Department of Space Engineering and Rocketry

Birla Institute of Technology, Mesra, Ranchi - 835215 (India)

Institute Vision

To become a Globally Recognized Academic Institution in consonance with the social, economic and ecological environment, striving continuously for excellence in education, research and technological service to the National needs.

Institute Mission

- To educate students at Undergraduate, Post Graduate Doctoral and Post-Doctoral levels to perform challenging engineering and managerial jobs in industry.
- To provide excellent research and development facilities to take up Ph.D. programmes and research projects.
- To develop effective teaching and learning skills and state of art research potential of the faculty.
- To build national capabilities in technology, education and research in emerging areas.
- To provide excellent technological services to satisfy the requirements of the industry and overall academic needs of society.

Department Vision

To effectively integrate teaching, research and innovation for significant contribution towards National Aerospace Programmes and related activities

Department Mission

- To impart quality education and advanced research training leading to postgraduate and doctoral degree
- To generate modern infrastructure and conducive research atmosphere for carrying out innovative sponsored research projects
- To nurture spirit of excellence and professional leadership in students and faculty members through exposure to leading academic/research organisations and external experts
- To create attractive opportunities for sustained interaction and collaboration with academia and industry

Program Educational Objectives (PEO)

PEO 1 : To develop strong foundation in students to understand and analyse advance research problems in Space Engineering and Rocket Science.
PEO 2: Nurture professional graduates to develop ability in analysing real life problems of Space Technology.
PEO 3 : To foster attitude towards continuous learning for developmental activities in research, academia and industry.
PEO 4 : To improve professional skills for teamwork with ethical awareness and practice in achieving goal.

Program Outcomes (PO)

PO 1 : An ability to independently carry out research and development work to solve practical problems in Aerodynamics

PO 2 : An ability to write and present substantial technical report and research article

PO 3 : Students should be able to demonstrate a degree of mastery over and above the bachelor program in the areas of Aerodynamics.

PO 4: Ability to design, perform and interpret data from experiments and correlate them with numerical and theoretical solutions

PO 5 : Students should be committed to professional ethics, responsibilities and norms of practices.

PO 6 : An ability to recognize the need for continuous learning throughout his professional career in the context of technological challenges and advancements

COURSE INFORMATION SHEET

Course code: SR 550
Course title: Liquid & Hybrid Rocket Propulsion
Pre-requisite(s): NA
Co- requisite(s): NA
Credits: L:3 T:0 P:0
Class schedule per week: 03
Class: M.Tech
Semester / Level: II/05
Branch: SER
Name of Teacher:

Course Objectives

This course enables the students:

A.	To explain the working theory of liquid rocket engine, cryogenic engine and hybrid rocket propulsion system.
B.	To identify the fundamental concept of the feed systems of the liquid rocket propulsion system in terms of designing in a practical applications.
C.	To identify the concept of thrust chamber and other combustion devices of liquid rocket engine in the design approach.
D.	To generate sufficient information on the precautions and designing challenges of a cryogenic propulsion system.
E.	To create a basic platform for designing a hybrid rocket propulsion system.

Course Outcomes

After the completion of this course, students will be able:

1.	To get the knowledge on the various basic terms and performance parameters used in a liquid rocket engine.
2.	To analyze and investigate various types of feed system used in a liquid rocket engine and later utilize it in the designing process.
3.	To comprehend the concept of thrust chamber and other combustion devices of liquid rocket engine in the design approach.
4.	To describe the basic information related to the designing challenges of the cryogenic propulsion system.
5.	To explain the limitations and designing challenges of the hybrid rocket motor.

Syllabus

Liquid Propellants and LPR Engine: Basic Elements of an LPR Engine; Performance Parameters of selected existing Liquid Rocket Engines.

[L=6]

Feed Systems: Types of feed system in liquid rocket engine, Purpose; Types of Pressure Feed Systems; Methods of Tank- pressure Control; Types of Pressurization Systems; Desirable Characteristics of Pressurants; Tank Pressurant requirements and its Determination; Pressurized Gas Systems, Elements of Pump Feed Systems; Centrifugal Pumps and Axial Flow Pumps; Turbines; Design Layout of Turbo-pump Assemblies; Control Valves and their selection; Transient Pressures due to Valve Closure and Valve Opening; Design of the Wall Thickness of Propellant Line; Frictional Losses in Propellant Feed Lines, Overall design of feed systems both pressure fed and turbo pump fed systems.

[L=10]

Thrust Chambers and Auxiliary Combustion Devices: Basic Thrust Chamber Elements; Combustion Chamber Design and Characteristic Length; Combustion Process; Performance Parameters; Engine Design and Control; Configuration Layout; Materials and Selection; Types of Injectors; Injector Design and Performance; Ignition Devices; Heat Transfer; Regenerative Cooling; design of regenerative cooled engines, Uncooled Chambers; Combustion Instability; Nozzle Flow; Nozzle Design; Thrust Vector Control. Design of liquid rockets with sub system design.

[L=9]

Cryogenic Propulsion: Cryogenic Loading Problems; Temperature and Pressure Effects on Loading; Tank Collapse; Phenomenon of Thermal Stratification; Effect of Thermal Stratification on Rocket Engine Performance; Prediction and Methods of Elimination of Thermal Stratification.

[L=7]

Hybrid Rocket Propulsion: Introduction; Classification; System Arrangement and Components; Typical Fuels and Oxidizers; Advantages and Disadvantages; Application Areas; Performance and Limitations; Performance Parameters of selected existing Hybrid Rocket Engines; System Integration; Manufacturing Methods for Low- and High- Thrust Engines. Design of hybrid rockets with sub system design including grain design.

[L=8]

Text books:

1. Design of Liquid Propellant Rocket Engine – Huzel, D. K. & Huang, D. H., NASA SP-125
2. Fundamental of Hybrid Rocket Combustion and Propulsion, Martin J. Chiaverini and Kennith K. Kuo, Progress in Aeronautics & Astronautics, Vol. 218, AIAA.
3. Safety in the Handling of Cryogenic Fluids, Frederick J. Edeskuty and Walter F. Stewart. The International Cryogenic Monograph Series, Springer Science + Business Media New York.

Reference books:

1. Rocket Propellant and Pressurization Systems – Ring, E.

2. Heterogeneous Combustion – Wolfhard,H. G., Progress in Aeronautics & Astronautics, Vol. 15, AIAA.
3. Liquid Rocket and Propellants – Bollinger, L. E., Progress in Aeronautics & Astronautics, Vol. AIAA.
4. Cryogenic Systems – Barron, R.
5. Thermodynamic Properties of Cryogenic Fluids, Richard T Jacobsen, Steven G Penoncello and Eric W. Lemmon, The International Cryogenic Monograph Series, Springer Science + Business Media New York.

Gaps in the syllabus (to meet Industry/Profession requirements)

POs met through Gaps in the Syllabus

Topics beyond syllabus/Advanced topics/Design

POs met through Topics beyond syllabus/Advanced topics/Design

Course Delivery methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

Mapping between Objectives and Outcomes

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	Program Outcomes					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	1	2	1	1	3
CO2	3	2	3	2	2	3
CO3	3	3	3	2	2	3
CO4	2	1	2	1	1	3
CO5	3	2	3	2	-	3

If satisfying and < 34% = 1, 34-66% = 2, > 66% = 3

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method
CO1	CD1,CD2,CD3
CO2	CD1, CD2,CD3,CD4
CO3	CD1, CD2,CD3
CO4	CD1, CD2
CO5	CD1, CD2

COURSE INFORMATION SHEET

Course code: SR 551
Course title: Solid Rocket Propulsion
Pre-requisite(s): NA
Co- requisite(s): NA
Credits: L:3 T:0 P:0
Class schedule per week: 03
Class: M.Tech
Semester / Level: II/05
Branch: SER
Name of Teacher:

Course Objectives

This course enables the students:

A.	To demonstrate the information and implications of the types of grain suitable for a particular solid rocket motor.
B.	To examine the importance of various performance parameters used in solid rocket motor in terms of its implication.
C.	To generate the sufficient information on the types of the nozzle and its utilization in practical applications.
D.	To apply the basic knowledge of an igniters in the designing process of a solid rocket motor.
E.	To examine the various types of instabilities occurring in solid rocket motor along with their remedies.

Course Outcomes

After the completion of this course, students will be able:

1.	To interpret different types of propellant grain and its significance in the designing of solid rocket motor.
2.	To analyze the various performance parameters used in solid rocket motor.
3.	To apply the basic knowledge of nozzle in the practical applications.
4.	To describe the concept of ignition system in designing the igniters for a solid rocket motor.
5.	To predict the various types of instabilities occurring in solid rocket motor along with their remedies.

Syllabus

Solid Rocket Motor: Introduction to Solid Rocket, Classification, Types of Grain and its importance, Propellant Characteristics, Star Configuration; Design Criteria; Segmented Grains; Burning Surface Area Evaluation; Dual Thrust Grains. Structural Analysis of Propellant Grain, Types of Mechanical Load, Structure Failure of Grains.

[L=9]

Performance of Solid Rocket Motor: Prediction and Measurements of Specific Impulse, Computation of Adiabatic Flame Temperature; Theoretical Performance Evaluation of Solid Rocket Propellants; Equilibrium and Frozen Flow; Methods of Calculating Equilibrium Composition; Experimental Determination of Rocket Performance.

[L=9]

Nozzle: Isentropic Flow through Nozzles, Nozzle Configuration; Convergent- Divergent Nozzles, Bell Nozzles, Annular Nozzles, Adopted Nozzles, Submerged Nozzles; Nozzle Flow and Design Optimization; Nozzle Construction; Throat Inserts.

[L=7]

Associated Systems : Ignition and Ignition Delay; Selection Criteria of Igniter Composition, Quantity and Location; Design of Igniters; Sample Calculation; Igniters for Solid Rocket Motor; Igniter Hardware; Igniter Pellets; Pyrogen Igniters; Extinction of Solid Rocket Motors; Restart of Solid Rocket Motors; Inhibition and Inhibitors; Insulation and Liners; Thrust Vector Control; Mechanism and Methods of TVC; Testing and Integration with Vehicle.

[L=9]

Combustion Instability: Types of Instability – Bulk Mode, Transverse Mode and Axial Mode Instabilities; Causes of Instability in Solid Rocket Motors; Analysis of Instability in Solid Rocket Motors; Remedial Methods.

[L=6]

Text books:

1. Solid Rocket Propulsion – Barrere, M., et. Al
2. Rocket Propulsion Elements – Sutton, G. P. and Biblarz, O., 7th Ed.

Reference books:

1. Solid Rocket Technology – Shorr, M. and Zaehringer, A. J.
2. Understanding Aerospace Chemical Propulsion, H S Mukunda
3. Rocket Propulsion, K Ramamurthi.
4. Introduction to Rocket Technology, V. I. Feodosiev and G. B. Siniarev
5. Materials for Missiles and Spacecraft, E. R. Parker

Gaps in the syllabus (to meet Industry/Profession requirements)

POs met through Gaps in the Syllabus

Topics beyond syllabus/Advanced topics/Design

POs met through Topics beyond syllabus/Advanced topics/Design

Course Delivery methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Mapping between Objectives and Outcomes

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	Program Outcomes					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	3	2	1	3
CO2	3	2	3	2	2	3
CO3	1	1	2	1	1	3
CO4	3	1	3	1	1	2
CO5	3	1	3	1	1	2

If satisfying and < 34% = 1, 34-66% = 2, > 66% = 3

Mapping Between COs and Course Delivery (CD) methods

Course Outcomes	Course Delivery Method
CO1	CD1,CD2, CD6
CO2	CD1, CD2, CD6
CO3	CD1, CD6
CO4	CD1, CD2, CD6
CO5	CD1,CD2, CD6

COURSE INFORMATION SHEET

Course code: SR 552
Course title: Rocket Combustion Processes
Pre-requisite(s): NA
Co- requisite(s):NA
Credits: 3 L:3 T:0 P:0
Class schedule per week: 3
Class: M.Tech
Semester / Level: II/05
Branch: SER
Name of Teacher:

Course Objectives

This course enables the students:

A.	To understand details of combustion process associated with double base and composite propellants and compare the condensed and gas phase theories related to them.
B.	To apply the concept of metal combustion in metallized composite solid propellants
C.	To identify the changes in energetics and combustion behaviour including erosive burning.
D.	To understand combustion of liquid propellants in rocket motor with emphasis on atomization and related combustion models.
E.	To comprehend combustion model of hybrid propellants in view of existing theories of hybrid combustion and related operating parameters in a hybrid rocket motor.

Course Outcomes

After the completion of this course, students will be able to:

CO1	Comprehend principal concepts and predict the related theory for a typical case of solid propellant combustion.
CO2	Identify the effect of metal addition on the combustion processes and analyse its effect on energetics and combustion behaviour.
CO3	Illustrate the concept of erosive burning and interpret the instabilities associated with it and their remedial methods.
CO4	Summarize the effect of atomization and droplet size distribution in the combustion of liquid propellant and evaluate the effect of different parameters in the combustion process.
CO5	Comprehend the theories of hybrid combustion and evaluate the effect of related operating parameters in a hybrid rocket motor.

Syllabus

Solid Propellant Combustion : Combustion of Double Base Propellants; Combustion Mechanisms in Condensed Phase and Gas Phase; Theories of Combustion of D. B. Propellants – Boys & Corner Theory, Two- temperature Postulate of composite propellant; Deflagration of Ammonium Perchlorate; Degradation of Fuel Binders; Combustion Mechanism of Composite Propellants; Theories of Combustion – Outline of Thermal Theory, GDF Model and Multiple Flame (BDP) Combustion Model.

[11L]

Combustion of Metals : Physical Considerations; Description and Classification of Various Burning Metals; Experimental Nature of Metal Powder Combustion; Theories of Combustion of Metal powders; Metal Combustion in deflagrating propellants; Effect of Aluminum on Propellant Burning Rate; Equilibrium Composition of Combustion Products of Metallized Propellants.

[7L]

Erosive Burning : Introduction; Threshold Velocity; Laboratory Methods for Determination of the Erosion Function; Theories of Erosive Burning– Levoneir and Robillard's Theory; Vandenkerckhove Theory; Effect of Erosion on Geometry of Central Port; Effect of Cross- Flow Velocity, Free Stream Gas Composition, Effect of Propellant Characteristics and Combustion Chamber Pressure on Erosive Burning; Negative Erosion Phenomenon.

[7L]

Liquid Propellant Combustion : Physico- Chemical Description of Combustion in a Liquid Propellant Rocket Motor; Atomization and Droplet Size Distribution in Injection Sprays; Spherico- symmetric Model of Fuel Burning in Oxidizing Atmosphere; Correlation for Non- spherical Model; Effect of Drag on Combustion; Effect of Pressure on Combustion; Droplet Burning Rate Measurement; Combustion Models for Monopropellants.

[7L]

Hybrid Propellant Combustion : Introduction; Combustion Model for a Hybrid Fuel Burning in an Oxidizer Stream; Theories of Hybrid Combustion – Laminar Boundary Layer Theories, Turbulent Boundary Layer Theories, Theories Based on Chemical Kinetics; Effect of Pressure and Mass Flow Rate on Hybrid Combustion; Transient Behaviour of Hybrid Regression Rate; Temperature Profile inside the Regressing Solid Fuel; Combustion of Metallized Hybrid Fuel; Effect of Radiation, Burning Time, Length and Port Size on Fuel Regression Rate. **[8L]**

Text books:

1. Fundamentals of Solid Propellant Combustion, Kuo, K.K., Summerfield, M., Progress in Astronautics & Aeronautics, Vol. 90, AIAA. 1984.
2. Heterogeneous Combustion, Wolfhard, H.G., Glassman, I., Green, L., Progress in Astronautics & Aeronautics, Vol. 15, AIAA. 1964.

Reference books:

1. Liquid Propellant Rockets, Altman, D., Carter, J. M., Penner, S.S., Summerfield, M., Princeton University Press, 1960.

2. Fundamental of Hybrid Rocket Combustion and Propulsion, Chiaverini, M.J., Kuo, K.K., Progress in Astronautics & Aeronautics, Vol. 218, AIAA. 2007.

Gaps in the syllabus (to meet Industry/Profession requirements)

POs met through Gaps in the Syllabus

Topics beyond syllabus/Advanced topics/Design

POs met through Topics beyond syllabus/Advanced topics/Design

Course Delivery methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Mapping between Objectives and Outcomes

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	Program Outcomes					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	2	1		3
CO2	2	1	2	1		3
CO3	3	2	3	2	3	3
CO4	2	1	3	2		1
CO5	3	3	3	2	2	3

If satisfying and < 34% = 1, 34-66% = 2, > 66% = 3

Mapping Between COs and Course Delivery (CD) methods

Course Outcomes	Course Delivery Method
CO1	CD1,CD2, CD6
CO2	CD1, CD2, CD6
CO3	CD1, CD6
CO4	CD1, CD2, CD6
CO5	CD1,CD2, CD6

COURSE INFORMATION SHEET

Course code: SR 553
Course title: Ignition and Extinction in Chemical Rocket
Pre-requisite(s): NA
Co- requisite(s): NA
Credits: L:3 T:0 P:0
Class schedule per week: 3 Lectures
Class: M.Tech.
Semester / Level: II/05
Branch: Space Engineering & Rocketry
Name of Teacher:

Course Objectives

This course enables the students to:

A.	Identify and interpret the factors affecting the ignition energy release and its mechanism for any given ignition source.
B.	Examine the suitability of ignitions for any chemical rocket based on its merits and demerits.
C.	Judge the type of igniters to be designed for any chemical rocket propulsion system.
D.	Generate the sufficient information about the flame spreading and its mechanism in solid rocket motor.
E.	Assess the knowledge of solid propellant extinction in the designing process of a solid rocket motor.

Course Outcomes

After the completion of this course, students will be able to:

1.	Interpret different types of igniters and its applications in the propulsion system.
2.	Analyze the ignition mechanism and its sequence mainly for solid rocket applications.
3.	Design an igniter for the given chemical rocket propulsion system for the given thrust range.
4.	Describe the concept of flame spreading and ignition transient in a solid rocket motor.
5.	Predict the various mechanism of extinction utilized in the solid rocket motor along with their advantages and disadvantages.

Syllabus

Module I:
Ignition & Factors affecting Ignition Energy : Introduction; Process of Self-ignition; Induction Period; Limits of Self-ignition; Forced ignition; Basic Idea of Ignition by Spark; Pilot Flames; Hot Gases and Shock Waves; Effect of Composition, Type of Electrode, Spark Duration, Pressure, Temperature, Diluents, Effect of Mixture Velocity and Turbulence on Ignition Energy.

[8L]

Module II:
Ignition Mechanism : Sequence of Ignition; Theories of Ignition – Thermal Ignition Theory, Gas- Phase Theory and Heterogeneous Theory; Pre- ignition Reactions; Effect of Catalyst on Ignition Process; Shock Tube and Ignition Experiments.

[7L]

Module III:
Igniters for Chemical Rocket : Igniters for Solid Rocket Motors – Role and Requirements; Classification of Igniters based on Mounting Locations and Energy Release Systems; Construction and Initiation Systems; Hardware Components; Design of Pyrotechnic and Pyrogen Igniters; Testing and Evaluation; Igniters for Liquid Propellant Engines, Hypergolic Ignition and Ignition Delay; Catalyst Induced Ignition; Igniters for Cryogenic Engines – Spark Torch, Pyrotechnic, Pyrogen and Plasma Igniters; Igniters for Hybrid Motors and Air Breathing Engines; Laser Induced Ignition and its Applications.

[11L]

Module IV:
Flame Spreading and Ignition Transient: Physical Processes during Ignition Transient; Ignition Transient Models and Experiments; Flame Spreading over Solid Propellants, Fuels, Defects and Cracks.

[6L]

Module V:
Extinction: Controlled Termination of Thrust – Approaches; Energy Balance at Burning Surface; Dynamic Extinction by Fast Depressurization, Fast Deradiation and other Quenching Techniques, like Injection of Flame Inhibitors, Heat Sink, etc.; Theories and Experiments of Extinction.

[8L]

Text books:

1. Fuels & Combustion – Sharma, S.P. & Mohan, C., Tata- McGraw Hill, 1984 **(T1)**
2. Fundamental Aspects of Solid Propellant Rockets, Williams, F.A., Barrère, M., Huang, N.C., The Advisory Group for Aerospace Research and Development of N.A.T.O. [by] Technivision Services, 1969.**(T2)**

Reference books:

1. Advanced Chemical Rocket Propulsion Elements – Timnat, Y.M., Academic Press, 1987.**(R1)**

2. Fundamentals of Solid Propellant Combustion – Kuo, K.K., Summerfield, M., Progress in Astronautics & Aeronautics, Vol. 90, AIAA. 1984.**(R2)**
3. Solid Rocket Technology – Shorr, M. and Zaehringer, A. J.**(R3)**
4. Understanding Aerospace Chemical Propulsion, H S Mukunda**(R4)**
5. Rocket Propulsion, K Ramamurthi.**(R5)**

Gaps in the syllabus (to meet Industry/Profession requirements)

POs met through Gaps in the Syllabus

Topics beyond syllabus/Advanced topics/Design

POs met through Topics beyond syllabus/Advanced topics/Design

Course Delivery methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

Mapping between Course Outcome and Program Outcomes

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	2	1	1	3
CO2	2	2	3	2	1	3
CO3	3	3	3	2	2	3
CO4	2	2	3	1	2	3
CO5	1	1	2	2	1	3

If satisfying and < 34% = 1, 34-66% = 2, > 66% = 3

Mapping between COs and Course Delivery (CD) methods

Course Outcomes	Course Delivery Method
CO1	CD1,CD2,CD3, CD6
CO2	CD1, CD2, CD3, CD6
CO3	CD1, CD6
CO4	CD1, CD2, CD3, CD6
CO5	CD1,CD2, CD3, CD6

COURSE INFORMATION SHEET

Course code: SR 554
Course title: Advanced Propulsion Systems
Pre-requisite(s): Elements of Rocket Propulsion
Co- requisite(s): Nil
Credits: 3 L:3 T:0 P:0
Class schedule per week: 3
Class: ME
Semester / Level: II/05
Branch: Propulsion
Name of Teacher:

Course Objectives

This course enables the students:

A.	To understand the concept of various types of advanced propulsion system
B.	To apply the concept of the different combustion systems used in scramjet, ramjet propulsion and hypersonic propulsion
C.	To analyse the characteristics of nuclear propulsion and the hazards associated with it
D.	To interpret the various electric propulsion system and the ways power generation in space
E.	To interpret the various micro-propulsion systems developed and emerging technologies involved

Course Outcomes

After the completion of this course, students will be:

CO1	To understand the concept of various types of advanced chemical propulsion system and its application to real systems.
CO2	To demonstrate the utilization of combustion systems in scramjet, ramjet propulsion and hypersonic propulsion.
CO3	To infer the concept of nuclear rockets and evaluate the performance, operation parameters and handling hazard involved
CO4	To differentiate between electro-thermal and pure electric thrusters and interpret the concept for power generation in space.
CO5	To appraise the various micro-propulsion systems developed and emerging technologies involved.

Syllabus

Advanced Chemical Propulsion System: High Performance Chemical Propulsion Systems, Tripropellants; Metalized Propellants; Free Radical Propulsion; Flight Hybrid Rocket Propulsion Systems.

[8L]

Scramjet and Hypersonic Propulsion: Scramjet and Ram Rocket Propulsion System; Scramjet Inlets; Scramjet Performance, Introduction to Hypersonic Propulsion; Developments in High Speed Vehicle Propulsion System; Aerodynamic Shape of a Hypersonic Vehicle with an Air Breathing Engine; Engine Cycle; Diffusion Flame Combustion and Supersonic Combustion; Supersonic Flow Combustors; Dual-mode Combustion System.

[10L]

Nuclear Propulsion System : Types of Nuclear Propulsion Systems; Heat Transfer in Nuclear Rockets; Gaseous Core Nuclear Rockets; Pure Nuclear Propulsion System; Operation, Performance and Application Areas; Nuclear Hazards; Nuclear Power Generation in Space.

[7L]

Electric Propulsion System : Overview of Application Areas; Ideal Flight Performance; Electro-thermal Thrusters – Resistojets and Arcjets. Pure Electric Thrusters – Electrostatic, Electro Magnetic and Hall- effect Thrusters; Optimum Flight Performance; Electric Power Generation in Space.

[7L]

Micropropulsion System : Recent Micro Spacecraft Developments; Micro-propulsion Options; Primary Set of Micropropulsion Requirements; Chemical Propulsion Options; Review of Electric Propulsion Technologies for Micro and Nano- satellites; Emerging Technologies: MEMS and MEMS- Hybrid Propulsion System.

[8L]

Text books:

1. Developments in High Speed- Vehicle Propulsion System, Murthy, S.N.B, Curran, E.T., Progress in Astronautics & Aeronautics, Vol.165, AIAA, 1996.
2. Scramjet Propulsion, Curran, E.T., Murthy, S.N.B., Progress in Astronautics & Aeronautics, Vol. 189, AIAA,2001.
3. Micropropulsion for Small Spacecraft, Paul, Z., Progress in Astronautics &Aeronautics, Vol. 187, AIAA,2000.

Reference books:

1. Rocket Propulsion Elements, Sutton, G.P., Biblarz, O., 7th Ed. John Wiley & Sons, Inc., New York, 2001.

Gaps in the syllabus (to meet Industry/Profession requirements)

POs met through Gaps in the Syllabus

Topics beyond syllabus/Advanced topics/Design

POs met through Topics beyond syllabus/Advanced topics/Design

Course Delivery methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

Mapping between Objectives and Outcomes

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	Program Outcomes					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	1	2	2
CO2	3	2	3	3	1	2
CO3	3	3	3	3	2	3
CO4	3	2	3	3	1	3
CO5	3	3	3	3	2	3

Mapping Between COs and Course Delivery (CD) methods

Course Outcomes	Course Delivery Method
CO1	CD1,CD2, CD6
CO2	CD1, CD2, CD6
CO3	CD1, CD6
CO4	CD1, CD2, CD6
CO5	CD1,CD2, CD6

COURSE INFORMATION SHEET

Course code: SR 555
Course title: Heat Transfer in Space Applications
Pre-requisite(s): NA
Co- requisite(s): NA
Credits: L:3 T:0 P:0
Class schedule per week: 3 Lectures
Class: M.Tech.
Semester / Level: II/05
Branch: Space Engineering & Rocketry
Name of Teacher:

Course Objectives

This course enables the students to:

1.	Identify various heat transfer mechanism and its utilities in the spacecraft applications.
2.	Select and examine the suitability of material at higher temperature of the spacecraft.
3.	Assess various equation for the analysis of heat transfer problem in the spacecraft.
4.	Analyze the thermal environmental effect on the spacecraft structure during launch and ascent phases.
5.	Interpret the heat transfer process and its controlling mechanisms of the various devices used in spacecraft.

Course Outcomes

After the completion of this course, students will be able to:

CO1	Distinguish different modes of heat transfer and utilize effectively in space application.
CO2	Apply the knowledge of the heat transfer mechanism in the design of spacecraft thermal system.
CO3	Analyze the heat transfer equation for the spacecraft applications.
CO4	Examine the influence of thermal environment on the spacecraft during its various phases of launch.
CO5	Interpret the working principles of various high temperature resistive devices and hardware of the spacecraft.

Syllabus

Module I:
Introduction to heat transfer: Heat Transfer Mechanisms, Conduction, Convection and Radiation, Basic equations governing these Heat Transfer, Simultaneous Heat Transfer Mechanism.

[8L]

Module II:
Spacecraft Thermal Design: Fundamental of Thermal Radiation, Spacecraft Surface Material, Thermal Blanket, Diurnal and Annual Variations of Solar Heating, Need of Spacecraft Thermal Control – Temperature Specification – Energy Balance in a Spacecraft, Factors that influence Energy Balance in a spacecraft – Principles of Spacecraft Thermal Control.

[10L]

Module III:
Spacecraft Thermal Analysis: Formulation of Energy, Momentum and Continuity Equations for problems in Spacecraft Heat Transfer – Development of Discretized Equation – Treatment of Radiative Heat Exchange (for non-participative media based on radiosity and Gebhart method) – incorporation of Environmental Heat Flux in energy equation – Numerical Solution Methods – input parameters required for analysis.

[10L]

Module IV:
Spacecraft Thermal Environments: Launch and Ascent – Earth Bound Orbits – Interplanetary Mission and Re-entry Mission.

[5L]

Module V:
Devices and Hardware for Spacecraft TCS: Passive Thermal Control - mechanical joints – heat sinks and doublers – phase change materials – thermal louvers and switches – heat pipes Thermal Coating Materials – thermal insulation – Ablative Heat Transfer – Active Thermal Control Techniques: electrical heaters, HPR fluid systems, space borne cooling systems. Application of principles for the Development of Spacecraft TCS.

[8L]

Text books:
1. Fundamentals of Heat and Mass Transfer, Incropera, F.P., DeWitt, D.P., 7th ed., John Wiley, 2011**(T1)**.
2. Spacecraft Thermal Control Handbook, Volume I: Fundamental Technologies, Gilmore, D.G., 2nd ed., The Aerospace Press, AIAA, 2002**(T2)**.

Reference books:
1. Elements of Space Technology, Meyer, R.X., Academic Press, 1999 **(R1)**.
2. Numerical Methods for Engineers, Chapra, S.C., Canale, R.P., 7th ed., McGraw-Hill 2014**(R2)**.

Gaps in the syllabus (to meet Industry/Profession requirements)

POs met through Gaps in the Syllabus

Topics beyond syllabus/Advanced topics/Design

POs met through Topics beyond syllabus/Advanced topics/Design

Course Delivery methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

Mapping between Course Outcome and Program Outcomes

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	1	2	1	2	3
CO2	3	2	3	2	3	3
CO3	2	2	3	2	2	3
CO4	1	1	2	1	1	2
CO5	2	1	2	1	2	3

If satisfying and < 34% = 1, 34-66% = 2, > 66% = 3

Mapping between COs and Course Delivery (CD) methods

Course Outcomes	Course Delivery Method
CO1	CD1,CD2, CD6
CO2	CD1, CD2, CD6
CO3	CD1, CD6
CO4	CD1, CD2, CD6
CO5	CD1,CD2, CD6

COURSE INFORMATION SHEET

Course code: SR 556
Course title: Solid rocket propulsion lab
Pre-requisite(s): NA
Co- requisite(s): NA
Credits: 2 L:0 T:0 P:3
Class schedule per week: 4
Class: M.Tech
Semester / Level: II/05
Branch: SER
Name of Teacher:

Course Objectives

This course enables the students:

A.	To understand the significance of the experiment with respect to theoretical information.
B.	To collect and interpret data obtained from experiments.
C.	To examine the results in a group of team and evaluate it to utilize in preparing the report.
D.	To explain the working and designing procedure of the solid rocket motor.
E.	To follow and utilize all the safety features required during the experimentations

Course Outcomes

After the completion of this course, students will be able:

CO1	To analyze the types of error observed during the experiments.
CO2	To explain the significance of the processing of the propellants in correlation with practical applications.
CO3	To comprehend and illustrate various methods of improving the burn rate in a solid rocket motor
CO4	To operate the solid rocket experimental setup and generate results for the meaning analysis as an individual and as in a group.
CO5	To identify the equipments used in the experiment along with their significance of using them.

List of the Experiments:

1. **<u>Experiment No. 1</u>**
   Name : Introduction to solid rocket and its processing lab
   Objective : To introduce and give brief information about the equipments used in solid rocket propulsion lab.

2. **<u>Experiment No. 2</u>**
   Name : Preparation of fuel grain
   Objective : Processing of solid composite propellant grain with different perforations having compositions as PVC-DBP and AP.
3. **<u>Experiment No. 3</u>**
   Name : Rheological study
   Objective : To study the rheological properties of the freshly prepared solid propellant mix.

4. **<u>Experiment No. 4</u>**
   Name : Heat of Combustion
   Objective : To determine the heat of combustion of solid propellant sample at least at two different inert gas pressures.

5. **<u>Experiment No. 5</u>**
   Name : Study of mechanical properties
   Objective : To evaluate the mechanical properties of composite solid propellant.

6. **<u>Experiment No. 6</u>**
   Name SEM Analysis
   Objective : To study the surface morphology of solid propellant with the help of Scanning Electron Microscope.

7. **<u>Experiment No. 7</u>**
   Name : Experiments on STA
   Objective : Thermal decomposition study of solid propellant with the help of Simultaneous Thermal Analyzer.
   <u>Experiment No. 8</u>
   Name : Burn rate measurement at higher pressure
   Objective : To measure the burn rate of solid propellant strands at various pressures by using Crawford Bomb set-up.

   <u>Experiment No. 9</u>
   Name : Burn rate measurement at sub-atmospheric pressure
   Objective : To measure the burn rate of solid propellant strands at sub-atmospheric pressures.

8. **<u>Experiment No. 10</u>**
   Name : Preparation of igniter
   Objective : To prepare pyrotechnic igniters and determine its ignition delay.

9. **<u>Experiment No. 11</u>**
   Name : Solid Rocket Static Firing

Objective : To perform static solid rocket firing and determine its performance parameters such as thrust and Specific impulse.

Reference books:

1. Rocket Propulsion Elements – Sutton, G. P. and Biblarz, O., 7th Ed.
2. Understanding Aerospace Chemical Propulsion, H S Mukunda.
3. Rocket Propulsion, K Ramamurthi.

Gaps in the syllabus (to meet Industry/Profession requirements)

POs met through Gaps in the Syllabus

Topics beyond syllabus/Advanced topics/Design

POs met through Topics beyond syllabus/Advanced topics/Design

Course Delivery methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

Mapping between Program Outcome and Course Outcomes

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	**Program Outcomes**					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	1	3	2	1	2
CO2	3	2	1	1	2	3
CO3	2	1	2	2	1	3
CO4	2	2	3	1	1	2
CO5	2	1	3	1	1	3

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Mapping between COs and Course Delivery (CD) methods

Course Outcomes	Course Delivery Method
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CO2	CD1, CD2, CD6
CO3	CD1, CD6
CO4	CD1, CD2, CD6
CO5	CD1,CD2, CD6

COURSE INFORMATION SHEET

Course code: SR 557
Course title: Liquid and Hybrid Propulsion Lab
Pre-requisite(s): NA
Co- requisite(s):NA
Credits: 2 L:0 T:0 P:3
Class schedule per week: 4
Class: M.Tech
Semester / Level: II/05
Branch: SER
Name of Teacher:

Course Objectives

This course enables the students:

A.	To understand the significance of the experiment with respect to theoretical information.
B.	To collect and interpret data obtained from experiments.
C.	To examine the results in a group of team and evaluate it to utilize in preparing the report.
D.	To explain the working and designing procedure of the liquid and hybrid rocket motor.
E.	To follow and utilize all the safety features required during the experimentations

Course Outcomes

After the completion of this course, students will be able:

CO1	To analyze the types of error observed during the experiments.
CO2	To explain the various methods of improving the burn rate in a hybrid rocket motor
CO3	To operate the experimental setup and collect data as an individual and as in a group.
CO4	To demonstrate the output of the results for the meaningful analysis.
CO5	To identify the equipments used in the experiment with their significance of using them.

List of the Experiments:

1. **Experiment No. 1**
   Name : Introduction to liquid and hybrid lab
   Objective : To introduce and give brief information about the equipments used in liquid and hybrid lab
2. **Experiment No. 2**
   Name : Preparation of fuel grain

Objective : Processing of PVC-Plastisol based hybrid fuel grain with tubular perforation of two different compositions.

3. **Experiment No. 3**
Name : Effect of solid loading on regression rate
Objective : To study the effect of solid loading on the regression rate of PVC based fuel in a hybrid rocket motor.

4. **Experiment No. 4**
Name : Pressure Effect on Regression Rate
Objective : To Study the effect of chamber pressure on regression rate in a hybrid rocket motor.

5. **Experiment No. 5**
Name : Processing of paraffin based fuel
Objective : To measure regression rate of paraffin based fuel and compare with the PVC based fuel in a hybrid rocket.

6. **Experiment No. 6**
Name : Effect of injectors
Objective : To study the effect of varying oxidizer injectors on the regression rate of hybrid fuel.

7. **Experiment No. 7**
Name : Performance Evaluation through CEA Software
Objective : To Evaluate the theoretical performace parameters of the given fuel and oxidizer combinations at various O/F ratios.

8. **Experiment No. 8**
Name : Effect of protrusion on efficiencies
Objective : To study the effect of protrusion on the efficiencies of hybrid rocket motor.

9. **Experiment No. 9**
Name : Synthesis of energetic fuel
Objective : Synthesis of the Aniline-Furfuryldehyde condensate as hybrid fuel.

10. **Experiment No. 10**
Name : Ignition delay test
Objective : To conduct hypergolic ignition delay test for the Aniline-Furfuryldehyde hybrid fuel with red fuming nitric acid.

11. **Experiment No. 11**
Name : Effect of burn duration on regression rate
Objective : To study the effect of burn duration on the regression rate using PVC-DBP as a hybrid fuel.

12. **Experiment No. 12**
Name : Liquid rocket firing
Objective : To conduct experiment on a liquid rocket firing set-up to understand the operation of liquid rocket engine.

Reference books:

1. Design of Liquid Propellant Rocket Engine – Huzel, D. K. & Huang, D. H., NASA SP-125.
2. Fundamental of Hybrid Rocket Combustion and Propulsion, Martin J. Chiaverini and Kennith K. Kuo, Progress in Aeronautics & Astronautics, Vol. 218, AIAA.
3. Rocket Propulsion Elements – Sutton, G. P. and Biblarz, O., 7th Ed.
4. Understanding Aerospace Chemical Propulsion, H S Mukunda

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