



ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

DIPARTIMENTO
DI INGEGNERIA INDUSTRIALE

Regolamento didattico del Corso di Laurea Magistrale LM-33 in Mechanical Engineering for Sustainability, sede di Forlì

INDICE

ART. 1 CARATTERISTICHE DEL CORSO DI STUDIO	3
ART. 2 REQUISITI PER L'ACCESSO AL CORSO	3
ART. 3 PIANI DI STUDIO INDIVIDUALI	3
ART. 4 MODALITÀ DI SVOLGIMENTO DELLE ATTIVITÀ FORMATIVE E TIPOLOGIA DELLE FORME DIDATTICHE	3
ART. 5 FREQUENZA E PROPEDEUTICITÀ	3
ART. 6 PERCORSO A TEMPO PARZIALE E PERCORSO BREVE	4
ART. 7 PROVE DI VERIFICA DELLE ATTIVITÀ FORMATIVE	4
ART. 8 ATTIVITÀ FORMATIVE A SCELTA DALLO STUDENTE	4
ART. 9 CRITERI DI RICONOSCIMENTO DEI CREDITI ACQUISITI IN ALTRI CORSI DI STUDIO.....	4
ART. 10 CRITERI DI RICONOSCIMENTO DELLE CONOSCENZE E ABILITÀ EXTRAUNIVERSITARIE.....	5
ART. 11 TIROCINIO CURRICULARE	5
ART. 12 PROVA FINALE	5

Qualora, unicamente a scopo di sintesi, nel presente Regolamento sia usata la sola forma maschile, questa è da intendersi riferita in maniera inclusiva a tutte le persone che operano nell'ambito della comunità stessa.

ART. 1 CARATTERISTICHE DEL CORSO DI STUDIO

Il Corso di studio, erogato in lingua inglese in modalità convenzionale, è a libero accesso, con verifica delle conoscenze. Il numero di studenti iscrivibili e le modalità di svolgimento della selezione saranno resi pubblici ogni anno con il relativo bando di concorso.

ART. 2 REQUISITI PER L'ACCESSO AL CORSO

Conoscenze richieste per l'accesso e modalità di ammissione

Per essere ammessi al Corso di studio occorre essere in possesso di una laurea, di un diploma universitario di durata triennale, o di altro titolo di studio conseguito all'estero, riconosciuto idoneo.

Occorre, altresì, il possesso dei seguenti requisiti curriculari:

Essere in possesso di una laurea nelle classi:

L-8

L-9

ovvero una laurea equivalente dei previgenti ordinamenti, avendo conseguito almeno 18 CFU nell'ambito delle scienze matematiche e informatiche, 12 CFU nell'ambito delle scienze fisiche (FIS) e 18 CFU nell'ambito dei settori caratterizzanti dell'ingegneria meccanica (ING-IND/08, ING-IND/09, ING-IND/10, ING-IND/12, ING-IND/13, ING-IND/14, ING-IND/15, ING-IND/16, ING-IND/17).

L'ammissione al Corso è subordinata, inoltre, al superamento della verifica dell'adeguatezza della personale preparazione effettuata da parte di una Commissione sulle conoscenze a livello universitario di base in matematica, fisica ed ingegneria. La verifica avviene mediante valutazione dei titoli e colloquio e si svolgerà secondo le modalità e le procedure indicate nel "Bando di ammissione" pubblicato nel sito di corso di studio.

È richiesta la conoscenza della lingua inglese di livello B2 del CEFR - Quadro Comune Europeo di riferimento per la conoscenza delle lingue. L'accertamento avviene attraverso le modalità indicate nel bando di ammissione.

Per l'accesso al corso è necessario possedere conoscenze nella lingua italiana equivalenti ad un livello non inferiore al B2 del QACER.

Gli studenti stranieri non in possesso di questo requisito dovranno inserire nel proprio piano di studi attività finalizzate al raggiungimento del livello richiesto.

Nel caso di mancato superamento della verifica è preclusa l'iscrizione al Corso.

ART. 3 PIANI DI STUDIO INDIVIDUALI

È prevista la possibilità di presentazione di piani di studio individuali con le modalità, i criteri e i termini resi noti tramite il sito del Corso.

I piani di studio individuali, approvati dal Consiglio di Corso di studio, non possono comunque prescindere dal rispetto dell'ordinamento didattico.

ART. 4 MODALITÀ DI SVOLGIMENTO DELLE ATTIVITÀ FORMATIVE E TIPOLOGIA DELLE FORME DIDATTICHE

Il piano didattico allegato indica le modalità di svolgimento delle attività formative e la relativa suddivisione in ore di didattica frontale, di esercitazioni pratiche o di tirocinio, nonché la tipologia delle forme didattiche.

Eventuali ulteriori informazioni in merito saranno rese note annualmente sul sito del Corso.

ART. 5 FREQUENZA E PROPEDEUTICITÀ

La frequenza non è obbligatoria e non sono presenti propedeuticità.

Nel caso in cui la scelta guidata 'Sustainable Automation' fosse attiva, gli studenti che intendono selezionarla al secondo anno di corso devono aver sostenuto 6 CFU in ING-INF/04 nella precedente carriera o al primo anno del percorso di laurea magistrale.

Non è permesso l'accesso agli esami se lo studente non è regolarmente iscritto al corso. Inoltre, lo studente non è autorizzato ad accedere all'esame di un corso al quale è iscritto per uno specifico anno accademico se le lezioni di tale corso non sono ancora terminate.

ART. 6 PERCORSO A TEMPO PARZIALE E PERCORSO BREVE

Lo studente ha la possibilità di completare il Corso di studio con modalità flessibile in un tempo inferiore (percorso breve) o superiore alla durata normale (percorso a tempo parziale).

ART. 7 PROVE DI VERIFICA DELLE ATTIVITÀ FORMATIVE

Il piano didattico prevede i casi in cui le attività formative si concludono con un esame con votazione in trentesimi oppure con un giudizio di idoneità.

Le modalità di svolgimento delle verifiche sono stabilite annualmente dal Consiglio di Corso di studio e rese note agli studenti prima dell'inizio delle lezioni nei programmi degli insegnamenti pubblicati sul sito del Corso.

Sono previsti almeno 6 appelli per le verifiche distribuiti nell'arco dell'anno solare, distanziati l'uno dall'altro non meno di 15 giorni.

ART. 8 ATTIVITÀ FORMATIVE A SCELTA DALLO STUDENTE

Lo studente può scegliere tra le attività formative attivate in Ateneo purché coerenti con il percorso formativo.

Il corso di studio considera coerenti con il progetto formativo le attività formative individuate dal Consiglio di Corso di studio e previste nell'allegato piano didattico.

Se lo studente sceglie un'attività formativa diversa da quelle considerate coerenti, secondo i sopraddetti criteri predeterminati, deve fare richiesta al Consiglio di Corso di studio nei termini previsti annualmente e resi noti tramite il sito del Corso.

Il Consiglio valuterà la coerenza della scelta con il percorso formativo dello studente.

ART. 9 CRITERI DI RICONOSCIMENTO DEI CREDITI ACQUISITI IN ALTRI CORSI DI STUDIO

I crediti formativi universitari acquisiti in altri corsi di studio di Atenei italiani o esteri sono riconosciuti dal Consiglio di Corso di studio fino a concorrenza dei crediti dello stesso settore scientifico disciplinare previsti dal piano didattico allegato.

Il riconoscimento dei crediti avviene sulla base dei seguenti criteri:

- analisi del programma svolto;
- valutazione della congruità dei settori scientifico disciplinari e dei contenuti delle attività formative in cui lo studente ha maturato i crediti con gli obiettivi formativi specifici del Corso di studio e delle singole attività formative da riconoscere, perseguendo comunque la finalità di mobilità degli studenti.

I crediti formativi universitari acquisiti in Corsi di studio della stessa classe sono riconosciuti per non meno della metà.

Qualora, effettuati i riconoscimenti in base alle norme del presente Regolamento, residuino crediti non utilizzati, il Consiglio di Corso di studio può riconoscerli valutando il caso concreto sulla base delle affinità didattiche e culturali.

Il riconoscimento è relativo ad insegnamenti impartiti o alle attività formative svolte in inglese.

ART. 10 CRITERI DI RICONOSCIMENTO DELLE CONOSCENZE E ABILITÀ EXTRAUNIVERSITARIE

Possono essere riconosciute conoscenze e abilità extrauniversitarie nei casi previsti dalla normativa vigente. La richiesta di riconoscimento sarà valutata dal Consiglio di Corso di studio tenendo conto del numero massimo di crediti riconoscibili fissato nell'ordinamento didattico del Corso.

Il riconoscimento potrà avvenire qualora l'attività sia ritenuta coerente con gli obiettivi formativi specifici del Corso di studio.

ART. 11 TIROCINIO CURRICULARE

Il Corso di Studio, su richiesta dello studente, può consentire, con le procedure stabilite dal Regolamento generale di Ateneo per lo svolgimento dei tirocini o dai programmi internazionali di mobilità per tirocinio, e in conformità alle norme dell'Unione Europea, lo svolgimento di un tirocinio finalizzato alla preparazione della prova finale / tesi di laurea o comunque collegato ad un progetto formativo mirato ad affinare il suo processo di apprendimento e formazione.

Tali esperienze formative della durata massima di 12 mesi, che dovranno concludersi entro la data del conseguimento del titolo di studio, potranno essere svolte prevedendo l'attribuzione di crediti formativi nell'ambito di quelli attribuiti alla prova finale.

ART. 12 PROVA FINALE

a. Caratteristiche della prova finale

La prova finale consiste nell'esposizione e discussione, davanti alla Commissione per la prova finale di Laurea Magistrale, di una tesi, scritta in lingua inglese in forma di trattato, elaborata in modo originale dallo studente, sotto la guida di un relatore, su un argomento coerente con gli obiettivi formativi del Corso di Studio. La dissertazione deve dimostrare la padronanza degli argomenti, capacità critica, l'attitudine a operare in modo autonomo e una capacità di comunicazione di buon livello.

b. Modalità di svolgimento della prova finale

La prova finale consiste in una tesi scritta in inglese, discussa oralmente pubblicamente.

L'argomento dell'elaborato di tesi appartiene normalmente a un settore scientifico disciplinare tra quelli previsti dal Regolamento Didattico del Corso di Studio. Lo svolgimento avviene sotto la supervisione di un relatore, che solitamente è un docente del Corso di Studio. Il conferimento della lode richiede il giudizio unanime della Commissione.

Il voto della prova finale avrà una valutazione numerica espressa mediante frazione in $n/110$, dove n non deve superare 110. L'accordo unanime della Commissione è obbligatorio per l'attribuzione della votazione $110/110$ con lode. Eventuali ulteriori dettagli sulle modalità di assegnazione dell'argomento dell'elaborato, sullo svolgimento delle relative attività, nonché sulla definizione del relatore possono essere precisati dal Consiglio di Corso di Studio in appositi regolamenti.

La Commissione per la prova finale di Laurea Magistrale è nominata dal Consiglio di Corso di Studio, con le modalità e nella composizione previste dal Regolamento Didattico di Ateneo.

Le modalità di redazione e le regole di attribuzione del voto sono pubblicate sul sito del Corso di studio.

La Commissione Paritetica docenti-studenti ha espresso parere favorevole sulla coerenza dei crediti assegnati alle singole attività formative e gli specifici obiettivi formativi programmati previsti dal piano didattico, ai sensi dell'articolo 12 comma 3 del DM 270/04 e ss.mm.ii.

Anno Accademico 2026/2027
Classe LM-33-INGEGNERIA MECCANICA
Corso 6720-MECHANICAL ENGINEERING FOR SUSTAINABILITY

Primo Anno di Corso

Gruppo: Compulsory Courses

TAF: **Ambito:**

Cfu min: **Cfu max:**

Note:

Attività formativa	TIP	SSD	TAF	CFU	ORE F/E/L/N	FREQ.	VER.
6720 000 000 B2377 - 0 - ELECTRIC ENERGY CONVERSION		ING-IND/32		6	60/0/0/0	No	Voto
Ambito: 1144 - Attivita' formative affini o integrative			C				
Obiettivi: The course delivers the principles of electromechanical energy conversion and suitable skills for the analysis of the main electrical machines for residential and industrial applications, along with the principles of power electronics devices and basic architectures.							
Obiettivi inglese: The course delivers the principles of electromechanical energy conversion and suitable skills for the analysis of the main electrical machines for residential and industrial applications, along with the principles of power electronics devices and basic architectures.							
6720 000 000 B2369 - 0 - ENGINEERING DESIGN (I.C.)				12			Voto
Modulo integrato: B2370 - MACHINE DESIGN		ING-IND/14		6	60/0/0/0	No	
Ambito: 215 - Ingegneria meccanica			B				
Obiettivi: At the end of the integrated course, the student can plan and manage the conceptual and structural design of products and systems, optimizing components and architectures while considering material behavior, fracture mechanics, and sustainability. The student can apply virtual and physical prototyping methods throughout the product development cycle to evaluate design alternatives and support informed engineering decisions.							
In this module the students acquire in-depth knowledge of the methods and instruments necessary for the optimal structural design of mechanical components, plates, shells and pressure vessels. They deepen their knowledge of engineering materials' nonlinear behaviour and fracture mechanics. They learn the principles of the design for sustainability.							
Obiettivi inglese: At the end of the integrated course, the student can plan and manage the conceptual and structural design of products and systems, optimizing components and architectures while considering material behavior, fracture mechanics, and sustainability. The student can apply virtual and physical prototyping methods throughout the product development cycle to evaluate design alternatives and support informed engineering decisions.							
In this module the students acquire in-depth knowledge of the methods and instruments necessary for the optimal structural design of mechanical components, plates, shells and pressure vessels. They deepen their knowledge of engineering materials' nonlinear behaviour and fracture mechanics. They learn the principles of the design for sustainability.							

Modulo integrato: B2371 - DESIGN METHODS FOR INDUSTRIAL ENGINEERING	ING-IND/15	6	60/0/0/0	No	
Ambito: 215 - Ingegneria meccanica					B
<p>Obiettivi: At the end of the integrated course, the student can plan and manage the conceptual and structural design of products and systems, optimizing components and architectures while considering material behavior, fracture mechanics, and sustainability. The student can apply virtual and physical prototyping methods throughout the product development cycle to evaluate design alternatives and support informed engineering decisions.</p> <p>In this module, the student learns to plan and manage the conceptual design phase and the early prototyping of products and systems. Conceptual design methods are taught as techniques used to optimize products, find critical elements, identify proper design alternatives and strategies, and define the product architecture. Moreover, the student learns the main features of virtual and physical prototyping technologies and how to use and integrate them in the product development cycle and in the product lifecycle.</p> <p>Obiettivi inglese: At the end of the integrated course, the student can plan and manage the conceptual and structural design of products and systems, optimizing components and architectures while considering material behavior, fracture mechanics, and sustainability. The student can apply virtual and physical prototyping methods throughout the product development cycle to evaluate design alternatives and support informed engineering decisions.</p> <p>In this module, the student learns to plan and manage the conceptual design phase and the early prototyping of products and systems. Conceptual design methods are taught as techniques used to optimize products, find critical elements, identify proper design alternatives and strategies, and define the product architecture. Moreover, the student learns the main features of virtual and physical prototyping technologies and how to use and integrate them in the product development cycle and in the product lifecycle.</p>					
6720 000 000 B2373 - 0 - MACHINES AND SUSTAINABLE ENERGY SYSTEMS	ING-IND/08	9	90/0/0/0	No	Voto
Ambito: 215 - Ingegneria meccanica					B
<p>Obiettivi: The student is able to face the design of modern energy systems (combined groups, cogeneration groups) for the production of electricity and refrigeration cycles (compression, absorption, air). He is also able to deal with the fluid-dynamic design of the compressible turbomachines. Finally, the student acquires the basic knowledge on systems for the production of electricity and heat from renewable sources.</p> <p>Obiettivi inglese: The student is able to face the design of modern energy systems (combined groups, cogeneration groups) for the production of electricity and refrigeration cycles (compression, absorption, air). He is also able to deal with the fluid-dynamic design of the compressible turbomachines. Finally, the student acquires the basic knowledge on systems for the production of electricity and heat from renewable sources.</p>					
6720 000 000 B2374 - 0 - MATHEMATICAL MODELS FOR INDUSTRIAL ENGINEERING	MAT/07	6	60/0/0/0	No	Voto
Ambito: 1144 - Attività formative affini o integrative					C
<p>Obiettivi: The course focuses on the advanced mathematics areas which are most commonly used in mechanical and industrial engineering applications. At the end of the course the student is able to build, use and validate physical-mathematical models.</p> <p>Obiettivi inglese: The course focuses on the advanced mathematics areas which are most commonly used in mechanical and industrial engineering applications. At the end of the course the student is able to build, use and validate physical-mathematical models.</p>					
6720 000 000 B2375 - 0 - MECHANICAL PLANTS AND INDUSTRIAL LOGISTICS	ING-IND/17	9	90/0/0/0	No	Voto
Ambito: 215 - Ingegneria meccanica					B
<p>Obiettivi: At the end of the course, the student knows theoretical principles, functional schemes, methodologies for choice of components, design methods, optimization criteria both on technical and economic point of view, standards and rules regarding the mechanical plants which are auxiliary systems present in the production systems in order to make available the necessary services for the correct development of production processes.</p> <p>Obiettivi inglese: At the end of the course, the student knows theoretical principles, functional schemes, methodologies for choice of components, design methods, optimization criteria both on technical and economic point of view, standards and rules regarding the mechanical plants which are auxiliary systems present in the production systems in order to make available the necessary services for the correct development of production processes.</p>					
6720 000 000 B2376 - 0 - MECHANICS AND DYNAMICS OF MACHINES	ING-IND/13	9	90/0/0/0	No	Voto
Ambito: 215 - Ingegneria meccanica					B
<p>Obiettivi: The student acquires advanced concepts and methods for the functional design of the machines and is able to develop models of mechanical systems, with reference to multibody systems and mechanical vibrations.</p> <p>Obiettivi inglese: The student acquires advanced concepts and methods for the functional design of the machines and is able to develop models of mechanical systems, with reference to multibody systems and mechanical vibrations.</p>					

Gruppo: Elective Course - 6 CFU**TAF: D Ambito: 1008 - A scelta dello studente****Cfu min: 6 Cfu max: 6**

Note: Students must choose one course among those (1st or 2nd semester) - Students who are interested in selecting the 'Sustainable Automation' guided choice in the second year must have already registered at least 6 credits in the scientific disciplinary sector ING-INF/04 in the previous career (degree) or in the first year of this master's degree.

Attività formativa	TIP	SSD	TAF	CFU	ORE F/E/L/N	FREQ.	VER.
6720 000 000 B2379 - 0 - EXPERIMENTAL FLUID MECHANICS		ICAR/01		6	60/0/0/0	No	Voto
Ambito: 1008 - A scelta dello studente			D				
Obiettivi: Students learn advanced fluid mechanics with applications in aerodynamics, compressible hydromechanics and turbulence mixing, and related experimental methods including ultrasound and optical velocimetry for the investigation of fluid flow							
Obiettivi inglese: Students learn advanced fluid mechanics with applications in aerodynamics, compressible hydromechanics and turbulence mixing, and related experimental methods including ultrasound and optical velocimetry for the investigation of fluid flow							
6720 000 000 73369 - 0 - MATERIALS CHEMISTRY		CHIM/07		6	60/0/0/0	No	Voto
Ambito: 1008 - A scelta dello studente			D				
Obiettivi: The course is focused on the applications of the principles of chemistry to the description of the behaviour of the solid state. At the end of the course the student will have the basis to understand the relationships between the nature and arrangements of the atoms, ions or molecules comprising a material and its overall bulk structural and physical properties. The acquired competences on advanced materials will be focused on aerospace structural design.							
Obiettivi inglese: The course is focused on the applications of the principles of chemistry to the description of the behaviour of the solid state. At the end of the course the student will have the basis to understand the relationships between the nature and arrangements of the atoms, ions or molecules comprising a material and its overall bulk structural and physical properties. The acquired competences on advanced materials will be focused on aerospace structural design.							
6720 000 000 37261 - 0 - NUMERICAL ANALYSIS		MAT/08		6	60/0/0/0	No	Voto
Ambito: 1008 - A scelta dello studente			D				
Obiettivi: The student learns the numerical methods for differential problems. At the end of the course the student knows the numerical-mathematical aspCFU and the main algorithmic methodologies that deal with the numerical solution of differential problems of interest in Engineering.							
Obiettivi inglese: The student learns the numerical methods for differential problems. At the end of the course the student knows the numerical-mathematical aspCFU and the main algorithmic methodologies that deal with the numerical solution of differential problems of interest in Engineering.							
6720 000 000 B2378 - 0 - THEORY OF SYSTEMS AND CONTROLS FOR AUTOMATION		ING-INF/04		6	60/0/0/0	No	Voto
Ambito: 1008 - A scelta dello studente			D				
Obiettivi: At the end of the course the student handles Linear Time-Invariant systems and their representation through Laplace transform and inverse transform and transfer functions, the basic principles of linear-system stability and the response modes (1st and 2nd order elementary systems and their composition to implemented higher-order systems). Students know how to use Bode and Nyquist diagrams and root locus to describe structural properties of linear systems, and how to design controllers for linear systems, lead and lag networks, PID controllers, cascade controllers. Nonlinear system control, with linearization-based control will also be introduced.							
Obiettivi inglese: At the end of the course the student handles Linear Time-Invariant systems and their representation through Laplace transform and inverse transform and transfer functions, the basic principles of linear-system stability and the response modes (1st and 2nd order elementary systems and their composition to implemented higher-order systems). Students know how to use Bode and Nyquist diagrams and root locus to describe structural properties of linear systems, and how to design controllers for linear systems, lead and lag networks, PID controllers, cascade controllers. Nonlinear system control, with linearization-based control will also be introduced.							

Secondo Anno di Corso

Gruppo: Compulsory CoursesTAF: **Ambito:**

Cfu min: Cfu max:

Note:

Attività formativa	TIP	SSD	TAF	CFU	ORE F/E/L/N	FREQ.	VER.
6720 000 000 B2391 - 0 - ADVANCED AND SUSTAINABLE MANUFACTURING		ING-IND/16		6	60/0/0/0	No	Voto

Ambito: 215 - Ingegneria meccanica

B

Obiettivi: The student will acquire the skill to select advanced manufacturing technologies for metallic material processing, as well as implementing and comprehending the relationships between process parameters and product characteristics. The student will be able to evaluate the suitability and consistency of technologies in order to obtain specific requirements for the finished product, as well as to evaluate the different processes in terms of sustainability and environmental impact.

Obiettivi inglese: The student will acquire the skill to select advanced manufacturing technologies for metallic material processing, as well as implementing and comprehending the relationships between process parameters and product characteristics. The student will be able to evaluate the suitability and consistency of technologies in order to obtain specific requirements for the finished product, as well as to evaluate the different processes in terms of sustainability and environmental impact.

Gruppo: Elective Courses - 12 CFUTAF: **D Ambito: 1008 - A scelta dello studente**

Cfu min: 12 Cfu max: 12

Note: Students must choose 2 courses among those (1st or 2nd semester) not included in year 1 and not included in the selected guided choice

Attività formativa	TIP	SSD	TAF	CFU	ORE F/E/L/N	FREQ.	VER.
6720 000 000 B2392 - 0 - ELECTRIC DRIVES (6 CFU)		ING-IND/32		6	60/0/0/0	No	Voto

Ambito: 1008 - A scelta dello studente

D

Obiettivi: This module focuses on analysis and design of electric drives. The ecological transition requires electrification, and electric drives can enable sustainable industry and domestic applications. At the end of the course, students will be able to use electric technologies for the analysis, the choice and use of the main electrical drives for residential and industrial applications.

Obiettivi inglese: This module focuses on analysis and design of electric drives. The ecological transition requires electrification, and electric drives can enable sustainable industry and domestic applications. At the end of the course, students will be able to use electric technologies for the analysis, the choice and use of the main electrical drives for residential and industrial applications.

6720 000 000 B2393 - 0 - ENGINEERING AND TECHNOLOGY OF CONTROL SYSTEMS (6 CFU)		ING-INF/04		6	60/0/0/0	No	Voto
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Ambito: 1008 - A scelta dello studente

D

Obiettivi: This module focuses on the technological architectures and main components (PLC, field bus, electric servomotors) which enable meeting sustainability goals in industrial automation systems. Students will analyze problems, distinguishing between functional and technological matters; they will get used to the basic concepts of real-time controller implementation in the field of industrial automation, learning how to analyze and design the "logic control" of an automatic machine compliant to the standard IEC61131-3, and finally they will learn how to choose the proper electric servomotor based on the motion control task specification.

Obiettivi inglese: This module focuses on the technological architectures and main components (PLC, field bus, electric servomotors) which enable meeting sustainability goals in industrial automation systems. Students will analyze problems, distinguishing between functional and technological matters; they will get used to the basic concepts of real-time controller implementation in the field of industrial automation, learning how to analyze and design the "logic control" of an automatic machine compliant to the standard IEC61131-3, and finally they will learn how to choose the proper electric servomotor based on the motion control task specification.

6720 000 000 B2395 - 0 - EXERGY AND PINCH POINT ANALYSIS FOR SUSTAINABLE ENERGY USE (6 CFU)	ING-IND/10	6	60/0/0/0	No	Voto
D					
<p>Ambito: 1008 - A scelta dello studente</p> <p>Obiettivi: On completion of this module, the student will be able to calculate entropy generation and Energy losses in a thermodynamic/energy system; determine conditions leading to minimal entropy generation in a system; make the necessary assumptions on system definition, operating conditions etc. required to carry out a consistent Energy analysis, suggesting possible improvements; calculate Energy content, reversible work, isentropic efficiency, Energy loss and irreversibility and energy efficiency for different parts of an energy system; apply the Energy analysis method to energy systems; calculate adiabatic flame temperature and Energy loss in combustion processes; determine the pinch temperature and the minimal required thermal load for a suitable industrial process; design heat exchanger networks according to the principles of pinch analysis; suggest measures to reduce heating and cooling needs in an existing heat exchanger network; evaluate pros and cons of traditional and renewable energy sources within the framework of sustainable energy use.</p> <p>Obiettivi inglese: On completion of this module, the student will be able to calculate entropy generation and Energy losses in a thermodynamic/energy system; determine conditions leading to minimal entropy generation in a system; make the necessary assumptions on system definition, operating conditions etc. required to carry out a consistent Energy analysis, suggesting possible improvements; calculate Energy content, reversible work, isentropic efficiency, Energy loss and irreversibility and energy efficiency for different parts of an energy system; apply the Energy analysis method to energy systems; calculate adiabatic flame temperature and Energy loss in combustion processes; determine the pinch temperature and the minimal required thermal load for a suitable industrial process; design heat exchanger networks according to the principles of pinch analysis; suggest measures to reduce heating and cooling needs in an existing heat exchanger network; evaluate pros and cons of traditional and renewable energy sources within the framework of sustainable energy use.</p>					
6720 000 000 B2379 - 0 - EXPERIMENTAL FLUID MECHANICS	ICAR/01	6	60/0/0/0	No	Voto
D					
<p>Ambito: 1008 - A scelta dello studente</p> <p>Obiettivi: Students learn advanced fluid mechanics with applications in aerodynamics, compressible hydromechanics and turbulence mixing, and related experimental methods including ultrasound and optical velocimetry for the investigation of fluid flow</p> <p>Obiettivi inglese: Students learn advanced fluid mechanics with applications in aerodynamics, compressible hydromechanics and turbulence mixing, and related experimental methods including ultrasound and optical velocimetry for the investigation of fluid flow</p>					
6720 000 000 B2399 - 0 - HEATING, REFRIGERATION AND THERMAL STORAGE	ING-IND/10	6	60/0/0/0	No	Voto
D					
<p>Ambito: 1008 - A scelta dello studente</p> <p>Obiettivi: On completion of this course, the student will be able to describe in detail the components of heating, refrigeration, and thermal storage systems; know which traditional and new-generation heating, refrigeration and thermal storage systems are suitable candidates for industrial, commercial, and residential applications; analyse in terms of Energy balances the heating, refrigeration and thermal storage system both in their components and as a whole; combine the exergetic and economic analysis for the purpose of Energy Audits, Diagnosis of Thermal System Operation or Design of Thermal Systems.</p> <p>Obiettivi inglese: On completion of this course, the student will be able to describe in detail the components of heating, refrigeration, and thermal storage systems; know which traditional and new-generation heating, refrigeration and thermal storage systems are suitable candidates for industrial, commercial, and residential applications; analyse in terms of Energy balances the heating, refrigeration and thermal storage system both in their components and as a whole; combine the exergetic and economic analysis for the purpose of Energy Audits, Diagnosis of Thermal System Operation or Design of Thermal Systems.</p>					
6720 000 000 B2390 - 0 - MANUFACTURING TECHNOLOGIES FOR COMPOSITE MATERIALS	ING-IND/16	6	60/0/0/0	No	Voto
D					
<p>Ambito: 1008 - A scelta dello studente</p> <p>Obiettivi: The student will be introduced to different technologies for the fabrication of components made of polymeric and composite materials with thermoplastic and thermosetting matrix, and will be able to select the most appropriate technology based on the required performance, the production footprint, and the number of components to be produced. The student will be able to understand and define manufacturing cycles to meet specific requirements on the final component, including those related to sustainability requirements.</p> <p>Obiettivi inglese: The student will be introduced to different technologies for the fabrication of components made of polymeric and composite materials with thermoplastic and thermosetting matrix, and will be able to select the most appropriate technology based on the required performance, the production footprint, and the number of components to be produced. The student will be able to understand and define manufacturing cycles to meet specific requirements on the final component, including those related to sustainability requirements.</p>					
6720 000 000 73369 - 0 - MATERIALS CHEMISTRY	CHIM/07	6	60/0/0/0	No	Voto
D					
<p>Ambito: 1008 - A scelta dello studente</p> <p>Obiettivi: The course is focused on the applications of the principles of chemistry to the description of the behaviour of the solid state. At the end of the course the student will have the basis to understand the relationships between the nature and arrangements of the atoms, ions or molecules comprising a material and its overall bulk structural and physical properties. The acquired competences on advanced materials will be focused on aerospace structural design.</p> <p>Obiettivi inglese: The course is focused on the applications of the principles of chemistry to the description of the behaviour of the solid state. At the end of the course the student will have the basis to understand the relationships between the nature and arrangements of the atoms, ions or molecules comprising a material and its overall bulk structural and physical properties. The acquired competences on advanced materials will be focused on aerospace structural design.</p>					

6720 000 000 B2397 - 0 - MECHANICAL DESIGN WITH ADVANCED MATERIALS (6 CFU)	ING-IND/14	6	60/0/0/0	No	Voto
Ambito: 1008 - A scelta dello studente	D				
Obiettivi: The students acquire in-depth knowledge of the mathematical foundation of the Finite element Method. They are proficient in using a commercial FEM code to solve structural dynamic and static problems.					
Obiettivi inglese: The students acquire in-depth knowledge of the mathematical foundation of the Finite element Method. They are proficient in using a commercial FEM code to solve structural dynamic and static problems.					
6720 000 000 C8576 - 0 - MECHANICS OF ROBOTS AND AUTOMATIC MACHINES (6 Cfu)	ING-IND/13	6	60/0/0/0	No	Voto
Ambito: 1008 - A scelta dello studente	D				
Obiettivi: Students acquire the necessary tools to perform a functional analysis -aimed at designing purposes- of automatic machines and robots. In particular, students gain skills both from the theoretical viewpoint (kinematic, static and dynamic analyses of complex mechanisms) and from the practical one (kinetostatic simulations of planar and spatial mechanisms by means of multibody software).					
Obiettivi inglese: Students acquire the necessary tools to perform a functional analysis -aimed at designing purposes- of automatic machines and robots. In particular, students gain skills both from the theoretical viewpoint (kinematic, static and dynamic analyses of complex mechanisms) and from the practical one (kinetostatic simulations of planar and spatial mechanisms by means of multibody software).					
6720 000 000 B2398 - 0 - MODELING AND CONTROL OF SUSTAINABLE POWERTRAINS	ING-IND/08	6	60/0/0/0	No	Voto
Ambito: 1008 - A scelta dello studente	D				
Obiettivi: At the end of the course the student knows how to model sustainable powertrain systems, and how power can be controlled, to optimize efficiency and well-to-wheel emissions.					
Obiettivi inglese: At the end of the course the student knows how to model sustainable powertrain systems, and how power can be controlled, to optimize efficiency and well-to-wheel emissions.					
6720 000 000 37261 - 0 - NUMERICAL ANALYSIS	MAT/08	6	60/0/0/0	No	Voto
Ambito: 1008 - A scelta dello studente	D				
Obiettivi: The student learns the numerical methods for differential problems. At the end of the course the student knows the numerical-mathematical aspCFU and the main algorithmic methodologies that deal with the numerical solution of differential problems of interest in Engineering.					
Obiettivi inglese: The student learns the numerical methods for differential problems. At the end of the course the student knows the numerical-mathematical aspCFU and the main algorithmic methodologies that deal with the numerical solution of differential problems of interest in Engineering.					
6720 000 000 B2394 - 0 - POWERTRAINS FOR SUSTAINABLE MOBILITY (6 CFU)	ING-IND/08	6	60/0/0/0	No	Voto
Ambito: 1008 - A scelta dello studente	D				
Obiettivi: At the end of the course the student knows the basics of sustainable powertrain technologies, from the use of natural resources down to energy conversion, including power and emissions control.					
Obiettivi inglese: At the end of the course the student knows the basics of sustainable powertrain technologies, from the use of natural resources down to energy conversion, including power and emissions control.					
6720 000 000 B2396 - 0 - STRUCTURAL FEM MODELING APPLICATIONS (6 CFU)	ING-IND/14	6	60/0/0/0	No	Voto
Ambito: 1008 - A scelta dello studente	D				
Obiettivi: The students acquire in-depth knowledge of the mathematical foundation of the Finite element Method. They are proficient in using a commercial FEM code to solve structural dynamic and static problems.					
Obiettivi inglese: The students acquire in-depth knowledge of the mathematical foundation of the Finite element Method. They are proficient in using a commercial FEM code to solve structural dynamic and static problems.					

6720 000 000 B2386 - 0 - SUSTAINABLE DESIGN OF INDUSTRIAL PLANTS	ING-IND/17	6	60/0/0/0	No	Voto
D					
<p>Ambito: 1008 - A scelta dello studente</p> <p>Obiettivi: Knowledge and comprehension of the course contents in relation to the sustainable design of production systems. The course allows the student to comprehend theoretical principles, functional schemes and methodologies for measuring, designing and control the sustainability in industrial plant. Skills and capabilities in the application of the previously mentioned contents will be discussed in relation to real industrial cases where operators and machines cooperate. The student learns the tools and methods for the evaluation/measurement of the industrial sustainability in terms of social, environmental and economic impact.</p> <p>Obiettivi inglese: Knowledge and comprehension of the course contents in relation to the sustainable design of production systems. The course allows the student to comprehend theoretical principles, functional schemes and methodologies for measuring, designing and control the sustainability in industrial plant. Skills and capabilities in the application of the previously mentioned contents will be discussed in relation to real industrial cases where operators and machines cooperate. The student learns the tools and methods for the evaluation/measurement of the industrial sustainability in terms of social, environmental and economic impact.</p>					

6720 000 000 B2378 - 0 - THEORY OF SYSTEMS AND CONTROLS FOR AUTOMATION	ING-INF/04	6	60/0/0/0	No	Voto
D					
<p>Ambito: 1008 - A scelta dello studente</p> <p>Obiettivi: At the end of the course the student handles Linear Time-Invariant systems and their representation through Laplace transform and inverse transform and transfer functions, the basic principles of linear-system stability and the response modes (1st and 2nd order elementary systems and their composition to implemented higher-order systems). Students know how to use Bode and Nyquist diagrams and root locus to describe structural properties of linear systems, and how to design controllers for linear systems, lead and lag networks, PID controllers, cascade controllers. Nonlinear system control, with linearization-based control will also be introduced.</p> <p>Obiettivi inglese: At the end of the course the student handles Linear Time-Invariant systems and their representation through Laplace transform and inverse transform and transfer functions, the basic principles of linear-system stability and the response modes (1st and 2nd order elementary systems and their composition to implemented higher-order systems). Students know how to use Bode and Nyquist diagrams and root locus to describe structural properties of linear systems, and how to design controllers for linear systems, lead and lag networks, PID controllers, cascade controllers. Nonlinear system control, with linearization-based control will also be introduced.</p>					

Gruppo: Final project - 15 CFU**TAF: Ambito:****Cfu min: 15 Cfu max: 15**

Note: Students must select the activities of one of the three following groups, up to 15 cfu.

Attività formativa	TIP	SSD	TAF	CFU	ORE F/E/L/N	FREQ. VER.
Group A - Final project (15 cfu)				0-15		
6720 000 000 B2415 - 0 - FINAL PROJECT (15 CFU)				15	0/0/0/0	No
E						
<p>Ambito: 1018 - Per la prova finale</p> <p>Obiettivi: The students must be able to independently develop a research subject in one of the key areas characterising the study program, to prepare a written report and to defend it orally, demonstrating the achievement of the course learning objectives. Students will also be able to interact with professionals with different academic and scientific background and to critically analyse results, according to the scientific research status as well.</p> <p>Obiettivi inglese: The students must be able to independently develop a research subject in one of the key areas characterising the study program, to prepare a written report and to defend it orally, demonstrating the achievement of the course learning objectives. Students will also be able to interact with professionals with different academic and scientific background and to critically analyse results, according to the scientific research status as well.</p>						
Group B - Final project (9 + 6 CFU)				0-15		

6720 000 000 B2416 - 0 - FINAL PROJECT (9 CFU)	9	0/0/0/0	No	
Ambito: 1018 - Per la prova finale	E			
Obiettivi: The students must be able to independently develop a research subject in one of the key areas characterising the study program, to prepare a written report and to defend it orally, demonstrating the achievement of the course learning objectives. Students will also be able to interact with professionals with different academic and scientific background and to critically analyse results, according to the scientific research status as well.				
Obiettivi inglese: The students must be able to independently develop a research subject in one of the key areas characterising the study program, to prepare a written report and to defend it orally, demonstrating the achievement of the course learning objectives. Students will also be able to interact with professionals with different academic and scientific background and to critically analyse results, according to the scientific research status as well.				
6720 000 000 B2418 - 0 - INTERNSHIP ABROAD IN PREPARATION FOR THE FINAL PROJECT (6 CFU)	6	0/0/150/0	No	Giudizio
Ambito: 1018 - Per la prova finale	E			
Obiettivi: At the end of the internship abroad in preparation for the final project, the student acquires knowledge in a range of professional fields through participation in practical activities and experiences, either at external structures or in university facilities, within the topic chosen for the final project. In addition, the student can interact with different professional figures and work in a team; he/she develops communication skills in a foreign language, shows independent judgment, knows how to interpret technical reports drafted by collaborators or supervisors, knows how to draw up reports on the activities carried out within the topic chosen for the final project.				
Obiettivi inglese: At the end of the internship abroad in preparation for the final project, the student acquires knowledge in a range of professional fields through participation in practical activities and experiences, either at external structures or in university facilities, within the topic chosen for the final project. In addition, the student can interact with different professional figures and work in a team; he/she develops communication skills in a foreign language, shows independent judgment, knows how to interpret technical reports drafted by collaborators or supervisors, knows how to draw up reports on the activities carried out within the topic chosen for the final project.				
6720 000 000 B2643 - 0 - INTERNSHIP IN PREPARATION FOR THE FINAL PROJECT (6 CFU)	6	0/0/150/0	No	Giudizio
Ambito: 1018 - Per la prova finale	E			
Obiettivi: At the end of the internship in preparation for the final project, the student acquires knowledge in a range of professional fields through participation in practical activities and experiences, either at external structures or in university facilities, within the topic chosen for the final project. In addition, the student can interact with different professional figures and work in a team; he/she develops communication skills, shows independent judgment, knows how to interpret technical reports drafted by collaborators or supervisors, knows how to draw up reports on the activities carried out within the topic chosen for the final project.				
Obiettivi inglese: At the end of the internship in preparation for the final project, the student acquires knowledge in a range of professional fields through participation in practical activities and experiences, either at external structures or in university facilities, within the topic chosen for the final project. In addition, the student can interact with different professional figures and work in a team; he/she develops communication skills, shows independent judgment, knows how to interpret technical reports drafted by collaborators or supervisors, knows how to draw up reports on the activities carried out within the topic chosen for the final project.				
6720 000 000 B2417 - 0 - PREPARATION FOR THE FINAL PROJECT ABROAD (6 CFU)	6	0/0/0/0	No	Giudizio
Ambito: 1018 - Per la prova finale	E			
Obiettivi: Students interested in theses of larger complexity extend their basic knowledge through extensive literature research and the study of topics not explicitly addressed in courses that are part of their curriculum. The student, guided by a professor and included in a major project carried out abroad, collaborates with the structured staff for the preparation of the university final project.				
Obiettivi inglese: Students interested in theses of larger complexity extend their basic knowledge through extensive literature research and the study of topics not explicitly addressed in courses that are part of their curriculum. The student, guided by a professor and included in a major project carried out abroad, collaborates with the structured staff for the preparation of the university final project.				
Group C - Final project (3 + 12 CFU)	0-15			
6720 000 000 90765 - 0 - FINAL PROJECT (3 CFU)	3	0/0/0/0	No	
Ambito: 1018 - Per la prova finale	E			
Obiettivi: The students must be able to independently develop a research subject in one of the key areas characterising the study program, to prepare a written report and to defend it orally, demonstrating the achievement of the course learning objectives. Students will also be able to interact with professionals with different academic and scientific background and to critically analyse results, according to the scientific research status as well.				
Obiettivi inglese: The students must be able to independently develop a research subject in one of the key areas characterising the study program, to prepare a written report and to defend it orally, demonstrating the achievement of the course learning objectives. Students will also be able to interact with professionals with different academic and scientific background and to critically analyse results, according to the scientific research status as well.				

6720 000 000 B2421 - 0 - INTERNSHIP ABROAD IN PREPARATION FOR THE FINAL PROJECT (12 CFU)	12	0/0/300/0	No	Giudizio
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Ambito: 1018 - Per la prova finale

E

Obiettivi: At the end of the internship abroad in preparation for the final project, the student acquires knowledge in a range of professional fields through participation in practical activities and experiences, either at external structures or in university facilities, within the topic chosen for the final project. In addition, the student can interact with different professional figures and work in a team; he/she develops communication skills in a foreign language, shows independent judgment, knows how to interpret technical reports drafted by collaborators or supervisors, knows how to draw up reports on the activities carried out within the topic chosen for the final project.

Obiettivi inglese: At the end of the internship abroad in preparation for the final project, the student acquires knowledge in a range of professional fields through participation in practical activities and experiences, either at external structures or in university facilities, within the topic chosen for the final project. In addition, the student can interact with different professional figures and work in a team; he/she develops communication skills in a foreign language, shows independent judgment, knows how to interpret technical reports drafted by collaborators or supervisors, knows how to draw up reports on the activities carried out within the topic chosen for the final project.

6720 000 000 B2422 - 0 - INTERNSHIP IN PREPARATION FOR THE FINAL PROJECT (12 CFU)	12	0/0/300/0	No	Giudizio
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Ambito: 1018 - Per la prova finale

E

Obiettivi: At the end of the internship in preparation for the final project, the student acquires knowledge in a range of professional fields through participation in practical activities and experiences, either at external structures or in university facilities, within the topic chosen for the final project.

In addition, the student can interact with different professional figures and work in a team; he/she develops communication skills, shows independent judgment, knows how to interpret technical reports drafted by collaborators or supervisors, knows how to draw up reports on the activities carried out within the topic chosen for the final project.

Obiettivi inglese: At the end of the internship in preparation for the final project, the student acquires knowledge in a range of professional fields through participation in practical activities and experiences, either at external structures or in university facilities, within the topic chosen for the final project.

In addition, the student can interact with different professional figures and work in a team; he/she develops communication skills, shows independent judgment, knows how to interpret technical reports drafted by collaborators or supervisors, knows how to draw up reports on the activities carried out within the topic chosen for the final project.

6720 000 000 B2420 - 0 - PREPARATION FOR THE FINAL PROJECT ABROAD (12 CFU)	12	0/0/0/0	No	Giudizio
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Ambito: 1018 - Per la prova finale

E

Obiettivi: Students interested in theses of larger complexity extend their basic knowledge through extensive literature research and the study of topics not explicitly addressed in courses that are part of their curriculum. The student, guided by a professor and included in a major project carried out abroad, collaborates with the structured staff for the preparation of the university final project.

Obiettivi inglese: Students interested in theses of larger complexity extend their basic knowledge through extensive literature research and the study of topics not explicitly addressed in courses that are part of their curriculum. The student, guided by a professor and included in a major project carried out abroad, collaborates with the structured staff for the preparation of the university final project.

Gruppo: Guided Choice - 18 CFU

TAF: Ambito:

Cfu min: 18 Cfu max: 18

Note: Students must select only one of the three guided choices - Students who select the 'Sustainable Automation' guided choice in the second year must have already registered at least 6 credits in the scientific disciplinary sector ING-INF/04 in the previous career (degree) or in the first year of this master's degree

Attività formativa	TIP	SSD	TAF	CFU	ORE F/E/L/N	FREQ.	VER.
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GC1 - Sustainable Automation

0-18

6720 000 000 B2382 - 0 - MECHANICS OF ROBOTS AND AUTOMATIC MACHINES	ING-IND/13	6	60/0/0/0	No	Voto
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Ambito: 215 - Ingegneria meccanica

B

Obiettivi: Students acquire the necessary tools to perform a functional analysis -aimed at designing purposes- of automatic machines and robots. In particular, students gain skills both from the theoretical viewpoint (kinematic, static and dynamic analyses of complex mechanisms) and from the practical one (kinetostatic simulations of planar and spatial mechanisms by means of multibody software).

Obiettivi inglese: Students acquire the necessary tools to perform a functional analysis -aimed at designing purposes- of automatic machines and robots. In particular, students gain skills both from the theoretical viewpoint (kinematic, static and dynamic analyses of complex mechanisms) and from the practical one (kinetostatic simulations of planar and spatial mechanisms by means of multibody software).

6720 000 000 B2380 - 0 - TECHNOLOGIES AND CONTROLS FOR INDUSTRIAL AUTOMATION (I.C.)		12		Voto
Modulo integrato: 28553 - ELECTRIC DRIVES	ING-IND/32	6	60/0/0/0	No
Ambito: 1144 - Attivita' formative affini o integrative	C			
<p>Obiettivi: At the end of the integrated course, the student can analyze, select, and apply electric drives and automation technologies for sustainable industrial and residential applications. The student can design and implement logic and motion control systems, evaluate technological architectures and components, and integrate electric servomotors and controllers to meet functional and sustainability requirements. This module focuses on analysis and design of electric drives. The ecological transition requires electrification, and electric drives can enable sustainable industry and domestic applications. At the end of the course, students will be able to use electric technologies for the analysis, the choice and use of the main electrical drives for residential and industrial applications.</p> <p>Obiettivi inglese: At the end of the integrated course, the student can analyze, select, and apply electric drives and automation technologies for sustainable industrial and residential applications. The student can design and implement logic and motion control systems, evaluate technological architectures and components, and integrate electric servomotors and controllers to meet functional and sustainability requirements. This module focuses on analysis and design of electric drives. The ecological transition requires electrification, and electric drives can enable sustainable industry and domestic applications. At the end of the course, students will be able to use electric technologies for the analysis, the choice and use of the main electrical drives for residential and industrial applications.</p>				
Modulo integrato: B2381 - ENGINEERING AND TECHNOLOGY OF CONTROL SYSTEMS	ING-INF/04	6	60/0/0/0	No
Ambito: 1144 - Attivita' formative affini o integrative	C			
<p>Obiettivi: At the end of the integrated course, the student can analyze, select, and apply electric drives and automation technologies for sustainable industrial and residential applications. The student can design and implement logic and motion control systems, evaluate technological architectures and components, and integrate electric servomotors and controllers to meet functional and sustainability requirements. This module focuses on the technological architectures and main components (PLC, field bus, electric servomotors) which enable meeting sustainability goals in industrial automation systems. Students will analyze problems, distinguishing between functional and technological matters; they will get used to the basic concepts of real-time controller implementation in the field of industrial automation, learning how to analyze and design the "logic control" of an automatic machine compliant to the standard IEC61131-3, and finally they will learn how to choose the proper electric servomotor based on the motion control task specification.</p> <p>Obiettivi inglese: At the end of the integrated course, the student can analyze, select, and apply electric drives and automation technologies for sustainable industrial and residential applications. The student can design and implement logic and motion control systems, evaluate technological architectures and components, and integrate electric servomotors and controllers to meet functional and sustainability requirements. This module focuses on the technological architectures and main components (PLC, field bus, electric servomotors) which enable meeting sustainability goals in industrial automation systems. Students will analyze problems, distinguishing between functional and technological matters; they will get used to the basic concepts of real-time controller implementation in the field of industrial automation, learning how to analyze and design the "logic control" of an automatic machine compliant to the standard IEC61131-3, and finally they will learn how to choose the proper electric servomotor based on the motion control task specification.</p>				
GC2 - Sustainable Design and Manufacturing		0-18		
6720 000 000 B2387 - 0 - ADVANCED DESIGN METHODS (I.C.)		12		Voto
Modulo integrato: B2388 - STRUCTURAL FEM MODELING APPLICATIONS	ING-IND/14	6	60/0/0/0	No
Ambito: 1144 - Attivita' formative affini o integrative	C			
<p>Obiettivi: At the end of the integrated course, the student possesses advanced knowledge of structural design methods for composite and additively manufactured components, including material characterization and optimization for performance, cost, and sustainability. The student can apply the Finite Element Method, both theoretically and through commercial software, to analyze and design static and dynamic structural systems. The students acquire in-depth knowledge of the mathematical foundation of the Finite element Method. They are proficient in using commercial FEM code to solve structural dynamic and static problems.</p> <p>Obiettivi inglese: At the end of the integrated course, the student possesses advanced knowledge of structural design methods for composite and additively manufactured components, including material characterization and optimization for performance, cost, and sustainability. The student can apply the Finite Element Method, both theoretically and through commercial software, to analyze and design static and dynamic structural systems. The students acquire in-depth knowledge of the mathematical foundation of the Finite element Method. They are proficient in using commercial FEM code to solve structural dynamic and static problems.</p>				
Modulo integrato: B2389 - MECHANICAL DESIGN WITH ADVANCED MATERIALS	ING-IND/14	6	60/0/0/0	No
Ambito: 1144 - Attivita' formative affini o integrative	C			
<p>Obiettivi: At the end of the integrated course, the student possesses advanced knowledge of structural design methods for composite and additively manufactured components, including material characterization and optimization for performance, cost, and sustainability. The student can apply the Finite Element Method, both theoretically and through commercial software, to analyze and design static and dynamic structural systems. The students acquire in-depth knowledge of the methods and instruments necessary for the optimal structural design of composite structures, particularly laminates and sandwiches, They learn the principles of the design for additive manufacturing, the mechanical properties of AM materials and the experimental methods for their determination. Optimal design criteria will be performance, cost and sustainability (reduction of the number of parts, lightweight design, and design for disassembly).</p> <p>Obiettivi inglese: At the end of the integrated course, the student possesses advanced knowledge of structural design methods for composite and additively manufactured components, including material characterization and optimization for performance, cost, and sustainability. The student can apply the Finite Element Method, both theoretically and through commercial software, to analyze and design static and</p>				

dynamic structural systems.

The students acquire in-depth knowledge of the methods and instruments necessary for the optimal structural design of composite structures, particularly laminates and sandwiches, They learn the principles of the design for additive manufacturing, the mechanical properties of AM materials and the experimental methods for their determination. Optimal design criteria will be performance, cost and sustainability (reduction of the number of parts, lightweight design, and design for disassembly).

6720 000 000 B2390 - 0 - MANUFACTURING TECHNOLOGIES FOR COMPOSITE MATERIALS	ING-IND/16	6	60/0/0/0	No	Voto
Ambito: 215 - Ingegneria meccanica	B				
Obiettivi: The student will be introduced to different technologies for the fabrication of components made of polymeric and composite materials with thermoplastic and thermosetting matrix, and will be able to select the most appropriate technology based on the required performance, the production footprint, and the number of components to be produced. The student will be able to understand and define manufacturing cycles to meet specific requirements on the final component, including those related to sustainability requirements.					
Obiettivi inglese: The student will be introduced to different technologies for the fabrication of components made of polymeric and composite materials with thermoplastic and thermosetting matrix, and will be able to select the most appropriate technology based on the required performance, the production footprint, and the number of components to be produced. The student will be able to understand and define manufacturing cycles to meet specific requirements on the final component, including those related to sustainability requirements.					
GC3 - Sustainable Energy and Industry			0-18		

6720 000 000 B2386 - 0 - SUSTAINABLE DESIGN OF INDUSTRIAL PLANTS	ING-IND/17	6	60/0/0/0	No	Voto
Ambito: 215 - Ingegneria meccanica	B				
Obiettivi: Knowledge and comprehension of the course contents in relation to the sustainable design of production systems. The course allows the student to comprehend theoretical principles, functional schemes and methodologies for measuring, designing and control the sustainability in industrial plant. Skills and capabilities in the application of the previously mentioned contents will be discussed in relation to real industrial cases where operators and machines cooperate. The student learns the tools and methods for the evaluation/measurement of the industrial sustainability in terms of social, environmental and economic impact.					
Obiettivi inglese: Knowledge and comprehension of the course contents in relation to the sustainable design of production systems. The course allows the student to comprehend theoretical principles, functional schemes and methodologies for measuring, designing and control the sustainability in industrial plant. Skills and capabilities in the application of the previously mentioned contents will be discussed in relation to real industrial cases where operators and machines cooperate. The student learns the tools and methods for the evaluation/measurement of the industrial sustainability in terms of social, environmental and economic impact.					

6720 000 000 B2383 - 0 - SUSTAINABLE USE OF ENERGY (I.C.)		12			Voto
Modulo integrato: B2384 - POWERTRAINS FOR SUSTAINABLE MOBILITY	ING-IND/08	6	120/0/0/0	No	
Ambito: 1144 - Attivita' formative affini o integrative	C				
Obiettivi: At the end of the integrated course, the student can perform detailed energy and exergy analyses of thermodynamic and energy systems, including sustainable powertrains, evaluating losses, efficiencies, and opportunities for improvement. The student can design heat exchanger networks, assess combustion and renewable energy technologies, and apply principles of minimal entropy generation and sustainability in energy conversion and system optimization.					
In this module the student learns the basics of sustainable powertrain technologies, from the use of natural resources down to energy conversion, including power and emissions control.					
Obiettivi inglese: At the end of the integrated course, the student can perform detailed energy and exergy analyses of thermodynamic and energy systems, including sustainable powertrains, evaluating losses, efficiencies, and opportunities for improvement. The student can design heat exchanger networks, assess combustion and renewable energy technologies, and apply principles of minimal entropy generation and sustainability in energy conversion and system optimization.					
In this module the student learns the basics of sustainable powertrain technologies, from the use of natural resources down to energy conversion, including power and emissions control.					

Modulo integrato: B2385 - EXERGY AND PINCH POINT ANALYSIS FOR SUSTAINABLE ENERGY USE	ING-IND/10	6	60/0/0/0	No	
Ambito: 1144 - Attivita' formative affini o integrative	C				
Obiettivi: At the end of the integrated course, the student can perform detailed energy and exergy analyses of thermodynamic and energy systems, including sustainable powertrains, evaluating losses, efficiencies, and opportunities for improvement. The student can design heat exchanger networks, assess combustion and renewable energy technologies, and apply principles of minimal entropy generation and sustainability in energy conversion and system optimization.					
On completion of this module, the student will be able to calculate entropy generation and Energy losses in a thermodynamic/energy system; determine conditions leading to minimal entropy generation in a system; make the necessary assumptions on system definition, operating conditions etc. required to carry out a consistent Energy analysis, suggesting possible improvements; calculate Energy content, reversible work, isentropic efficiency, Energy loss and irreversibility and energy efficiency for different parts of an energy system; apply the Energy analysis method to energy systems; calculate adiabatic flame temperature and Energy loss in combustion processes; determine the pinch temperature and the minimal required thermal load for a suitable industrial process; design heat exchanger networks according to the principles of pinch analysis; suggest measures to reduce heating and cooling needs in an existing heat exchanger network; evaluate pros and cons of traditional and renewable energy sources within the framework of sustainable energy use.					

Obiettivi inglese: At the end of the integrated course, the student can perform detailed energy and exergy analyses of thermodynamic and energy systems, including sustainable powertrains, evaluating losses, efficiencies, and opportunities for improvement. The student can design heat exchanger networks, assess combustion and renewable energy technologies, and apply principles of minimal entropy generation and sustainability in energy conversion and system optimization.

On completion of this module, the student will be able to calculate entropy generation and Energy losses in a thermodynamic/energy system; determine conditions leading to minimal entropy generation in a system; make the necessary assumptions on system definition, operating conditions etc. required to carry out a consistent Energy analysis, suggesting possible improvements; calculate Energy content, reversible work, isentropic efficiency, Energy loss and irreversibility and energy efficiency for different parts of an energy system; apply the Energy analysis method to energy systems; calculate adiabatic flame temperature and Energy loss in combustion processes; determine the pinch temperature and the minimal required thermal load for a suitable industrial process; design heat exchanger networks according to the principles of pinch analysis; suggest measures to reduce heating and cooling needs in an existing heat exchanger network; evaluate pros and cons of traditional and renewable energy sources within the framework of sustainable energy use.

Gruppo: Laboratories and Internship -12 CFU

TAF: F Ambito: 1147 - Altre conoscenze utili per

Cfu min: 12 Cfu max: 12

Note: Students must choose two activities up to 12 cfu (Each lab is made up of two modules of 3 ECTS)

Attività formativa	TIP	SSD	TAF	CFU	ORE F/E/L/N	FREQ. VER.
6720 000 000 C8493 - 0 - CONDITION MONITORING AND PREDICTIVE MAINTENANCE LABORATORY-(I.C.)				6		Voto
Modulo integrato: C8492 - VIBRATION MEASUREMENTS AND ANALYSIS		ING-IND/13		3	30/0/0/0	No
Ambito: 1147 - Altre conoscenze utili per l'inserimento nel mondo del lavoro			F			
Obiettivi: At the end of the integrated course, the student masters the theoretical, methodological, and practical foundations of Condition Monitoring and Predictive Maintenance for industrial equipment. The student is able to design and perform experimental vibration analyses, apply signal processing and numerical modeling techniques, and implement advanced Machine Learning-based diagnostic and predictive strategies for the dynamics and health assessment of mechanical systems. At the end of this module the student is able to arrange and conduct experimental tests to detect mechanical vibrations of mechanisms and machines, with different devices and transducers. The student knows numerical modelling methods and tools to analyze the dynamics of complex mechanical systems, including elastodynamic phenomena. The student gains knowledge about the main signal processing and analysis techniques for vibration response characterization and diagnostics of mechanical systems, enabling Condition Monitoring and Predictive Maintenance strategies.						
Obiettivi inglese: At the end of the integrated course, the student masters the theoretical, methodological, and practical foundations of Condition Monitoring and Predictive Maintenance for industrial equipment. The student is able to design and perform experimental vibration analyses, apply signal processing and numerical modeling techniques, and implement advanced Machine Learning-based diagnostic and predictive strategies for the dynamics and health assessment of mechanical systems. At the end of this module the student is able to arrange and conduct experimental tests to detect mechanical vibrations of mechanisms and machines, with different devices and transducers. The student knows numerical modelling methods and tools to analyze the dynamics of complex mechanical systems, including elastodynamic phenomena. The student gains knowledge about the main signal processing and analysis techniques for vibration response characterization and diagnostics of mechanical systems, enabling Condition Monitoring and Predictive Maintenance strategies.						
Modulo integrato: B2405 - PREDICTIVE MAINTENANCE		ING-INF/04		3	30/0/0/0	No
Ambito: 1147 - Altre conoscenze utili per l'inserimento nel mondo del lavoro			F			
Obiettivi: At the end of the integrated course, the student masters the theoretical, methodological, and practical foundations of Condition Monitoring and Predictive Maintenance for industrial equipment. The student is able to design and perform experimental vibration analyses, apply signal processing and numerical modeling techniques, and implement advanced Machine Learning-based diagnostic and predictive strategies for the dynamics and health assessment of mechanical systems. This module aims to provide the conceptual, methodological, and practical bases for the Predictive Maintenance of industrial equipment. At the end of the course, the student is able to apply the most advanced techniques based on Machine Learning and Neural Networks, characterizing Industry 4.0, of Condition Monitoring and Predictive Maintenance. Finally, significant cases related to industrial machines will be analyzed.						
Obiettivi inglese: At the end of the integrated course, the student masters the theoretical, methodological, and practical foundations of Condition Monitoring and Predictive Maintenance for industrial equipment. The student is able to design and perform experimental vibration analyses, apply signal processing and numerical modeling techniques, and implement advanced Machine Learning-based diagnostic and predictive strategies for the dynamics and health assessment of mechanical systems. This module aims to provide the conceptual, methodological, and practical bases for the Predictive Maintenance of industrial equipment. At the end of the course, the student is able to apply the most advanced techniques based on Machine Learning and Neural Networks, characterizing Industry 4.0, of Condition Monitoring and Predictive Maintenance. Finally, significant cases related to industrial machines will be analyzed.						

6720 000 000 B2406 - 0 - DESIGN AND VIRTUAL PROTOTYPING OF AUTOMATIC MACHINES LABORATORY (I.C.)		6		Giudizio
Modulo integrato: B2407 - DESIGN OF AUTOMATIC MACHINES	ING-IND/14	3	0/0/30/0	No
Ambito: 1147 - Altre conoscenze utili per l'inserimento nel mondo del lavoro		F		
Obiettivi: At the end of the integrated course, the student understands the architecture and design principles of automatic machines and is able to perform their conceptual and embodiment design. The student also acquires skills in immersive and semi-immersive visualization, animation, and interaction with mechanical systems through XR technologies, applying software and hardware tools for virtual prototyping and design evaluation.				
The students acquire in-depth knowledge of the architecture of different types of automatic machines. They learn how to do the conceptual or the embodiment design of an automatic machine of industrial interest.				
Obiettivi inglese: At the end of the integrated course, the student understands the architecture and design principles of automatic machines and is able to perform their conceptual and embodiment design. The student also acquires skills in immersive and semi-immersive visualization, animation, and interaction with mechanical systems through XR technologies, applying software and hardware tools for virtual prototyping and design evaluation.				
The students acquire in-depth knowledge of the architecture of different types of automatic machines. They learn how to do the conceptual or the embodiment design of an automatic machine of industrial interest.				
Modulo integrato: B2408 - VIRTUAL PROTOTYPING	ING-IND/15	3	0/0/30/0	No
Ambito: 1147 - Altre conoscenze utili per l'inserimento nel mondo del lavoro		F		
Obiettivi: At the end of the integrated course, the student understands the architecture and design principles of automatic machines and is able to perform their conceptual and embodiment design. The student also acquires skills in immersive and semi-immersive visualization, animation, and interaction with mechanical systems through XR technologies, applying software and hardware tools for virtual prototyping and design evaluation.				
The student learns the basic functions for the digital representation and animation of industrial systems and for the interaction with virtual scenarios through XR (Extended Reality) technologies. Moreover, the student makes practice on software and hardware tools for advanced virtual prototyping.				
Obiettivi inglese: At the end of the integrated course, the student understands the architecture and design principles of automatic machines and is able to perform their conceptual and embodiment design. The student also acquires skills in immersive and semi-immersive visualization, animation, and interaction with mechanical systems through XR technologies, applying software and hardware tools for virtual prototyping and design evaluation.				
The student learns the basic functions for the digital representation and animation of industrial systems and for the interaction with virtual scenarios through XR (Extended Reality) technologies. Moreover, the student makes practice on software and hardware tools for advanced virtual prototyping.				
6720 000 000 B2411 - 0 - DIGITAL ENGINEERING LABORATORY (I.C.)		6		Giudizio
Modulo integrato: B2412 - VIRTUALIZATION OF MECHATRONIC SYSTEMS	ING-IND/13	3	0/0/30/0	No
Ambito: 1147 - Altre conoscenze utili per l'inserimento nel mondo del lavoro		F		
Obiettivi: At the end of the integrated course, the student understands and applies the main techniques for modeling, simulating, and visualizing complex mechatronic systems through Digital Twins. The student is able to develop and represent 3D Digital Twins in Mixed Reality environments using appropriate software and hardware tools, and to implement simulations for multibody dynamics, virtual commissioning, and real-time data-driven system analysis.				
The students learn the main approaches and techniques to model complex mechatronic systems. The development of the Digital Twins of robots and automatic machines will be taught through the practical use of alternative software tools available at the computer lab. Different kinds of Digital Twins are developed according to the scope of their simulations, in particular dealing with Multibody systems dynamics, Virtual Commissioning, and real-time simulations of physical prototypes fed by measured data.				
Obiettivi inglese: At the end of the integrated course, the student understands and applies the main techniques for modeling, simulating, and visualizing complex mechatronic systems through Digital Twins. The student is able to develop and represent 3D Digital Twins in Mixed Reality environments using appropriate software and hardware tools, and to implement simulations for multibody dynamics, virtual commissioning, and real-time data-driven system analysis.				
The students learn the main approaches and techniques to model complex mechatronic systems. The development of the Digital Twins of robots and automatic machines will be taught through the practical use of alternative software tools available at the computer lab. Different kinds of Digital Twins are developed according to the scope of their simulations, in particular dealing with Multibody systems dynamics, Virtual Commissioning, and real-time simulations of physical prototypes fed by measured data.				

Modulo integrato: B2414 - EXTENDED REALITY FOR DIGITAL TWIN OF MECHATRONIC SYSTEMS	ING-IND/15	3	0/0/30/0	No	
Ambito: 1147 - Altre conoscenze utili per l'inserimento nel mondo del lavoro		F			
Obiettivi: At the end of the integrated course, the student understands and applies the main techniques for modeling, simulating, and visualizing complex mechatronic systems through Digital Twins. The student is able to develop and represent 3D Digital Twins in Mixed Reality environments using appropriate software and hardware tools, and to implement simulations for multibody dynamics, virtual commissioning, and real-time data-driven system analysis.					
The student learns, through practice, the technologies to visualize the Digital Twin of a Mechatronic system in a Mixed Reality environment. The student makes practice on software and hardware tools for the creation or digitalization and the representation of a 3D Digital Twin of the system including virtual overlays.					
Obiettivi inglese: At the end of the integrated course, the student understands and applies the main techniques for modeling, simulating, and visualizing complex mechatronic systems through Digital Twins. The student is able to develop and represent 3D Digital Twins in Mixed Reality environments using appropriate software and hardware tools, and to implement simulations for multibody dynamics, virtual commissioning, and real-time data-driven system analysis.					
The student learns, through practice, the technologies to visualize the Digital Twin of a Mechatronic system in a Mixed Reality environment. The student makes practice on software and hardware tools for the creation or digitalization and the representation of a 3D Digital Twin of the system including virtual overlays.					
6720 000 000 B5050 - 0 - LEARNING BY DOING INTERNSHIP		6	0/0/150/0	No	Giudizio
Ambito: 1147 - Altre conoscenze utili per l'inserimento nel mondo del lavoro		F			
Obiettivi: The student acquires direct knowledge of professional fields through learning by doing engineering activities consistent with the educational objectives of the study program.					
Obiettivi inglese: The student acquires direct knowledge of professional fields through learning by doing engineering activities consistent with the educational objectives of the study program.					
6720 000 000 B2409 - 0 - SUSTAINABLE INDUSTRY LABORATORY (I.C.)		6			Giudizio
Modulo integrato: 60351 - INDUSTRIAL AUTOMATION	ING-INF/04	3	0/0/30/0	No	
Ambito: 1147 - Altre conoscenze utili per l'inserimento nel mondo del lavoro		F			
Obiettivi: At the end of the integrated course, the student masters the conceptual and methodological tools for modeling, analyzing, and designing automatic control systems for industrial plants and processes, and acquires practical skills in managing and optimizing physical and informational flows through flexible and sustainable automation solutions applied to manufacturing and service systems.					
This module aims to provide the conceptual, methodological, and practical bases that allow to analyze and design automatic control systems of industrial plants and processes. At the end of the course, the student is able to model, analyze and setup a controller for dynamic systems with discrete events, in the area of industrial automation. Finally, some significant cases of industrial processes and plants will be analyzed.					
Obiettivi inglese: At the end of the integrated course, the student masters the conceptual and methodological tools for modeling, analyzing, and designing automatic control systems for industrial plants and processes, and acquires practical skills in managing and optimizing physical and informational flows through flexible and sustainable automation solutions applied to manufacturing and service systems.					
This module aims to provide the conceptual, methodological, and practical bases that allow to analyze and design automatic control systems of industrial plants and processes. At the end of the course, the student is able to model, analyze and setup a controller for dynamic systems with discrete events, in the area of industrial automation. Finally, some significant cases of industrial processes and plants will be analyzed.					
Modulo integrato: B2410 - SUSTAINABLE INDUSTRIAL LOGISTICS	ING-IND/17	3	0/0/30/0	No	
Ambito: 1147 - Altre conoscenze utili per l'inserimento nel mondo del lavoro		F			
Obiettivi: At the end of the integrated course, the student masters the conceptual and methodological tools for modeling, analyzing, and designing automatic control systems for industrial plants and processes, and acquires practical skills in managing and optimizing physical and informational flows through flexible and sustainable automation solutions applied to manufacturing and service systems.					
Through the direct and experimental application, both physical and simulative, of the design and control of physical and information flows, the student learns tools and methods for both the manufacturing and service industry management with a particular focus for an efficient and sustainable resource utilization. The student also knows the application of flexible automation concepts leading to effective supply chain management.					
Obiettivi inglese: At the end of the integrated course, the student masters the conceptual and methodological tools for modeling, analyzing, and designing automatic control systems for industrial plants and processes, and acquires practical skills in managing and optimizing physical and informational flows through flexible and sustainable automation solutions applied to manufacturing and service systems.					
Through the direct and experimental application, both physical and simulative, of the design and control of physical and information flows, the student learns tools and methods for both the manufacturing and service industry management with a particular focus for an efficient and sustainable resource utilization. The student also knows the application of flexible automation concepts leading to effective supply chain management.					

6720 000 000 B2400 - 0 - SUSTAINABLE MOBILITY LABORATORY (I.C.)

6

Giudizio

Modulo integrato: B2401 - POWERTRAIN TESTING

ING-IND/08

3

0/0/30/0

No

Ambito: 1147 - Altre conoscenze utili per l'inserimento nel mondo del lavoro

F

Obiettivi: At the end of the integrated course, the student understands the principles and methodologies for testing and analyzing sustainable powertrain systems, including test facilities, equipment, and data-driven modeling and control, and is able to design and evaluate thermal management solutions for traditional and innovative mobility systems based on thermal requirements and performance criteria.

At the end of this module the student learns the basics of sustainable powertrain testing, including test facilities and testing equipment characteristics, test procedures, data analysis, modeling and control based on test data.

Obiettivi inglese: At the end of the integrated course, the student understands the principles and methodologies for testing and analyzing sustainable powertrain systems, including test facilities, equipment, and data-driven modeling and control, and is able to design and evaluate thermal management solutions for traditional and innovative mobility systems based on thermal requirements and performance criteria.

At the end of this module the student learns the basics of sustainable powertrain testing, including test facilities and testing equipment characteristics, test procedures, data analysis, modeling and control based on test data.

Modulo integrato: B2402 - THERMAL CONTROL

ING-IND/10

3

0/0/30/0

No

Ambito: 1147 - Altre conoscenze utili per l'inserimento nel mondo del lavoro

F

Obiettivi: At the end of the integrated course, the student understands the principles and methodologies for testing and analyzing sustainable powertrain systems, including test facilities, equipment, and data-driven modeling and control, and is able to design and evaluate thermal management solutions for traditional and innovative mobility systems based on thermal requirements and performance criteria.

Upon completion of the Lab the student will be able to know the systems, both traditional and new, which are used for thermal control of mobility related systems; calculate the thermal requirements for automotive thermal control devices; choose and design a suitable solution for thermal control problems arising in automotive applications.

Obiettivi inglese: At the end of the integrated course, the student understands the principles and methodologies for testing and analyzing sustainable powertrain systems, including test facilities, equipment, and data-driven modeling and control, and is able to design and evaluate thermal management solutions for traditional and innovative mobility systems based on thermal requirements and performance criteria.

Upon completion of the Lab the student will be able to know the systems, both traditional and new, which are used for thermal control of mobility related systems; calculate the thermal requirements for automotive thermal control devices; choose and design a suitable solution for thermal control problems arising in automotive applications.

Legenda:

CFU: crediti formativi universitari

TAF: tipologia attività formativa (A-di base; B-caratterizzanti; C-affini o integrative; F-ulteriori attività formative; D-a scelta autonoma dello studente; S- stages e tirocini presso imprese, enti pubblici o privati, ordini professionali; E-per la prova finale)

SSD: settore scientifico disciplinare

F/E/L/N: indica le ore Frontali/Esercitazioni/Laboratori/Ore di esercitazione e/o laboratorio tenute da non docenti

Freq.: segnala l'esistenza di un obbligo di frequenza

Ver.: indica la modalità di verifica del profitto finale

TIP.: indica la tipologia delle forme didattiche. Queste possono essere CON: convenzionali, E-L: in e-learning, MIX: miste, C/E: convenzionali e/o e-learning. Il corso di studio può definire annualmente una delle modalità.