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ESE 2019 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Electronics & Telecommunication Engineering

Test-8: Advanced Communication Topics + Computer Organization and Architecture
Signals and Systems-1 + Electronic Measurement and Instrumentation-1
Electromagnetics-2 + Basic Electrical Engineering-2

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Test Centres					Student's Signature
Delhi ☑	Bhopal ☐	Noida ☐	Jaipur ☐	Indore ☐	
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Instructions for Candidates

1. Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
2. Answer must be written in English only.
3. Use only black/blue pen.
4. The space limit for every part of the question is specified in this Question Cum Answer Booklet. Candidate should write the answer in the space provided.
5. Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
6. Last two pages of this booklet are provided for rough work. Strike off these two pages after completion of the examination.

FOR OFFICE USE	
Question No.	Marks Obtained
Section-A	
Q.1	45
Q.2	
Q.3	47
Q.4	
Section-B	
Q.5	41
Q.6	37
Q.7	40
Q.8	
Total Marks Obtained	210

Signature of Evaluator Ch. Ravi Sir

Cross Checked by JDA

Section A : Advanced Communication Topics + Computer Organization and Architecture

(a) Assume a memory system with two banks, one of which stores even-addressed words and the other one stores odd-addressed words (interleaving of odd and even addresses). Also assume that the banks have independent connections to the processor, so that there are no conflicts for the memory bus, and that the processor can execute up to 2 memory operations in a given cycle. However, the memory operations must be executed in order. Also make the simplifying assumption that the latency of each memory bank is one processor cycle, so the banks are never busy handling requests from previous cycles. Finally, assume that the processor always has 2 memory operations that it would like to execute on a given cycle.

(i) If the addresses of each memory request are very random, how many memory operations will the processor be able to execute each cycle on average?

(ii) If each memory bank returns 8 bytes of data per request, and processor cycles are 10 ns long, what is the peak bandwidth (in bytes/s) of this memory system, and what is the bandwidth that it will achieve on average?

[12 marks]

(i.) As the requests are random addresses, the possibility of the two addresses are –

			Prob.
odd + even	→	2 operations	1/4
odd + odd	→	1 operation	1/4
even + odd	→	2 operations	1/4
even + even	→	1 operation	1/4

On an average, No. of operations per cycle

$= \frac{1}{4} \times 2 + \frac{1}{4} \times 1 + \frac{1}{4} \times 2 + \frac{1}{4} \times 1 =$ 1.5 operations per cycle.

(ii.) peak bandwidth ≡ When two operations are performed.

peak bandwidth $\equiv \frac{2 \times 8 \text{ bytes}}{10 \text{ ns}} = 1.6 \times 10^9$ bytes/sec

$= 1.6$ GBPS.

on an averge,

No. of operations = 1.5

$\Rightarrow$ Average Bandwidth $= 1.5 \times \frac{8 \text{ bytes}}{10 \times 10^{-9} \text{ sec}}$.

$= 1.2 \times 10^{9}$ bytes/sec

$= 1.2$ GBps

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(b) Most systems allow programs to allocate more memory to its address space during execution. Data allocated in the heap segments of programs is an example of such allocated memory. What is required to support dynamic memory allocation in the following schemes?

(i) Contiguous-memory allocation

(ii) Pure segmentation

(iii) Pure paging

[12 marks]

(i.) Contigous memory allocation

In this, large continous array of memory cells must be available to allocate memory space during execution.

(ii.) Pure segmentation

In this, randomly distributed small memory or cells or group of cells also can be used in allocation of memory during execution.

(iii.) Pure Paging

In this, similar to segmentation space is alloted in distributed manner. If the ~~main~~ storage ~~memory~~ is full, it can also be stored in the form of pages in the main memory with the references in the page table.

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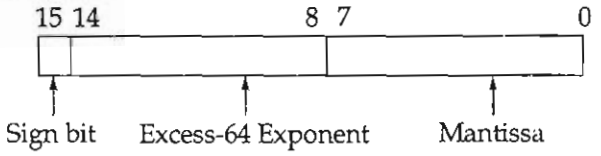
Q.1 (c) Consider the following floating point format:



Mantissa is a pure fraction in sign-magnitude form.

(i) Represent the decimal number 0.239×2^{13} in the hexadecimal format without normalization and rounding off.

(ii) The normalized representation for the above floating point format is specified as follows: The mantissa has an implicit 1 preceding the binary (radix) point. Assume that only 0's are padded-in while shifting a field. Determine the normalized representation of the decimal number (0.239×2^{13}).

[4 + 8 marks]

(i) 0.239×2^{13}

converting into binary,

0.00111101×2^{13}

Actual Exponent $= (13)_{10} = (1101)_2$

Bias exponent $= 1101 + (64)_{10}$

$= 1000000 + 1101 = 1001101$

Sign = +ve ⇒ 0

Representation ⇒ | 0 | 1001101 | 00111101 |

$(4\ D\ 3\ D)_{16}$.

(ii) 0.00111101×2^{13}

$0.00111101001011 \times 2^{13}$

On Normalisation

$1.1101001011 \times 2^{10}$

AE = 10 = 1010

BE = 10111010

1010

10011010

sign = +ve ⇒ 0

Representation ⇒

0	1001010	11101001

(4 A E 9)$_{16}$.

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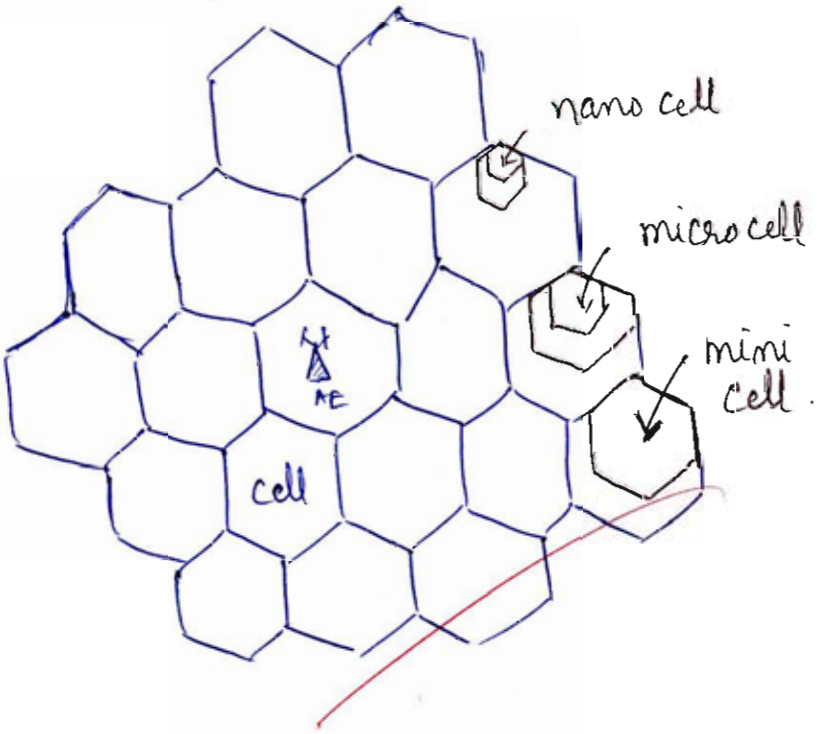
Q.1 (d) Explain different techniques used to increase the capacity of a cellular system. **[12 marks]**

The capacity of cells can be increased by using space diversity techniques and frequency reuse technique.

The cells of a cellular network are further divided into micro, mini and nano cells.



The capacity can be increased by using freq uency reuse techniques.

$$n = i^2 + j^2 + ij$$

where i and j are integers.

A cell using frequency $f_1, f_2 \ldots f_n$ can be optimised by using space diversity

If each micro cell in the larger cell

uses n frequencies, then the increase in capacity is given by –

Capacity with diversity = No. of micro cell * No. of freq in micro cell.

Q.1 (e) Compare different communication switching techniques (circuit switching, datagram packet switching and virtual circuit packet switching).

[12 marks]

Circuit switching	Data packet switching	Virtual circuit switching
(1) A fixed path is set up before transmission	(1) No fixed path is set up	(1) No fixed path is set up.
(2) during congestion it fails to respond.	(2) during congestion it responds by the routing	(2) during congestion next best path is selected
(3) packets arrive in sequence	(3) packets arrive in any order but rearrange at the receiver	(3) packets arrive in sequence
(4) High speed switching	(4) comparitively low speed	(4) comparitively low speed.
Eg- GSM	Eg- LTE	Eg- HSPA.

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Q.2 (a) (i) Explain some important performance and compatibility requirements of the optical detectors.

(ii) When 3×10^{11} photons each with a wavelength of 0.85 μm are incident on a photodiode, on average 1.2×10^{11} electrons are collected at the terminals of the device. If the device is operating at a wavelength of 0.85 μm, then calculate the incident optical power required to obtain a photocurrent of 2.5 μA.

[10 + 10 marks]

Q.2 (b) A QPSK signal is transmitted by satellite. Raised cosine filtering is used with a roll-off factor of 0.20. The minimum required $[E_b/N_0]$ at the receiver input to receive the data satisfactorily is 9.6 dB. The total link losses amount to 200 dB, the receiver $[G/T]$ is 32 dB/K and the transponder bandwidth is 36 MHz. Determine the maximum data rate that can be accommodated and the minimum [EIRP] required at this data rate.

[20 marks]

Q.2 (c) (i) List the major characteristics of CISC and RISC architectures of processor design.

(ii) Consider the sequence of machine instructions given below:

MUL R5, R0, R1
DIV R6, R2, R3
ADD R7, R5, R6
SUB R8, R7, R4

Here, R0 to R8 are general purpose registers. In the given instructions, the first register (from left) stores the result of the operation performed on the second and the third registers. This sequence of instructions is to be executed in a pipelined instruction processor with the following 4 stages:

Instruction fetch and decode (IF), operand fetch (OF), perform operation (PO) and write back the result (WB). The IF, OF and WB stages take 1 clock cycle for any instruction. The PO stage takes 1 clock cycle for ADD or SUB instructions, 3 clock cycles for MUL instruction and 5 clock cycles for DIV instruction. The pipelined processor uses operand forwarding from PO stage to the OF stage. Determine the total number of clock cycles required to execute the given sequence of instructions.

[8 + 12 marks]

Q.3 (a) If a CPU issues one memory request for every instruction and the computer runs at 200 MIPS, about how many CPUs will it take to saturate a 400 MHz bus? Assume that a memory reference requires one bus cycle. Now repeat this problem for a system in which caching is used and the caches have a 90% hit rate. What cache hit rate would be needed to allow 32 CPUs to share the bus without overloading it? **[20 marks]**

CPU generating 200×10^6 ~~instruction~~ access per sec.

Bus capacity = 400×10^6 per sec.

⇒ No. of CPUs required to saturate the bus

$$= \frac{400 \times 10^6}{200 \times 10^6} = \boxed{2 \text{ CPUs}}$$

When cache memory 'h' are used.

Let the number of CPUs used be N.

400 MHz = memory access * No. of CPUs per sec.

$$400 \times 10^6 = (1-H) * 200 \times 10^6 * N$$

$$2 = (1-0.9) * N$$

$$\Rightarrow \boxed{N = 20 \text{ CPUs}}$$

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Given N = 32 CPUs –

$$400 \text{ MHz} = (1-H) * 200 \times 10^6 * 32$$

$$1-H = \frac{400}{200 \times 32} = 0.0625$$

or $\boxed{\text{Hit Rate, } H = \frac{15}{16} = 0.9375}$

.3 (b) **(i)** What is a transaction in database? Explain its properties with an example?

(ii) Explain how to check conflict serializability and view serializability of the following schedule:

$S : r_1(X) ; r_3(Y) ; r_3(X) ; r_2(Y) ; r_2(Z) ; w_3(Y) ; w_2(Z) ; r_1(Z) ; w_1(X) ; w_1(Z)$

[15 + 10 marks]

Transaction refers to either reading or ~~Write~~ Writing the contents of a database by creating its temporary copy

Eg. The properties of ~~transactions in~~ databases are –
ACID properties.

(1) Atomicity:
The database must be precise to atomic level of the data stored.

(2) Concurrency
The database must always be concurrent.

Eg: A → 1000

B → 500

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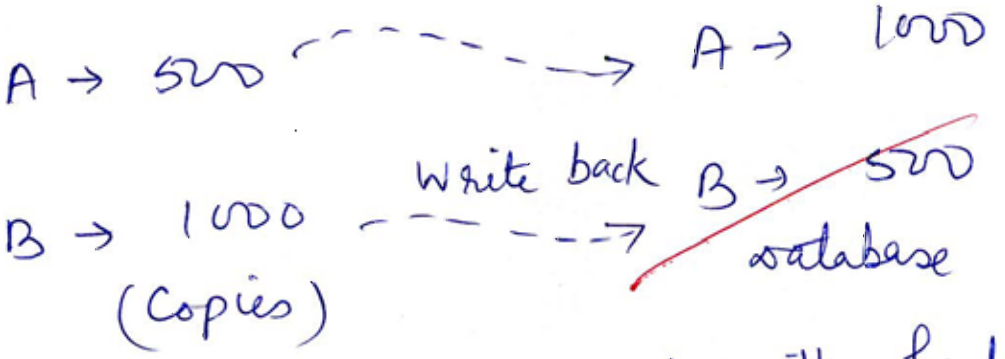
transaction : A → A − 500

B → B + 500



If the modified data is not written back after commit statement, data concurrency will be lost.

(iii.) Integrity

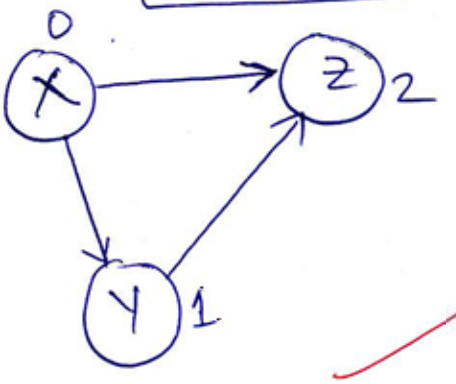
(iv.)

(ii) Conflicts are of 3 types –

1. Write Write conflict
2. Read Write conflict.
3. Write – Read conflict

~~Serisation is~~ Serialization is done by ensuring no such conflicts occur.

T	X	Y	Z
1	R_1		
2		R_3	
3	R_3		
4		R_2	
5			R_2
6		W_3	
7			W_2
8			R_1
9	W_1		
10			W_1



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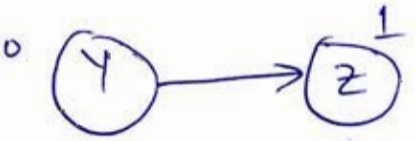

The schedule can be serialised.

by $X \rightarrow Y \rightarrow Z$.

(c) A fiber optic link has to be constructed by joining cables each with a length of 0.5 km and an attenuation of 4 dB/km. Cables are connected with splices, each giving a loss of 2 dB. The coupling loss at each side of the link is 1 dB. An LED with emitted power of 1 mW is used as the source and an APD with sensitivity of "–100 dBm" is used as detector. If a system margin of 4 dB is required, then calculate the maximum possible length of the link, without using any repeater.

[15 marks]

Given information –

$\ell = 0.5\,km$

$\alpha = 4\,dB/km$.

$L_{splice} = 2\,dB$.

$L_{coupl.} = 1\,dB$.

$P_{in} = 1mW = 0\,dBm$

$P_s = -100\,dBm$.

$P_{System\ margin} = 4\,dB$.

let the no. of cables be N

$\Rightarrow$ attenuation loss $= 4 \times 0.5 \times N = 2N\,dB$

No. of splices $= N-1 \Rightarrow$ Splice loss $= 2(N-1)\,dB$.

$P_{in} - loss - margin = P_{sens.}$

$0 - 2N - 2(N-1) - 2 - 4 = -100$.

$+2N + 2N + 2 - 2 + 4 = +100$

$4N = 96$

$N = 24$.

$\Rightarrow$ Total length $= 24 \times 0.5 = 12\,kms$

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Q.4 (a) A satellite system has the following parameters:

Parameter	Uplink	Downlink
[EIRP]	54 dBW	34 dBW
[G/T]	0	17 dBK^{-1}
[FSL]	200 dB	198 dB
[RFL]	2 dB	2 dB
[AA]	0.5 dB	0.5 dB
[AML]	0.5 dB	0.5 dB

Calculate the overall carrier-to-noise spectral density ratio of the system.

[20 marks]

Q.4 (b) Write a C program to delete duplicate elements from an array.

[20 marks]

Q.4 (c) A datagram network allows routers to drop packets whenever they need to. The probability of a router discarding a packet is "α". Consider the case of a source host connected to the source router, which is connected to the destination router, and then to the destination host. If either of the routers discards a packet, the source host eventually times out and tries again. If both host-router and router-router lines are counted as hops, then what is the mean number of

(i) hops a packet makes per transmission?

(ii) transmissions a packet makes?

(iii) hops required per received packet?

[20 marks]

Section B : Signals and Systems-1 + Electronic Measurements and Instrumentation-1 + Electromagnetics-2 + Basic Electrical Engineering-2

Q.5 (a) **(i)** By using appropriate Fourier transform properties, find the Fourier transform of $g(t) = te^{-|t|}$.

(ii) By using the result of part (i), along with the duality property, determine the Fourier transform of $y(t) = \frac{4t}{(1+t^2)^2}$.

[6 + 6 marks]

(i.) $g(t) = te^{-|t|}$

$= te^{-t}u(t) + te^{t}u(-t) = t\left[e^{-t}u(t) + e^{t}u(-t)\right]$

By using property,

$e^{-t}u(t) \rightleftharpoons \frac{1}{j\omega+1}$ $\quad (\omega \to -\omega)$

$e^{t}u(-t) \rightleftharpoons \frac{1}{1-j\omega}$

Also, using differentiation property,

$t^n x(t) \rightleftharpoons \frac{(-1)^n}{j^n}\frac{d^n X(\omega)}{d\omega^n}$

$g(t) \rightleftharpoons \frac{(-1)}{j}\frac{d}{d\omega}\left[\frac{1}{j\omega+1} - \frac{1}{j\omega-1}\right]$

$= t \frac{d}{ds}\left[\frac{+2}{s^2-1}\right] = j\frac{d}{d\omega}\left[\frac{-2}{\omega^2+1}\right]$

$= \frac{2(2s)}{(s^2-1)^2} = \frac{-2j(-2\omega)}{(\omega^2+1)^2}$

$$g(\omega) = -\frac{+4j\omega}{(\omega^2+1)^2}$$

(ii.) By using duality Property

$y(t) \rightleftharpoons Y(\omega)$

$Y(t) \rightleftharpoons 2\pi\, y(-\omega)$

2 $t e^{-|t|} \overset{\mathcal{F}}{\rightleftharpoons} \dfrac{4j\omega}{(\omega^2+1)^2}$

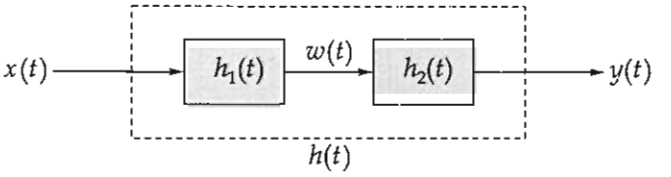
$\dfrac{4t}{(t^2+1)^2} \overset{\mathcal{F}}{\rightleftharpoons} +j\omega e^{-|\omega|}$

2π

Q.5 (b) The system shown in the figure below is formed by connecting two systems in cascade. The impulse responses of the individual systems are given by,

$h_1(t) = e^{-2t}\,u(t)$ and

$h_2(t) = 2e^{-t}\,u(t)$



(i) Find the impulse response $h(t)$ of the overall system.

(ii) Determine whether the overall system is BIBO stable or not.

[6 + 6 marks]

(i) $h(t) = h_1(t) * h_2(t)$

Taking laplace transform

$H(s) = H_1(s)\,H_2(s)$

$= \frac{1}{s+2} * \frac{2}{s+1} = \frac{2}{(s+1)(s+2)}$

$= \frac{2}{s+1} - \frac{2}{s+2}$

Taking inverse laplace tranform

$h(t) = 2e^{-t}u(t) - 2e^{-2t}u(t)$

$$\boxed{h(t) = 2\left[e^{-t} - e^{-2t}\right]u(t)} \qquad \sigma > -1$$

(ii) As the ROC includes imaginary axis and the system is causal, poles lie on LHS

the system is stable.

Verification –

$$h(t) = 2\left[e^{-t} - e^{-2t}\right]u(t)$$

For a system to be stable, its impulse response must be absolutely integrable.

$$\int_{-\infty}^{\infty} |h(t)|\,dt$$

$$= \int_{0}^{\infty} 2\left|e^{-t} - e^{-2t}\right| dt$$

$$= \frac{2}{-1}\left(e^{-t}\right)_0^{\infty} - \frac{2}{-2}\left(e^{-2t}\right)_0^{\infty}$$

$$= -2(0-1) + 1(0-1)$$

$$= 2 - 1 = \boxed{1} \Rightarrow \text{BIBO stable.}$$

Q.5 (c) The coil of a moving coil voltmeter (20 mm long and 10 mm wide) has 100 turns on it. The control spring exerts a torque of 200×10^{-6} N-m, when the deflection is 100 divisions on full scale. If the flux density of the magnetic field in the air gap is 1.0 Wb/m^2, estimate the resistance that must be put in series with the coil to give one volt per division. The resistance of the voltmeter coil may be neglected.

[12 marks]

Given Information —

$l = 20\,mm$

$W = 10\,mm$

$N = 100$

$K\theta_{fs} = 200 \times 10^{-6}$ N-m.

$B = 1.0\,Wb/m^2$

deflecting torque $= T_D = BIAN$

For 1 volt, ~~let~~ current $I = 1/R$

$$T_D = 1 \times \frac{1}{R} \times (20\times10^{-3} \times 10\times10^{-3}) \times 100$$

$$= \frac{0.02}{R}\ N\text{-m}.$$

For 100 division, controlling torque $= 200\times10^{-6}$ N-m

$\Rightarrow$ For one division, $T_C = 2\times10^{-6}$ N-m

At Equilibrium,

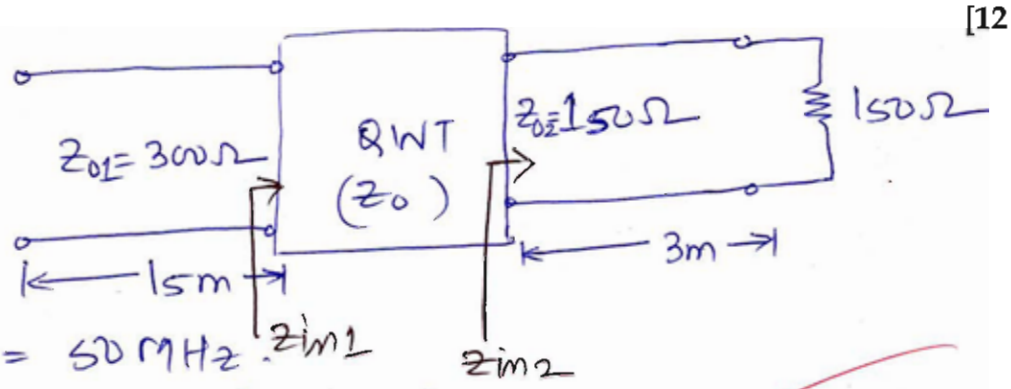
$T_C = T_D$.

$$\frac{0.02}{R} = 2\times10^{-6}$$

$$R = \frac{2\times10^{-2}}{2\times10^{-6}} = 10\,k\Omega$$

(d) A 15 m length of 300 Ω line must be connected to a 3 m length of 150 Ω line that is terminated in a 150 Ω resistor. Assuming the lossless condition for the air dielectric lines and operation at a fixed frequency of 50 MHz, find the value of Z_0 of a quarter wave section which is used to match the two lines to get a VSWR = 1 on the main line. If no quarter wave transformer is used, what is the VSWR on the main line?

[12 marks]



$f = 50\ MHz$

$\lambda = \frac{3\times10^8}{50\times10^6} = 6\ m$

$$Z_{in2} = Z_{02}\left(\frac{Z_L + jZ_0\tan(\beta l)}{Z_0 + jZ_L\tan(\beta l)}\right)$$

$\Rightarrow Z_{in2} = Z_{02} = 150\Omega$ (matched load)

For matching the two transmission lines, characteristic impedence of QWT be Z_0.

$$Z_{in1} = Z_0\left(\frac{Z_L + jZ_0\tan\left(\frac{2\pi}{\lambda}\cdot\frac{\lambda}{4}\right)}{Z_0 + jZ_L\tan\left(\frac{2\pi}{\lambda}\cdot\frac{\lambda}{4}\right)}\right)$$

$$Z_{in1} = Z_0\left(\frac{Z_0}{Z_L}\right) = \frac{Z_0^2}{Z_L}$$

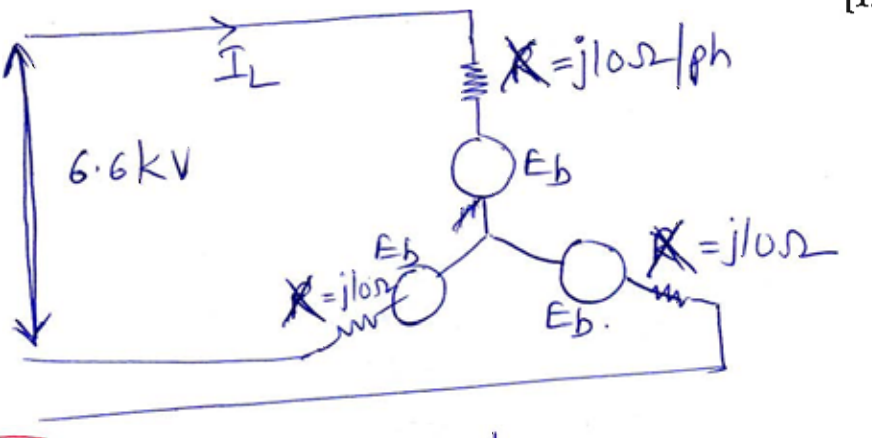
$$300 = \frac{Z_0^2}{150} \Rightarrow Z_0 = \sqrt{300\times150} = 212.13\Omega$$

If No QWT is used,

$$VSWR = \frac{Z_0}{Z_L} = \frac{300}{150} = 2.$$

Q.5 (e) A three phase synchronous motor of 1000 kW and 6.6 kV has synchronous reactance of 10 Ω per phase. The efficiency of the motor is 90%. Neglecting armature resistance, determine the minimum current and the corresponding induced emf at full load.

[12 marks]



$1000 \times 10^3 = \sqrt{3}\, V_L I_L \cos\phi$.

$1000 \times 10^3 = \sqrt{3} \times 6.6 \times 10^3 \times I_L \cos\phi$

or $\boxed{I_L \cos\phi = 87.47\,A}$ → (1)

minimum current ⇒ maximum power factor.

⇒ $\cos\phi = 1$ or $\boxed{I_L = 87.47\,A}$

By using KVL

$\frac{6.6 \times 10^3}{\sqrt{3}} - I_L \times jX = E_b$.

$3810.51 - j87.47 \times 10 = E_b$.

$\boxed{E_b = 3909.61 \angle -1.928^\circ}$

(a) Two resistors R_1 and R_2 are connected in series and then in parallel. The values of resistances are

$$R_1 = 100 \pm 0.1\ \Omega \text{ and } R_2 = 50 \pm 0.03\ \Omega$$

Calculate the uncertainty in the combined resistance for both series and parallel arrangements.

[20 marks]

When connected in series,

$R_{Eq} = R_1 + R_2$.

$$\Rightarrow \frac{\Delta R_{Eq}}{R_{Eq}} = \frac{R_1}{R_{Eq}} \cdot \frac{\Delta R_1}{R_1} + \frac{R_2}{R_{Eq}} \cdot \frac{\Delta R_2}{R_2} \quad \rightarrow (1)$$

$R_{Eq} = 100 + 50 = 150\ \Omega$

$$\frac{\Delta R}{R_{Eq}} = \frac{100}{150} \times \frac{0.1}{100} + \frac{50}{150} \times \frac{0.03}{50}$$

$$\frac{\Delta R}{R_{Eq}} = 8.667 \times 10^{-4} \quad \text{or} \quad 0.0867\ \%$$

$$\Delta R = 150 \times 8.667 \times 10^{-4} = 0.13\ \Omega.$$

When connected in parallel.

$$R_{Eq} = \frac{R_1 R_2}{R_1 + R_2} = \frac{100 \times 50}{150} = 33.334\ \Omega.$$

$$R'_{Eq} = \frac{100.1 \times 50.03}{100.1 + 50.03} = 33.357\ \Omega$$

$$R''_{Eq} = \frac{99.9 \times 49.97}{99.9 + 49.97} = 33.309\ \Omega$$

$$\Rightarrow \Delta R = \max\{0.023, 0.025\}$$

$$\Delta R = 0.025\ \Omega$$

$$\frac{\Delta R}{R} = \frac{0.025}{33.334} = 0.075\ \%$$

Q.6 (b) A square waveguide operates at 4.5 GHz in the dominant mode. If the group velocity of this wave is determined to be 1.8×10^8 m/s, then calculate the largest dimension of the waveguide. Assume that the waveguide is filled with a dielectric material of relative permittivity 2.50.

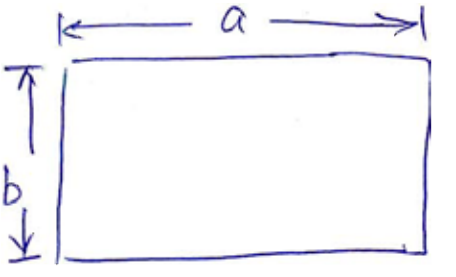
[20 marks]

$f_0 = 4.5$ GHz.

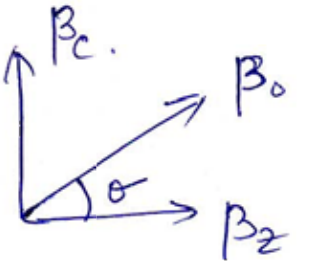
$V_g = 1.8 \times 10^8$ m/s.

$\epsilon_r = 2.50$.

$$\lambda_0 = \frac{c'}{f_0} = \frac{3\times10^8}{\sqrt{2.5}\times4.5\times10^9}$$



$$\boxed{\lambda_0 = 0.042 \text{ m}}$$



Free space velocity, $c' = \frac{c}{\sqrt{\epsilon_r}} = \frac{3\times10^8}{\sqrt{2.5}} = 1.897\times10^8$ m/s

group velocity, $V_g = c\cos\theta$

$$1.8\times10^8 = 1.897\times10^8\cos\theta$$

$$\Rightarrow \cos\theta = \frac{1.8}{1.897} = 0.948 \rightarrow (2)$$

From phasors,

$$\beta_c = \beta_0 \sin\theta.$$

$$\frac{2\pi}{\lambda_c} = \frac{2\pi}{\lambda_0}\sin\theta$$

or $$\lambda_c = \frac{\lambda_0}{\sin\theta} = \frac{0.042}{\sqrt{1-\cos^2\theta}} = \frac{0.042}{\sqrt{1-0.948^2}}$$

$$= 0.132 \text{ mts} \rightarrow (3)$$

Given Information - ~~dominant~~ Mode operation

$\Rightarrow \lambda_c = 2a$. (For TE_{10} mode)

$$0.132 = 2a.$$

or $$\boxed{a = \frac{0.132}{2} = 0.066 \text{ mts}.}$$

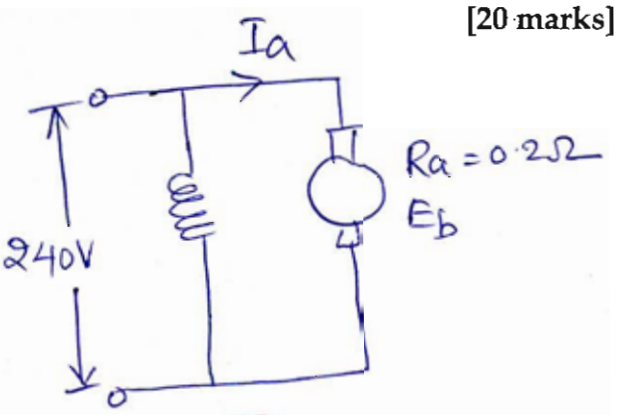
Q.6 (c) A 240 V shunt motor has an armature resistance of 0.2 Ω and takes armature current of 20 A on full load. The electromagnetic torque being constant, by how much must the flux be reduced to increase the speed by 40%?

[20 marks]

Given Information –

$R_a = 0.2\Omega$

$I_{a(FL)} = 20A.$



~~For a shunt motor,~~

$T = K\phi I_a.$

For constant torque, $\phi I_a = \text{constant} \rightarrow (1)$

$E_b = K\phi N. \rightarrow (2)$

$E_b = 240 - I_a R_a. = 240 - 0.2 I_a \rightarrow (3)$

$\frac{E_{b2}}{E_{b1}} = \frac{\phi_2 N_2}{\phi_1 N_1} = \frac{\phi_2}{\phi_1} \times 1.4$ (As $N_2 = 1.4 N_1$)

$\hookrightarrow (4)$

$E_{b1} = 240 - 0.2 \times 20 = 240 - 4 = 236A$

$\frac{240 - 0.2 I_{a2}}{236} = \frac{20}{I_{a2}} \times 1.4$ [As $\frac{\phi_2}{\phi_1} = \frac{I_1}{I_2}$ from (1)]

$240 I_{a2} - 0.2 I_{a2}^2 = 6608.$

or $(0.2) I_{a2}^2 - 240 I_{a2} + 6608 = 0$

on solving,

$\boxed{I_{a2} = 28.19A.}$

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$\Rightarrow$ From (1)

$$\frac{\phi_2}{\phi_1} = \frac{I_{a1}}{I_{a2}} = \frac{20}{28.19} = 0.7$$

$\Rightarrow \phi_2 = 0.7\,\phi_1$

or Flux must be reduced by 30%

or Flux must be reduced to 70%.

Q.7 (a) A system with input $x(t)$ and output $y(t)$ is characterized by the following differential equation:

$$\frac{d^3y(t)}{dt^3}+6\frac{d^2y(t)}{dt^2}+11\frac{dy(t)}{dt}+6y(t)=x(t)$$

(i) Evaluate the zero-state response of this system for the input, $x(t) = e^{-4t}u(t)$.

(ii) By considering the following initial conditions, evaluate the zero-input response of the system for $t > 0$.

$$y(0^-)=1,\ \left.\frac{dy(t)}{dt}\right|_{t=0^-}=-1 \text{ and } \left.\frac{d^2y(t)}{dt^2}\right|_{t=0^-}=1$$

[20 marks]

(i.)

Given Information –

$$\frac{d^3y(t)}{dt^3}+6\frac{d^2y(t)}{dt^2}+11\frac{dy(t)}{dt}+6y(t)=x(t) \quad \rightarrow (1)$$

$\rightarrow (2)$

$$x(t)=e^{-4t}u(t)$$

Apply laplace transform on eqn (1) and eqn (2)

$$s^3Y(s)+6s^2Y(s)+11sY(s)+6Y(s)=X(s) \quad \rightarrow (3)$$

$$X(s)=\frac{1}{s+4} \quad \rightarrow (4)$$

substitute eqn (4) in eqn (3)

$$Y(s)=\frac{1}{(s^3+6s^2+11s+6)}\cdot\frac{1}{(s+4)}$$

$$=\frac{1}{(s+1)(s+2)(s+3)(s+4)}$$

calculating Residues and applying partial fraction

$$Y(s)=\frac{\frac{1}{6}}{s+1}-\frac{\frac{1}{2}}{s+2}+\frac{\frac{1}{2}}{s+3}-\frac{\frac{1}{6}}{s+4}$$

Take inverse laplace transform,

$$Y(s)=u(t)\left(\frac{1}{6}e^{-t}-\frac{1}{2}e^{-2t}+\frac{1}{2}e^{-3t}-\frac{1}{6}e^{-4t}\right)$$

(ii) $ZIR \Rightarrow x(t) = 0$

$y(0^-) = 1, \quad y'(0^-) = -1, \quad y''(0^-) = 1$

Applying unilateral laplace transform on eqn (1)

$$s^3Y(s) - s^2y(0^-) - sy'(0^-) - y''(0^-) + 6\left[s^2y(s) - sy(0^-) - y'(0^-)\right] + 11\left[sy(s) - y(0^-)\right] + 6y(s) = 0$$

$$Y(s)\left[s^3 + 6s^2 + 11s + 6\right] - s^2 + s - 1 - 6s + 6 - 11 = 0$$

$$Y(s)\left[s^3 + 6s^2 + 11s + 6\right] = s^2 + 5s + 6$$

$$Y(s) = \frac{s^2 + 5s + 6}{s^3 + 6s^2 + 11s + 6}$$

$$Y(s) = \frac{s^2 + 5s + 6}{(s+1)(s^2 + 5s + 6)}$$

$$Y(s) = \frac{1}{s+1}$$

Taking inverse laplace transform,

$$\boxed{y(t) = e^{-t}u(t)}$$

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Q.7 (b) A resistance, with approximate value of 80 Ω, is to be measured by voltmeter-ammeter method using a 1 A ammeter having a resistance of 2 Ω and a 50 V voltmeter having a resistance of 5000 Ω.

(i) Suggest which one of the two possible methods should be used?
Supposing in the suggested method the following measurements are made:

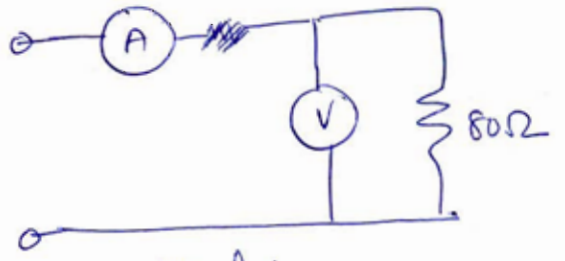
$I = 0.42$ A and $V = 35.5$ V

Calculate the true value of the resistance.

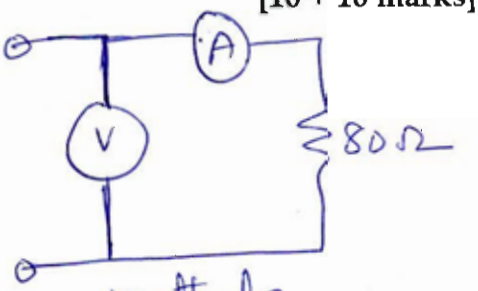
(ii) What is the resulting error if the accuracy of the instruments is ±0.5% at full scale and the errors are standard deviations.

[10 + 10 marks]

(i.)

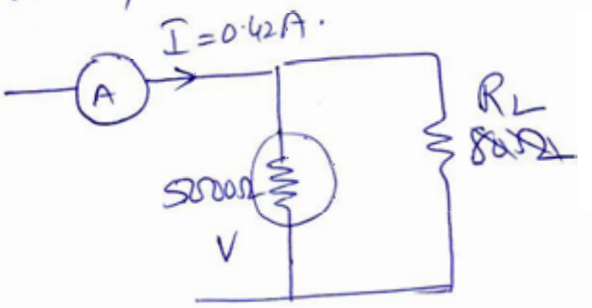


method 1



method 2

Method 1 is preferred when the resistance to be measured is of low value.
Method 2 is preferred when the resistance to be measured is of high value.
In this case as $R_L = 80\,\Omega$ is of comparitively low value, method 1 must be preferred.



By current The voltmeter will measure voltage about the parallel combination

$R_{Eq} = R_L \| 5000$.

$R_{Eq} = \frac{V}{I} = \frac{35.5}{0.42} = 84.5238\,\Omega$

$$\frac{1}{5000} + \frac{1}{R_L} = \frac{1}{84.5238}$$

$$\frac{1}{R_L} = \frac{1}{84.5238} - \frac{1}{5000}$$

$$\boxed{R_L = 85.97\,\Omega}$$

(ii.) $R = \frac{V}{I}$

$$\sigma_R = \sqrt{\left(\frac{\partial R}{\partial V}\right)^2 \sigma_V^2 + \left(\frac{\partial R}{\partial I}\right)^2 \sigma_I^2}$$

$$= \sqrt{\left(\frac{1}{I}\right)^2 \sigma_V^2 + \left(\frac{V}{I^2}\right)^2 \sigma_I^2}$$

$$= \sqrt{\left(\frac{1}{0.42}\right)^2 \times 0.5^2 + \left(\frac{35.5}{0.42^2}\right)^2 \times 0.5^2}$$

$$\sigma_V = \frac{0.5}{100} \times 50 = 0.25 \qquad \sigma_I = \frac{0.5}{100} \times 1 = 0.005$$

$$\sigma_R = \sqrt{\left(\frac{1}{0.42}\right)^2 0.25^2 + \left(\frac{35.5}{0.42^2}\right)^2 \times 0.005^2}$$

$$\sigma_R = 1.169.$$

$$\%\,\sigma_R = \frac{1.169}{85.97} = 1.359\,\%$$

Q.7 (c) A vertical Hertzian dipole radiates 1 kW power. Find the electric field and Poynting vector at a distance of 10 km from the dipole in the horizontal plane passing through the dipole. What is the direction of the electric field at the observation point? **[20 marks]**

directive gain of hertzian dipole = 1.5

$P_{radiated} = 1.5 \times 1 = 1.5\,kW.$

At a distance of 10km, power density will be-

$$P_d = \frac{P_{rad}}{4\pi R^2} = \frac{1.5 \times 10^3}{4\pi \times (10 \times 10^3)^2}$$

$$= 1.193 \times 10^{-6}\ W/m^2$$

Poynting vector $= P = 1.193\ \mu W/m^2\ \hat{a}_R$

Electric field = E_0

$$P = \frac{E_0^2}{2\eta}$$

Assuming the medium to be air, $\eta = 120\Pi$.

$$P = 1.193 \times 10^{-6} = \frac{E_0^2}{2 \times 120\Pi}$$

$$E_0 = 0.0299 \text{ V/m}$$

$$\boxed{E_0 \simeq 30 \text{ mV/m}}$$

For a hertzian dipole,

$$E_\theta = \frac{j I_0 \beta dl \sin\theta e^{-j\beta r}}{4\Pi r} \hat{a}_\theta$$

direction would be $\hat{a}_\theta$.

Q.8 (a) **(i)** What do you understand by a distortionless line? Derive the necessary conditions to make a line distortionless.

(ii) For a transmission line, the primary constants are $R = 0.2\ \Omega/\text{m}$, $L = 0.3\ \mu\text{H/m}$, $G = 0$ and $C = 15\ \text{pF/m}$. Find the phase and attenuation constants of the line at 900 MHz.

[12 + 8 marks]

(b) A 20 kW, 400 V DC shunt generator has no load rotational losses of 800 W. The armature and shunt field resistances are 0.3 Ω and 200 Ω respectively. Determine the input power and efficiency of the generator. Also calculate the maximum efficiency and the corresponding output power.

[20 marks]

(c) Determine the impulse response $h(t)$ of an initially relaxed LTI system from the following facts:

(i) When the input to the system is $x(t) = e^{2t}$, the output is $y(t) = \frac{1}{6}e^{2t}$.

(ii) $h(t)$ satisfies the differential equation, $\frac{dh(t)}{dt} + 2h(t) = e^{-4t}u(t) - bu(t)$.

Where b is an unknown constant. Your answer must not contain any unknown constant.

[20 marks]

Space for Rough Work

Space for Rough Work

$s+1 \;)\; s^3+6s^2+11s+6 \;(\; s^2+5s+6$

$(s+1)$

$-s^3+s^2$

$5s^2+11s+6$

$5s^2+5s$

$6s+6$