FCL 1.470 and JAR-FCL 2.470

| **Syllabus reference** | **Syllabus details and associated Learning Objectives** | *Aeroplane* | | *Helicopter* | | | *IR* |
|---|---|---|---|---|---|---|---|
| | | ATPL | CPL | ATPL /IR | ATPL | CPL | |
| LO | Define the terms aerofoil section, aerofoil element, chordline, chord, thickness, thickness to chord ratio of section, camberline, camber, leading edge radius | | | x | x | x | |
| LO | Describe different aerofoil sections, symmetrical and asymmetrical | | | x | x | x | |
| **082 01 02 02** | **Aerodynamic forces on aerofoil elements** | | | | | | |
| LO | Define the angle of attack | | | x | x | x | |
| LO | Describe the pressure distribution on the upper and lower surface | | | x | x | x | |
| LO | Describe the boundary layers on the upper and lower surfaces for small angles of attack ( below the onset of stall) | | | x | x | x | |
| LO | Describe the resultant force due to the pressure distribution and the friction around the element, the boundary layers and the velocities in the wake, the loss of momentum due to friction forces | | | x | x | x | |
| LO | Resolve the resultant force into the components « lift » and « drag » | | | x | x | x | |
| LO | Define the lift-coefficient and the drag coefficient, equations | | | x | x | x | |
| LO | Show that lift-coefficient is a function of the angle of attack, draw the graph. | | | x | x | x | |
| LO | Explain that the drag is due to the pressure forces on the surfaces and to the friction forces of the boundary layers. Define the term :profile drag | | | x | x | | |
| LO | Draw the graph of the lift (lift-coefficient) as a function of the drag (drag-coefficient) and define the lift/drag ratio | | | x | x | x | |
| LO | Use the equations of lift and drag to show the influence of the speed and the density on the lift and drag for a given angle of attack and to calculate lift and drag | | | x | x | x | |
| LO | Define the action line of the resultant aerodynamic force, the centre of pressure, the pitching moment about the leading edge. | | | x | x | x | |
| LO | Explain that the pitching moment about the Centre of pressure is zero | | | x | x | x | |

CHAPTER 19: DETAILED THEORETICAL KNOWLEDGE SYLLABUS AND LEARNING OBJECTIVES
Subject – 082 – Principles of Flight (H)
See Appendix 1 to JAR-FCL 1.470 and JAR-FCL 2.470

| **Syllabus reference** | **Syllabus details and associated Learning Objectives** | *Aeroplane* | | *Helicopter* | | | *IR* |
|---|---|---|---|---|---|---|---|
| | | ATPL | CPL | ATPL /IR | ATPL | CPL | |
| LO | For a symmetrical aerofoil section, explain the position of the centre of pressure a quarter chord behind the leading edge, fixed position independent of the angle of attack for usual values of the angle.<br>Remark usual means angles smaller than the angle of stall | | | x | x | x | |
| LO | For the asymmetrical aerofoil section of different cambers, explain the position of the centre of pressure, the influence of the angle of attack on centre of pressure and the pitching moment about the line a quarter chord behind the leading edge | | | x | x | x | |
| **082 01 02 03** | **Stall** | | | | | | |
| LO | Explain the boundary layer separation with increasing angle of attack beyond the stall onset, the decrease of the lift and the increase of drag. Define the separation point and line. | | | x | x | x | |
| LO | Draw the graph of lift- and drag-coefficient as a function of the angle of attack before and beyond the stall onset | | | x | x | x | |
| LO | Describe how the stall phenomenon displaces the centre of pressure and the appearance of pitching moments about the line at quarter chord behind the leading edge | | | x | x | x | |
| **082 01 02 04** | **Disturbances due to profile contamination** | | | | | | |
| LO | Explain ice contamination, the modification of the section profile and the surfaces due to ice and snow, influence on lift and drag and L/D ratio, on the angle of attack at stall onset, effect of the weight increase | | | x | x | x | |
| LO | Explain the erosion effect of heavy rain on the aerofoil and subsequent increase of profile drag | | | x | x | x | |
| **082 01 03 00** | **The three-dimensional airflow round a blade (wing) and a fuselage** | | | | | | |
| **082 01 03 01** | **The blade (wing)** | | | | | | |

CHAPTER 19: DETAILED THEORETICAL KNOWLEDGE SYLLABUS AND LEARNING OBJECTIVES
Subject – 082 – Principles of Flight (H)
See Appendix 1 to JAR-FCL 1.470 and JAR-FCL 2.470

| **Syllabus reference** | **Syllabus details and associated Learning Objectives** | *Aeroplane* | | *Helicopter* | | | *IR* |
|---|---|---|---|---|---|---|---|
| | | ATPL | CPL | ATPL /IR | ATPL | CPL | |
| LO | Describe the planform of the blade (wing), rectangular and tapered blades, untwisted and twisted blades | | | x | x | x | |
| LO | Define the root chord and the tip chord, the mean chord, the aspect ratio and the blade or wing twist | | | x | x | x | |
| **082 01 03 02** | **Airflow pattern and influence on lift on a wing** | | | | | | |
| LO | Explain the spanwise flow in the case of a wing in a uniform upstream airflow and the appearance of the tip vortices which are a loss of energy. | | | x | x | x | |
| LO | Show that the strength of the vortices increases as the angle of attack and the lift increase. | | | x | x | x | |
| LO | Show that the vortices causes induced velocities, thus downwash. | | | x | x | x | |
| LO | Define the effective airvelocity as the resultant of the undisturbed airvelocity and the induced velocity and define the effective angle of attack | | | x | x | x | |
| LO | Explain the span-wise lift distribution and how it can be modified | | | x | x | x | |
| **082 01 03 03** | **Induced drag** | | | | | | |
| LO | Explain the induced drag and drag-coefficient, the influence of the angle of attack, of the aspect ratio | | | x | x | x | |
| **082 01 03 04** | **The airflow round a fuselage** | | | | | | |
| LO | Describe the aircraft fuselage and the external components which cause drag, the airflow round the fuselage, influence of the pitch angle of the fuselage | | | x | x | x | |
| LO | Define the parasite drag as the result of the pressure drag and the friction drag | | | x | x | x | |
| LO | Define the interference drag | | | x | x | x | |
| LO | Describe the forms to minimise the drag | | | x | x | x | |

CHAPTER 19: DETAILED THEORETICAL KNOWLEDGE SYLLABUS AND LEARNING OBJECTIVES
Subject – 082 – Principles of Flight (H)
See Appendix 1 to JAR-FCL 1.470 and JAR-FCL 2.470

| **Syllabus reference** | **Syllabus details and associated Learning Objectives** | *Aeroplane* | | *Helicopter* | | | *IR* |
|---|---|---|---|---|---|---|---|
| | | ATPL | CPL | ATPL /IR | ATPL | CPL | |
| LO | The formula of the parasite drag and explain the influence of the speed | | | x | x | x | |
| **082 02 00 00** | **TRANSONIC AERODYNAMICS and COMPRESSIBILITY EFFECTS** | | | | | | |
| **082 02 01 00** | **Airflow speeds and velocities** | | | | | | |
| **082 02 01 01** | **Speeds and Mach number** | | | | | | |
| LO | Define the speed of sound in air | | | x | x | x | |
| LO | State: the speed of sound is proportional to the square root of the absolute temperature (Kelvin) | | | x | x | x | |
| LO | Explain the variation of speed of sound with altitude | | | x | x | x | |
| LO | Define Mach number | | | x | x | x | |
| LO | Explain the meaning of incompressibility and compressibility of air, relate this to the value of Mach numbers | | | x | x | x | |
| LO | Define subsonic, transonic and supersonic flows in relation to the value of the Mach number | | | x | x | x | |
| **082 02 01 02** | **Shock waves** | | | | | | |
| LO | Describe the shock wave in a supersonic flow and the pressure and speed variation through the shock | | | x | x | x | |
| LO | Describe the appearance of local supersonic flows at the upper face of a wing section and the recompression through a shock when the wing section is in an upstream high subsonic flow | | | x | x | x | |
| LO | Describe the effect of the shock on the lift, drag, pitching moment and the $C_L/C_D$ ratio, drag divergence Mach number | | | x | x | x | |
| **082 02 01 03** | **Influence of aerofoil section and blade planform** | | | | | | |

CHAPTER 19: DETAILED THEORETICAL KNOWLEDGE SYLLABUS AND LEARNING OBJECTIVES
Subject – 082 – Principles of Flight (H)
See Appendix 1 to JAR-FCL 1.470 and JAR-FCL 2.470

| **Syllabus reference** | **Syllabus details and associated Learning Objectives** | *Aeroplane* | | *Helicopter* | | | *IR* |
|---|---|---|---|---|---|---|---|
| | | ATPL | CPL | ATPL /IR | ATPL | CPL | |
| LO | Explain the different shapes which allows higher upstream Machnumbers without appearance of the shock on the upper surface:<br>- Reducing the section thickness to chord ratio<br>- Special aerofoil sections as supercritical shapes<br>- A planform with sweep-angle, positive and negative | | | x | x | x | |
| **082 03 00 00** | **ROTORCRAFT TYPES** | | | | | | |
| **082 03 01 00** | **Rotorcraft** | | | | | | |
| **082 03 01 01** | **Autogyro and helicopter** | | | x | x | x | |
| LO | Define the autogyro and the helicopter. | | | x | x | x | |
| LO | Explain the rolling moment on an autogyro with fixed blades, the necessity to use flapping hinges and the ensuing reduction of the moment arm, the flapback of the blades. | | | x | x | x | |
| **082 03 02 00** | **Helicopters** | | | | | | |
| **082 03 02 01** | **Helicopters configurations** | | | x | x | x | |
| LO | Describe the single main rotor helicopter and the other configurations : tandem, co-axial, side by side, synchropter (intermeshing blades), the compound helicopter, tilt-wing and tilt-rotor | | | x | x | x | |
| **082 03 02 02** | **The helicopter, characteristics and associated terminology** | | | | | | |
| LO | Describe the general lay-out of a single main rotor helicopter, fuselage, engine or engines, main gearbox , main rotor shaft and rotor hub | | | x | x | x | |
| LO | Mention the tailrotor at the aft of the fuselage. | | | x | x | x | |
| LO | Define the rotordisc area and the blade area, the blades turning in the hubplane | | | x | x | x | |

CHAPTER 19: DETAILED THEORETICAL KNOWLEDGE SYLLABUS AND LEARNING OBJECTIVES
Subject – 082 – Principles of Flight (H)
See Appendix 1 to JAR-FCL 1.470 and JAR-FCL 2.470

| **Syllabus reference** | **Syllabus details and associated Learning Objectives** | *Aeroplane* | | *Helicopter* | | | *IR* |
|---|---|---|---|---|---|---|---|
| | | ATPL | CPL | ATPL /IR | ATPL | CPL | |
| LO | Describe the teetering rotor with the hinge axis on the shaft axis and the rotor with more than two blades with hinge axes with offset | | | x | x | x | |
| LO | Define the fuselage centre line and the three axes, roll, pitch and normal | | | x | x | x | |
| LO | Define the gross weight and the gross mass (units), the disc and blade loading | | | x | x | x | |
| **082 04 00 00** | **MAIN ROTOR AERODYNAMICS** | | | | | | |
| **082 04 01 00** | **Hover flight outside ground effect (OGE)** | | | | | | |
| **082 04 01 01** | **Airflow through the rotordiscs and round the blades** | | | | | | |
| LO | Define the circumferential velocity of the blade sections, proportional to the angular velocity of the rotor (RPM) and the radius of the section. | | | x | x | x | |
| LO | Keep the blade fixed and define the undisturbed upstream air velocity relative to the blade | | | x | x | x | |
| LO | Based on Newton's second law (momentum) explain that the vertical force on the disc, the rotor thrust, produces vertical downwards velocities in the rotor disc plane. The values of these induced airspeeds increases as the thrust increases and decreases with increasing rotor diameter. Mention that the velocities some distance downstream are twice the value of the induced speed in the disc plane | | | x | x | x | |
| LO | Explain that the production of the induced flow requires a power on the shaft, the induced power. The induced power is minimal if the induced velocities have the same value on the whole disc, flow uniformity over the disc. | | | x | x | x | |
| LO | Mention uniform and non uniform induced velocities over the rotor disc | | | x | x | x | |
| LO | Explain that the downwash airflow produces a downwards drag on the fuselage | | | x | x | x | |
| LO | Explain that the vertical rotor thrust must be in equilibrium with the weight augmented with the vertical drag on the fuselage | | | x | x | x | |

CHAPTER 19: DETAILED THEORETICAL KNOWLEDGE SYLLABUS AND LEARNING OBJECTIVES
Subject – 082 – Principles of Flight (H)
See Appendix 1 to JAR-FCL 1.470 and JAR-FCL 2.470

| **Syllabus reference** | **Syllabus details and associated Learning Objectives** | *Aeroplane* | | *Helicopter* | | | *IR* |
|---|---|---|---|---|---|---|---|
| | | ATPL | CPL | ATPL /IR | ATPL | CPL | |
| LO | Define the relative air velocities to the blade sections as the vector component of the upstream air velocities and the induced velocities | | | x | x | x | |
| LO | Define the pitch angle and the angle of attack of a blade section | | | x | x | x | |
| LO | Explain the lift and the profile drag on a blade element | | | x | x | x | |
| LO | Explain the resulting lift and the thrust on the blade, define the resulting rotor thrust | | | x | x | x | |
| LO | Explain the necessity of a collective pitch angles change, the influence on the angles of attack and on the rotor thrust and the necessity of blade feathering | | | x | x | x | |
| LO | Explain the blade twist necessary to obtain the uniform induced airspeed over the disc | | | x | x | x | |
| LO | Explain the blade taper | | | x | x | x | |
| LO | Explain how the profile drag on the blade elements results in a torque on the main shaft and define the resulting rotor profile power | | | x | x | x | |
| LO | Explain the influence of the air density on the required powers | | | x | x | x | |
| LO | Show the tip vortices and their downwards and spiral movement, and the effect on the airflow over the blade tips as these pass over the vortice | | | x | x | x | |
| **082 04 01 02** | **Anti-torque force and tail rotor** | | | | | | |
| LO | Explain based on Newton's third law the need of a tail rotor thrust, the required value is proportional to the main-rotor torque, the tail rotor power is related to the tail rotor thrust | | | x | x | x | |
| LO | Explain the necessity of blade feathering of the tail rotor blades and the control by the yaw pedals, the maximum and minimum values of the pitch angles of the blades | | | x | x | x | |
| **082 04 01 03** | **Total power required and hover altitude OGE** | | | | | | |
| LO | Define the ancillary equipment and it's power requirement | | | x | x | x | |
| LO | Define the total power required | | | x | x | x | |

CHAPTER 19: DETAILED THEORETICAL KNOWLEDGE SYLLABUS AND LEARNING OBJECTIVES
Subject – 082 – Principles of Flight (H)
See Appendix 1 to JAR-FCL 1.470 and JAR-FCL 2.470

| **Syllabus reference** | **Syllabus details and associated Learning Objectives** | *Aeroplane* | | *Helicopter* | | | *IR* |
|---|---|---|---|---|---|---|---|
| | | ATPL | CPL | ATPL /IR | ATPL | CPL | |
| LO | Discuss the influence of the ambient pressure , temperature and the moisture on the required power | | | x | x | x | |
| **082 04 02 00** | **Vertical climb** | | | | | | |
| **082 04 02 01** | **Relative airflow and angles of attack** | | | | | | |
| LO | Describe the climb speed and the opposite downwards air velocity relative to the blades | | | x | x | x | |
| LO | Define the relative air velocities and the angle of attack of the blade sections | | | x | x | x | |
| LO | Explain how the angle of attack is controlled with the collective pitch angle control or blade feathering | | | x | x | x | |
| **082 04 02 02** | **Power and vertical speed** | | | | | | |
| LO | Define the total main rotor power required as the sum of the induced power, the climb power and the rotor profile power | | | x | x | x | |
| LO | Explain that the total main rotor power increases when the rate of climb increases | | | x | x | x | |
| LO | Explain the increase of the required tail rotor thrust and tail rotor power | | | x | x | x | |
| LO | Define the total required power in vertical flight | | | x | x | x | |
| **082 04 03 00** | **Forward flight** | | | | | | |
| **082 04 03 01** | **Airflow and forces in uniform inflow distribution** | | | | | | |
| LO | Explain the assumption of a uniform inflow distribution on rotor disc | | | x | x | x | |
| LO | Define the azimuth angle of the blade : the advancing blade on 90° and the retreating blade on 270°. | | | x | x | x | |
| LO | Show the upstream air velocities relative to the blade sections and the difference between the advancing and retreating blade. Define the area of reverse flow. Explain the importance of the forward speed related to the tip circumferential speed. | | | x | x | x | |

CHAPTER 19: DETAILED THEORETICAL KNOWLEDGE SYLLABUS AND LEARNING OBJECTIVES
Subject – 082 – Principles of Flight (H)
See Appendix 1 to JAR-FCL 1.470 and JAR-FCL 2.470

| **Syllabus reference** | **Syllabus details and associated Learning Objectives** | *Aeroplane* | | *Helicopter* | | | *IR* |
|---|---|---|---|---|---|---|---|
| | | ATPL | CPL | ATPL /IR | ATPL | CPL | |
| LO | Assuming constant pitch angles and rigid blade attachements explain the huge roll moment | | | x | x | x | |
| LO | Show that through cyclic feathering this imbalance could be eliminated. This require a low angle of attack (low pitch angle) on the advancing blade and a high angle of attack (high pitch angle) on the retreating blade | | | x | x | | |
| LO | Describe the high velocities on the advancing bladetip and the compressiblity effects which limits the maximum speed of the helicopter | | | x | x | x | |
| LO | Describe the low air velocities on the retreating bladetip as a function of the circumferential speed and the forward speed, the necessity of high angle of attack and the onset of stall | | | x | x | x | |
| LO | Define the tip speed ratio and show the limits | | | x | x | x | |
| LO | Explain the rotor thrust perpendicular to the rotor disc and the necessity to tilt the thrust vector forward. (Realisation will be explained in 082 05 00 00) | | | x | x | x | |
| LO | Explain the vertical equilibrium and the horizontal equilibrium in steady straight level flight | | | x | x | x | |
| **082 04 03 02** | **The flare (power flight)** | | | | | | |
| LO | Explain the flare in powered flight, the rearwards tilt of the rotor disc and the thrust vector. Show the horizontal component opposite to the speed | | | x | x | x | |
| LO | State the increase of the thrust due to the upwards inflow, and show the modifications of the angles of attack | | | x | x | x | |
| LO | Explain the increase of rotor RPM in the case of a non-governed rotor | | | x | x | x | |
| LO | Explain the actions taken by the pilot | | | x | x | x | |
| **082 04 03 03** | **Non uniform inflow distribution in relation to inflow rol** | | | | | | |

CHAPTER 19: DETAILED THEORETICAL KNOWLEDGE SYLLABUS AND LEARNING OBJECTIVES
Subject – 082 – Principles of Flight (H)
See Appendix 1 to JAR-FCL 1.470 and JAR-FCL 2.470

| **Syllabus reference** | **Syllabus details and associated Learning Objectives** | *Aeroplane* | | *Helicopter* | | | *IR* |
|---|---|---|---|---|---|---|---|
| | | ATPL | CPL | ATPL /IR | ATPL | CPL | |
| LO | Explain that the uniform inflow distribution is an assumption to simplify the theory and describe the real inflow distribution which modifies the angle of attack and the lift especially on the forward and backward blades | | | x | x | x | |
| **082 04 03 04** | **Power and maximum speed** | | | | | | |
| LO | Explain that the induced velocities and induced power decrease as the helicopter speed increases | | | x | x | x | |
| LO | Define the profile drag and the profile power and their increase with helicopter speed | | | x | x | x | |
| LO | Define the parasite drag and the parasite power and the increase with helicopter speed | | | x | x | x | |
| LO | Define the total drag and the increase with helicopter speed | | | x | x | x | |
| LO | Describe the tail rotor power and the power required by the ancillary equipment | | | x | x | x | |
| LO | Define the total power requirement as a sum of the partial powers and explain how this total power varies with helicopter speed | | | x | x | x | |
| LO | Explain the influence of the helicopter mass, the air density and additional external equipment on the partial powers and the total power required | | | x | x | x | |
| LO | Explain the translational lift and show the decrease of required total power as the helicopter speed increases in the low speed region | | | x | x | x | |
| **082 04 04 00** | **Hover and forward flight in ground effect (IGE)** | | | | | | |
| **082 04 04 01** | **Airflow in ground effect, downwash** | | | | | | |
| LO | Explain how the vicinity of the ground changes the downwards flow pattern and the consequences on the lift (thrust) at constant rotor power. Show that the ground effect is related to the height of the rotor above the ground and the rotor diameter. Show the required rotor power at constant AUM as a function of height above the ground. Describe the influence of the forward speed | | | x | x | x | |
| **082 04 05 00** | **Vertical descent** | | | | | | |

CHAPTER 19: DETAILED THEORETICAL KNOWLEDGE SYLLABUS AND LEARNING OBJECTIVES
Subject – 082 – Principles of Flight (H)
See Appendix 1 to JAR-FCL 1.470 and JAR-FCL 2.470

| **Syllabus reference** | **Syllabus details and associated Learning Objectives** | *Aeroplane* | | *Helicopter* | | | *IR* |
|---|---|---|---|---|---|---|---|
| | | ATPL | CPL | ATPL /IR | ATPL | CPL | |
| **082 04 05 01** | **Vertical descent, power on** | | | | | | |
| LO | Describe the airflow through the rotor disc in a trouble-free vertical descent, power on, the ascent airflow opposite to the helicopter velocity, the relative airvelocity and the angle of attack | | | x | x | x | |
| LO | Explain the vortex ring state, the settling with power. State the approximate values of vertical descent speeds for the formation of vortex ring related to the values of the induced velocities | | | x | x | x | |
| LO | Describe the relative airflow along the blades, the root stalls, the loss of lift on the blade tip, the turbulence. Show the effect of raising the lever and discuss the effects on the controls | | | x | x | x | |
| **082 04 05 02** | **Autorotation** | | | | | | |
| LO | State the need for early recognition of the failure and initiation of recovery, the recovery actions | | | x | x | x | |
| LO | Explain that the collective lever position must be lowered sufficient quickly to avoid the rapid decay of rotor RPM, the influence of the rotational inertia of the rotor on the rate of decay | | | x | x | x | |
| LO | Show the up flow and the induced flow through the rotordisc, the rotational velocity and the relative airflow, the inflow and inflow angles | | | x | x | x | |
| LO | Show how the resultant aerodynamic forces on the blade elements varies from root to tip and the three zones ; the inner stalled ring (stall region), the middle autorotation ring (driving region) and the outer anti-autorotation ring (driven region). Explain the RPM stability at a given collective pitch | | | x | x | x | |
| LO | Explain the control of the rotor RPM with collective pitch | | | x | x | x | |
| LO | Show the need of negative tailrotor thrust to obtain the yaw control | | | x | x | x | |

CHAPTER 19: DETAILED THEORETICAL KNOWLEDGE SYLLABUS AND LEARNING OBJECTIVES
Subject – 082 – Principles of Flight (H)
See Appendix 1 to JAR-FCL 1.470 and JAR-FCL 2.470

| **Syllabus reference** | **Syllabus details and associated Learning Objectives** | *Aeroplane* | | *Helicopter* | | | *IR* |
|---|---|---|---|---|---|---|---|
| | | ATPL | CPL | ATPL /IR | ATPL | CPL | |
| LO | Explain that the resultant upwards rotor thrust is approximately equal to the drag of a plain disc (diameter equal to the rotor disc) and justify the influence of helicopter mass and air density | | | x | x | x | |
| LO | Explain the final increase in rotor thrust by pulling the collective to decrease the vertical descent speed and the decay in rotor RPM | | | x | x | x | |
| **082 04 06 00** | **Forward flight – Autorotation** | | | | | | |
| **082 04 06 01** | **Airflow through the rotor disc** | | | | | | |
| LO | Explain the factors affecting inflow angle and angle of attack, the autorotative power distribution and the asymmetry over the rotor disc in forward flight | | | x | x | x | |
| **082 04 06 02** | **Flight and landing** | | | | | | |
| LO | Show the effect of forward speed on the vertical descent speed | | | x | x | x | |
| LO | Explain the effects of gross weight, rotor RPM and altitude (density) on endurance and range | | | x | x | x | |
| LO | Explain the manoeuvers of turning and touchdown | | | x | x | x | |
| LO | Explain the height-velocity avoidance graph or dead man's curves | | | x | x | x | |
| **082 05 00 00** | **MAIN ROTOR MECHANICS** | | | | | | |
| **082 05 01 00** | **Flapping of the blade in hover** | | | | | | |
| **082 05 01 01** | **Forces and stresses on the blade** | | | | | | |
| LO | Show the centrifugal force due to the rotor RPM and blade mass on the blade attachement to the hub. Apply the formula on an example. Justify the upper limit of the rotor RPM | | | x | x | x | |
| LO | Assume a rigid attachement and show the huge bending moment and stresses due to lift (thrust) and moment arm on the attachment | | | x | x | x | |

CHAPTER 19: DETAILED THEORETICAL KNOWLEDGE SYLLABUS AND LEARNING OBJECTIVES
Subject – 082 – Principles of Flight (H)
See Appendix 1 to JAR-FCL 1.470 and JAR-FCL 2.470

| **Syllabus reference** | **Syllabus details and associated Learning Objectives** | *Aeroplane* | | *Helicopter* | | | *IR* |
|---|---|---|---|---|---|---|---|
| | | ATPL | CPL | ATPL /IR | ATPL | CPL | |
| LO | Explain that the flapping hinge does not transfer the moment, show the small flapping hinge offset on a fully articulated rotor, and the zero offset in the case of a teetering rotor | | | x | x | x | |
| LO | Describe the flexible element on the hingeless rotor, the bending of the flexure, the equivalent flapping hinge offset compared to that of the articulated rotor | | | x | x | x | |
| **082 05 01 02** | **Centrifugal turning moment** | | | | | | |
| LO | Describe the centrifugal forces on the mass elements of a twisted blade and/or a blade with pitch applied, and the components of these forces. Show the couple of the in plane components and the centrifugal turning moment, the ensuing forces on the pitch links and the control mechanism | | | x | x | x | |
| LO | Explain the methods of counteracting by hydraulics, bias springs and balance masses | | | x | x | | |
| **082 05 01 03** | **Coning angle in hover** | | | | | | |
| LO | Show how the lift (thrust) and the centrifugal force result in the equilibrium of the blade about the flapping hinge (the blade weight is negligible) | | | x | x | x | |
| LO | Define the tip path plane and the coning angle | | | x | x | x | |
| LO | Explain the influence of the rotor RPM and the lift on the coning angle, justify the lower limit of the rotor RPM, relate the lift on one blade to the gross weight | | | x | x | x | |
| LO | Explain the effect of the mass of the blade on the tip path and the tracking | | | x | x | | |
| **082 05 02 00** | **Flapping angles of the blade in forward flight** | | | | | | |
| **082 05 02 01** | **Forces on the blade in forward flight without cyclic feathering** | | | | | | |
| LO | Assume rigid attachments of the blade to the hub and show the periodic lift, moment and stresses on the attachment, the ensuing metal fatigue, the roll moment on the helicopter and justify the necessity of flapping hinges | | | x | x | x | |
| LO | Assume no cyclic pitch and describe the lift on the advancing and the retreating blades | | | x | x | x | |

CHAPTER 19: DETAILED THEORETICAL KNOWLEDGE SYLLABUS AND LEARNING OBJECTIVES
Subject – 082 – Principles of Flight (H)
See Appendix 1 to JAR-FCL 1.470 and JAR-FCL 2.470

| **Syllabus reference** | **Syllabus details and associated Learning Objectives** | *Aeroplane* | | *Helicopter* | | | *IR* |
|---|---|---|---|---|---|---|---|
| | | ATPL | CPL | ATPL /IR | ATPL | CPL | |
| LO | State the azimuthal phase lag (90°or less) between the input (applied lift) and the output (flapping angle). Justify the rotor flapback for this situation and the rearwards tilting of the tip path plane. The rotor thrust perpendicular to the tip path plane (or rotor disc) is also tilted to the rear. Show the resultant rearwards component of the rotor thrust | | | x | x | x | |
| **082 05 02 02** | **Cyclic pitch (feathering) in helicopter mode, forward flight** | | | | | | |
| LO | Show the necessity of forward tilt of the rotor thrust, thus the tip path plane or rotor disc | | | x | x | x | |
| LO | Show how applied cyclic pitch modifies the lift (thrust) on the advancing and retreating blades and produces the required forward tilting of the tip path plane and the rotor thrust | | | x | x | x | |
| LO | Show the cone described by the blades and define the virtual axis of rotation (or the no flapping axis). Define the plane of rotation | | | x | x | x | |
| LO | Define the reference system in which we define the movements: the shaft axis and the hub plane | | | x | x | x | |
| LO | Describe the swashplates, the pitch link and the pitch horn. Explain how the collective lever moves the non rotating swashplate up or down alongside the shaft axis | | | x | x | x | |
| LO | Describe the mechanism with which the required cyclic pitch can be produce by tilting of the swashplate with the cyclic stick. ~~Show the necessity of the control advance angle to compensate for the phase angle~~Define the advance angle | | | x | x | x | |
| LO | Define the no-feathering or control plane (control orbit) and the no-feathering axis or control axis | | | x | x | x | |
| LO | Explain the transitional lift effect when the speed increases | | | x | x | x | |
| LO | Justify the increase of the tilt angle of the thrust vector, thus the rotor disc, to obtain an increase of the speed, the controls of the cyclic and the collective lever | | | x | x | x | |

CHAPTER 19: DETAILED THEORETICAL KNOWLEDGE SYLLABUS AND LEARNING OBJECTIVES
Subject – 082 – Principles of Flight (H)
See Appendix 1 to JAR-FCL 1.470 and JAR-FCL 2.470

| **Syllabus reference** | **Syllabus details and associated Learning Objectives** | *Aeroplane* | | *Helicopter* | | | *IR* |
|---|---|---|---|---|---|---|---|
| | | ATPL | CPL | ATPL /IR | ATPL | CPL | |
| **082 05 03 00** | **Blade lag motion in forward flight** | | | | | | |
| **082 05 03 01** | **Forces on the blade in the disc plane (tip path plane) in forward flight** | | | | | | |
| LO | Explain the forces of the Coriolis effect due to flapping on the blade attachement to the hub and the resulting periodic forces and stresses, the necessity of lead-lag hinges to avoid metal fatigue | | | x | x | x | |
| LO | Describe the profile drag forces on the blade elements and the periodic variation of these forces | | | x | x | x | |
| **082 05 03 02** | **The drag or lag hinge** | | | | | | |
| LO | Describe the drag hinge of the fully articulated rotor and the lag flexure in the hingeless rotor | | | x | x | x | |
| LO | Explain the necessity of drag dampers | | | x | x | x | |
| **082 05 03 03** | **Ground resonance** | | | | | | |
| LO | Explain the movement of the centre of gravity of the blades due to the lead-lag movements in the multi-blade rotor | | | x | x | x | |
| LO | Show the effect of this oscillating force on the fuselage and the danger of resonance between this alternating force and the fuselage and undercarriage. State the conditions likely to lead to the ground resonance. Describe the recovery actions | | | x | x | x | |
| **082 05 04 00** | **Forces and moments on the hub of different rotor systems** | | | | | | |
| **082 05 04 01** | **See-saw or teetering rotor** | | | | | | |
| LO | Show that the rotor thrust acts on the single zero-offset flapping hinge, thus no moment on the hub. Explain the danger of negative g. | | | x | x | x | |
| LO | Explain the operation of the underslung teetering rotor | | | x | x | x | |
| **082 05 04 02** | **Fully articulated rotor** | | | | | | |

CHAPTER 19: DETAILED THEORETICAL KNOWLEDGE SYLLABUS AND LEARNING OBJECTIVES
Subject – 082 – Principles of Flight (H)
See Appendix 1 to JAR-FCL 1.470 and JAR-FCL 2.470

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|---|---|---|---|---|---|---|---|
| | | ATPL | CPL | ATPL /IR | ATPL | CPL | |
| LO | Explain how the blade forces act on the flapping hinges with small offset and the resulting moment on the hub, compare with the teetering rotor | | | x | x | x | |
| **082 05 04 03** | **Hingeless rotor, bearingless rotor** | | | | | | |
| LO | Show the forces on the flapping hinges with large offset (virtual hinge) and the resulting moments, compare with other rotor systems | | | | | | |
| **082 05 05 00** | **Blade sailing** | | | | | | |
| **082 05 05 01** | **Blade sailing and causes** | | | | | | |
| LO | Define blade sailing, influence of low rotor RPM and adverse wind | | | x | x | x | |
| **082 05 05 02** | **Minimising the danger of blade sailing** | | | | | | |
| LO | Describe the actions to minimise danger and the demonstrated wind envelope for engaging-disengaging rotors | | | x | x | x | |
| **082 05 05 03** | **Droop stops** | | | | | | |
| LO | Explain the utility of the droop stops, retraction of the stops | | | x | x | x | |
| **082 05 06 00** | **Vibrations due to main rotor** | | | | | | |
| **082 05 06 01** | **Origins of the vertical vibrations** | | | | | | |
| LO | Explain the lift (thrust) variations per revolution of a blade and the resulting vertical rotorthrust variation (vertical bouncing)in the case of perfect identical blades. | | | x | x | x | |
| LO | Show the resulting frequencies (b-per-revolution) as a function of the number of blades b | | | x | x | x | |
| LO | Explain the thrust variation in case of a out of track blade, causes, frequencies (one-per-rev) | | | x | x | x | |
| LO | Explain the importance of the hinges offset on the effect of the vibrations on the fuselage | | | x | x | x | |

CHAPTER 19: DETAILED THEORETICAL KNOWLEDGE SYLLABUS AND LEARNING OBJECTIVES
Subject – 082 – Principles of Flight (H)
See Appendix 1 to JAR-FCL 1.470 and JAR-FCL 2.470

| **Syllabus reference** | **Syllabus details and associated Learning Objectives** | *Aeroplane* | | *Helicopter* | | | *IR* |
|---|---|---|---|---|---|---|---|
| | | ATPL | CPL | ATPL /IR | ATPL | CPL | |
| **082 05 06 02** | **Lateral vibrations** | | | | | | |
| LO | Explain the imbalance on the blade, causes, effects | | | x | x | x | |
| LO | Explain the frequencies , lateral one-per-rev vibration | | | x | x | x | |
| **082 06 00 00** | **TAIL ROTORS** | | | | | | |
| **082 06 01 00** | **Conventional tail rotor** | | | | | | |
| **082 06 01 01** | **Tail rotor description** | | | | | | |
| LO | Describe the two-bladed rotor with teetering hinge, the rotors with more than two blades | | | x | x | x | |
| LO | Show the flapping hinges and the feathering bearing | | | x | x | x | |
| LO | Discuss the dangers to ground personnel, to the rotorblades, possibilities of minimising these dangers | | | x | x | x | |
| **082 06 01 02** | **Tail rotor aerodynamics** | | | | | | |
| LO | Explain the airflow round the blades in hover and in forward flight, the effects of the tip speeds on the noise production and the compressibility, limits | | | x | x | x | |
| LO | Explain in hovering the effect of wind on the tail rotor aerodynamics and thrust, problems | | | x | x | x | |
| LO | Explain the tail rotor thrust and the control through pitch control (feathering) | | | x | x | x | |
| LO | Explain tail rotor flapback, and the effects of the delta three hinges device | | | x | x | x | |
| LO | Explain the effects of the tail rotor failure | | | x | x | x | |
| LO | Explain the loss of tail rotor effectiveness, vortex ring state, causes, side wind and yaw speed | | | x | x | x | |
| **082 06 01 03** | **Strakes on the tailboom** | | | | | | |

CHAPTER 19: DETAILED THEORETICAL KNOWLEDGE SYLLABUS AND LEARNING OBJECTIVES
Subject – 082 – Principles of Flight (H)
See Appendix 1 to JAR-FCL 1.470 and JAR-FCL 2.470

| **Syllabus reference** | **Syllabus details and associated Learning Objectives** | *Aeroplane* | | *Helicopter* | | | *IR* |
|---|---|---|---|---|---|---|---|
| | | ATPL | CPL | ATPL /IR | ATPL | CPL | |
| LO | Describe the strake and explain the functiom of the device | | | x | x | x | |
| **082 06 02 00** | **The fenestron** | | | | | | |
| **082 06 02 01** | **Technical lay-out** | | | x | x | x | |
| LO | Show the technical lay-out of a Fenestron tail rotor | | | x | x | x | |
| **082 06 02 02** | **Control concepts** | | | | | | |
| LO | Explain the control concepts of a Fenestron tail rotor | | | x | x | x | |
| **082 06 02 03** | **Advantages and disadvantages** | | | | | | |
| LO | Explain the advantages and disadvantages of a Fenestron tail rotor | | | x | x | x | |
| **082 06 03 00** | **The NOTAR** | | | | | | |
| **082 06 03 01** | **Technical lay-out** | | | | | | |
| LO | Show the technical lay-out of a NOTAR | | | x | x | x | |
| **082 06 03 02** | **Control concepts** | | | | | | |
| LO | Explain the control concepts OF A NOTAR | | | x | x | x | |
| **082 06 03 03** | **Advantages and disadvantages** | | | | | | |
| LO | Explain the advantages and disadvantages of a NOTAR | | | x | x | x | |
| **082 06 04 00** | **Vibrations** | | | | | | |
| **082 06 04 01** | **Tail rotors vibrations** | | | | | | |
| LO | Explain the sources of vibration in a tail rotor and the resulting high frequencies | | | x | x | x | |
| **082 07 00 00** | **EQUILIBRIUM, STABILITY AND CONTROL** | | | | | | |
| **082 07 01 00** | **Equilibrium and helicopter attitudes** | | | | | | |

CHAPTER 19: DETAILED THEORETICAL KNOWLEDGE SYLLABUS AND LEARNING OBJECTIVES
Subject – 082 – Principles of Flight (H)
See Appendix 1 to JAR-FCL 1.470 and JAR-FCL 2.470

| **Syllabus reference** | **Syllabus details and associated Learning Objectives** | *Aeroplane* | | *Helicopter* | | | *IR* |
|---|---|---|---|---|---|---|---|
| | | ATPL | CPL | ATPL /IR | ATPL | CPL | |
| **082 07 01 01** | **Hover** | | | | | | |
| LO | Explain that the vectorsum of the forces is equal to zero | | | x | x | x | |
| LO | Indicate the forces and moments around the lateral axis acting on a helicopter in a steady hover | | | x | x | x | |
| LO | Describe how the centre of gravity position and the wind influence the pitch angle in a steady hover | | | x | x | x | |
| LO | Indicate the forces and moments around the longitudinal axis acting on a helicopter in a steady hover | | | x | x | x | |
| LO | Deduce how the roll angle in a steady hover without wind results from the forces and moments around the longitudinal axis | | | x | x | x | |
| LO | Explain how the cyclic is used to create equilibrium of forces and moments around the lateral axis in a steady hover | | | x | x | x | |
| LO | Explain the consequence of the cyclic stick reaching its forward or aft limit during an attempt to take off to the hover | | | x | x | x | |
| LO | Explain the influence of the density altitude on the equilibrium of forces and moments in a steady hover | | | x | x | x | |
| **082 07 01 02** | **Forward flight** | | | | | | |
| LO | Explain that the vectorsum of the different forces is equal to zero | | | x | x | x | |
| LO | Indicate the forces and moments around the lateral axis acting on a helicopter in a steady, straight and level flight | | | x | x | x | |
| LO | Explain the influence of All Up Mass on the forces and moments around the lateral axis in forward flight | | | x | x | x | |
| LO | Explain the influence of the position of the centre of gravity on the forces and moments around the lateral axis in forward flight | | | x | x | x | |

CHAPTER 19: DETAILED THEORETICAL KNOWLEDGE SYLLABUS AND LEARNING OBJECTIVES
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|---|---|---|---|---|---|---|---|
| | | ATPL | CPL | ATPL /IR | ATPL | CPL | |
| LO | Explain the role of the cyclic stick position in creating equilibrium of forces and moments around the lateral axis in forward flight | | | x | x | x | |
| LO | Explain how forward speed influences the fuselage attitude | | | x | x | x | |
| LO | Explain the contribution on the equilibrium of forces and moments of the roll effect because of coning and roll resulting from non uniform inflow distribution | | | x | x | x | |
| **082 07 02 00** | **Stability** | | | | | | |
| **082 07 02 01** | **Static longitudinal, roll and directional stability** | | | | | | |
| LO | Define the meaning of static stability | | | x | x | x | |
| LO | Explain the contribution of the main rotor in speed stability | | | x | x | x | |
| LO | Explain the contribution of the main rotor in angle of attack stability | | | x | x | x | |
| LO | Describe the influence of the horizontal stabilizer on static longitudinal stability | | | x | x | x | |
| LO | Explain the effect of hinge offset on static stability behaviour | | | x | x | x | |
| LO | Describe the influence of the tail rotor on static directional stability | | | x | x | x | |
| LO | Describe the influence of the vertical stabilizer on static directional stability | | | x | x | x | |
| LO | Explain the influence of the main rotor on the static roll stability | | | x | x | x | |
| LO | Describe the influence of the longitudinal position of the center of gravity on the static longitudinal stability | | | x | x | x | |
| **082 07 02 02** | **Static stability in the hover** | | | | | | |
| LO | Describe the initial movements of a hovering helicopter after the occurrence of a horizontal gust | | | x | x | x | |
| **082 07 02 03** | **Dynamic stability** | | | | | | |

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|---|---|---|---|---|---|---|---|
| | | ATPL | CPL | ATPL /IR | ATPL | CPL | |
| LO | Define the characteristics of dynamic stability | | | x | x | x | |
| LO | Explain why static stability is a precondition for dynamic stability | | | x | x | x | |
| LO | Describe the possible periodic and a-periodic modes of dynamic stability | | | x | x | x | |
| **082 07 02 04** | **Longitudinal stability** | | | | | | |
| LO | Explain the individual contributions of angle of attack and speed stability together with the stabilizer and fuselage on the dynamic longitudinal stability | | | x | x | x | |
| LO | Explain the principle of stability augmentation systems | | | x | x | x | |
| LO | Define the characteristics of the phugoid | | | x | x | x | |
| **082 07 02 05** | **Roll stability and directional stability** | | | | | | |
| LO | Explain the meaning of dihedral of a helicopter | | | x | x | x | |
| LO | Describe how dihedral influences the static roll stability | | | x | x | x | |
| LO | Explain how static roll stability and static directional stability together may lead to Dutch roll | | | x | x | x | |
| LO | Explain which stability features together may result in spiral dive and the reason why | | | x | x | x | |
| LO | Explain the static directional stability features of a tandem rotor type helicopter | | | x | x | x | |
| **082 07 03 00** | **Control** | | | | | | |
| **082 07 03 01** | **Manoeuvre stability** | | | | | | |
| LO | Define the meaning of stick force stability | | | x | x | x | |
| LO | Define the meaning of stick position stability | | | x | x | x | |
| LO | Explain the meaning of the stick force diagram and the trimspeed | | | x | x | x | |

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|---|---|---|---|---|---|---|---|
| | | ATPL | CPL | ATPL /IR | ATPL | CPL | |
| LO | Explain the meaning of stick force per g | | | x | x | x | |
| LO | Explain how a bob weight influences stick force per g | | | x | x | x | |
| LO | Explain how helicopter control can be limited because of available stick travel | | | x | x | x | |
| LO | Explain how the position of the centre of gravity influences the remaining stick travel | | | x | x | x | |
| **082 07 03 02** | **Control power** | | | | | | |
| LO | Explain the meaning of control moment | | | x | x | x | |
| LO | Explain the importance of the centre of gravity position on control moment | | | x | x | x | |
| LO | Explain how the changes of magnitude of rotor thrust of a helicopter type during manoeuvres influence the control moment | | | x | x | x | |
| LO | Explain which control moment provides control for a helicopter rotor with zero hinge offset (central flapping hinge) | | | x | x | x | |
| LO | Explain the different type of rotor control moments which together provide the control of helicopters with a hingeless or a fully articulated rotor system | | | x | x | x | |
| LO | Explain the influence of hinge offset on controllability | | | x | x | x | |
| **082 07 03 03** | **Static and ~~D~~dynamic roll over** | | | | | | |
| LO | Explain the mechanism which causes static and dynamic roll over | | | x | x | x | |
| LO | Explain the required pilot action when dynamic roll over is starting to develop | | | x | x | x | |
| **082 08 00 00** | **HELICOPTER FLIGHT MECHANICS** | | | | | | |
| **082 08 01 00** | **Performances / Flight Limits** | | | | | | |
| **082 08 01 01** | **Hover and vertical flight** | | | | | | |

CHAPTER 19: DETAILED THEORETICAL KNOWLEDGE SYLLABUS AND LEARNING OBJECTIVES
Subject – 082 – Principles of Flight (H)
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|---|---|---|---|---|---|---|---|
| | | ATPL | CPL | ATPL /IR | ATPL | CPL | |
| LO | Show the power required OGE and IGE and the power available, the OGE and IGE maximum hover height. Define hover with limited power.<br>Remark - (See subject 021, piston engines and turbine engines) | | | x | x | x | |
| LO | Explain the effects of AUM, ambient temperature and pressure, density altitude and moisture | | | x | x | x | |
| LO | Discuss the rate of climb in a vertical flight | | | x | x | x | |
| **082 08 01 02** | **Forward flight** | | | | | | |
| LO | Compare the power required and the power available as a function of speed in straight and level flight | | | x | x | x | |
| LO | Define the maximum speed limited by power and the value relative to VNE and VNO | | | x | x | x | |
| LO | Use the graph, total power/speed, to determine the speeds of maximum rate of climb and the maximum angle of climb | | | x | x | x | |
| LO | Use the graph, total power/speed, to define the TAS for maximum range and maximum endurance, consider the case of the piston engine and the turbine engine. | | | x | x | x | |
| LO | Explain the effects of tail or head wind on the speed for maximum range | | | x | x | x | |
| LO | Explain the effects of AUM, pressure and temperature, density altitude, humidity | | | x | x | x | |
| **082 08 01 03** | **Manoeuvering** | | | | | | |
| LO | Define the load factor, the radius of turn and the rate of turn when manoeuvering | | | x | x | x | |
| LO | Explain the relationship between the bank angle, the airspeed and the radius of turn, between the bank angle and the load factor when manoeuvering | | | x | x | x | |
| LO | Explain the influence of AUM, pressure and temperature, density altitude, humidity on manoeuvering | | | x | x | x | |

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|---|---|---|---|---|---|---|---|
| | | ATPL | CPL | ATPL /IR | ATPL | CPL | |
| LO | Define the limit load factors and the certification categories | | | x | x | x | |
| **082 08 02 00** | **Special conditions** | | | | | | |
| **082 08 02 01** | **Operating with limited power** | | | | | | |
| LO | Explain the operations with limited power, use the graph, total power/speed, to show the limitations on vertical flight and level flight. | | | x | x | x | |
| LO | Discuss the power checks and procedures for take-off and landing | | | x | x | x | |
| LO | Discuss manoeuvres with limited power | | | x | x | x | |
| **082 08 02 02** | **Overpitch, overtorque** | | | | | | |
| LO | Describe overpitching and show the consequences | | | x | x | x | |
| LO | Discuss the situations likely to lead to overpitching | | | x | x | x | |
| LO | Describe overtorqueing and show the consequences | | | x | x | x | |
| LO | Discuss the situations likely to lead to overtorqueing | | | x | x | x | |

**END**