HIGH VOLTAGE ENGINEERING

Subject Code : EE854PE
Regulations : R16 - JNTUH
Class : IV Year B.Tech EEE II Semester

Department of Electrical and Electronics and Engineering

BHARAT INSTITUTE OF ENGINEERING AND TECHNOLOGY

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HIGH VOLTAGE ENGINEERING (EE854PE)
COURSE PLANNER

I. COURSE OVERVIEW

Electrical Insulation is the backbone of all modern power system networks. Different dielectrics that constitute the insulating systems are subjected to a variety of stresses during their lifetime. A thorough knowledge of the fundamental properties of the materials and their failure mechanisms during service, is essential for appropriate and optimal design. Further, in the current competitive market scenario, transmission at extra high voltages and operation of equipment at close to their design limits have necessitated strict design criteria and high testing standards. As a result, high voltage insulation technology has undergone many changes, with advances being made in the area of testing, measurement and development of new materials.

II. PRE REQUISITES:

The knowledge of following subjects is essential to understand the subject:

1. Fundamentals of Electromagnetics
2. Electric Power systems
3. Electrical Measurements

III. COURSE OBJECTIVE:

1	To know about generation voltages and currents to test the electrical equipments.
2	To make the students to do research or projects them self.

IV. COURSE OUTCOMES:

At the end of the course the student will be in a position to –

S. No	Description	Bloom's taxonomy level
1	Student will be able to uunderstand the general aspects of electrical testing methods	Knowledge, Understand (Level 1, Level 2)
2	Student will be able to design and analysis of high voltage	Knowledge, Understand (Level 1, Level 2)
3	Student will be able to understand the need for testing and procedures of the electrical devices	Knowledge, Apply (Level 1, Level 3)
4	Student will be able to understand the significance of high voltages and high currents	Apply, Evaluate (Level 3, Level 5)
5	Student will be able to understand the need for high voltages, high currents and testing methods	Apply, Analyze, Evaluate (Level 3, Level 4, Level 5)

V. HOW PROGRAM OUTCOMES ARE ASSESSED

Program Outcomes		Level	Proficiency assed by
PO1	**Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.	3	Assignments, Mock tests

PO2	**Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.	2	Assignments, Mock tests
PO3	**Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.	2	Assignments, Mock tests
PO4	**Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.	2	Assignments, Mock tests
PO5	**Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.	1	Assignments, Mock tests
PO6	**The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.	1	Assignments, Mock tests
PO7	**Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.	-	-
PO8	**Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.	-	-
PO9	**Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.	-	-
PO10	**Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.	-	-
PO11	**Project management and finance:** Demonstrate knowledge and understanding of the engineering	-	-

	and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.		
PO12	**Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.	-	-

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) - : None

VI. HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED

Program Specific Outcomes		Level	Proficiency assed by
PSO1	Design and development of high voltages and current equipments to know the performance of electrical equipments by testing.	1	Assignments, seminars
PSO2	Testing techniques for research and advanced studies in Electrical and Electronics engineering	1	Assignments, seminars

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) - : None

VII. COURSE CONTENT:

JNTUH SYLLABUS

UNIT – I:

Introduction to High voltage engineering: Electric field stresses. Gas/ Vaccum as insulator, Liquid dielectrics. Solids and composites, Estimation and control of Electric stress , Numerical methods for electric field computation. Surge voltages, their distribution and control, Applications of insulating materials in transformers, rotating machines, circuit breakers, cables, power capacitors and bushings.

UNIT – II:

Breakdown in Dielectric materials: Gases as insulating media, collision process, Ionization process, Townsend's criteria of breakdown in gases, Paschen's law. Liquid as Insulator, pure and commercial liquids, breakdown in pure and commercial liquids.Intrinsic breakdown, electromechanical breakdown, thermal breakdown, breakdown of solid dielectrics in practice, Breakdown in composite dielectrics, solid dielectrics used in practice.

UNIT – III:

Generation & measurement of high voltages and currents: Generation of High Direct Current Voltages, Generation of High alternating voltages, Generation of Impulse Voltages, Generation of Impulse currents, Tripping and control of impulse generators. Measurement of High Direct Current voltages, Measurement of High Voltages alternating and impulse, Measurement of High Currents-direct, alternating and Impulse, Oscilloscope for impulse voltage and current measurements.

UNIT – IV:

Over voltages and insulation co-ordination: Natural causes for over voltages – Lightning phenomenon, Overvoltage due to switching surges, system faults and other abnormal

conditions, Principles of Insulation Coordination on High voltage and Extra High Voltage power systems.

UNIT – V:

Testing of materials & electrical apparatus: Measurement of D.C Resistivity, Measurement of Dielectric Constant and loss factor, Partial discharge measurements. Testing of Insulators and bushings, Testing of Isolators and circuit breakers, Testing of cables, Testing of Transformers, Testing of Surge Arresters, Radio Interference measurements.

GATE SYLLABUS: NOT APPLICABLE
IES SYLLABUS: NOT APPLICABLE

SUGGESTED BOOKS:

TEXT BOOK:

1. High Voltage Engineering by M.S.Naidu and V. Kamaraju, TMH Publications.
2. High Voltage Engineering by C.L.Wadhwa, New Age Internationals (P) Ltd.

REFERENCES:

1. High Voltage Engineering: Fundamentals by E.Kuffel, W.S.Zaengl,by Elsevier.
2. High Voltage Insulation Engineering by Ravindra Arora, Wolfgang New Age Internationals (P) Ltd.
3. High voltage Engineering, Theory and Practice , Mazen Abdel Salam, Hussein Anis, Ahdan EI-Morshedy, Roshdy Radwan, Marcel Dekker

VIII.LESSON PLAN-COURSE SCHEDULE:

Lecture No.	Week No.	Topic	Course learning outcomes	Reference
UNIT – 1, Introduction to High voltage engineering				
1.	1	Electric Field Stress, Gas / Vaccum as Insulator	Explaining	Text Book No. 1, 2
2.		Liquid Dielectrics, Solids and Composites	Know about materials	
3.		Estimation and Control of Electric Stress	Analyzing	
4.		Numerical methods for electric field computation	Analyzing	
5.	2	Surge voltages, their distribution and control	Explain	
6.		Applications of insulating materials in transformers	Explain	
7.		rotating machines,	Explain	
8.		circuit breakers& Problems	Analyzing	
9.	3	cable power capacitors , Bushings	Explain	
10.		*Latest trends in High Voltage engineering*	Analyzing	
11.		Review of Unit-I		
12.		***Mock Test – I***		

UNIT – 2, Breakdown in Dielectric materials				
13.	4	Gases as insulating media	Explain	Text Book No. 1, 2
14.		collision process	Explain	
15.		Ionization process	Explain	
16.		Townsend's criteria of breakdown in gases	Analyzing	
		Tutorial / Bridge Class # 1		
17.	5	Pastern's law	Analyzing	
18.		Liquid as Insulator&problems	Analyzing	
19.		pure and commercial liquids	Explain	
20.		breakdown in pure and commercial liquids& Problems	Explain	
		Tutorial / Bridge Class # 2		
21.	6	Intrinsic breakdown, electromechanical breakdown	Analyzing	
22.		Problems & thermal breakdown, breakdown of solid dielectrics in practice	Analyzing	
23.		Breakdown in composite dielectrics& solid dielectrics used in practice	Analyzing	
24.		Revision		
		Tutorial / Bridge Class # 3		
UNIT – 3, Generation & measurement of high voltages and currents				
25.	7	Generation of High Direct Current Voltages	Analyzing	Text Book No. 1, 2
26.		Generation of High alternating voltages	Analyzing	
27.		Generation of Impulse Voltages	Explain	
28.		Tripping and Control of Impulse Generators	Explain	
		Tutorial / Bridge Class # 4		
29.	8	Generation of Impulse currents	Explain	
30.		Tripping and control of impulse generators	Explain	
31.		Online and off line and off line tapchanger effects	Explain	
32.		Revision		
		Tutorial / Bridge Class # 5		
I Mid Examinations (Week 9)				
UNIT – 3 Contd.				
33.	10	Measurement of High Direct Current voltages	Explain	Text Book No. 1, 3
34.		Measurement of High Voltages alternating and impulse	Explain	
35.		Measurement of High Currents-direct, alternating currents, Impulse currents	Explain	

36.		Oscilloscope for impulse voltage and current measurements.	Explain	
		Tutorial / Bridge Class # 6		
UNIT – 4, Testing of materials & electrical apparatus				
37.	11	Natural causes for over voltages	Explain	Text Book No. 1, 2
38.		Lightning phenomenon	Explain	
39.		Overvoltage due to switching surges, system faults	Explain	
40.		Testing techniques for different objectives	Analyzing	
		Tutorial / Bridge Class # 7		
41.		Principles of Insulation	Explain	
42.		Principles of Insulation	Explain	
43.		Coordination of High voltage power systems	Analyzing	
		Tutorial / Bridge Class # 8		
44.	13	Coordination of High voltage power systems	Explain	
45.		Coordination of Extra High Voltage power systems.	Explain	
46.		Coordination of Extra High Voltage power systems	Explain	
47.		Revision		
		Mock Test - II		
UNIT – 5, Testing of materials & electrical apparatus				
48.	14	Measurement of D.C Resistivity	Explain	Text Book No. 1, 2 Ref.Book No.1,2
49.		Measurement of Dielectric Constant and loss factor	Explain	
50.		Partial discharge measurements. Testing of Insulators	Explain	
51.		*Testing of Transformers*	Analyzing	
		Tutorial / Bridge Class # 9		
52.	15	Testing of bushings	Explain	
53.		Testing of Isolators	Explain	
54.		Testing of circuit breakers	Explain	
55.		*Testing of kraft paper*	Explain	
		Tutorial / Bridge Class # 10		
56.	16	Testing of cables	Analyzing	
57.		Testing of Transformers,	Explain	
58.		Testing of Surge Arresters	Explain	
59.		Radio Interference measurements	Analyzing	
		Tutorial / Bridge Class # 11		
60.	17	Revision		

61.		Revision		
62.		Revision		
63.		Revision		
		Tutorial / Bridge Class # 12		
II Mid Examinations (Week 18)				

IX.MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:

Course Outcomes	Program Outcomes (PO)												Program Specific Outcomes (PSO)	
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	2	-	1	1	-	1	-	-	-	-	-	-	2	1
CO2	2	1	2	1	-	1	-	-	-	-	-	-	2	2
CO3	2	1	2	1	-	1	-	-	-	-	-	-	2	2
CO4	2	2	1	2	1	2	-	-	-	-	-	-	2	2
CO5	3	2	2	2	2	2	-	-	-	-	-	-	2	3
Avg	2.2	1.2	1.6	1.4	0.6	1.4	-	-	-	-	-	-	2	2

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High) -:None

X. QUESTION BANK: (JNTUH)

DESCRIPTIVE QUESTIONS:

UNIT-I

Short Answer Questions-

S.No	Question	Blooms Taxonomy Level	Course Outcome
1	What is Electric field stress?	Knowledge	1
2	State the methods for electric field computation?	Understand	1
3	How Gas/ Vacuum acts as insulator?	Understand	1
4	what is Surge voltage?	Knowledge	1
5	Name the applications of insulating materials in transformers.	Knowledge	1

Long Answer Questions-

S.No	Question	Blooms Taxonomy Level	Course Outcome
1	Explain the applications of insulating materials in the construction of circuit breakers.	Knowledge	1
2	Explain about the tracking in solid insulating materials. machines.	Evaluate	1
3	Discuss the applications of gases and gaseous mixture as insulating medium in high voltage cables.	Evaluate	1

4	Discuss in detail about the features and properties of solid dielectrics and its com-posits.	Analyze	1
5	Explain two important conditions to be satisfied for a collision of an electron with an atom to be an ionizing one.	Analyze	1
6	Explain the properties and applications of paper and paper board solid di- electrics used in high voltage engineering.	Analyze	1
7	Indicate the solid insulation applications in: (a)Power cables (b)HV bushings (c) Small size rotating	Knowledge	1
8	What is surge voltage? Explain distribution and control of surge voltage.	Evaluate	1
9	Explain Numerical methods for electric field computation.	Knowledge	1
10	Indicate the solid insulation applications in: **(a)** circuit breakers (b) cables (c) power capacitors.	Knowledge	1

UNIT-II

Short Answer Questions-

S.No	Question	Blooms Taxonomy Level	Course Outcome
1	State Paschen's law.	Knowledge	2
2	State Townsend's criteria of breakdown in gases	Knowledge	2
3	Explain collision process & Ionization process	Knowledge	2
4	What are the various sources to get the initiatory electron?	Analyze	2
5	What causes breakdown in solid dielectrics.	Knowledge	2

Long Answer Questions-

S.No	Question	Blooms Taxonomy Level	Course Outcome
1	The following observations were made in an experiment for determination of dielectric strength of transformer oil. Determine the power law equation. Gap Spacing (mm): 4, 6, 8, 10 Breakdown voltage: 88, 13, 16, 21	Knowledge	2
2	2. (a) Explain short term and long term breakdown mechanics that occur in a composite solid dielectrics. (b) Explain briefly about various solid dielectrics used in practice. medium is not possible without an initiatory electron.	Knowledge	2

3	What are the various sources to get the initiatory electron?	Understand	2
4	Explain breakdown mechanism in pure liquids.	Create	2
5	Explain the phenomena of thermal breakdown in solid dielectrics.in composite solid dielectric materials.	Create	2
6	Explain about the tracking in solid insulating materials	Knowledge	
7	Explain the properties and applications of paper and paper board solid di- electrics used in high voltage engineering.	Analyze	2
8	Discuss briefly about the breakdown mechanism	Evaluate	2
9	Explain the phenomena of thermal breakdown in solid dielectrics.	Evaluate	2
10	Explain why current growth in the gap of gaseous is not possible without an initiatory electron.	Understand	2

UNIT-III

Short Answer Questions-

S.No	Question	Blooms Taxonomy Level	Course Outcome
1	Wire the expression for voltage efficiency of single stage impulse generator.	Evaluate	4
2	State the conditions to be satisfied by a potential divider to be used for impulse work	Analyze	4
3	Write any two advantages of AC testing transformers.	Analyze	4
4	What are the different oscilloscopes used for impulse voltage and current measurements.	Knowledge	4
5	Name any two generators used for Impulse Voltages.	Knowledge	4

Long Answer Questions-

S.No	Question	Blooms Taxonomy Level	Course Outcome
1	Explain different schemes for cascade connection of Transformers for producing very high AC voltage.	Evaluate	4
2	What are the problems associated with measuring very high impulse voltages? Explain how these can be taken care during measurements.	Evaluate	4

3	Describe with a neat sketch, the working of a Van de Graaf generator	Evaluate	4
4	What are the factors that limit maximum voltage applied?	Evaluate	4
5	What is capacitance voltage transformer? Explain with phasor diagram how a tuned capacitance voltage transformer can be used for voltage measurements in power systems?	Evaluate	4
6	An impulse current generator has total capacitance of 15 μF, the charging voltage of 125 kV, the circuit inductance 2 mH and the dynamic resistance 1ohm. Find the peak current and wave shape of the wave.	Evaluate	4
7	Give the schematic arrangement of an impulse potential divider with an oscilloscope connected for measuring impulse voltages. Explain the arrangement used to minimize the errors?	Evaluate	4
8	Explain why the use of series resistant transformers are advantages over AC testing transformers.	Evaluate	4

UNIT-IV

Short Answer Questions-

S.No	Question	Blooms Taxonomy Level	Course Outcome
1	What is Lightning phenomenon?	Knowledge	3
2	Write any two causes for over voltages?	Evaluate	3
3	Name the over voltages due to switching surges?	Knowledge	3
4	Name the over voltages due to system faults?	Knowledge	3
5	Give the names of methods used for calibrating the partial discharge detectors.	Understand	3

Long Answer Questions-

S.No	Question	Blooms Taxonomy Level	Course Outcome
1	Give the mathematical models for lightning discharges and explain them.	Knowledge	3
2	Explain the concept of apparent charge in partial discharge measurements.	Knowledge	3
3	Briefly explain the methods used for calibrating the partial discharge detectors	Understand	3
4	Explain the concept of apparent charge in partial discharge measurements.	Knowledge	3
5	Describe a simple experiment technique to measure partial discharge.	Evaluate	3

6	Explain different aspects of insulation design and insulation co-ordination adopted for EHV.	Knowledge	3
7	What are partial discharges and how are they detected under power frequency operating conditions?	Understand	3
8	Describe a simple experiment technique to measure partial discharge	Knowledge	3
9	Explain Principles of Insulation Coordination on High voltage?	Knowledge Evaluate	3
10	Explain Principles of Insulation Coordination on Extra High Voltage power systems	Knowledge Evaluate	3

UNIT-5

Short Answer Questions-

S.No	Question	Blooms Taxonomy Level	Course Outcome
1	How do you measure the D.C Resistivity?	Understand	5
2	What is Dielectric Constant?	Evaluate	5
3	What is loss factor?	Knowledge	5
4	How do you measure the Radio Interference?	Understand	5
5	Give the names of methods for testing Surge Arresters and cables.	Understand	5

Long Answer Questions-

S.No	Question	Blooms Taxonomy Level	Course Outcome
1	Mention the different electrical tests done on isolators and circuits breakers.	Knowledge	5
2	Why is synthetic testing advantageous over other testing methods for short circuit tests?	Knowledge	5
3	Give the lay out for synthetic testing and explain.	Understand	5
4	Describe the impulse current tests performed on lighting arrestors.	Understand	5
5	How do you conclude that the arrester has passed the test?	Understand	5
6	Explain the method of impulse testing of high voltage transformers.	Understand	5
7	What is the procedure adopted for locating the failure.	Knowledge	5
8	Explain the terms. (i) Withstand voltage (ii) Flash over voltage (iii) 50% Flash over voltage	Understand	5
9	Explain the operation of high voltage Schering bridge when the test specimen is grounded ?	Understand	5
10	Explain the operation of high voltage Schering bridge when the test specimen has high loss factor?	Knowledge	5

OBJECTIVE QUESTIONS:
JNTUH:
UNIT-1

1. Which of the following technique/method is-used for the measurements of ac high frequency voltages ?
(A) Peak voltmeter (B) Series resistance micro ammeter
(C) Resistance potential divider (D) Any of the above.

2. Which of the following method or technique can be used for the measurement of high dc voltages ?
(A) Generating voltmeter (B) Electrostatic voltmeter
(C) Peak voltmeter (D) Any of the above.

3. All of the following methods/techniques can be used for the measurement of high ac voltages EXCEPT
(A) Potential dividers (B) Potential transformers
(C) Electrostatic voltmeters **(D) Half effect generators**.

4. Surge diverters are
(A) non-linear resistors in series with spark gaps which act as fast switches
(B) arc quenching devices
(C) shunt reactors to limit the voltage rise due to Ferranti effect
(D) over-voltages of power frequency harmonics.

5. Impulse voltages are characterized by
(A) polarity (B) peak value (C) time of half the peak value **(D) all of the above.**

6. Paschen's law is associated with
(A) breakdown voltage (B) ionization (C) thermal radiations (D) none of the above.

7. The essential condition for the Paschen's law to be valid is that
(A) voltage must be dc (B) voltage must be ac
(C) temperature must be constant (D) humidity must be low.

8. The breakdown voltage in gases depends on
(A) distance between the electrodes (B) relative air density
(C) humidity **(D) all of the above.**

9. At unvarying temperature breakdown voltage in a uniform field is a function of the product of gas pressure and distance between the electrodes. The above statement is known as
(A) Electron avalanche (B) Thermal stability principle
(C) Paschen's law (D) Breakdown voltage law.

10. Large capacity generators are manufactured to generate power at
(A) 440 V **(B) 6.3 to 10.5 kV** (C) 132 kV to 220 kV (D) 400 kV.

11. Which soil has the least specific resistance?
(A) Land (B) Loamy soil (C) Clay **(D) Peat.**

22. Which soil has the maximum specific resistance?
(A) Black cotton soil **(B) Sand** (C) Peat (D) Loamy soil.

13. In sphere gaps, the sphere are made of
(A) aluminum (B) brass (C) bronze **(D) any of the above.**

14. In 'plasma' state a gas
(A) loses electrical conductivity **(B) conducts electricity**
(C) becomes perfect insulator (D) attracts moisture.

15. Which of the following statement about corona is incorrect?
(A) Corona gives rise to radio interference

(B) Corona results in loss of power in transmission
(C) Corona discharge can be observed as red luminescence
(D) Corona is always accompanied by a hissing noise.
16. Switching surge is
(A) high voltage dc (B) high voltage ac
(C) short duration transient voltage (D) hyperbolically dying voltage.
17. Moles bridge is used to measure
(A) properties of dielectric at dc **(B) dispersion in insulation**
(C) high frequency high voltages (D) modulation ratio frequencies.
18. Insulators for high voltage applications are tested for
(A) power frequency tests (B) impulse tests
(C) both (A) and (B) above (D) none of the above.
19. Impulse testing of transformers is done to determine the ability of
(A) bushings to withstand vibrations **(B) insulation to withstand transient voltages**
(C) windings to withstand voltage fluctuations (D) all of the above.
20. Transformers contribute to radio interference due to
(A) corona discharges in air (B) internal or partial discharges in insulation
(C) sparking **(D) any of the above.**
21. As compared to air the relative dielectric strength of sulphur hexafluoride is nearly
(A) 1.5 times **(B) 2.5 times** (C) 4.0 times (D) 5.0 times.
22. The electrical breakdown strength of insulating materials depends on
(A) nature of applied voltage (B) imperfections in dielectric material
(C) pressure, temperature and humidity **(D) all of the above.**
23. Which of the following gas has been used as insulating medium in electrical appliances?
(A) Nitrogen (B) Carbon dioxide **(C) Sulphur hexafluoride** (D) Freon.
24. Vacuum insulation is used in all of the following EXCEPT
(A) Particle accelerators **(B) EHT of color TV** (C) Field emission tubes (D) X-rays.
25. Liquids are generally used as insulating materials up to voltage stresses of about
(A) 100 MV/cm (B) 50 MV/cm **(C) 50 kV/cm** (D)500 V/cm.
26. Electro-mechanical breakdown of solid insulating materials occurs due to
(A) magnetic bum (B) vibrations
(C) mechanical stresses produced by the electrical field
(D) electrical stresses produced by the voltage fluctuations.
27. Match the following:
(F is force exerted on a charge q in the electric field E and S is the closed surface containing charge q, D is the flux density).

Equation	**Nomenclature**
(a) φ_s E dS = q / ε_0	(i) Poisson's equation
(b) ▼ .D = ρ	(ii) Laplace's equation
(c) $▼^2$.φ = - ρ/ ε_0	(iii) Guass theorem
(d) $▼^2$.φ = 0	(iv) Charge density

(A) a - (i), b - (ii), c - (iii), d - (iv) (B) a - (ii), b - (i), c - (iv), d - (iii)
(C) a - (iv), b - (i), c - (ii), d - (iii) **(D) a - (iii), b - (iv), c - (i), d - (ii).**
28. Surge voltage originate in power systems due to
(A) lightning (B) switching operations (C) faults **(D) any of the above.**

29. All of the following are the preferred properties of a dielectric gas EXCEPT
(A) high dielectric strength (B) physiological inertness
(C) low atomic number (D) good heat transfer.
30. Corona results in
(A) improvement in power factor (B) increased capacitive reactance of transmission lines
(C) radio interference (D) better regulation.
31. Dielectric strength in case of mica can be expected to be more than
(A) 500 kV/mm (B) 1500 kV/mm (C) 2500 kV/mm (D) 3500 kV/mm.
32. All of the following dielectric materials are preferred for high frequency applications EXCEPT
(A) Polyethylene **(B) Butyl rubber** (C) Teflon (D) Polystyrene.
33. Polar dielectrics are normally used for
(A) high frequencies (B) microwaves **(C) dc and power frequencies** (D) none of the above.
34. Which of the following is a polar dielectric?
(A) Teflon (B) Quartz **(C) Nylon** (D) Polyethylene.
35. Which of the following is a non-polar dielectric?
(A) Polystyrene (B) Phenolic plastics (C) Plasticized cellulose acetate (D) Castor oil.
36. The impurity in liquid dielectric which has significant effect in reducing the breakdown strength, is
(A) dust (B) dissolved gases **(C) moisture** (D) ionic impurities.
37. The relationship between the breakdown voltage V and gap d is normally given as
(A) $d = kV^2$ (B) $d=kV^3$ (C) $V = kd$ **(D) $v = kd^n$.**
38. A good dielectric should have all the following properties EXCEPT
(A) high mechanical strength (B) high resistance to thermal deterioration
(C) high dielectric loss (D) freedom from gaseous inclusions.
39. The variety of paper used for insulation purpose is
(A) blotting paper (B) rice paper **(C) craft paper** (D) mill-board.
40. Which variety of mica is hard and brittle?
(A) Muscovite (B) Phlogopite (C) Fibiolite **(D) Lipidolite.**
41. Corona effect can be identified by
(A) bushy sparks **(B) faint violet glow** (C) red light (D) arcing between conductors and earth.
42. The phenomenon of corona is generally accompanied by
(A) a bang **(B) a hissing sound** (C) magnetic hum (D) all of the above.
43. Van de Graaff generators are useful for
(A) Very high voltage and low current applications
(B) Very high voltage and high current applications
(C) Constant high voltage and current applications
(D) High voltage pulses only.
44. In Van de Graaff generators output voltage is controlled by
(A) controlling the corona source voltage (B) controlling the belt speed
(C) controlling the lower spray point (D) any of the above.
45. A Tesla coil is a
(A) cascaded transformer (B) coreless transformer
(C) high frequency resonant transformer (D) low impedance transformer.

Fill in the blanks with appropriate words:

1. Air surrounding corona region gets converted into _____.
2. Corona is responsible for considerable loss of power from _____ voltage transmission.
3. When the voltage is high corona appears like _____ glowing spots distributed along the length of the wire.
4. In a Townsend discharge the current increases gradually as a function of the _____.
5. High dielectric strength of gases is attributed to _____ and _____.
6. In addition to insulating properties SF_6 possesses excellent _____ properties.
7. Addition of 30% SF_6 to air dielectrics, dielectric strength of air by about _____ percent.
8. Under normal atmospheric conditions, the breakdown voltage for air is _____.
9. Corona loss is more in _____.
10. Disruptive discharge voltage is the voltage which produces the loss of _____ strength of an insulation.

WEBSITES:
1. www.cpri.in/
2. www. hve.iisc.ernet.i
3. www.epes.co.uk
4. www.nptel.ac.in

EXPERT DETAILS:
1) Prof V. Kama Raju Retired Principal JNTUK
2) Dr. S.S.Tulasiram,professor, JNTUH

JOURNALS:
1. Journal Of High Voltage Engineering (CHINA) , ISSN 1003-6520
2. ELSEVIER Journal Of High Voltage Engineering, Print ISBN 9780080242125, Electronic ISBN 9781483285658

XVI. LIST OF TOPICS FOR STUDENT SEMINARS:
1. Applications of insulating materials
2. Townsend's criteria of breakdown in gases
3. Measurement of High voltages (DC & AC)
4. Principles of Insulation Coordination on High voltage and Extra High Voltage power systems. Testing of materials & electrical apparatus

XVII. CASE STUDIES / SMALL PROJECTS:
1. Novel application of labview in high voltage engineering
2. Impulse Generator and Lightning characteristics simulation using Orcad Pspice software
3. High-Voltage Measurement Techniques
4. High Voltage DC Upto 2kv from AC by Using Diode and Capacitors in Voltage Multiplier