Learn LaTeX

Explaining basics in latex...

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First Edition

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Chapter 1

Latex Basics

1.1 Introduction:

This chapter deals with the very basic tools and concepts involved in LaTeX,which are the basic building blocks in writing a **STEM** paper.

1.2 How to write formula using Latex:

There are two ways to write formula using Latex:

- Using $_$: This is used to write formula in the line.
- Using $$_$$: This used to create a separate environment for the formula.Often complex,space taking and which are not aligning to a line are written using this functionality.

1.2.1 Code:

```
The Euler's form of a complex number is given by:  $e^{i\pi}$
\\The Euler's form of a complex number is given by:  $$e^{i\pi}$$
```

1.2.2 Output:

The Euler's form of a complex number is given by: $e^{i\pi}$
The Euler's form of a complex number is given by:

$$e^{i\pi}$$

1.3 Different mathematical functions using Latex:

Before starting your code make sure that yo included **amsmath** package in the start of the code

1.3.1 Scaling the size of the bracket:

In order to scale the size of the brackets according to the sie of he formula we have to specify left and right in the code.

Code:

```
$$(\frac{1}{n}+1)$$
$$\left(\frac{1}{n}+1\right)$$
```

Output:

$$(\frac{1}{n}+1)$$
$$\left(\frac{1}{n}+1\right)$$

1.3.2 Limits:

Limits can be given in latex using **lim** in **amsmath** package.

Code:

```
$$e= \lim_{n\to\infty}\left(\frac{1}{n}+1\right)^nS$$
```

Output:

$$e=\lim_{n\to\infty}\left(\frac{1}{n}+1\right)^n$$

1.3.3 nTH root:

The nTH root of a number is given using **sqrt** function.
Note: Take care of the type of bracket being used.

Code:

```
$$\sqrt[n]{n!}$$
```

Output:

$$\sqrt[n]{n!}$$

1.3.4 Summation:

The summation can be given using the keyword **sum**.

Code:

```
$$e=\sum_{n=0}^{\infty}\frac{1}{n!}$$
$$\sum_{n=1}^{n}n=n(n+1)/2$$
```

Output:

$$e=\sum_{n=0}^{\infty}\frac{1}{n!}$$

$$\sum_{n=1}^{n}n=n(n+1)/2$$

1.3.5 Continued fractions:

Continued fractions are fractions that extend upto infinity following a certain pattern.
Here **ddots** is used to give diagonal dots

Code:

```
$$e=2+\frac{1}{1+\frac{1}{2+\frac{2}{3+\frac{3}{4+\frac{4}{5+\ddots}}}}}$$
```

Output:

$$e = 2 + \cfrac{1}{1 + \cfrac{1}{2 + \cfrac{2}{3 + \cfrac{3}{4 + \cfrac{4}{5 + \ddots}}}}}$$

1.3.6 Integration:

Code:

```
$$\int_{a}^{b}f(x)dx$$
$$\iint_S f(x,y)dxdy$$
$$\iiint_V f(x,y,z)dxdydz$$
$$\int_{a}^{b}\int_{c}^{d}\int_{e}^{f}f(x,y,z)dxdydz$$
```

Output:

$$\int_{a}^{b} f(x)dx$$

$$\iint_S f(x,y)dxdy$$

$$\iiint_V f(x,y,z)dxdydz$$

$$\int_{a}^{b}\int_{c}^{d}\int_{e}^{f} f(x,y,z)dxdydz$$

1.3.7 Vectors:

Here **cdot** stands for centre dot.
Here **times** gives cross symbol.

Code:

```
$$\Vec{v}=<v_1, v_2, v_3>$$
$$\Vec{v}\cdot\Vec{w}$$
$$\Vec{v}\times\Vec{w}$$
```

Output:

$$\vec{v} =< v_1, v_2, v_3 >$$

$$\vec{v} \cdot \vec{w}$$

$$\vec{v} \times \vec{w}$$

1.3.8 Matrices:

Code:

```
$$\begin{bmatrix}
1 & 2 & 3\\ 4 & 5 & 6\\7 & 8 & 9\\10 & 11 & 12
\end{bmatrix}$$
```

Output:

$$\begin{bmatrix}
1 & 2 & 3\\ 4 & 5 & 6\\7 & 8 & 9\\10 & 11 & 12
\end{bmatrix}$$

1.4 How to add images:

In order to add images in latex we have to use package named **graphicx**.
Here **[h!]** is used in order to add image at a particular location.

1.4.1 Code:

```
\begin{figure}[h!]
    \centering
    \includegraphics[scale= 0.5]{landscape.jpeg}
    \caption{Landscape}
    \label{fig:enter-label}
\end{figure}
```

1.4.2 Output:

Figure 1.1: Landscape

1.5 Adding references to an equation:

In order to add reference to an equation we can use the keyword **equation**. **label** and **ref** are used to refer the equation in any other area of interest.

1.5.1 Code:

```
\begin{equation}\label{1}\int_{a}^{b}f(x)dx\end{equation}
Equation \ref{1} is basic formula for integration.
```

1.5.2 Output:

$$\int_{a}^{b} f(x)dx \tag{1.1}$$

Equation 1.1 is basic formula for integration.

1.6 Align, Split and Multiline Equation:

1.6.1 Multilining:

In order to multiline an equation we have to use the keyword **align**.
For multilining an equation we have to use '\\'.

Code:

```
\begin{align}
e=\sum_{n=0}^{\infty}\frac{1}{n!}
= \lim_{n\to\infty}\left(\frac{1}{n}+1\right)^n
\end{align}
\begin{align}
e=\sum_{n=0}^{\infty}\frac{1}{n!}\\
= \lim_{n\to\infty}\left(\frac{1}{n}+1\right)^n
\end{align}
```

Output:

$$e=\sum_{n=0}^{\infty}\frac{1}{n!} = \lim_{n\to\infty}\left(\frac{1}{n}+1\right)^n \tag{1.2}$$

$$e=\sum_{n=0}^{\infty}\frac{1}{n!} \tag{1.3}$$

$$= \lim_{n\to\infty}\left(\frac{1}{n}+1\right)^n \tag{1.4}$$

Note:

Here you can notice the difference between equation 2 and 3,4.Also notice that equation 3,4 is not aligned. Hence we go to the next part called **aligning**.

1.6.2 Aligning:

In order to align the two equations we use the symbol **&**.
"**&**" tells to latex where the object need to be vertically aligned.

Code:

```
\begin{align}
e=&\sum_{n=0}^{\infty}\frac{1}{n!}\\
= &\lim_{n\to\infty}\left(\frac{1}{n}+1\right)^n
\end{align}
```

Output:

$$e = \sum_{n=0}^{\infty} \frac{1}{n!} \tag{1.5}$$

$$= \lim_{n\to\infty} \left(\frac{1}{n}+1\right)^n \tag{1.6}$$

Note:

Here you can notice that there are two references for the same equation which are in different lines.
Hence we go to the next part called **splitting**.

1.6.3 Splitting:

Splitting is nothing but giving two or more equations the same reference.

Code:

```
\begin{align}
\begin{split}
e=&\sum_{n=0}^{\infty}\frac{1}{n!}\\
= &\lim_{n\to\infty}\left(\frac{1}{n}+1\right)^n
\end{split}
\end{align}
```

Output:

$$\begin{split} e &= \sum_{n=0}^{\infty} \frac{1}{n!} \\ &= \lim_{n\to\infty} \left(\frac{1}{n}+1\right)^n \end{split} \tag{1.7}$$

1.6.4 What if the equation overlaps with reference?

Yes you heard it right.In order to avoid this situation we can use the keyword **multline** instead of **equation**.
Let us see an example:

Code:

```
\begin{equation}
    e^x\approx 1+x+\frac{x^2}{2!}+\frac{x^3}{3!}+\frac{x^4}{4!}+\frac{x^5}
    {5!}+\frac{x^6}{6!}+\frac{x^7}{7!}+\frac{x^8}{8!}+\frac{x^9}{9!}+\frac
    {x^{10}}{10!}+\frac{x^{11}}{11!}+\frac{x^{12}}{12!}+\frac{x^{13}}
    {13}+\frac{x^{14}}{14!}
\end{equation}
\begin{multline}
    e^x\approx 1+x+\frac{x^2}{2!}+\frac{x^3}{3!}+\frac{x^4}{4!}+\frac{x^5}
    {5!}+\frac{x^6}{6!}+\frac{x^7}{7!}\\+\frac{x^8}{8!}+\frac{x^9}{9!}+\frac
    {x^{10}}{10!}+\frac{x^{11}}{11!}+\frac{x^{12}}{12!}+\frac{x^{13}}
    {13}+\frac{x^{14}}{14!}
\end{multline}
```

Output:

$$e^x\approx 1+x+\frac{x^2}{2!}+\frac{x^3}{3!}+\frac{x^4}{4!}+\frac{x^5}{5!}+\frac{x^6}{6!}+\frac{x^7}{7!}+\frac{x^8}{8!}+\frac{x^9}{9!}+\frac{x^{10}}{10!}+\frac{x^{11}}{11!}+\frac{x^{12}}{12!}+\frac{x^{13}}{13}+\frac{x^{14}}{14!} \tag{1.8}$$

$$\begin{multline}e^x\approx 1+x+\frac{x^2}{2!}+\frac{x^3}{3!}+\frac{x^4}{4!}+\frac{x^5}{5!}+\frac{x^6}{6!}+\frac{x^7}{7!}\\+\frac{x^8}{8!}+\frac{x^9}{9!}+\frac{x^{10}}{10!}+\frac{x^{11}}{11!}+\frac{x^{12}}{12!}+\frac{x^{13}}{13}+\frac{x^{14}}{14!} \tag{1.9}\end{multline}$$

Note:

From the above outputs we observe that by using **multline** with the symbol "\\"(near {7!}) we get more elegant equation with reference not overlapping with the equation.

1.7 Tables and Tabular:

1.7.1 Tabular:

Tabular gives us the outline of a table with only vertical lines
The lines inside the bracket after tabular ($\{c|c\}$) gives us the number of vertical lines.
The horizontal lines are given by **hline** function.
& is used as placeholder.
Here:

- **c** refers to center.
- **r** refers to right.
- **l** refers to left.

Code:

```
\begin{center}
\begin{tabular}{c|c}
    1 & 2 \\
    3 & 4
\end{tabular}
\begin{tabular}{|c|r|}
\hline
    1 & 2 \\\hline
    3 & 40000000\\\hline
\end{tabular}
\begin{tabular}{|c|l|}
\hline
    1 & 2 \\\hline
    3 & 40000000\\\hline
\end{tabular}
\end{center}
```

Output:

1	2
3	4

1	2
3	40000000

1	2
3	40000000

1.7.2 Table:

Table is similar to **tabular**.In fact tabular is a part of table.
Tabular gives the outline and contents for the table while **table** gives the caption and necessary references to the table made using tabular.

Code:

```
\begin{table} [h!]
    \begin{center}
    \begin{tabular}{|c|l|}
    \hline
        1 & 2 \\\hline
        3 & 40000000\\\hline
    \end{tabular}
    \end{center}
    \caption{Example Table}
    \label{tab:my_label}
\end{table}
```

Output:

1	2
3	40000000

Table 1.1: Example Table

1.8 New theorem environments:

Before starting to form new theorem environments make sure that you use the packages **amsmath,amsthm,amsfonts**.
In this section we are going to see how to use new theorem environment in order to write theorems.

Lemma: A true statement used in proving other true statements (that is, a less important theorem that is helpful in the proof of other results).

Corollary: A true statement that is a simple deduction from a theorem or proposition.

Proof: The explanation of why a statement is true

1.8.1 Types:

- **newtheorem{theorem}{Theorem}[section]**
  This is the example presented in the introductory code but it has the additional parameter [section] that restarts the theorem counter at every new section.

- **newtheorem{corollary}{Corollary}[theorem]**
  An environment called corollary is created, the counter of this new environment will be reset every time a new theorem environment is used.

- **newtheorem{lemma}[theorem]{Lemma}**
  In this case, the even though a new environment called lemma is created, it will use the same counter as the theorem environment.

1.8.2 Code1:

```
\newtheorem{thm}{Theorem}
\begin{thm}
    Let \(f\) be a function whose derivative exists in every point,
    then \(f\) is a continuous function.
\end{thm}
\begin{thm}[Pythagorean theorem]
    This is a theorem about right triangles and can be summarised in
    the next equation \[ x^2 + y^2 = z^2 \]
\end{thm}
```

1.8.3 Output1:

Theorem 1. *Let f be a function whose derivative exists in every point, then f is a continuous function.*

Theorem 2 (Pythagorean theorem)**.** *This is a theorem about right triangles and can be summarised in the next equation*

$$x^2 + y^2 = z^2$$

1.8.4 Code2:

```
\newtheorem{theorem}{Theorem}[section]
\newtheorem{corollary}{Corollary}[theorem]
\newtheorem{lemma}[theorem]{Lemma}
```

```
\begin{theorem}
    Let \(f\) be a function whose derivative exists in every point,
    then \(f\) is a continuous function.
\end{theorem}
\begin{theorem}[Pythagorean theorem]
    This is a theorem about right triangles and can be summarised in
    the next equation \[ x^2 + y^2 = z^2 \]
\end{theorem}
\begin{corollary}
    There's no right rectangle whose sides measure 3cm, 4cm, and 6cm.
\end{corollary}
\begin{lemma}
    Given two line segments whose lengths are \(a\) and \(b\)
    respectively there is a real number\(r\) such that \(b=ra\).
\end{lemma}
```

1.8.5 Output2:

Theorem 1.8.1. *Let f be a function whose derivative exists in every point, then f is a continuous function.*

Theorem 1.8.2. *This is a theorem about right triangles and can be summarised in the next equation*

$$x^2 + y^2 = z^2$$

Corollary 1.8.2.1. *There's no right rectangle whose sides measure 3cm, 4cm, and 6cm.*

Lemma 1.8.3. *Given two line segments whose lengths are a and b respectively there is a real number r such that $b = ra$.*

1.8.6 Note:

From the two outputs we observe that on using an additional block called [**section**] we can specify the section in which the theorem is being written.
Also in the code the \newtheorem{theorem}{Theorem}[section]:

- The first block specifies the name by which environment will be referred.
- The second block specifies the label of the environment.
- The third block gives the section to the theorem.

1.9 Custom Macros:

This is used to shorten or customize a command in order to make latex easier.

In the code **\newcommand{\R}{\mathbb{R}}**:

- The first block specifies the new command.
- The second block specifies the old command.

1.9.1 Code:

```
Real numbers are given by the symbol $\mathbb{R}$
\newcommand{\R}{\mathbb{R}}
\\Real numbers are given by the symbol $\R$
```

1.9.2 Output:

Real numbers are given by the symbol $\mathbb{R}$
Real numbers are given by the symbol $\mathbb{R}$

Chapter 2

Thesis Writing

2.1 Introduction

This chapters majorly deals with the tools that are useful in writing a STEM thesis using Latex.

2.2 Document classes:

There are 5 different document classes in latex ,namely:

- **book**: for real books
- **report**: for longer reports containing several chapters, small books, thesis, etc..
- **article**: for articles in scientific journals, presentations, short reports, program documentation, invitations, etc..
- **beamer**: For writing presentations
- **letter**: For writing letters

So in order to write a **thesis** we have to use the document class **report**.

2.3 Abstract, Dedication and Acknowledgement:

In order to give Abstract, Dedication and Acknowledgement we have to use **chapter** keyword.

2.3.1 Code:

```
\chapter*{Abstract}
\chapter*{Dedication}
\chapter*{Acknowledgement}
```

2.4 Separate Chapter Files:

Since thesis is gonna be large it is very difficult to organise all the chapters in a single latex file. So in order to manage this we can create separate files for different chapters and we can organize it easily. An example of this is shown in the figure below.

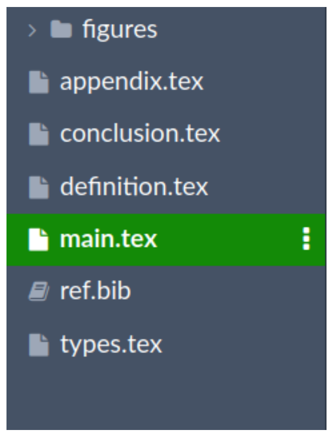


Figure 2.1: Separate chapter files

2.4.1 Explanation:

Here in this example I have created 6 files and a folder for images .

- **main.tex** file is the main file that is used to create a pdf.
- **definition.tex,types.tex** and **conclusions.tex** are the chapter files which are included in tex files.
- **appendix.tex** is appendix file
- **ref.bib** is the bibliography file

2.4.2 Steps to add chapter files in main file:

1. Create separate chapter files for the chapters.
2. In order to add the chapter in the main file use the command:
   \include{filename}

2.5 Hierarchy of Headings:

The headings in a document follows the following hierarchy.

1. **chapter**
2. **section**
3. **subsection**
4. **subsubsection**

2.6 Table of contents and list of figures:

Table of contents gives us the idea of the overall content and structure of article or a report.
List of figures is same as table of contents but it gives us the idea of precise location of figures only.

2.6.1 Code:

```
\tableofcontents
\listoffigures
\addcontentsline{toc}{chapter}{Conclusion}
\include{conclusion}
```

2.6.2 Note:

In the above code we encounter a command \addcontentsline. This command is used to add the chapters or sections which are **unnumbered**.

Syntax explanation:

```
\addcontentsline{toc}{chapter}{Conclusion}
\include{conclusion}
```

Here:

- The first block refers to table of contents.
- The second block tells us whether we have to add chapter or section in the table of contents.
- The third block is where we have to give the name of the chapter or section.

2.7 Appendices:

Appendices generally contain information that is NOT ESSENTIAL to the essay/report that you have written, but supports analysis and validates your conclusions. However, sometimes an appendix may be used for ESSENTIAL tables and figures that are too large to fit into the text of an essay/report.

Use keyword **appendix** before including the appendix file.

2.7.1 Code:

```
\appendix
\include{appendix}
```

2.8 Bibliography and Citations:

- \cite{label}:To insert a citation where label is the label of a bibliographic entry in a .bib file.
- \bibliography{bibfilename}:To insert a bibliography where bibfilename is the name of a .bib file.
- \bibliographystyle{stylename}:To choose a BibTeX bibliographic style

Before using bibliography create a reference file in order to store the data about referred books and articles.

2.9 Footnotes:

Footnotes (sometimes just called 'notes') are what they sound like—a note (or a reference to a source of information) which appears at the foot (bottom) of a page. In a footnote referencing system, you indicate a reference by: Putting a small number above the line of type directly following the source material.

2.9.1 Code:

I want to do a footnote\footnote[3]{This is my first footnote}

2.10 Margins:

Consider the code **\documentclass[twoside]{report}**:

Here twoside means that the document will have (possibly different) left and right pages, like in a book, to be printed on both sides of the paper.

In order to define the margins we have to use the package **geometry** and command **newgeometry**.

2.10.1 Code:

```
\newgeometry{
top = 0.75in,
bottom = 0.75in,
inner = 0.75in,
outer = 1.5in
}
```

2.11 Example Thesis:

Now let us see a sample thesis and understand the structure of thesis.

2.11.1 Flow of code:

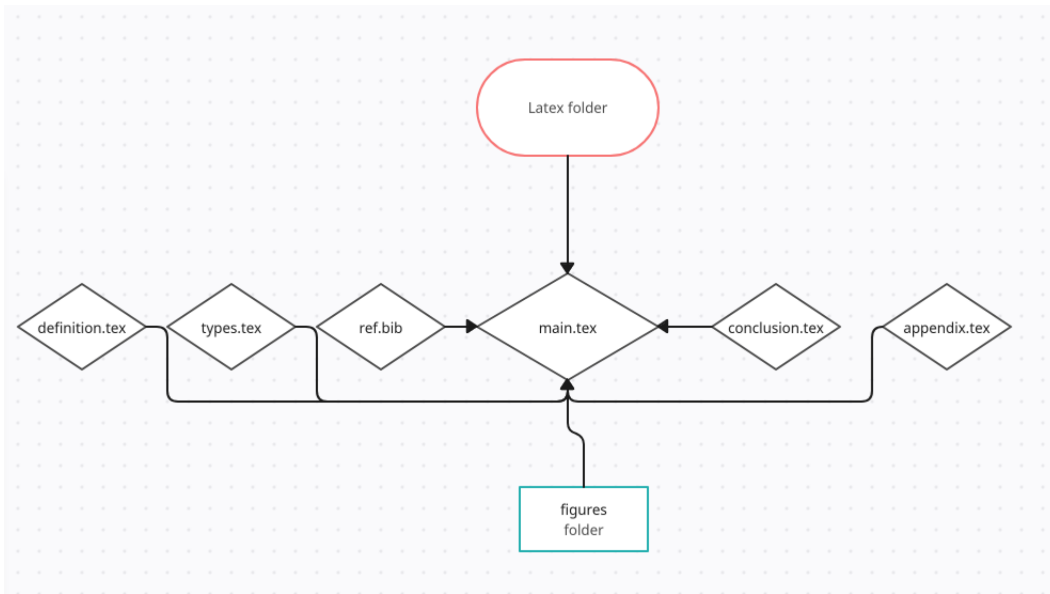


Figure 2.2: Flow of code

2.11.2 Code:

main.tex:

```
\documentclass[twoside]{report}
\usepackage{graphicx} % Required for inserting images
\usepackage{xcolor}
\usepackage{amsmath}
\usepackage[hidelinks]{hyperref}
\usepackage{geometry}

\newgeometry{
top = 0.75in,
bottom = 0.75in,
inner = 0.75in,
outer = 1.5in
```

```
}

\title{Sample Thesis On Calculus\\{\Large Indian Institute Of Technology, Madras}}
\author{Rakshan V P}
\date{July 2023}

\begin{document}

\maketitle

\chapter*{Abstract}
Integral Calculus is the branch of calculus where we study integrals and their properties. I


\chapter*{Dedication}
For the readers who read this pdf...

\chapter*{Acknowledgements}
I want to thank all the websites which I referred to...

\tableofcontents
\listoffigures
\include{definition}
\include{types}
\addcontentsline{toc}{chapter}{Conclusion}
\include{conclusion}
\appendix
\include{appendix}

\bibliographystyle{plain}
\bibliography{ref}
\end{document}
```

definition.tex:

```
\chapter{Definition}
If we know the f' of a function that is differentiable in its domain,
we can then calculate f. In differential calculus, we used to call f',
the derivative of the function f. In integral calculus, we call f the
anti-derivative or primitive of the function f'. And the process of
finding the anti-derivatives is known as anti-differentiation or
integration. As the name suggests, it is the inverse of finding
differentiation\cite{texbook}.
\begin{figure}[h]
```

```
    \centering
    \includegraphics[scale=0.4]{figures/thesis2.png}
    \caption{Introductory}
    \label{fig:enter-label}
\end{figure}
```

types.tex:

```
\chapter{Types}
Integration can be classified into two different categories, namely,
\begin{itemize}
    \item Definite Integral
    \item Indefinite Integral
\end{itemize}
\section{Definite Integral}
An integral that contains the upper and lower limits (i.e.) start and end value is known as

A definite Integral is represented as:
\textcolor{violet}{$$\int_{a}^{b}f(x)dx$$}
\begin{figure}[h]
    \centering
    \includegraphics[scale=0.2]{figures/thesis1.png}
    \caption{definite integral}
    \label{fig:enter-label}
\end{figure}

\section{Indefinite Integral}
Indefinite integrals are not defined using the upper and lower limits. The indefinite integr

The integration of a function f(x) is given by F(x) and it is represented by:

\textcolor{violet}{$$\int_{}^{}f(x) dx = F(x) + C$$}

where R.H.S. of the equation means integral of f(x) with respect to x
\begin{itemize}
    \item F(x) is called anti-derivative or primitive.

    \item f(x) is called the integrand.

    \item dx is called the integrating agent.

    \item C is called the constant of integration.

    \item x is the variable of integration.
```

```
\end{itemize}
\begin{figure}[h]
    \centering
    \includegraphics[scale=0.4]{figures/thesis3.png}
    \caption{Indefinite integral}
    \label{fig:enter-label}
\end{figure}

I want to do a footnote\footnote[3]{This is my first footnote}
```

appendix.tex:

```
\chapter{Appendix}
This is the appendix
```

conclusions.tex:

```
\chapter*{Conclusions}
This is the conclusion part.
```

ref.bib:

```
@book{texbook,
    author = {R D Sharma},
    title = {R D Sharma Mathematics},
    publisher = {Dhanpat Rai Publication},
    year = 2023
}
```

2.11.3 Output:

The output is attached on Appendix A

Chapter 3

Making LaTeX document beautiful

3.1 Introduction

This chapter mainly deals with the tips and tricks in order to make your latex document beautiful.

3.2 Columns and Minipage:

3.2.1 twocolumn:

The keyword **twocolumn** is used to print the text in two columns in a single page.

Code:

```
\documentclass[twocolumn]{report}
\usepackage{lipsum}

\begin{document}
\section{Columns:}
\begin{itemize}
    \item twocolumn
    \item multicols
    \item Minipage
\end{itemize}
\lipsum[1-5]
\end{document}
```

Output:

The output is attached in Appendix B.1

3.2.2 multicols and multicols*:

The keyword **multicols** is used to print text in multiple columns and also used to print a particular text over multiple columns.

The difference between **multicols** and **multicols*** is that **multicols** distributes the text in evenly manner while **multicols*** distributes the text in uneven manner.(i.e., It completes the first column and then goes to the second column)

Code1:

```
\documentclass{report}
\usepackage{lipsum}
\usepackage{multicol}

\begin{document}
\begin{multicols}{2}[\textbf{multicols is used to spread a line over
two or more columns as a single line.}]
\section{Columns:}
\lipsum[1-3]
\end{multicols}
\end{document}
```

Output1:

The output is attached in Appendix B.2

Code2:

```
\documentclass{report}
\usepackage{lipsum}
\usepackage{multicol}

\begin{document}
\begin{multicols*}{2}[\textbf{multicols is used to spread a line over
two or more columns as a single line.}]
\section{Columns:}
\lipsum[1-3]
\end{multicols*}
\end{document}
```

Output2:

The output is attached in Appendix B.3

3.2.3 Minipage:

Minipage is same as multicols but the major advantage here is that we can alter the width of columns.
Also this function can be used for **images,tables,etc..**

Code:

```
\documentclass{report}
\usepackage{lipsum}

\begin{document}
\begin{minipage}{0.6\textwidth}
\lipsum[1]
\end{minipage}
\hspace{10pt}
\begin{minipage}{0.3\textwidth}
\lipsum[2]
\end{minipage}
\end{document}
```

Output:

The output is attached in Appendix B.4

3.3 Margin Notes and Whitespaces:

3.3.1 Margin Notes:

Margin Notes are notes which are gonna be outside the margin (or) in the margin region.

Command:\marginpar{Enter your note here}

3.3.2 Whitespaces:

Usually in latex, especially while writing formulae whitespaces are ignored even it is typed.
So in order to give whitespaces we can use the following keywords.

- \: For one space
- **quad**:For four spaces
- **qquad**:For eight spaces

- **hspace**[ ]:For custom spacing.
- **hfill**:For filling the whole line in evenly manner.
- **vfill**:For filling the whole page in evenly manner.

Code:

```
\[ \frac{x}{y},\frac{du}{dt} and \frac{d^2 u}{dx^2},\frac{\partial
u}{\partial t}
   = h^2 \left( \frac{\partial^2 u}{\partial x^2}
      + \frac{\partial^2 u}{\partial y^2}
      + \frac{\partial^2 u}{\partial z^2} \right)\]
\vfill
\[ \frac{x}{y},\quad\frac{du}{dt} and \frac{d^2 u}{dx^2},\qquad
\frac{\partial u}{\partial t}
   = h^2 \left( \frac{\partial^2 u}{\partial x^2}
      + \frac{\partial^2 u}{\partial y^2}
      + \frac{\partial^2 u}{\partial z^2} \right)\]
\vfill
\[ \frac{x}{y},\hspace{1in}\frac{du}{dt} and \frac{d^2 u}{dx^2},\hspace{2in}\frac{\partial u
   = h^2 \left( \frac{\partial^2 u}{\partial x^2}
      + \frac{\partial^2 u}{\partial y^2}
      + \frac{\partial^2 u}{\partial z^2} \right)\]
\vfill
This is line1\hfill This is line2\hfill This is line3.
```

Output:

$$\frac{x}{y},\frac{du}{dt} and \frac{d^2 u}{dx^2},\frac{\partial u}{\partial t} = h^2 \left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2} \right)$$

$$\frac{x}{y},\quad\frac{du}{dt} and \frac{d^2 u}{dx^2},\qquad \frac{\partial u}{\partial t} = h^2 \left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2} \right)$$

$$\frac{x}{y},\hspace{1in}\frac{du}{dt} and \frac{d^2 u}{dx^2},\hspace{2in}\frac{\partial u}{\partial t} = h^2 \left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2} \right)$$

This is line1 This is line2 This is line3.

3.4 Linebreaks,Indent and Paragraph Spacing:

- In latex \\ is used as linebreak.
- In order to do indentation we have to use keyword **noindent**
- In order to skip some space between paragraphs we can use package **parskip**.

  Syntax:

  ```
  \usepackage{skip=20pt,indent=40pt}{parskip}
  ```

3.5 Annotating Equations:

3.5.1 UnderBraces

Code:

```
\[ \underbrace{\frac{x}{y}}_{I.c},\frac{du}{dt} and \frac{d^2
u}{dx^2}\]
```

Output:

$$\underbrace{\frac{x}{y}}_{I.c},\frac{du}{dt} and \frac{d^2 u}{dx^2}$$

3.5.2 Highlighting

Code:

```
\usepackage{tcolorbox}
\[\colorbox{yellow}{$\frac{x}{y}$},\colorbox{orange}{$\frac{du}{dt} and
\frac{d^2 u}{dx^2}$}\]
```

Output:

$$\colorbox{yellow}{$\frac{x}{y}$},\colorbox{orange}{$\frac{du}{dt} and \frac{d^2 u}{dx^2}$}$$

3.5.3 With Arrows

Code:

```
\usepackage{witharrows}

\WithArrowsOptions{displaystyle,tikz=blue}
\[\begin{WithArrows}
x(t)=e^t  \Arrow{Do integration}
\\\int_{a}^{b}x(t)dt
\end{WithArrows}\]
```

Output:

$$\begin{aligned} x(t) &= e^t \\ \int_a^b x(t)dt & \end{aligned} \quad \text{\textit{Do integration}}$$

3.6 Writing Code In Latex:

In order to write code in latex we can use the package **minted**.
Basically minted is a pigment package which colors the code according to the specified language.

3.6.1 Code:

```
\begin{minted}{python}
\# Python program to find the factorial of a number provided by the user.

# change the value for a different result
num = 7

# To take input from the user
#num = int(input("Enter a number: "))

factorial = 1

# check if the number is negative, positive or zero
if num < 0:
   print("Sorry, factorial does not exist for negative numbers")
elif num == 0:
   print("The factorial of 0 is 1")
else:
   for i in range(1,num + 1):
```

```
        factorial = factorial*i
    print("The factorial of",num," is",factorial)
\end{minted}
```

3.6.2 Output:

```python
# Python program to find the factorial of a number provided by the user.

# change the value for a different result
num = 7

# To take input from the user
#num = int(input("Enter a number: "))

factorial = 1

# check if the number is negative, positive or zero
if num < 0:
   print("Sorry, factorial does not exist for negative numbers")
elif num == 0:
   print("The factorial of 0 is 1")
else:
   for i in range(1,num + 1):
       factorial = factorial*i
   print("The factorial of",num,"is",factorial)
```

Chapter 4

Tikz

4.1 Introduction

This chapter majorly deals with the a package called **tikz** which is useful in making beautiful diagrams and graphs in latex. In order to start with we have use the packages

\usepackage{tkiz,pgfplots}
\usetikzlibrary{positioning}

4.2 Drawing Lines,Circles and Ellipses

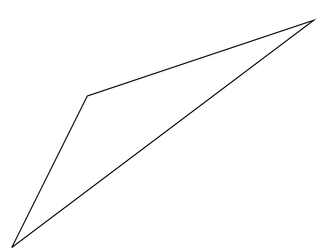
4.2.1 Lines:

In order to draw a line we have to specify the points and use the symbol **--**.

Code

```
\begin(center)
\tikz \draw (0,0)--(1,2)--(4,3)--(0,0);
\end(center)
```

Output



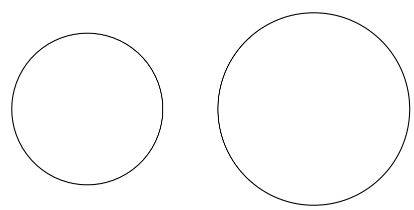
4.2.2 Circle:

Similar to lines in order to draw a circle first we have to specify the starting point but we have to use the keyword **circle** and then specify the radius.
Note that the default unit of measurement is in **cm**.

Code

```
\begin{center}
\begin{tikzpicture}
    \draw (0,0) circle(1);
    \draw (3,0) circle(0.5in);
\end{tikzpicture}
\end{center}
```

Output



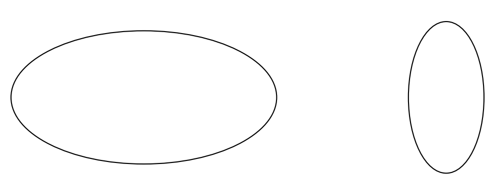
4.2.3 Ellipse:

For ellipse we have to use the same syntax as circle but we have to use the keyword **ellipse**.Also we have to give major and minor axis lengths in parameters bracket.

Code

```
\begin{center}
\begin{tikzpicture}
    \draw (7,0) ellipse(0.5 and 1);
    \draw (3,0) ellipse(50pt and 25pt);
\end{tikzpicture}
\end{center}
```

Output



4.3 Rectangles and Grids:

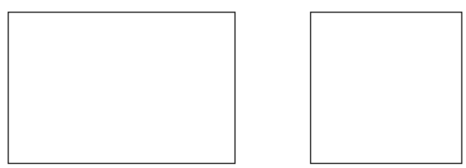
4.3.1 Rectangle:

In order to draw a rectangle we have to specify the initial corner and the opposing corner in parameter brackets.

Code

```
\begin{center}
\begin{tikzpicture}
    \draw (0,0) rectangle (3,2);
    \draw (4,0) rectangle (6,2);
\end{tikzpicture}
\end{center}
```

Output



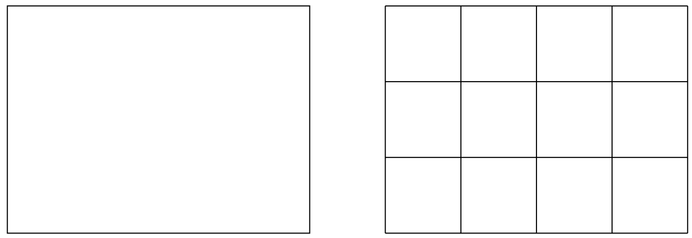
4.3.2 Grid:

grid is used to fill the rectangle with horizontal and vertical lines with spacing of 1cm in between them.

Code

```
\begin{center}
\begin{tikzpicture}
    \draw (0,0) rectangle (4,3);
    \draw (5,0) grid (9,3);
\end{tikzpicture}
\end{center}
```

Output



4.4 Centering and Scaling

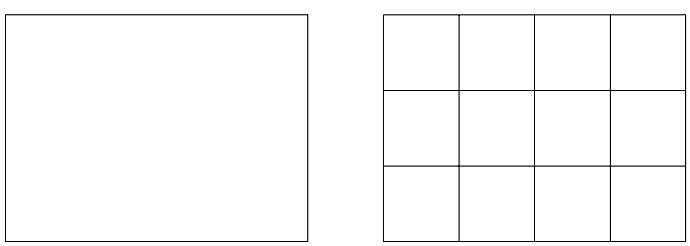
4.4.1 Centering

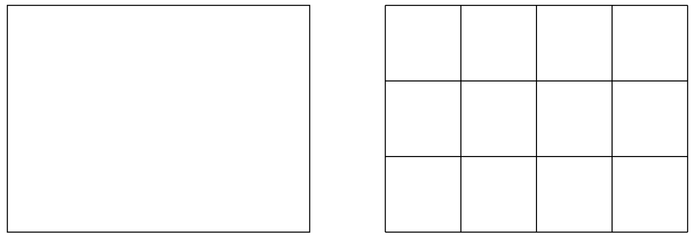
In order to center a figure or content we will use the keyword **center**.

Code

```
\begin{tikzpicture}
    \draw (0,0) rectangle (4,3);
    \draw (5,0) grid (9,3);
\end{tikzpicture}
\vspace{1in}
\begin{center}
\begin{tikzpicture}
    \draw (0,0) rectangle (4,3);
    \draw (5,0) grid (9,3);
\end{tikzpicture}
\end{center}
```

Output





4.4.2 Scaling

Scaling means changing the meaurements of a figure according to our wish.

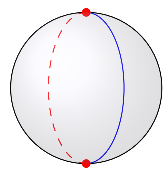
Command:[{scale=2}]

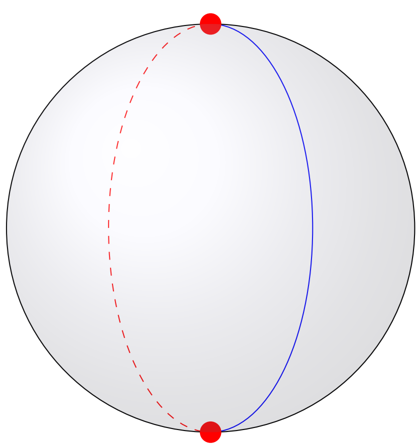
Code

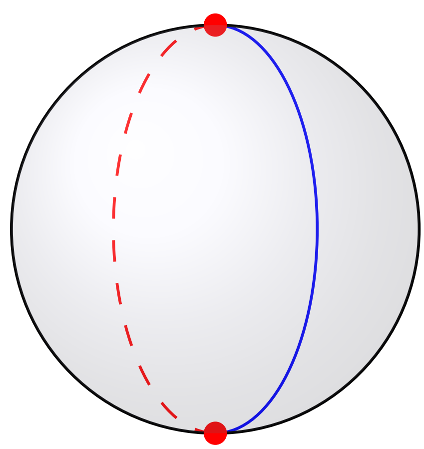
```
\begin{center}
    \begin{tikzpicture}
        \draw[blue] (0,1) arc (90:-90:0.5cm and 1cm);
        \draw[dashed, red] (0,1) arc (90:270:0.5cm and 1cm);
        \draw (0,0) circle (1cm);
        \filldraw[red] (0,1) circle  (0.05);
        \filldraw[red] (0,-1) circle (0.05);
        \shade[ball color=blue!10!white,opacity=0.20] (0,0) circle (1cm);
        \end{tikzpicture}
\end{center}

\vspace{1in}

\begin{center}
        \begin{tikzpicture}[{scale=2.7}]
        \draw[blue] (0,1) arc (90:-90:0.5cm and 1cm);
        \draw[dashed, red] (0,1) arc (90:270:0.5cm and 1cm);
        \draw (0,0) circle (1cm);
        \filldraw[red] (0,1) circle  (0.05);
        \filldraw[red] (0,-1) circle (0.05);
        \shade[ball color=blue!10!white,opacity=0.20] (0,0) circle (1cm);
        \end{tikzpicture}
\hspace{0.1in}
    \scalebox{2.7}{
    \begin{tikzpicture}
        \draw[blue] (0,1) arc (90:-90:0.5cm and 1cm);
        \draw[dashed, red] (0,1) arc (90:270:0.5cm and 1cm);
        \draw (0,0) circle (1cm);
```

```
        \filldraw[red] (0,1) circle  (0.05);
        \filldraw[red] (0,-1) circle (0.05);
        \shade[ball color=blue!10!white,opacity=0.20] (0,0) circle (1cm);
        \end{tikzpicture}
    }
\end{center}
```

Output







Note:

From the outputs we observe that on using

- **scale** only the size of the object increases but not the thickness of the line.
- **scalebox** not only increases the size of the object but also increases the thickness os the lines.

4.5 Color,Dashed,Fill,Shading

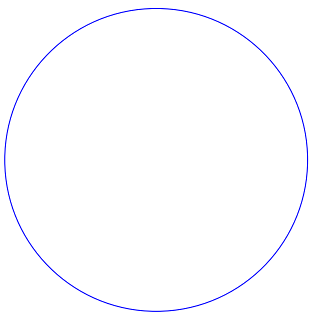
4.5.1 Color

In order to give color to a line we have to put the color inside square brackets as shown below.

Code

```
\tikz\draw[blue] (0,0) circle(2);
```

Output



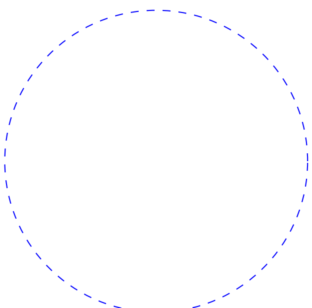
4.5.2 Dashed

In order to give dashed line we have to use keyword **dashed** within square brackets.

Code

```
\tikz\draw[blue,dashed] (0,0) circle(2);
```

Output



4.5.3 Arc

In order to draw an arc we can use the keyword **arc** and give the following parameters,
For circular arc:**(start angle:stop angle:radius)**

- with radius: radius
- starts: from (x,y)
- with center: (x-r*cos(start angle), y-r*sin(start angle)) and
- ends at: (x-r*cos(start angle)+r*cos(stop angle), y-r*sin(start angle)+r*sin(stop angle)).

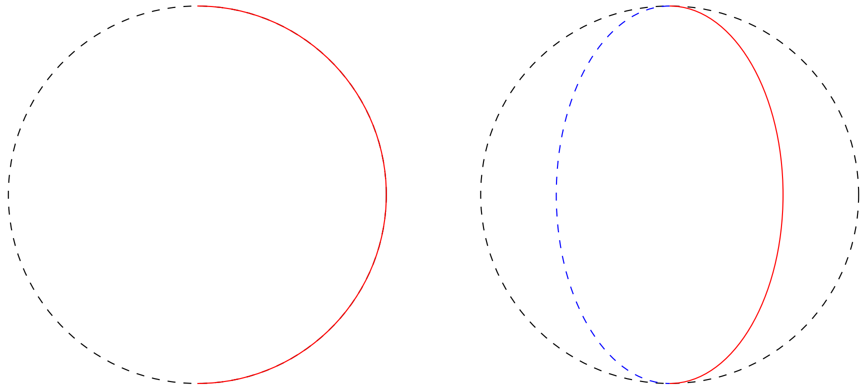
For elliptical arc arc:**(start angle:stop angle:minor and major axis distances)**

- with radius: radius
- starts: from (x,y)

Code

```
\begin{center}
\begin{tikzpicture}
    \draw[dashed] (0,0) circle (2.5);
    \draw[red] (0,2.5) arc (+90:-90:2.5);
\end{tikzpicture}
\hspace{1cm}
\begin{tikzpicture}
    \draw[dashed] (7,0) circle (2.5);
    \draw[red] (7,2.5) arc (+90:-90:1.5 and 2.5);
    \draw[blue,dashed] (7,2.5) arc (90:270:1.5 and 2.5);
\end{tikzpicture}
\end{center}
```

Output



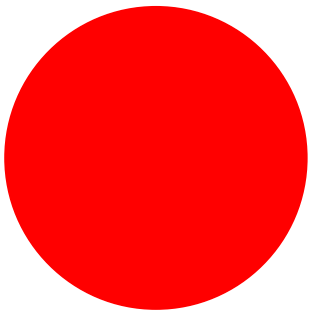
4.5.4 Fill

In order to draw a shape filled with a particular color we have to use the keyword **filldraw**.

Code

```
\tikz \filldraw[red] (0,0) circle(2);
```

Output



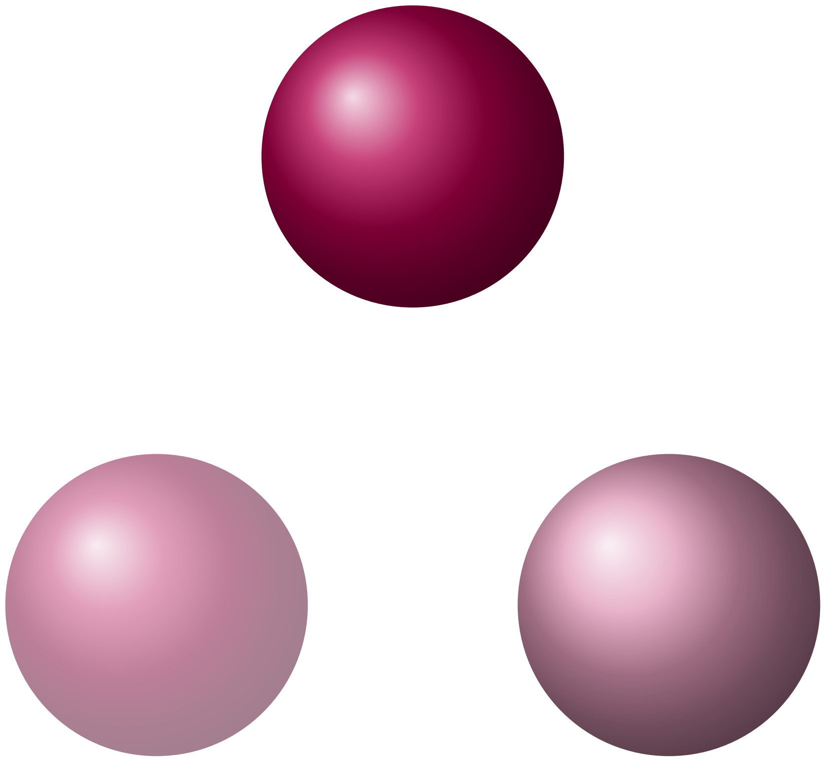
4.5.5 Shading

In order to shade a particular shape we can use the keyword **shade**.
In order to shade the shape with two or more different colors we can use the parameter **ball color**

Code

```
\begin{center}
\tikz \shade[ball color=blue!30!red] (0,0) circle (2);
\end{center}

\vspace{0.5in}

\begin{center}
\tikz \shade[ball color=blue!30!red,opacity=0.5] (0,0) circle (2);
\hspace{1in}
\tikz \shade[ball color=blue!30!red!40!white] (0,0) circle (2);
\end{center}
```

Output



Note

The number after the symbol specifies the percentage of color that must be used.

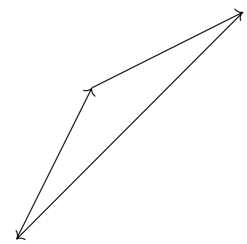
4.6 Arrows and Thickness

4.6.1 Arrow

Code

```
\begin{center}
\begin{tikzpicture}
\draw[->] (0,0)--(1,2);
\draw[->] (1,2)--(3,3);
\draw[->] (3,3)--(0,0);
\end{tikzpicture}
\end{center}
```

Output



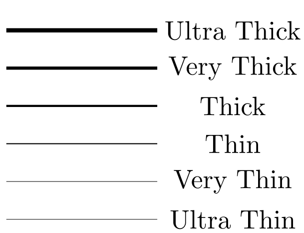
4.6.2 Thickness

Various thickness levels are demonstrated in the below code.

Code

```
\begin{tikzpicture}
\draw[ultra thick] (0,3) -- (2,3);
\draw[very thick] (0,2.5) -- (2,2.5);
\draw[thick] (0,2) -- (2,2);
\draw[thin] (0,1.5) -- (2,1.5);
\draw[very thin] (0,1) -- (2,1);
\draw[ultra thin] (0,.5) -- (2,.5);

\draw node at (3, 3) {Ultra Thick};
\draw node at (3, 2.5) {Very Thick};
\draw node at (3, 2) {Thick};
\draw node at (3, 1.5) {Thin};
\draw node at (3, 1) {Very Thin };
\draw node at (3, 0.5) {Ultra Thin};
\end{tikzpicture}
```

Output



4.7 Nodes

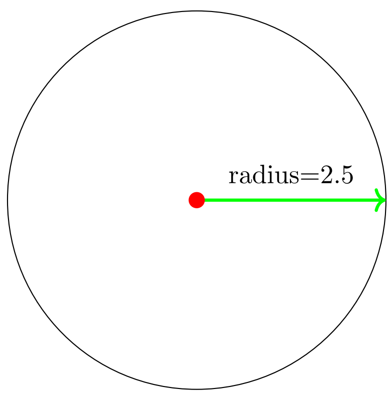
This is one of the most powerful tools in latex.This is majorly used to write text in Tikz. The simplest example of a node is some text which is placed on a given coordinate, but a node can also be a bit of text surrounded by a circle, rectangle, or other simple shape

4.7.1 Example1

Code

```
\begin{center}
\begin{tikzpicture}
\draw (0,0) circle (2.5);
\draw[very thick,green,->] (0,0)--(2.5,0);
\draw node[above,yshift=0.1cm] at (1.25,0) {radius=2.5};
\filldraw[red](0,0)circle(0.1);
\end{tikzpicture}
\end{center}
```

Output



4.7.2 Example2

Code

```
%Using anchor
\begin{center}
\begin{tikzpicture}
\filldraw[blue](0,0)circle(0.1) node[anchor=west]{This example is to demonstrate anchor}
\end{tikzpicture}
\begin{tikzpicture}
```

```
\filldraw[red](0,-1)circle(0.1) node[anchor=east]{This example is to demonstrate anchor}
\end{tikzpicture}
\end{center}
```

Output

●This example is to demonstrate anchor

This example is to demonstrate anchor●

4.7.3 Example3

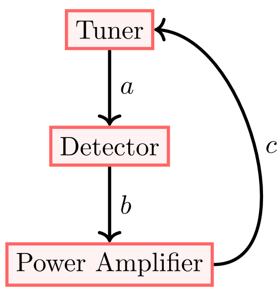
This example demonstrates how to make beautiful block diagram using nodes.

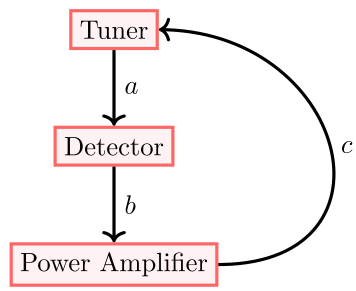
Code

```
%Code with looseness=1
\begin{tikzpicture}[EG/.style={rectangle,draw=red!60,fill=red!5,very
thick,minimum size=5mm}] %Style specifications of box

%Nodes
\node[EG]  (Tuner)                             {Tuner};
\node[EG]  (Detector)      [below=of Tuner]    {Detector};
\node[EG]  (Power)         [below=of Detector]{Power Amplifier};

%Lines
\draw[->,very thick](Tuner.south) to node[right] {$a$} (Detector.north);
\draw[->,very thick](Detector.south) to node[right] {$b$} (Power.north);
\draw[->,very thick](Power.east) [out=0,in=0,looseness=1]to node[right] {$c$}
(Tuner.east);
\end{tikzpicture}
\hspace{0.5in}
%Code with Looseness=2
\begin{tikzpicture}[EG/.style={rectangle,draw=red!60,fill=red!5,very
thick,minimum size=5mm}] %Style specifications of box

%Nodes
\node[EG]  (Tuner)                             {Tuner};
\node[EG]  (Detector)      [below=of Tuner]    {Detector};
\node[EG]  (Power)         [below=of Detector]{Power Amplifier};

%Lines
\draw[->,very thick](Tuner.south) to node[right] {$a$} (Detector.north);
\draw[->,very thick](Detector.south) to node[right] {$b$} (Power.north);
```

```
\draw[->,very thick](Power.east) [out=0,in=0,looseness=2]to node[right] {$c$}
(Tuner.east);
\end{tikzpicture}
\end{center}
```

Output





Code explanation

In both diagrams, the nodes (components) are defined using the style "EG," which sets the shape, color, and size of the nodes. The nodes are positioned using the "below" option relative to the previous node, resulting in a vertical arrangement.

In the first diagram, the signal flows from the Tuner to the Detector using an arrow labeled "a," and from the Detector to the Power Amplifier using an arrow labeled "b." The signal then flows from the Power Amplifier to the Tuner in a circular fashion using a curved arrow labeled "c." The "looseness=1" option on the curved arrow determines the amount of curvature in the arrow. In this case, it is set to 1, which results in a moderate curve.

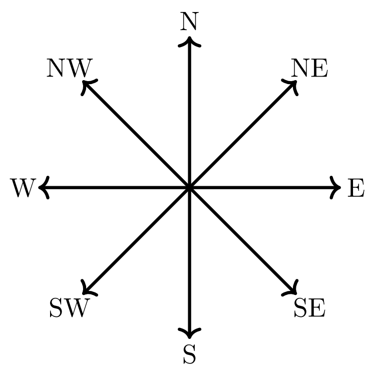
In the second diagram, the code is similar, but the "looseness" option on the curved arrow is set to 2. This value increases the curvature of the arrow, making it more pronounced and forming a larger loop in the signal flow.

Also in both the codes the command **to node**[**right**] **{a}** specifies that the text **a** must be on right side of the arrow.

Overall, these diagrams visualize the signal flow and connections between the components in the system, with the difference between them being the curvature of the arrow connecting the Power Amplifier back to the Tuner.

4.7.4 Example4

Important note before starting the code:
There are 8 points in a rectangle which are named after the directions.

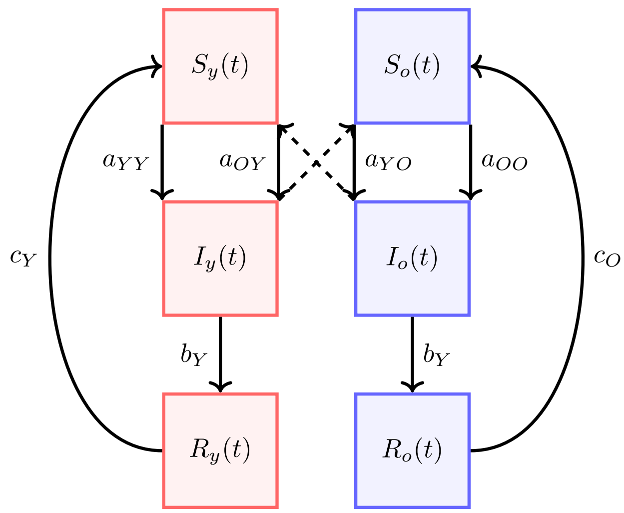


Code

```
\begin{center}
\begin{tikzpicture}
[L/.style={rectangle,draw=red!60,fill=red!5,very thick,minimum
size=15mm},R/.style={rectangle,draw=blue!60,fill=blue!5,very thick,minimum
size=15mm}]

%Nodes
\node[L] (sy)                {$S_y(t)$};
\node[L] (iy) [below=of sy]  {$I_y(t)$};
\node[L] (ry) [below=of iy]  {$R_y(t)$};

\node[R] (so) [right=of sy]  {$S_o(t)$};
\node[R] (io) [right=of iy]  {$I_o(t)$};
\node[R] (ro) [right=of ry]  {$R_o(t)$};

%Lines
\draw[->,very thick](sy.south west) to node[left] {$a_{YY}$} (iy.north west);
\draw[->,very thick](sy.south east) to node[left] {$a_{OY}$} (iy.north east);
\draw[->,very thick](so.south west) to node[right] {$a_{YO}$} (io.north west);
\draw[->,very thick](so.south east) to node[right] {$a_{OO}$} (io.north east);

\draw[->,very thick,dashed](iy.north east) to (so.south west);
\draw[->,very thick,dashed](io.north west) to (sy.south east);

\draw[->,very thick](iy.south) to node[left] {$b_Y$} (ry.north);
\draw[->,very thick](io.south) to node[right] {$b_Y$} (ro.north);
```

```
\draw[->,very thick](ry.west) [out=180,in=180,looseness=1] to node[left] {$c_Y$}
(sy.west);
\draw[->,very thick](ro.east) [out=0,in=0,looseness=1] to node[right] {$c_O$}
(so.east);

\end{tikzpicture}
\end{center}
```

Output



Chapter 5

Plots using tikz

5.1 Introduction

This chapter mainly deals with making 2D and 3D plots using the packages tikz and pgfplots.

5.2 2D plots

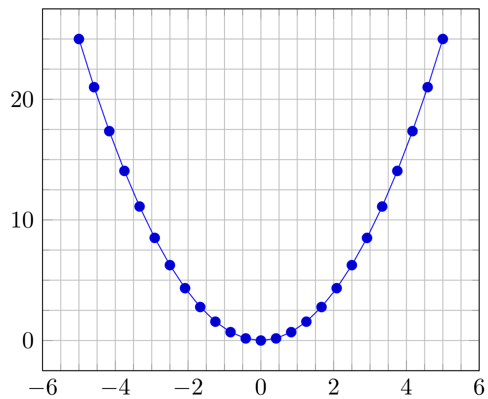
Let us see an example of making 2D plots.

5.2.1 Example1

Code

```
\begin{tikzpicture}[{scale = 0.9}]
\begin{axis}
\addplot {x^2};
\end{axis}
\end{tikzpicture}
```

Output



5.3 Customising a plot

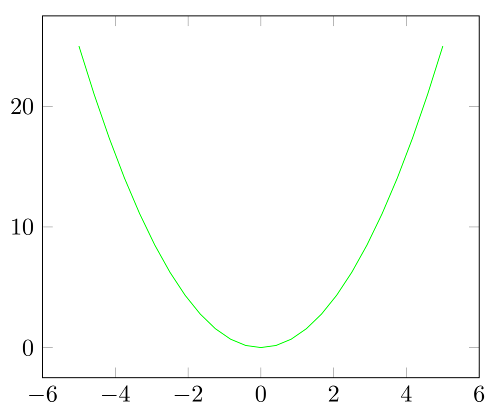
We can customise a plot according to our wish with the parameters specified in square brackets. Let us take example1 and customise it.

5.3.1 Color

Code

```
\begin{tikzpicture}[{scale=0.9}]
\begin{axis}
\addplot[color=green]{x^2};
\end{axis}
\end{tikzpicture}
```

Output

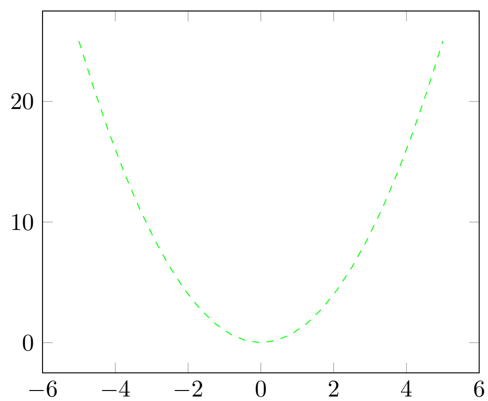


5.3.2 Dashed

Code

```
\begin{tikzpicture}[{scale=0.9}]
\begin{axis}
\addplot[color=green,dashed]{x^2};
\end{axis}
\end{tikzpicture}
```

Output

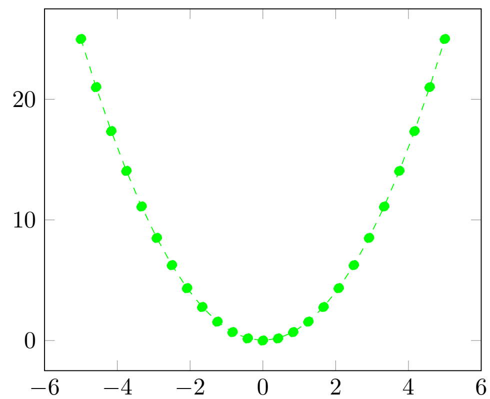


5.3.3 Points or marks

Code

```
\begin{tikzpicture}[{scale=0.9}]
\begin{axis}
\addplot[color=green,dashed,mark=*]{x^2};
\end{axis}
\end{tikzpicture}
```

Output



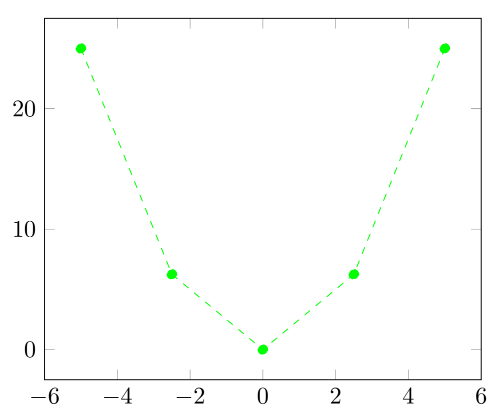
5.3.4 Sampling

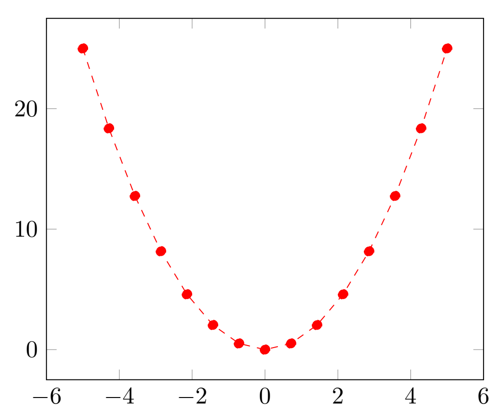
By using the parameter **sample** we can specify the number of points that must be used in constructing the curve.

Code

```
\begin{axis}
\addplot[color=green,dashed,mark=*,samples=5]{x^2};
\end{axis}
\end{tikzpicture}
\begin{tikzpicture}[{scale=0.9}]
\begin{axis}
\addplot[color=red,dashed,mark=*,samples=15]{x^2};
\end{axis}
\end{tikzpicture}
```

Output





5.4 Adjusting axis bounds,placements,labels and titles

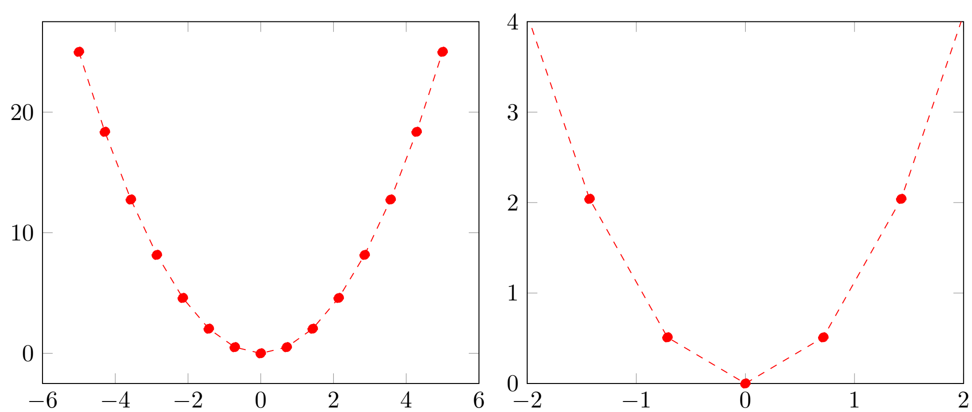
5.4.1 Axis bounds

We can specify the minimum and maximum bounds of both axis using the parameters which can be specified within square brackets near the **\begin{axis}**.

Code

```
\begin{tikzpicture}[{scale=0.9}]
\begin{axis}
\addplot[color=red,dashed,mark=*,samples=15]{x^2};
\end{axis}
\end{tikzpicture}
%Customised axis bounds
\begin{tikzpicture}[{scale=0.9}]
\begin{axis}[xmin=-2,xmax=2,ymin=0,ymax=4]
\addplot[color=red,dashed,mark=*,samples=15]{x^2};
\end{axis}
\end{tikzpicture}
```

Output



5.4.2 Placement

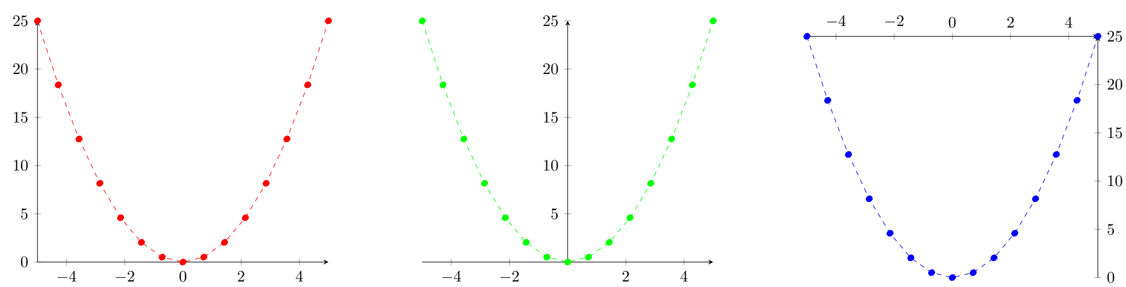
We can place the axis according to our wish. Some examples are shown in the output.

Code

```
%Left sided axis
\begin{tikzpicture}[{scale=0.6}]
```

```
\begin{axis}[axis lines=left]
\addplot[color=red,dashed,mark=*,samples=15]{x^2};
\end{axis}
\end{tikzpicture}
\hspace{1cm}
%middle axis
\begin{tikzpicture}[{scale=0.6}]
\begin{axis}[axis lines=middle]
\addplot[color=green,dashed,mark=*,samples=15]{x^2};
\end{axis}
\end{tikzpicture}
\hspace{1cm}
%Right sided axis
\begin{tikzpicture}[{scale=0.6}]
\begin{axis}[axis lines=right]
\addplot[color=blue,dashed,mark=*,samples=15]{x^2};
\end{axis}
\end{tikzpicture}
```

Output



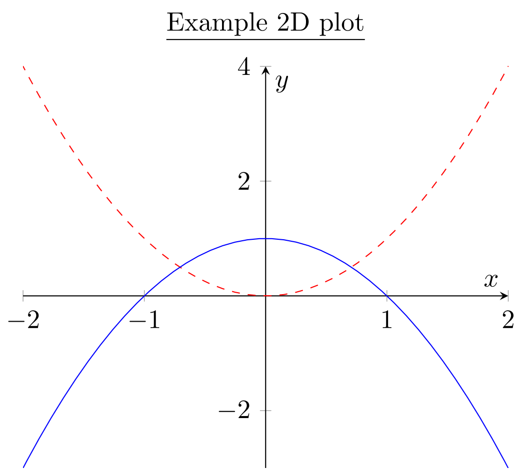
5.4.3 Labelling and Titling

We can also label and title the plot using the parameters option itself.

Code

```
\begin{tikzpicture}
\begin{axis}[xmin=-2,xmax=2,ymin=-3,ymax=4, xlabel=$x$,ylabel=$y$,title=
{\underline{Example 2D plot}},axis lines=middle]
\addplot[color=red,dashed,samples=100]{x^2};
\addplot[color=blue,samples=100]{1-x^2};
\end{axis}
\end{tikzpicture}
```

Output



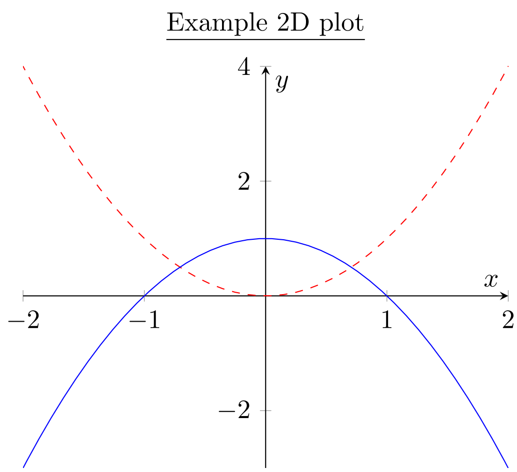
5.4.4 Plot Domain

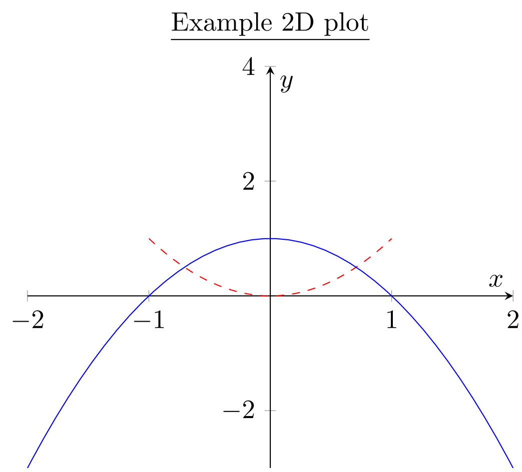
We can also set the domain of the plot using the parameter **domain**.

Code

```
%Without plot domain
\begin{tikzpicture}
\begin{axis}[xmin=-2,xmax=2,ymin=-3,ymax=4, xlabel=$x$,ylabel=$y$,title={\underline{Example
\addplot[color=red,dashed,samples=100]{x^2};
\addplot[color=blue,samples=100]{1-x^2};
\end{axis}
\end{tikzpicture}
%With plot domain
\begin{tikzpicture}
\begin{axis}[xmin=-2,xmax=2,ymin=-3,ymax=4, xlabel=$x$,ylabel=$y$,title={\underline{Example
\addplot[color=red,dashed,samples=100,domain=-1:1]{x^2};
\addplot[color=blue,samples=100]{1-x^2};
\end{axis}
\end{tikzpicture}
```

Output





5.5 Tick,Tick labels,Grid lines and Adding text nodes

This section deals with the manipulation of the default settings which are in pgfplots.

5.5.1 Tick and Tick Labels

Consider a plot of **sine** or **cosine** function where we want the x-axis points to be in terms of π. But pgf pots by default set the points in steps of 1. Here comes the usage of **ticks** and **tick labels**.

Ticks are used to define the positions where we want to add labels while the tick labels specifies the label that must be added in a particular loaction.

5.5.2 Grid lines

Grid lines are lines that cross the chart plot to show axis divisions. Grid lines help viewers of the chart see what value is represented by an unlabeled data point. Especially for large or complicated charts, grid lines give valuable cues to the viewer.

5.5.3 Adding text nodes:

We have already learnt about nodes in previous chapter. Let us try to implement that concept in plots here.

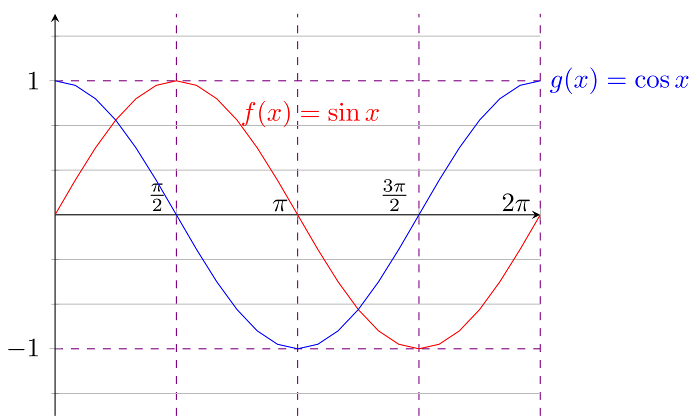
5.5.4 Example

Let us see an example in order to demonstrate the above features.

Code

```
\begin{tikzpicture}
\begin{axis}[clip=false,
             xmin=0,xmax=2*pi,ymax=1.5,ymin=-1.5,
             xtick={0,pi/2,pi,3*pi/2,2*pi},
             xticklabels={$0$,$\frac{\pi}{2}$,$\pi$,$\frac{3*\pi}{2}$,$2*\pi$},
             xticklabel style={anchor=south east},
             xmajorgrids=true,
             major grid style={dashed,draw=red!50!blue},
             grid=both,minor tick num=2,
             axis lines=middle
            ]

    \addplot[domain=0:2*pi,red]{sin(deg(x))}  node[right,pos=0.35]{$f(x)=\sin x$};
    \addplot[domain=0:2*pi,blue]{cos(deg(x))} node[right,pos=1]{$g(x)=\cos x$};
\end{axis}
\end{tikzpicture}
```

Output



Note

In the node command(**node[right,pos=0.35]**) the keyword **pos** refers to the position in which the text node has to be placed. For example here **pos=0.35** means that the node must be placed at **35%** of the graph.

5.6 Scatter plot

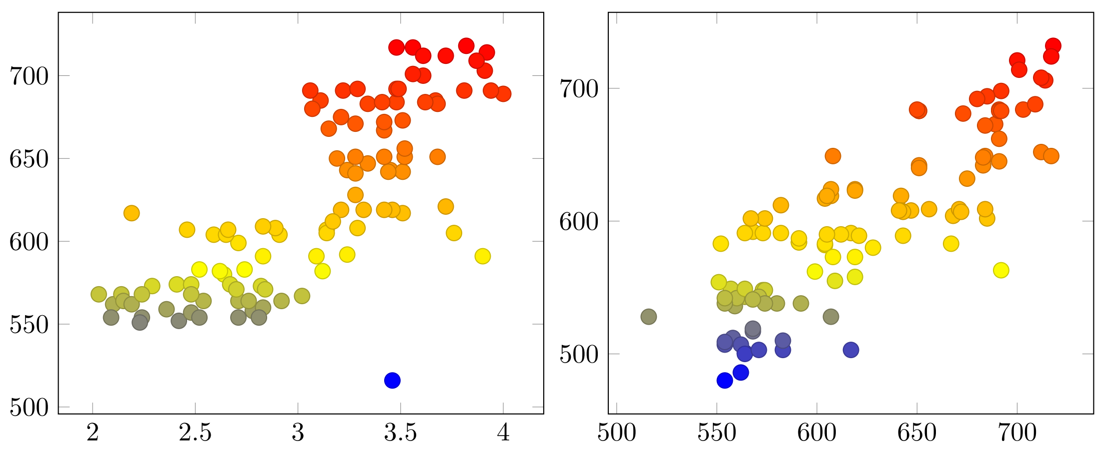
5.6.1 With imported data

Let us import a text file containing some random data. The data file is attached in **Appendix C.1**.

Code

```
%Code with default x-axis an defined y axis
\begin{tikzpicture}
\begin{axis}
\addplot+[only marks,scatter,mark size=2.9pt]
table[meta=ma]
{scattered_example.txt};
\end{axis}
\end{tikzpicture}
%Code with both x and y axis defined
\begin{tikzpicture}
\begin{axis}
\addplot+[only marks,scatter,mark size=2.9pt]
table[x=ma,y=ve]
{scattered_example.txt};
\end{axis}
```

Output



Code Explanation

In this example:

- The symbol + after **addplot** is used to add extra features to the existing features.

- The parameter **scatter** is used to give scattered color coding to the points.
- **table**[**x=ma,y=ve**] is used to set x and y points from a set of data containing multiple columns.
- While **table**[**meta=ma**] is used to set only y points while the x points by default is the first column of the data set.

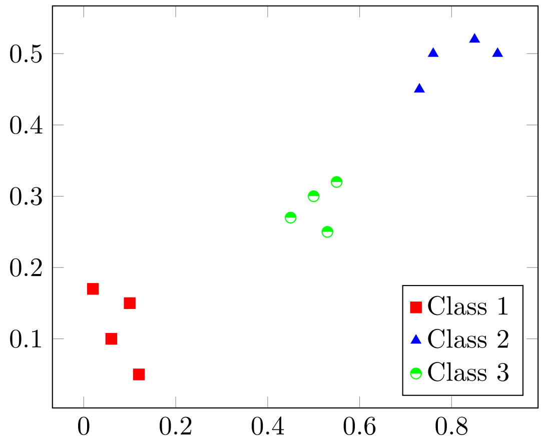
5.6.2 Color coded scattered plot

We can also specify parameters for different set of points in the plot.Here is an example for the same.

Code

```
\begin{tikzpicture}
\begin{axis}[legend pos=south east]

\addplot[only marks,scatter,scatter src=explicit symbolic,
scatter/classes={
a={mark=square*,red},
b={mark=triangle*,blue},
c={mark=halfcircle*,green}}]
table[x=x,y=y,meta=label]
{
x    y    label
0.1  0.15 a
0.45 0.27 c
0.02 0.17 a
0.06 0.1  a
0.9  0.5  b
0.5  0.3  c
0.85 0.52 b
0.12 0.05 a
0.73 0.45 b
0.53 0.25 c
0.76 0.5  b
0.55 0.32 c
};
\legend{Class 1,Class 2,Class 3}
\end{axis}
\end{tikzpicture}
```

Output



Note

This example is similar to the previous example with the customisation of parameters using "**scatter/classes**".

5.7 Stacked bar chart

5.7.1 Example1

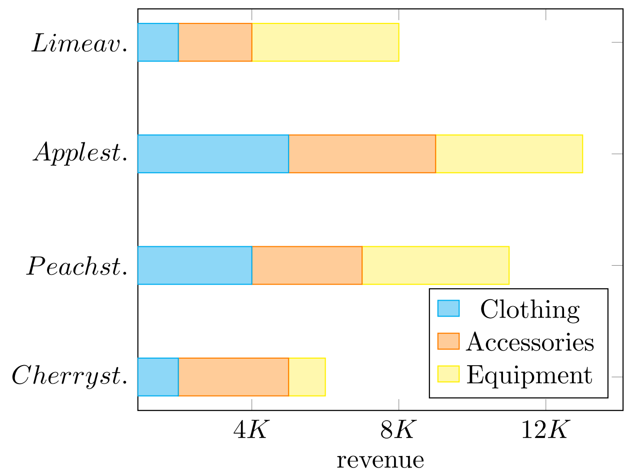
This example is used to represent xbar stacked plot.

Code

```
\begin{tikzpicture}
\begin{axis}[xbar stacked,
             legend pos=south east,
             xtick={0,4,8,12},
             xticklabels={$0$,$4K$,$8K$,$12K$},
             xticklabel style={anchor=north},
             ytick={0,1,2,3},
             yticklabels={$Cherry st.$,$Peach st.$,$Apple st.$,$Lime av.$},
             xlabel={revenue},
             bar width=5mm,
             ]

    \addplot+[draw=cyan,fill=cyan!40] coordinates
    {(2,0) (4,1) (5,2) (2,3)} ;
    \addplot+[draw=orange,fill=orange!40] coordinates
    {(3,0) (3,1) (4,2) (2,3)} ;
```

```
    \addplot+[draw=yellow,fill=yellow!40] coordinates
    {(1,0) (4,1) (4,2) (4,3)} ;

    \legend{Clothing,Accessories,Equipment};
\end{axis}
\end{tikzpicture}
```

Output



Note

Here in coordinates[(1,2)] the first element represents the height and the second element represents the y-axis points.

5.7.2 Example2

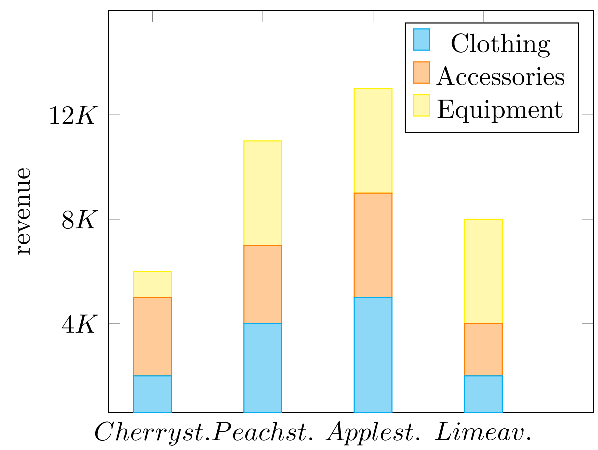
Now let us take example 1 and convert it into ybar stacked plot.

Code

```
\begin{tikzpicture}
\begin{axis}[ybar stacked,
             legend pos=north east,
             ymax=16,xmax=4,
             ytick={0,4,8,12},
             yticklabels={$0$,$4K$,$8K$,$12K$},
             yticklabel style={anchor=east},
             xtick={0,1,2,3},
             xticklabels={$Cherry st.$,$Peach st.$,$Apple st.$,$Lime av.$},
             ylabel={revenue},
             bar width=5mm,
```

```
            ]

    \addplot+[draw=cyan,fill=cyan!40] coordinates
    {(0,2) (1,4) (2,5) (3,2)} ;
    \addplot+[draw=orange,fill=orange!40] coordinates
    {(0,3) (1,3) (2,4) (3,2)} ;
    \addplot+[draw=yellow,fill=yellow!40] coordinates
    {(0,1) (1,4) (2,4) (3,4)} ;

    \legend{Clothing,Accessories,Equipment};
\end{axis}
\end{tikzpicture}
```

Output



Note

Here in coordinates[(1,2)] the first element represents the x-axis points and the second element represents the height.

5.8 3D plots

Plotting a 3D graph is similar to that of plotting a 2D graph except some additional functionalities. A detailed explanation is given in **Appendix C.2**.

Appendix A

Sample Thesis

Scroll down...

Sample Thesis On Calculus

Indian Institute Of Technology, Madras

Rakshan V P

July 2023

Abstract

Integral Calculus is the branch of calculus where we study integrals and their properties. Integration is an essential concept which is the inverse process of differentiation. Both the integral and differential calculus are related to each other by the fundamental theorem of calculus. In this article, you will learn what is integral calculus, why it is used, its types, formulas, examples, and applications of integral calculus in detail.

Dedication

For the readers who read this pdf...

Acknowledgements

I want to thank all the websites which I referred to...

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2 Types **8**
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2.2 Indefinite Integral 8

Conclusion **10**

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Chapter 1

Definition

If we know the f' of a function that is differentiable in its domain, we can then calculate f. In differential calculus, we used to call f', the derivative of the function f. In integral calculus, we call f the anti-derivative or primitive of the function f'. And the process of finding the anti-derivatives is known as anti-differentiation or integration. As the name suggests, it is the inverse of finding differentiation[1].

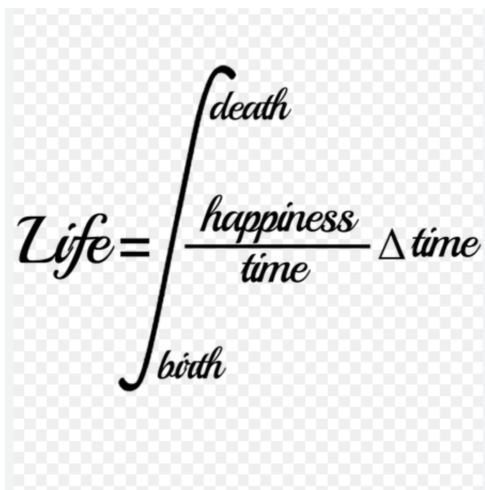

Figure 1.1: Introductory

Chapter 2

Types

Integration can be classified into two different categories, namely,

- Definite Integral
- Indefinite Integral

2.1 Definite Integral

An integral that contains the upper and lower limits (i.e.) start and end value is known as a definite integral. The value of x is restricted to lie on a real line, and a definite Integral is also called a Riemann Integral when it is bound to lie on the real line[1].

A definite Integral is represented as:

$$\int_a^b f(x)dx$$

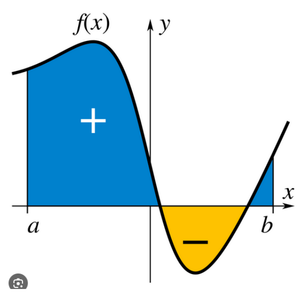

Figure 2.1: definite integral

2.2 Indefinite Integral

Indefinite integrals are not defined using the upper and lower limits. The indefinite integrals represent the family of the given function whose derivatives are f, and it returns a function of the independent variable[1].

The integration of a function f(x) is given by F(x) and it is represented by:

$$\int f(x)dx = F(x) + C$$

where R.H.S. of the equation means integral of f(x) with respect to x

- F(x) is called anti-derivative or primitive.
- f(x) is called the integrand.
- dx is called the integrating agent.
- C is called the constant of integration.
- x is the variable of integration.

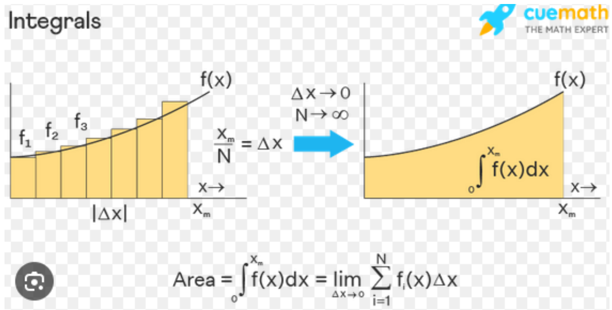

Figure 2.2: Indefinite integral

I want to do a footnote[3]

[3]This is my first footnote

Conclusions

This is the conclusion part.

Appendix A

Appendix

This is the appendix

Bibliography

[1] R D Sharma. *R D Sharma Mathematics*. Dhanpat Rai Publication, 2023.

Appendix B

Outputs of different column functions

B.1 Output for twocolumn

Scroll Down...

0.1 Columns:

- twocolumn
- multicols
- Minipage

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B.2 Output for multicols

Scroll Down...

multicols is used to spread a line over two or more columns as a single line.

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B.3 Output for multicols*

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multicols is used to spread a line over two or more columns as a single line.

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B.4 Output for Minipage

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Appendix C

Plots using tikz

C.1 scattered_example.txt

GPA ma ve co un
3.45 643 589 3.76 3.52
2.78 558 512 2.87 2.91
2.52 583 503 2.54 2.4
3.67 685 602 3.83 3.47
3.24 592 538 3.29 3.47
2.1 562 486 2.64 2.37
2.82 573 548 2.86 2.4
2.36 559 536 2.03 2.24
2.42 552 583 2.81 3.02
3.51 617 591 3.41 3.32
3.48 684 649 3.61 3.59
2.14 568 592 2.48 2.54
2.59 604 582 3.21 3.19
3.46 619 624 3.52 3.71
3.51 642 619 3.41 3.58
3.68 683 642 3.52 3.4
3.91 703 684 3.84 3.73
3.72 712 652 3.64 3.49
2.15 564 501 2.14 2.25
2.48 557 549 2.21 2.37
3.09 591 584 3.17 3.29
2.71 599 562 3.01 3.19
2.46 607 619 3.17 3.28
3.32 619 558 3.01 3.37
3.61 700 721 3.72 3.61
3.82 718 732 3.78 3.81
2.64 580 538 2.51 2.4

2.19 562 507 2.1 2.21
3.34 683 648 3.21 3.58
3.48 717 724 3.68 3.51
3.56 701 714 3.48 3.62
3.81 691 684 3.71 3.6
3.92 714 706 3.81 3.65
4 689 673 3.84 3.76
2.52 554 507 2.09 2.27
2.71 564 543 2.17 2.35
3.15 668 604 2.98 3.17
3.22 691 662 3.28 3.47
2.29 573 591 2.74 3
2.03 568 517 2.19 2.74
3.14 607 624 3.28 3.37
3.52 651 683 3.68 3.54
2.91 604 583 3.17 3.28
2.83 560 542 3.17 3.39
2.65 604 617 3.31 3.28
2.41 574 548 3.07 3.19
2.54 564 500 2.38 2.52
2.66 607 528 2.94 3.08
3.21 619 573 2.84 3.01
3.34 647 608 3.17 3.42
3.68 651 683 3.72 3.6
2.84 571 543 2.17 2.4
2.74 583 510 2.42 2.83
2.71 554 538 2.49 2.38
2.24 568 519 3.38 3.21
2.48 574 602 2.07 2.24
3.14 605 619 3.22 3.4
2.83 591 584 2.71 3.07
3.44 642 608 3.31 3.52
2.89 608 573 3.28 3.47

C.2 3D Plots

Scroll down..

3D plots

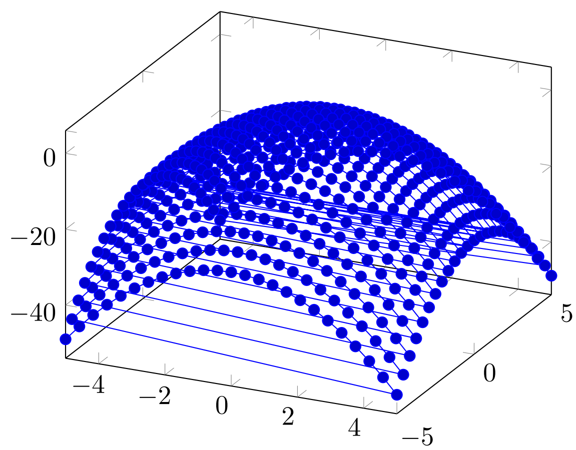
Plotting

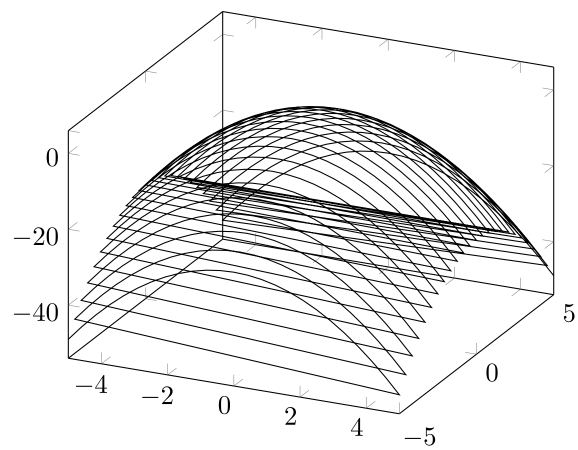
In order to plot a 3D graph we have to use **addplot3** instead of **addplot**.

Code

```
%Code with default parameters
\begin{tikzpicture}
\begin{axis}
\addplot3 {1-x^2-y^2};
\end{axis}
\end{tikzpicture}
%Code with blank parameters
\begin{tikzpicture}
\begin{axis}
\addplot3[] {1-x^2-y^2};
\end{axis}
\end{tikzpicture}
```

Output





Note

From the outputs we observe that on using blank **square brackets** near addplot3 it considers it as blank(or)undefined parameters while without square brackets it is using default parameters.

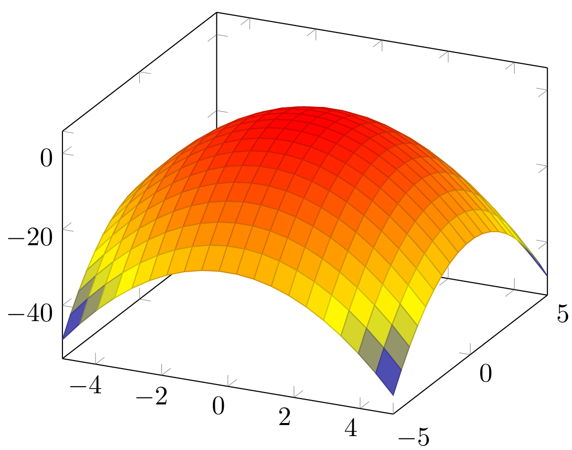
Surface,Mesh and sampling

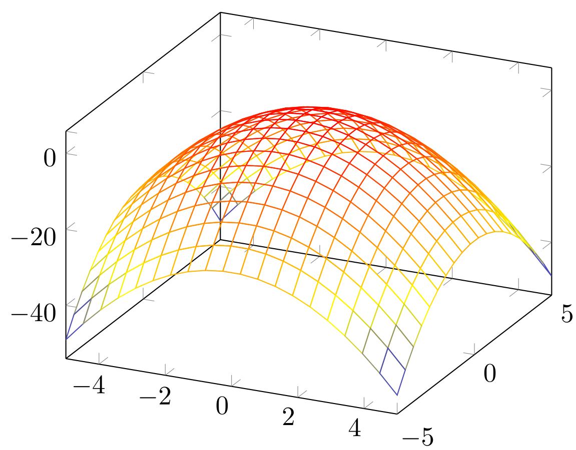
The keyword **surf** gives only the surface with default color mapping while the keyword **mesh** gives only the grids in the surface. Like 2D plots we can also sample the plot in 3D.

Code

```
%Surface
\begin{tikzpicture}
\begin{axis}
\addplot3[surf,samples=20]{1-x^2-y^2};
\end{axis}
\end{tikzpicture}
%Mesh
\begin{tikzpicture}
\begin{axis}
\addplot3[mesh,samples=20]{1-x^2-y^2};
\end{axis}
\end{tikzpicture}
```

Output





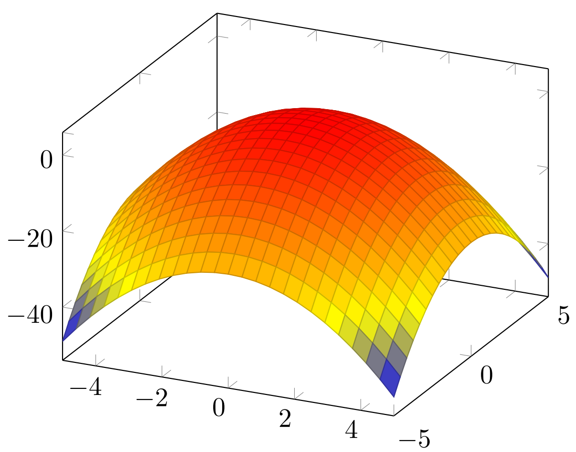
Getting rid of grid lines

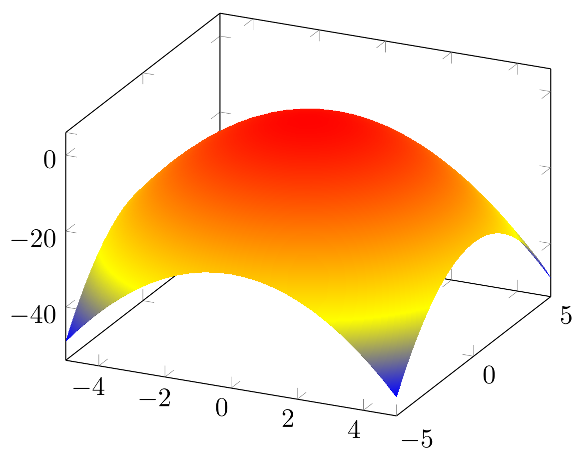
In order to get rid of grid lines we have to use the parameter [**shader=interp**].

Code

```
%With grid lines
\begin{tikzpicture}
\begin{axis}
\addplot3[surf]{1-x^2-y^2};
\end{axis}
\end{tikzpicture}
%Without grid lines
\begin{tikzpicture}
\begin{axis}
\addplot3[surf,shader=interp]{1-x^2-y^2};
\end{axis}
\end{tikzpicture}
```

Output





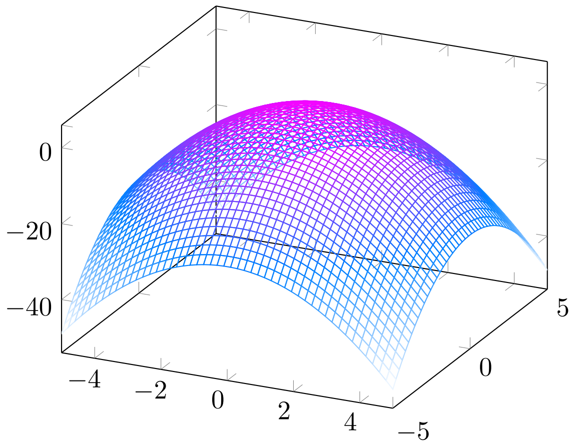
Color Mapping

We can even change the color mapping options for a 3D graph.

Code

```
\begin{tikzpicture}
\begin{axis}[colormap/cool]
\addplot3[mesh,samples=50]{1-x^2-y^2};
\end{axis}
\end{tikzpicture}
```

Output



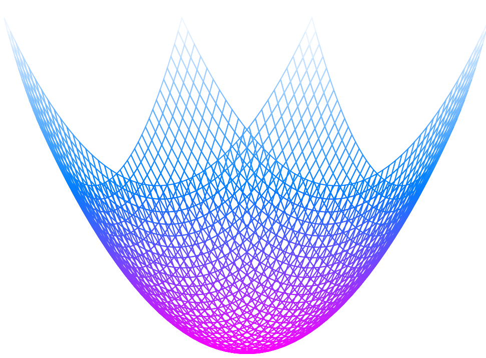
Hiding The Axis and changing the view point

We can hide the axis using **hide axis** option.In a 3D plot we can also change the view point of the plot according to our wish.

Code

```
\begin{tikzpicture}
\begin{axis}[colormap/cool,hide axis,view={60}{180}]
\addplot3[mesh,samples=50]{1-x^2-y^2};
\end{axis}
\end{tikzpicture}
```

Output



3D plots with x,y,z parameters separately specified

Code

```
\begin{tikzpicture}
\begin{axis}
\addplot3+[domain=0:5*pi,samples=60,sample y=0]
({sin(deg(x))},
 {cos(deg(x))},
 {x});
\end{axis}
\end{tikzpicture}
```

Output