

PRACTICAL WORK BOOK
For Academic Session 2013

ELECTROMAGNETIC FIELDS (EE-281)

For
T.E (BO) & T.E (MD)

Name:

Roll Number:

Class:

Batch:

Semester/Term:

Department :



Department of Electrical Engineering
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LAB SESSION 01

Introduction to Coordinate Systems

OBJECT:

To study different coordinate systems used in Electromagnetic Fields.

THEORY

There are three coordinate systems to provide symmetry to electromagnetic fields related problems.

- Rectangular Coordinate Systems.
- Circular Cylindrical Coordinate Systems.
- Spherical Coordinate System.

Rectangular Coordinate Systems

In rectangular coordinate system, the three coordinate axes are drawn mutually at right angles to each other and are called x, y and z axes.

Three quantities are mainly considered:

- Differential elements of length.
- Differential area.
- Differential volume.

In case of rectangular coordinate system differential elements of length are dx ,dy , and dz.

Differential areas are described as following:

- $dydz_{ax}$ where a_x is an unit normal vector normal to yz plane.
- $dzdx_{ay}$ where a_y is an unit normal vector normal to zx plane.
- $dx dy_{az}$ where a_z is an unit normal vector normal to xy plane.

Differential volume in case of rectangular coordinate system is defined as $dx dy dz$ i.e multiple of differential elements of length.

Rectangular Coordinate System is used as analogy for infinite sheet of charge related problems in electromagnetic fields. All the problems of infinite sheet of charge or parallel plate capacitor are solved with rectangular coordinate system.

Circular Cylindrical Coordinate System:

Circular Cylindrical Coordinate System is represented by (ρ, ϕ, z) .

Any point is considered as the intersection of three mutually perpendicular surfaces. These surfaces are circular cylinder ($\rho = \text{constant}$), a plane ($\phi = \text{constant}$), and another plane ($z = \text{constant}$).

In case of cylindrical coordinate system the differential elements of length are $d\rho$, $\rho d\phi$, and dz .

Differential surface areas are defined as following:

$\rho d\phi dz a_\rho$ where a_ρ is an unit vector normal to $\rho = \text{constant}$ plane.

$d\rho dz a_\phi$ where a_ϕ is an unit vector normal to $\phi = \text{constant}$ plane.

$\rho d\rho d\phi a_z$ where a_z is an unit vector normal to $z = \text{constant}$ plane.

Differential volume is defined by $\rho d\rho d\phi dz$ i.e multiple of three differential elements of length.

Circular Cylindrical Coordinate System is used as an analogy for solving infinite line charge related problems in electromagnetic fields. Therefore all the problem associated with infinite long line charge are considered by cylindrical coordinate system due to symmetry.

Spherical Coordinate System

Spherical Coordinate System is represented by (r, θ, ϕ) . Any point is considered as the intersection of three mutually perpendicular surfaces. A sphere $r = \text{constant}$, a cone $\theta = \text{constant}$, and a plane $\phi = \text{constant}$.

Differential elements of length in Spherical Coordinate System are: dr , $r d\theta$, $r \sin\theta d\phi$.

Differential surface areas in spherical coordinate system are defined as following:

$r dr d\theta a_\phi$ where a_ϕ is an unit vector normal to $\phi = \text{constant}$ plane.

$r^2 \sin\theta d\theta d\phi a_r$ where a_r is an unit vector normal to $r = \text{constant}$ sphere.

$r \sin\theta dr d\phi a_\theta$ where a_θ is an unit vector normal to $\theta = \text{constant}$ cone.

Differential volume in spherical coordinate system is defined by $r^2 \sin\theta dr d\theta d\phi$ i.e multiple of three differential elements of length.

Spherical Coordinate System is used as analogy for point charge in electromagnetic fields. Therefore all the problems related to point charge are solved by spherical coordinate system due to symmetry.

Coordinate Systems are used to provide the basic foundation for studying the different concepts of electromagnetic field.

PROCEDURE

In this experiment it is required to draw (on A4 size paper) the diagrams representing the rectangular, cylindrical and the spherical coordinate system with their unit vectors, differential elements of length, differential areas, and differential volume and submit with the work book.

RESULTS

Diagrams representing the rectangular, cylindrical, and spherical system with complete required details are attached

LAB SESSION 02

Conversion of point between the coordinate systems

OBJECT:

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

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 analyzed with the help of coordinate system, for instance, in the case 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.

$$x = \rho \cos \phi$$

$$y = \rho \sin \phi$$

$$z = z$$

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

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

$$y = r \sin\theta \sin\phi$$

$$z = r \cos\theta$$

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.

LAB SESSION 03

Conversion of vector between the coordinate systems

OBJECT:

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

THEORY:

For the analysis of electromagnetic field, 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,

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

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

$$\mathbf{A} = A_\rho \mathbf{a}_\rho + A_\theta \mathbf{a}_\theta + A_z \mathbf{a}_z \quad (2)$$

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

To find “ A_ρ ” we take dot product between \mathbf{A} (Cartesian) and unit vector \mathbf{a}_ρ (which is of desired direction).

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

Similarly to find “ A_θ ” we take dot product between \mathbf{A} (Cartesian) and unit vector \mathbf{a}_θ .

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

Similarly to find “ A_z ”

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

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}_ρ	\mathbf{a}_θ	\mathbf{a}_z
\mathbf{a}_x	$\cos\theta$	$-\sin\theta$	0
\mathbf{a}_y	$\sin\theta$	$\cos\theta$	0
\mathbf{a}_z	0	0	1

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

$$\begin{aligned} A_\rho &= A_x \cos\theta + A_y \sin\theta & \text{i.e } A_x \cos\theta + A_y \sin\theta \\ A_\theta &= A_x (-\sin\theta) + A_y \cos\theta + 0 & \text{i.e } -A_x \sin\theta + A_y \cos\theta \\ A_z &= A_z \end{aligned}$$

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 , θ , 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.

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

So, the values of A_r , A_θ and A_ϕ are required .

To find the values of “ A_r ” we take the dot product between ‘ A ’ of Cartesian and ‘ \mathbf{a}_r ’ .
 i.e.

$$\begin{aligned} A_r &= \mathbf{A} \cdot \mathbf{a}_r \\ &= (A_x \mathbf{a}_x + A_y \mathbf{a}_y + A_z \mathbf{a}_z) \cdot \mathbf{a}_r \\ A_r &= A_x \mathbf{a}_x \cdot \mathbf{a}_r + A_y \mathbf{a}_y \cdot \mathbf{a}_r + A_z \mathbf{a}_z \cdot \mathbf{a}_r \quad \text{-----(6)} \end{aligned}$$

Similarly

$$\begin{aligned} A_\theta &= \mathbf{A} \cdot \mathbf{a}_\theta \\ &= (A_x \mathbf{a}_x + A_y \mathbf{a}_y + A_z \mathbf{a}_z) \cdot \mathbf{a}_\theta \\ A_\theta &= A_x \mathbf{a}_x \cdot \mathbf{a}_\theta + A_y \mathbf{a}_y \cdot \mathbf{a}_\theta + A_z \mathbf{a}_z \cdot \mathbf{a}_\theta \quad \text{-----(7)} \end{aligned}$$

And ,

$$\begin{aligned} A_\phi &= \mathbf{A} \cdot \mathbf{a}_\phi \\ &= (A_x \mathbf{a}_x + A_y \mathbf{a}_y + A_z \mathbf{a}_z) \cdot \mathbf{a}_\phi \\ A_\phi &= A_x \mathbf{a}_x \cdot \mathbf{a}_\phi + A_y \mathbf{a}_y \cdot \mathbf{a}_\phi + A_z \mathbf{a}_z \cdot \mathbf{a}_\phi \quad \text{-----(8)} \end{aligned}$$

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}_θ	\mathbf{a}_ϕ
\mathbf{a}_x	$\sin\theta \cos\phi$	$\cos\theta \cos\phi$	$-\sin\phi$
\mathbf{a}_y	$\sin\theta \sin\phi$	$\cos\theta \sin\phi$	$\cos\phi$
\mathbf{a}_z	$\cos\theta$	$-\sin\theta$	0

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

$$A_r = A_x \sin\theta \cos\phi + A_y \sin\theta \sin\phi + A_z \cos\theta \quad \text{-----(9)}$$

$$A_\theta = A_x \cos\theta \cos\phi + A_y \cos\theta \sin\phi + A_z (-\sin\theta) \quad \text{-----(10)}$$

$$A_{\theta} = A_x(-\sin\theta) + A_y \cos\theta + 0 \quad \text{_____}(11)$$

Now given a point in spherical system (r , θ , θ) 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.

LAB SESSION 04

The electrical field lines of point charge

OBJECT:

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

THEORY:

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

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

Now we consider the electric field intensity due to line charge

$$E = \rho_L / 2\pi\epsilon_0\rho \mathbf{a}_p$$

Let for simplicity,

$$\rho_L = 2\pi\epsilon_0$$

$$\boxed{E = 1 / \rho \mathbf{a}_p} \text{ ----- (2)}$$

Knowing,

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

And

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

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 then y = x

C = -1 then y = -x

C = 0 then y = 0

1/C=0 then 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 combined manner.

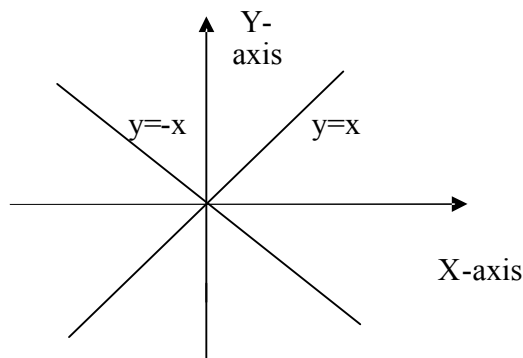
RESULTS:

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

$$C = 0 \text{ then } y = 0$$
$$1/C = 0 \text{ then } x = 0$$

$$C = -1$$

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.

LAB SESSION 05

Equipotential and electric field lines for the electric dipole

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: $V = Qd \cos \theta / 4\pi\epsilon_0 r^2$

And electric field intensity due to dipole is given by:

$$E = Qd / 4\pi\epsilon_0 r^3 (2 \cos \theta \mathbf{a}_r + \sin \theta \mathbf{a}_\theta)$$

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 μ C 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 μ C 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 $Q = 20 \mu\text{C}$ and $d = 0.25\text{mm}$ then repeat above

If $Q = 10 \mu\text{C}$ and
 $d = 1\text{mm}$

If $Q = 5 \mu\text{C}$ and
 $d = 2\text{mm}$

If $Q = 2.5 \mu\text{C}$ and
 $d = 3\text{mm}$

If $Q = 1.5 \mu\text{C}$ and
 $d = 4\text{mm}$

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:

Submit the graph representing the Electric Field Intensity (E) in terms of Q and d. Also submit the analytical report which shows the effect of changing the Q and d on electric field intensity.

LAB SESSION 06

Iterative method for plotting the Electric Field and Equipotential Lines

OBJECT: 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 $Q / 4\pi\epsilon = 1$ and $\Delta I = 0.1$

Consider the range $-5 < x, y < 5$

THEORY: In this practical a numerical technique is developed using an interactive computer program. 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 and equipotential lines can be plotted for coplanar points sources with computer programmes. Suppose we have N point charges located at position vectors $r_1, r_2, r_3, \dots, r_N$. The electric field intensity E and potential V at position vector 'r' are given respectively by:

$$E = \sum_{K=1}^N Q_K (r - r_K) / 4\pi\epsilon |r - r_K|^3 \text{ _____(1)}$$

And

$$V = \sum_{K=1}^N Q_K / 4\pi\epsilon |r - r_K| \text{ _____(2)}$$

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

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

And

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

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

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

or

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

and

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

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 program.

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,

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

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

Move along the equipotential line from the old line point (x , y) to a new point (x + Δx , y + Δy). 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 program.

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 program.

- 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.

PROCEDURE:

In this experiment, it is required to apply the iterative method to find the electric field and equipotential due to two point charges and four point charges using the computer simulation with the help of C language.

RESULTS:

Manual solution and computer program to sketch the electric field and equipotential due to two point charges and four point charges is attached.

LAB SESSION 07

Introduction to MATLAB

OBJECT:

Introduction to MATLAB and its commands to solve the Engineering Problems.

APPARATUS:

MATLAB Software, computer, floppy disk.

THEORY:

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation.

Typical uses include Math and Computation Algorithm Development, Data Acquisition, Modeling, Simulation, and Prototyping. Data analysis, Exploration, and Visualization. Scientific and Engineering Graphics Application Development, including Graphical User Interface (GUI) building.

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non-interactive language such as C or Fortran.

The name MATLAB stands for matrix laboratory. MATLAB has evolved over a period of years with input from many users. In university environments, it is the standard instructional tool for introductory and advanced courses in mathematics, engineering, and science. In industry, MATLAB is the tool of choice for high-productivity research, development, and analysis.

MATLAB features a family of add-on application-specific solutions called toolboxes. Very important to most users of MATLAB, toolboxes allow you to learn and apply specialized technology. Toolboxes are comprehensive collections of MATLAB functions (M-files) that extend the MATLAB environment to solve particular classes of problems. Areas in which toolboxes are available include signal processing, control systems, neural networks, fuzzy logic, wavelets, simulation, and many others.

The MATLAB System

The MATLAB system consists of five main parts:

Development Environment

This is the set of tools and facilities that help you use MATLAB functions and files. Many of these tools are graphical user interfaces. It includes the MATLAB desktop and Command Window, a command history, an editor and debugger, and browsers for viewing help, the workspace, files, and the search path.

The MATLAB Mathematical Function Library

This is a vast collection of computational algorithms ranging from elementary functions, like sum, sine, cosine, and complex arithmetic, to more sophisticated functions like matrix inverse, matrix eigenvalues, Bessel functions, and Fast Fourier Transforms.

The MATLAB Language

This is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features. It allows both "programming in the small" to rapidly create quick and dirty throw-away programs, and "programming in the large" to create large and complex application programs.

Graphics

MATLAB has extensive facilities for displaying vectors and matrices as graphs, as well as annotating and printing these graphs. It includes high-level functions for two-dimensional and three-dimensional data visualization, image processing, animation, and presentation graphics. It also includes low-level functions that allow you to fully customize the appearance of graphics as well as to build complete graphical user interfaces on your MATLAB applications.

The MATLAB Application Program Interface (API).

This is a library that allows you to write C and Fortran programs that interact with MATLAB. It includes facilities for calling routines from MATLAB (dynamic linking), calling MATLAB as a computational engine, and for reading and writing MAT-files.

PROCEDURE:

Students are required to verify the following commands on MATLAB.
Open command window in MATLAB and enter following commands and expressions.

General Expressions:

- 1) date
- 2) ans=8/10
- 3) 5*ans
- 4) r=8/10
- 5) s=20*r
- 6) 8+3*5=23
- 7) 8+(3*5)=23
- 8) (8+3)*5=55
- 9) $4^2-12-8/4^2=0$
- 10) $4^2-12-8/(4*2)$
- 11) $3*4^2+5$
- 12) $(3*4)^2+5=140$
- 13) $27^{1/3}+32^{0.2}$
- 14) $6*10/13+18/5*7+5*9^2$
- 15) $6(35^{1/4})+14^{0.35}$
- 16) c=cross (a, b) to find cross product between two vectors.
- 17) c=dot (a, b) to find dot product between two vectors.

Addition, Subtraction, Multiplication, and Division of complex numbers:

- 1) S=3+7i
- 2) W=5-9i
- 3) W+S=8-2i
- 4) W*S=78+8i
- 5) W/S=-0.8276-1.0690i
- 6) Find $(-3+7i)*(-3-7i)$

Exercise:

1. Given $x = -5+9i$
 $y = 6-2i$
Use MATLAB to show that:

$$\begin{aligned}x+y &= 1+7i \\xy &= -12+64i \\x/y &= -1.2+1.1i\end{aligned}$$

2. Given: $a=2i+3j+4k$
 $b=5i+6j+7k$

Use MATLAB to find (a cross b) and (a dot b).

Plotting with MATLAB**Example:**

```
x= [0:0.02:8];  
y=5*Sin(x);  
plot(x,y),xlabel('x'),ylabel('y')
```

Exercise:

Use MATLAB to plot the function $s=2\sin(3t+2)+\sqrt{5t+1}$ over the interval $0 < t < 5$. Put a title on the plot and properly label the axes. The variable s represents the speed in feet per second. The variable t represents the time in seconds. Attach the commands used and the graph of the function with work book.

RESULTS:

Different commands of the MATLAB system are verified and graph of the exercise is attached.

LAB SESSION 08

Conversion of point within two coordinate systems using MATLAB

OBJECT:

Using the MATLAB program, convert a point from rectangular coordinate system into the spherical coordinate system.

APPARATUS:

MATLAB Software, computer, floppy disk.

THEORY:

In this practical MATLAB programming is used to convert a point from one coordinate system to another coordinate system. Let us suppose it is required to compute the cylindrical point (ρ, ϕ) from the rectangular coordinates (x,y) .

where

$$\rho = \sqrt{x^2 + y^2}$$
$$\phi = \tan^{-1}(y/x)$$

Following steps are used to implement the program.

1. Enter the coordinates (x,y) .
2. Compute the value of ρ i.e $\rho = \text{sqrt}(x^2+y^2)$.
3. Compute the angle ϕ :
if $x > 0$
then $\text{phi} = \text{atan}(y/x)$
else
then $\text{phi} = \text{atan}(y/x) + \text{pi}$
4. Convert the angle to degrees :
 $\text{phi} = \text{phi} * (180/\text{pi})$
5. display the result ρ and phi .
6. stop.

MATLAB Coding:

```
x=input('Enter the value of x: ');
y=input('Enter the value of y: ');
rho = sqrt(x^2+y^2);
if x>=0
phi=atan(y/x)
else
phi=atan(y/x)+pi;
end
```

```
disp('The radius is: ')
disp(ρ)
phi = phi*(180/pi);
disp('The angle in degree is: ')
disp(phi)
```

Type the above MATLAB coding in the MATLAB programming editor and save the file. Now run the program and get the output on the command window.

EXERCISE:

Write a program in the MATLAB to convert rectangular coordinate system point (x,y,z) to spherical coordinate system point (r, θ , ϕ) and submit with the work book. Verify the result from the MATLAB command window.

RESULTS:

MATLAB source program to convert rectangular coordinate system point to spherical coordinate system point is attached.

LAB SESSION 09

Solution of Lorentz Force Equation with MATLAB

OBJECT:

To solve the Lorentz Force Equation with the help of MATLAB.

APPARATUS:

MATLAB Software, computer, floppy disk.

THEORY:

Knowing that the force on the charged particle is

$$\mathbf{F} = Q\mathbf{E}$$

The force is in the same direction as the electric field intensity (for a positive charge) and is directly proportional to both E and Q.

A charged particle in motion in a magnetic field of flux density \mathbf{B} is found experimentally to experience a force whose magnitude is proportional to the product of the magnitudes of the charge Q, its velocity \mathbf{v} , and the flux density \mathbf{B} , and to the sine of the angle between the vectors \mathbf{v} and \mathbf{B} . The direction of force is perpendicular to both \mathbf{v} and \mathbf{B} and is given by a unit vector in the direction of $\mathbf{v} \times \mathbf{B}$. The force may therefore be expressed as:

$$\mathbf{F} = Q\mathbf{v} \times \mathbf{B}$$

A mathematical difference in the effect of the electric and magnetic fields on charged particle is now apparent, for a force which is always applied in a direction at right angles to the direction in which the particle is proceeding can never change the magnitude of the particle velocity. In other words, acceleration vector is always normal to the velocity vector. The kinetic energy of the particle remains unchanged, and it follows that the steady magnetic field is incapable of transferring energy to the moving charge. The electric field, on the other hand, exerts a force on the particle which is independent of the direction in which the particle is progressing and therefore effects an energy transfer between field and particle in general.

The force on a moving particle arising from combined electric and magnetic field is obtained easily by superposition:

$$\mathbf{F} = Q(\mathbf{E} + \mathbf{v} \times \mathbf{B})$$

This equation is known as the Lorentz force equation, and its solution is required in determining electron orbits in the magnetron, proton paths in the cyclotron, plasma

characteristics in a magneto hydrodynamic(MHD) generator,or,in general, charged particle motion in combined electric and magnetic fields.

Exercise:

The point charge $Q=18 \text{ nC}$ has a velocity of $5 \times 10^6 \text{ m/s}$ in the direction $a_v = 0.60a_x + 0.75a_y + 0.30a_z$. Calculate the magnitude of the force exerted on the charge by the field : (a) $B = -3a_x + 4a_y + 6a_z \text{ mT}$ (b) $E = -3a_x + 4a_y + 6a_z \text{ kV/m}$ (c) B and E acting together.

Procedure:

(1) In this experiment it is required to solve the above mentioned problem manually and then verify the results using the MATLAB. Students are required to submit the manual solution and the commands used in the MATLAB to solve the problem, with the work book.

(2) Submit the two page report to describe the significance of Lorentz Force Equation in Electrical Machines.

RESULTS:

(1) Manual solution of the problem and MATLAB commands are attached.

(2) Report to describe the significance of Lorentz Force Equation in Electrical Machines is submitted.

LAB SESSION 10

Study of Yagi-Uda Antenna

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 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 antennas 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 directors i.e yagi-uda antenna is an array of driven element and one or more parasitic elements. The driven element is a resonant half wave dipole usually of metallic .The parasitic elements receive their excitation 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 provides 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 :

Students are required to submit a two page analytical report describing the main features of yagi-uda antenna with diagrams and submit with the work book.

RESULTS:

Report to describe the main features of yagi-uda antenna with diagrams is submitted with the work book.

LAB SESSION 11

Study of Rhombic Antenna

OBJECT:

To construct and study the behavior of Rhombic Antenna.

APPARATUS:

Oscilloscope and rhombic antenna.

THEORY:

Rhombic antenna is based on the principle of traveling 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 efficient antenna of broad 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 lobe 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 :

Students are required to submit a two page analytical report describing the main features of rhombic antenna with diagrams and submit with the work book.

RESULTS:

Report to describe the main features of rhombic antenna with diagrams is submitted with the work book.

