WALTER D'AMBROGIO

Programme of "Meccanica Applicata" "Applied Mechanics"		
Number of ECTS credits: 9 (workload is 225 hours; 1 credit = 25 hours)		
I1M128, Compulsory 1st Cycle in INDUSTRIAL ENGINNERING (track in Mechanical Engineering), 2nd year , 2nd semester		
Teacher: **Prof. Walter D'Ambrogio**		
1	**Course objectives and Learning outcomes**	The goal of this course is to examine the fundamental laws that govern the operation of machines, to perform the functional analysis of mechanical components and the dynamic analysis of mechanical systems. On successful completion of this course, the student should understand the basic language of mechanics and be able to identify, model and analyse the most important mechanical components and mechanical systems.
2	**Dublin descriptors**	Topics of the module include: **Kinematics:** Elements of planar kinematics. Kinematics of a point. Cartesian coordinates, local and polar coordinetes. Complex polar notation. Kinematics of plane rigid motion: translational motion, rotational motion around a fixed axis. General plane motion: fundamental formula of kinematics and theorem of Rivals. Velocity pole. Acceleration pole. Constraints. Kinematic pairs: prismatic, revolute, helical. Force-closed pairs. Kinematics of relative motion: frame velocity and acceleration, Coriolis acceleration. Examples: four-bar linkage, yoke mechanism. **Dynamics:** Forces. Operations on forces. Moment of a force. Couple. Resultant of forces. Cardinal equations of statics. Newton laws. Linear momentum and angular momentum. Angular momentum of a rigid body: moment of inertia, principal axes of inertia. Cardinal equations of dynamics. Inertia forces. D'Alembert formulation. Type of forces acting on mechanical systems. Free body diagram. Dynamic equivalence: substitution masses. Work and energy. Conservation of energy. Power. Steady-state and periodic motion of a machine. Mechanical efficiency. Reduction of forces and masses. Conservation of linear and angular momentum. Static and dynamic balancing of rotors. Gyroscopic effect. **Friction:** Dry friction: static friction, limit friction, sliding friction. Driving wheel of a vehicle. Pin-joint with dry friction: friction circle. Rolling friction: driving wheel; towing on rollers. **Friction based mechanical devices:** Brakes and clutches: approaching motion, Reye's wear hypothesis. Plane pad brake: pivoted and floating shoe. Band brake. Disc brake. Drum brake: pivoted and floating shoe; simplified and wear hypothesis analysis. Approaching direction. Direction of pressure resultant. Line of action of friction resultant. Poles of normal actions, tangential actions and total actions. Plane clutch: single-disc and multi-disc. Cone clutch. Screw-and-nut mechanism: functions and mounting variations. Action exchanged between screw and nut. Equivalent wedges. Self-locking mechanism. Efficiency. **Couplings:** types of fixed, elastic and articulated couplings. Oldham coupling. Schmidt coupling. Universal (Hooke, Cardan) coupling. Double universal coupling: constant velocity solution. **Flexible elements:** Wire ropes, chains, belts. Stiffness (elastic or inelastic) of flexible elements. Static applications: mechanical advantage. Fixed pulley. Movable pulley. Hoist. Dynamic applications. Belt drives. Belt-pulley interaction: no-slip assumption; local and global slip. V-belt drives. Transmission ratio and efficiency of belt drives. Tightening of belt and pulley: tightening pulley; belt tensioner; forced assembly. **Linkages:** Kinematic chains: simple and compound chains, closed and open chains. Binary, ternary and multiple joints. Binary, ternary and quaternary links. Degrees of freedom of a planar mechanism. Planar mechanisms: crank, rocker, connecting rod. One degree of freedom linkages. Kinematics of linkages. Vector loop technique. Position analysis: numerical solution using Newton method. Velocity and acceleration analysis. Mobility analysis: Grashof rule for four-bar linkage. **Gears:** Friction wheels: transmission ratio. Spur gears. Involute to a circle.

		Generating plane. Fundamental quantities for gears and transmission ratio. Effect of center distance variation. Modular sizing. Minimum number of teeth to avoid interference. Slip velocity. Rack and pinion. Exchanged forces and reactions of the supports. Parallel helical gears: tooth forming, helix angle, transverse and normal quantities. Minimum number of teeth: equivalent spur gear. Exchanged forces and reaction of the supports. Transmission of motion between intersecting shafts. Bevel gears: fundamental geometry, exchanged forces, minimum number of teeth. Transmission of motion between crossed shafts: helical gears. Worm gears: transmission ratio, exchanged forces, efficiency. **Gear trains:** Transmission ratio. Planetary gear trains: Willis formula. Exchanged forces in a planetary gear. Compound planetary gear. Automotive differential gear train. Non symmetric differential gear train. **Transients:** Transients in mechanical systems. Static characteristics of prime movers and driven machines. Steady-state velocity. Stability of steady-state motion. Starting regime: direct coupling between engine and driven machine. Coupling between engine and driven machine by a drivetrain. Transient with clutch. Systems in periodic motion: flywheel. **Vibrations:** Free undamped system. Equivalent stiffness. Torsional systems. Free damped system: critical damping, logarithmic decrement. Forced vibrations: phase vectors. Gain and phase diagrams. Resonance of an undamped system. Working principle of seismometer and accelerometer. Step response. Impulse response. Response to generic forcing: convolution integral. Critical speeds of rotors: Jeffcott rotor. 2 degree of freedom systems. Vibration modes. Coupling of coordinates. Principal coordinates. **Elements of lubrication:** Rolling bearings. Lubricated bearings. Viscosity. Reynolds equation. Full film lubrication: supporting capacity and tangential force. Linear slides: plane slider, step-shaped slider, curved slider, compound slider. Bidirectional guides. On successful completion of this module, the student should: - have profound **knowledge** of planar mechanisms and demonstrate **capacity** of performing velocity and acceleration analysis of planar linkages; - demonstrate **capacity** of identifying the forces acting on a mechanical system and of performing a dynamic analysis; - have **knowledge** and demonstrate **ability** to identify the exchanged forces in the relevant types of brakes and clutches; - have **knowledge** and demonstrate **ability** to identify the exchanged forces in mechanical devices used to transmit motion, such as couplings, linkages, belt systems, gear trains, screw and nut systems; - have **knowledge** of the static characteristics of engines and driven machines, and demonstrate **capacity** of analyzing the steady-state and transient behavior of systems made by an engine coupled to a driven machine either directly, ot by a drivetrain and/or a clutch; - have **knowledge** and demonstrate **capacity** of analyzing one degree of freedom vibrating systems; - have **knowledge** of two degree of freedom vibrating systems; - have **knowledge** of rolling and lubricated bearings and demonstrate **capacity** of analyzing the performance of lubricated bearings.
3	**Prerequisites and learning activities**	The student must know the basic notions of Mathematics and Physics contained in the exams Mathematical Analysis 1 and 2, Geometry and Physics 1
4	**Teaching methods and language**	Lectures and exercises. Language: Italian **Ref. Text books** Walter D'Ambrogio, ***Lecture notes*** available to registered users at link http://www.didattica.univaq.it/moodle/course/view.php?id=4665 Ferraresi, Raparelli, ***Meccanica Applicata***, CLUT Editrice, Torino, 2007. Belforte, ***Meccanica Applicata alle Macchine***, Ed. Levrotto & Bella, Torino, 1997.
5	**Assessment methods**	Written and oral exam. DA MOTIVARE MEGLIO