N. SUBJECT 082 — PRINCIPLES OF FLIGHT (HELICOPTER)

(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 minute (RPM), or degrees per second (deg/s), or radians per second (rad/s).

Density is the mass of the fluid per unit volume, in SI units kg/m^3.

(2) AERONAUTICAL DEFINITIONS

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

The cross section of a blade perpendicular to the feathering axis, the blade section at a distance (radius) from the hub centre shows the shape of the aerofoil.

Such section is characterised by a contour, a leading and trailing edge, a chord line, a chord, a camber line, the maximum thickness or depth, the thickness-to-chord ratio.

The blade element is a spanwise piece of the blade. It is assumed that its radial extension is small such that the aerodynamic forces don't vary with radial distance. The aerodynamic forces on the blade element produce lift, drag and a pitching moment.

The centre of pressure is defined as the point on the chord where the resultant of all aerodynamic forces acts such that the pitching moment about this point 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 as a function of the radial distance (the chord lines are not parallel). If the pitch angle decreases towards the tip, this is called washout.

The vector sum of the undisturbed upstream velocity and the thrust-induced velocity is the relative velocity.

In the helicopter theory we use the following definitions for 'angle of attack', 'lift' and 'drag':

— The angle between the relative velocity and the chord line is the angle of attack α or AoA, called effective angle of attack. The geometric angle of attack is the angle between the undisturbed upstream velocity and the chord line.

— Lift is the component of the aerodynamic force on a blade element perpendicular to the relative velocity.

— Profile drag is the component of the aerodynamic force on a blade element parallel to the relative velocity.

Profile drag is produced by the pressure forces and by skin-friction forces that act on the surface of the blade element.

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

Disc loading is by definition the mass M or weight W of the helicopter divided by the area of the disc. (The disc area is πR^2, R being the blade-tip radius)

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

Blade loading is by definition the mass (weight) divided by the total planform area of the blades.

The area of a rectangular blade is given by chord times tip radius. For tapered blades, the mean geometric chord is taken as an approximately equivalent chord.

Blade loading is defined as the mass or weight of the helicopter divided by the total area of all blades.

Rotor solidity is the ratio of the total blade area to the disc area.

(4) PLANES, AXES, REFERENCE SYSTEMS OF THE ROTOR

— 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. Another name for this axis is no-flapping axis.

— Rotor-disc plane: another name for the tip-path plane.

— Rotor disc: the disc traced out by the blade tips in the tip-path plane.

— Plane of rotation: the plane parallel to the tip-path plane through the hub centre.

— No-feathering plane: is also called the control plane. This is the reference plane relative to which the pitch of the rotating blade has no variation during a full rotation. 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 counted in the rotation sense from the direction opposite to the helicopter velocity.

(5) REFERENCE SYSTEMS (sometimes called frames of reference)

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.

(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 local pitch angle.

— Pitch angle of the blade: the pitch angle 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.

— Advance angle: the azimuthal angle between the flapping axis and the point where the pitch link is connected to the swash plate (not to be confused with the phase lag from pitch input to flapping response).

The induced velocity is the velocity induced by the rotor thrust in the plane of the rotor disc (about 10 m/s for a light helicopter in hover). The slipstream velocity continues to increase downstream of the rotor. In the hover out-of-ground-effect (HOGE), 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 resolvable in two components: lift and drag. Lift is perpendicular to the relative air velocity, and drag is parallel to the relative air velocity.

The aerodynamic force may also be resolved into thrust perpendicular to the tip-path plane (or plane of rotation) and drag parallel to the tip-path plane. This drag is the sum of the profile drag and the induced drag.

Because the angle between the lift vector and the thrust vector is very small, the magnitudes of these two vectors may be taken as equal.

The blade thrust is the sum of the thrusts of all blade elements along the blade radius.

The sum of the thrusts of all blades is the (total) rotor thrust acting perpendicular to the tip-path plane in the direction of the virtual rotation axis.

The result of the induced drag forces on all the blade elements of all blades is a torque on the shaft which — multiplied by the angular velocity of the rotor — gives the required induced power.

The result of all the profile drags is a torque on the shaft which — multiplied by the angular velocity of the rotor — gives the required 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; 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. They are replaced by flexible elements at the root of the blades which allow flapping and lead-lag movements. The feathering bearing allows feathering of the blade.

4. Bearingless rotor: There are no hinges or bearings. Flapping and lead or lag are obtained by flexing flexible elements called elastomeric hinges and feathering is obtained 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. Elastomeric 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 resulting from the induced velocity in the rotor disc for the generation of lift. For any given thrust, the induced power is minimum when the induced velocity is uniform over the rotor disc. Such velocity distribution can be approximated by using some blade twist (a truly uniform velocity cannot be obtained).

The rotor profile drag results from the component opposite to the blade velocities of all the profile drags of the blade elements of all the blades.

The resulting power is the rotor profile power or the profile-drag power (sum of the powers to overcome the torque).

The parasite drag is the drag on the helicopter fuselage including the drag of the rotor hub and all external equipment such 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.

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 power in straight and level flight decreases as speed increases. The phenomenon is called translational lift.

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

(9) PHASE ANGLE IN FLAPPING MOVEMENT OF THE BLADE

The cyclic movement tilts the rotor disc in the direction of the intended helicopter velocity.

The flapping response is approximately 90° later than the applied cyclic pitch (somewhat less than 90° for hingeless rotors).

The pitch mechanism consists of the swash plate and for each blade a pitch link attached to the swash plate and a pitch horn attached to the blade.

(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 subset of the components that constitutes the major part of the aircraft is symmetrically disposed in the port and starboard sense.

Syllabus reference	**Syllabus details and associated Learning Objectives**	*Aeroplane*		*Helicopter*			*IR*
		ATPL	CPL	ATPL /IR	ATPL	CPL	
080 00 00 00	**PRINCIPLES OF FLIGHT**						
082 00 00 00	**PRINCIPLES OF FLIGHT — HELICOPTER**						
082 01 00 00	**SUBSONIC AERODYNAMICS**						
082 01 01 00	**Basic concepts, laws and definitions**						

Syllabus reference	**Syllabus details and associated Learning Objectives**	*Aeroplane*		*Helicopter*			*IR*
		ATPL	CPL	ATPL /IR	ATPL	CPL	
082 01 01 01	**SI units and conversion of units**						
LO	List the fundamental quantities and units in SI system: mass (kg), length (m), time (s).			x	x	x	
LO	Show and apply tables of conversion of units of English units to SI units and vice versa.			x	x	x	
LO	The units of the physical quantities should be mentioned when they are introduced.			x	x	x	
082 01 01 02	**Definitions and basic concepts about air**						
LO	Describe air temperature and pressure as functions of height.			x	x	x	
LO	Use the table of the International Standard Atmosphere.			x	x	x	
LO	Define air density; explain the relationship between density, pressure and temperature.			x	x	x	
LO	Explain the influence of moisture content on density.			x	x	x	
LO	Define pressure altitude and density altitude.			x	x	x	
082 01 01 03	**Newton's laws**						
LO	Describe Newton's second law: force equals product of mass and acceleration.			x	x	x	
LO	Distinguish mass and weight, units.			x	x	x	
LO	Describe the other form of the second law, applicable to thrust.			x	x	x	
LO	Describe Newton's third law: action and reaction, force and torque.			x	x	x	
082 01 01 04	**Basic concepts of airflow**						
LO	Describe steady and unsteady airflow.			x	x	x	
LO	Define 'streamline' and 'stream tube'.			x	x	x	
LO	Equation of continuity or mass conservation.			x	x	x	

Syllabus reference	**Syllabus details and associated Learning Objectives**	*Aeroplane*		*Helicopter*			*IR*
		ATPL	CPL	ATPL /IR	ATPL	CPL	
LO	Mass-flow rate through a stream-tube section.			x	x	x	
LO	Describe the relation between the external force on a stream tube and the momentum variation of the airflow.			x	x	x	
LO	State the Bernoulli's equation in a non-viscous airflow, use this equation to explain and define static pressure, dynamic pressure and total pressure.			x	x	x	
LO	Define the stagnation point in a flow around an aerofoil and explain the pressure obtained in the stagnation point.			x	x	x	
LO	Describe the pitot system and explain the measurement of 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 a two-dimensional and a three-dimensional airflow.			x	x	x	
LO	Explain that viscosity is a feature of a fluid (gas or liquid).			x	x	x	
LO	Describe the airflow over a flat surface and explain the tangential friction between air and surface and the development of a boundary layer.			x	x	x	
LO	Define a laminar boundary layer, a 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**						

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’, ‘chord line’, ‘chord’, ‘thickness’, ‘thickness-to-chord ratio of section’, ‘camber line’, ‘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 at 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 aerodynamic 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 the lift coefficient is a function of the angle of attack, draw the graph.			x	x	x	
LO	Explain how drag is caused by pressure forces on the surfaces and by friction forces in the boundary layers. Define the term ‘profile drag’.			x	x	x	
LO	Draw the graph of lift (or of the lift coefficient) as a function of drag or of the drag coefficient and define the lift–drag ratio.			x	x	x	

Syllabus reference	**Syllabus details and associated Learning Objectives**	*Aeroplane*		*Helicopter*			*IR*
		ATPL	CPL	ATPL /IR	ATPL	CPL	
LO	Use the equations of lift and drag to show the influence of speed and density on 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 aerodynamic force, the centre of pressure, the pitching moment.			x	x	x	
LO	Know that the pitching moment about the centre of pressure is zero by definition.			x	x	x	
LO	Know that symmetrical aerofoils have the centre of pressure a quarter chord behind the leading edge independently of the angle of attack as long as the angle of attack remains smaller than the angle of stall.			x	x	x	
LO	Taking an asymmetrical aerofoil section with different cambers, know the position of the centre of pressure, the influence of the angle of attack on the centre of pressure and the pitching moment about a line which is a quarter chord behind the leading edge.			x	x	x	
082 01 02 03	**Stall**						
LO	Explain the boundary layer separation when the angle of attack increases beyond stall onset and the decrease of lift and the increase of drag. Define the 'separation point and line'.			x	x	x	
LO	Draw a 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 how pitching moments appear about the line at quarter chord behind the leading edge.			x	x	x	
082 01 02 04	**Disturbances due to profile contamination**						

Syllabus reference	Syllabus details and associated Learning Objectives	*Aeroplane*		*Helicopter*			*IR*
		ATPL	CPL	ATPL /IR	ATPL	CPL	
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 wing and subsequent increase of profile drag.			x	x	x	
082 01 03 00	**Three-dimensional airflow around a blade (wing) and a fuselage**						
082 01 03 01	**The blade**						
LO	Describe different planforms of blades, and describe 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 twist.			x	x	x	
082 01 03 02	**Airflow pattern and influence on lift**						
LO	Explain the spanwise flow in the case of a blade 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 downwash causes vortices.			x	x	x	
LO	Define the effective air velocity as the resultant of the undisturbed air velocity and the induced velocity and define the effective angle of attack.			x	x	x	
LO	Explain the spanwise lift distribution and how it can be modified by twist.			x	x	x	
082 01 03 03	**Induced drag**						

Syllabus reference	Syllabus details and associated Learning Objectives	*Aeroplane*		*Helicopter*			*IR*
		ATPL	CPL	ATPL /IR	ATPL	CPL	
LO	Explain the thrust-induced drag, the influence of the angle of attack and of the aspect ratio.			x	x	x	
082 01 03 04	**The airflow around a fuselage**						
LO	Describe the aircraft fuselage and the external components which cause drag, the airflow around the fuselage, influence of the pitch angle of the fuselage.			x	x	x	
LO	Define parasite drag as the sum of pressure drag and friction drag.			x	x	x	
LO	Define 'interference drag'.			x	x	x	
LO	Describe fuselage shapes that minimise drag.			x	x	x	
LO	Know 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 that the speed of sound is proportional to the square root of the absolute temperature (unit 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 number.			x	x	x	
LO	Define subsonic, high subsonic and supersonic flows in relation to the value of the Mach number.			x	x	x	
082 02 01 02	**Shock waves**						

Syllabus reference	**Syllabus details and associated Learning Objectives**	*Aeroplane*		*Helicopter*			*IR*
		ATPL	CPL	ATPL /IR	ATPL	CPL	
LO	Describe a shock wave in a supersonic flow and the pressure and speed changes by the shock.			x	x	x	
LO	Describe the appearance of local supersonic flows at the upper surface of a blade section and the compression by a shock when the section is in an upstream high subsonic flow.			x	x	x	
LO	Describe the effect of the shock on lift, drag, the 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**						
LO	Explain the different shapes which allow higher upstream Mach numbers without generating a shock wave on the upper surface: — reducing the section thickness-to-chord ratio; — special aerofoil sections as supercritical shapes; — 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	**Rotorcraft types**						
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	**Helicopter configurations**						

Syllabus reference	**Syllabus details and associated Learning Objectives**	*Aeroplane*		*Helicopter*			*IR*
		ATPL	CPL	ATPL /IR	ATPL	CPL	
LO	Describe the single main rotor helicopter and the other configurations: tandem, coaxial, side by side, synchrocopter (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 layout of a single main rotor helicopter, fuselage, engine or engines, main gearbox, main rotor shaft and rotor hub.			x	x	x	
LO	Mention the tail rotor at the aft of the fuselage, the fenestron and the NOTOR (No Tail Rotor).			x	x	x	
LO	Define the rotor disc area and the blade area, the blades turning in the hubplane.			x	x	x	
LO	Describe the teetering rotor with the hinge axis on the shaft axis and the rotor with more than two blades with offset hinge axes.			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 rotor disc and around the blades**						
LO	Define the circumferential (tangential) velocity of the blade sections, which equals the angular velocity of the rotor multiplied by 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	

Syllabus reference	**Syllabus details and associated Learning Objectives**	*Aeroplane*		*Helicopter*			*IR*
		ATPL	CPL	ATPL /IR	ATPL	CPL	
LO	Based on Newton's second law (momentum), explain that the vertical force on the disc, the rotor thrust, produces vertical downward velocities in the rotor-disc plane. The values of these thrust-induced velocities increase as the thrust increases and decrease with increasing rotor diameter. Know that the velocities some distance downstream are twice the value of the induced speed in the disc plane.			x	x	x	
LO	Explain why the production of the induced flow requires a power on the shaft, the induced power. The induced power is smallest if the induced velocities have the same value on the whole disc (flow uniformity over the disc).			x	x	x	
LO	Describe uniform and typical non-uniform velocities through the rotor disc.			x	x	x	
LO	Explain why the vertical rotor thrust must be somewhat higher than the weight because of the vertical drag on the fuselage.			x	x	x	
LO	Describe the vertical air velocities relative to the rotor disc as the sum 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 element.			x	x	x	
LO	Explain lift and the profile drag of 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	

Syllabus reference	Syllabus details and associated Learning Objectives	*Aeroplane*		*Helicopter*			*IR*
		ATPL	CPL	ATPL /IR	ATPL	CPL	
LO	Explain the necessity of collective pitch angle changes, 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 a more even induced airspeed over the disc.			x	x	x	
LO	Describe the different blade shapes (as viewed from above).			x	x	x	
LO	Explain how the profile drag on the blade elements generates a torque on the main shaft and define the resulting rotor profile power.			x	x	x	
LO	Explain the influence of air density on the required powers.			x	x	x	
LO	Show the effect on the airflow over the blade tips.			x	x	x	
082 04 01 02	**Anti-torque force and tail rotor**						
LO	Based on Newton's third law, explain the need of a tail-rotor thrust, the required value being proportional to the main-rotor torque. Show that the tail-rotor power is proportional 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 Outside Ground Effect (OGE)**						
LO	Define the ancillary equipment and its power requirement.			x	x	x	
LO	Define the total power required.			x	x	x	
LO	Describe the influence of ambient pressure, temperature and moisture on the required power.			x	x	x	

Syllabus reference	Syllabus details and associated Learning Objectives	*Aeroplane*		*Helicopter*			*IR*
		ATPL	CPL	ATPL /IR	ATPL	CPL	
082 04 02 00	**Vertical climb**						
082 04 02 01	**Relative airflow and angles of attack**						
LO	Describe the climb speed and the opposite vertical air velocity relative to the rotor disk.			x	x	x	
LO	Explain the relative air velocities and the angle of attack of the blade elements.			x	x	x	
LO	Explain how the angle of attack is controlled by the collective pitch angle control.			x	x	x	
082 04 02 02	**Power and vertical speed**						
LO	Define the total main-rotor power as the sum of the parasite power, the induced power, the climb power and the rotor profile power.			x	x	x	
LO	Explain why the total main-rotor power increases when the rate of climb increases.			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 the rotor disc.			x	x	x	
LO	Define the azimuth angle of a blade, the advancing blade angular range centred at 90°, and the retreating blade range centred at 270°.			x	x	x	
LO	Show the upstream air velocities relative to the blade elements and the different effects on the advancing and retreating blade. Define the area of reverse flow. Explain the influence of forward speed on the tip circumferential speed.			x	x	x	

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 attachments, explain the huge roll moment by the asymmetric lift distribution.			x	x	x	
LO	Show that through cyclic feathering this imbalance could be eliminated by a low angle of attack (accomplished by a low-pitch angle) on the advancing blade and a high angle of attack (accomplished by a high-pitch angle) on the retreating blade.			x	x	x	
LO	Describe the high air velocity at the advancing blade tip and the compressibility effects which limit the maximum speed of the helicopter.			x	x	x	
LO	Describe the low air velocities on the retreating blade tip resulting from 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 equilibrium conditions in steady straight and level flight.			x	x	x	
082 04 03 02	**The flare (powered flight)**						
LO	Explain the flare in powered flight, the rearward tilt of the rotor disc and of the thrust vector. Show the horizontal thrust component opposite to the speed.			x	x	x	
LO	State the increase of the thrust due to the upward 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	

Syllabus reference	**Syllabus details and associated Learning Objectives**	*Aeroplane*		*Helicopter*			*IR*
		ATPL	CPL	ATPL /IR	ATPL	CPL	
LO	Explain the actions to be taken by the pilot.			x	x	x	
082 04 03 03	**Non-uniform inflow distribution in relation to inflow roll**						
LO	Explain why 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 fuselage 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	

Syllabus reference	Syllabus details and associated Learning Objectives	*Aeroplane*		*Helicopter*			*IR*
		ATPL	CPL	ATPL /IR	ATPL	CPL	
LO	Describe 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 downward flow pattern and the consequences on lift (thrust) at constant rotor power. Show that the ground effect depends on 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**						
082 04 05 01	**Vertical descent, power on**						
LO	Describe the airflow to the rotor disc in a trouble-free vertical descent, power on, the airflow opposite to the helicopter velocity, the relative air velocity 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 airflow relative to the blades, the root stall, 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**						

Syllabus reference	**Syllabus details and associated Learning Objectives**	*Aeroplane*		*Helicopter*			*IR*
		ATPL	CPL	ATPL /IR	ATPL	CPL	
LO	State the need for early recognition of malfunctions and for a quick initiation of recovery. Describe the recovery actions.			x	x	x	
LO	Explain that the collective lever position must be lowered sufficient quickly to avoid a rapid decay of rotor RPM, explain the influence of the rotational inertia of the rotor on the rate of decay.			x	x	x	
LO	Show the induced flow through the rotor disc, the rotational velocity and the relative airflow, the inflow and inflow angles.			x	x	x	
LO	Show how the aerodynamic forces on the blade elements vary from root to tip and distinguish 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 tail-rotor thrust for yaw control.			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 at 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**						

Syllabus reference	Syllabus details and associated Learning Objectives	*Aeroplane*		*Helicopter*			*IR*
		ATPL	CPL	ATPL /IR	ATPL	CPL	
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 how the centrifugal forces depend on rotor RPM and blade mass and how they pull on the blade attachment to the hub. Apply the formula to an example. Justify the upper limit of the rotor RPM.			x	x	x	
LO	Assume a rigid attachment and show how thrust may cause huge oscillating bending moments which stress the attachment.			x	x	x	
LO	Explain why flapping hinges do not transfer such moments. Show the small flapping hinge offset on fully articulated rotors and zero offset in the case of teetering rotors.			x	x	x	
LO	Describe the working principle of the flexible element in the hingeless rotor and describe the equivalent flapping hinge offset compared to that of the articulated rotor.			x	x	x	
082 05 01 02	**Centrifugal turning moment**						

Syllabus reference	**Syllabus details and associated Learning Objectives**	*Aeroplane*		*Helicopter*			*IR*
		ATPL	CPL	ATPL /IR	ATPL	CPL	
LO	Describe the centrifugal forces on the mass elements of a blade with pitch applied and the components of these forces. Show how these forces generate a moment which tries to reduce the blade-pitch angle.			x	x	x	
LO	Explain the methods of counteracting by hydraulics, bias springs and balance masses.			x	x	x	
082 05 01 03	**Coning angle in hover**						
LO	Show how the equilibrium of the moments about the flapping hinge of lift (thrust) and of the centrifugal force determine the coning angle of the blade (the blade weight being negligible).			x	x	x	
LO	Define the tip-path plane and the coning angle.			x	x	x	
LO	Explain the influence of rotor RPM and 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	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 for flapping hinge.			x	x	x	
LO	Assume no cyclic pitch and describe the lift on the advancing and the retreating blades.			x	x	x	

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 pitch) and the output (flapping angle). Explain the rotor flapback (the rearward tilting of the tip-path plane and the rotor thrust).			x	x	x	
082 05 02 02	**Cyclic pitch (feathering) in helicopter mode, forward flight**						
LO	Show that in order to assume and maintain forward flight, the rotor-thrust vector must get a forward component by tilting the tip-path plane.			x	x	x	
LO	Show how the applied cyclic pitch modifies the lift 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 swash plates, the pitch link and the pitch horn. Explain how the collective lever moves the non-rotating swash plate up or down alongside the shaft axis.			x	x	x	
LO	Describe the mechanism by which the desired cyclic blade pitch can be produced by tilting the swash plate with the cyclic stick.			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 translational lift effect when the speed increases.			x	x	x	

Syllabus reference	**Syllabus details and associated Learning Objectives**	*Aeroplane*		*Helicopter*			*IR*
		ATPL	CPL	ATPL /IR	ATPL	CPL	
LO	Justify the increase of the tilt angle of the thrust vector and of the tip-path plane disc in order to increase the speed.			x	x	x	
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 Coriolis force due to flapping, the resulting periodic moments in the hub plane and the resulting periodic stresses which make lead-lag hinges necessary to avoid material 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 for 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 multiblade rotor.			x	x	x	
LO	Show the effect on the fuselage and the danger of resonance between this force and the fuselage and undercarriage. State the conditions likely to lead to ground resonance.			x	x	x	
082 05 04 00	**Rotor systems**						
082 05 04 01	**See-saw or teetering rotor**						
LO	Explain that a teetering rotor is prone to mast bumping in low G situations because of having no flapping hinge offset.			x	x	x	
082 05 04 02	**Fully articulated rotor**						

Syllabus reference	**Syllabus details and associated Learning Objectives**	*Aeroplane*		*Helicopter*			*IR*
		ATPL	CPL	ATPL /IR	ATPL	CPL	
LO	Describe the fully articulated rotor with hinges and feathering bearings.			x	x	x	
LO	Describe ball and roller bearings and elastomeric bearings, advantages and disadvantages.			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 them with other rotor systems.			x	x	x	
082 05 05 00	**Blade sailing**						
082 05 05 01	**Blade sailing and causes**						
LO	Define blade sailing, the influence of low rotor RPM and of headwind.			x	x	x	
082 05 05 02	**Minimising the danger**						
LO	Describe the actions to minimise danger and the demonstrated wind envelope for engaging and 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 rotor-thrust variation in the case of perfect identical blades.			x	x	x	
LO	Show the resulting frequencies and amplitudes as a function of the number of blades.			x	x	x	
LO	Explain the thrust variation in case of an out-of-track blade, causes, frequencies (one-per-revolution).			x	x	x	

Syllabus reference	Syllabus details and associated Learning Objectives	*Aeroplane*		*Helicopter*			*IR*
		ATPL	CPL	ATPL /IR	ATPL	CPL	
LO	Explain the importance of the hinges offset on the effect of the vibrations on the fuselage.			x	x	x	
082 05 06 02	**Lateral vibrations**						
LO	Explain imbalances of a blade, causes, and effects.			x	x	x	
LO	Explain the frequencies lateral one-per-revolution 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	Describe the dangers to ground personnel, to the rotor blades, possibilities of minimising these dangers.			x	x	x	
082 06 01 02	**Tail-rotor aerodynamics**						
LO	Explain the airflow around 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 the tail-rotor flapback, and the effects of delta-three hinges.			x	x	x	
LO	Describe roll moment and drift as side effects of the tail rotor.			x	x	x	
LO	Explain the effects of the tail-rotor failure.			x	x	x	

Syllabus reference	**Syllabus details and associated Learning Objectives**	*Aeroplane*		*Helicopter*			*IR*
		ATPL	CPL	ATPL /IR	ATPL	CPL	
LO	Explain the loss of tail-rotor effectiveness, vortex-ring state, causes, crosswind and yaw speed.			x	x	x	
082 06 01 03	**Strakes on the tail boom**						
LO	Describe the strake and explain the function of the device.			x	x	x	
082 06 02 00	**The fenestron**						
082 06 02 01	**Technical layout**						
LO	Show the technical layout 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.			x	x	x	
082 06 03 00	**The NOTAR**						
082 06 03 01	**Technical layout**						
LO	Show the technical layout.			x	x	x	
082 06 03 02	**Control concepts**						
LO	Explain the control concepts.			x	x	x	
082 06 03 03	**Advantages and disadvantages**						
LO	Explain the advantages and disadvantages.			x	x	x	
082 06 04 00	**Vibrations**						
082 06 04 01	**Tail-rotor vibrations**						
LO	Explain the sources of vibration of the tail rotor and the resulting high frequencies.			x	x	x	
082 06 04 02	**Balancing and tracking**						
LO	Explain balancing and tracking of the tail rotor.			x	x	x	
082 07 00 00	**EQUILIBRIUM, STABILITY AND CONTROL**						
082 07 01 00	**Equilibrium and helicopter attitudes**						

Syllabus reference	**Syllabus details and associated Learning Objectives**	*Aeroplane*		*Helicopter*			*IR*
		ATPL	CPL	ATPL /IR	ATPL	CPL	
082 07 01 01	**Hover**						
LO	Explain why the vector sum of forces and moments must be zero in any acceleration-free situation.			x	x	x	
LO	Indicate the forces and the moments about the lateral axis in a steady hover.			x	x	x	
LO	Indicate the forces and the moments about the longitudinal axis in a steady hover.			x	x	x	
LO	Deduce how the roll angle in a steady hover without wind results from the moments about the longitudinal axis.			x	x	x	
LO	Explain how the cyclic is used to create equilibrium of moments about 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 why the vector sum of forces and of moments must be zero in unaccelerated flight.			x	x	x	
LO	Indicate the forces and the moments about 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 (AUM) on the forces and moments about 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 about the lateral axis in forward flight.			x	x	x	

Syllabus reference	**Syllabus details and associated Learning Objectives**	*Aeroplane*		*Helicopter*			*IR*
		ATPL	CPL	ATPL /IR	ATPL	CPL	
LO	Explain the role of the cyclic stick position in creating equilibrium of forces and moments about the lateral axis in forward flight.			x	x	x	
LO	Explain how forward speed influences the fuselage attitude.			x	x	x	
LO	Describe and explain the inflow roll effect.			x	x	x	
082 07 02 00	**Stability**						
082 07 02 01	**Static longitudinal, roll and directional stability**						
LO	Define static stability; give an example of static stability and of static instability.			x	x	x	
LO	Explain the contribution of the main rotor to speed stability.			x	x	x	
LO	Describe the influence of the horizontal stabiliser on static longitudinal stability.			x	x	x	
LO	Explain the effect of hinge offset on static stability.			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 stabiliser 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 centre 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**						

Syllabus reference	Syllabus details and associated Learning Objectives	*Aeroplane*		*Helicopter*			*IR*
		ATPL	CPL	ATPL /IR	ATPL	CPL	
LO	Define dynamic stability; give an example of dynamic stability and of dynamic instability.			x	x	x	
LO	Explain why static stability is a precondition for 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 stabiliser 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 a phugoid.			x	x	x	
082 07 02 05	**Roll stability and directional stability**						
LO	Explain the effect of a dihedral on a helicopter.			x	x	x	
LO	Describe how a dihedral influences the static roll stability.			x	x	x	
LO	Know that a large static roll stability together with a small directional stability may lead to a Dutch roll.			x	x	x	
LO	Explain which stability features taken 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	**Manoeuver 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 trim speed.			x	x	x	

Syllabus reference	**Syllabus details and associated Learning Objectives**	*Aeroplane*		*Helicopter*			*IR*
		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 the control moment.			x	x	x	
LO	Explain the importance of the centre of gravity position on the control moment.			x	x	x	
LO	Explain how the changes of magnitude of rotor thrust of a helicopter 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 dynamic rollover**						
LO	Explain the mechanism which causes dynamic rollover.			x	x	x	
LO	Explain the required pilot action when dynamic rollover is starting to develop.			x	x	x	
082 08 00 00	**HELICOPTER FLIGHT MECHANICS**						
082 08 01 00	**Flight limits**						
082 08 01 01	**Hover and vertical flight**						

Syllabus reference	**Syllabus details and associated Learning Objectives**	*Aeroplane*		*Helicopter*			*IR*
		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 (see subject 020, piston engines and turbine engines).			x	x	x	
LO	Explain the effects of All-Up Mass (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 V_{NE} and V_{NO}.			x	x	x	
LO	Use the graph to determine the speeds of maximum rate of climb and the maximum angle of climb.			x	x	x	
LO	Use the graph to define the TAS for maximum range and maximum endurance, consider the case of the piston engine and the turbine engine. Explain the effects of tailwind or headwind 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	**Manoeuvring**						
LO	Define the load factor, the radius of turn and the rate of turn.			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.			x	x	x	
LO	Explain the influence of All-Up Mass (AUM), pressure and temperature, density altitude, humidity.			x	x	x	

Syllabus reference	Syllabus details and associated Learning Objectives	*Aeroplane*		*Helicopter*			*IR*
		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 to show the limitations on vertical flight and level flight, discuss the power checks and procedures for take-off and landing.			x	x	x	
LO	Describe manoeuvres with limited power.			x	x	x	
082 08 02 02	**Overpitch, overtorque**						
LO	Describe overpitching and show the consequences.			x	x	x	
LO	Describe situations likely to lead to overpitching.			x	x	x	
LO	Describe overtorqueing and show the consequences.			x	x	x	
LO	Describe situations likely to lead to overtorqueing.			x	x	x	