## SYLLABUS OF A MODULE

Polish name of a module	Podstawy spalania	
English name of a module	Combustion	
ISCED classification - Code	0715	
ISCED classification - Field of study	Mechanics and metal trades	
Languages of instruction	English	
Level of qualification:	2 – MSc (EQF 7)	
Number of ECTS credit points	5	
Examination:	EW – exam written	

#### Number of hours per semester:

Lecture	Exercises	Laboratory	Seminar	E-learning	Project
30	30	0	0	0	0

## **MODULE DESCRIPTION**

#### **MODULE OBJECTIVES**

- O1. Students know theory of combustion fundamentals.
- O2. Students acquire skills in combustion issues calculations.

# PRELIMINARY REQUIREMENTS FOR KNOWLEDGE, SKILLS AND OTHER COMPETENCES

- 1. Fundamentals of mathematics and thermodynamics.
- 2. Fundamentals of thermal machinery principles.
- 3. Capability of using source literature.
- 4. Data analysis and presentation of results.

#### **LEARNING OUTCOMES**

- LO 1 The student possesses knowledge on combustion
- LO 2 The student possesses knowledge on fundamentals of construction and operation of thermal machinery
- LO 3 The student has ability to determine basic parameters in various combustion processes.

## MODULE CONTENT

Lec 2-3 - Combustion definition. Premixed and diffusion combustion. Deflagration and detonation. Global reaction of combustion. Stochiometry. Flammability limits. Enthalpy. UHV, LHV. Fuel specifications. 2   Lec 4-5 - Thermochemistry. Energy conservation law. Combustion at constant pressure and constant volume. Adiabatic flame temperature. Reactants and products. Chemical equilibrium. Dissociation. Gibbs function. Equilibrium constant. 2   Lec 7-8 - Combustion mechanism: H2-02, CO-02, methane, NO3 formation. 2   Lec 7-13 - Laminar premixed combustion. Description. Simplified analysis. Flame analysis in the Bunsen burner. Flame thickness. Laminar flame speed. 3   Combustion in the spark ignited engine. 1 1   L 14 - Ignition. Theory and models by Semenov and Frank-Kamenetski. 1 1   L 15-16 - Laminar diffusion combustion. Models of carbon particle combustion. 2 2   Lec 13 - Londuction to turbulent combustion. 1 1 2   L 14 - Ignition. Theory and models by Semenov and Frank-Kamenetski. 1 1   L 15-16 - Laminar diffusion combustion. 2 2 2   Coal burner description. 2 2 2 2   L 2e 13 - Solid fuel combustion. Rankine-Hugoniot curve. Structure of detonation wave. Detonation speed. 2 2   Lec 24-24. Measurements in combustion. Regulations and limits for toxic emi	Type of classes – LECTURE	Number of hours	
detonation. Global reaction of combustion. Stoichiometry. Flammability limits. 2   Enthalpy. UHV, LHV. Fuel specifications. 2   Lee 4-5 - Thermochemistry. Energy conservation law. Combustion at constant pressure and constant volume. Adiabatic flame temperature. Reactants and products. 2   Chemical equilibrium. Dissociation. Gibbs function. Equilibrium constant. 2   Lee 6 - Introduction to collision theory. Elementary reactions and rates. 1   Lee 7-8 - Combustion mechanism: types of elementary reactions. Time scales. 2   Lee 11-13 - Laminar premixed combustion. Description. Simplified analysis. Flame analysis in the Bunsen burner. Flame thickness. Laminar flame speed. 3   Combustion in the spark ignited engine. 2 1   Lee 17 - Introduction to turbulent combustion. 1 1   Lee 17 - Introduction to turbulent combustion. 1 1   Lee 20-11 - Solid fuel combustion. Rankine-Hugoniot curve. Structure of detonation and combustion. Combustion. Rankine-Hugoniot curve. Structure of detonation wave. Detonation speed. 2   Lee 22-30 - Detonation combustion. Regulations and limits for toxic emissions. 2 2   Lee 23-6 - Toxic products of combustion. Regulations and limits for toxic emissions. 2 2   Lee 24 - Measurements in combustion Regulations and limits for toxic emissions. 2 2	Lec 1 – Fundamental laws in thermodynamics and combustion science.	1	
Lec 4-5 - Thermochemistry. Energy conservation law. Combustion at constant pressure and constant volume. Adiabatic flame temperature. Reactants and products. Chemical equilibrium. Dissociation. Gibbs function. Equilibrium constant. 2   Lec 6 - Introduction to collision theory. Elementary reactions and rates. 1   Lec 9-10 - Selected combustion mechanisms: H <sub>2</sub> -O <sub>2</sub> , CO-O <sub>2</sub> , methane, NO <sub>3</sub> formation. 2   Lec 9-10 - Selected combustion mechanisms: H <sub>2</sub> -O <sub>2</sub> , CO-O <sub>2</sub> , methane, NO <sub>3</sub> formation. 2   Lec 11-13 - Laminar premixed combustion. Description. Simplified analysis. Flame analysis in the Bunsen burner. Flame thickness. Laminar flame speed. 3   Combustion in the spark ignited engine. 1   Let 14 - Ignition. Theory and models by Semenov and Frank-Kamenetski. 1   Let 17 - Introduction to turbulent combustion. 1   Let 18-19 - Combustion of liquid fuels. Simplified model of droplet evaporation and combustion. Combustion. Rankine-Hugoniot curve. Structure of detonation wave. Detonation speed. 2   Lec 24 - Measurements in combustion. 1 1   Lec 25-26 - Toxic products of combustion removal. Pretreatment and after treatment. 3-way catalytic converter. SCR and NSCR. PM traps. 2   Lec 29-30 - Trends in clean combustion process of gaseous, liquid and solid fuels. Reaction rate. Mole and mass fractions. Air-to-fuel stoichiometric ratio. 4   Let 19-10 - Thermodynamic equilibrium with species dissociation. 2			
Lec 6 - Introduction to collision theory. Elementary reactions and rates. 1   Lec 9.10 - Selected combustion mechanisms. H2-02, CO-02, methane, NO, formation. 2   Lee 9.10 - Selected combustion mechanisms. H2-02, CO-02, methane, NO, formation. 3   Combustion in the spark ignited engine. 3   L 14 - Ignition. Theory and models by Semenov and Frank-Kamenetski. 1   L 15-16 - Laminar diffusion combustion. Flame length. Soot formation. 2   Lee 17 - Introduction to turbulent combustion. 1   Lee 18-19 - Combustion in the compression ignition engine. 2   Lee 22-23 - Detonation combustion. Models of carbon particle combustion. Examples. Coal burner description. 2   Lee 24 - Measurements in combustion. Rankine-Hugoniot curve. Structure of detonation wave. Detonation speed. 2   Lee 23-0 - Toxic products of combustion Regulations and limits for toxic emissions. 2   Lee 24-0 - Trends in clean combustion recess of gaseous, liquid and solid fuels. Reaction rate. Mole and mass fractions. Air-to-fuel stoichiometric ratio. Equivalence ratio. 4   Tut 5-18 - Calculations of enthalpy of reaction, heat of combustion, lower heating value (LHV) and higher heating value (HHV) of fuels. 4   Tut 5-18 - Calculations of enthalpy of reaction, heat of combustion, lower heating value (LHV) and higher heating value (HHV) of fuels. 4   Tut 5-18 - Calculations of oliabab	Lec 4-5 – Thermochemistry. Energy conservation law. Combustion at constant pressure and constant volume. Adiabatic flame temperature. Reactants and products.		
Lec 9-10 - Selected combustion mechanisms: H2-O2, CO-O2, methane, NO3 formation. 2   Lec 11-13 - Laminar premixed combustion. Description. Simplified analysis. Flame analysis in the Bunsen burner. Flame thickness. Laminar flame speed. 3   Combustion in the spark ignited engine. 1   L 14 - Ignition. Theory and models by Semenov and Frank-Kamenetski. 1   L 15-16 - Laminar diffusion combustion. Flame length. Soot formation. 2   Lec 17 - Introduction to turbulent combustion. 1   Lec 20-21 - Solid fuel combustion. Models of carbon particle combustion. Examples. Coal burner description. 2   Lec 22-23 - Detonation combustion. Rankine-Hugoniot curve. Structure of detonation wave. Detonation speed. 1   Lec 24 - Measurements in combustion. Regulations and limits for toxic emissions. 2   Lec 25-26 - Toxic products of combustion Regulations and limits for toxic emissions. 2   Lec 29-30 - Trends in clean combustion process of gaseous, liquid and solid fuels. Reaction rate. Mole and mass fractions. Air-to-fuel stoichiometric ratio. Equivalence ratio. 4   Tut 5-18 - Calculations of enthalpy of reaction, heat of combustion, lower heating value (LHV) and higher heating value (HHV) of fuels. 4   Tut 1-14 - Calculations of olimbartic filme temperature at C <sub>P</sub> and C <sub>V</sub> . 4   Tut 19-22 - Determination of energy losses and boiler efficiency. Energy and exergy balance. 4	Lec 6 – Introduction to collision theory. Elementary reactions and rates.	1	
Lee 11-13 – Laminar premixed combustion. Description. Simplified analysis. Flame analysis in the Bunsen burner. Flame thickness. Laminar flame speed. 3   Combustion in the spark ignited engine. 1   L 14 – Ignition. Theory and models by Semenov and Frank-Kamenetski. 1   L 15-16 – Laminar diffusion combustion. Flame length. Soot formation. 2   Lee 17 – Introduction to turbulent combustion. 1   Lee 18-19 – Combustion of liquid fuels. Simplified model of droplet evaporation and combustion. Combustion. Models of carbon particle combustion. Examples. Coal burner description. 2   Lee 22-23 – Detonation combustion. Rankine-Hugoniot curve. Structure of detonation wave. Detonation speed. 2   Lee 24 – Measurements in combustion. Regulations and limits for toxic emissions. 2   Lee 25-26 – Toxic products of combustion Regulations and limits for toxic emissions. 2   Lee 29-30 – Trends in clean combustion technologies. 2   Suma 30   Type of classes – TUTORIAL Number of hours   Tut 5-18 – Calculations of enthalpy of reaction, heat of combustion, lower heating value (LHV) and higher heating value (HHV) of fuels. 4   Tut 9-10 – Thermodynamic equilibrium with species dissociation. 2   Tut 15-18 – Calculations of adiabatic flame temperature at C <sub>F</sub> and C <sub>Y</sub> . 4   Tut 19-22 – Determination of energy losses and	Lec 7-8 – Combustion mechanism. types of elementary reactions. Time scales.	2	
Lee 11-13 – Laminar premixed combustion. Description. Simplified analysis. Flame analysis in the Bunsen burner. Flame thickness. Laminar flame speed. 3   Combustion in the spark ignited engine. 1   L 14 – Ignition. Theory and models by Semenov and Frank-Kamenetski. 1   L 15-16 – Laminar diffusion combustion. Flame length. Soot formation. 2   Lee 17 – Introduction to turbulent combustion. 1   Lee 18-19 – Combustion of liquid fuels. Simplified model of droplet evaporation and combustion. Combustion. Models of carbon particle combustion. Examples. Coal burner description. 2   Lee 22-23 – Detonation combustion. Rankine-Hugoniot curve. Structure of detonation wave. Detonation speed. 2   Lee 24 – Measurements in combustion. Regulations and limits for toxic emissions. 2   Lee 25-26 – Toxic products of combustion Regulations and limits for toxic emissions. 2   Lee 29-30 – Trends in clean combustion technologies. 2   Suma 30   Type of classes – TUTORIAL Number of hours   Tut 5-18 – Calculations of enthalpy of reaction, heat of combustion, lower heating value (LHV) and higher heating value (HHV) of fuels. 4   Tut 9-10 – Thermodynamic equilibrium with species dissociation. 2   Tut 15-18 – Calculations of adiabatic flame temperature at C <sub>F</sub> and C <sub>Y</sub> . 4   Tut 19-22 – Determination of energy losses and	Lec 9-10 – Selected combustion mechanisms: H <sub>2</sub> -O <sub>2</sub> , CO-O <sub>2</sub> , methane, NO <sub>x</sub> formation.	2	
L 15-16 – Laminar diffusion combustion. Flame length. Soot formation. 2   Lec 17 – Introduction to turbulent combustion. 1   Lec 18-19 – Combustion of liquid fuels. Simplified model of droplet evaporation and combustion. Combustion in the compression ignition engine. 2   Lec 20-21 – Solid fuel combustion. Models of carbon particle combustion. Examples. Coal burner description. 2   Lec 22-23 – Detonation combustion. Rankine-Hugoniot curve. Structure of detonation wave. Detonation speed. 2   Lec 24 – Measurements in combustion. Regulations and limits for toxic emissions. 2   Lec 25-26 – Toxic products of combustion. Regulations and limits for toxic emissions. 2   Lec 27-28 – Methods for toxic substances removal. Pretreatment and after treatment. 3-way catalytic converter. SCR and NSCR. PM traps. 2   Lec 29-30 – Trends in clean combustion process of gaseous, liquid and solid fuels. Reaction rate. Mole and mass fractions. Air-to-fuel stoichiometric ratio. Equivalence ratio. 4   Tut 5-8 – Calculations of enthalpy of reaction, heat of combustion, lower heating value (LHV) and higher heating value (HHV) of fuels. 4   Tut 15-18 – Calculations of adiabatic flame temperature at C <sub>P</sub> and C <sub>V</sub> . 4   Tut 15-18 – Calculations of ondustion – one film model. 4   Tut 27-28 – Calculations of laminar flame speed. 2   Tut 29-30 – Calculation of detonation flame velocity. 2	analysis in the Bunsen burner. Flame thickness. Laminar flame speed.	3	
Lec 17 - Introduction to turbulent combustion.1Lec 18-19 - Combustion of liquid fuels. Simplified model of droplet evaporation and combustion. Combustion in the compression ignition engine.2Lec 20-21 - Solid fuel combustion. Models of carbon particle combustion. Examples. Coal burner description.2Lec 22-23 - Detonation combustion. Rankine-Hugoniot curve. Structure of detonation wave. Detonation speed.2Lec 24 - Measurements in combustion. Regulations and limits for toxic emissions.2Lec 25-26 - Toxic products of combustion. Regulations and limits for toxic emissions.2Lec 29-30 - Trends in clean combustion technologies.2Suma30Type of classes - TUTORIALNumber of hoursTut 5-8 - Calculations of enthalpy of reaction, heat of combustion, lower heating value (LHV) and higher heating value (HHV) of fuels.4Tut 1-14 - Calculations of adiabatic flame temperature at C <sub>P</sub> and C <sub>V</sub> .4Tut 15-18 - Calculations of volumetric composition of the wet and dry flue gases.4Tut 19-22 - Determination of energy losses and boiler efficiency. Energy and exergy balance.4Tut 27-28 - Calculations of aliabatic flame temperature at C <sub>P</sub> and C <sub>V</sub> .4Tut 27-28 - Calculations of aliabatic flame temperature at C <sub>P</sub> and C <sub>V</sub> .4Tut 27-28 - Calculations of energy losses and boiler efficiency. Energy and exergy balance.4Tut 27-28 - Calculations of aliabatic flame temperature at C <sub>P</sub> and C <sub>V</sub> .4Tut 27-28 - Calculations of aliabatic flame temperature at C <sub>P</sub> and C <sub>V</sub> .4Tut 27-28 - Calculations of laminar flame speed.2<	L 14 – Ignition. Theory and models by Semenov and Frank-Kamenetski.		
Lec 18-19 - Combustion of liquid fuels. Simplified model of droplet evaporation and combustion. Combustion in the compression ignition engine. 2   Lec 20-21 - Solid fuel combustion. Models of carbon particle combustion. Examples. Coal burner description. 2   Lec 22-23 - Detonation combustion. Rankine-Hugoniot curve. Structure of detonation wave. Detonation speed. 2   Lec 24 - Measurements in combustion. Regulations and limits for toxic emissions. 2   Lec 25-26 - Toxic products of combustion. Regulations and limits for toxic emissions. 2   Lec 27-28 - Methods for toxic substances removal. Pretreatment and after treatment. 3-way catalytic converter. SCR and NSCR. PM traps. 2   Lec 29-30 - Trends in clean combustion process of gaseous, liquid and solid fuels. Reaction rate. Mole and mass fractions. Air-to-fuel stoichiometric ratio. Equivalence ratio. 4   Tut 5-8 - Calculations of enthalpy of reaction, heat of combustion, lower heating value (LHV) and higher heating value (HHV) of fuels. 4   Tut 1-14 - Calculations of ovaluestic flame temperature at CP and CV. 4   Tut 29-10 - Thermodynamic equilibrium with species dissociation. 2   Tut 1-14 - Calculations of volumetric composition of the wet and dry flue gases. 4   Tut 29-20 - Determination of energy losses and boiler efficiency. Energy and exergy balance. 4   Tut 23-26 - Solid particle combustion - one film model. 4   Tut 29-30 - Calc		2	
combustion. Combustion in the compression ignition engine.2Lec 20-21 - Solid fuel combustion. Models of carbon particle combustion. Examples. Coal burner description.2Lec 22-23 - Detonation combustion. Rankine-Hugoniot curve. Structure of detonation wave. Detonation speed.2Lec 24 - Measurements in combustion.1Lec 25-26 - Toxic products of combustion. Regulations and limits for toxic emissions.2Lec 27-28 - Methods for toxic substances removal. Pretreatment and after treatment. 3- way catalytic converter. SCR and NSCR. PM traps.2Lec 29-30 - Trends in clean combustion technologies.2Type of classes - TUTORIALNumber of hoursTUT 1-4 - Calculations of combustion process of gaseous, liquid and solid fuels. Reaction rate. Mole and mass fractions. Air-to-fuel stoichiometric ratio. Equivalence ratio.4Tut 5-8 - Calculations of enthalpy of reaction, heat of combustion, lower heating value (LHV) and higher heating value (HHV) of fuels.4Tut 1-14 - Calculations of onlumetric composition of the wet and dry flue gases.4Tut 19-10 - Thermodynamic equilibrium with species dissociation.2Tut 23-26 - Solid particle combustion - one film model.4Tut 27-28 - Calculations of laminar flame speed.2Tut 23-26 - Solid particle combustion - one film model.4Tut 27-28 - Calculation of detonation flame velocity.2		1	
Coal burner description.2Lec 22-23 – Detonation combustion. Rankine-Hugoniot curve. Structure of detonation wave. Detonation speed.2Lec 24 – Measurements in combustion.1Lec 25-6 – Toxic products of combustion. Regulations and limits for toxic emissions.2Lec 27-28 – Methods for toxic substances removal. Pretreatment and after treatment. 3- way catalytic converter. SCR and NSCR. PM traps.2Lec 29-30 – Trends in clean combustion technologies.2Suma30Type of classes – TUTORIALNumber of hoursTUT 1-4 – Calculations of combustion process of gaseous, liquid and solid fuels. Reaction rate. Mole and mass fractions. Air-to-fuel stoichiometric ratio. Equivalence ratio.4Tut 5-8 – Calculations of enthalpy of reaction, heat of combustion, lower heating value (LHV) and higher heating value (HHV) of fuels.4Tut 1-14 – Calculations of adiabatic flame temperature at C <sub>P</sub> and C <sub>V</sub> .4Tut 1-14 – Calculations of adiabatic flame temperature at C <sub>P</sub> and C <sub>V</sub> .4Tut 19-22 – Determination of energy losses and boiler efficiency. Energy and exergy balance.4Tut 27-28 – Calculations of laminar flame speed.2Tut 29-30 – Calculation of detonation flame velocity.2	combustion. Combustion in the compression ignition engine.	2	
wave. Detonation speed. 2   Lec 24 – Measurements in combustion. 1   Lec 25-26- Toxic products of combustion. Regulations and limits for toxic emissions. 2   Lec 27-28 – Methods for toxic substances removal. Pretreatment and after treatment. 3- way catalytic converter. SCR and NSCR. PM traps. 2   Lec 29-30 – Trends in clean combustion technologies. 2   Suma 30   Type of classes – TUTORIAL Number of hours   TUT 1-4 – Calculations of combustion process of gaseous, liquid and solid fuels. Reaction rate. Mole and mass fractions. Air-to-fuel stoichiometric ratio. Equivalence ratio. 4   Tut 5-8 – Calculations of enthalpy of reaction, heat of combustion, lower heating value (LHV) and higher heating value (HHV) of fuels. 4   Tut 1-14 – Calculations of adiabatic flame temperature at C <sub>P</sub> and C <sub>V</sub> . 4   Tut 15-18 – Calculations of volumetric composition of the wet and dry flue gases. 4   Tut 23 -26 – Solid particle combustion – one film model. 4   Tut 27-28 – Calculations of laminar flame speed. 2   Tut 29-30 – Calculation of detonation flame velocity. 2	Coal burner description.	2	
Lec 25-26 – Toxic products of combustion. Regulations and limits for toxic emissions. 2   Lec 27-28 – Methods for toxic substances removal. Pretreatment and after treatment. 3-way catalytic converter. SCR and NSCR. PM traps. 2   Lec 29-30 – Trends in clean combustion technologies. 2   Suma 30   Type of classes – TUTORIAL Number of hours   TUT 1-4 – Calculations of combustion process of gaseous, liquid and solid fuels. Reaction rate. Mole and mass fractions. Air-to-fuel stoichiometric ratio. 4   Equivalence ratio. 4   Tut 5-8 – Calculations of enthalpy of reaction, heat of combustion, lower heating value (LHV) and higher heating value (HHV) of fuels. 4   Tut 1-14 – Calculations of adiabatic flame temperature at C <sub>P</sub> and C <sub>V</sub> . 4   Tut 1-14 – Calculations of enthalpy of reaction of the wet and dry flue gases. 4   Tut 19-22 – Determination of energy losses and boiler efficiency. Energy and exergy balance. 4   Tut 23 -26 – Solid particle combustion – one film model. 4   Tut 27-28 – Calculations of laminar flame speed. 2   Tut 29-30 – Calculation of detonation flame velocity. 2		2	
Lec 27-28 – Methods for toxic substances removal. Pretreatment and after treatment. 3- way catalytic converter. SCR and NSCR. PM traps.2Lec 29-30 – Trends in clean combustion technologies.2Suma30Type of classes – TUTORIALNumber of hoursTUT 1-4 – Calculations of combustion process of gaseous, liquid and solid fuels. Reaction rate. Mole and mass fractions. Air-to-fuel stoichiometric ratio. Equivalence ratio.4Tut 5-8 – Calculations of enthalpy of reaction, heat of combustion, lower heating value (LHV) and higher heating value (HHV) of fuels.4Tut 9-10 – Thermodynamic equilibrium with species dissociation.2Tut 11-14 – Calculations of volumetric composition of the wet and dry flue gases.4Tut 19-22 – Determination of energy losses and boiler efficiency. Energy and exergy balance.4Tut 23 -26 – Solid particle combustion – one film model.4Tut 29-30 – Calculations of laminar flame speed.2Tut 29-30 – Calculation of detonation flame velocity.2	Lec 24 – Measurements in combustion.		
way catalytic converter. SCR and NSCR. PM traps.2Lec 29-30 – Trends in clean combustion technologies.2Suma30Tupe of classes – TUTORIALNumber of hoursTUT 1-4 – Calculations of combustion process of gaseous, liquid and solid fuels. Reaction rate. Mole and mass fractions. Air-to-fuel stoichiometric ratio. Equivalence ratio.4Tut 5-8 – Calculations of enthalpy of reaction, heat of combustion, lower heating value (LHV) and higher heating value (HHV) of fuels.4Tut 9-10 – Thermodynamic equilibrium with species dissociation.2Tut 11-14 – Calculations of adiabatic flame temperature at CP and CV.4Tut 19-22 – Determination of energy losses and boiler efficiency. Energy and exergy balance.4Tut 23 -26 – Solid particle combustion – one film model.4Tut 27-28 – Calculations of laminar flame speed.2Tut 29-30 – Calculation of detonation flame velocity.2		2	
Suma30Type of classes – TUTORIALNumber of hoursTUT 1-4 – Calculations of combustion process of gaseous, liquid and solid fuels. Reaction rate. Mole and mass fractions. Air-to-fuel stoichiometric ratio. Equivalence ratio.4Tut 5-8 – Calculations of enthalpy of reaction, heat of combustion, lower heating value (LHV) and higher heating value (HHV) of fuels.4Tut 9-10 – Thermodynamic equilibrium with species dissociation.2Tut 11-14 – Calculations of adiabatic flame temperature at C <sub>P</sub> and C <sub>V</sub> .4Tut 15-18 – Calculations of volumetric composition of the wet and dry flue gases.4Tut 19-22 – Determination of energy losses and boiler efficiency. Energy and exergy balance.4Tut 23 - 26 – Solid particle combustion – one film model.4Tut 27-28 – Calculations of laminar flame speed.2Tut 29-30 – Calculation of detonation flame velocity.2	way catalytic converter. SCR and NSCR. PM traps.		
Type of classes – TUTORIALNumber of hoursTUT 1-4 – Calculations of combustion process of gaseous, liquid and solid fuels. Reaction rate. Mole and mass fractions. Air-to-fuel stoichiometric ratio. Equivalence ratio.4Tut 5-8 – Calculations of enthalpy of reaction, heat of combustion, lower heating value (LHV) and higher heating value (HHV) of fuels.4Tut 9-10 – Thermodynamic equilibrium with species dissociation.2Tut 11-14 – Calculations of adiabatic flame temperature at CP and CV.4Tut 19-22 – Determination of energy losses and boiler efficiency. Energy and exergy balance.4Tut 23 - 26 – Solid particle combustion – one film model.4Tut 29-30 – Calculation of detonation flame velocity.2			
Type of classes – TUTORIAL of hours   TUT 1-4 – Calculations of combustion process of gaseous, liquid and solid fuels. Reaction rate. Mole and mass fractions. Air-to-fuel stoichiometric ratio. Equivalence ratio. 4   Tut 5-8 – Calculations of enthalpy of reaction, heat of combustion, lower heating value (LHV) and higher heating value (HHV) of fuels. 4   Tut 9-10 – Thermodynamic equilibrium with species dissociation. 2   Tut 11-14 – Calculations of adiabatic flame temperature at C <sub>P</sub> and C <sub>V</sub> . 4   Tut 15-18 – Calculations of volumetric composition of the wet and dry flue gases. 4   Tut 19-22 – Determination of energy losses and boiler efficiency. Energy and exergy balance. 4   Tut 23 -26 – Solid particle combustion – one film model. 4   Tut 27-28 – Calculations of laminar flame speed. 2   Tut 29-30 – Calculation of detonation flame velocity. 2	Suma		
Reaction rate. Mole and mass fractions. Air-to-fuel stoichiometric ratio.4Equivalence ratio.1Tut 5-8 – Calculations of enthalpy of reaction, heat of combustion, lower heating value (LHV) and higher heating value (HHV) of fuels.4Tut 9-10 – Thermodynamic equilibrium with species dissociation.2Tut 11-14 – Calculations of adiabatic flame temperature at CP and CV.4Tut 15-18 – Calculations of volumetric composition of the wet and dry flue gases.4Tut 19-22 – Determination of energy losses and boiler efficiency. Energy and exergy balance.4Tut 23 -26 – Solid particle combustion – one film model.4Tut 27-28 – Calculations of laminar flame speed.2Tut 29-30 – Calculation of detonation flame velocity.2	Type of classes – TUTORIAL		
(LHV) and higher heating value (HHV) of fuels. 4   Tut 9-10 – Thermodynamic equilibrium with species dissociation. 2   Tut 11-14 – Calculations of adiabatic flame temperature at C <sub>P</sub> and C <sub>V</sub> . 4   Tut 15-18 – Calculations of volumetric composition of the wet and dry flue gases. 4   Tut 19-22 – Determination of energy losses and boiler efficiency. Energy and exergy balance. 4   Tut 23 -26 – Solid particle combustion – one film model. 4   Tut 27-28 – Calculations of laminar flame speed. 2   Tut 29-30 – Calculation of detonation flame velocity. 2			
Tut 11-14 – Calculations of adiabatic flame temperature at C <sub>P</sub> and C <sub>V</sub> . 4   Tut 15-18 – Calculations of volumetric composition of the wet and dry flue gases. 4   Tut 19-22 – Determination of energy losses and boiler efficiency. Energy and exergy balance. 4   Tut 23 -26 – Solid particle combustion – one film model. 4   Tut 27-28 – Calculations of laminar flame speed. 2   Tut 29-30 – Calculation of detonation flame velocity. 2	<b>Tut 5-8</b> – Calculations of enthalpy of reaction, heat of combustion, lower heating value (LHV) and higher heating value (HHV) of fuels.	4	
Tut 11-14 – Calculations of adiabatic flame temperature at C <sub>P</sub> and C <sub>V</sub> . 4   Tut 15-18 – Calculations of volumetric composition of the wet and dry flue gases. 4   Tut 19-22 – Determination of energy losses and boiler efficiency. Energy and exergy balance. 4   Tut 23 -26 – Solid particle combustion – one film model. 4   Tut 27-28 – Calculations of laminar flame speed. 2   Tut 29-30 – Calculation of detonation flame velocity. 2	<b>Tut 9-10</b> – Thermodynamic equilibrium with species dissociation.	2	
Tut 15-18 – Calculations of volumetric composition of the wet and dry flue gases. 4   Tut 19-22 – Determination of energy losses and boiler efficiency. Energy and exergy balance. 4   Tut 23 -26 – Solid particle combustion – one film model. 4   Tut 27-28 – Calculations of laminar flame speed. 2   Tut 29-30 – Calculation of detonation flame velocity. 2	<b>Tut 11-14</b> – Calculations of adiabatic flame temperature at $C_P$ and $C_V$ .		
Tut 19-22 – Determination of energy losses and boiler efficiency. Energy and exergy balance.4Tut 23 -26 – Solid particle combustion – one film model.4Tut 27-28 – Calculations of laminar flame speed.2Tut 29-30 – Calculation of detonation flame velocity.2			
Tut 23 -26 - Solid particle combustion - one film model.4Tut 27-28 - Calculations of laminar flame speed.2Tut 29-30 - Calculation of detonation flame velocity.2	Tut 19-22 – Determination of energy losses and boiler efficiency. Energy and exergy		
Tut 27-28 - Calculations of laminar flame speed.2Tut 29-30 - Calculation of detonation flame velocity.2		4	
Tut 29-30 - Calculation of detonation flame velocity.2			
	*		
Allma All	Suma	<u> </u>	

## **TEACHING TOOLS**

<b>1.</b> – Lecture with the use of multimedia presentations
2. – Tutorials of combustion calculation
3. – Instructions to classes
4. – Own codes and commercial software

## WAYS OF ASSESSMENT (F-FORMATIVE, S-SUMMATIVE)

F1. - assessment of the ability to apply the acquired knowledge while doing the exercises

F2. - evaluation of reports on the implementation of exercises covered by the curriculum

**F3.** - assessment of activity during classes

**S1.** - assessment of the ability to solve the problems posed and the manner of presentation obtained results - pass mark \*

S2. - assessment of mastery of the teaching material being the subject of the lecture - exam

\*) in order to receive a credit for the module, the student is obliged to attain a passing grade in all classes as well as in achievement tests.

## STUDENT'S WORKLOAD

L.p.	Forms of activity	Average number of hours required for realization of activity			
1	1. Contact hours with teacher				
1.1	Lectures	30			
1.2	Tutorials	30			
1.3	Laboratory	0			
1.4	Seminar	0			
1.5	Project	0			
1.6	Consulting teacher during their duty hours	5			
1.7	Examination	3			
Total number of contact hours with teacher:		68			
2	. Student's individual work				
2.1	Preparation for tutorials and tests	17			
2.2	Preparation for laboratory exercises, writing reports on laboratories	0			
2.3	Preparation of project	0			
2.4	Preparation for final lecture assessment	0			
2.5	Preparation for examination	20			
2.6	Individual study of literature	20			
	Total number of hours of student's individual work:	57			
	Overall student's workload:	125			
Overall number of ECTS credits for the module		5 ECTS			
Number of ECTS points that student receives in classes requiring teacher's supervision:		2.72 ECTS			
Number of <b>ECTS</b> credits acquired during practical classes including laboratory exercises and projects:		1.20 ECTS			

### BASIC AND SUPPLEMENTARY RESOURCE MATERIALS

- 1. Cengel Y, Boles M, Thermodynamics: An Engineering Approach, McGraw-Hill Education; 8 edition, 2014
- Moran JN, Shapiro HN, Principles of Engineering Thermodynamics, John Wiley & Sons Inc, 2015
- 3. Mayhew Y, Rogers GFC, Mayhew YR, Engineering Thermodynamics : Work and Heat Transfer, Longman, Pearson Education Limited, 1996
- 4. Borman GL, Ragland K.M.: Combustion Engineering, McGraw Hill, 1998
- 5. Drysdale D, An introduction to fire dynamics, New York, Wiley&Son 1990
- 6. Glassman I, Yetter R.A.: Combustion, Academic Press, 2008
- 7. Turns S, An Introduction to Combustion: Concepts and Applications, McGraw-Hill, 2000
- 8. Warnatz J, Maas U, Dibble RW, Combustion: Physical and chemical fundamentals, modeling and simulation, experiments, pollutant formation, Springer 2001

#### MODULE COORDINATOR (NAME, SURNAME, E-MAIL ADDRESS)

Stanislaw Szwaja, Associate Professor, CzUT, Department of Thermal Machinery, szwaja@imc.pcz.pl