Integral University, Lucknow

University Polytechnic

Study and Evaluation Scheme

Program: Diploma in Civil Engineering

Semester –V

S. No.	Course code	Course Title	Type of Paper	Period Per hr./week/sem.			Evaluation Scheme				Sub. Total	Credit	Total Credits	Attributes						
				L	T	P	CT	TA	Total	ESE				Employability	Entrepreneurship	Skill Development	Gender Equality	Environment & Sustainability	Human Value	Professional Ethics
THEORIES																				
1	DCE – 501	Design of Reinforced Concrete Structure-I	Core	03	01	00	40	20	60	40	100	3:1:0	4	Y	Y	Y		Y		
2	DCE – 502	Transportation Engineering- I	Core	03	01	00	40	20	60	40	100	3:1:0	4	Y		Y			Y	
3	DCE – 503	Environmental Pollution & Control.	Core	03	01	00	40	20	60	40	100	3:1:0	4	Y	Y	Y		Y		
4	DCE – 504	Irrigation Engineering	Core	03	01	00	40	20	60	40	100	3:1:0	4	Y		Y		Y		
5	DCE – 505	Surveying – II	Core	03	01	00	40	20	60	40	100	3:1:0	4	Y	Y	Y				
6	DCE - 506	Construction Management & Accounts – I	Core	03	01	00	40	20	60	40	100	3:1:0	4	Y	Y					Y
7	DCE - 554	Civil Engineering Drawing – II	Core	00	00	03	40	20	60	40	100	0:0:1.5	1.5	Y	Y	Y				
8	DCE - 555	Surveying Lab – II	Core	00	00	03	40	20	60	40	100	0:0:1.5	1.5	Y	Y	Y				
9	DCE - 557	Field exposure	Core	00	00	00	-	-		40	40	0:0:0	0	Y		Y				Y
10	GP - 551	General Proficiency		-	-	-	-	-	60	-	60								Y	Y
Total				**18**	**06**	**06**	**320**	**160**	**540**	**360**	**900**		**27**							

DESIGN OF REINFORCED CONCRETE STRUCTURE – I

(DCE -501)

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UNIT – 1 Introduction

Concept of reinforced concrete structures, advantages and disadvantages. Different materials used in RCC with their properties. Load and loading standard as per IS: 875 Concept of design of reinforced concrete based on working stresses method and limit state method and their difference.

Design based on Working Stress Method: Assumptions in the theory of simple bending for RCC beams. Flexural strength of a singly reinforced RCC beam. Position of the Neutral Axis. Resisting moment of the section, critical neutral axis, and actual neutral axis, concept of balanced, under reinforced and over-reinforced sections. 10

UNIT – 2

Shear Strength: Permissible shear stresses as per IS: 456. Development of stresses in reinforcement, development length and anchoring of bars.

Bond Strength: Concept of bond, local and average, permissible bond stresses for plain and deformed bars as per IS, minimum length of embedment of bars, minimum splice length, actual bond stress in RCC beams and slabs, bond length as per IS: 456.

Design of Lintel.

Design of a Cantilever Beam and Slab. 10

UNIT – 3

Design of singly reinforced beams as per IS: 456 from the given data such as span load and properties of material used.

Design of Doubly Reinforced Concrete Beams:

(i) Doubly reinforced concrete beam and its necessity. (ii) Strength of a double reinforced concrete beam section. (iii) Method of design: Simple problems only. (iv) Reinforcement details of doubly reinforced concrete beam. 6

UNIT – 4 DESIGN BASED ON LIMIT STATE METHOD:

[A] Fundamentals of Limit State Method:

(i) Theory of limit state method. **(ii)** Partial safety factors. **(iii)** Flexural strength. **(iv)** Shear strength. **(v)** Development length of bars. **[B] Design of the following: (i)** Singly reinforced rectangular beam. **(ii)** One way slab (simply supported.) 6

UNIT – 5 PRE – STRESSED CONCRETE:

(i) Concept of prestressing. **(ii)** Situations where prestressed concrete is used. **(iii)** Materials used in prestressed concrete and their specifications as per IS. **(iv)** Post-tensioning and pre-tensioning. **(v)** Systems of prestressing. **(vi)** Freyssinet, Magnol-Blaten and Lee-Mecall **(vii)** Sketch showing Prestressing arrangement for RCC beam (No numerical problems be asked in the examination.) 6

Ref Books:

1. Reinforced cement concrete : AK Jain.
2. Reinforced cement concrete : Sushil kumar

TRANSPORTATION ENGG.-I

(DCE-502)

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UNIT – 1 Introduction

(i) Importance of Highway transportation. **(ii)** Functions of IRC. **(iii)** IRC classification of roads. **(iv)** Organisation of state highways department.

Road Geometrics: Glossary of terms used in geometrics and their importance: Right of way, Formation width, Road margin, Road Shoulder, Carriage way, Side slopes, Kerbs, formation levels, Camber and Gradient. **(i)** Design and average running speed, Stopping and passing sight distances. **(ii)** Curves necessity, Horizontal and Vertical curves including Transition curves and Super elevation, Methods of providing Super elevation. **(iii)** Use of IRC design tables and specifications for finding elements of Road geometrics. Drawing of typical cross sections in cutting and filling on straight and at a curve. **(iv)** Under pass & over pass (fly overs and bridges). 8

UNIT – 2 Highway Surveys Plans and Road Materials

Designation of a topographic map. Reading the data given on a topographic map. **(ii)** Basic considerations governing alignment for a road in plain and hilly area**. (iii)** Highway location. Marking of alignment. Importance of various stages viz: **(a) Reconnaissance survey:** Conduct reconnaissance and prepare reconnaissance report. **(b) Preliminary survey:** Object, organizing, conducting and information to be collected. **(c)** Location survey. **(d)** Standards for preparing the highway plans as per Ministry of Transport. **Road Materials:**

(i) Different types of road materials in use: Soil, Aggregates Binders.

(ii) Function of soil as Highway sub grade.

(iii) C.B.R: Method of finding. CBR value and its significance.

(iv) Testing aggregates: Abrasion test, Impact test, Crushing Strength test, Water Absorption test and Soundness test. **(v) Aggregates:** Availability of road aggregates in India, Requirements of road aggregates as per IS Specifications.

(vi) Binders: Common binders: Cement, Bitumen and Tar, Properties as per IS specifications, penetration and Viscosity test, procedures and significance. Cut back and emulsion and their uses. **IN THE Base course:** Methods of construction as per Ministry of Shiping and transport (Government of India)

.**(vii) IN THE Surfaceing:** Methods of constructions as per Mininstry of Surface and Transport, Government of India, specifications and quality control;equipment

used . **Maintenance of Track:** NOTE:The study of the subject must be supplemented by a visit to a nearbyrailway station. 10

UNIT – 3 Road Pavements, Types and Their Construction

- **(i)** **Road pavement:** Flexible and rigid pavement, their merits and demerits, typical cross-sections, Functions of various components.
- **(ii)** **(ii)** Sub-grade preparation - Setting out Alignment of road, setting out Bench marks, control pegs for Embankment and cutting, Borrow pits, Making profiles of Embankment, Construction of Embankment, Compaction, Stabilization, Preparation of sub grade. Methods of checking camber, Gradient and Alignment as per recommendations of IRC, Equipment used for sub gradepreparation.

(iii) Flexible pavements: Sub base necessity and purpose. Purpose of Stabilization. **Types of Stabilization: (a)** Mechanical stabilization. **(b)** Lime stabilization. **(c)** Cement stabilization. **(d)** Fly ash stabilization. **(e)** Granular sub base **(iv) Base course: (a)** Brick soling. **(b)** Stone soling. **(c)** Metalling: water bound macadam and bituminous macadam. **(v) Surfacing: Types of surfacing: (a)** Surface dressing. **(b)** (i) Premix carpet. (ii) Semi dense carpet (S.D.C) **(c)** Asphalt concrete. **(d)** Grouting. **(vi) Rigid pavements:** Construction of concrete roads as per IRC Specifications, Form laying, Mixing and placing the concrete, Compacting and finishing, Curing, joints in concrete pavement, Equipment used. 8

UNIT – 4 Hill Roads and Road Drainage

(i) Introduction: Typical cross-sections showing all details of a typical hill road in cut, partly in cut and partly in fill. **(ii) Landslides:** Causes, preventions and control measures.

Road Drainage: (i) Necessity of road drainage work, Cross drainage works. **(ii)** Surface and subsurface drains and storm water drains. Location, spacing and typical details of side drains, side ditches for surface drainage. Intercepting drains, Pipe drains in hill roads, Details of drains in cutting embankment, typical cross-sections.

Air Port: Basic Element, Runway and Taxi Way.

Tunnel: Introduction, Classification and Construction Method 8

UNIT – 5 Road Maintenance and Arboriculture

(i) Common types of road failures-their causes and Remedies such as bagie action. **(ii)** Maintenance of bituminous roads such as patch work and resurfacing. Maintenance of concrete roads-filling cracks, repairing joints, maintenance of shoulders (berms), maintenance of traffic control devices.

Construction Equipment: Output and use of the following plant and equipments: (i) Hot Mix Plant & Mix all battery. (ii) Tipper, Tractors (wheel and crawler) Scraper, Bull-dozer, Dumpers, Shovels, Grader, Roller, Dragline. (iii) Asphalt mixer and tar boilers. (iv) Road pavers.

Arboriculture: Names of trees used in arboriculture, distance of trees from centre of roads and distance between centre to centre of trees, Tree gaurds, maintenance and revenue from trees.

(i) Traffic studies, Methods of collection and Presentation of volume count data. **(ii)** Traffic control devices - Signs, markings and signals, their effectiveness and location, installation of signs, IRC standards.

(iii) Segregation of traffic. **(iv)** Types of intersections and choice of each. **(v) Accidents:** Types, causes and remedies.

Ref Books:

ENVIRONMENTAL POLLUTION & CONTROL

(DCE-503)

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UNIT 1: ECOLOGY OF ENVIRONMENT

Elements of environment: Earth, water, air, space and energy. Ecology: Living and non living concept leading to ecology. Ecosystem: Terrestrial, aquatic and marine affect of environmental pollution on ecological balances.

Pollution and its Classification: Definition, Classification, Air, Water, Solid waste, Thermal, Noise and Radio active pollutions. Different parameter of pollution. 6

UNIT 2: WATER POLLUTION

Sources, Transport of Pollutants, Effect of water pollutants on man, animal, plant and material, various types of pollutants. Mainly discuss various types of wastes from community, general characteristics of domestic & industrial wastes and their affects on environment, disposal methods on land and water, criteria of disposal by dilution. Stream sanitation. Sampling and monitoring instrumentation for water pollution and control. 7

UNIT 3 AIR POLLUTION

Sources, Types of air pollutants, Transport of air pollutants, dispersion by single and multiple sources. Control equipment, filter, electrostatic precipitators, and wet scrubbers, fume combustion by incineration, Air pollution control in new and old plants.

Solid Waste Pollution: Review of various types of solid waste, sources, and components of solid waste, city garbage and industrial solid waste handling and disposal equipment .Method of disposal, salvage and recovery, Volume reduction in solid waste. 7

UNIT – 4 NOISE POLLUTION

Sources, measurement of pollution. Degree of noise, Echoes and their control. Industrial noise, unit characteristics occupational injuries due to noise, criteria and standard for occupational injuries due to noise. Means to control noise in industry.

Radio Active Pollution: Sources and affect on human, animals, plants and materials, measurement, means to control, preventive measures. 7

UNIT – 5 THERMAL POLLUTION:

Various pollutants. Affects on environment, preventive measures.

Legislation: Preliminary knowledge of the following Acts and rules made there under:

- The Water (Prevention and Control of Pollution) Act - 1974.

- The Air (Prevention and Control of Pollution) Act - 1981.

- The Environmental Protection (Prevention and Control of Pollution) Act -1986. Rules notified under EP Act 1986 Viz.

The Manufacture, Storage and Import of Hazardous Chemical (Amendment) Rules, 2000

The Hazardous Wastes (Management and Handling) Amendment Rules, 2003.

Bio-Medical Waste (Management and Handling) (Amendment) Rules, 2003.

The Noise Pollution (Regulation and Control) (Amendment) Rules, 2002.

Municipal Solid Wastes (Management and Handling) Rules, 2000.

The Recycled Plastics Manufacture

IRRIGATION

ENGINEERING (DCE-504)

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UNIT -1 Introduction

Definition of irrigation. Necessity of irrigation. History of development of irrigation in India. Types of irrigation Sources of irrigation water. **Rain Fall & Run – Off:** Definition of rainfall & run-off, catchments area, Dicken's & Ryve's formulae. Types of rain gauges - Autometic & Non - Automatic Stream gauging.

Water Requirement of Crops: Definition of crop season Duty, Delta and Base Period, their Relationship Gross command area, culturable command area Intensity of Irrigation, Irrigable area Water requirement of different crops-Kharif and Rabi

UNIT – 2 Lift Irrigation

Types of Wells: shallow & deep well, aquifer types , ground water flow, construction of open wells and tube wells. Yield of an open/tube well and problems Methods of lifting water - manual and mechanical devices, use of wind mills. **Flow Irrigation:** Irrigation canals, Perennial Irrigation, Different Parts of irrigation canals and their functions. Sketches of different canal cross-sections. Classification of canals according to their Alignment. Design of irrigation canals - Chezy's formula, Mannings formula, Kennedy's and Lacey's silt theorys and equations, comparison of above two silt theorys. equations, critical velocity ratio. Use of Garrets and Lacey's charts. Various types of canal lining - Advantages & disadvantages

UNIT – 3 Canal Head Worksand Regulatory Works

Definition, object, general layout, functions of different parts. Difference between Weir and Barrage **Regulatory Works:** Functions and explanation of terms used. Cross and Head regulators. Falls. Energy dissipaters. Outlets-Different types. Escapes

UNIT – 4 Cross Drainage Works

Functions and necessity of the following types: Aqueduct, Syphon, Superpassage, Level crossing, inlet and outlet. **Constructional details of the above Dams:** Earthen dams-types, causes of failure Classification into masonry & concrete dams, Labelled cross-section of gravity dam. Spillway.

UNIT – 5

Water Logging and Drainage: Definition, causes and affects, detection, prevention and remedies. Surface and sub-surface drains and their layout. **Major Irrigation Projects in India Practice:** Visits to at least one of the Irrigation Projects and write specific report about the same.

Ground Water Recharge: Aim, Method and Advantage.

Ref Books:

1. Irrigation Engg : B.C. Punmia
2. Irrigation Engg: Sushil Kumar

SURVEYING II

(DCE-505)

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UNIT – 1 Plane Table surveying

(i) Purpose of plane table surveying. Equipment used in plane table survey (a) Plane table, (b) Alidade (Plain and Telescopic),(c) accessories. **(ii)** Method of plane tabling (a) centering (b) leveling (c) Orientation. **(iii)** Methods of plane table surveying (a) Radiation, (b) Intersection, (c) Traversing (d) Resection. **(iv)** Two point problem. **(v)** Three point problem by (a) Mechanical Method (Tracing paper) (b) Bessel's Graphical Method. (c) Trial and error method. Errors in plane table survey and precautions to control them. Testing and adjustment of plane

table and alidade. 8

UNIT – 2 Contouring

Concept of contour, Purpose of contouring, Contour interval and horizontal equivalent, Factors affecting contour interval, characteristics of contour, Methods of contouring direct and indirect, use of stadia measurements in contour survey. Interpolation of contours; Use of contour map, Drawing cross section from a contour map, Marking alignment of a road, railway and a canal on a contour map, Computation of earthwork and reservoir capacity from a contour map. 8

UNIT – 3 Theodolite Surveying

Working of a transit vernier theodolite, Fundamental axes of a theodolite and their relation, Temporary adjustments of a transit theodolite, least count and concept of transiting, swinging, face left, face right and changing face, Measurement of horizontal and vertical angles. Prolonging a line (forward and backward) Measurement of bearing of a line, Traversing by included angles and deflection angle method, traversing by stadia measurement, Theodolite triangulation and plotting a traverse, concept of coordinate and solution of omitted measurements (one side affected), Errors in theodolite survey and precautions taken to minimise them, Limits of precision in theodolite traversing. Principle and working of a micro-optic theodolite. Brief introduction to tacheometry. 8

UNIT – 4 Total Station & Auto Level and Curves

Working and application of total station and auto level. **Simple circular curves: (i)** Need and definition of a simple circular curve; Elements of simple circular curve, Degree of the curve, radius of the curve, tangent length, point of

intersection (Apex point), tangent point, length of curve, long chord, deflection angle, apex distance and mid-ordinate. 6

UNIT – 5 Curves

Setting out of simple circular curve: (a) By linear measurements only:

- Offsets from the tangents.

- Successive bisection of arcs.

- Offsets from the chord produced.

(b) By Tangential angles using a theodolite. **(ii) Transition Curves:** Need (centrifugal force and super elevation) and definition of transition curve, requirements of transition curves; length of transition curves for roads by cubic parabola; calculation of offsets for a transition curve; setting out of a transition curve by tangential offsets only. **(iii)** Vertical curves Setting out of a vertical curve. 7

Ref Books:

1 Surveying Engg : B.C. Punmia

CONSTRUCTION MANAGEMENT& ACCOUTS I

(DCE – 506)

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UNIT – 1 Introduction

(i) Classification of construction into light, heavy and industrial construction. **(ii) The construction team:** Owner, Engineer and Contractors, their functions and interrelationship. **(iii) Resources for construction industry:** Men, Machines, Materials, Money and Management. **(iv)** Main objectives of Civil engineering management. **(v)** Functions of construction management, planning, organizing, staffing, and directing, controlling and coordinating, meaning of each of these with respect to a construction job.

Construction Planning: (i) Stages at which planning is done. Pre tender and contract planning by the contractor. **(ii) Scheduling**: Definition, **Methods of scheduling:** Bar charts and CPM, advantages of scheduling. No problem on CPM to be set in the examination. **(iii)** Planning and scheduling of construction jobs by bar charts. **(iv)** Preparation of construction schedule, labour schedule, material schedule, and equipment schedule. **(v)** Limitations of bar charts. (vi) Cost - time balancing. 8

UNIT – 2 Organizations

(i) Types of organization: Line, staff, functional and their characteristics. **(ii)** Principles of organization (only meanings of the following and their significance), Span of control, Delegation of authority and responsibility, Ultimate authority and responsibility, Unity of command, contact, unity of assignment, job definition, increasing organization relationship. **(iii)** Motivation and human relationship concept, need and fundamentals. **Site Organization: (i)** Factors influencing, job layout from site plan. **(ii)** Principle of storing and stacking materials at site. **(iii)** Location of equipment. **(iv)** Preparation of actual job layout for a building. **(v)** Organizing labour at site. **Construction Labour: (i)** Conditions of construction workers in India, wages paid to workers. **(ii)** Trade unions connected with construction industry and trade Union Act. **(iii)** Labour welfare. **(iv)** Payment of wages Act. Minimum wages Act. **(v)** Workmen compensation Act. **(vi)** Contract Labour Act. **Inspection and Quality Control: (i)** Principles of inspection. **(ii)** Major items in construciton job requiring quality control. **Control of Progress: (i)** Methods of recording progress. **(ii)** Analysis of progress. **(iii)** Taking corrective actions keeping head of office informed. 7

UNIT – 3 Accidents and Safety in Construction and Accounts

(i) Accidents - causes. **(ii) Safety measures for:** (a) Excavation work: (b) Drilling and blasting. (c) Hot bituminous works. (d) Scaffolding, ladders, forms work. (e) Demolitions. **(iii)** Safety campaign.

ACCOUNTS Introduction: (i) Necessity of account. **(ii) List of reference book on accounts :** (a) Civil Services Rules, Vol, I, II and III (b) PWD Accounts codes. (c) Manual of orders. (d) Departmental financial rules. (e) State Treasury rules. **Organization: (i)** Establishments in the PWD. **(ii) Regular establishment:**

(a) Permanent establishment. (b) Temporary establishment. **(iii)** Work charged establishment. (iv) Contingency establishment. **Outline of P.W.D. System of Accounts: (i)** Necessity of a system of accounts. **(ii)** P.W.D. system of accounts. **(iii) Classification of transactions:** (a) Necessity of maintaining the accounts by Head of Accounts: (b) Heads of Account: (i) Major Heads. (ii) Minor Heads. (iii) Detailed Heads. (Detailed Heads of Accounts not to be memorized). 8

UNIT – 4 Cash and Stores

(i) Definition of cash. **(ii)** Precautions in custody of cash. **(iii)** Treasury challan - procedure to fill the prescribed form. **(iv)** Imprest account and temporary advance. **(v)** Definition of imprest and rules for maintaining imprest account. Actual filling of the prescribed form. **(vi)** Definition of temporary advance, Its difference from the imprest account, maintenance of temporary advance account.

Stores:

(i) What are stores, their necessity and safe custody? **(ii) Classification of Stores:** (a) Stores debatable to suspense heads-stock. (b) Stores debatable to final heads: Tools and plant. Road metal Material charged direct to

works. 6

UNIT -5 Road Metal

(a) Meaning. (b) Rules for maintaining road metal returns filling up the prescribed form. (c) Method of checking. (d) Shortages and surpluses. **Materials charged direct to works**: Necessity, circumstance under which materials are directly charged to work. (a) Material at site Accounts (M.A.S), Rules for actual filling of prescribed form i.e. - Detailed statement of materials compared with estimated requirements and - Report of the value and verification of unused materials. (b) Disposal of surplus materials at the work site.

(c) Definition of: - Issue rate. - Storage rate. - Storage charges. - Supervision charges - Assets and liabilities. Issue of materials to contractors.

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Ref Books:

CIVIL ENGG. DRAWING – II

(DCE-554)

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UNIT – 1: STEEL STRUCTURAL DRAWING

[1] Preparation of a working drawing (elevation, plan, details of joints at ridge, eaves and other connections) for a riveted steel roof truss resting on a masonry wall for the given span, shape of the truss and the design data regarding the size of the members and the connections. Also calculate the quantity of steel for the truss. **[2 Sheets]**

[2] **Tubular Steel Roof Trusses:** Types of trusses for different spans. Details of column - truss connection. Simple trusses using tubular sections, North light provision. **[1 Sheet]**

3. Steel connections (a, b, c, d) riveted and (e) welded all unstiffened.

(a) Beam to beam connections (seated and framed)

(b) Beam to column (seated and framed)

(c) Column base connections (slab base & gusseted base) **[1 Sheet for a, b, c,]**

UNIT – 2: R.C.C. STRUCTURES (On Computer by Auto Cad)

(a.) PUBLIC BUILDING: Plan elevation & sections of a public building like School. Hospital, Canteen, Community hall, guest house. At least double storied showing details of following RCC elements:

(i) R.C.C. beam singly reinforced and doubly reinforced giving the size and number of bars, stirrups their size and spacing.

(ii) Details of reinforcement for a RCC square and circular column with isolated square footing.

(iii) Details of reinforcement for a cantilever beam with given data regarding the size of the beam and the reinforcement, Anchorage of reinforcement. **[2 Sheets]**

UNIT - 3

[1] Details of reinforcement in plan and section for a simply supported RCC. One way slab with intermediate support and two way slab. Bar bending schedule should be prepared.

[2] Details of reinforcement of a two storied internal and corner column. In this, the details of reinforcement at the junction with beams must be shown. **[2 Sheets]**

UNIT - 4

[1] Details of reinforcement of the junction of a secondary beam with the main beam with the given data.

[2] Sectional details of T-beam showing details of bars.

[3] Details of reinforcement for a cantilever retaining wall with the given design data regarding the reinforcement, size and shape of the wall.

[4] Details of reinforcement in a simple circular over head water tank. **[3 Sheets]**.

Unit – 5 IRRIGATION ENGINEERING:

[1] Typical sections of a channel. Typical Cross-section of an unlined and lined channel in cutting, partly cutting and fully in filling.

[2] Typical L-section of a distributory.

[3] Plan and cross-section of tube well with pump house.

[4] Plan, cross-section and L-section of a distributory fall with details of wing wall, pitching,

flooring and tube well. **[3 Sheets]**

Ref Books:

1. Civil Engg Drawing : V.B.Sikka
2. Civil Engg Drawing : Gurucharan Singh

SURVEYING - II. Lab.

(DCE-555)

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List of Experiments

[1] **Setting the plane table Plate-1**.

(b) Marking the North direction.

(c) Plotting a few points by radiation method.

[2] Orientation by Plate-2.

(a) Trough compass

(b) back sighting.

[3] Plotting a few points by intersection method.

[4] Two point problem.

[5] Three point problem by

(a) Tracing paper method.

(b) Bessel's graphical method.

(c) Trail and error method.

[6] Contouring

Preparing a contour plan by radial line method by the use of a Tangent Clinometers / Tachometer.

[7] To find the difference of level between two distant points by taking staff readings on different stations from the single setting.

[8] To find the difference of level between two points by taking at least four change points.