2521/305
2601/305
ELECTRICAL POWER SYSTEMS AND
ELECTROMAGNETIC FIELD THEORY
June/July 2019
Time: 3 hours

THE KENYA NATIONAL EXAMINATIONS COUNCIL

DIPLOMA IN ELECTRICAL AND ELECTRONIC ENGINEERING (POWER OPTION)

MODULE III

ELECTRICAL POWER SYSTEMS AND ELECTROMAGNETIC FIELD THEORY

3 hours

INSTRUCTIONS TO CANDIDATES

You should have the following for this examination:
Answer booklet;
Mathematical table;
Non-programmable scientific calculator;
Drawing instruments.
*This paper consists of **TWO** sections; **A** and **B**.*
*Answer **THREE** questions from section **A** and **TWO** questions from section **B**.*
All questions carry equal marks.
Maximum marks for each part of a question are as indicated.
Candidates should answer the questions in English.
Take: $\varepsilon_0 = 8.85 \times 10^{-12}$ F/m
$\mu_o = 4\pi \times 10^{-7}$ H/m

This paper consists of 8 printed pages.

Candidates should check the question paper to ascertain that all the pages are printed as indicated and that no questions are missing.

SECTION A: ELECTRICAL POWER SYSTEMS

*Answer **THREE** questions from this section.*

1. (a) State **three** methods of reducing the system transfer reactance for improvement of steady-state stability. (3 marks)

   (b) Derive the swing equation of a synchronous generator. (6 marks)

   (c) The ABCD constants of a nominal π network representing a three phase transmission line are:

   $A = D = 0.94\angle 0.8^\circ$, $B = 66\angle 72^\circ\,\Omega$, $C = 0.002\angle 91^\circ$ siemens.

   Given that both sending-end and receiving end voltages are kept constant at 132 KV, determine the steady-state stability limit with:

   (i) the ABCD constants as indicated;

   (ii) both series resistance and shunt admittance neglected.

   (11 marks)

2. (a) Explain the operation of a synchronous phase modifier as used in transmission lines. (4 marks)

   (b) With the aid of a labelled circuit and phasor diagram, of a nominal-π-network, show that the sending voltage is given by:

   $$V_s = \left(1 + \frac{YZ}{2}\right)V_r + I_r Z$$ (6 marks)

   (c) A transmission line has a span of 280 m between level supports. The conductor has an effective diameter of 2.04 cm and weighs $0.875\,kg/m$. Its ultimate strength is 8080 kg. The conductor has an ice coating of radial thickness 1.3 cm and is subjected to a wind pressure of $4.01\,gm/cm^2$ of projected area. If the factor of safety is 2, determine the vertical sag. (10 marks)

3. (a) Distinguish between symmetrical and unsymmetrical faults. (4 marks)

(b) The line currents of a 3-phase system supplying unbalanced load are:

$I_R = (120 + j\,60)A$

$I_Y = (120 - j\,120)A$

$I_B = (-150 + j\,100)A$

Determine the following symmetrical components:

(i) I_{RO};
(ii) I_{RI};
(iii) I_{R2}.

(8 marks)

(c) **Figure 1** shows an unloaded three-phase system with a single-line to ground fault at point F. The system neutral is solidly grounded. Show that the fault current:

$$I_R = \frac{3\,E_R}{Z_0 + Z_1 + Z_2 + 3\,Z_f}$$

Where:

Z_f = fault impedance.
Z_0 = zero sequence impedance.
Z_1 = positive sequence impedance.
Z_2 = Negative sequence impedance.

(8 marks)

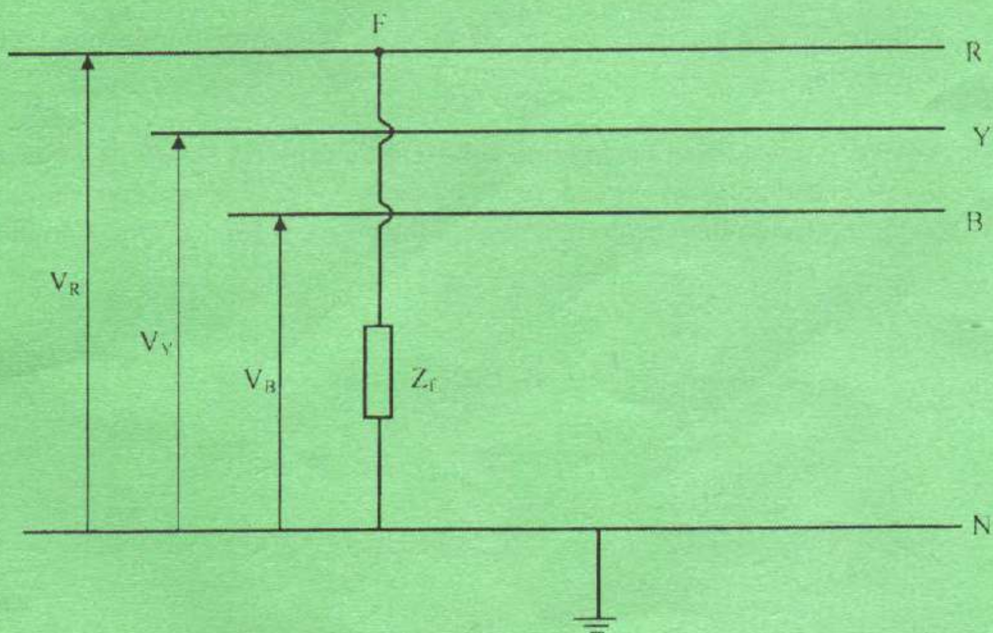

Fig. 1

4. (a) Explain **three** functions of spark gaps of a valve-type surge arrester. (6 marks)

(b) With the aid of a labelled typical voltage surge waveform, describe the $\frac{1}{60}$ voltage surge. (4 marks)

(c) A 100 km long, 3-phase, 50 Hz transmission line has the following line constants:

Resistance/phase/km = $0.2\,\Omega$
Inductance/phase/km = 2 mH
Capacitance (line to neutral)
per km = $0.015\,\mu F$.

If the line supplies a star-connected load of 50 MW at 132 KV, 0.8 power factor lagging, use the nominal - T- method to determine the sending end:

(i) voltage;
(ii) current.

(10 marks)

5. (a) With reference to protective relays, explain the following terms:

(i) pick-up current;

(ii) plug-setting multiplier;

(iii) current setting.

(6 marks)

(b) With the aid of a labelled diagram, describe the operation of induction type directional power relay. (8 marks)

(c) A 3-phase transformer having line-voltage ratio of $415\,V/11\,kV$ is connected in star-delta and protective transformers on the 415 V side have a current ratio of 600/6 A. Determine the current ratio of the protective transformers on the 11 kV side.

(6 marks)

SECTION B: ELECTROMAGNETIC FIELD THEORY

*Answer **TWO** questions from this section.*

6. (a) (i) State **two** properties of electromagnetic waves.

(ii) Explain the reason for using three dimensional co-ordinate system in the analysis of electromagnetic fields.

(4 marks)

(b) (i) State Stoke's theorem.

(ii) **Figure 2** shows a diagram of an elemental electric charge located in space. Using cylindrical co-ordinate system, write the expressions for the surface area for the element.

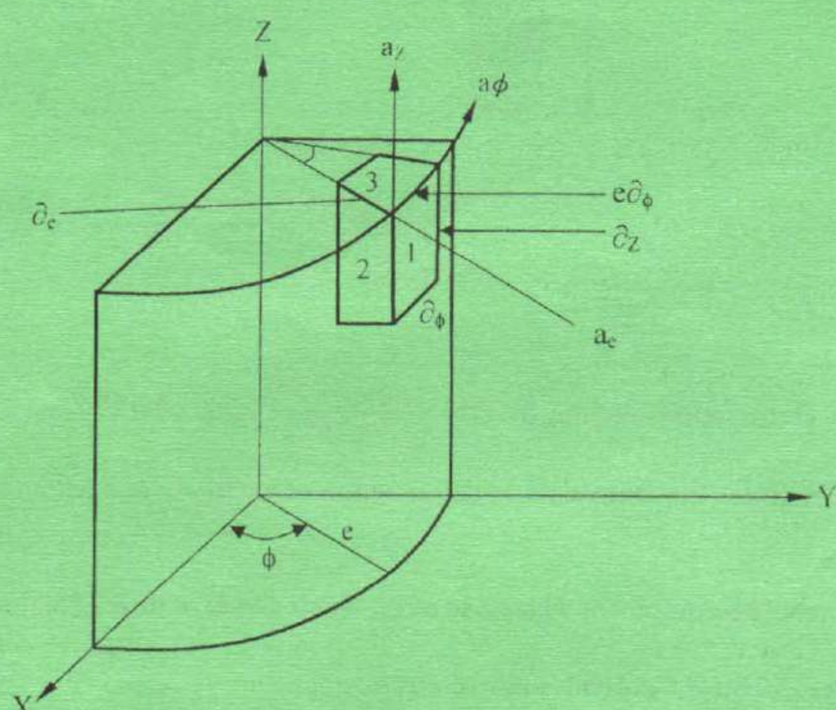

Fig. 2

(iii) **Figure 3** shows a line charge distribution in which a cylindrical charge tube oriented along the Z axis has a line charge density $\rho_l = 2Z$. Z is the distance from bottom end of the tube.

Determine the total charge contained. (10 marks)

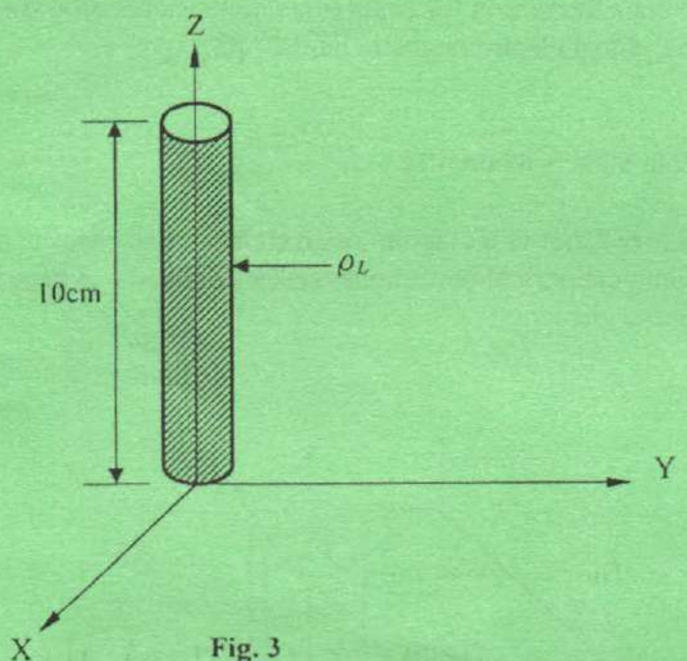

Fig. 3

(c) A vector field is defined by $\hat{G} = \frac{2x}{(1+y^2)}\hat{a}_x + (y+Z+11)\hat{a}_y + (5x - Z^2)\hat{a}_z$

Determine the unit vector in the direction of vector $\hat{G}$ at a point $(1, 2, -3)$. (6 marks)

7. (a) State **two** equipment which use electrostatic fields in their operation. (2 marks)

(b) (i) State Coulomb's law of electrostatics.

(ii) A point charge $Q_1 = 2\,\mu C$ is located at $P_1(3, 7, -4)$ in free space and a second point charge $Q_2 = -5\,\mu C$ is at a point $P_2(2, 4, -1)$. Determine the total electric field strength at a point (12, 15, 18) due to both charges. (10 marks)

(c) (i) Distinguish between convection and conduction currents in electromagnetic fields study.

(ii) State the Maxwell's equations for time varying fields in integral form. (6 marks)

(d) **Figure 4** shows a parallel plate capacitor connected to an alternating generator of voltage V volts. Redraw the circuit and indicate displacement current I_d and the capacitor current I_c. (2 marks)

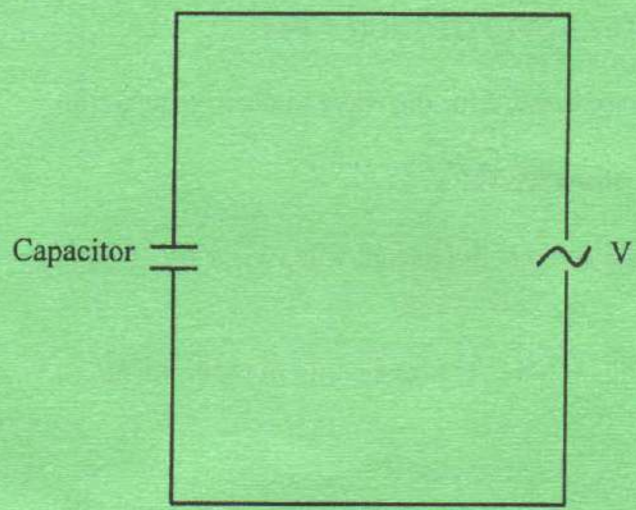

Fig. 4

8. (a) (i) State the Biot Savarts law.

(ii) **Figure 5** shows a cylindrical Gaussian surface for magnetostatic field at the interface between two different dielectrics of permittivities μ_1 and μ_2 respectively. Using Gauss law, show that the normal component of the magnetic flux density (B) is continuous across the boundary. (6 marks)

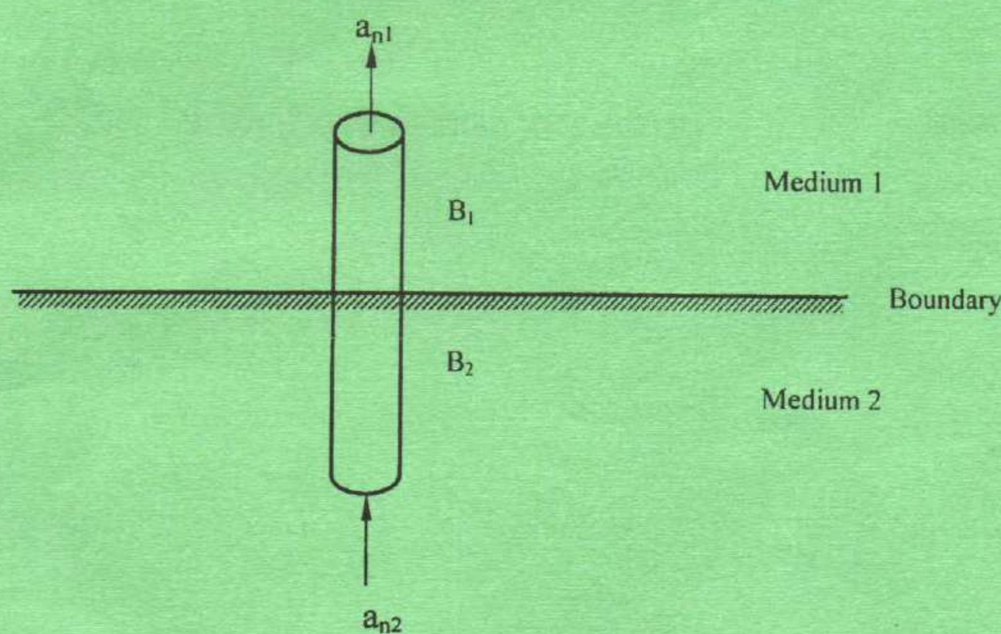

Fig.5

(b) (i) Define 'uniform plane wave' as used in electromagnetic fields.

(ii) The equation of a wave in a lossless medium is described by:

$$E_y(x,t) = C_1 \cos(wt - Bx) + C_2 \cos(wt + Bx).$$

(I) Obtain the expression for the wave in positive direction.

(II) Determine the wave velocity.

(III) Describe the wave at the instant when $C_1 = C_2$.

(6 marks)

(c) A $9.4 \times 10^{9} Hz$ uniform plane wave is propagating in space where $\mu_r = 2$ and $\varepsilon_r = 3$. Determine the:

(i) velocity of propagation;

(ii) phase constant;

(iii) intrinsic impedance.

(8 marks)

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