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The Open University of Sri Lanka
Department of Electrical and Computer Engineering
ECX6333 – Microwave Engineering and Applications
Final Examination 2013/2014

Time: 0930 - 1230 hrs. Date: 2014- 08 - 21.

Answer any FIVE questions.

1.

(a) Write Maxwell's equations. [4]

(b) (i) Using Maxwell's equations show that $\nabla^2 E - \frac{1}{c^2}\frac{\partial^2 E}{\partial t^2} = 0$ for free space. [3]

(ii) Also find the value of c. [1]

(c) (i) If a medium has a charge density ρ, find the relationship between ρ and its time derivative $\frac{d\rho}{dt}$ using (a). [4]

(ii) Show that ρ is exponentially decaying. [4]

(iii) A wave is propagating in a large block of copper. Show that the charge density in the medium will quickly disappear. [Hint: You may find the time taken by the charge density to come to 0.1 % of its initial value] [4]

For copper : $\varepsilon = \varepsilon_0 = 8.85 \times 10^{-12} F/m$, $\sigma = 5.8 \times 10^7 S/m$

You may assume the following vector identity.

$\nabla.(\nabla \times \underline{A}) = 0$, $\nabla \times (\nabla \times \underline{A}) = \nabla(\nabla.\underline{A}) - \nabla^2 \underline{A}$

2.

When an electromagnetic wave is incident on a perfect conducting plane (*yz*-plane) at an angle θ_i as in Fig.2 (a) the resulting combined Electric field component is in the y-direction and its value is given by

$$E_y = 2E_0 \sin(\beta x \cos\theta_i)$$

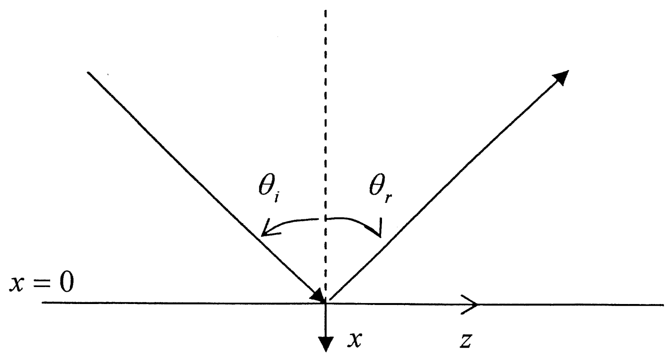

Fig.2 (a)

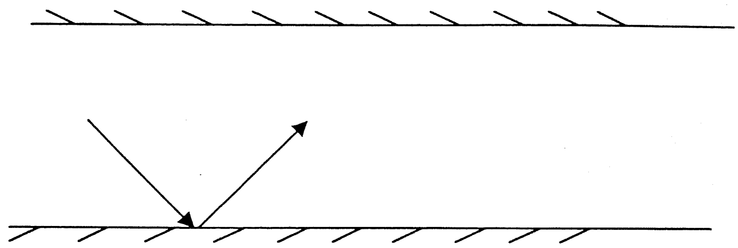

Fig.2(b)

(a) State the boundary conditions for the E field at the metal surface. [2]

(b) Show that E_y satisfies the above boundary conditions. [2]

(c) If a similar metal surface is placed parallel to the given surface, with the help of a sketch show how the electro magnetic wave is propagated between the two metal surfaces. (refer to Fig.2(b)) [3]

(d) Applying the boundary conditions for the E field at the second metal surface show that $\cos\theta_i = \dfrac{m\pi}{\beta a} = \dfrac{m\lambda}{2a}$ where a is the distance between two metal surfaces. [4]

(e) Using (d) deduce that the maximum possible value for λ is $\dfrac{2a}{m}$ [4]

(f) For $\lambda = \dfrac{2a}{m}$,

(i) sketch the reflections that take place between the two metal surfaces. [3]
(ii) comment on the propagation of the wave. [2]

3.

(a) A rectangular waveguide is given below:

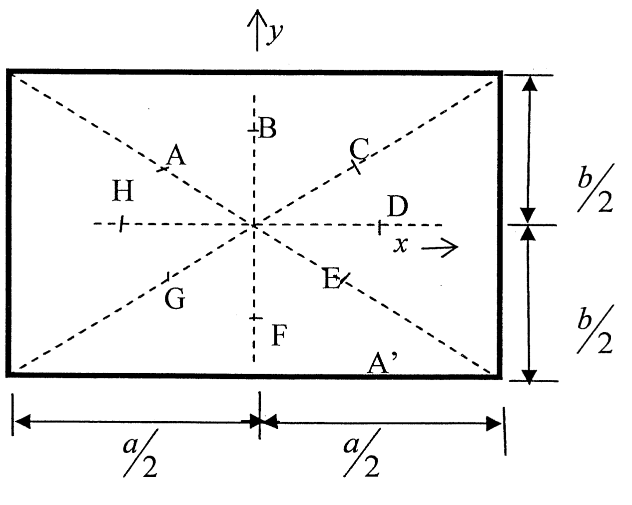

Fig.3

x- and y axes are selected as given in Fig.3. For the dominant TM_{11} mode the values of the magnetic field components are as follows:

$$H_x = k\cos\left(\frac{\pi x}{a}\right)\sin\left(\frac{\pi y}{b}\right)$$

$$H_y = -k\sin\left(\frac{\pi x}{a}\right)\cos\left(\frac{\pi y}{b}\right), \quad H_z = 0.$$

(i) How would you find the direction of the resultant H –field at a given point on the x-y plane? [2]

(ii) Find the direction of H-field at points B, F, D, H, C, G, A and E shown on the figure. Mark the direction of H-field at each point on a diagram. [8]

(iii) Using the results of (ii) sketch the field pattern of the H-field inside the waveguide. [5]

(b) (i) Why is the inner surface of a waveguide made out of a thin layer of a metal with very high conductivity? [3]

(ii) What factors will decide the thickness of this layer? [2]

4.

(a) For a circular waveguide the phase constant is given by

$$\beta_z = \sqrt{\omega^2\mu\varepsilon - \left(\frac{\rho_{nm}}{a}\right)^2} \text{ for the } TM \text{ mode.}$$

(i) What is ρ_{nm}? [2]

(ii) Write an equation for β_z for *TE* mode. [2]

(iii) Using (ii) deduce the cutoff wavelength for the *TE* mode. [3]

(iv) What is the dominant *TE* mode? Justify your answer. [4]

(v) Find the cutoff wavelength for the dominant *TE* mode if the radius of the waveguide is 4 cm. [4]

(b) A rectangular cavity resonator is filled with air. Find the resonance frequency of the oscillator for the TE_{211} mode, if the cavity has a length of 2 *cm.* and a cross section with $a = 3$ *cm.* and $b = 1.5$ *cm.* [5]

5.

In a Magic Tee junction ports 1 and 2 are the main arms.

(a) Draw the Magic Tee and label different ports. [3]

(b) Power is fed to ports 1 and 2.
Sketch the electric field pattern in all ports. [2]

(c) If power is fed from port 3,

(i) sketch the field patterns in ports 1 and 2. [2]

(ii) what can you say about the power coupled to port 4. [2]

(iii) write the value of element s_{34} of the $[s]$ matrix. [3]

(d) Obtain the s-matrix for an ideal Magic Tee junction if ports 3- and 4 are matched. [8]

6.

(a) (i) How did the cellular communication network evolve? [2]

(ii) What were the major drawbacks of the other long distance r.f. communication networks? [2]

(b) Briefly explain the following:

(i) cell and base station. [4]

(ii) cell cluster and frequency reuse. [4]

(c) 50.5 *MHz* bandwidth is allocated to a cellular communication system. From the allocated bandwidth 2.5 *MHz* is reserved for control purposes. The system provides full duplex communication using 25 *kHz* simplex channels. Distribute voice channels and control channels reasonably within each cell, considering the frequency reuse factor as $\frac{1}{12}$. [8]

7.

(a) A cellular network is planned for a city. The city has an area of 1800 km^2. It is proposed to cover up the area with cells having a cell radius of 2.63 *km*. Allocated bandwidth for the system is 21 *MHz*. The system is supposed to provide full duplex communication using 50 *kHz* full duplex channels. Size of a cluster is 12. The offered traffic per user is 0.025 *Erlangs*. The grade of service of the system is 2%.

(i) Show that the area of a cell is approximately 18 km^2 [3]

(ii) Find the number of cells in the service area. [3]

(iii) Find the number of channels per cell. [4]

(iv) Find the total number of users served. [4]

(b) (i) What is meant by *scattering* of electromagnetic waves? [3]

(ii) How does scattering affect signal reception in a cellular communication system? [3]

8.

(a) With the help of suitable diagrams describe the principle of operation of the following:

(i) Traveling wave tube (*TWT*) amplifier. [3]

(ii) Gunn diode oscillator. [3]

(b) (i) An isotropic antenna transmits a total power of P_0. Find the power density at a distance *R*. [3]

(ii) If the above antenna is directive and has a gain G, find the power reflected by a passive reflector placed at a distance R. [3]
Assume that the reflector is perfect and its effective cross-sectional area is σ.

(iii) Now a portion of the power reflected by the reflector given in (ii) is received back by the same antenna whose aperture is A. Derive an expression for the power received by the antenna. [3]

(iv) Show that in order to increase the range of a radar by 50 %, the transmitted power of the antenna has to be increased approximately 5-fold. [5]

k	$J_0(x)$	$J_1(x)$	$J_2(x)$	$J_3(x)$	$J_4(x)$	$J_5(x)$
1	2.4048	3.8317	5.1356	6.3802	7.5883	8.7715
2	5.5201	7.0156	8.4172	9.7610	11.0647	12.3386
3	8.6537	10.1735	11.6198	13.0152	14.3725	15.7002
4	11.7915	13.3237	14.7960	16.2235	17.6160	18.9801
5	14.9309	16.4706	17.9598	19.4094	20.8269	22.2178
k	$J_0'(x)$	$J_1'(x)$	$J_2'(x)$	$J_3'(x)$	$J_4'(x)$	$J_5'(x)$
1	3.8317	1.8412	3.0542	4.2012	5.3175	6.4156
2	7.0156	5.3314	6.7061	8.0152	9.2824	10.5199
3	10.1735	8.5363	9.9695	11.3459	12.6819	13.9872
4	13.3237	11.7060	13.1704	14.5858	15.9641	17.3128
5	16.4706	14.8636	16.3475	17.7887	19.1960	20.5755

Bessel functions of the first kind - Roots of $J_n(x) = 0$ **and** $J_n'(x) = 0$

Erlang B Traffic Table

Maximum Offered Load Versus B and N
B is in %

N/B	0.01	0.05	0.1	0.5	1.0	2	5	10	15	20	30	40
1	.0001	.0005	.0010	.0050	.0101	.0204	.0526	.1111	.1765	.2500	.4286	.6667
2	.0142	.0321	.0458	.1054	.1526	.2235	.3813	.5954	.7962	1.000	1.449	2.000
3	.0868	.1517	.1938	.3490	.4555	.6022	.8994	1.271	1.603	1.930	2.633	3.480
4	.2347	.3624	.4393	.7012	.8694	1.092	1.525	2.045	2.501	2.945	3.891	5.021
5	.4520	.6486	.7621	1.132	1.361	1.657	2.219	2.881	3.454	4.010	5.189	6.596
6	.7282	.9957	1.146	1.622	1.909	2.276	2.960	3.758	4.445	5.109	6.514	8.191
7	1.054	1.392	1.579	2.158	2.501	2.935	3.738	4.666	5.461	6.230	7.856	9.800
8	1.422	1.830	2.051	2.730	3.128	3.627	4.543	5.597	6.498	7.369	9.213	11.42
9	1.826	2.302	2.558	3.333	3.783	4.345	5.370	6.546	7.551	8.522	10.58	13.05
10	2.260	2.803	3.092	3.961	4.461	5.084	6.216	7.511	8.616	9.685	11.95	14.68
11	2.722	3.329	3.651	4.610	5.160	5.842	7.076	8.487	9.691	10.86	13.33	16.31
12	3.207	3.878	4.231	5.279	5.876	6.615	7.950	9.474	10.78	12.04	14.72	17.95
13	3.713	4.447	4.831	5.964	6.607	7.402	8.835	10.47	11.87	13.22	16.11	19.60
14	4.239	5.032	5.446	6.663	7.352	8.200	9.730	11.47	12.97	14.41	17.50	21.24
15	4.781	5.634	6.077	7.376	8.108	9.010	10.63	12.48	14.07	15.61	18.90	22.89
16	5.339	6.250	6.722	8.100	8.875	9.828	11.54	13.50	15.18	16.81	20.30	24.54
17	5.911	6.878	7.378	8.834	9.652	10.66	12.46	14.52	16.29	18.01	21.70	26.19
18	6.496	7.519	8.046	9.578	10.44	11.49	13.39	15.55	17.41	19.22	23.10	27.84
19	7.093	8.170	8.724	10.33	11.23	12.33	14.32	16.58	18.53	20.42	24.51	29.50
20	7.701	8.831	9.412	11.09	12.03	13.18	15.25	17.61	19.65	21.64	25.92	31.15
21	8.319	9.501	10.11	11.86	12.84	14.04	16.19	18.65	20.77	22.85	27.33	32.81
22	8.946	10.18	10.81	12.64	13.65	14.90	17.13	19.69	21.90	24.06	28.74	34.46
23	9.583	10.87	11.52	13.42	14.47	15.76	18.08	20.74	23.03	25.28	30.15	36.12
24	10.23	11.56	12.24	14.20	15.30	16.63	19.03	21.78	24.16	26.50	31.56	37.78
25	10.88	12.26	12.97	15.00	16.13	17.51	19.99	22.83	25.30	27.72	32.97	39.44
26	11.54	12.97	13.70	15.80	16.96	18.38	20.94	23.89	26.43	28.94	34.39	41.10
27	12.21	13.69	14.44	16.60	17.80	19.27	21.90	24.94	27.57	30.16	35.80	42.76
28	12.88	14.41	15.18	17.41	18.64	20.15	22.87	26.00	28.71	31.39	37.21	44.41
29	13.56	15.13	15.93	18.22	19.49	21.04	23.83	27.05	29.85	32.61	38.63	46.07
30	14.25	15.86	16.68	19.03	20.34	21.93	24.80	28.11	31.00	33.84	40.05	47.74
31	14.94	16.60	17.44	19.85	21.19	22.83	25.77	29.17	32.14	35.07	41.46	49.40
32	15.63	17.34	18.21	20.68	22.05	23.73	26.75	30.24	33.28	36.30	42.88	51.06
33	16.34	18.09	18.97	21.51	22.91	24.63	27.72	31.30	34.43	37.52	44.30	52.72
34	17.04	18.84	19.74	22.34	23.77	25.53	28.70	32.37	35.58	38.75	45.72	54.38
35	17.75	19.59	20.52	23.17	24.64	26.44	29.68	33.43	36.72	39.99	47.14	56.04
36	18.47	20.35	21.30	24.01	25.51	27.34	30.66	34.50	37.87	41.22	48.56	57.70
37	19.19	21.11	22.08	24.85	26.38	28.25	31.64	35.57	39.02	42.45	49.98	59.37
38	19.91	21.87	22.86	25.69	27.25	29.17	32.62	36.64	40.17	43.68	51.40	61.03
39	20.64	22.64	23.65	26.53	28.13	30.08	33.61	37.72	41.32	44.91	52.82	62.69
40	21.37	23.41	24.44	27.38	29.01	31.00	34.60	38.79	42.48	46.15	54.24	64.35
41	22.11	24.19	25.24	28.23	29.89	31.92	35.58	39.86	43.63	47.38	55.66	66.02
42	22.85	24.97	26.04	29.09	30.77	32.84	36.57	40.94	44.78	48.62	57.08	67.68
43	23.59	25.75	26.84	29.94	31.66	33.76	37.57	42.01	45.94	49.85	58.50	69.34