2602/304
ELECTROMAGNETIC FIELDS THEORY
AND COMMUNICATION SYSTEMS
Oct./Nov. 2022
Time: 3 hours

THE KENYA NATIONAL EXAMINATIONS COUNCIL

DIPLOMA IN ELECTRICAL AND ELECTRONIC ENGINEERING (TELECOMMUNICATION OPTION)

MODULE III

ELECTROMAGNETIC FIELDS THEORY AND COMMUNICATION SYSTEMS

3 hours

INSTRUCTIONS TO CANDIDATES

You should have the following for this examination:
Answer booklet;
Drawing instruments;
Mathematical tables/non programmable electronic calculator.
*This paper consists of **TWO** sections; **A** and **B**.*
*Answer any **TWO** questions from section **A** and any **THREE** questions from section **B** in the answer booklet provided.*
All questions carry equal marks.
Maximum marks for each part of a question are as shown.
Candidates should answer the questions in English.

Take: ***Permittivity of free space,*** $\varepsilon_0 = 8.85 \times 10^{-12}\ F/m$
Permeability of free space, $\mu_0 = 4\pi \times 10^{-7}\ H/m$
Free space wave velocity $c = 3 \times 10^8\ m/s$
Wave impedance of free space, $Z_0 = 377\Omega$

This paper consists of 6 printed pages.

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

Turn over

SECTION A: ELECTROMAGNETIC FIELDS THEORY

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

1. (a) (i) State **three** classes of waves in the electromagnetic spectrum.

(ii) Figure 1 shows a waveform. Identify the parts labelled A and B.

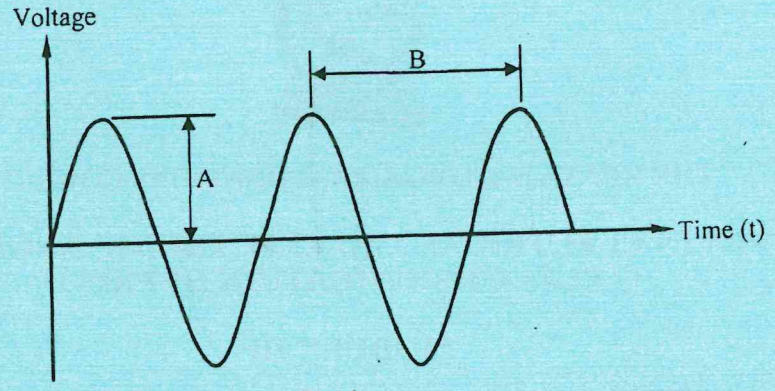

Fig. 1

(5 marks)

(b) State Biot-Savart's law. (2 marks)

(c) Two parallel rectangular plates measuring 20 cm by 40 cm carry an electric charge of 0.2 μC. The plates are spaced 5 mm apart and the voltage between them is 0.25 kV. Determine the:

(i) capacitance of the arrangement;
(ii) electric flux density;
(iii) electric field strength.

(6 marks)

(d) With the aid of a labelled diagram, describe the hysteresis loop of magnetization.

(7 marks)

2. (a) Write Maxwell's equations in integral form for time varying fields. (4 marks)

(b) A coil of 300 turns is wound uniformly on a ring of non-magnetic material. The ring has a mean circumference of 40 cm and a uniform cross-sectional area of 4 cm^2. The current flowing through the coil is 5 A. Determine the:

(i) magnetic field strength;
(ii) flux density;
(iii) total magnetic flux in the ring.

(6 marks)

(c) Describe Transverse Electromagnetic (TEM) wave. (2 marks)

(d) A lossless transmission line has the following parameters:

Inductance, L =0.25 $\mu H/m$
Capacitance, C = 20 pF/m
Resistance, R = 0
Conductance, G = 0

A wave of 100 MHz propagates through the line. Determine the:

(i) attenuation constant;
(ii) phase constant;
(iii) wavelength;
(iv) velocity of propagation.

(8 marks)

3. (a) Describe poynting vector with respect to electromagnetic fields. (2 marks)

(b) An electromagnetic wave has magnetic and electric field strength of 5 T and 2 V/m respectively. Determine the:

(i) magnetic field energy density;
(ii) electric field energy density;
(iii) total energy in the wave.

(6 marks)

(c) A material with a susceptibility of 2 has a magnetic flux density of B = 0.03 T. Determine the:

(i) relative permeability;

(ii) magnetic field strength;

(iii) magnetization.

(6 marks)

(d) (i) Define electric field intensity.

(ii) A point charge Q = 10 nC is located at point (2, 3, 5) in free space. Determine the electric field intensity at point (6, 7, 8) due to the charge.

(6 marks)

SECTION B: COMMUNICATIONS SYSTEMS

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

4. (a) List **two**:

(i) advantages of satellite communication over terrestrial microwave links;
(ii) reasons why satellite communications use frequencies above 1 GHz.
(4 marks)

(b) With the aid of a labelled diagram, describe the operation of a star VSAT network topology. (5 marks)

(c) Draw a labelled block diagram of the power sub-system of a space satellite. (4 marks)

(d) An earth station operating at 9 GHz radiates 3 kW of power towards a space satellite station located 36,000 km away. The gain of the transmitting antenna is 50 dB and the receiving antenna, whose efficiency is 75% receives 2.4 μW. Determine the gain of the receiving antenna, in dB. (7 marks)

5. (a) Define each of the following with respect to Radar systems:

(i) maximum unambiguous range;
(ii) range resolution.
(2 marks)

(b) With the aid of a labelled block diagram, describe the operation of a continuous wave Radar system. (8 marks)

(c) A 6 GHz Radar system detects a moving target over a range of 800 km in 25 seconds. Determine the:

(i) doppler frequency shift of the system;
(ii) target relative velocity.
(6 marks)

(d) A Radar system operates at 7.5 GHz with a pulse repetition frequency of 800 pulses per second. Determine the lowest two blind speeds for the system. (4 marks)

6. (a) State **three** defining features of 3G cellular networks. (3 marks)

(b) Draw a labelled diagram of a GSM cellular network architecture. (5 marks)

(c) Define each of the following with respect to television network:

(i) monochromaticity;
(ii) hue;
(iii) polarization.
(3 marks)

(d) Figure 2 shows a block diagram of a colour TV transmitter.

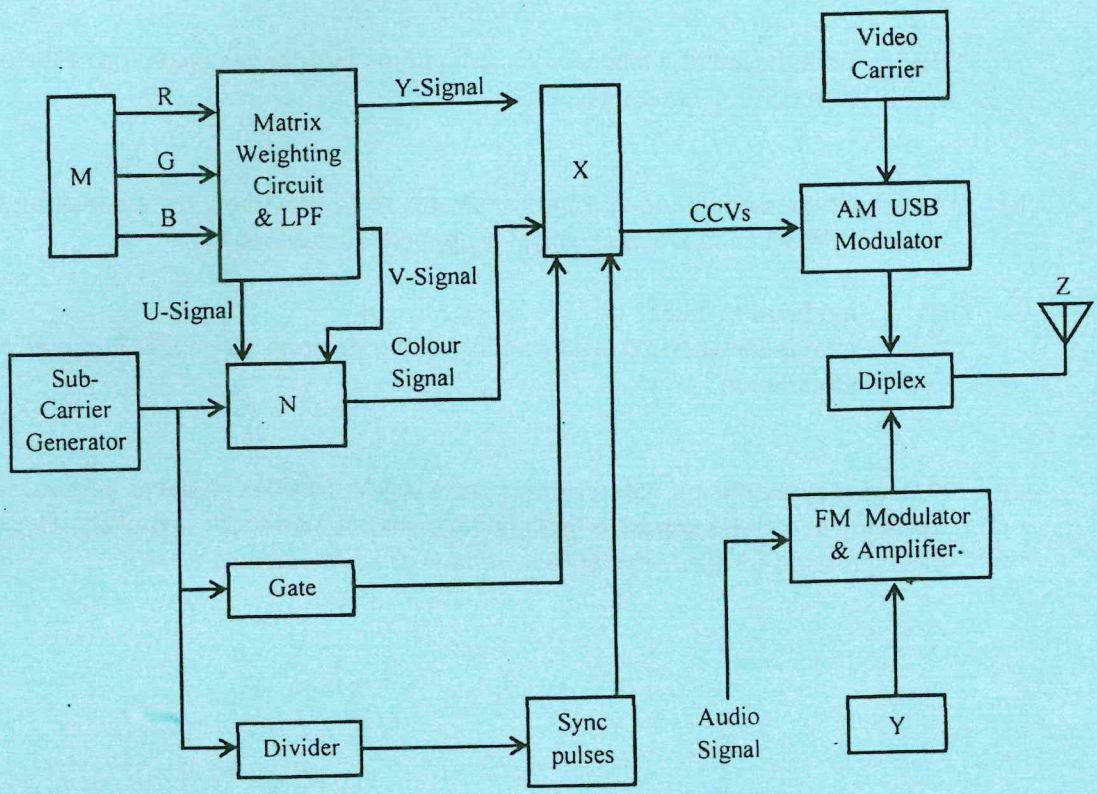

Fig. 2

(i) identify the parts labelled M, N, X, Y and Z;

(ii) state the function of parts M, N, X and Z.

(9 marks)

7. (a) State **three** causes of attenuation in wavelength. (3 marks)

(b) With the aid of a labelled diagram, describe the operation of a reflex klystron oscillator. (8 marks)

(c) A rectangular waveguide with an internal width of 4 cm has a characteristic wave impedance of 650 Ω and the signal carried is in $TE_{1,0}$ mode. Determine the:

(i) cut-off wavelength;
(ii) signal wavelength;
(iii) phase velocity;
(iv) group velocity.

(9 marks)

8. (a) (i) List **two** merits of the single side band suppressed carrier (SSBSC) radio systems.

(ii) With the aid of a labelled block diagram, describe the operation of the phase shift SSBSC radio transmitter.

(9 marks)

(b) An amplitude modulation transmitter radiates 150 kW without the modulating signal and 220 kW when modulating signal is applied. Determine the:

(i) modulation index;
(ii) total radiated power with a additional modulating signal that produces 25% modulation.

(6 marks)

(c) A frequency modulator whose carrier wave is 6 V, 14 MHz produces a frequency deviation of 24 kHz when the modulating signal of 3sin 6280t is applied. Derive the expression for the instantaneous voltage of the modulated wave. (5 marks)

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