PRACTICAL WORK BOOK

For The Course
EE-281 Electromagnetic Field

For

Second Year
(Electrical Engineering)

Name of Student: ________________________________

Class: ______________ Batch: _____________

Discipline: ________________________________

Class Roll No.: _________ Examination Seat No. ________

Complied by: Engr. Muhammad Amir Qureshi (Lab engineer)
Supervised by: Engr. Shoaib Siddiqui (Assistant Professor)

DEPARTMENT OF ELECTRICAL ENGINEERING

NED University of Engineering & Technology, Karachi-75270, Pakistan

SR. NO	DATE	EXPERIMENT	REMARKS
1.		To write a computer program to convert coordinates of a point from one coordinate system to other.	
2.		To write a program which takes a vector in Cartesian components and convert it into spherical or cylindrical at a given point.	
3.		To sense the presence of electromagnetic field / radiation in the atmosphere.	
4.		To construct and study the behavior of yagi-uda antenna .	
5.		To construct and study the behavior of Rhombic antenna .	
6.		To sketch the electrical field lines of point charge using the computer program.	
7.		To sketch the equipotential and electric field lines for the electric dipole using the computer program.	
8.		To develop a computer program to plot the electric field and equipotential lines due to: (a) Two point charges Q and -4Q located at (x,y) = (-1,0) and (1,0) respectively. (b) Four point charges Q, -Q, Q and -Q located at (x,y) = (-1,-1), (1,-1), (1,1) and (-1,1) respectively. Take $Q / 4\pi\varepsilon = 1$ and $\Delta I = 0.1$ Consider the range $-5 \leq x,y \leq 5$	

EXPERIMENT NO 1

OBJECT: To write a computer program to convert coordinates of a point from one coordinate system to other.

APPARATUS: Computer, Floppy disk, and C-Language compiler.

THEORY: Coordinate system is mathematical tools with which the concepts of electromagnetic field are explained .Our concern in EMF is the charge densities for example point charge and sheet of charge. These charge densities are well explained and analyze with the help of coordinate system, for instance, in the of point charge the preferred coordinate system will be spherical because of symmetry, for line charge we consider cylindrical coordinate system and for sheet of charge the Cartesian coordinate system is used for analysis.

In Cartesian system the coordinate point are (x, y, z) with limits from $-\infty$ to $+\infty$ each . Here x, y, z represents the planes of infinite extent.

In cylindrical system the coordinate point are (ρ,φ,z) . ρ describes the radius of cylinder from 0 to ∞ , φ describes the plane with limits from 0 to 2π and z describes the another plane with limits from $-\infty$ to $+\infty$.

In spherical system the coordinate point are (r,θ,φ) , r represents radius of sphere with limits 0 to ∞ , θ describes the cone with limits 0 to π and φ describes the plane with limits 0 to 2π.

Now it is frequently required to convert a point from one coordinate system to other, for which the following equations are used.

$$x = \rho \cos\theta$$

$$y = \rho \sin\theta$$

$$z = z$$

So a point in cylindrical system can be converted into Cartesian system.
Similarly,

$$\rho = \sqrt{x^2 + y^2}$$

$$\phi = Tan^{-1} y / x$$

$$z = z$$

These equations are used to transform a point from Cartesian system to cylindrical system.

For converting a point from Cartesian to spherical system, we used the following equations.

$$R = \sqrt{x^2 + y^2 + z^2}$$

$$\theta = Cos^{-1}(z / r)$$

$$\phi = Tan^{-1}(y / x)$$

And for converting from spherical to Cartesian system we use

$$x = r \sin\theta \cos\phi$$
$$y = r \sin\theta \cos\phi$$
$$z = r \cos\theta$$

PROCEDURE: In this experiment it is required to transform a point of one coordinate system to another system. For which students are required to write a program in C-language, which can take a point of any coordinate system and transform it to the required coordinate system.

RESULT :

Source code of the program is attached.

EXPERIMENT NO. 2

OBJECT:

To write a program which takes a vector in Cartesian components and convert it into spherical or cylindrical at a given point.

EQUIPMENT:

Computer, floppy disk, C-language compiler

THEORY:

For the analysis of electromagnetic filed, it is often required to transform a vector from one coordinate system to another.

Transforming from Cartesian to Cylindrical System:

Let a vector is given in Cartesian system,

$$\mathbf{A} = A_x\,\mathbf{a}_x + A_y\,\mathbf{a}_y + A_z\,\mathbf{a}_z \qquad (1)$$

Now it is required to transform it into cylindrical system i:e

$$\mathbf{A} = A_\rho\,\mathbf{a}_\rho + A_\varnothing\,\mathbf{a}_\varnothing + A_z\,\mathbf{a}_z \qquad (2)$$

So, the values of A_ρ ,$A_\varnothing$ and A_z will be required. For which we follow the procedure as given below.

To find "A_ρ" we take dot product between A (Cartesian) and unit vector a_ρ (which is of desired direction).

$$A_\rho = A\,.\,\mathbf{a}_\rho = A_x\,\mathbf{a}_x\,.\,\mathbf{a}_\rho + A_y\,\mathbf{a}_y\,.\,\mathbf{a}_\rho + A_z\,\mathbf{a}_z\,.\,\mathbf{a}_\rho \qquad \_\_\_\_\_\_(3)$$

Similarly to find "$A_\varnothing$" we take dot product between A(Cartesian) and unit vector $\mathbf{a}_\varnothing$.

$$A_\varnothing = A\,.\,\mathbf{a}_\varnothing = A_x\,\mathbf{a}_x\,.\,\mathbf{a}_\varnothing + A_y\,\mathbf{a}_y\,.\,\mathbf{a}_\varnothing + A_z\,\mathbf{a}_z\,.\,\mathbf{a}_\varnothing \,\_\_\_\_\_\_ \quad (4)$$

Similarly to find "A_z"

$$A_z = A\,.\,\mathbf{a}_z = A_x\,\mathbf{a}_x\,.\,\mathbf{a}_z + A_y\,\mathbf{a}_y\,.\,\mathbf{a}_z + A_z\,\mathbf{a}_z\,.\,\mathbf{a}_z\,\_\_\_\_\_\_\_\_ \quad (5)$$

So as we see from equations(3) to (5) that there is dot product between unit vector of dissimilar coordinates system which are summarized in tabular form as under

	$\mathbf{a}_\rho$	$\mathbf{a}_\varnothing$	$\mathbf{a}_z$
$\mathbf{a}_x$	CosØ	-SinØ	0
$\mathbf{a}_y$	SinØ	CosØ	0
$\mathbf{a}_z$	0	0	1

So , by using , the table , equations (3) ,(4) , (5) becomes,

$A_\rho = A_x \,Cos\varnothing + A_y \,Sin\varnothing \quad \Rightarrow \quad A_x \,Cos\varnothing + A_y \,Sin\varnothing$
$A_\varnothing = A_x \,(-Sin\varnothing) + A_y \,Cos\varnothing + 0 \quad \Rightarrow \quad -A_x \,Sin\varnothing + A_y \,Cos\varnothing$
$A_z = A_z$

Now if we are given any vector in Cartesian form

$$\mathbf{A} = A_x \,\mathbf{a}_x + A_y \,\mathbf{a}_y + A_z \,\mathbf{a}_z$$

And cylindrical point (ρ , Ø , z) we can transform it to cylindrical system using above equations.

Transforming Cartesian to Spherical system:

Now let same vector $\mathbf{A} = A_x \,\mathbf{a}_x + A_y \,\mathbf{a}_y + A_z \,\mathbf{a}_z$ is given and it is required to transform to Spherical coordinate system i.e.

$$\mathbf{A} = A_r \,\mathbf{a}_r + A_\theta \,\mathbf{a}_\theta + A_\varnothing \,\mathbf{a}_\varnothing$$

So, the values of A_r , A_θ and $A_\varnothing$ are required .
To find the values of " A_r" we take the dot product between 'A' of Cartesian and '$\mathbf{a}_r$'.
i.e.

$A_r = A \,.\, \mathbf{a}_r$
$\quad = (A_x \,\mathbf{a}_x + A_y \,\mathbf{a}_y + A_z \,\mathbf{a}_z) \,.\, \mathbf{a}_r$
$A_r = A_x \,\mathbf{a}_x \,.\, \mathbf{a}_r + A_y \,\mathbf{a}_y \,.\, \mathbf{a}_r + A_z \,\mathbf{a}_z \,.\, \mathbf{a}_r$ ____________ (6)

Similarly

$A_\theta = A \,.\, \mathbf{a}_\theta$
$\quad = (A_x \,\mathbf{a}_x + A_y \,\mathbf{a}_y + A_z \,\mathbf{a}_z) \,.\, \mathbf{a}_\theta$
$A_\theta = A_x \,\mathbf{a}_x \,.\, \mathbf{a}_\theta + A_y \,\mathbf{a}_y \,.\, \mathbf{a}_\theta + A_z \,\mathbf{a}_z \,.\, \mathbf{a}_\theta$ ____________ (7)

And ,

$A_\varnothing = A \,.\, \mathbf{a}_\varnothing$
$\quad = (A_x \,\mathbf{a}_x + A_y \,\mathbf{a}_y + A_z \,\mathbf{a}_z) \,.\, \mathbf{a}_\varnothing$
$A_\theta = A_x \,\mathbf{a}_x \,.\, \mathbf{a}_\varnothing + A_y \,\mathbf{a}_y \,.\, \mathbf{a}_\varnothing + A_z \,\mathbf{a}_z \,.\, \mathbf{a}_\varnothing$ ___________ (8)

Again there is a dot product between unit vectors of dissimilar coordinate system for which we use the following table.

	$\mathbf{a}_r$	$\mathbf{A}_\theta$	$\mathbf{a}_\varnothing$
$\mathbf{a}_x$	Sinθ CosØ	Cosθ CosØ	–SinØ
$\mathbf{a}_y$	Sinθ SinØ	Cosθ SinØ	CosØ
$\mathbf{a}_z$	Cosθ	–Sinθ	0

So , the equations (6) , (7) , (8) becomes

$A_r = A_x \,Sin\theta \,Cos\varnothing + A_y \,Sin\theta \,Sin\varnothing + A_z \,Cos\theta$ ___________(9)
$A_\theta = A_x \,Cos\theta \,Cos\varnothing + A_y \,Cos\theta \,Sin\varnothing + A_z \,(-Sin\theta)$ ________(10)

$$A_{Ø} = A_x \cos\theta + A_y(-\sin\theta) + 0 \qquad \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_(11)}$$

Now given a point in spherical system (r , θ , Ø) and a vector in Cartesian system can be easily converted into vector of spherical coordinate system .

PROCEDURE:

In this experiment students are required to write a computer program in C-language, which get input in the form of Cartesian coordinate system and then transform it into cylindrical or spherical system.

RESULT:

Source code of the program is attached.

EXPERIMENT NO 3

OBJECT: To sense the presence of electromagnetic field / radiation in the atmosphere.

APPARATUS: Solenoid , oscilloscope .

THEORY: A radiowave is generally known as an electromagnetic wave because it is made up of combination of both electric and magnetic fields. Whenever voltage is applied to antenna, an electric field will be set up. At the same time the voltage will cause the current to flow in the antenna. This current flow will produce a magnetic field. The electric and magnetic field are at right angles to each other. These electric and magnetic fields are emitted from the antenna and propagate through space over very long distance.

PRACTICAL / PROCESS:

RESULT:

EXPERIMENT NO 4

OBJECT: To construct and study the behavior of yagi-uda antenna .

APPARATUS : oscilloscope , yagi-uda antenna .

THEORY: An antenna is made up of one or more conductors of a specific length that radiate radio waves wave generated by the transmitter or that collect radio waves at the receiver . There are different types of antenna in use today . Some of commonly used antenna are dipole antenna , folded dipole , ground plane antenna and yagi-uda antenna . Yagi-uda antenna consists of a driven element , a reflector and one or more director's i.e yagi-uda antenna is an array of an driven element and oooooone or more parasitic elements . The driven element is a resosnant half wave dipole usually of metallic .
The parasitic elements receive their exitation from the induced voltage in them by the current flow in the driven element .

GENERAL CHARACTERISTIC OF YAGI-UDI ANTENNA :

1) With spacing of 0.1λ to 0.15λ a frequency band of order 2% is obtained .
2) It provide gain of order of 8db and front to back ratio of about 20db .
3) By increasing the number of elements the directivity can be increased .
4) It is usually a fixed frequency device .

PROCEDURE :

RESULT :

EXPERIMENT NO 5

OBJECT: To construct and study the behavior of Rhombic antenna .

APPARATUS: oscilloscope and rhombic antenna .

THEORY: Rhombic antenna is based on the principle of travelling wave radiator . By application of return conductor two wires are pulled at one point so that diamond or rhombic shape is formed . A Rhombic antenna is a very effient antenna of board frequency capabilities . It is prominent in all radio communication facilities where space necessary for its structure is easily available . The length of antenna and the angles between them are carefully chosen in order to cancel the side lobes , bearing only single main lobes lying along the main axis rhombus . The ground reflection tends to leave the main lope upwards into the sky and lift is proportional to the length of antenna used .

This antenna is highly directional used for point to point sky wave propagation .

PROCEDURE :

RESULTS :

EXPERIMENT # 06

OBJECT: To sketch the electrical field lines of point charge using the computer program.

APPARATUS: Computer, floppy disk, C-language compiler.

THEORY: Electrical field lines for the vector electric field intensity are drawn with the help of steam lines equation given by:

$$d_y / d_x = E_y / E_x \qquad \text{———————— (1)}$$

Now we consider the electric field intensity due to line charge

$$E = \rho_L / 2\pi\varepsilon_o\rho \; \mathbf{a}_p$$

Let for simplicity,

$$\rho_L = 2\pi\varepsilon_o$$

$$\Rightarrow \quad \boxed{E = 1 / \rho \; \mathbf{a}_p} \qquad \text{———————— (2)}$$

Knowing,

$$\rho = \sqrt{x^2 + y^2}$$

And

$$\mathbf{a}_\rho = \{x \, \mathbf{a}_x + y \, \mathbf{a}_y\} \, / \, \sqrt{x^2 + y^2}$$

Equation (2) becomes,

$$E = (x\mathbf{a}_x + y\mathbf{a}_y) / (x^2 + y^2)$$

Equation (1) becomes,

$$d_y / d_x = \frac{y / (x^2 + y^2)}{x / (x^2 + y^2)}$$

Solving,

$$\ln y = \ln x + \ln C$$

$$\ln y = \ln Cx$$

$$\boxed{y = Cx}$$

Which is the stream line equation for point charge.
Now if,
$C = 1 \Rightarrow y = x$
$C = -1 \Rightarrow y = -x$
$C = 0 \Rightarrow y = 0$
$1/C = 0 \Rightarrow x = 0$

Which can be plotted.

PROCEDURE: Students are required to write a computer program which can draw electric field lines for the point charge taking different values of ‘C’ and show the result in a combined manner.

RESULTS:

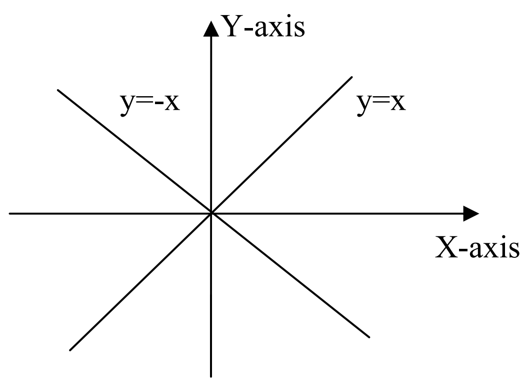
C	x	y
1	1	1
	2	2
	3	3
	4	4
	5	5

$C = 0 \Rightarrow y = 0$

$1/C = 0 \Rightarrow x = 0$

C = -1

x	y = -x
1	-1
2	-2
3	-3
4	-4
5	-5



Students are further required to make analysis report on the results of graph obtained from computer.

EXPERIMENT # 07

OBJECT: To sketch the equipotential and electric field lines for the electric dipole using the computer program.

THEORY: Electric dipole is the name given to two point charges of equal magnitude but opposite polarities separated by the distance which is small compared to distance to the point 'p' where the field is required.
Electric potential due to dipole is given by:

$V = Qd \cos\theta \ / \ 4\pi\varepsilon_o r^2$

And electric field intensity due to dipole is given by:

$E = Qd / 4\pi\varepsilon_o r^3 \ (2 \cos\theta \ \mathbf{a}_r + \sin\theta \ \mathbf{a}_r)$

Where (r, θ, ϕ) are of spherical coordinate system.

PROCEDURE: Students are required to write a computer program which can take input in the form of spherical point (r, θ, ϕ) the values of Q (charge) and d (separation between charges),and then plot the graph. Students are further required to write an exclusive analytical report by changing the values of Q and d and observing the effect on the field. A format is given below.
If Q = 5 μC and d = 1mm

r	θ	ϕ	E	V
2	45	55		
4	55	65		
6	40	60		
8	35	50		
10	30	45		
12	25	40		

If Q = 10 μC and d = 0.5mm

r	θ	ϕ	E	V
2	55	65		
4	50	60		
6	45	55		
8	40	50		
10	35	45		
12	30	40		

If Q = 20 μ C and d = 0.25mm then repeat above
If Q = 10 μ C and d = 1mm
If Q = 5 μ C and d = 2mm
If Q = 2.5 μ C and d = 3mm
If Q = 1.5 μ C and d = 4mm

ANALYSIS: Write the observation in terms of strength of the field. Write the value that gives the strongest field by the inspection of graphs.

RESULTS:

EXPERIMENT # 08

OBJECT: To develop a computer program to plot the electric field and equipotential lines due to:

(c) Two point charges Q and -4Q located at (x,y) = (-1,0) and (1,0) respectively.
(d) Four point charges Q, -Q, Q and -Q located at (x,y) = (-1,-1), (1,-1), (1,1) and (-1,1) respectively.

Take $Q / 4\pi\varepsilon = 1$ and $\Delta I = 0.1$

Consider the range $-5 \leq x,y \leq 5$

APPARATUS: PC, floppy disk, C-language compiler.

THEORY: In this practical a numerical technique is developed using an interactive computer programme. It generates data points for electric field lines and equipotential lines for arbitrary configuration of point sources.

The most commonly used numerical methods in electromagnetic fields are moment method, finite distance method, and finite element method. Partial difference equations are solved using the finite difference method or the finite element method. Integral equations are solved using the moment method. Although numerical methods give approximate solutions, the solutions are sufficiently accurate for engineering purposes.

Electric field lines are equipotential lines can be plotted for coplanar points sources with computer programmes. Suppose we have N point charges located at position vectors r_1, r_2, r_3……. r_N. The electric field intensity E and potential V at position vector 'r' are given respectively by:

$$E = \sum_{K=1}^{N} Q_K (r - r_K) / 4\pi\varepsilon \mid r - r_K \mid^3 \quad \text{———— (1)}$$

And

$$V = \sum_{K=1}^{N} Q_K / 4\pi\varepsilon \mid r - r_K \mid^3 \quad \text{———— (2)}$$

If the charges are on the same plane (Z = constant), equation (1) and (2) becomes,

$$E = \sum_{K=1}^{N} \frac{Q_K [(x - x_K) a_x + (y - y_K) a_y]}{4\pi\varepsilon [(x - x_K)^2 + (y - y_K)^2]^{3/2}} \quad \text{———— (3)}$$

And

$$V = \sum_{K=1}^{N} Q_K / 4\pi\varepsilon [(x - x_K)^2 + (y - y_K)^2]^{1/2} \quad \text{———— (4)}$$

PROCEDURE:

To plot the electric field lines follow these steps,

1- Chose a starting point on the field lines.
2- Calculate E_x and E_y at that point using equation (3)
3- Take a small step along the field line to a new point in the plane as shown in fig. A movement Δx and Δy along X and Y directions respectively. From the figure, it is evident that

$$\Delta x / \Delta l = E_x / E_y = \sqrt{\ } (E_x^2 + E_y^2)$$

or

$$\Delta x = \Delta l \ . E_x / [E_x^2 + E_y^2]^{1/2} \quad \text{———————} (5)$$

and

$$\Delta y = \Delta l \ . E_y / [E_x^2 + E_y^2]^{1/2} \quad \text{———————} (6)$$

Move along the field line from the old point (x,y) to a new point $x' = x + \Delta x$, $y' = y + \Delta y$.

4- Go back to step # 02 and repeat calculations. Continue to generate new points until a line is completed within a given range of coordinates. On completing the line, go back to step # 01 and choose another starting point. Note that since there are an infinite number of infinite lines, any starting point is likely to be on a field line. The point generated can be plotted manually and by using the computer programme.

To plot the equipotential lines follow these steps:

1- Choose a starting point.
2- Calculate the electric field (E_x, E_y) at the point from equation (3).
3- Move a small step along the line perpendicular to electric field lines at that point. Utilize the fact that if a line has slope m, a perpendicular line must have slope -1/m, since an electric field line and an equipotential line meeting at a given point are mutually orthogonal there,

$$\Delta x = -\Delta l \ . E_y / [E_x^2 + E_y^2]^{1/2} \quad \text{———————} (7)$$

$$\Delta y = \Delta l \ . E_x / [E_x^2 + E_y^2]^{1/2} \quad \text{———————} (8)$$

Move along the equipotential line from the old line point (x , y) to a new point ($x + \Delta x$, $y + \Delta y$). as a way of checking the new point calculate the potential at the new and old points using equation (04), they must be equal because the points are on the same equipotential line.

4- Go back to step # 02 and repeat the calculation. Continue to generate new points until a line is completed with a given range of x and y. After completing the line, go back to step # 01 and choose another starting point. Join the points generated by hand and confirm the result by using computer programme.

The value of incremental length Δl is crucial for accurate plots. Although the smaller the value of Δl, the more accurate the plots but it should be noted that the smaller the value of Δl, the more points generate and memory storage may be a problem. For example, a line may consist of more than 1000 generated points. In view of the large number of the points to be plotted, the points are usually stored in a data field and a graphics routine is used to plot the data.

CHECKS:

For both the E-field and equipotential lines, insert the following checks in the computer programme.

1- Check for singularity point E=0
2- Check whether the point generated is too close to a charge location.
3- Check whether the point is within the given range of $-5 < x,y > 5$
4- Check whether the equipotential line loops back to the starting point.

RESULTS: