higher education & training

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REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE

COMMUNICATION-ELECTRONICS N6

(8080246)

25 November 2022 (X-paper)
09:00–12:00

Drawing instruments and nonprogrammable calculators may be used.

This question paper consists of 6 pages and a formula sheet of 5 pages.

243Q1E2225

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DEPARTMENT OF HIGHER EDUCATION AND TRAINING
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE
COMMUNICATION-ELECTRONICS N6
TIME: 3 HOURS
MARKS: 100

INSTRUCTIONS AND INFORMATION

1. Answer all the questions.
2. Read all the questions carefully.
3. Number the answers according to the numbering system used in this question paper.
4. Start each question on a new page.
5. Use only a black or blue pen.
6. Write neatly and legibly.

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QUESTION 1

1.1 Design a π-section to match impedances of 600 Ω to 125 Ω with an attenuation of 40 $d\beta$. Draw the completed section of this attenuator and insert values. (10)

1.2 Draw a neat, labelled graph of ATTENUATION versus FREQUENCY for a band-stop filter. (2)

1.3 1.3.1 How is the attenuation of a prototype filter improved?

1.3.2 How is the characteristic impedance of a prototype filter improved? (2 × 1) (2)

1.4 Study FIGURE 1 below and choose the correct term from those in brackets. Write only the answer next to the question number (1.4.1–1.4.2) in the ANSWER BOOK.

1.4.1 FIGURE 1 shows the (input/output) half section for a composite filter.

1.4.2 FIGURE 1 shows a (high-pass/low-pass) filter.

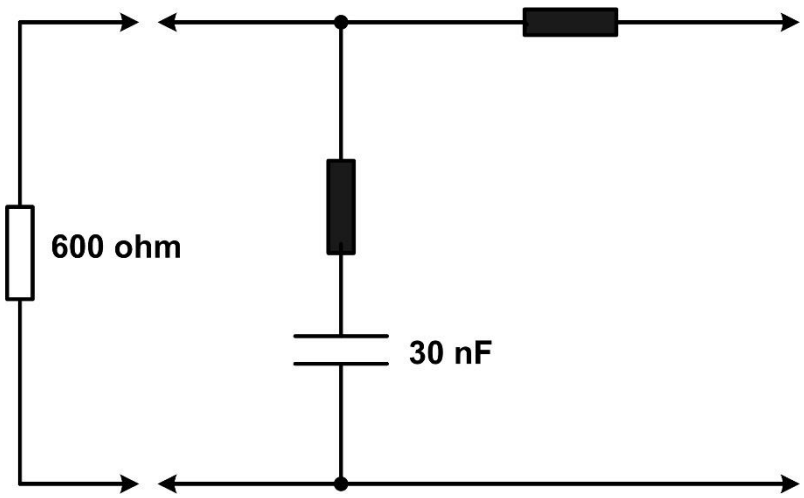


FIGURE 1

(2 × 1) (2)

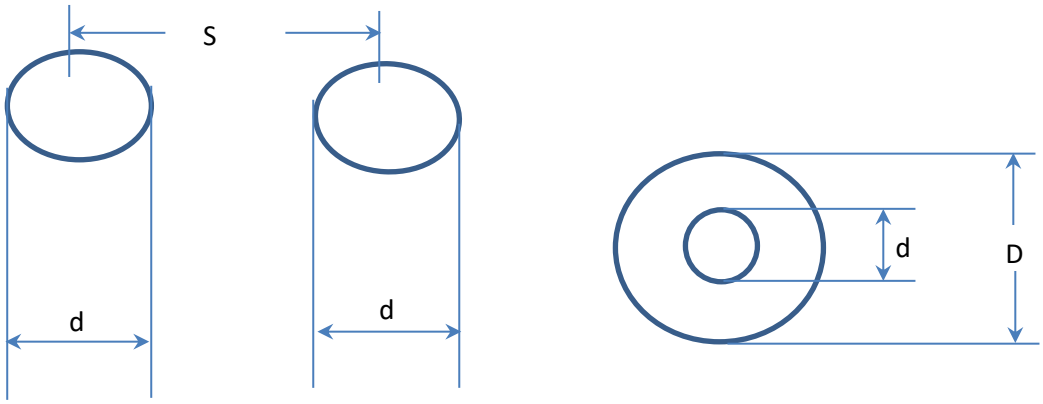
1.5 Determine the cut-off frequency for the filter in FIGURE 1. (4)

[20]

QUESTION 2

2.1 Name THREE elements that determine the characteristic impedance of a transmission line. (3)

2.2 The two diagrams below, together with their formulae, represent the transmission line geometry whereby a coaxial cable has a 75 Ω characteristic impedance and a nominal capacitance of 64 $\rho f/m$.



(a) Parallel wire > Z_0 = 276 log $\frac{25}{d}$ Ω

(b) Coaxial line > Z_0 = $\frac{138}{\sqrt{K}}$ log $\frac{D}{d}$

2.2.1 Calculate the inductance per metre if the inner conductor has a diameter of 0,584 mm and the dielectric constant of the insulation is 2,23. (8)

2.2.2 Calculate the outer conductor diameter of the coaxial cable. (2)

2.3 Design an attenuator network that will match an output impedance of 400 ohms to an input impedance of 280 ohms.

Sketch the completed network and insert all relevant values. (6)

2.4 Indicate whether the following statement is TRUE or FALSE by writing only 'True' or 'False' next to the question number (2.4) in the ANSWER BOOK.

A transmission line provides a means of conveying signals or power from one point to another. (1)

[20]

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QUESTION 3

3.1 The following information was obtained during a test on a transmission line at a frequency of 900 radians/second.

R = 75 ohms/km
G = 50 μ-mhos/km
L = 2,5 mH/km
C = 0,6 pF/km

Calculate the following:

3.1.1 The wavelength of the transmission (6)

3.1.2 The velocity of the transmission (2)

3.2 For the primary line constants in QUESTION 3.1, determine the characteristic impedance of the transmission line. (2)

3.3 What conclusion can be drawn from the answer you obtained in QUESTION 3.2? (3)

3.4 Discuss the term *standing-wave ratio*. (3)

3.5 Explain how the reactive component can be tuned out of a transmission line. Make use of a simple sketch to support your description. (4)

[20]

QUESTION 4

4.1 Indicate whether the following statements are TRUE or FALSE by writing only 'True' or 'False' next to the question number (4.1.1–4.1.4) in the ANSWER BOOK.

4.1.1 Intrinsic noise enters the receiver from outside the receiver.

4.1.2 Extrinsic noise is generated within the receiver itself.

4.1.3 Signal-to-noise ratio is the ratio of signal power to noise power at the same point in a circuit.

4.1.4 Noise factor is the ratio of signal to noise at the input to signal to noise at the output.

(4 × 1) (4)

4.2 Draw a fully labelled circuit diagram of a diode noise generator that is used to determine the noise figure of a receiver under test when it is not practical to calculate the equivalent noise resistance under transit-time conditions. (5)

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4.3 The following information regarding a two-stage amplifier is given:

	STAGE 1	STAGE 2
Gain	15	30
Input resistance	9 kΩ	27 kΩ
Equivalent resistance	12 kΩ	18 kΩ
Output resistance	21 kΩ	25 MΩ

Determine the following:

4.3.1 The equivalent noise resistance (6)

4.3.2 The output noise voltage for a bandwidth of 10 MHz and a temperature of 24 °C (2)

4.4 Determine the value of the input resistor to an amplifier which has a frequency range of 90 kHz to 120 kHz. A noise voltage of 18 μV is generated at a temperature of 25 °C.

Take Boltzmann's constant as $1{,}38 \times 10^{-23}$ J/K. (3)
[20]

QUESTION 5

5.1 Draw a neat, labelled circuit diagram of a Class C modulator using an NPN transistor.

Indicate all the relevant waveforms. (7)

5.2 Determine the bandwidth of a channel that has a channel capacity of 2 000 000 bits/s and a signal-to-noise ratio of 15 dB. (5)

5.3 Determine the minimum power needed to detect a target of 36 m^2 at a distance of 300 km if the following information is given:

Operating frequency = 1,5 GHz
Received power = $0{,}9 \times 10^{-12}$ watts
Antenna gain = 20 dB
Atmospheric attenuation = 0,005 dB/km (8)
[20]

TOTAL: 100

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COMMUNICATION-ELECTRONICS N6

FORMULA SHEET

1. Filters

Low-pass

$$f_c = \frac{1}{\pi \sqrt{L \,.\, C}} \qquad Z_o = \sqrt{\frac{L}{C}}$$

High-pass

$$f_c = \frac{1}{4 \,.\, \pi \sqrt{L \,.\, C}} \qquad Z_o = \sqrt{\frac{L}{C}}$$

Low-pass m-derived sections (also for half-sections)

T-section *π-section*

$$\textit{Series } L = \frac{m \,.\, L}{2} \qquad \textit{Shunt } C = \frac{m \,.\, C}{2}$$

$$\textit{Shunt } C = m \,.\, C \qquad \textit{Series } L = m \,.\, L$$

$$\textit{Shunt } L = \frac{1 - m^2}{4 \,.\, m} \,.\, L \qquad \textit{Series } C = \frac{1 - m^2}{4 \,.\, m} \,.\, C$$

$$m = \sqrt{1 - \frac{f_c^2}{f_\infty^2}} \qquad L = \frac{Z_o}{\pi \,.\, f_c} \qquad C = \frac{1}{\pi \,.\, Z_o \,.\, f_c}$$

High-pass m-derived sections (also for half-sections)

T-section *π-section*

$$\textit{Series } C = \frac{2 \,.\, C}{m} \qquad \textit{Series } C = \frac{C}{m}$$

$$\textit{Shunt } C = \frac{4 \,.\, m}{1 - m^2} \,.\, C \qquad \textit{Series } L = \frac{4 \,.\, m}{1 - m^2} \,.\, L$$

$$\textit{Shunt } L = \frac{L}{m} \qquad \textit{Shunt } L = \frac{2 \,.\, L}{m}$$

$$m = \sqrt{1 - \frac{f_\infty^2}{f_c^2}} \qquad L = \frac{Z_o}{4 \,.\, \pi \,.\, f_c} \qquad C = \frac{1}{4 \,.\, \pi \,.\, Z_o \,.\, f_c}$$

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Band-pass sections

$$\textit{Series } L = \frac{Z_o}{2 \,.\, \pi \,[f_2 - f_1]} \qquad \textit{Series } C = \frac{f_2 - f_1}{2 \,.\, \pi \,.\, Z_o \,.\, f_1 \,.\, f_2}$$

$$\textit{Shunt } L = \frac{Z_o \,[f_2 - f_1]}{4 \,.\, \pi \,.\, f_1 \,.\, f_2} \qquad \textit{Shunt } C = \frac{1}{\pi \,.\, Z_o \,[f_2 - f_1]}$$

Band-stop sections

$$\textit{Series } L = \frac{Z_o \,[f_2 - f_1]}{2 \,.\, \pi \,.\, f_1 \,.\, f_2} \qquad \textit{Series } C = \frac{1}{2 \,.\, \pi \,.\, Z_o \,[f_2 - f_1]}$$

$$\textit{Shunt } L = \frac{Z_o}{4 \,.\, \pi \,.\, [f_2 - f_1]} \qquad \textit{Shunt } C = \frac{f_2 - f_1}{\pi \,.\, Z_o \,.\, f_1 \,.\, f_2}$$

2. *Attenuators* *Symmetrical*

Bridged T-type

$$Z_B = Z_o \,[N - 1]$$

$$Z_c = \frac{Z_o}{N - 1}$$

$$Z_A = Z_o$$

where $dB = 20 \log N$

Asymmetrical

L-type

$$Z_A = \sqrt{R_1 \,(R_1 - R_2)}$$

$$Z_B = \sqrt{\frac{(R_1 \,.\, R_2^2)}{R_1 - R_2}}$$

T-Type

$$Z_1 = R_1 \left[\frac{N^2 + 1}{N^2 - 1}\right] - 2 \sqrt{R_1 \,.\, R_2} \left[\frac{N}{N^2 - 1}\right]$$

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$$Z_2 = 2\sqrt{R_1 \,.\, R_2}\left[\frac{N}{N^2-1}\right]$$

$$Z_3 = R_2\left[\frac{N^2+1}{N^2-\ 1}\right] - 2\sqrt{R_1 \,.\, R_2}\left[\frac{N}{N^2-1}\right]$$

where $dB = 20 \log N$

π-type

$$Z_A = R_1\left[\frac{N^2-1}{N^2-2\,.\,N\,.\,S+1}\right]$$

$$Z_B = \frac{\sqrt{R_1 \,.\, R_2}}{2}\left[\frac{N^2-1}{N}\right]$$

$$Z_c = R_2\left[\frac{N^2-1}{N^2-2\,.\,N/S+1}\right]$$

where $dB = 20 \log N$ *and* $S = \sqrt{\frac{R_1}{R_2}}$

Insertion loss $= 20 \log \frac{I_1}{I_2}$

3. Transmission lines

$$Z_o = \sqrt{Z_{o/c} \,.\, Z_{s/c}} \qquad Z_o = \sqrt{\frac{R + j\omega L}{G + j\omega C}}$$

$$\gamma = \sqrt{[R + j\omega L]\,[G + j\omega C]} \qquad \gamma = \alpha + j\beta$$

$$\lambda = \frac{2\,.\,\pi}{\beta} \qquad V = \frac{\omega}{\beta} \qquad t = \frac{d}{v}$$

$L.G = C.R$

$$VSWR = \frac{Z_R}{Z_o} \text{ or } \frac{Z_o}{Z_R}$$

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$$Also\ VSWR = \frac{1+\rho}{1-\rho}$$

$$\rho = \frac{Z_R - Z_o}{Z_R + Z_o}$$

$$\rho = \frac{V_{(reflected)}}{V_{(incident)}}$$

Normalised impedance

$$Z_o^{'} = \frac{R}{Z_o} \pm j\,\frac{X}{Z_o}$$

4. Noise

$$E_n = \sqrt{4KT\Delta fR} \qquad E_n = \sqrt{4KT\Delta f\ [R_1 + R_2]}$$

$$R_{eq} = R_A + \frac{R_B}{A_1^2} + \frac{R_c}{A_1^2\ .\ A_2^2}$$

where $R_A = R_{1in} + R_{1eq}$

$$R_B = \frac{R_{1(out)}\ .\ R_{2(in)}}{R_{1(out)} + R_{2(in)}} + R_{2(eq)}$$

$$R_c = R_{2out}$$

$$F = 1 + \frac{R_{eq}^{'}}{R_a} \qquad R_{eq}^{'} = R_{eq} - R_t$$

$$F = \frac{S/N_{(in)}}{S/N_{(out)}} \qquad F = 1 + \frac{T_{eq}}{T_o}$$

$$C = \Delta f \log_2 [1 + S/N]$$

where $dB = 10\ \log\ S/N$

5. Modulation

$$m = \frac{V_m}{V_c} \qquad \eta = \frac{P_{dc}}{P_c} \times 100\,\%$$

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$$P_{dc} = I_{mean} \times V_{dc}$$

$$P_{\text{mod}} = \frac{P_{SB}}{\eta}$$

$$P_{SB} = \frac{m^2 \,.\, P_c}{2}$$

$$P_T = P_c + P_{SB}$$

6. Antennae

$$P_r = P_d \times A \qquad A = \frac{\lambda^2}{4 \,.\, \pi}$$

$$\lambda = \frac{c}{f}$$

$$P_r = P_d \times A \,.\, G_r \quad \textit{where}$$

$$dB = 10 \log\, G$$

$$P_d = \frac{E^2}{120 \,.\, \pi}$$

$$P_d = \frac{P_t \,.\, G_t}{4 \,.\, \pi \,.\, d^2}$$

$$P_d = \frac{30 \,.\, G \,.\, P_t}{120 \,.\, \pi \,.\, d^2}$$

$$P_t = \frac{[4 \,.\, \pi]^3 \,.\, d^4 \,.\, P_r}{G_t \,.\, G_r \,.\, Q \,.\, \lambda^2}$$

$$P_r = \frac{10 \,.\, P_t \,.\, G_t}{4 \,.\, \pi \,.\, d^2}$$

$$E_r = \frac{\sqrt{30 \,.\, P_r}}{d}$$

$$E_S = \frac{\sqrt{30 \,.\, P_t \,.\, G_t}}{d}$$

$$A = \frac{G \,.\, \lambda^2}{4 \,.\, \pi}$$

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