

**Jharkhand University of Technology**

**Ranchi, 834010**



**SYLLABUS**

**For Diploma Program in  
Metallurgical Engineering**

**(Effective from 2024-25)**

**DEPARTMENT OF METALLURGICAL ENGINEERING**

**(4<sup>th</sup> – SEMESTER)**

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# PHYSICAL METALLURGY

Subject Code -MET401

1. **Rationale: Physical metallurgy** is the science of making useful products out of metals. Metal parts can be made in a variety of ways, depending on the shape, properties, and cost desired in the finished product. Most notable of the first-period accomplishments was the development of the first accurate iron-base phase diagram, which organized ferrite allotropes and carbides with the constraints imposed by the Gibbs phase rule. It is **important** to know the effect of chemical composition, heat treatment and production process on the final component in order to achieve components with optimal properties. This field of expertise, comprise all the steps from solidification to final product. **Physical metallurgists** study how a metal inter behavior structure in different conditions including in a hot environment or when it's put under stress

2 .**Course Outcomes:** At the end of the Course, the student will be able to:

CO-01	Analyze the crystal structure of metals and diffusion in solids
CO-02	Understand the deformation mechanisms in metals
CO-03	Analyze the Iron – Carbide equilibrium diagram
CO-04	Understand the solidification of metals and alloys
CO-05	Analyze the Binary equilibrium diagrams of Metals and Alloys
CO-06	Analyze the microstructure, properties & applications of Cast iron family

3.**Course Content**

Week	C O	PO*	Lecture (Knowledge)	Practice (Skill)
1	01	01 , 07	1. Introduction, crystal systems and Bravais lattice systems 2. Effective number of atoms and packing factor for: i) BCC ii) FCC 3. Effective number of atoms and packing factor for: iii) HCP crystal structure	To study the different crystal structures by using ball, ball and stick or wire models.

2	01	01, 07	1. Types of crystal imperfections , point imperfections	Metallurgical Microscope: Principles and Operations
			2. Dislocation -Screw dislocation, edge dislocation	
			3. Explanation and procedure of miller indices of planes and direction.	
3	01	01, 07	1. Diffusion, types of diffusion mechanisms, Factor affecting the diffusion.	Diffusion experiments can do by taking some liquids and study the rate of concentration /Min.
	02	01,07	1. Deformation by slip, Deformation by twinning 2. Difference between slip and twinning	Grain size measurement for different materials by comparison method
4	02	01,07	1. Recovery, Recrystallization, and Grain growth.	Grain size measurement for different materials by different methods
			2. Grain size and its measurement by comparison	
			3. Grain size measurement by different methods.	
5	03	01,04,07	1. Iron – Iron carbide equilibrium diagram	Specimen Preparation techniques for Metallographic Analysis.
			2. Iron – Iron carbide equilibrium diagram	
			3. Allotropic transformation in pure iron	
6	03	01,04,07	1. Invariant Reactions ( Peritectic , Eutectic , Eutectoid)	Microstructural Analysis of Carbon steel and Alloy steels
			2. Phases of Iron –Carbide Equilibrium diagram	
			3. Salient features of upper and lower critical temperature lines in hypo and hyper eutectoid steels and importance.	
7	03	01,04,07	1. Transformations of different steels on hypo eutectoid side during slow cooling.	Microstructural Analysis of Carbon steel and Alloy steels
			2. Transformations of different steels on hypo eutectoid side during slow cooling.	
			3. Transformations of different steels hyper eutectoid side during slow cooling.	
8	04	01,07	1. Cooling curve for pure metal	Case Study on

			2. Cooling curve of a binary alloy forming solid solution	nonmetallic inclusions in steels, its effects on properties and quality
			3. Solid solution- types of solid solutions-substitutional solid solution	
9	04	01,07	1. Solid solution- interstitial solid solution	Microstructural Analysis of Non ferrous metals
			2. Hume –Rothery Rules for formation of substitutional solid solution	
			3. nucleation and grain growth	
10	05	01,07	1. Basic terms: system, Phase, Number of components, Degrees of freedom or variance of the system	Experiment setup to check the Solid to liquid transformation at different temperature
			2. Interpretation of equilibrium diagrams – the phases that are present (phase rule),	
			3. Interpretation of equilibrium diagrams the chemical composition of each phase, the relative of amount of each phase (lever rule)	
11	05	01,07	1. Types of phase diagrams- eutectic system (For type-1 give examples of Bismuth-cadmium, Al-Si, Tin-zinc)	Draw Phase diagram and identify phases and apply lever rule to calculate the composition of phase
			2. Eutectic system - For type -2 give examples of lead-tin, lead –antimony),	
			3. Peritectic system, eutectoid system, (give examples of Cu-tin, Cu-Al, Zn-Al) .	
12	06	01,04,07	1. Description of Cast Iron and its Classification	Microstructural analysis of Grey Cast Iron , Nodular Cast Iron
			2. Study the characteristics of Grey Cast Iron	
			3. Study the characteristics of Nodular Cast Iron	
13	06	01,04,07	1. Study the characteristics of Malleable Cast Iron	Microstructural analysis of Malleable Cast Iron , White Cast Iron
			2. Study the characteristics of White Cast Iron	
			3. Study the casting defects and its remedies	
<b>Total in hours</b>			<b>39</b>	<b>52</b>

**Reference Books:**

Sl. No.	Description
1	Introduction to physical metallurgy : Sidney H Avner
2	Physical Metallurgy : Vijendra singh
3	Engineering Physical Metallurgy : Prof. Y. Lakhtin
4	Principles of Engg. metallurgy : L Krishna reddy
5	The Principles of Metallographic Laboratory practice : Geroqe L Kehl
6	Material science and metallurgy : O P Khanna

#### LIST OF SOFTWARE/LEARNING WEBSITES/ Virtual labs

- 2 [http://vlabs.iitb.ac.in/vlabs-dev/labs/nitk\\_labs/physical-metallurgy/labs/index.php](http://vlabs.iitb.ac.in/vlabs-dev/labs/nitk_labs/physical-metallurgy/labs/index.php)
- 3 [http://vlabs.iitb.ac.in/vlabs-dev/labs/nitk\\_labs/physical-metallurgy/labs/microstructural-analysis-nitk/posttest.html](http://vlabs.iitb.ac.in/vlabs-dev/labs/nitk_labs/physical-metallurgy/labs/microstructural-analysis-nitk/posttest.html)
- 4 <http://vlabs.iitb.ac.in/vlab/>
- 5 <https://www.doitpoms.ac.uk/tlplib/diffusion/fick2.php>
- 6 <https://www.youtube.com/watch?v=5vaYfd0fekI>
- 7 [Phase Diagrams 1 - Binary Eutectics - YouTube](#)
- 8 [Phase Diagrams - YouTube](#)
- 9 [Muddiest Point- Phase Diagrams I: Eutectic Calculations and Lever Rule - YouTube](#)
- 10 <https://www.youtube.com/watch?v=uG35D euM-0>

#### Equipment/software list with Specification for a batch of 20 students

Sl. No.	Particulars	Specification	Quantity
01	Metallurgical Micro scope	Examination of inter behavior of different Metals and Alloys through Metallurgical Microscope	
02	Image analyser software	Software with CCD attachment to microscope	
03	Specimen Mounting Machine	Standard configuration	
04	Polishing machines ( Rough and fine polishing)- belt type	Standard configuration	
05	Disc Polishing machines – Cloth type	Standard configuration	
06	Grinding Machine	Standard configuration	
07	Sample leveler	Standard configuration	
08	Hand polishing stand	Standard configuration	
09	Specimen cutoff machine	Standard configuration	
10	Specimen dryer	Standard configuration	

# TESTING OF METALLIC MATERIALS

Subject Code -MET402

1. **Rationale:** Testing of Metals is a comprehensive source of information on commonly used testing methods for metals and their products. In this course diploma engineers are required to analyze the mechanical properties of metals by destructive testing's. Materials testing studies the behavior of materials under different loads. In particular, the relationship between the acting forces and the resulting deformation and the limit stresses that lead to failure of components are considered. The characteristic values obtained from the testing process are used for materials development, designing components and in quality assurance. There is a range of standardized testing methods to characterize the mechanical properties of materials as precisely as possible.

2 **Course Outcomes:** At the end of the Course, the student will be able to:

CO-01	Apply hardness testing methods to determine hardness value of different metals
CO-02	Determine tensile properties of ferrous & nonferrous metals
CO-03	Determine compression , ductility properties of different materials
CO-04	Understand the fatigue conditions & creep in metals
CO-05	Determine torsion & shear strength of metals
CO-06	Determine the impact strength of steel.

3 **Course Content**

Week	CO	PO*	Lecture(Knowledge)	Practice (Skill)
1	01	05	1. Introduction on testing of metals ,Introduction to hardness, importance of hardness 2. brief explanation of Indentation Hardness, types of hardness 3. Brinell hardness test	1. Conduct Brinell hardness test on different materials

2	01	01,04	1. Rockwell hardness test	1. Conduct Rockwell hardness test on different materials
			2. Rebound hardness test, shore's scleroscope	2. Rebound hardness test
			3. Vicker's hardness test	3. Conduct Vickers hardness test on different material
3	02	01	1. Tensile test – Load , deformation, Stress ,strain	1. Conduct the Tensile test on mild steel
			2. Importance of tensile test	
			3. Different types of tensile specimens and its importance	
4	02	01	1. Different types of gauge length and its importance	1. Conduct the Tensile test on mild steel by varying the gauge length
			2. Stress-strain diagram for ductile material	
			3. Stress-strain diagram for brittle material	
5	02	01,02,04	1. Brief explanation of proof stress	1. Virtual lab on tensile test
			2. Fracture mechanism for ductile material	
			3. Fracture mechanism for brittle material	
6	03	01,02,04	1. Compression Test – Importance of compression test	1. Conduct the compression test on metals or non- metals
			2. Compression strength on ductile materials	
			3. Compression strength on brittle materials	
7	03	01,04	1. Ductility test- Brief explanation of Erichsen cupping test	1. Conduct the cupping test for sheet metal
			2. Erichsen cupping testing Equipment	
			3. Variables which effect cupping test	
8	03	01,04,07	1. Ductility test- Brief explanation of Bend test	1. Conduct the bend for various materials
			2. Experiment perform in bending machine	
			3. Types of bend test	

9	04	01,07	1. Introduction to Fatigue test- Fatigue test procedure	1. Conduct fatigue test through Virtual lab
			2. Fatigue failure fracture	
			3. Effect of variables on fatigue test	
10	04	01,07	1. Creep test-brief explanation about creep curve	1. Conduct creep test through Virtual lab
			2. Equi-cohesivetemperature	
			3. Factors which effect creep	
11	05	01,04,07	1. Torsion test-standardtorsion test specimen	1. Conduct a torsion test on metals
			2. Principle of Torsion test	
			3. Shear test - standard sheartest specimen	
12	05	01,04,07	1. Shear test - Principle of Shear test ( Single shear)	1. Conduct a shear test on metals
	06		2. Introduction to Impact test-types of impact test	
	3. Izod Impact test – Explanation and test Specimens.			
13	06	01,04,07	1. Charpy impact test- Explanation and charpy test Specimens	1. Conduct the impact test on metals ( Izod and Charpy)
			2. Effect of variables on impacttest	
			3. Fracture Mechanism	
<b>Total in hours</b>			<b>39</b>	<b>52</b>

#### Reference:

Sl.No.	Description
1	Testing of Metallic Materials : A.V.K. Surya Narayan
2	Mechanical Metallurgy : Dieter
3	Material science by O P Khanna

#### LIST OF SOFTWARES/LEARNING WEBSITES:

<https://www.youtube.com/watch?v=D8U4G5kpcM>

<https://www.youtube.com/watch?v=RjXJpeH78iU>

<https://www.youtube.com/watch?v=V0R5GVCxBy4>

<https://www.youtube.com/watch?v=tpGhqQvftAo> <https://www.youtube.com/watch?v=S2zdehCLYh4>

[https://www.youtube.com/watch?v=C19aGzday\\_w](https://www.youtube.com/watch?v=C19aGzday_w) <https://www.youtube.com/watch?v=D8U4G5kpcM>

<https://www.youtube.com/watch?v=RjXJpeH78iU> <https://www.youtube.com/watch?v=V0R5GVCxBy4>

<https://www.youtube.com/watch?v=jIsEKtA323A&spfreload=10>

#### Equipment list with Specification for a batch of 20 students

Sl. No.	Particulars	Specification	Quantity
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01	Universal Testing Machine		
02	Rockwell hardness testing machine		
03	Brinell hardness testing machine		
04	Vickers hardness testing machine		
05	Shores scleroscope		
06	Erichsen Cupping testing machine		
07	Impact testing machine		

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# FUELS AND REFRACTORIES

Subject Code -MET403

1. **Rationale: The Fuels and Refractories** focuses on the sources and efficient use of energy available to modern industry which help to students for their careers in metallurgy engineering where knowledge of Fuels and Refractories can be applied to the advancement of technology. All important metallurgical operations like extraction of metals, melting, heat treatment etc. are carried out in various metallurgical furnaces. Fuels are basic requirements of furnaces and play a major role in quality and cost of any metallurgical product. Optimum utilization and quality control of fuel is must in metallurgical operations. Refractories are very important material for construction of furnaces which help in the efficient utilization of heat in furnace. Knowledge of Temperature Measurement and Control is must for functioning of furnaces. Thus Fuels and Refractories will enable students to solve metallurgical problems upon graduation while at the same time, provide a firm foundation for the pursuit of graduate studies in metallurgy engineering

2. **Course Outcomes:** At the end of the Course, the student will be able to:

CO-01	Analyze the concept of formation of Coal , metallurgical Coke
CO-02	Analyze the importance and firing appliances for liquid fuels
CO-03	Analyze the manufacturing of gaseous fuels and its combustion rates
CO-04	Analyze the various refractories under load and it properties

### 3. Course Content

Week	C O	PO*	Lecture (Knowledge)	Practice (Skill)
1	01	01,04, 07	Introduction & Classification of fuels	1. To study and identify the different types of fuels
			Fuel combustion, ignition temperature, run of mine coal (ROM), carbonization of coal	
			Wood-Explanation, burning characteristics of wood, uses of wood	
2	01	01,04, 07	Wood charcoal state, process of wood Carbonization, Uses of wood charcoal	1. Analysis of coal-determination of moisture, volatile matter, ash and fixed carbon in Coal by proximate analysis
			Coal –Explanation, in situ theory, drift theory	
			Explanation of peat, lignite, bituminous coal, anthracite coal.	
			Analysis of coal-determination of moisture, volatile matter, ash and fixed carbon in Coal by proximate analysis	2. Determination of carbon and hydrogen,

3	01	01,04, 07	Determination of carbon and hydrogen, nitrogen, sulphur And oxygen in coal by ultimate analysis	nitrogen, sulphur And oxygen in coal by ultimate analysis
			Carbonization of coal, stages of carbonization	
4	01	01,04, 07	Explanation of Low Temperature Carbonization (LTC) and High Temperature Carbonization (HTC)	1. Analyze the Water absorbent test of coals at low and high temperature.
			Metallurgical coke production by using beehive oven	
			Calorific value – definition, higher or gross calorific value and lower or net calorific Value	
5	01	01,04, 07	units of calorific value, determination of calorific value by bomb calorimeter (Gross & Net calorific value) – Working and observations	1. Determine the calorific value for coal and coke by Bomb Calorimeter.
			units of calorific value, determination of calorific value by bomb calorimeter (Gross & Net calorific value) – Working and observations	
			Brief explanation of storage of coal, Advantages and disadvantages of solid fuels	
6	02	01,04, 07	Introduction of liquid fuels - state petroleum, production of Petroleum, classification of Petroleum	1. To determine the viscosity (in 'Redwood viscometer') of a liquid hydrocarbon and effect of temperature on the viscosity.
			Paraffin crude petroleum, naphthalene crude petroleum	
			Explanation of viscometer	
7	02	01,04, 07	Refining of petroleum, petroleum products and their uses.	1. To determine the viscosity (in 'Say

			Petrol- brief explanation, knocking of petrol, octane number.	bolt viscometer') of a liquid hydrocarbon and effect of temperature on the viscosity.
			Diesel- brief explanation, knocking of diesel, cetane number	
8	02	01,04, 07	Cracking –state cracking, types of cracking-thermal cracking. Flash point and fire point of liquid fuels.	1. Determination of flash point and fire point for petrol and diesel through Abels apparatus
			Explanation of Abels apparatus	
			Advantage and Disadvantage of liquid fuels	
9	03	01,04, 07	Introduction of gases fuels - Natural Gas –Explanation, Properties & application	1. Production of Gobar gas
			Gobar gas –production of gobar gas	
			Producer gas - its uses	
10	03	01,04, 07	Water gas – its uses	1. To study the precaution on LPG gas during utilization
			Liquefied petroleum gas (LPG) - Explanation	
			Liquefied petroleum gas(LPG)- properties & uses	
11	03	01,04, 07	Combustion calculations – state complete and incomplete combustion, minimum air required in kg for complete combustion of 1 kg of fuel, simple calculations	1. Conduct Abrasion test for Refractories
	04	01,04, 07	Introduction of refractories - Definition, Classification of Refractories depending upon their chemical nature	
			Acid Refractories, Basic Refractories,	
12	04	01,04, 07	Neutral Refractories, Requisites of good refractory for particular job	1. Conduct the Refractories under load (RUL) test
			Fire clay refractories – manufacturing , properties ,uses	
			Silica refractories – properties ,uses	
13	04	01,04, 07	Magnesite refractories – properties ,uses	1. Conduct Permeability test For refractories
			Dolomite refractories – properties , uses	
			Testing of Refractories Refractoriness under load (RUL) test, Permeability test	

<b>Total in hours</b>	<b>39</b>	<b>52</b>
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**Reference Books:**

<b>Sl. No.</b>	<b>Description</b>
1	Fuels, Furnace and Refractories – O.P.Gupta
2	Refractories – W. Trinks
3	Fuels , Solid , Liquid and gases – S. S. Brame & J.G.King
4	Refractories - F.H. Norton

**LIST OF SOFTWARE/LEARNINGWEBSITES**

1. <https://www.youtube.com/watch?v=QEa36qNo86E>
2. <https://www.youtube.com/watch?v=rIQxXp2IQg>
3. <https://www.youtube.com/watch?v=8W8SW98-sXQ>
4. <https://www.youtube.com/watch?v=gYnGgre83CI>
5. <https://www.youtube.com/watch?v=7U6mxjthKqw>
6. <https://www.youtube.com/watch?v=5ze5qUYrlmQ>
7. <https://www.youtube.com/watch?v=Y5pRrbxENWg>

**Equipment/software list with Specification for a batch of 20 students**

<b>Sl. No.</b>	<b>Particulars</b>	<b>Specification</b>	<b>Quantity</b>
01	Redwood viscometer	Standard configuration	
02	Abels apparatus	Standard configuration	
03	Bomb Calorimeter	Standard configuration	
04	Metallurgical Furnace	Standard configuration	
05	Weighing balance	Standard configuration	
06	Refractory Strength Testing machine	Standard configuration	
07	Say bolt Viscometer	Standard configuration	

# Operations Management

Subject Code -MET404

**1. Rationale:** The success of any organisation not only depends on quality of its products and services but also depends on the people within it. Thus, an operational manager has to play a prominent role in an organisation with human capital and machines. Therefore, managerial skills are essential for enhancing their employability and career growth. This course is therefore designed to provide basic concepts in operations management, forecasting techniques, capacity planning, aggregate planning, master production schedule, quality, and inventory and supply chain management for effective utilisation of resources and competitive advantage through operational excellence

**2. Course Outcomes:** On Completion of course, the student will be able to:

CO-01	Prepare a production capacity utilization plan based on demand forecasted and available production capacity for a given product.
CO-02	Prepare a master production plan based on a production capacity utilization plan and a material management plan for a given product.
CO-03	Prepare a process plan using time study, motion study and other appropriate methods to ensure process efficiency.
CO-04	Prepare a quality assurance plan based on a given quality model which is suitable for either a product or a service organisation.

### 3. Course Content

Week	CO	PO*	Lecture (Knowledge)	Practice (Skill)
1	01	01	<b>Introduction to Operation Management</b>	<ul style="list-style-type: none"> <li>• Virtual Tour Organization (You tube)</li> <li>• Problems on Productivity</li> </ul>
			1. Introduction to Operation Management - Operation Functions	
			2. Evolutions and Historical Events in Operational Management	
2	01	01	<b>DEMAND FORECASTING</b>	Problems on <ul style="list-style-type: none"> <li>• Qualitative Forecast - Delphi method, Market Research</li> <li>• Quantitative Forecast - Time series Method</li> </ul> a) Moving average (Naïve forecast, Simple moving Average, Weighted moving Average)
			1. Demand Forecasting- Demand Behavior-Trend Cycle - Seasonal Background - Steps in Forecasting Process	
			2. Short range and Long Range Forecast	
3	01	01	3. Qualitative Forecast methods	
			1. Quantitative Forecast methods	Problems on <ul style="list-style-type: none"> <li>b) Exponential smoothing</li> </ul>
			2. Seasonal Adjustments	

			3. Forecast Accuracy	
4	01	01	<b>CAPACITY AND AGGREGATE PLANNING</b> 1. Need for Capacity Planning – Capacity expansion Strategies – Capacity planning Models.	Problems on • Capacity Planning, • Aggregate planning
			2. Aggregate planning- Methods	• Master production Schedule
			3. Master production Schedule	
5	01	01	<b>PROCESS PLANNING</b> 1. Make or Buy Decision Outsourcing- Factors for Outsourcing decision- Process Selection – Batch , Mass ,Continuous	• Virtual Tour on Batch ,Mass and continuous Process • Develop an Operation Sheet indicating Process Plan, Process flow chart
			Components of e-manufacturing	
6	03	01	1.Motion Study	• Develop Job Process chart with Process Symbols
			2. Man- Machine chart	• Develop Man- Machine chart for a given Process
			3. Concepts on Time Study	• Case study on Time Study Principles
7	02	01	<b>INVENTORY MANAGEMENT</b> 1. Elements of Inventory Management- Inventory Costs-Carrying, Ordering and Shortage Costs	Problems on • ABC Classification System • Economic Order Quantity Models • The Production Quantity Model
			2.Inventory Control Systems- Continuous Inventory System (Fixed-Order-Quantity System) Periodic Inventory System (Fixed-Time-Period System)	
			3. Concept on ABC Classification, Economic Order Quantity Models, Production Quantity Model	
8	02	01,02	1. Order Quantity for A Periodic Inventory System Order Quantity with Variable Demand	Case study on JIT ( Eg:Toyoto Production System)
			2. JIT -Pull System	
			3 Kanban's System	
9	02	01	<b>Supply Chain Management</b> 1. Supply Chains Supply Chains for Service Providers	Study on • The Bullwhip Effect • Risk Pooling • Green Supply Chains
			2. Value Chains The Management of Supply Chains	
			3. Vendor Selection- Vendor evaluation and Vendor Development , Negotiations	
10	02	01	1. Supply Chain Uncertainty and Inventory	Study on • Information Technology: Supply Chain Enabler • Bar Codes • Radio Frequency Identification • Build-To-Order (BTO)
			2.E-Business, Electronic Data Interchange	
			3. Supply Chain Integration-Collaborative Planning, Forecasting, And Replenishment	
11	02	01,07	1. Material Requirements Planning (MRP) Enterprise Resource Planning (ERP),	Case study on Procurement- Outsourcing. • E-Procurement

			2. Warehouse Management Systems Collaborative Logistics, Distribution Outsourcing	<ul style="list-style-type: none"> <li>• E-Market places</li> <li>• ERP MODULES</li> </ul>
			3. Finance/Accounting- Sales/Marketing- Production/Materials Management- Human Resources	
12	04	01,04,07	QUALITY MANAGEMENT 1. Quality from The Customer's Perspective Dimensions of Quality for Manufactured Products Dimensions of Quality for Services	Practice on Quality Tools <ul style="list-style-type: none"> <li>• Process Flowcharts</li> <li>• Cause-And-Effect Diagrams</li> <li>• Check sheets And Histograms</li> <li>• Pareto Analysis</li> <li>• Scatter Diagrams</li> </ul>
			2. Quality from The Producer's Perspective A Final Perspective On Quality The Cost of Quality The Cost of Achieving Good Quality	
			3. The Cost of Poor Quality The Quality-Productivity Ratio Quality Management System	
13	04	04,05,07	1. TQM and QMS The Focus of Quality Management— Customers	Practice on The Deming Wheel (PDCA Cycle) <ul style="list-style-type: none"> <li>• Process Control Charts</li> <li>• Statistical Quality Control</li> <li>• ISO 9000</li> <li>• ISO14000</li> </ul>
			2. Quality Management in The Supply Chain The Role of Employees in Quality Improvement Kaizen and Continuous Improvement Quality Circles	
			3. Process Improvement Teams Six Sigma The Breakthrough Strategy: DMAIC	
<b>Total in hours</b>			<b>39</b>	<b>52</b>

#### Reference:

Sl. No.	Description
1	Production and Operations Management – Creating Value along the Supply Chain By Russel and Taylor , Wiley Publications , 7 <sup>th</sup> Edition
2	Modern Production and Operation Management By Buffa and Sarin, Wiley Publications, 8 <sup>th</sup> edition
3	Production and Operations Management By Chary, Tata Mc Graw Hill Publications
4	Production and Operations Management- Concepts, Models and Behaviour By Adam and Ebert, Prentice Hall Publications

#### LIST OF SOFTWARES/ LEARNING WEBSITES:

1. [www.youtube.com/watch?v=SF53ZZsP4ik](http://www.youtube.com/watch?v=SF53ZZsP4ik)
2. [www.youtube.com/watch?v=iPZIQ3Zx5zc](http://www.youtube.com/watch?v=iPZIQ3Zx5zc)

#### Tools/ Equipment/ Software's required

1. ERP Software