UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 3. Examination in Engineering: October 2019

Module Number: EE3302 **Module Name: Engineering Electromagnetism**

[Three Hours]

[Answer **all questions**, each question carries ten marks]

(Permittivity of free space $\xi_0 = 10^{-9}/(36\pi)$ F/m and Permeability of free space $\mu_0 = 4\pi\times10^{-7}$ H/m)

Q1 a) Find the gradient of the following vector fields given in Cartesian, Cylindrical and Spherical coordinate systems.

i. $V = e^{-z}\sin 2x \cosh y$

ii. $U = \rho^2 z \cos 2\phi$

iii. $W = 10r\sin^2\theta\cos\phi$ [4.5 Marks]

b) States the divergence theorem. [1 Mark]

c) Determine the divergence of these vector fields given in Cartesian, Cylindrical and Spherical coordinate systems.

i. $P = x^2 yz\underset{\sim}{a}_x + xz\underset{\sim}{a}_z$

ii. $Q = \rho\sin\phi\underset{\sim}{a}_\rho + \rho^2 z\underset{\sim}{a}_\phi + z\cos\theta\,\underset{\sim}{a}_z$

iii. $T = \frac{1}{r^2}\cos\theta\underset{\sim}{a}_r + r\sin\theta\cos\theta\underset{\sim}{a}_\theta + \cos\theta\,\underset{\sim}{a}_\phi$ [4.5 Marks]

Q2. a) States the coulomb's low. [2 Marks]

b) States the electric field intensity. [2 Marks]

c) The finite sheet $0 \le x \le 1, 0 \le y \le 1$ on the $z = 0$ plane has a charge density $\rho_s = xy(x^2 + y^2\ 25)^{3/2}$ nC/m^2. Find the

i. total charge on the sheet.

ii. electric field at (0,0,5).

iii. force experienced by a -1 mC charge located at (0,0,5). [6 Marks]

Q3. a) i) States the Biot-Sarvart's law. [1Mark]

ii) States the Ampere's circuit law. [1 Mark]

b) i) States the Divergence theorem. [1 Mark]

ii) States the Stokes's theorem. [1 Mark]

c) Compute the value of the magnetic field in the air-gap of the device shown in Figure Q3 by neglecting both fringing effect in the air-gap and leakage flux. The parameters are given as $I_1 = 2$ A, $N_1 = 200$ turns, h = l_1 =10 cm, $l_2 = 5$ cm, w = 1 cm, l_g= 2 mm and $\mu = 2000\mu_0$.

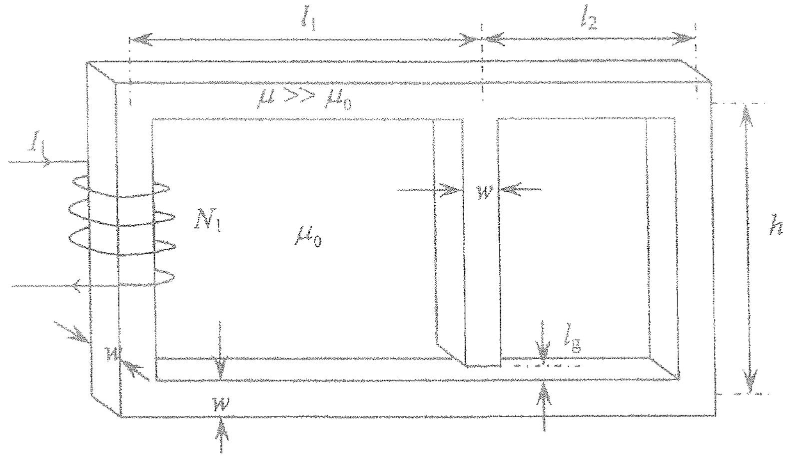

Figure Q3

[6 Marks]

Q4. The magnetic field component of a plane wave in a lossless dielectric ($\mu_r = 1$) is

$$\bar{H} = 30\sin(2\pi\times10^8 t - 5x)\bar{a}_z \; mA/m$$

a) Find relative permittivity (ξ_r). [1 Mark]

b) Calculate the wave length and wave velocity. [2 Marks]

c) Determined the wave impedance. [1 Mark]

d) Determined the polarization of the wave. [2 Marks]

e) Find the corresponding electric field component. [2 Marks]

f) Find the displacement current density. [2 Marks]

c) i) Reproduce the circuit diagram of a RC phase shift oscillator with the usual notations for components and indicate the amplifier, the feedback loop and the output.

ii) The feedback factor of the RC phase shift oscillator is given by

$$\beta = \frac{R^3}{(R^3 - 5\,R\,X_c^2) + j\,(X_c^3 - 6\,R^2 X_c)}$$

I. Explain the phase shift required by the feedback (loop) to oscillate the circuit.

II. Calculate the oscillator frequency.

III. Calculate the gain required for the amplifier.

[4 Marks]

Q5 a) i) State two differences between passive and active filters.

ii) Name the four basic types of filters, sketch their frequency responses and define the cut off frequencies for each type.

[2 Marks]

b) Figure Q5 b) shows a bandpass filter circuit.

i) Calculate the transfer function of the filter using the Laplace transform method or the impedance division method.

ii) Calculate the quality factor and the center frequency by comparing the transfer function in part b) i) with the standard transfer function of the bandpass filter.

iii) Calculate the resonant frequency of the filter circuit.

iv) The cut-off frequencies of this filter are given by

$$\omega_0 \sqrt{1 + \frac{1}{4Q^2}} \pm \frac{\omega_0}{2Q}$$

where ω_0 is the center frequency and Q is the quality factor.
Calculate the upper and lower cut off frequencies when R = 0.1 kΩ, L = 2 mH, C = 6 µF and hence define the bandwidth of the filter.

[5 Marks]

c) i) Explain the difference between a Butterworth filter and a Chebyshev filter considering their typical frequency responses.

ii) Using the data in Table 5 and the VCVS (Voltage Controlled Voltage Source) design circuit in Figure Q5 c), design a second order high pass Chebyshev filter with a cut-off frequency 2.5 kHz and a gain in the passband of 2. The constant $K = 10^{-4}/(fC)$ where f is the desired cut-off frequency in Hz. Take C = 0.05 µF.

[3 Marks]

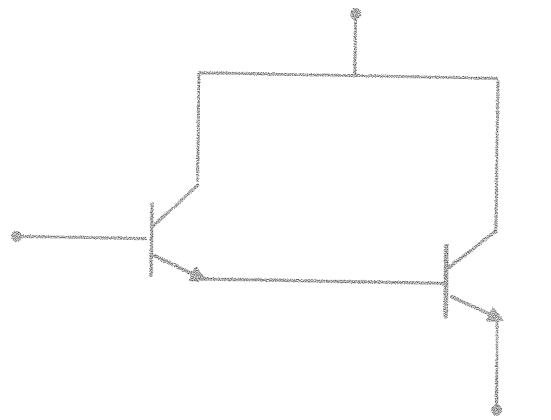

Figure Q1 a): Darlington Pair

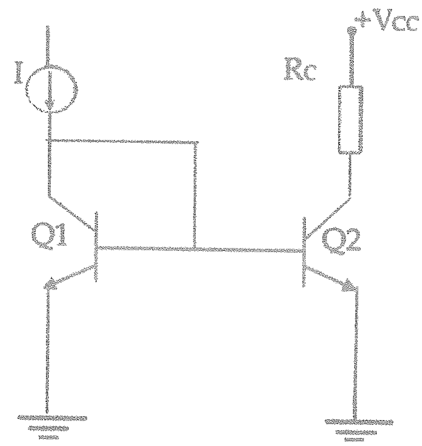

Figure Q1 b): Current Mirror Circuit

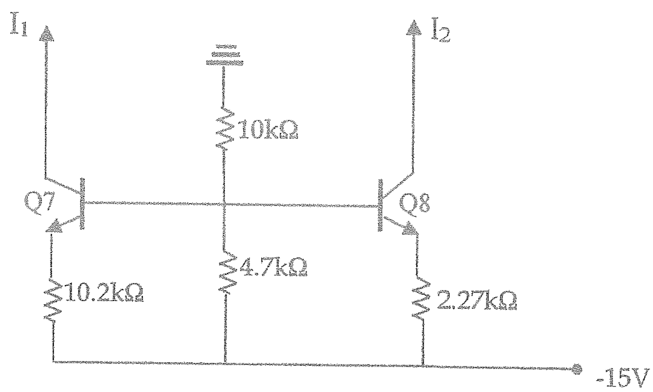

Figure Q1 c): Bias circuit for operational amplifier

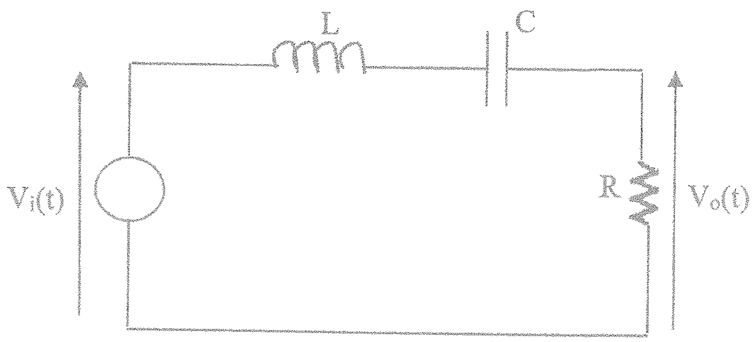

Figure Q5 b): Bandpass Filter Circuit

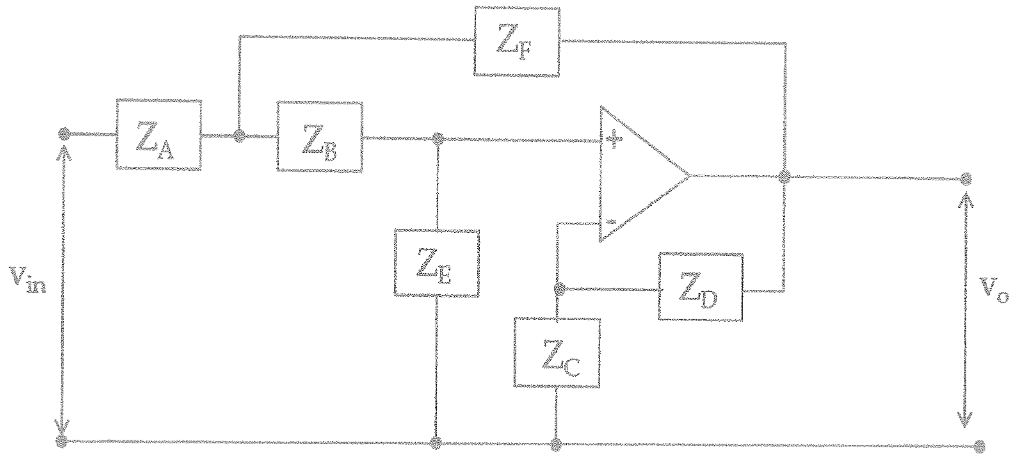

Figure Q5 c): VCVS Design Circuit

Table 5

Table 14–1
VCVS Filter Components

	Z_A	Z_B	Z_C	Z_D	Z_E	Z_F
Low-Pass Filter	R_1	R_2	R_3	R_4	C_1	C
High-Pass Filter	C	C	R_3	R_4	R_2	R_1

Table 14–2
Second-Order Low-Pass Butterworth VCVS Filter Designs

	Circuit Element Values[a]					
Gain	1	2	4	6	8	10
R_1	1.422	1.126	0.824	0.617	0.521	0.462
R_2	5.399	2.250	1.537	2.051	2.429	2.742
R_3	Open	6.752	3.148	3.203	3.372	3.560
R_4	0	6.752	9.444	16.012	23.602	32.038
C_1	0.33C	C	2C	2C	2C	2C

[a] Resistances in kilohms for a *K* parameter of 1.

Table 14–3
Second-Order Low-Pass Chebyshev VCVS Filter Designs (2 dB)

	Circuit Element Values[a]					
Gain	1	2	4	6	8	10
R_1	2.328	1.980	1.141	0.786	0.644	0.561
R_2	13.220	1.555	1.348	1.957	2.388	2.742
R_3	Open	7.069	3.320	3.292	3.486	3.670
R_4	0	7.069	9.959	16.460	24.261	33.031
C_1	0.1C	C	2C	2C	2C	2C

[a] Resistances in kilohms for a *K* parameter of 1.

Table 14–4
Second-Order High-Pass Chebyshev VCVS Filter Designs (2 dB)

	Circuit Element Values[a]					
Gain	1	2	4	6	8	10
R_1	0.640	1.390	2.117	2.625	3.040	3.399
R_2	3.259	1.500	0.985	0.794	0.686	0.613
R_3	Open	3.000	1.313	0.953	0.784	0.681
R_4	0	3.000	3.939	4.765	5.686	6.133

[a] Resistances in kilohms for a *K* parameter of 1.

Source: Reprinted from *Rapid Practical Designs of Active Filters*, D. Johnson and J. Hilburn.