TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2082 Chaitra

Exam.	Regular		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV/ II	Time	3 hrs.

Subject: - High Voltage Engineering *(EE 751)*

- ✓ *Candidates are required to give their answers in their own words as far as practicable.*
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

1. a) What are the major emerging electrical energy storage technologies? [4]

   b) Discuss the use of FACTS and HVDC technologies for the development of Nepal power sector. [2+2]

   c) Explain the concept of touch potential and step potential with necessary figures. How can these be prevented and their effects minimized? [4+4]

2. a) What will be the no-load sending-end voltage and the voltage rise from the sending-end to the receiving-end for a 50 Hz, 300 km long line if the receiving-end voltage is 220 kV? Solve by considering both the long line and nominal π-circuit line models. Also show the voltage rise by the phasor diagram. Resistance of the line is negligible. [8]

   b) An overhead transmission line has l = 1 mH/km and c = 11.11 nF/km. The conductor plus ground resistance amounts to 0.4 Ω /km. (i) Taking a single-phase representation, calculate (a) the velocity of propagation, (b) the surge impedance, (c) the attenuation factor for 400 km, and (d) the maximum value of open-end voltage. [8]

3. a) A tower has a 40-Ω footing resistance and two ground wires each with Z_g = 500 Ω. The lightning stroke surge impedance is Z_s = 400 Ω. For lightning current surge = 50 kA, crest, calculate the tower top potential (i) considering all impedances, (ii) neglecting the ground wire and stroke surge impedances, (iii)The line-to-ground has a coupling factor between line and ground conductors K_f = 0.2. The tower-footing resistance is 40 Ω. Using tower top potential obtained in (i) above, find the voltage experienced by the insulator string. [8]

   b) A 400 kV line has the following details: N = 2, r = 0.0318 mm, B = bundle spacing = 0.4572 m, height H = 13 m, phase separation S = 12 m in horizontal configuration. Surface voltage gradients are 16.815 kV/cm and 16.015 kV/cm for the center phase and for outer phases, respectively. The R-O-W provided is 15 m from the outer phases at ground. Is the design satisfactory if the RI level is to be limited to 40 dB at 1 MHz at the edge of R-O-W? Use CIGRE formula: $RI_i(dB) = 3.5g_m + 6d - 33\log_{10}(D_i/20) - 30$ [8]

4. a) A 3-phase 750 kV horizontal line has minimum height at midspan of 12 m, sag of 12 m, and phase spacing of 15 m. Conductors are 4 × 0.035 m with bundle spacing of 45.72 cm. Calculate the capacitance and charge matrices. [10]

   b) Will there be a sustained discharge in a gas with an electrode separation of 4 cm if its primary and secondary ionization coefficients are 2.43/cm and 6.823×10^{-4}? [3]

   c) An air bubble of 0.5 mm thickness is embedded in a solid insulation of 1.0 cm having a relative dielectric constant of 3.0. The voltage applied across the solid is 30 kV (rms) of 50 Hz. Calculate the voltage at which internal discharge will occur if the break down strength of the air is 30 kV (peak)/cm. [3]

5. a) Describe the major breakdown mechanisms in solid dielectrics. [8]

   b) What are the general tests that are carried out on high voltage equipment? Explain with clean circuit diagram the method of measurement of high voltage using resistance divider and micro-ammeter. [4+4]

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TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2082 Shrawan

Exam.	Back		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV / II	Time	3 hrs.

Subject: - High Voltage Engineering *(EE 751)*

- ✓ *Candidates are required to give their answers in their own words as far as practicable.*
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

1. a) Elaborate why power electronics is considered vital for modern power systems. [6]
   b) What is back-to-back DC? What are its advantages? [2+2]
   c) Describe different types of earthing. [6]
2. a) A 400-kV 400-km line has the distributed parameters $r = 0.031\ \Omega$/km, $l = 1$ mH/km, and $c = 10$ nF/km. The equivalent lumped parameters for the circuit are assumed as $R = 12.4\ \Omega$, $L = 400$ mH, and $C = 4\mu$F. It is excited by an equivalent step voltage of magnitude $E = 420\sqrt{2}/\sqrt{3} = 343$ kV. Calculate (i) the attenuation factor a, (ii) the natural angular frequency and frequency, and (iii) the peak value of voltage across C with the line holding of
   - no trapped charge and
   - an initial trapped-charge voltage of 343 kV

   [8]
   b) A transformer whose winding has a surge impedance of 1,000 Ω is to be connected to an overhead line with $Z_0 = 400\ \Omega$. The lightning surge has a peak value of 1,500 kV coming in the line while the transformer voltage is to be limited to 800kV, peak. Suggest an alternative to a lightning arrester by using a cable to connect the line to the transformer. Determine its surge impedance and voltage rating. [8]
3. a) A 132 kV line is terminated by transformer and is protected by an arrestor of rating 120 kV located at the incoming line. The BIL withstand voltage of the transformer is chosen to be 500 kV. The protective ratio of transformer is 1.2. Check whether the transformer is properly coordinated with the arrester if a lightning strike of 8,000 kV incident at the arrester. [8]

Discharge current	Residual voltage
10kA	300kV
20kA	360kV

   b) A 765kV line has following details: N = 4, d = 3.05 cm, bundle spacing, B = 45.72 cm, height H = 20 m, phase separation S = 14 m in horizontal configuration. The maximum conductor surface voltage gradients are 20 kV/cm and 18.4 kV/cm for the center and outer phases respectively. Calculate the radio interference at a distance of 15 m from the outer phases using CIGRE formula. [8]
4. a) A 400 kV three phase transmission line has flat horizontal configuration with two sub-conductors per bundle and a phase spacing of 11.3 m. The height of the phase conductors is 11.875 m and 8.85 m at tower and at midspan respectively. The radius of each sub-conductor in the bundle is 3.17 cm and the separation between the sub-conductors is 45.72 cm. Calculate the capacitance and charge matrices of this line for both untransposed and transposed configurations. [8]
   b) What are the major breakdown mechanisms in solids? Describe the breakdown mechanisms in actual working conditions. [2+6]
5. a) Why is the routine measurement of electrical insulation of equipment necessary? How can the results be interpreted based on the values of leakage currents? [3+5]
   b) How are gaseous and liquid dielectric materials monitored for impurities? [8]

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TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2081 Chaitra

Exam.	Regular		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV/ II	Time	3 hrs.

Subject: - High Voltage Engineering *(EE 751)*

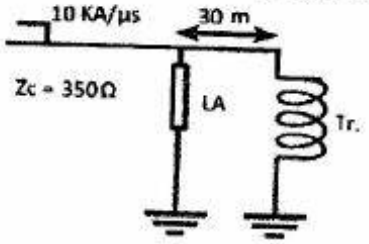
- ✓ *Candidates are required to give their answers in their own words as far as practicable.*
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

1. a) Explain the criteria of choosing HVDC and HVAC system on the basis of cost, transmission power and length. [6]
   b) What is earth resistivity? Describe a method to measure it. [1+3]
   c) What are the major physiological effects of electric shock? Compare the severity of electric shock between DC and AC supplies and different frequencies of AC. [3+3]
2. a) Starting from the expression for switching voltage as: [8]

$$V_c(t) = (E - V_o)\left[1 - e^{-\alpha t}\frac{\sqrt{\alpha^2+\omega^2}}{\omega}\cos(\omega t - \varphi)\right] + V_o$$

   Derive the expression for maximum switching over voltage magnitude and condition for it. What is the effect of increasing R, L and C in the value of maximum switching over voltage.

   b) A 400 kV, 50 Hz, 180 km long HV transmission line has r = 0.015 Ω/km, L = 3 mH/km and c = 12 nF/km determine temporary over voltage in p.u. at receiving end at no-load with and without considering the line resistance. [8]
3. a) The BIL of LA = 1008 kV, BIL of Transformer = 1260 kV.
   Check whether the transformer is properly coordinated? If not, find the required distance between LA and transformer for proper co-ordination. [4]



   b) Derive the expression for the overvoltage due to interruption of low inductive current. Analyze different switching scenarios. [4]
   c) A 765-kV line has following details: N = 4, d = 3.05 cm, bundle spacing, B = 45.72 cm, height H = 20 m, phase separation S = 14 m in horizontal configuration. The maximum conductor surface voltage gradients are 20 kV/cm and 18.4 kV/cm for the center and outer phases respectively. Calculate the SPL or AN in dB at a distance of 35 m along ground from the center phase. Assume the microphone is kept at ground level. Use empirical formula: AN = 120 log Em(i) + 55 logd – 11.4 logD(i) + 26.4 log N – 128.4 db where Em is in kV/cm, d is in cm and D is in m. scenarios. [8]

4. a) A 500 kV, three phase transmission line has flat horizontal configuration with two sub-conductors per bundle. The inter- phase spacing of the line is 15 m. The radius of each sub- conductor in a bundle is 5 cm and the separation between sub- conductors in a bundle is 30 cm. Calculate the capacitance matrix for both the untransposed and transposed conditions if the average clearance of the line is 18 m. [8]

   b) What are pure and commercial liquids? What are the mechanisms of breakdown in commercial liquids? [8]

5. a) An air bubble of 0.5mm thickness is embedded in a solid insulation of 1.0 cm having a relative dielectric constant of 3. The voltage applied across the solid is 30 kV (RMS) of 50 Hz. Calculate the voltage at which internal discharge will occur if the breakdown strength of air is 30 kV (peak)/cm. [8]

   b) Describe the construction and working mechanism of electrostatic voltmeter. [8]

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TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2080 Chaitra

Exam.	Regular		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV / II	Time	3 hrs.

Subject: - High Voltage Engineering *(EE 751)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

1. a) Discuss the different new trends emerging in EHV systems worldwide and how Nepal can adopt those trends to modernize and upgrade its power sector. [8]
   b) Explain the method of earth resistivity measurement with diagram and derive the value. [4]
   c) What are the major causes of high gradient electric fields? [4]

2. a) A tower of a 735 kV line has a 40 Ω footing resistance and two ground wires each with Zg = 500 Ω. The lightning stroke surge impedance is Zs = 400 Ω. For Is = 50 kA, crest, calculate: [8]
   (i) The tower top potential (a) considering all impedances, (b) neglecting the ground wire and stroke surge impedances, and (c) considering only one ground wire and stroke surge impedance
   (ii) The minimum number of standard (dry FOV 125 kV, rain FOV 80 kV) discs required to prevent back-flashover in the insulator string in case (a) of above if the coupling factor between the line and ground conductors is 0.2.
   b) What is ferroresonance? Write about the causes of ferroresonance in power system. [4]
   c) Explain how interruption of low inductive current causes overvoltage in power system. [4]

3. a) The arrester used in a line has its spark over voltage of 420 kV. A surge having steepness of 500 kV/μs on the front reaches the arrester terminal at time t = 0 and travels towards the transformer. BIL withstand voltage of the transformer is 500 kV and the PR required for transformer protection is 1.25. (i) Check whether the transformer is properly coordinated? (ii) Compute the voltage at the transformer terminal when the arrester is kept 40 m away from transformer. (iii) What is the maximum distance allowed between the transformer and the arrester in case of this surge? Assume that the residual voltage (discharge voltage) of the arrester is equal to its spark over voltage. [8]
   b) A 400-kV line in horizontal configuration has H = 14 m and phase spacing S = 15 m. The conductors are 4 × 0.0318 m diameter with bundle spacing of 0.4572 m. By the Mangoldt formula, the maximum conductor surface voltage gradients are calculated as 16.2 kV/cm and 17.3 kV/cm for the outer and center phases respectively. [8]
   (i) Using the CIGRE formulas given below, compute the RI levels at of the line at a distance of 30 meters at ground level from the outer phase in average fair and rainy weathers.
   (ii) What will be the values at 1 MHz?
   Formula: $RI = 3.5g_m + 6d - 33\log10(D_r/20) - 30$

4. a) A 400 kV three phase transmission line has flat horizontal configuration with 2×3.17 cm diameter bundle in each phase and a phase spacing of 11.3 m. The heights of the phase conductors are 11.875 m and 8.85 m at tower and at midspan respectively. The separation between the sub-conductors is 45.72 cm. Calculate the charge matrix of this line. [8]
   b) Explain the Paschen's law and with reference to this law, discuss how break down strength of vacuum and high pressure gas is higher than air at normal pressure. [8]

5. a) Explain the breakdown mechanisms of solid insulating bodies occurring due to actual working conditions. [8]
   b) Write about the high voltage measurement using electrostatic voltmeter. [8]

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TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2079 Chaitra

Exam.	Regular		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV / II	Time	3 hrs.

Subject: - High Voltage Engineering *(EE 751)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

1. a) Compare HVDC and HVAC transmission system with suitable justifications and explain HVDC scope of application in Nepal power system. [8

   b) Describe the step and touch potentials. Why does a person have an electric shock and point out the safety precautions and regulations in electrical system? [2+6

2. a) Starting from the expression for switching voltage as:

$$V_c(t) = (E - V_o)\left[1 - e^{-\alpha t}\frac{\sqrt{\alpha^2 + \omega^2}}{\omega}\cos(\omega t - \varphi)\right] + V_o \quad \text{Where; } \tan\varphi = \frac{\alpha}{\omega}$$

   Derive the expression for maximum switching over voltage magnitude and condition for it. Also discuss the effect of increasing R, L and C in the maximum switching over voltage. [8

   b) A surge of 200 kV travelling in a line of natural impedance 500 ohms arrives at a junction with two lines of impedances 600 ohms and 200 ohms respectively. Find the surge voltages and currents transmitted into each branch line. [8

3. a) Develop the charge coefficient matrix of P phase conductors on a transmission tower with two ground wires which are at or near the ground potential. [8

   b) A 765 kV line has following details: N = 4, d = 3.05 cm, B = bundle spacing = 45.72 cm, height = 20 m, phase separation S = 14 m in horizontal configuration. The maximum conductor surface voltage gradients are 20 kV/cm and 18 kV/cm for the center and outer phases respectively. Calculate the AN in dB(A) at a distance of 30 m along ground from center phase. Assume microphone is kept in ground level. Use empirical formula:

$$AN = 120 \log_{10} E_m(i) + 55 \log_{10} d - 10.4 \log_{10} D(i) + 26.4 \log_{10} N - 128.4 \text{ dB}$$

   Where, E_m is in kV/cm, d is in cm and D is in m. [8

4. a) Write about significance of volt-time characteristics curve in insulation coordination. Describe general working principle of a surge arrester. [4+4

   b) Explain different non-destructive tests carried out for insulators. [8

5. a) In an experiment with a certain gas, it was found that the steady state current is 5.5×10^{-8} A at 8 kV at a distance of 0.4 cm between the plane electrodes. Keeping the field constant and reducing the distance to 0.1 mm results in a current of 5.5×10^{-9} A. Calculate Townsend's primary ionization coefficient. [8

   b) Explain the breakdown of solid dielectric due to Treeing and Tracking. [8

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TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2078 Chaitra

Exam.	Regular		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV / II	Time	3 hrs.

Subject: - High Voltage Engineering *(EE 751)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

1. a) Why are FACTS devices required in a power system? Describe with diagram the major FACTS devices. [3+5]
   b) Explain Wenner's test method for measurement of earth resistivity and derive the relation for the resistivity. [8]
2. a) A tower of a 735 kV line has a 40-ohm footing resistance and two ground wires each with Z_g = 500 ohms. The lightning stroke surge impedance is Z_s = 400 ohm. For I_s = 50 kA, crest, calculate [8]
   (i) the tower top potential (a) considering all impedances, (b) neglecting the ground wire and stroke surge impedances and (c) considering only one ground wire and stroke surge impedance
   (ii) the voltage experienced by the insulator string in case (a) of above if the coupling factor between the line and ground conductors is 0.2.
   b) An overhead line with Z_0 = 400 ohms continues into a cable with Z_c = 100 Ω. A surge with a crest value of 1000 kV is coming towards the junction from the overhead line. Calculate the voltage in the cable. Again, if the end of the cable is connected to a transformer whose impedance is practically infinite to a surge, when the bushing capacitance is omitted. Calculate the transformer voltage. [8]
3. a) A transformer is protected by an arrester at the incoming line. The BIL withstand voltage of the transformer is chosen to be 500 kV. The protective ratio required for transformer protection is 1.2. A lightning strike at the arrester causes an arrester discharge current of 24 kA. Check whether the transformer is properly coordinated. Assume arrester residual voltage to be given by $200I_d^{0.25}$. [8]
   b) A 735 kV has the following details: N = 4, d = 3.05 cm, B = bundle spacing = 45.72 cm, height H = 20 m, phase separation S = 14 m in horizontal configuration. By the Mangoldt formula, the maximum conductor surface voltage gradients are 20 kV/cm and 18.4 kV/cm for the centre and outer phases, respectively. Calculate the SPL or AN in dB(A) at a distance of 30 m along ground from the centre phase (line centre). Assume that the microphone is kept at ground level. [8]
   Use empirical formula:
   AN (i) = 120 $\log_{10} E_{am}$ (i) + 55 $\log_{10}$ d – 11.4 $\log_{10}$ D(i) – 115.4, dB(A) Where, E_{am} is in kV/cm, d is in cm and D is in m.
4. a) A 400 kV, three phase transmission has flat horizontal configuration with two sub-conductors per bundle. The average ground clearance is 9.81 m and the inter phase spacing is 11.3 m. The radius of each sub-conductor in the bundle is 3.17 cm and the separation between the sub-conductors is 45.72 cm. Calculate the capacitance and charge matrices of this line. [8]
   b) An insulation disc of 154 mm thick and relative permittivity of 10 has an internal void of 0.1 mm thickness of dielectric strength of 46 kv/cm. Check whether the internal discharge will occur or not if 40 kV is applied across the insulator. [5]
   c) What are the different mechanism of breakdown in commercial liquids? [3]
5. a) List out the different mechanisms by which break down occurs in solid dielectric in practice. Explain two of them. [8]
   b) What are the different methods for measurement of high AC voltages? With neat diagram, explain the working principle of electrostatic voltmeter. [8]

TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2077 Chaitra

Exam.	Regular		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV / II	Time	3 hrs.

Subject: - High Voltage Engineering *(EE 751)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

1. a) Describe the necessity of HVDC systems for power delivery and their general configuration. What is HVDC back to back system? [5+3]

   b) What are the physiological effects of electric shocks? Explain the effects of electrical current in human body. [8]

2. a) A tower of a 735 kV line has a 40-ohm footing resistance and two ground wires each with Z_g = 500 ohms. The lightning stroke surge impedance is Z_s = 400 ohm. For I_s = 50 kA, crest, calculate

   (i) the tower top potential (a) considering all impedances, (b) neglecting the ground wire and stroke surge impedances, and (c) considering only one ground wire and stroke surge impedance [8]

   b) What are the major causes of switching over voltages? Explain how interruption of inductive current causes over voltage. [8]

3. a) For a 750 kV line, take Vw = 3000 kV, crest, travelling on the line and Vp = 1700 kN. The line surge impedance is Z = 3000 ohms. Calculate and discuss (i) the current flowing in the line before reaching the arrester, (ii) the current through the arrester, and (iii) the value of arrester resistance for this condition, and (iv) reflection and refraction coefficients for voltage and current. [8]

   b) A 750 kV flat horizontal configured transmission line has average ground clearance of 20 m and phase spacing of 15m. The line uses bundle conductor of 2 × 0.30 m diameter. Determine the audible noise at the horizontal distance of 20 m from the outer most conductor. Assume electric formula from below. [8]

   (i) 120log10(Em(i))+55log10(d)-11.4log10(D(i))+26.4log10(N)-128.4
   (ii) 120log10(Em(i))+55log10(d)-11.4log10(D(i))-115.4
   Em = kv/cm, D = m, d = cm

4. a) For the 3-phase 420 kV horizontal line having conductor diameter of 2 × 3.18 cm and bundle spacing 45.72 cm. The ground clearance is 15m and phase spacing is 11m. Calculate the inductance in both un-transposed and transposed condition. [8]

   b) What are the limitations of Townsends theory? Derive the relation given by Paschen law. [8]

5. a) In an experiment with a certain gas, it was found that the steady state current is 5.5×10^{-8} A at 8kV at a distance of 0.4 cm between the plane electrodes. Keeping the field constant and reducing the distance to 0.1 cm results in a current of 5.5×10^{-9} A. Calculate Townsend's primary ionization coefficient. [8]

   b) Explain different non-destructive tests that are carried out for different types of insulators. [8]

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TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2075 Bhadra

Exam.	Regular		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV / II	Time	3 hrs.

Subject: - High Voltage Engineering *(EE751)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt All questions.*
- ✓ *The figures in the margin indicate Full Marks.*
- ✓ *Assume suitable data if necessary.*

1. a) What are FACTS devices and HVDC transmission technology? How can these be utilized to upgrade Nepal's power industry?

   b) What are the physiological effects of electric shock? What are good safety practices to avoid shocks? [4+4]

   c) Write about oil pressure and gas pressure HV cables with necessary diagrams. [4]

2. a) A 3-phase, 220 kV transmission line has a length of 200 km, and inductance of 1.3 mH/km and a capacitance of 8.855×10^{-9} F/km. Calculate (i) the surge impedance of line (ii) the velocity of propagation (iii) the travel time of transient overvoltage (iv) propagation constant. [8]

   b) It's necessary to obtain a tower footing resistance of 20Ω in a soil of resistivity ρ_s = 100 Ω-m, using the three types of electrodes. Take a = 1.25 cm for rods and counter-poises and a depth y = 0.5 m for counter-poises. Calculate the required dimensions. [8]

3. a) A 132 kV transmission line is terminated by transformer at a substation. The transformer is protected by an arrester of rating 120 kV located at the incoming line. The BIL of the transformer is chosen to be 500 kV. The protective ratio required for transformer protection is 1.2. Check whether the transformer is properly coordinated with the arrester if a lightning stroke results in the arrested discharge current of 40 kA. [8]

   Relationship between discharge current and residual voltage:

Discharge Current	Residual Voltage
10 kA	300 kV
20 kA	360 kV

   b) A 400 kV line has conductors in horizontal configuration at average height H = 14 m and phase spacing S = 11m. The conductors of each phase are 2×0.0318 m diameter at B = 0.4572 spacing. Calculate the RI level of each phase at a distance of 30m from one of the outer phase at ground level at 0.5 MHz using the CIGRE formula. Take gm = 17.3 kV/cm on the center phase and 16.2 kV/cm in the two outer phases. What are the values for rainy weather? What is the total value of the RI in fair and rainy weathers? [8]

4. a) A 400 kV, three phase transmission line has flat horizontal configuration with two sub-conductors per bundle. The average ground clearance is 15 m and the inter phase spacing is 11m. The radius of each sub-conductor in the bundle is 3.18 cm and the separation between the sub-conductors is 45.72 cm. Calculate the capacitance matrixes for both the untransposed and the transposed conditions. [8]

   b) Explain 'electromechanical breakdown', 'thermal breakdown' and 'breakdown due to treeing and tracking' occurring in solid dielectrics. [2+3+3]

5. a) An air bubble of 0.5 mm thickness is embedded in a solid insulation of 1.0 cm having a relative dielectric constant of 3.0. The voltage applied across the solid is 30 kV (RMS) of 50 Hz. Calculate the voltage at which internal discharge will occur if the breakdown strength of air if 30 kV (peak)/cm. [8]

b) What are the general tests that are carried out on high voltage equipment? Explain with clean circuit diagram the method of measurement of high voltage using resistance divider and micro-ammeter. [8]

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TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2074 Bhadra

Exam.	Regular		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV / II	Time	3 hrs.

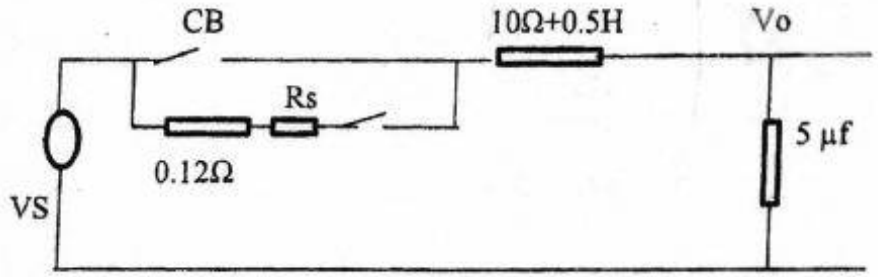
Subject: - High Voltage Engineering *(EE751)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

1. a) Compare HVAC and HVDC transmission system with suitable justifications.

   b) Improper Earthing leads to high electric potential, justify. Also explain how the system grounding have been incorporated in common practice?

2. a) Using the single phase equivalent lumped parameter model circuit of 3-phase, 400kV, 50Hz, 400 km long EHV line shown below, compute the switching resistance Rs to be inserted during the closing of circuit breaker so that maximum switching overvoltage will be limited to 1.8 pu.



   b) Show that when a loss less infinite line with receiving end open circuit switched on to a source the impedance offered to a travelling wave along the line is surge impedance of the line. Also with mathematical interpretation verify that these waves consist of both backward and forward waves. [1

3. a) A transformer is protected by a lightening arrestor at the incoming line. The BIL withstand voltage of the transformer is chosen to be 500 kV. The protective ratio required for transformer protection is 1.25. A lighting strike at the arrestor causes an arrestors discharge current of 24 kA. Check whether the transformer is properly coordinated? Assume arrestor residual voltage can be approximated by: $200\,I_d^{0.25}$. [8

   b) What are the general tests that are carried out on high voltage equipment? Explain with clean circuit diagram the method of measurement of high voltage using resistance divider and micro-ammeter. [8

4. a) Derive the Townsend's current growth equation based on two different ionization coefficients. [6

   b) In a experiment in a certain gas it was found that the steady state current is 5.5×10^{-8} A at 8Kv at a distance of 0.4cm between the plane electrodes. Keeping the field constant and reducing the distance to 0.1 cm results in current of 5.5×10^{-9}A. Calculate town sends primary ionization coefficient. [4

   c) Explain the breakdown phenomenon in commercial liquid in brief. [6

5. a) In a 3-phase overhead lines the conductors, diameter of 3 cm each are arranged in the form of an equilateral triangle. Assuming fair weather condition and air density factor of 0.95; irregularity factor of 0.96, find the minimum spacing between the conductors if the disruptive critical voltage does not exceed 230 kV between the lines. Breakdown strength of air may be assumed to be 30 kV (peak)/cm. [8

   b) How the Ferranti effect can be reduced in over voltage issues? Explain mathematically. [8]

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21 TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2074 Magh

Exam.	Back		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV / II	Time	3 hrs.

Subject - High Voltage Engineering *(EE751)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks***
- ✓ *Assume suitable data if necessary.*

1. a) "FACTS devices will initiate and accelerate the significant changes in power system". Elaborate the statement. [5]
   b) Explain the phenomeon of touch potential and step potential with necessary figures. [4]
   c) What are the effects of electric shock? Why and how are the effects different for DC and AC different frequencies of AC? [2+2]
2. a) Starting from the expression for switching voltage as: [8]

$$V_c(t) = (E - V_0)\left[1 - e^{\alpha t}\frac{\sqrt{\alpha^2+\omega^2}}{\omega}\cos(\omega t - \varphi)\right] + v_0 \text{ where; } \tan\varphi = \frac{\alpha}{\omega}$$

   Derive the expression maximum switching over voltage magnitude and condition for it. Also discuss the effect of increasing R,L and C in the maximum switching over voltage.

   b) A surge of 3000kV is travelling along a 132 kV line. The line surge impedance is 300 ohms and the protective level is 1700 kV. Determine (i) current through the arrester (ii) the value of the arrester resistance for this condition (iii) current and voltage reflection and refraction coefficients (iv) Optimal current rating of the arrester.
3. a) Obtain the expression for the co-ordination between transformer and lighting arrester in term of length L and surge current of $\frac{di}{dt}/\mu s$ and surge impedance of Zc. [8]
   b) Explain different non-disruptive tests that are carried out for different types of insulators. [8]
4. a) Explain Paschen's law and with reference to this law, discuss how the breakdown strength of vaccum and high pressure gas is higher than air at normal pressure. [8]
   b) In a 132 kV circuit breaker, the bushing to ground capacitance is 0.01μF and the transformer impedance succeeding the CB is 5H. the circuit breaker interrupts the magnetizing current of 7A(rms). Calculate the possible overvoltage due to current chopping [8]
      i) When magnetizing current is interrupted at zero value
      ii) When magnetizing current is interrupted at peak value
5. a) A square insulation disc of 154 mm thick and relative permittivity of 10 has an internal void of 0.1 mm square thickness of dielectric strength of 46 kV/cm. Check whether the internal discharge will occur or not if 40kV applied across insulator. (Assume air dielectric strength of 30 kV/cm (peak). [6]
   b) Explain how corona occurs in an EHV transmission line. [4]
   c) Explain with example how electromagnetic induction occurs in neighboring facilities. [6]

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TRIBHUVAN UNIVE
INSTITUTE OF ENGIN
Examination Control
2073 Bhadra

	Regular		
	BE	Full Marks	80
gramme	BEL	Pass Marks	32
ar / Part	IV / II	Time	3 hrs.

Subject: - High Voltage Engineering *(EE 751)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt <u>All</u> questions.*
- ✓ *The figures in the margin indicate <u>Full Marks</u>.*
- ✓ *Assume suitable data if necessary.*

1. a) What is your vision of the electric power system 25 years from now? [4]
   b) Explain the constructional features of belted cable used in HVAC transmission. [4]
   c) Explain different methods of earth resistivity measurement with diagrams. [8]

2. a) It is necessary to obtain a tower-footing resistance of 20 Ω in a soil of resistivity ρ_s=100 Ω-m using the most common three types of electrodes. Take a=1.25 cm for rods and counterpoises and a depth y=0.5 m for counterpoise. Calculate the required dimensions. [8]
   b) A surge of 100 kV travelling in a line of natural impedance 600 Ω arrives at a junction with two lines of impedances 800 Ω and 200 Ω respectively. Find the surge voltages and currents transmitted into each line. [8]

3. a) A lightning arrester with BIL rating of 1000 kV located at the end of the line having surge impedance of 300 Ω receives a travelling wave of 4200 kV. Determine (i) reflected voltage and current at the arrester location (ii) arrester discharge current and resistance offered by the arrester. [8]
   b) A 765 kV line has the following details: N=4, d=3.05 cm, B=bundle spacing=45.72 cm, height H=20 m, phase separation S=14 m in horizontal configuration. The maximum conductor surface voltage gradients are 20 kV/cm and 18.4 kV/cm for the center and outer phases, respectively. Calculate the SPL or AN in dB (A) at a distance of 30 m along ground from the center phase. Assume the microphone is kept at ground level.
   Use empirical formula: $AN=120 \log_{10}E_m(i) + 55 \log_{10}d - 11.4 \log_{10} D(i) + 26.4 \log_{10}N - 128.4$ db
   Where Em is in kV/cm, d is in cm and D is in m. [8]

4. a) A 400 kV, 3-phase bundled conductor line with two sub-conductors per phase has horizontal configuration with phase spacing of 11 m. The radius of each sub-conductor is 3.18 cm and bundle spacing is 45.72 cm. Calculate the capacitance matrix if the average ground clearance of the line is 15 m. [8]
   b) Elaborate the two theories proposed to explain the conduction and breakdown in commercial liquids. [8]

5. a) Determine the power loss in a solid dielectric of area 5 m^2 and thickness 5 cm having volume resistivity 6×10^{12} Ω-cm, loss tangent 0.02 and relative permittivity = 3.5 when subjected to (i) 60 kV rms, 50 Hz AC and (ii) 60 kV DC respectively. [8]
   b) What are the general tests that are carried out on high voltage equipment? [3]
   c) Explain the working principle of electrostatic voltmeter with neat diagrams. [5]

21 TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2073 Magh

Exam.	New Back (2066 & Later Batch)		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV / II	Time	3 hrs.

Subject: - High Voltage Engineering *(EE751)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

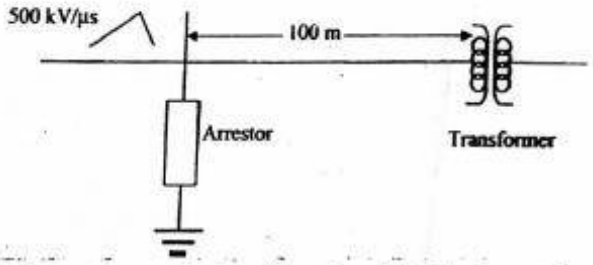
1. a) Why is it advisable to adopt HVDC power transmission system over HVAC system in long distance bulk power transmission? Explain the significance of back to back (B2B) HVDC connection in electric power systems. [6+2]

   b) List out the various types of earthing techniques commonly practiced in industry for personnel and equipment safety. Discuss how the properly designed earthing system in electric substation prevents the personnel from getting possible electric shock. [8]

2. a) Describe the expression for over-voltage due to lightning when a direct stroke falls on a power conductor, earth wire and on the tower. And hence discus the importance of Tower footing resistance in the resulting overvoltage. [8]

   b) A 400kV, 50Hz HV 400 km long HV transmission line has r = 0.025 Ω/Km, L = 1mH/Km and C = 12nF/Km. Assuming a perfectly loss less line determine the p.u. temporary over voltage at receiving end under no-load condition. What counter measure must be applied to limit this temporary over voltage at receiving end node to 1.04 p.u? [4+4]

3. a) For the system shown in figure below, the arrestor spark over voltage is 320 kV. A surge having steepness of 500 kV/μ_S on the front reached the arrestor terminal at time (t) = 0, and travels towards the transformer with the velocity equal to that of light wave. Compute the voltage at the (i) Arrestor location (ii) Transformer terminal. BIL withstand voltage of the transformer is 500 kV and the protective ratio required for transformer protection is 1.3. Check whether the transformer is properly coordinated? If not, under what condition will the system be properly coordinated? [4+4]



   b) A 500 kV, three phase transmission line has flat horizontal configuration with two sub-conductors per bundle. The inter-phase spacing of the line is 15m. The radius of each sub-conductor in a bundle is 5 cm and the separation between sub-conductors in a bundle is 30 cm. Calculate the inductance matrix if the average ground clearance of the line is 20m. [8]

4. a) A 765 kV, three phase transmission line has flat horizontal configuration. The inter-phase spacing of the line is 15m. The perfectly cylindrical phase conductor has radius of 2.5 cm. Atmospheric pressure and temperature are respectively equal to 75 cm of Hg and 35°C. The weather correction factor is 0.95. Check whether the corona occurs in the given transmission line? [8]

   b) List out the various mechanisms leading to electrical breakdown in solid insulating materials? Explain any two. [2+6]

5. a) Discuss how the electrical breakdown occurs in gaseous dielectrics. Explain any two. [8]
   b) What are the types of tests carried out on high voltage equipment? Explain with neat and clean circuit diagram the method of measurement of high voltage using sphere gaps. [2+6]

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Examination Control Division
2072 Ashwin

Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV / II	Time	3 hrs.

(45)

Subject: - High Voltage Engineering *(EE751)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt All questions.*
- ✓ *The figures in the margin indicate Full Marks.*
- ✓ *Assume suitable data if necessary.*

105

1. a) "EHV and UHV lines are necessary to transmit large blocks of power over long distances". Justify the statement. [5]
   b) Explain in brief the issues of EHV-AC power transmission. [3]
   c) Describe briefly the various causes of high gradient fields. [8]
2. a) Show that in a short circuited line, the voltage wave reduces periodically to zero where as the current wave reaches infinite value. [8]
   b) A 10 MVA, 132 kV transformer is connected to the end of the transmission line of surge impedance 400 Ω. The transformer has an equivalent capacitance of 0.002 μF and leakage inductance of 16 H. If a rectangular wave of 1000 kV travels through the line and strikes the transformer, find the surge voltage at the transformer. [8]
3. a) A 132 kV transmission line is terminated by transformer at a substation. The transformer is protected by an arrester of rating 120 kV located at the incoming line. The BIL of the transformer is chosen to be 500 kV. The protective ratio required for transformer protection is 1.2. Check whether the transformer is properly co-ordinate with the arrester if a lightning stroke results in the arrester discharge current of 40 kA. [8]

Discharge Current	Residual Voltage
10 kA	300 kV
20 kA	360 kV

Suppose the non-linear characteristic of arrester is expressed as; $V_d = k\, I_d^{\beta}$

Where, V_d is arrester residual voltage
I_d is arrester discharge current

   b) A 400 kV, 3-phase bundled conductor line with two sub-conductors per phase has horizontal configuration with inter-phase spacing of 11 m. The radius of each sub-conductor is 3.18 cm and bundle spacing is 45.72 cm. Calculate the capacitance matrix if the average ground clearance of the line is 15 m. [8]
4. a) In a 3-phase overhead line, each of the conductors has a diameter of 2.4 cm and the conductors are arranged in the form of an equilateral triangle. Assuming fair weather condition and irregularity factor of 0.96, find the minimum spacing between the conductors if the corona inception voltage does not exceed 208 kV between the lines. Assume the barometric pressure 72.2 cm of Hg, temperature 20°C and dielectric strength of air 21.1 kV (rms)/cm. [8]
   b) What are the general tests that are carried out on high voltage equipment? With neat diagram, explain the working principle of electrostatic voltmeter. [8]
5. a) In an experiment with a certain gas, it was found that the steady state current is 5.5×10^{-8} A at 8 kV at a distance of 0.4 cm between the plane electrodes. Keeping the field constant and reducing the distance to 0.1 cm results in a current of 5.5×10^{-9} A. Calculate Townsend's primary ionization coefficient. [3]
   b) Describe the methods for measurement of dielectric constant and loss factor. [3]

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INSTITUTE OF ENGINEERING
Examination Control Division
2072 Magh

Exam.	[illegible]		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV / II	Time	3 hrs.

Subject: - High Voltage Engineering *(EE751)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

1. a) Give reason for resurgence of HVDC system in electrical power system. Explain why AC system is still inevitable for power transmission. [4+4]
   b) Mention basic electrical safety rules and regulations. [4]
   c) Why is it necessary to measure earth resistivity? [4]

2. a) It is necessary to obtain a tower footing resistance of 16 Ω in a soil of resistivity ρ_s=100 Ω-m using the three common types of electrodes. Calculate the required dimensions if the radius of rod and counterpoise is 1.25 cm and depth of counterpoise is .0.6 m [8]
   b) A lightning arrester with BIL rating of 1000 kV located at the end of the line having surge impedance of 350 Ω receives a travelling wave of 4200 kV. Determine (i) reflected voltage and current at the arrester location (ii) arrester discharge current and resistance offered by the arrester. [8]

3. a) An infinite rectangular wave on a line having a surge impedance of 500 Ω strikes a transmission line terminated with a capacitance of 0.004 μF. Calculate the extent to which the wave front is retarded. [8]
   b) A 735 kV line has the following details: N=4, d=3.05 cm, B=bundle spacing=45.72 cm, height H=20 m, phase separation S=14 m in horizontal configuration. The maximum conductor surface voltage gradients are 20 kV/cm and 18.4 kV/cm for the center and outer phases, respectively. Calculate the SPL or AN in dB (A) at a distance of 30 m along ground from the center phase. Assume the microphone is kept at ground level. [8]

4. a) Develop the charge coefficient matrix of P phase conductors on a transmission tower with one or two ground wires which are at or near the ground potential. [8]
   b) Elaborate the different types of breakdown in solid dielectrics. [8]

5. a) Derive the Townsend's current growth equation in gaseous dielectrics. How is the current growth take place in the presence of secondary process? [4+4]
   b) Explain different non-destructive tests that are carried out for different types of insulations. [8]

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21 TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2071 Bhadra

Exam.	Regular / Back		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV / II	Time	3 hrs.

Subject: - High Voltage Engineering *(EE751)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt All questions.*
- ✓ *The figures in the margin indicate Full Marks.*
- ✓ *Assume suitable data if necessary.*

1. a) "The best frequency is a compromise between contradictory requirements". Justify the statement related with frequency standardization of AC system. [6]

   b) What are the different factors responsible for insulation failure and write about its possible remedies. [4]

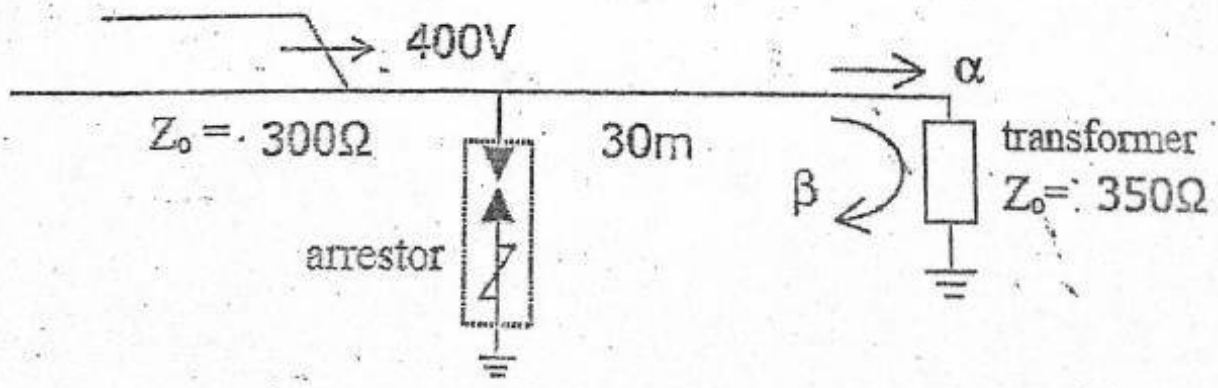
   c) What are the physiological effects of electric shock? What are good safety practices to avoid shocks? [6]

2. a) Starting with the mathematical expression given below. Justify that the voltage at the receiving end of a loss less line of 50 Hz operating frequency becomes infinity when the length of line is 1500 km at no-load condition. [8]

$$\begin{bmatrix} V_S \\ I_S \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

   b) A 3-phase single circuit transmission line is 400 km long. If the line is rated for 220 kV and has the parameters, R = 0.1 ohms/km, L = 1.26 mH/km, C = 0.009 μF/km, and G = 0, find (i) the surge impedance, and (ii) the velocity of propagation neglecting the resistance of the line. If a surge of 150 kV and infinitely long tail strikes at one end of the line, what is the time taken for the surge to travel to the other end of the line. [8]

3. a) A 400 kV line shown in figure below is effectively grounded which is protected by L.A. with PR = 3. The transformer has its protection ratio (TPR) = 1.25 with Zc = 350 Ω. Determine BIL of Tr. Also find the maximum distance between transformer and lightening arrestor so that the insulation co-ordination is properly met. [8]



   b) Develop the charge coefficient matrix of P phase conductors on a transmission tower with one or two ground wires which are at or near the ground potential. [8]

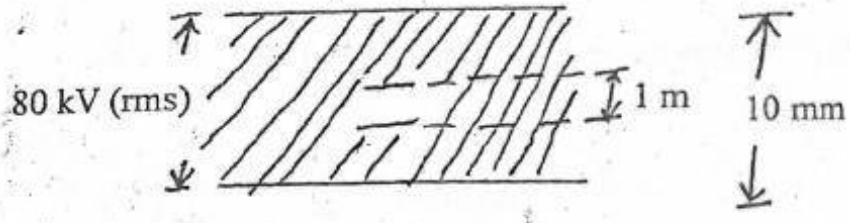
4. a) List out the different mechanisms by which break down occurs in solid dielectric in practice. Explain one of them. [8]

b) A 750 kV flat horizontally configured transmission line has average ground clearance of 20 m and phase spacing of 15 m. The line uses bundle conductor of 2 × 0.30 diameter in meter. Determine the audible noise (AN) at ground level at horizontal distance of 20 m from the outer most conductor. Assume electric field gradient at the surface of the conductor 20 kV/cm. Use empirical formula for AN due to i_{th} conductor as: [8]

$$AN(i) = 120 \log_{10} E_m(i) + 55 \log_{10} d - 11.4 \log_{10} N - 115.4$$

Here, E is in kV/cm, D in m and d in cm.

5. a) A solid dielectric specimen of dielectric constant of 4.0 has an internal void of thickness 1 mm. The specimen is 1 cm thick and is subjected to a voltage of 80 kV (rms). If the void is filled with air and if the breakdown strength of air can be taken as 30 kV (peak) per cm, find the voltage at which an internal discharge can occur. [8]



b) What are the different methods for measurement of high AC voltages? With neat diagram, explain the working principle of electrostatic voltmeter. [8]

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(45)

21 TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2071 Magh

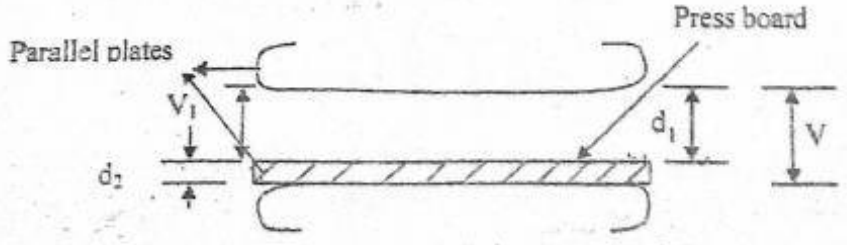
Exam.	New Back (2066 & Later Batch)		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV / II	Time	3 hrs.

Subject: - High Voltage Engineering *(EE751)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt <u>All</u> questions.*
- ✓ *The figures in the margin indicate <u>Full Marks</u>.*
- ✓ *Assume suitable data if necessary.*

1. a) Write in brief about the advantages and disadvantages of HVDC over AC transmission. [4]
   b) Write in brief about the Edison's publicity campaign to discourage the use of AC. [4]
   c) Write about the physiological effects of electric shock and the factors affecting its magnitude of damage. [8]
2. a) Derive the relation for over voltage in healthy phase when unsymmetrical single line to ground fault occurs in transmission line. Also derive the condition of effective grounding. ($X_0 = 5.16\ X_1$). [6+3]
   b) An overhead line of 300Ω surge impedance bifurcates into two lines of 150Ω and 90Ω surge impedances respectively. If a step wave of 150 kV is launched on the line, estimate the magnitude of waves transmitted on the bifurcated lines. [7]
3. a) What is volt-time curve regarding insulation co-ordination? Explain step-wise how Volt-Time curve is plotted for insulation co-ordination. [3+5]
   b) Taking a typical example of two conductors having charges +ql c/m and +q2 c/m respectively, placed at height of H_1 and H_2 respectively from ground develop the voltage matrix showing the proximate effect of conductor placed nearby. Consider the distance between the conductors is A_{12} and distance between one of the conductors and the image of other is I_{12}. [8]
4. a) A 735 kV line has the following details N = 4, d = 3.05 cm, bundle spacing = 45.72 cm, height = 20 m, phase separation = 14 m in horizontal configuration. The maximum conductor surface voltage gradients are 20 kV/cm and 18.4 kV/cm for the centre and outer phase respectively. Calculate the total Audible Noise level in dB at a distance 30 m along the ground from the centre phase. (Empherical relation for AN is: $AN(i) = 120 \log_{10} Em(i) + 55 \log_{10}(d) - 11.4 \log_{10} D(i) + 26.4 \log_{10} N - 128.4$) [8]
   b) Describe the streamer theory of breakdown in gases. [8]
5. a) An a.c. voltage of 60 kV is applied between two parallel plates rounded at the edges and placed 2.0 cm apart in air. A press board sheet of thickness 0.2 cm is placed on the lower plate, in parallel with the two plates. Calculate the voltage across the air gap and the press board sheet. The arrangement is shown in the figure below. [8]

given:- Permittivity of press board= 4



   b) Describe the construction and working principle of series impedance voltmeter used in measurement of high AC voltages. What are its drawbacks? [6+2]

TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2070 Bhadra

Exam.	Regular		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV / II	Time	3 hrs.

Subject: - High Voltage Engineering *(EE751)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt All questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

1. a) Discuss the classification of high voltages and the need of high voltage for transmission line. [4]
   b) Write in brief the advantages and disadvantages of HVDC over HVAC. [4]
   c) Explain Wenner's Test method for measurement of earth resistivity and derive the relation for the measurement of resistivity. [8]
2. a) Describe how the switching overvoltage takes place due to chopping of the magnetising current. Also show that the effect is minimum when switching takes place at zero crossing of current. [6]
   b) Explain in brief the effect of load rejection in power system. [4]
   c) A transmission line of 500 Ω surge impedance is connected to a cable of 60 Ω surge impedance at other end. If a surge of 500 kV travels along the line to the junction point. Find the voltage build-up at the junctions? [6]
3. a) For a 750 kV line, take V_w = 3000 kV crest, travelling on the line and V_p = 1700 kV. The line surge impedance is Z = 300 ohms. Calculate (a) the current flowing in the line before reaching the arrestor, (b) the current through the arrestor, and (c) the value of arrestor resistance for this condition and also find the reflection and refraction coefficient of voltage. [8]
   b) Develop the charge coefficient matrix of P phase conductors on a transmission tower with one or two ground wires which are at or near the ground potential. [8]
4. a) A 750-kV flat horizontally configured transmission line has average ground clearance of 20 m and phase spacing of 15 m. The line uses bundle conductor of 2*0.30 diameters in meter. Determine the Audible Noise (AN) at ground level at horizontal distance of 20 m from the outermost conductor. Assume electric field gradient at the surface of the conductor 20 kV/cm. Use empirical formula for AN due to i_{th} conductor as: [8]

   $AN(i) = 120 \log_{10} Em(i) + 55 \log_{10} d - 11.4 \log_{10} N - 115.4$

   Here Em: kV/cm, d is in cm and D is in metre.
   b) Explain Town Send's theory of breakdown in gases and derive the Town Send's current growth equation in gases including secondary ionization. [8]
5. a) An air bubble of 0.5 mm thickness is embedded in a solid insulation of 1.0 cm having a relative dielectric constant of 3.0. The voltage applied across the solid is 30 kV (RMS) of 50 Hz. Calculate the voltage at which internal discharge will occur if the breakdown strength of air is 30 kV (peak)/cm. [8]
   b) What are the general tests that are carried out on high voltage equipment? Explain with clean circuit diagram the method of measurement of high voltage using resistance divider and micro-ammeter. [8]

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(45)

21 TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2070 Magh

Exam.	New Back (2066 & Later Batch)		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV / II	Time	3 hrs.

Subject: - High Voltage Engineering *(EE751)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt <u>All</u> questions.*
- ✓ *The figures in the margin indicate <u>Full Marks</u>.*
- ✓ *Assume suitable data if necessary.*

1. a) Explain the criteria of choosing HVDC and HVAC system on the basis of cost, transmission power and length. [4]

   b) Explain in brief the role of Facts devices in the power system. [4]

   c) Explain how Improper Earthing may result in step potential and touch potential beyond safe value in power system with necessary diagram and formulae. [8]

2. a) With a mathematical justification show that charging reactive power supplied by the source per phase for a transmission line at no load is given by: [8]

$$Q_0 = Es^2 \sqrt{\frac{c}{t}} \tan\left(\frac{2\Pi L}{\lambda}\right)$$

   What l is inductance per unit length; c is the capacitance per unit length
   L is length of line
   λ is wave length

   b) A 3-phase, 220 kV transmission line has a length of 200 km, and inductance of 1.3 mH/km and a capacitance of $8.855*10^{-9}$F/km. [8]

   Calculate:
   i) The surge impedance of the line
   ii) The velocity of propagation
   iii) The travel time or time period of transient overvoltage
   iv) Propagation constant

3. a) A 400 kV line effectively grounded is protected by lighting Arrestor (LA) with Protection ratio (PR) = 3. The transformer has its protection ratio (TPR) = 1.25 with Zc = 350 Ω. Determine BIL of transformer. Now if LA is kept at 30 m from Transformer and there is a lighting discharge of 10kA with peak time of 1μS, Check whether the insulation is properly co-ordinated with LA or not. Also find maximum possible separation between transformer and LA achieving proper insulation co-ordination. [8]

   b) In a 3-phase overhead lines the conductors have a diameter of 3 cm each are are arranged in the form of an equilateral triangle. Assuming fair weather condition and air density factor of 0.95; irregularity factor of 0.96, find the minimum spacing between the conductors if the disruptive critical voltage does not exceed 230 kV between the lines. Breakdown strength of air may be assumed to be 30 kV (peak)/cm. [8]

4. a) Develop the voltage matrix showing the proximate effect of conductor placed nearby. Take the example of two conductors having charges +q1 c/m and +q2 c/m respectively, placed at height of H_1 and H_2 respectively from ground. The distance between the conductors is A_{12} and distance between one of the conductors and the image of other is I_{12}. [8]

   b) Explain Paschen's Law and with reference to this law discuss how the breakdown strength of vacuum and high pressure gas is higher than air at normal pressure. [8]

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21RE TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2069 Bhadra

Exam.	Regular / Back		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV / II	Time	3 hrs.

Subject: - High Voltage Engineering *(EG781EE)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt any Five questions.*
- ✓ *All questions carry equal marks.*
- ✓ *Assume suitable data if necessary.*

1. a) Discuss the various mechanism of vacuum break down.

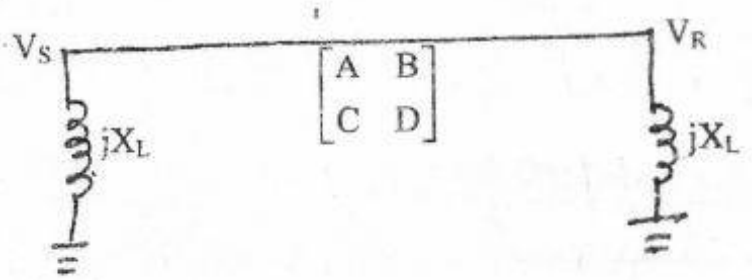
BE b) An insulation disc of 154mm thick has an internal air void of 0.01mm thickness. Check whether the interval discharge will occur or not during the withstand test at a voltage of 40 KV across the insulator? Take air has the dielectric strength of 46 KV/cm at 0.01mm thickness and the relative permittivity of the disc material is 10.

2. a) Explain the phenomena of electrical breakdown in commercial liquid dielectrics.

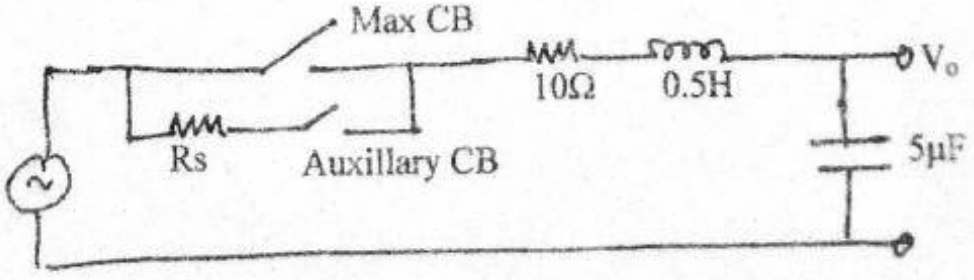
   b) Explain the Paschen's Law with reference to this law, discuss how the breakdown strength of vacuum and high pressure gas is higher than air at normal pressure.

3. a) An overhead line uses 5 nos. of insulator discs. The voltage along the different units of string is equalized by a suitable guard ring. Determine the theoretical value of the capacitance between the pin of different units and the guard ring as the function of capacitance between the pin and earth.

   b) A 750 KV, 500km transmission line has ABCD parameter given by A = 0.9 and B = j130Ω using the reactive shunt compensation scheme of figure, determine the value of X_L so that the receiving end voltage at no load could be controlled as $V_R = 1.05\ V_S$



4. a) Using the single phase equivalent lumped parameter model circuit of a 3-phase, 400 KV, 50Hz, 400 km long EHV transmission line shown below, compute the switching resistance R_S to be inserted during the closing of the CB so that the max switching over voltage will be limited to 1.8 pu.



b) A 3-phase overhead line has conductors of 30mm diameter and arranged in the form of equilateral triangle. Assume fair weather conditions, air density factor of 0.95 and irregularity factor of 0.95, find minimum spacing between conductors if disruptive critical voltage is not to exceed 230KV between lines. Breakdown strength of air is 30 KV/cm (peak).

5. a) A 132 KV transmission line is terminated by a transformer at a substation. The transformer is protected by an arrestor of rating 120 KV located at the incoming line. The BIL withstand voltage of the transformer is chosen to be 500KV. The protective ratio required for transformer protection is 1.2. Check whether the transformer is properly co-ordinated with the arrestor if a lighting strike of 8000 KV incident at the arrestor.

Discharge Current	Residual Voltage
10 KA	300 KV
20 KA	360 KV

b) A surge of 15KV magnitude travels along a cable towards its junction with an overhead line. The inductance and capacitance of the cable is 0.3mH/km and 0.4 μF/km respectively and that overhead line is 1.5mH/Km, 0.012 μF/km respectively. Find the voltage rise at the junction due to surge.

6. a) Starting from $I_S = C E_r + D.I_r$ the corresponding charging reactive power supplied by the source per phase at no load is given by

$$Q_0 = \frac{Es.E_r}{Z_0} \operatorname{Sin}\left(\frac{2\pi L}{\lambda}\right)$$

Here the symbols have usual meaning.

b) With suitable mathematical aid, show that neglecting the source impredance for a lossless line, the value of a shunt reactive compensation required at the receiving end at no load for sending end and receiving end voltages to be equal could be expressed as

$$X_P = \frac{Zc}{\tan\left(\beta l - \cos^{-1}\left(\frac{X_P}{\sqrt{Z^2c + Xp^2}}\right)\right)}$$

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21 TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2068 Bhadra

Exam.	Regular / Back		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV / II	Time	3 hrs.

Subject: - High Voltage Engineering

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt any **Five** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

1. a) The following data has been observed for studying Townsend's mechanism. The field is kept constant. [8]

Gap distance (mm)	Current observed (A)
0.5	6.5×10^{-14}
1.0	2.0×10^{-13}
1.5	4×10^{-13}
2.0	8×10^{-13}
2.5	1.2×10^{-12}
3.0	6.5×10^{-12}
3.5	6.5×10^{-11}
4.0	4.0×10^{-10}
5.0	1.2×10^{-8}

The minimum current is 6.5×10^{-14} A. Determine the Townsend's first and second ionization coefficient.

b) What is vacuum dielectrics and how it is classified? Discuss the various vacuum dielectric break down mechanisms. [2+1+5]

2. a) List out the different mechanisms by which break down occurs in solid dielectric in practice. Explain one of them. [4+6]

b) In a 132 KV circuit breaker the bushing to ground capacitance is 0.01μF and the transformer inductance succeeding the circuit breaker is 5H. Calculate the voltage appearing across the poles of the circuit breaker if it breaks magnetizing current of 10A flowing in the transformer. [6]

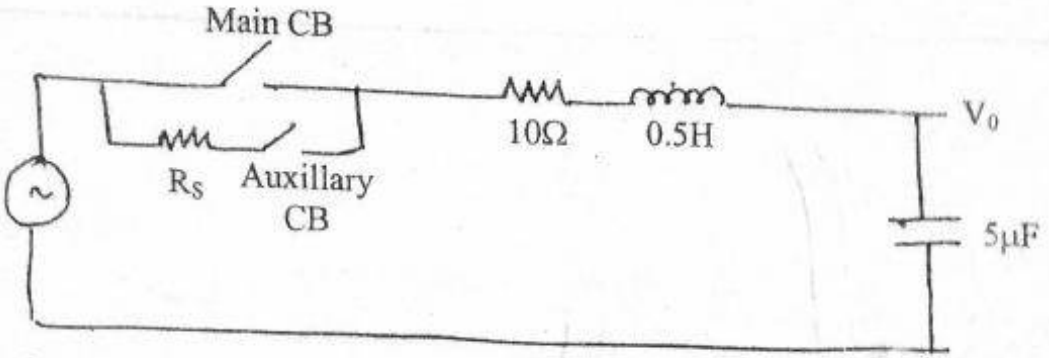
3. a) With a mathematical justification show that charging reactive power supplied by the source per phase for a transmission line at no load is given by: [6]

$$Q_0 = E_s^2 \sqrt{\frac{c}{l}} \tan\left(\frac{2\pi L}{x}\right)$$

Where C is the capacitance per unit length

l is inductance per unit length
L is length of line
X is wave length

b) Using the single phase equivalent lumped parameter model circuit of a 3-phase, 400kV, 50 HZ, 400Km long EHV transmission line shown below. Compute the switching resistance R_s to be inserted during the closing of the CB so that the maximum switching over voltage will be limited to 1.8pu. [10]



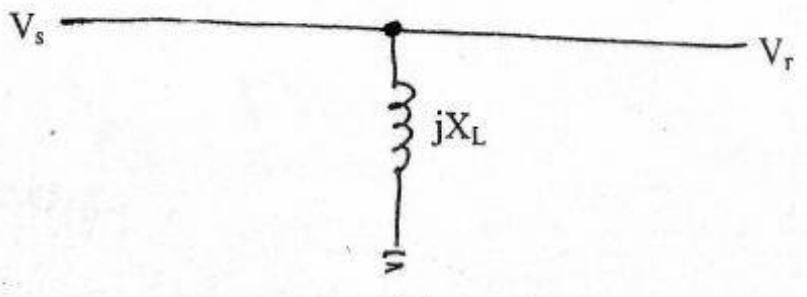
4. State whether the following statements are TRUE or FALSE. Also give their justification. [(1+3)×4]
   a) Increasing the cross-arm length, string efficiency can be increased.
   b) Underground cables are used to suppress the switching over voltage at substation transformer.
   c) Protective ratio depends upon the type of grounding system employed.
   d) Load rejection causes the terminal voltage to rise up.

5. a) A 3 phase overhead line has conductors of 30mm diameter and arranged in the form of equilateral triangle. Assume fair weather conditions, air density factor of 0.95 and irregularity factor of 0.95, find minimum spacing between conductors if disruptive critical voltage is not to exceed 230KV between lines. Breakdown strength of air is 30KV/cm (peak). [6]

   b) A 10KV surge travels on a line having a surge impedance of 400Ω. (i) Find the magnitude of incident current wave (ii) If the line is terminated by a resistance of 1000Ω, find rate of energy dissipated, the reflected voltage and current waves and rate of energy reflection. [2+8]

6. a) A 500KV EHV transmission line with surge impedance of 360Ω is effectively grounded. If the arrestor protective ratio is 2.83, determine the basic insulation withstand voltage level of the transformer for a protective ratio margin is 1.4. Also determine the arrestor resistance for a lightning stroke of 5KA. [8]

   b) A 400KV, 500km, 50HZ HV transmission line has r = 0.031Ω/km, l = 1mH/km and C = 10nF/km. Calculate the value of X_L of a reactor required at the middle of the line as shown in figure below so that the receiving end voltage at no load could be controlled as $V_r = V_s$. [8]



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21 TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2067 Mangsir

Exam.	Regular / Back		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV / II	Time	3 hrs.

Subject: - High Voltage Engineering

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt **All** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

1. a) How is the condition for breakdown obtained in Townsend discharge due to primary and secondary ionization [10]

   b) During an experiment in a particular gas, the steady state current is found to be 5.5×10^{-8}A at 8 kV at a distance of 0.4 cm between the plane electrodes. Keeping the field constant, reducing the distance to 0.1cm results in a current of 5.5×10^{-9}A. Calculate Townsend's primary ionization coefficient. [6]

2. a) What is vacuum and how it is classified? Discuss the various categories of vacuum breakdown mechanism. [6]

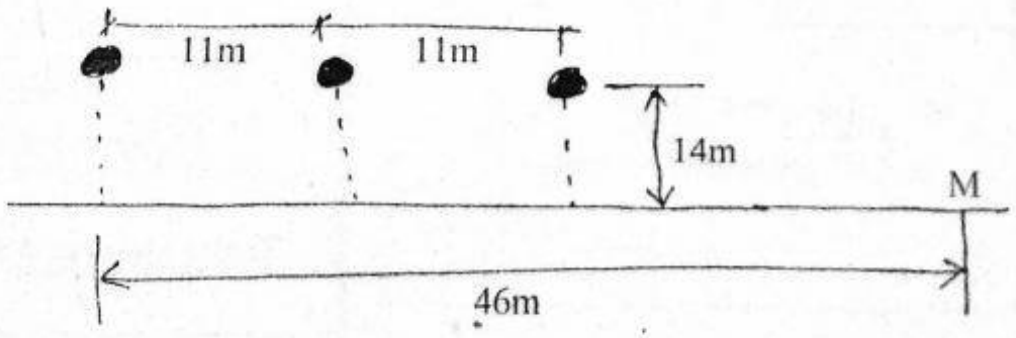
   b) An insulator disc 154mm thick has internal air void of 0.01 mm thickness. Check whether the internal discharge will occur or not during the withstand test of a voltage of 40KV across the insulator? Assume that air has the dielectric strength of 46KV/cm at 0.01 mm thickness and relative permittivity of the disc material is 10. [6]

   c) Discuss why the break down strength of vacuum and high pressure air is higher than air at normal pressure? [4]

3. a) Compute the temporary over voltage due to single line to ground fault for a 400KV, 50HZ, 3 phase, AC transmission line having r = 0.04Ω/km, l = 1.01 mH/km and C = 11 nf/kw if the fault is at the middle of the line. Take fault impedance of j 35Ω, generator grounding impendence 4+j50Ω. Take length of line = 400km. [12]

   b) Show that a phase shift of 6° between sending end and receiving end voltage takes place for each 100km length in a loss less long transmission line. [4]

4. a) With the help of transmission line and data given below, calculate the RI level of each phase at point M at 500KHZ in fair weather condition using CIGRE formula. Also calculate the RI level of the line.



Nominal voltage = 330KV
Bundle spacing = 45.72cm
Conductor diameter = 30mm
Number of conductors per phase = 2

Maximum surface gradient at central and outer phases at 330 KV are 1710 KV/m and 1600 KV/m respectively.

The CIGRE formula is given by

$$RI_i(dB) = 3.5E_m + 6d - 33\log_{10}\left(\frac{di}{20}\right) - 30$$

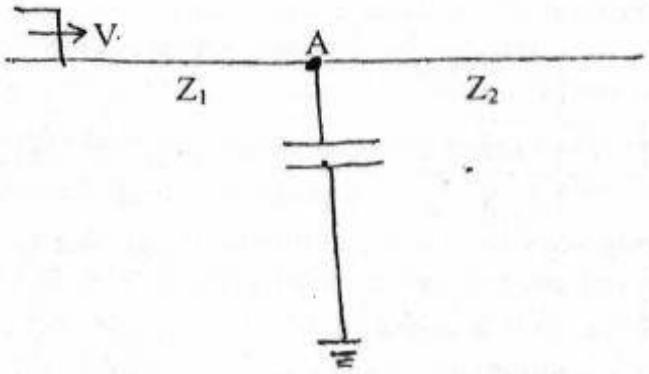
Where E_m in KV/cm, d in cm, Di in m. [8]

b) A 3 unit insulator string is fitted with guard ring. The capacitances of the link pins to metal work and guard ring can be assumed to be 15% and 5% of the capacitance of each unit. Determine the voltage distribution and string efficiency. [8]

5. a) A lightning arrestor with BIL rating of 1600KV located at the end of the line having surge impedance of 300Ω receives a traveling wave of 4200KV, determine the following: [8]

   i) Reflected voltage and current at the arrestor location
   ii) Arrestor discharge current and resistance offered by the arrestor

b) A capacitance is placed between the two lines having surge impedance Z_1 and Z_2 as shown below. A traveling wave (step in nature) V travels in the line having magnitude 4000KV as shown in diagram. Derive the expression and calculate the magnitude of voltage at the junction 'A' for time of 1μsec. Take $Z_1 = 400\Omega$, $Z_2 = 380\Omega$, C = 3nF. [8]



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11 TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
Examination Control Division
2066 Magh

Exam.	Regular/Back		
Level	BE	Full Marks	80
Programme	BEL	Pass Marks	32
Year / Part	IV / II	Time	3 hrs.

Subject: - High Voltage Engineering

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ *Attempt any **Five** questions.*
- ✓ *The figures in the margin indicate **Full Marks**.*
- ✓ *Assume suitable data if necessary.*

1. a) What is vacuum and how it is classified? Discuss the various categories of vacuum break down mechanism. [8]

   b) In an experiment in a certain gas, the steady state current is 5.5×10^{-8}A at 8KV at a distance of 0.4m between the plane electrodes. Keeping the field constant and reducing the distance to 0.1cm, results in a current of 5.5×10^{-9}A. Calculate Townsend's primary ionization coefficient. [4]

   c) Discuss why the breakdown strength of vacuum and high pressure gas is higher than air at normal pressure. [4]

2. a) Explain the conduction and breakdown mechanism in commercial liquid dielectric. [8]

   b) An insulator disc 154mm thick has an internal air void of 0.01mm thickness. Check whether the internal discharge will occur or not during the withstand test of a voltage of 40KV across the insulator? Air has the dielectric strength of 46 KV/cm at 0.01mm thickness and the relative permittivity of the disc material is 10. [8]

3. A 400KV high voltage transmission line has resistance = 0.031Ω/km, inductance = 1mH/km and capacitance = 10 nF/km. Compute the temporary over voltage due to single line to ground fault if the fault is at the end of the 400km long line. Consider the line resistance and generator neutral impedance of 5 + j50Ω. Neglect fault impedance. [16]

4. a) A string of five suspension insulators is to be fitted with a grading ring. If the pin to earth capacitances are equal to C, find the values of line to pin capacitances that would give a uniform voltage distribution along the string. [8]

   b) A transformer is protected by an arrester at the incoming line. The BIL withstand voltage of the transformer is chosen to be 500KV. A LA is kept 30m from transformer. A lightening surge of 3500KV having peak time of 1 μsec strikes on the line. Check whether the transformer is properly co-ordinated? Take surge impedance of the line to be 350Ω. [8]

5. a) A 750KV flat horizontally configured transmission line has average ground clearance of 20m and phase spacing of 15m. The line uses bundle conductor of 2×0.30m diameter. Determine the audible noise at ground level at a horizontal distance of 20m from the outer most conductor. Assume electric field gradient at the surface of the conductor is 20 KV/cm. Use emperical formula for AN due to i^{th} conductor as: [8]

   $$AN(i) = 120 \log_{10} Em(i) + 55 \log_{10} d - 11.4 \log_{10} Di + 26.4 \log_{10} N - 115.4$$

   Here

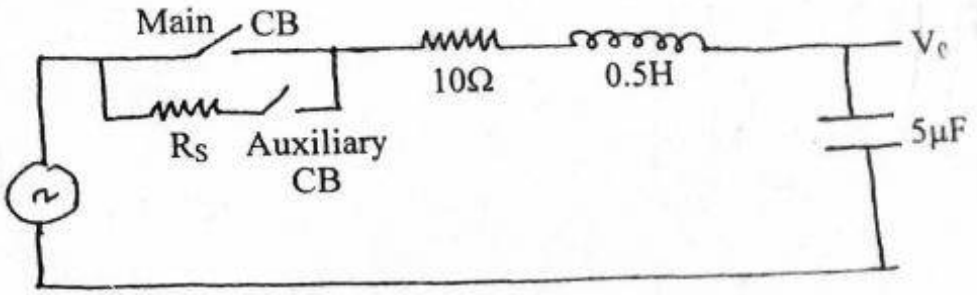
   Em : KV/cm d : cm D : m

b) A surge of 15KV magnitude travels along a cable towards its junction with an overhead line. The inductance and capacitance of the cable is 0.3 mH/km and 0.4 μF/km respectively and that of overhead line is 1.5 mH/km, 0.012 μF per km respectively. Find the voltage rise at the junction due to the surge. [8]

6. Using the single-phase equivalent lumped parameter model circuit of a 3 phase, 400KV, 50HZ, 400 km long EHV transmission line shown below in figure, compute: [8+8]

a) The maximum per unit switching over voltage while closing the main CB without external switching resistance R_S considering the trap charge across the capacitor as –1 pu.

b) Switching resistance R_S to be inserted during the closing of the CB so that the maximum switching over voltage in part (a) will be limited to 1.8 pu.



Switching over voltage is given as

$$(E - V_0)\left[1 - e^{-\alpha t}\frac{\sqrt{\alpha^2 + w^2}}{w}\cos(wt - \phi)\right]^{+V_0}$$

Where, $\tan\phi = \alpha/w \quad \phi = \tan{-1}\ \alpha/w$

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