# Academy of Technology

Aedconagar, Hooghly - 712121

**Department of Mechanical Engineering**

**Laboratory Manual**

**Of**

**Engineering Drawing & Computer Graphics**

**Semester: ($1^{st}$/$2^{nd}$)** **Paper code: (ES-ME 191/ES-ME 291)**

# 1.1 Principles of Engineering Graphics and their significance:

On one hand, it is a general principle of engineering drawings that they are projected using standardized, mathematically certain projection methods and rules. Thus, great effort is put into having an engineering drawing accurately depict size, shape, form, aspect ratios between features, and so on.
An engineering drawing, a type of technical drawing, is used to fully and clearly define requirements for engineered items.
Engineering drawing (the activity) produces engineering drawings (the documents). More than merely the drawing of pictures, it is also a language—a graphical language that communicates ideas and information from one mind to another.
Drawing plays vital role in the engineering and construction works. The drawing requires no language any one can read it. So, drawings of other countries structures can also be studied easily.

The drawing improves the imagination and new inventions can be developed. The estimate for the project can be done using the details provided in the drawing

The structure can be analyzed completely before construction by using drawing. So, every engineering construction department especially civil engineering requires drawing to start a project.

## 1.2 Drawing instruments,

The instruments used in engineering drawing are:

1) Drawing sheet
2) Drawing board
3) Mini drafter
4) Divider
5) Protractor
6) Set squares
7) French curves (5,6)
8) Pencils **(2H & 2B)**
9) Eraser
10) Drawing clips
11) Drawing paper box
12) Sharpener
13) Protractor(180,360)
14) Large size compass with interchangeable legs
15) Small bow compass
16) Large size Divider
17) Small bow Divider
18) Scale (Plain, Diagonal)

# 1.2 Different types of lines and their use:

| Illustration | Application |
|---|---|
| Thick | Outlines, visible edges, surface boundaries of objects, margin lines |
| Continuous thin | Dimension lines, extension lines, section lines leader or pointer lines, construction lines, boarder lines |
| Continuous thin wavy | Short break lines or irregular boundary lines – drawn freehand |
| Continuous thin with zig-zag | Long break lines |
| Short dashes, gap 1, length 3 mm | Invisible or interior surfaces |
| Short dashes | Center lines, locus lines<br>Alternate long and short dashes in a proportion of 6:1, |
| Long chain thick at end and thin elsewhere | Cutting plane lines |

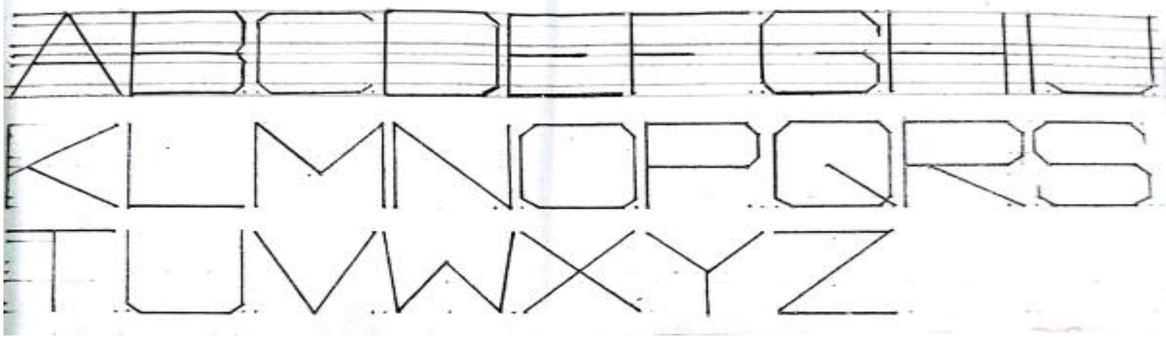
## 1.4 Lettering:

The writing of alphabets and numerals such as A, B, C, D…………………….Z and 1, 2, 3……………9, 0 respectively is called Lettering.

- **Classification Of Lettering**

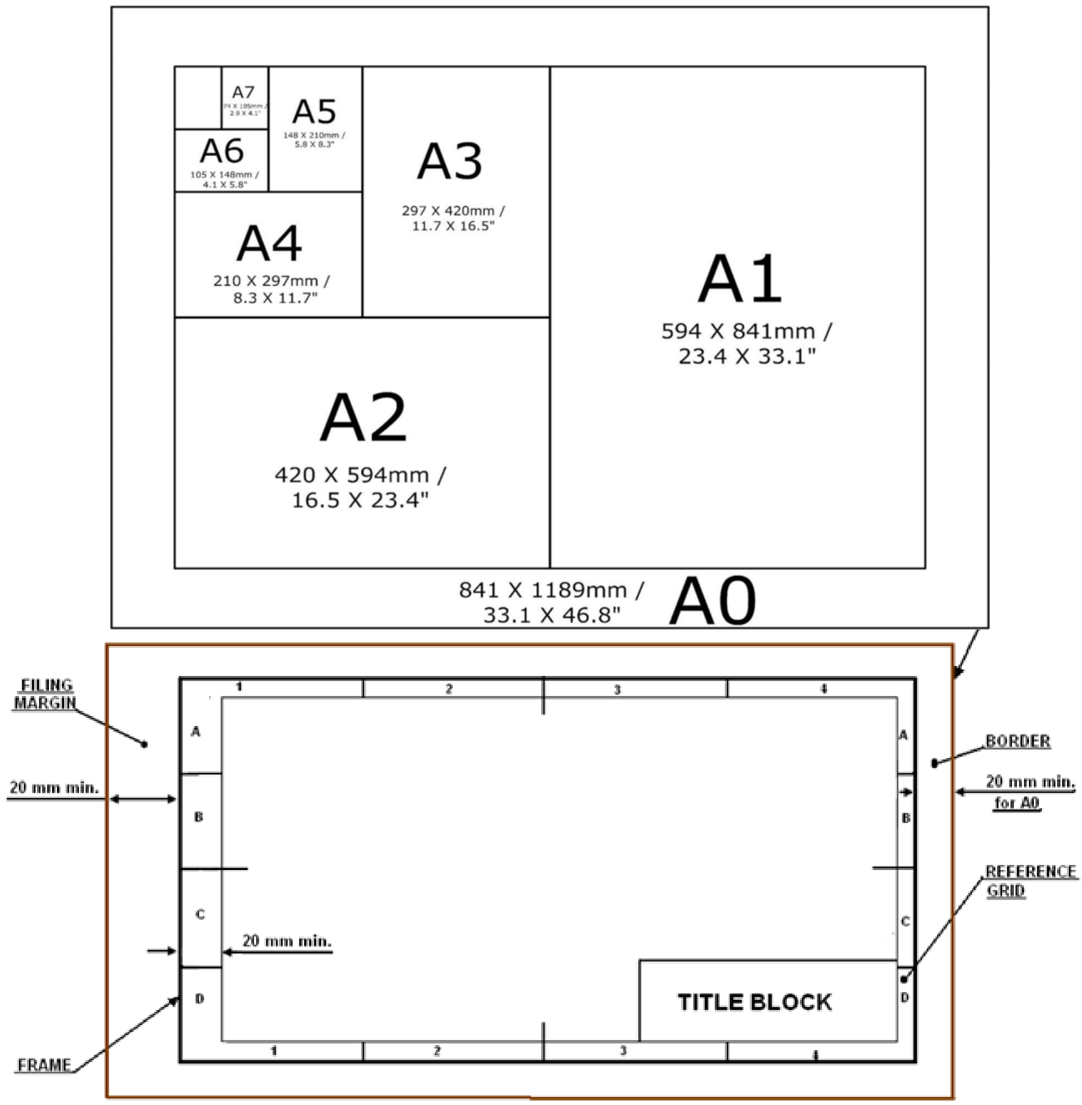
The lettering, in general, is classified in two categories :

1. **Gethic Lettering** (Lettering having all the alphabets or numerals of uniform thickness is called Gothic Lettering.)
2. **Roman Lettering**. (The lettering in which all the letters are formed by thick and thin elements is called Roman Lettering)NB.There are two another types of lettering i.e**.** **Mechanical Lettering** and **Free Hand Lettering.**



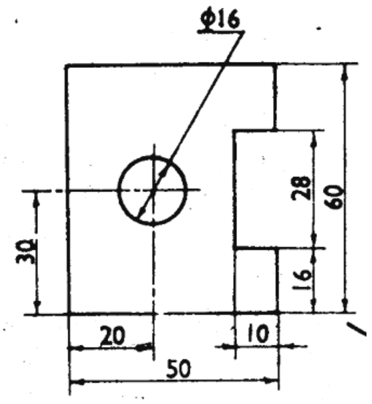
## 1.5 Drawing standards and codes:

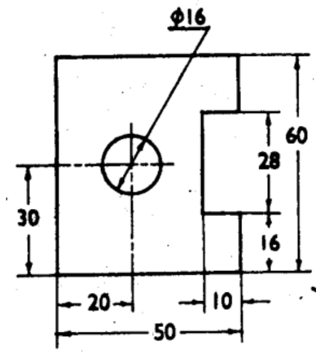
**Size of drawing sheet and Layout of Drawing sheet according to the standard:**




**International Standard Organisation (ISO) AND Bureau of Indian Standards (BIS)**
**Lines:**
IS:10714-1983 adopted from ISO:128-1982 describes general principles of presentation of Technical Drawing.
**Lettering for Technical Drawing:**
IS:9609-1983 adopted from ISO:3098/1-1974 describes various type of lettering.
**Methods of dimensioning:**
IS:10718-1983 equivalent to ISO:129-1985 illustrates method of dimensioning a drawing.

## 1.6 Dimensioning systems:

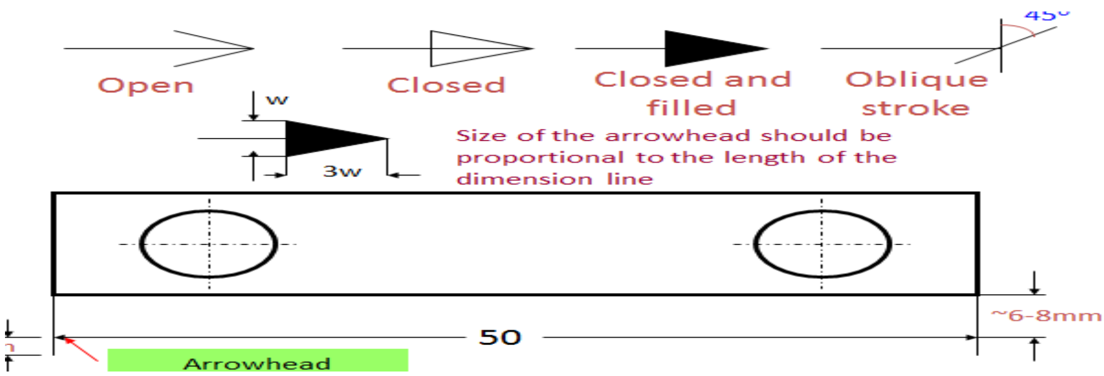


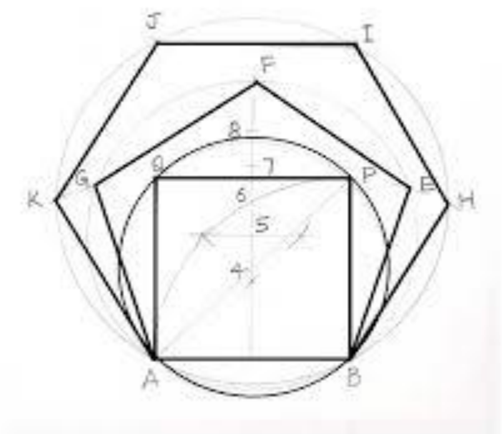

Aligned system
(readable from bottom and right edge of sheet)

Unidirectional system
(visible from bottom edge)

- **Arrowheads and dimension line positioning:**




### 1.7 Geometrical construction of polygon (General method):



# Scales

## 2.1 Scale:

Scale is defined as the ratio of the linear dimensions of the object as represented in a drawing to the actual dimensions of the same.

## 2.2 Representative fraction (R.F.):

$$R.F. = \frac{\text{Length of an object on the drawing}}{\text{Actual Length of the object}}$$

## 2.3 Types of Scale

There are **three** types of scales depending upon the **proportion** it indicates as

**(i)Reducing scale**: When the dimensions on the drawing are smaller than the actual dimensions of the object. It is represented by the scale and RF as
Scale: - 1cm=100cm or 1:100 and by RF=1/100 (less than one)

**(ii) Full scale**: Sometimes the actual dimensions of the object will be adopted on the drawing then in that case it is represented by the scale and RF as
Scale: - 1cm = 1cm or 1:1 and by R.F=1/1 (equal to one).

**(iii)Enlarging scale**: In some cases when the objects are very small like inside parts of a wrist watch, the dimensions adopted on the drawing will be bigger than the actual dimensions of the objects then in that case it is represented by scale and RF as
Scale: - 10cm=1cm or 10:1 and by R.F= 10/1 (greater than one)

There are another **four** types of scales depending upon the construction:

**(i)Plain Scales:** Plain scales read or measure upto **two** units or a unit and its sub-division, for example centimetres (cm) and millimetres (mm). When measurements are required upto first decimal, for example 2.3 m or 4.6 cm etc.

## Problem 1:

To construct a plain scale to show and decimeters when one meter is represented by 2.5 cm long enough to measure up to 6m.

## Solution:

1) Calculation:

a) R.F. $= \frac{Drawing\ size\ of\ an\ object}{Actual\ size\ of\ an\ object}$(in same units)

$$= \frac{2.5}{1 \times 100}$$

$= \frac{1}{40}$

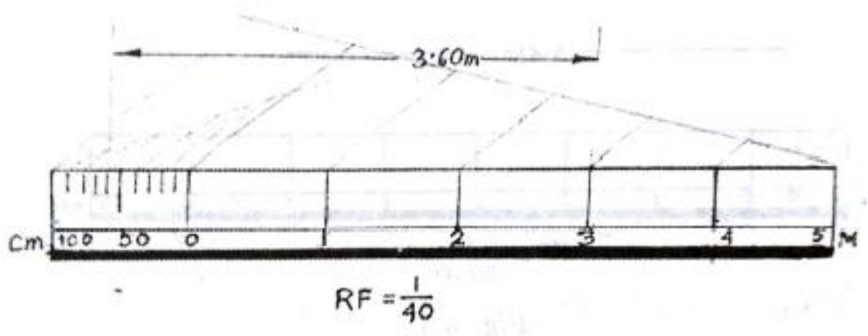
b) Length of the scale:

1 cm represents = 40 cm.

15 cm represent = 40 × 15 = 600 cm = 6m.

Length of the scale = 15 cm, which will be divided into 6 equal parts.

2) Construction:




**(ii) Diagonal Scales:**Diagonal scales are used to read or measure upto three units. For example: decimetres (dm), centimetres (cm) and millimetres (mm) or miles, This scale is used when very small distances such as 0.1 mm are to be accurately measured or when measurements are required upto second decimal. For example: 2.35dm or 4.68km etc.

## Problem 1:

Construct a diagonal scale of R.F. 1:2 showing division of 0.01 meter and capable of measuring 3 meters. Mark a distance of 2.57 meter on it.

## Solution:

3) Calculation:

c) R.F. $= \frac{Drawing\ size\ of\ an\ object}{Actual\ size\ of\ an\ object}$(in same units)

$= \frac{1}{20}$

d) Length of the scale:

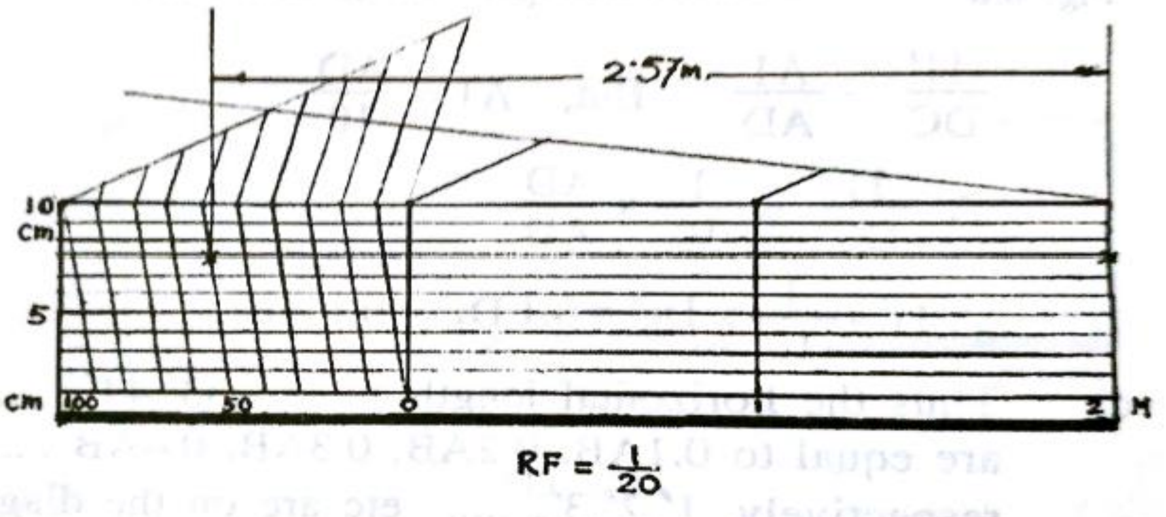
From R.F. we have,

1 cm represents = 20 cm.

15 cm represent = 20 × 15 = 300 cm = 3m.

Length of the scale = 15 cm, which will be divided into 3 equal parts.

4) Construction:




**(iii) Vernier scale**: A vernier scale is a visual aid that allows the user to measure more precisely than could be done unaided when reading a uniformly divided straight or circular measurement scale. It is a subsidiary scale that indicates where the measurement lies in between two of the graduations on the main scale.

Verniers are common on sextants used in navigation, scientific instruments used to conduct experiments, machinists' (or jewelers') measuring tools (all sorts, but especially calipers and micrometers) used to work materials to fine tolerances, on theodolites used in surveying, and in absolute encoders to measure linear or rotational displacements

## Problem 1:

construct a venire scale of R.F.=$\frac{1}{2500}$ and long enough to measure 200m to an accuracy of a meter. Show on it a distance of 158m.

## Solution:

5) Calculation:

e) R.F. = $\frac{Drawing\ size\ of\ an\ object}{Actual\ size\ of\ an\ object}$(in same units)

$= \frac{4}{2500}$

f) Length of the scale:

1 cm represents = 25000 cm.

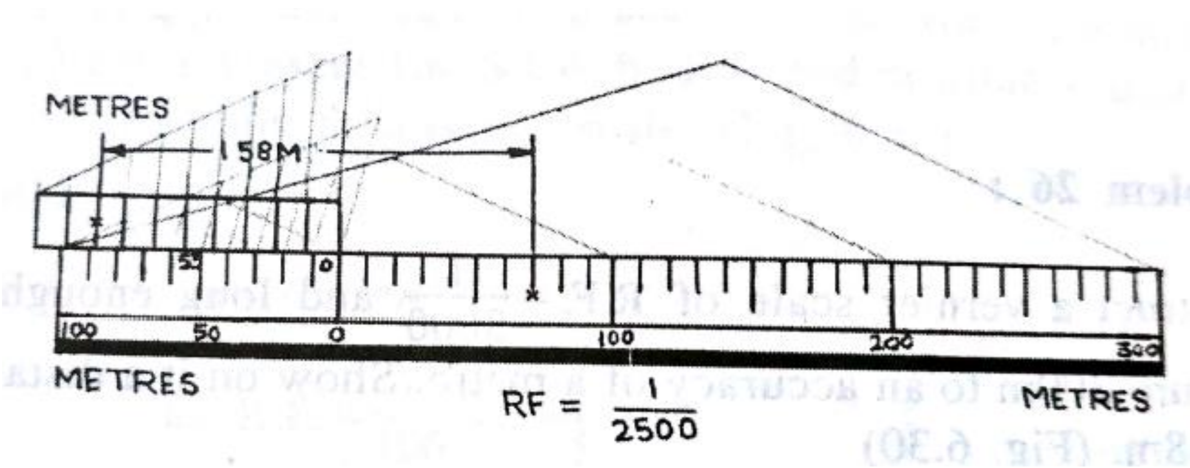
15 cm represent = 25000 × 15 = 375m

375 m represented by = 15cm

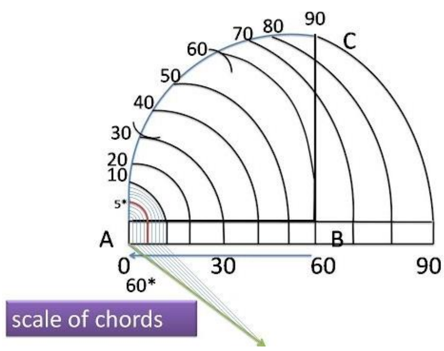
400 m represented by = $\frac{15 \times 400}{375}$ =16 cm.

Length of the scale = 16 cm, which will be divided into 4 equal parts.

6) Construction:




(iv) **Scale of chords** : A chord is a line drawn between two points on the circumference of a circle. Look at the centre point of this line. For a circle of radius r, each half will be so the chord will be . The line of chords scale represents each of these values linearly on a scale running from **0 to 60**.



## 2.4 Problems

1. The distance between B.E College & Howrah Station is 4km. It is represented on map by 8cm. Draw a suitable scale and mark a distance 4km 9hm on the scale.
2. On a railway map the distance between two-point 100 km. and it is shown by 2.5 cm. What is theR.F? Draw a diagonal scale to measure up to 700 km. Mark a distance 209 km onthe scale.
3. The R.F of a scale is 1/50000. Draw the scale to show km and hm. Show distance of 6.2 km.
4. Construct a scale of 1.5 cm = 1 dm to read up to 1 m and show on it a length of 0.6 m.
5. On a map 6cm$^2$ represent an area of land 2664 m$^{2.}$ Calculate the R.F. the Draw a scale to read up to single meter and long enough to show 3 hm. Draw a rectangular of 240 m x 108 m with the help of the scale.
6. A room of building of 512 cm$^3$ volume is represented by a similar block of 64 cm$^3$ volume. Find the R.F and construct a plane scale to measure up to 30m .Measure a distance of 24m on the scale.
7. Construct a diagonal scale of R.F = 1: 32,00,000 to show kilometers and long enough to measure up to 400km. Show the distance of 257km and 353km on your scale.
8. A car running at a speed of 54 km/hr. Construct a diagonal scale to show 1km by 4cm and to measure up to 5km. Mark also on the scale the distance covered by the car in 3min.
9. On a map 4.5 represent an area of land 2178 m$^2$ calculate the R.F . Draw a suitable scale to read up to single meter and long enough to show 3 hm at a time. Draw the rectangle of 223 m X 107 m. using this scale.
10. On a plan a square of 2 cm side represent a square of area 25 m$^2$ . Draw a suitable scale of the plan to read up to a single decimeter. Measure a distance of 3.25M.
11. Distance between A and b is 40 km. it is shown on a sheet by 8 cm. Find the R.F of the scale .Such that 90 km.and a single km can be read from it. Draw a triangle of side 25 km using the above scale.
12. Construct a Vernier scale of R.F = 1/20 and capable of reading metres ,decimetres and centimetres.Show on it the following length: 1)1.44m, 2)16.8 decimetres.

# Engineering Curves

## 3.1 Introduction

**Elliptical shape**

**Parabolic shape**

**Hyperbola**

**Spiral**

Curves formed by the intersection of a plane with a right circular cone. e.g. Parabola, hyperbola and ellipse

**Conic:**Conic is defined as the locus of a point moving in a plane such that the ratio of its distance from a fixed point and a fixed straight line is always constant.

Fixed point is called Focus. Fixed line is called Directrix.

**Conic Sections**

• Sections of a right circular cone obtained by cutting the cone in different ways

• Depending on the position of the cutting plane relative to the axis of cone, three conic sections can be obtained

– ellipse,

– parabola and

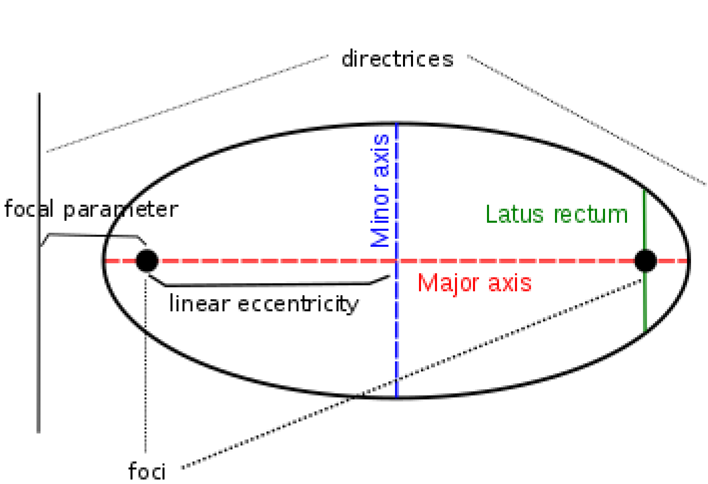
– hyperbola

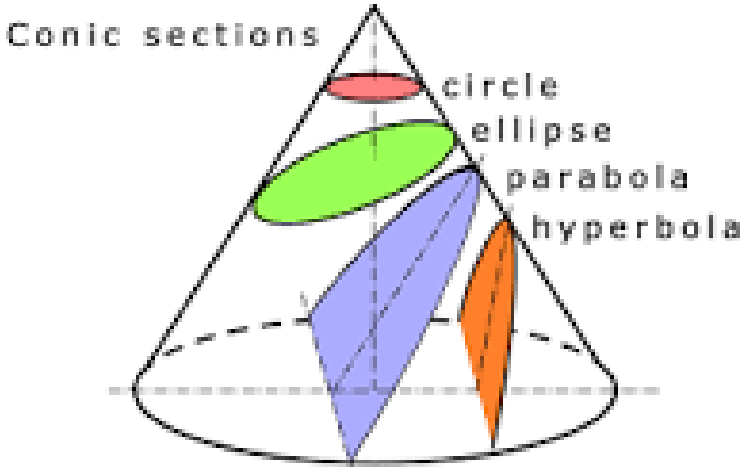
An ellipse is obtained when a section plane A–A, inclined to the axis cuts all the generators of the cone.

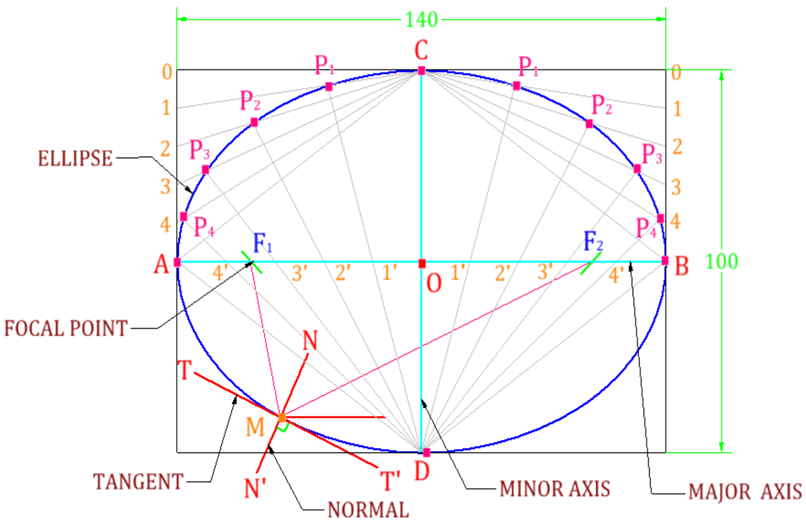
• A parabola is obtained when a section plane B–B, parallel to one of the generators cuts the cone.

Obviously, the section plane will cut the base of the cone.

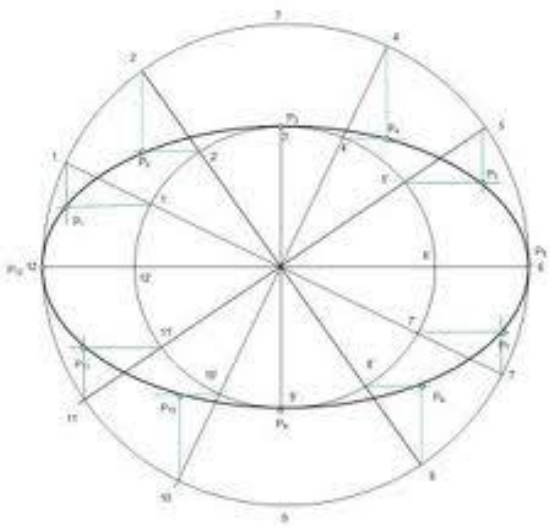
- A hyperbola is obtained when a section plane C–C, inclined to the axis cuts the cone on one side of the axis.
- A rectangular hyperbola is obtained when a section plane D–D, parallel to the axis cuts the cone.



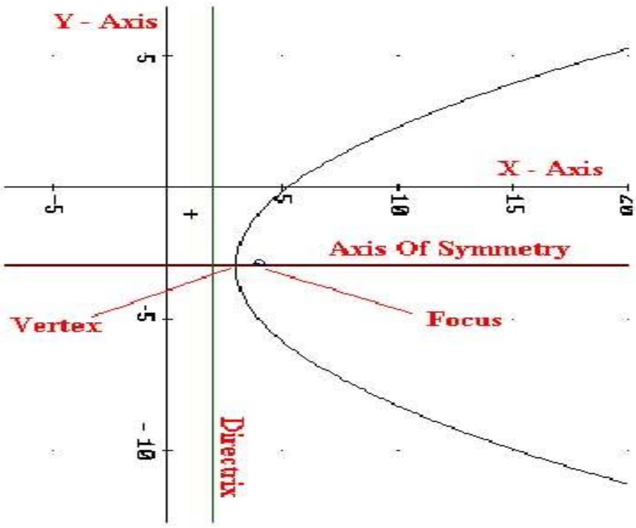



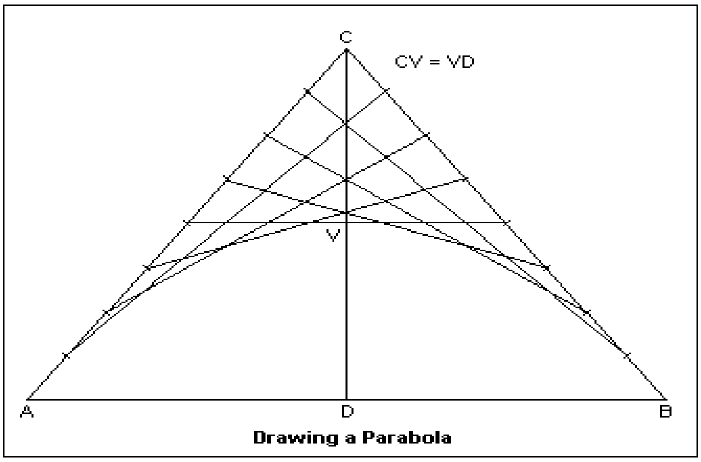




**OBLONG METHOD**



**CONCENTRIC CIRCLE METHOD**

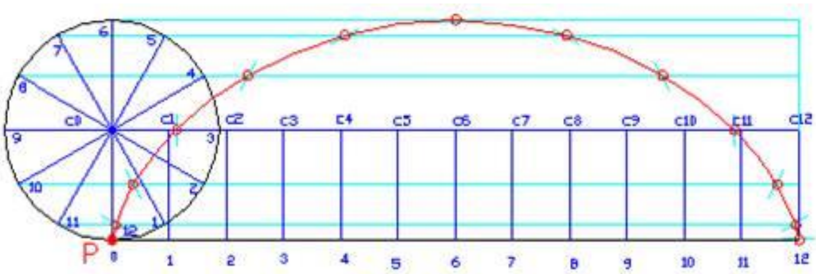


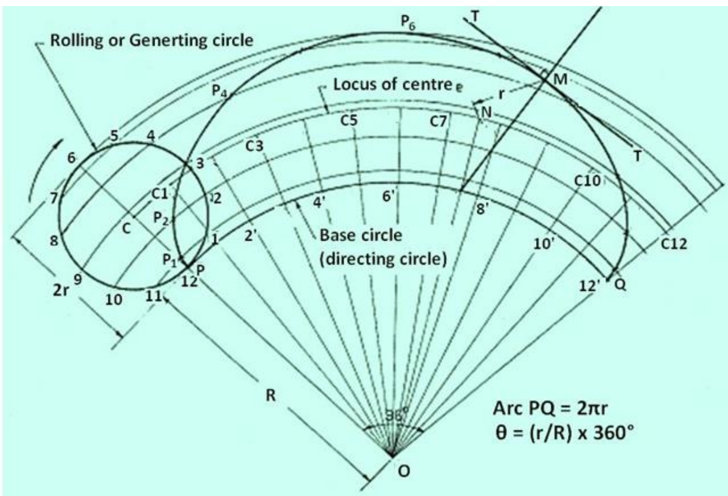

**PARABOLA BY INTERSECTING METHOD**

**PARABOLA BY GENERAL METHOD**

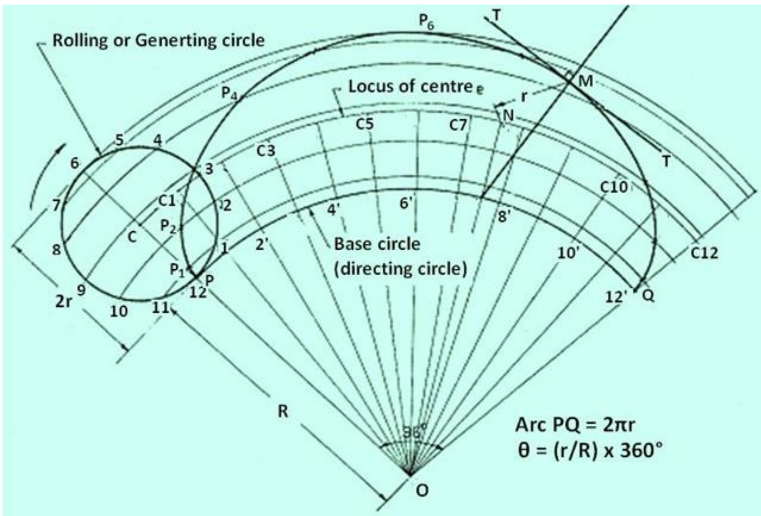
**Cycloid** is the curve traced by a point on the rim of a circular wheel as the wheel rolls along a straight line without slipping.



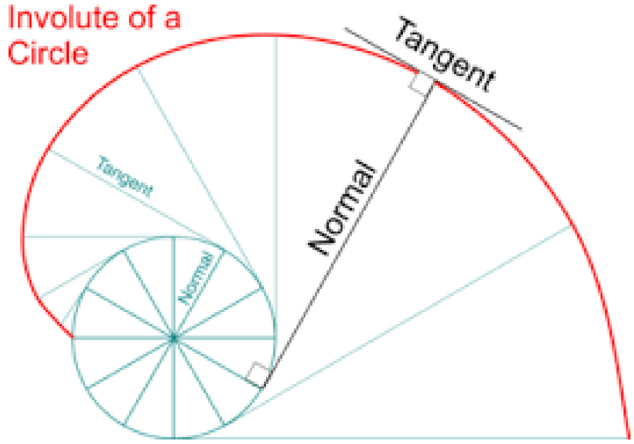

**Epicycloid** is a curve traced by a point on the circumference of a circle rolling on the exterior of another circle.



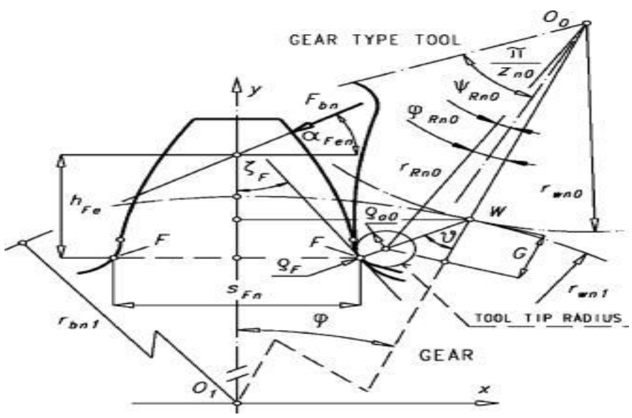
**Hypocycloid i**s the curve traced by a point on the circumference of a circle which is rolling on the interior of another circle.



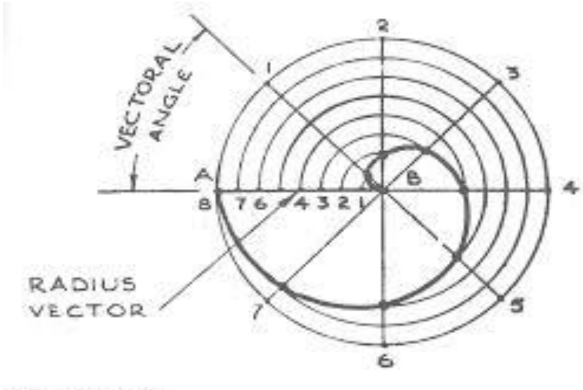

**Involute** is the locus of a point considered as the end of a taut string being unwound from a given curve in the plane of that curve.




**Example of involute:** involute gear



**Archemedian Spiral** is a plane curve generated by a point moving away from or toward a fixed point at a constant rate while the radius vector from the fixed point rotates at a constant rate.




Archimedian Spiral

**3.2 Problems:**

1.Draw an ellipsehaving major axis and minor axis of 90mm. and 60mm.,respectively (Concentric circle method).

2.consider a ball thrown in air which attains 100 m height and covers a horizontal distance of 150 m on ground. Draw the path of the ball (parabola by rectangle method)

3. Draw an ellipse having major axis and minor axis, say major axis = 100mm and minor axis = 70 mm. ((apply Oblong method).

4. Draw a line AB 12cm. long. Take a point F 4cm from the end A on this line. Locate another P 6cm from A and 4 cm. from the line AB. The line AB indicates the direction of the parabola where F is a focus and measures the latus- rectum.

5. Construct an ellipse when the distance between the two foci is 90mm and the minor axis is 65mm Long. Determine the length of the major axis and draw half of the ellipse by concentric Circle method and the other half by oblong method.

6. A beaker of 50mm. diameter partly filled up with water is tiled such that the highest point of the water surface is 60mm. away from the bottom surface of the beaker. Draw the shape of the water surface in the tiled position.

7. Four points of an ellipse from a rectangle of 40mm 50mm having longer side parallel to the major axis. The foci of the ellipse lie at distance of 10mm on either side of the rectangle. Draw the ellipse.

8.A fountain jet discharge water from ground level at an inclination of $50^0$ to the ground . The jet travels a horizontal distance of 90mm. from the point of discharge and falls on the ground. Trace the path of the jet in any suitable scale.

9. Draw an ellipse having focus distance 80mm and minor axis 70mm also find out the major axis. (Apply concentric circle / oblong method)

10.Draw a cycloid generated by a point P on the circumference of a circle of diameter 56 mm when the circle rolls along a straight line.Draw a normal and a tangent to the curve at any convenient point.

11.Draw an epicycloid generated by a point P on the circumference of a rolling circle of diameter 50 mm when it rolls outside a directing circle of 150 mm diameter for one complete revolution. Draw a normal and a tangent to the curve at any convenient point.

12.Draw a hypocycloid where the diameters of the rolling and the directing circles are equal to 50 mm and 150 mm respectively.

13.Draw an involute of a pentagon with each side of 15 mm length.

14.Draw an involute of a circle of 35 mm diameter.

15.Draw an Archimedean spiral of one convolution with the shortest and longest radius vectors of 10 mm and 50 mm respectively.

# PROJECTION

## 4.1 Introduction

In engineering, 3-dimensonal objects and structures are represented graphically on a 2-dimensional media. The act of obtaining the image of an object is termed "projection". The image obtained by projection is known as a "view". A simple projection system is shown in figure.

All projection theory are based on two variables:

- Line of sight
- Plane of projection.

### 4.2 Plane of Projection

A plane of projection (i.e, an image or picture plane) is an imaginary flat plane upon which the image created by the line of sight is projected. The image is produced by connecting the points where the lines of sight pierce the projection plane. In effect, 3-D object is transformed into a 2-D representation, also called projections. The paper or computer screen on which a drawing is created is a plane of projection.

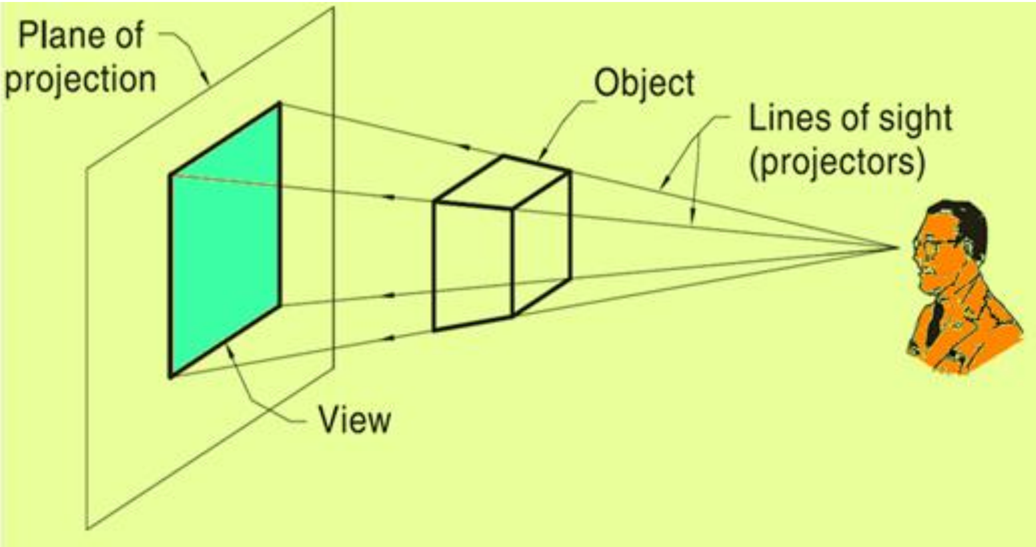



**Figure : A simple Projection system**

### 4.3 Projection Methods

Projection methods are very important techniques in engineering drawing.

Two projection methods used are:

- Perspective and
- Parallel

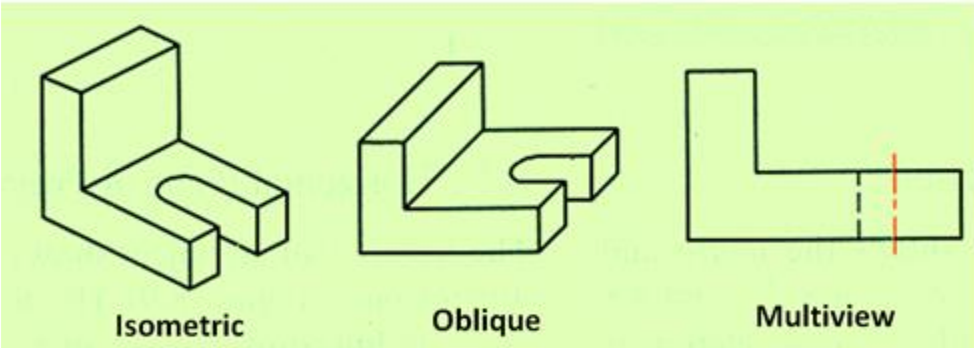
**Parallel projection**

- Distance from the observer to the object is infinite projection lines are parallel – object is positioned at infinity.
- Less realistic but easier to draw.

**Perspective projection**

- Distance from the observer to the object is finite and the object is viewed from a single point – projectors are not parallel.
- Perspective projections mimic what the human eyes see, however, they are difficult to draw.

Orthographic Projection Orthographic projection is a parallel projection technique in which the plane of projection is perpendicular to the parallel line of sight. Orthographic projection technique can produce either pictorial drawings that show all three dimensions of an object in one view or multi-views that show only two dimensions of an object in a single view. These views are shown in figure



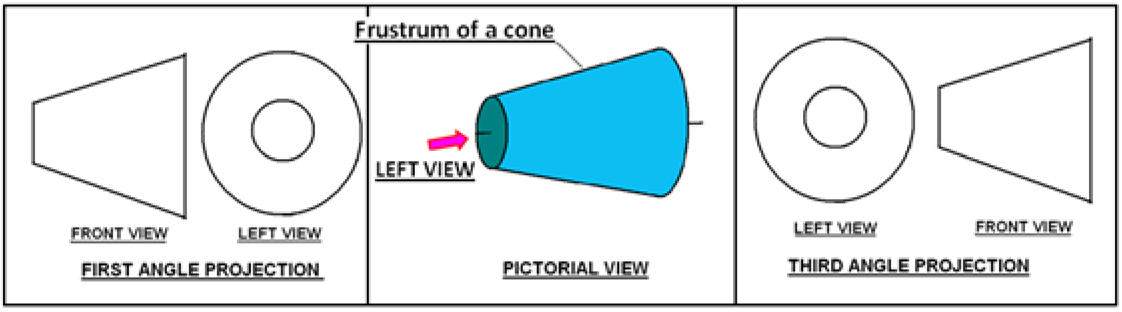

Orthographic projections of a solid showing isometric, oblique and multi-view drawings.

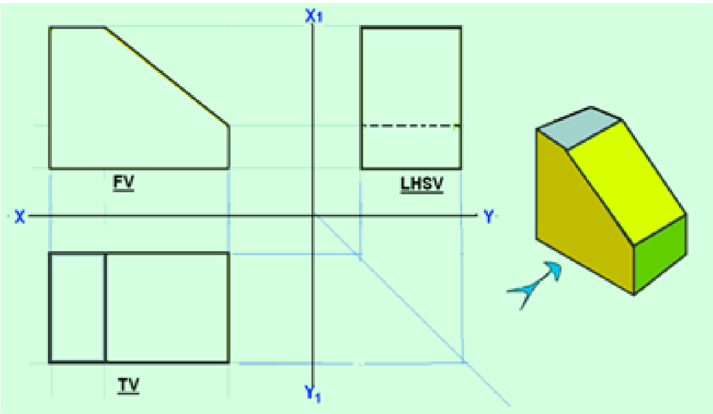
## 4.4 Difference between first angle and third angle projections:

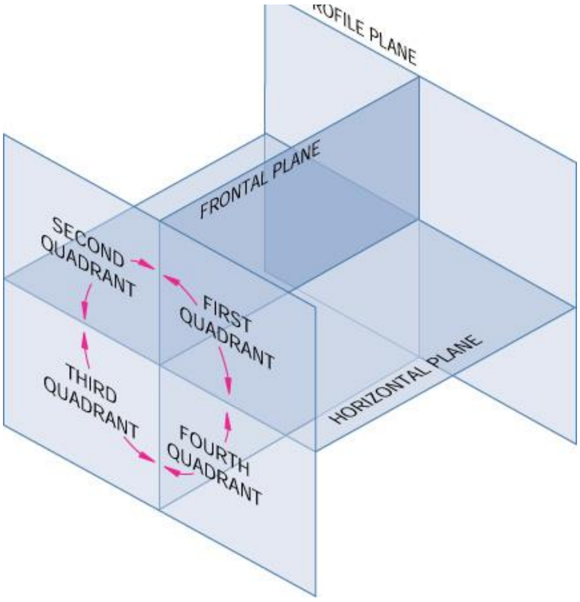
| First angle projection | Third-angle projection |
|---|---|
| Object is kept in the first quadrant. | Object is assumed to be kept in the third quadrant. |
| Object lies between observer and the plane of projection. | Plane of projection lies between the observer and the object. |
| The plane of projection is assumed to be non-transparent. | The plane of projection is assumed to be transparent. |
| Front (elevation) view is drawn above the XY line | Front (elevation) view is drawn below the XY line |
| Top (plan) view is drawn below the XY line | Top (plan) view is drawn above the XY line |
| Left view is projected on the right plane and vice versa | Left view is projected on the left plane itself. |
| Followed in India, European countries | Followed in USA |

## 4.5 Symbol of projection

The type of projection obtained should be indicated symbolically in the space provided for the purpose in the title box of the drawing sheet. The symbol recommended by BIS is to draw the two sides of a frustum of a cone placed with its axis horizontal The left view is drawn.




## 4.6 Problems on Projection of Points , Lines , Surfaces and Solids:

### <u>Projection of Points</u>

1. Draw the projection of the following points.
   - Point A which is 40 mm above HP and 55 mm in front of VP (First Quadrant)
   - Point B, which is 10 mm above HP and 15 mm behind VP.(Second Quadrant)
   - Point C, which is 25 mm below HP and 20 mm behind VP (Third Quadrant)
   - Point D, which is 20 mm below HP and 20 mm in front of VP(Fourth Quadrant)
   - Point E is on the reference line
   - Point F is on both HP and VP.

2. Draw the projection of following points on the same reference line keeping the projectors 15 mm apart.

i. In the HP & 25 mm BVP
ii. 30 mm AHP & In the VP.
iii. 45 mm AHP & 20 mm IVP
iv. In the HP &25 mm I VP
v. 40mm BHP& 25 mm IVP
vi. In the HP& In the VP

## Projection of Lines

1. Draw the projection of a line in the following position assuming each one to be of 50mm length.
(a) Line AB is parallel to the H.P and V.P 25mm behind the V.P and 30mm below H.P.
(b) Line C.D is in V.P parallel to the H.P and C is 30mm above the H.P.
(c) Line EF is parallel to and 25mm in front of the V.P and is in the H.P.
(d) Line GH is in both V.P and H.P.
(e) Line JK is perpendicular to the H.P and 20mm in front of the V.P the nearest point from the H.P is J which is 15mm above the H.P.
(f) Line LM is 30mm behind the V.P and perpendicular to H.P. L is the nearest point from the H.P. Which is 15mm above H.P.
(g) Line NP is 30mm below H.P and perpendicular to V.P. P is the nearest point from V.P. Which is 10mm in front of V.P.
(h) Line ST is perpendicular to H.P and behind V.P. The nearest point from the H.P is S which is 20mm from V.P and 15mm below H.P.

2. A straight line AB of 65mm long is parallel to the H.P and its elevation measure 35mm. The end A which is nearest to V.P is 15mm above H.P and 20mm in front of V.P.Draw the projection of line AB find out also the inclination with the V..P

3. Draw the projection of a line AB. Of length 7 cm. makes angle $35^0$ with H.P and $40^0$ with V.P point A3cm above H.P and 2.5 cm in front of V.P . Draw also the side elevation

4. Draw the projection of a line AB. Of length 7.5 cm. makes angle $40^0$ with H.P and $30^0$ with V.P point A is on H.P and 2.5 cm in front of V.P.

5. Draw the projection of a straight line AB of length 7cm. which makes an angle $32^0$ with H.P and $47^0$ with V.P Point A is 1.5 cm above H.P and 2 cm in front of V.P.

## Projection of Surfaces

1.(a) Draw the projection of the circular lamina of diameter 35 mm resting on a point on its circumference on H.P. Surface of the lamina makes an angle of $60_0$ with H.P.
(b) Draw the projection of the circular lamina of diameter 35 mm resting on a point on its circumference on V.P. Surface of the lamina makes an angle of $60_0$ with V.P.

2.(a) Draw the projection of the hexagonal lamina of side 35 mm resting on one its 8corner on V.P. Surface of the lamina makes an angle of $60_0$ with V.P.
(b) Draw the projection of the hexagonal lamina of side 35 mm resting on one its side on V.P. Surface of the lamina makes an angle of $60_0$ with V.P.

3. Draw the projection of the pentagonal lamina of side 3.5 cm resting on one its corner on H.P.

Surface of the lamina makes an angle of $60^0$ with H.P.

4. A rectangle ABCD of size 40mm x 60mm has a corner on H.P and 20mm away from V.P. All the side of the rectangle are equally inclined to H.P and parallel to V.P . Draw its projection.

5. Draw the projection of a pentagon of 40mm side having its surface inclined at $30^0$ to V.P and the side

6. An equilateral triangular plate of 50mm side has its plane parallel to H.P and 30mm away from its. Draw the projection when one of its side s is
(i) Perpendicular to V.P (ii) parallel to V.P and (iii) inclined to V.P at an angle $45^0$

## Projection of Solids:

1. Draw the projection of a cone having base diameter 60mm and axis 55mm long resting on HP. The axis of the solid is parallel to VP and inclined at $45_0$ to H.P.

2. Draw the projection of a cylinder having base diameter 60mm and axis 55mm long resting on HP. The axis of the solid is parallel to VP and inclined at $45_0$ to H.P.

3. Draw the projections of hexagonal prism of base 25mm side and axis 60mm long is resting on one of its corners of the base on H.P. The axis of the solid is inclined at $45_0$ to H.P.

4. Draw the projections of hexagonal prism of base 25mm side and axis 60mm long is resting on one of its corners of the base on H.P. The axis of the solid is inclined at $45_0$ to H.P.

5. Draw the projection of a cylinder of base 40mm diameter and axis height 55mm. When it is resting on H.P.on one of its base.

6.A cube of 40mm side is resting on its base on H.P. such that two of the vertical faces are equally inclined to V.P. Draw its projections and draw the side elevation.

7. Draw the projections of hexagonal prism of base 25mm side and axis 60mm long is resting on one of its corners of the base on H.P. The axis of the solid is inclined at $45^0$ to H.P.

8. Draw the projection of a pentagonal pyramid with side of base 30mm with a slant face on H.P. such that the axis is parallel to V.P.

9. Draw the projection of a cylinder of 50 diameter and axis 65mm long when it lying on H.P .with its axis inclined at $45^0$ to H.P. and parallel to V.P.

10. A hexagonal pyramid of base side 25mm and axis 60mm long is resting on an edge of the base on H.P. Draw the projections of the solid, Whe the axis makes an angle $45^0$ with V.P. and the base of the solid is nearer to V.P.

11. A cylinder with 50mm diameter of its base and axis 70mm has it axis inclined at $30^0$ to the V.P. and the elevation of the axis is inclined at $30^0$ to ground line xy. Draw the projections of the cylinder.

12. Draw the projection of a cube of edge 30mm resting on the ground on one of its corners with a solid diagonal perpendicular to V.P.

13. A hexagonal prism of 30mm side of base and 70mm height, resting on the H.P. such that the axis is inclined at 300 to the H.P. and 600 to the V.P. Draw its projections. Keep the top end of the prism near to the V.P.

14.Draw the projections of a cube of side 50mm which rests on a point of its corner on H.P. and one of its solid diagonal is parallel to H.P. and perpendicular to V.P.

15. A cone of base 80 mm diameter and height 100 mm lies with one of its generators on HP and the axis appears to be inclined to VP at an angle of 400 in the top view. Draw its top and front views.

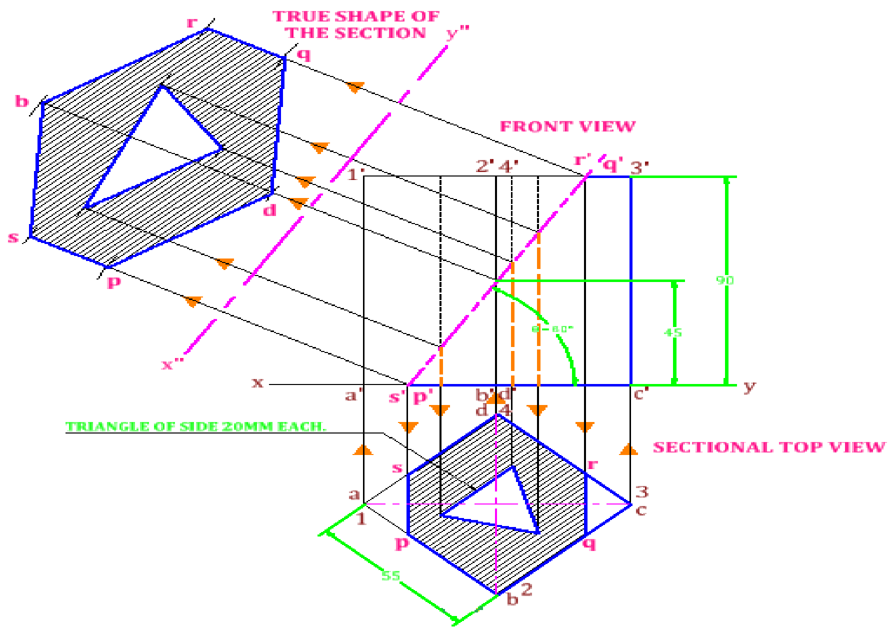
# Section of solids

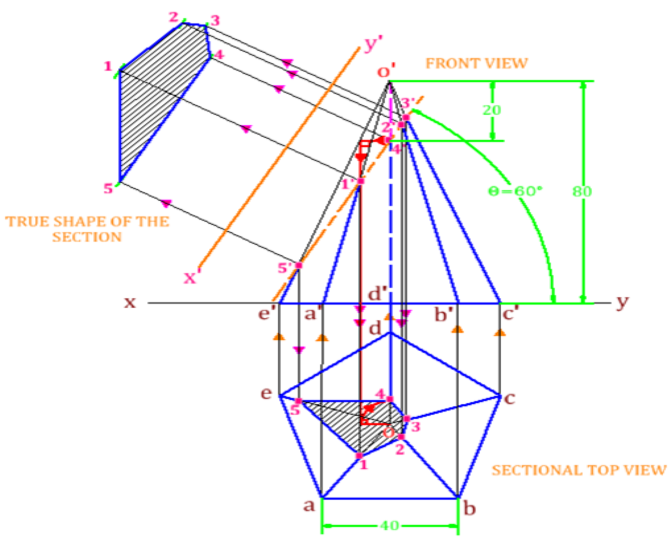
## 5.1 Introduction

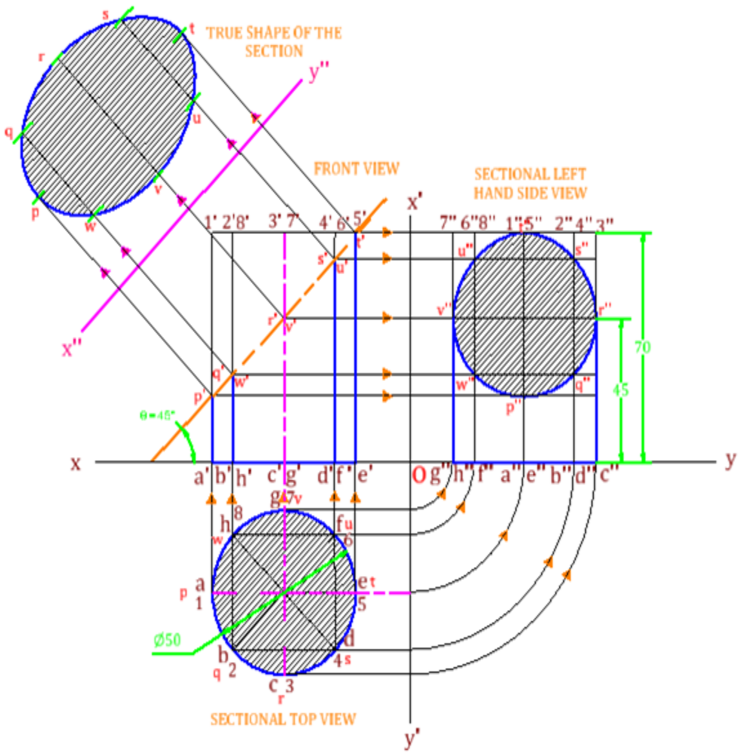
In engineering industries, when the internal structure of an object is complicated, it is very difficult to visualize the object from its orthographic views since there will be several hidden lines. In such case, the internal details are shown by sectional views. Sectional views are an important aspect of design and documentation since it is used to improve clarity and reveal interior features of parts.

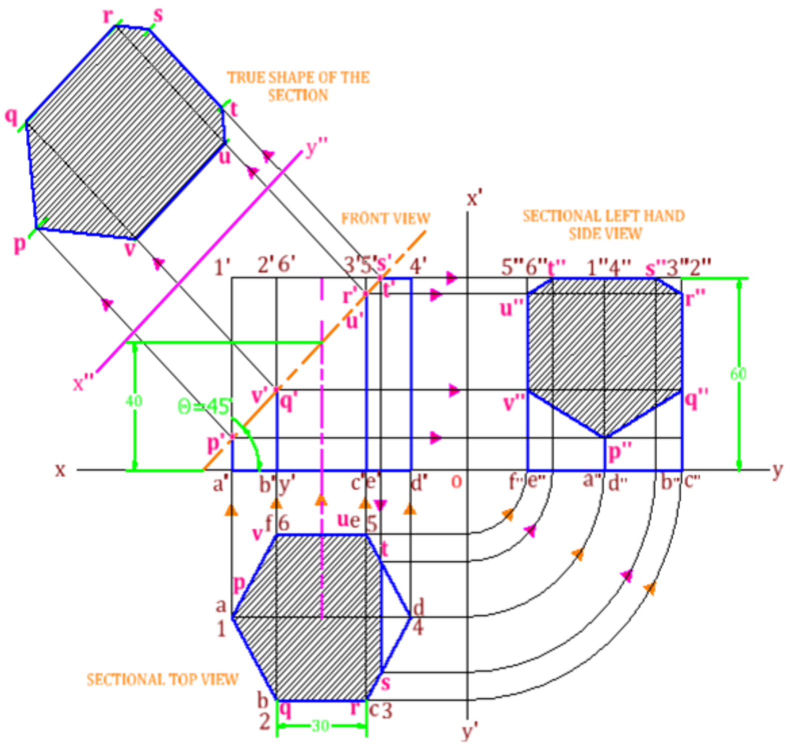
Sectional drawings are multi-view technical drawings that contain special views of a part or parts, that reveal interior features. A primary reason for creating a section view is the elimination of hidden lines, so that a drawing can be more easily understood or visualized. Traditional section views are based on the use of an imaginary cutting plane that cuts through the object to reveal interior features. This imaginary cutting plane is controlled by the designer

## 5.2 Examples:




TRUE SHAPE OF THE SECTION
FRONT VIEW
SECTIONAL LEFT HAND SIDE VIEW
SECTIONAL TOP VIEW
θ=45°
Ø50
70
45


TRUE SHAPE OF THE SECTION
FRONT VIEW
SECTIONAL LEFT HAND SIDE VIEW
SECTIONAL TOP VIEW
θ=45°
40
60
30

## 5.3 Problems of Section of Solids:

1. a cone having base diameter 60mm and axis 55mm long resting on HP. Its is cut by a plane passing through mid of the axis but makes an angle of 45$_0$ to the H.P. Draw the sectional plan and true shape of the section. Also develop the lateral surface.

2. Draw the projection of a cylinder having base diameter 60mm and axis 55mm long resting on HP. It is cut by a plane passing through mid of the axis but makes an angle of 45$_0$ to the H.P. Draw the sectional plan and true shape of the section. Also develop the lateral surface.

3. Draw the projections of hexagonal prism of base 25mm side and axis 60mm long is resting on one of its corners of the base on H.P. It is cut by a plane passing through mid of the axis but makes an angle of 45$_0$ to the H.P. Draw the sectional plan and true shape of the section. Also develop the lateral surface.

4. Draw the projections of hexagonal prism of base 25mm side and axis 60mm long is resting on one of its corners of the base on H.P. It is cut by a plane passing through mid of the axis but makes an angle of 45$_0$ to the H.P. Draw the sectional plan and true shape of the section. Also develop the lateral surface.

5. A pentagonal pyramid of base side 3.5 cm vertical ht. 5.5 cm is resting on its base on H.P such that one of the base side is parallel to V.P . It is cut by a sectional plane at an angle $45^0$ with H.P. Passing through mid of the axis. Draw the sectional plan and true shape of the section .

6. A triangular pyramid of base side 35mm ht. 5.5cm is resting on its base on H.P. Such that one of the base side is parallel to V.P. It is cut by a plane Passing through mid of the axis at an angle $45^0$ with H.P. Draw the sectional plan and true shape of the section.

7. A square prism of base side 3.5 cm vertical height 5.5 cm is resting on its base on H.P such that one of the base side is parallel to V.P. It is cut by a sectional plane at angle $40^0$ with H.P passing through mid of the axis. . Draw the sectional plan and true shape of the section.

8. A cylinder 50mm diameter and 70mm axis length has its axis parallel to V.P .but makes an angle of $30^0$ to the H.P. Its is cut by a plane passing through mid of the axis but makes an angle of $45^0$ to the H.P. Draw the sectional plane and true shape of the section.

9. A cone of base diameter 60 and axis 75mm rests on its base on H.P. It is cut by a plane perpendicular to the V.P. and parallel to the H.P. Draw the sectional plane , elevation and the true shape of the section. Name the true shape.

10. A square pyramid of base side 4 cm vertical height 6 cm is resting on its base on H.P such that one of the base side is parallel to V.P.It is cut by plane passing through a point on the axis located 1.5cm from its top at an angle of $55^0$ with H.P. Draw the sectional plan and true shape of the section.

11. A heaxagonalprism of side 30 mm and axis 60mm long resting on HP with one of its base side parallel to VP. Its axis is cut by a plane passing through 25mm from ground line makes an angle of $20^0$ with H.P. Draw the front view, sectional top view and true shape of the section.

12. A hexagonal prism of base side 30mm and height 75mm is resting on its base on H.P such that one of the bases is parallel to V.P. It is cut by a plane passing through the mid of the axis at an angle of $30^0$ with H.P. Draw the sectional plan, true shape and Develop the lateral surface of the sectional prism

13. A hexagonal pyramid of base side 35mm and vertical height 55mm is resting on its base on H.P. such that one of the base side is parallel to V.P. It is cut by a sectional plane at an angle with H.P. passing through mid of the axis. Draw the sectional plan, true shape and develop the lateral surface of the section.

14. A cone having base diameter 60mm and axis 55mm long resting on HP with its axis is parallel to VP. Its axis is cut by a plane passing through 45mm from ground line makes an angle of $45^0$ with H.P. and perpendicular to V.P. Draw the sectional top view and true shape and develop the lateral surface of the section.

# Development of surfaces

## 6.1 Introduction

A development is the unfold / unrolled flat / plane figure of a 3-D object. It is also called a pattern where the plane may show the true size of each area of the object. When the pattern is cut, it can be rolled or folded back into the original object as shown in figure 1.

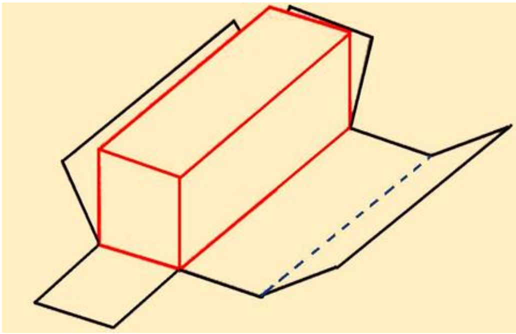


Figure 1. Typical development of the surface of a cuboid.

## 6.2 Types of development

There are three major types of development followed by industries.Examples are shown in figure 2.

- **Parallel line development**: In this parallel lines are used to construct the expanded pattern of each three-dimensional shape. The method divides the surface into a series of parallel lines to determine the shape of a pattern.
- **Radial line development**: In this, lines radiating from a central point to construct the expanded pattern of each three-dimensional shape is used. These shapes each form part of a cone and lines radiating from the vertex of the cone generate the expanded pattern of the curved surface as shown in the following explorations.
- **Triangulation method**: This is generally used for polyhedron, single curved surfaces, and warped surfaces.
- **Approximate development**: In this, the shapes obtained are only approximate. After joining, the part is stretched or distorted to obtain the final shape

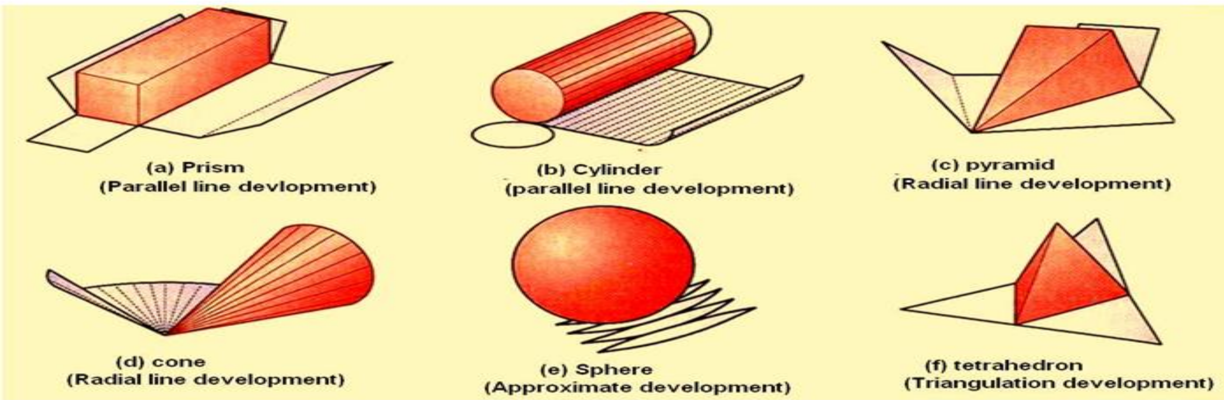
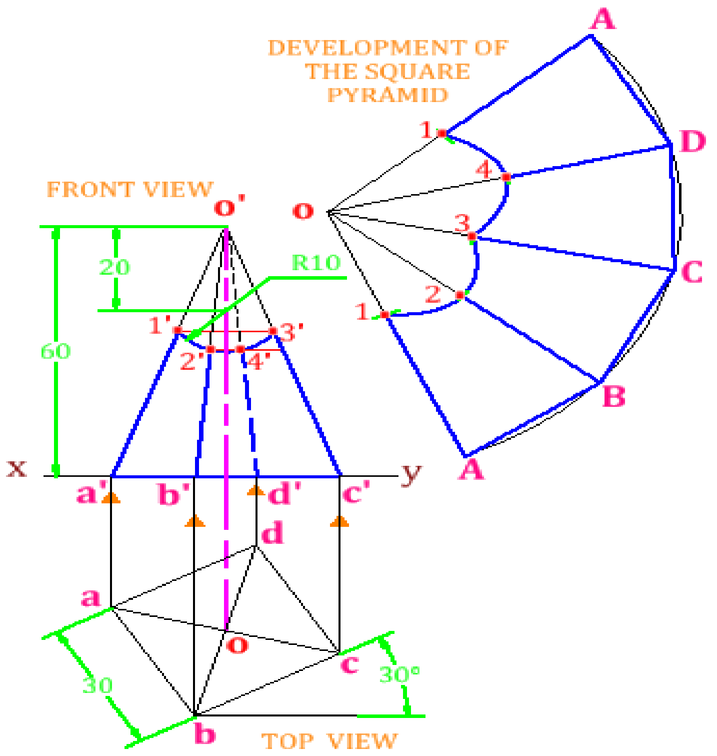
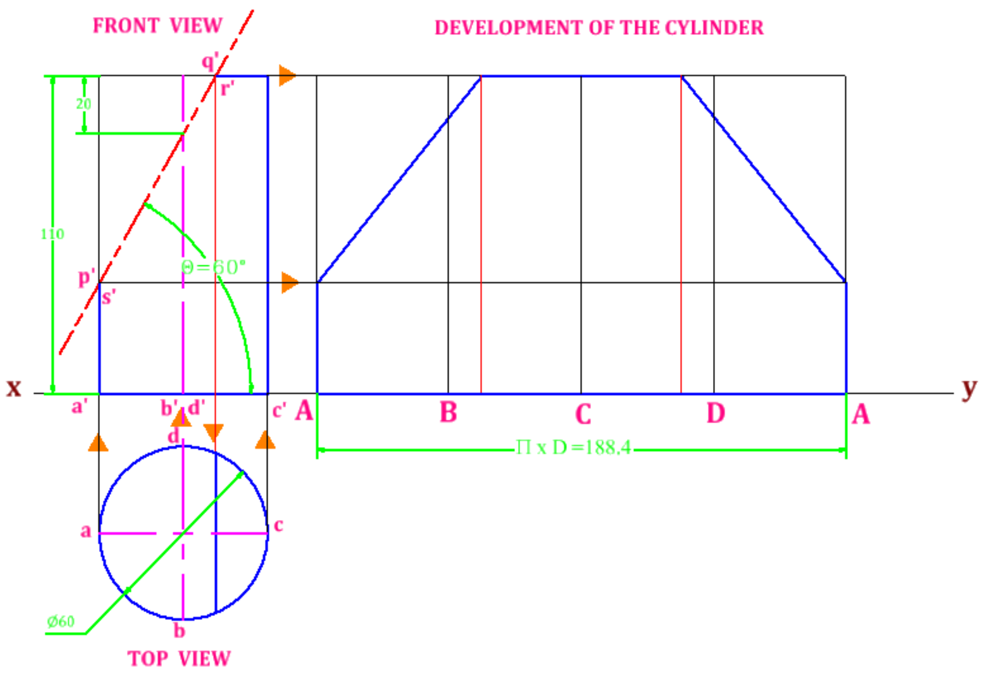



Figure 2. Typical examples of the various types of development.

## 6.3 Examples:


DEVELOPMENT OF
THE SQUARE
PYRAMID
FRONT VIEW
o'
o
20
R10
60
1'
3'
2'
4'
x
y
a'
b'
d'
c'
d
a
o
c
30
30°
b
TOP VIEW
A
D
C
B
A
1
4
3
2
1


FRONT VIEW
DEVELOPMENT OF THE CYLINDER
q'
r'
20
110
p'
s'
θ=60°
x
y
a'
b' d'
c'
A
B
C
D
A
Π x D =188.4
d
a
c
b
Ø60
TOP VIEW

## 6.4 Problems:

1. a cone having base diameter 60mm and axis 55mm long resting on HP. Its is cut by a plane passing through mid of the axis but makes an angle of $45_0$ to the H.P. Draw the sectional plan and true shape of the section. Also develop the lateral surface.

2. Draw the projection of a cylinder having base diameter 60mm and axis 55mm long resting on HP. It is cut by a plane passing through mid of the axis but makes an angle of $45^0$ to the H.P. Draw the sectional plan and true shape of the section. Also develop the lateral surface.

3. Draw the projections of hexagonal prism of base 25mm side and axis 60mm long is resting on one of its corners of the base on H.P. It is cut by a plane passing through mid of the axis but makes an angle of $45_0$ to the H.P. Draw the sectional plan and true shape of the section. Also develop the lateral surface.

4. Draw the projections of hexagonal prism of base 25mm side and axis 60mm long is resting on one of its corners of the base on H.P. It is cut by a plane passing through mid of the axis but makes an angle of $45_0$ to the H.P. Draw the sectional plan and true shape of the section. Also develop the lateral surface. 1. A cone of base diameter 5cm ht. 6.5 cm is resting on its base on H.P axis is parallel to V.P. It is cut by a plane passing through mid of the axis at an angle $45^0$ with H.P. Develop the lateral surface of the cut cone.

5. A pentagonal prism of base 3.5 and height 5.5 cm is resting on its base on H.P such that one of the base is Parallel to V.P .It is cut by plane passing through the mid of the axis. At an angle of $45^0$ with H.P. Develop the lateral surface of the cut prism

6. A cylinder base diameter 5cm and height 6cm is resting on its base on H.P it is cut by plane passing through mid of the axis at an angle of $30^0$ with H.P. Draw the develop surface of the remaining cylinder.

7. A pentagonal pyramid of base 4cm and height 6.5 cm is resting on its base on H.P such that one of the base is perpendicular to V.P .It is cut by plane passing through the mid of the axis. At an angle of $45^0$ with H.P. Develop the lateral surface of the cut prism

8.A square pyramid of 30mm side of base and height 60mm rests with its base on H.P .with one of the edges of the base is parallel to V.P. it is cut by a cutting plane perpendicular to V.P. and inclined at $45^0$ to H.P. bisecting the axis. Draw the development of the truncated pyramid.

9.A hexagonal prism of base 3cm and height 7 cm is resting on its base on H.P such that one of the base is perpendicular to V.P .It is cut by plane passing through a point on the axis located 2.5cm f9rom its top at an angle of $45^0$ with H.P. Develop the lateral surface of the cut prism

10. A square prism of base side 30mm and 65mm long axis standing with its base on H.P such that one of the base edges is parallel to V.P. it is cut by a section plane perpendicular to V.P and inclined at an angle of $45^0$ to H.P. and passing through the mid point of the axis of the prism. Draw the development of the lateral surface of the truncated prism.

11. A Hexagonal pyramid of base 3cm and height 6.cm is resting on its base on H.P such that one of the base is parallel to V.P .It is cut by plane passing through the mid of the axis at an angle of $30^0$ with H.P. Develop the lateral surface of the cut prism.

12. A Cylinder of 45mm base diameter 55mm long axis rests with its base on H.P. It is cut by a

perpendicular to V.P. and inclined at $60^0$ to H.P. The plane passing through a point on the axis located 12mm from its top. Draw the development of the lateral surfaces of the truncated cylinder.

13. A cylinder 40mm diameter and 70mm axis length has its axis parallel to V.P and perpendicular to H.P. It is cut by a plane passing through mid of the axis but makes an angle of $30^0$ to the H.P. Draw the sectional plane and true shape and develop the lateral surface of the section.

14. A cone of base diameter 50mm and height 65mm is resting on its base on H.P axis is parallel to V.P. It is cut by a plane passing through mid of the axis at an angle of $30^0$ with H.P. Develop the lateral surface of the cone.

# Isometric projection

## 7.1 Principles of Isometric projection:

When a solid is resting in its simple position, the front or top view, taken separately, gives an incomplete idea of the form of the object. When the solid is tilted from its simple position such that its axis is inclined to both H.P and V.P, the front view or the top view or sometimes both, give an „air idea of the pictorial form of the object, i.e., all the surfaces are visualized in a single orthographic view.

"Iso" means „equal" and "metric projection" means „a projection to a reduced measure". An isometric projection is one type of pictorial projection in which the three dimensions of a solid are not only shown in one view, but also their dimension can be scaled from this drawing.

Isometric projection is a method for visually representing three-dimensional objects in two dimensions in techinical and engineering drawings. It is an axonometric projection in which the three co-ordinate axes appear equally foreshortened and the angle between any two of them is 120 degrees.

**7.2 Isometric Scale:**

**Construction of isometric scale:**

 Draw a horizontal line OA.

 From O draw a line OC at 45 o to represent actual or true length and another line OB at 30 o to OA to measure isometric length.

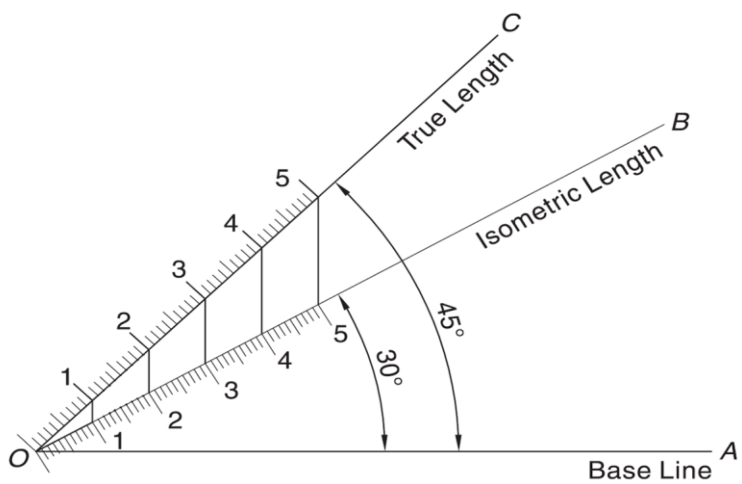
 On OC mark the point 0, 1, 2 etc to represent actual lengths.

 From these points draw verticals to meet OB at 0 , 1 , 2 etc. The length A1 represents the isometric scale length of A1' and so on.

$$\text{Isometric scale} = (\text{Isometric length}/\text{True length}) = \frac{\cos 45°}{\cos 30°} = \frac{1}{\sqrt{2}} \div \frac{\sqrt{3}}{2} = \frac{\sqrt{2}}{\sqrt{3}} = 0.8165$$

$$= 82\% \text{ (approximately)}$$

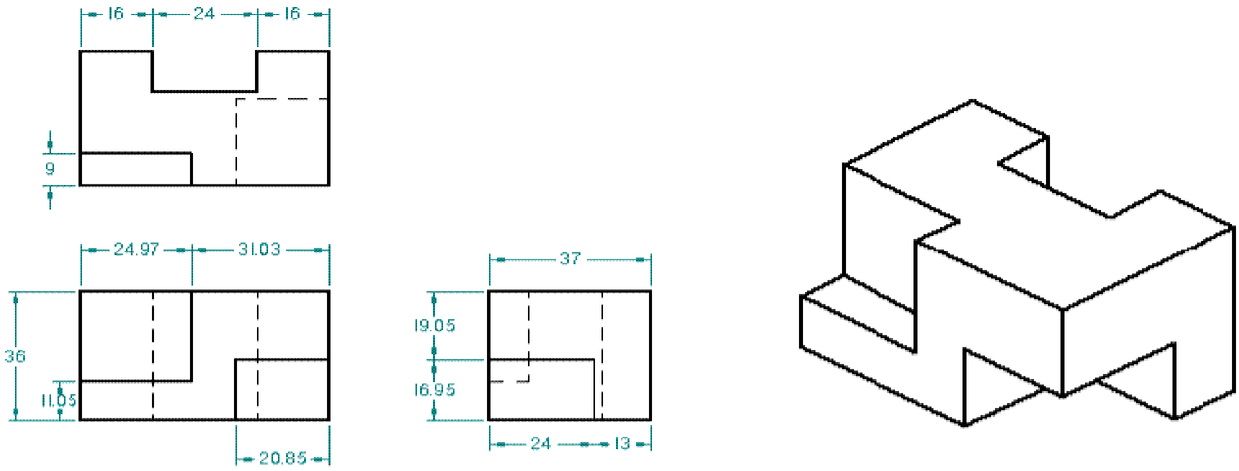
i.e., $\boxed{\text{Isometric length} = 0.82^* \text{ True length}}$



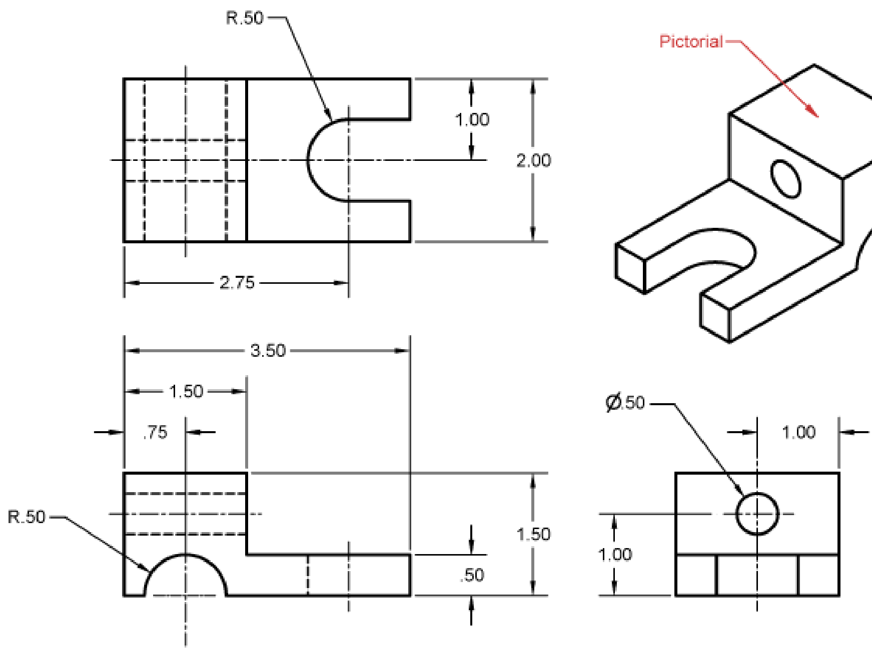
### 7.3 Difference between isometric view and isometric projection

| **Isometric View** | **Isometric Projection** |
|---|---|
| Drawn to actual scale | Drawn to isometric scale |
| When lines are drawn parallel to isometric axes, the true lengths are laid off. | When lines are drawn parallel to isometric axes, the lengths are foreshortened to 0.81 time the actual lengths. |

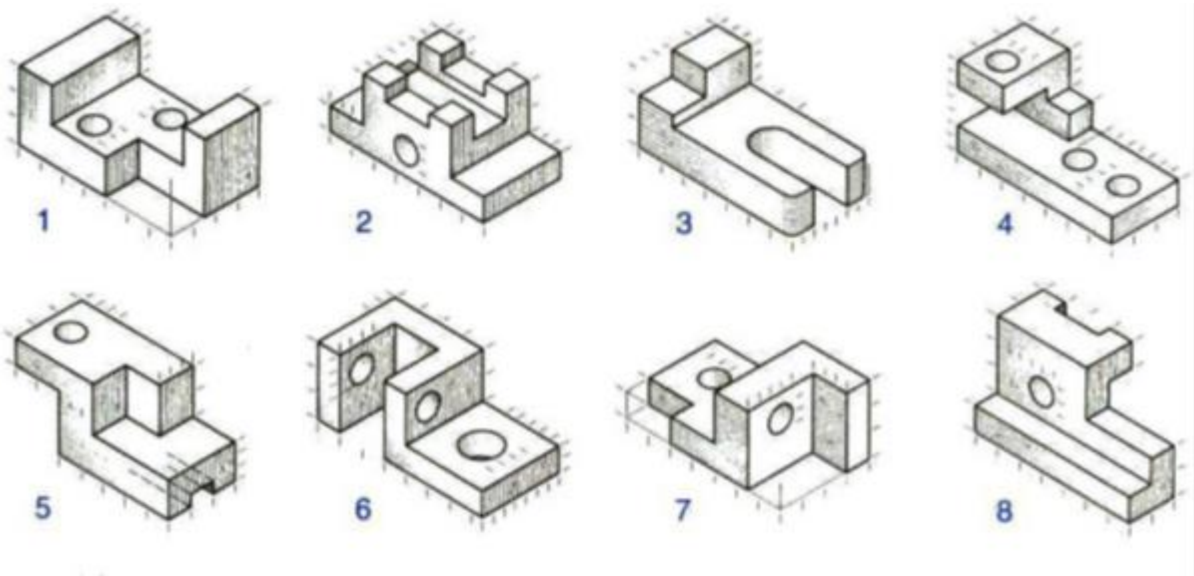
**Example 1 :**



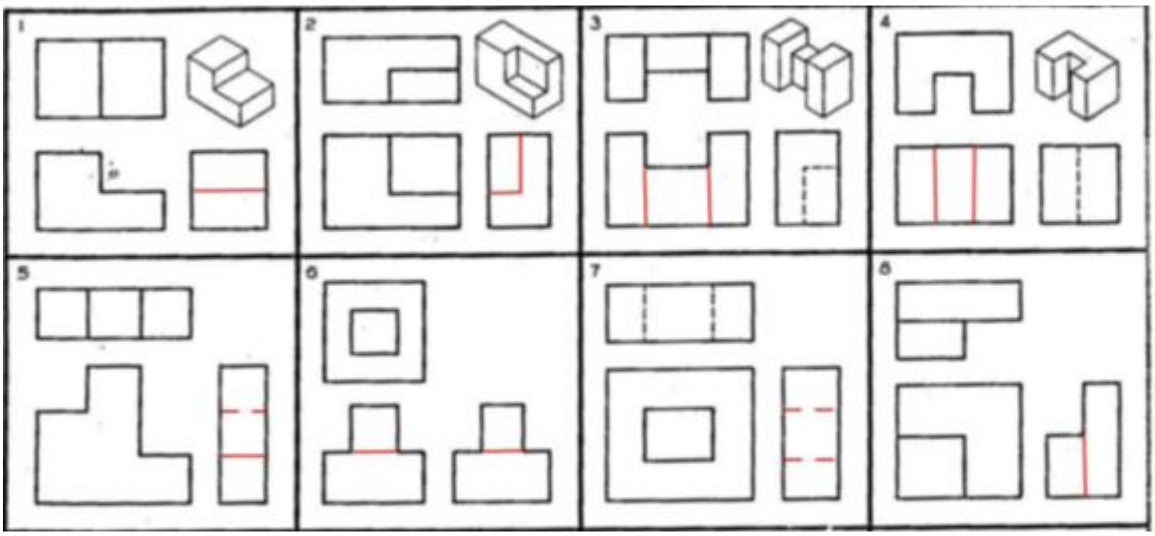

**Example 2 :**



## 7.4 Conversion of Isometric Views to Orthographic Views:




## 8.5 Conversion of Orthographic Views to Isometric Views:



# A manual on

# FreeCAD

# (An open source software)

Academy of Technology

Hooghly, 712121

# Part -1

# (For 1$^{st}$ Sem)

## 1. Introduction

FreeCAD is a free, open-source parametric 3D modeling application. Parametric is a term used to describe a dimension's ability to change the shape of model geometry as soon as the dimension value is modified. Feature-based is a term used to describe the various components of a model. For example, a part can consists of various types of features such as holes, grooves, fillets, and chamfers. A 'feature' is the basic unit of a parametric solid model. It is made primarily to model real-world objects, ranging from the small electronic components up to buildings and civil engineering projects, with a strong focus on 3D-printable objects. FreeCAD is free to download, use, distribute and modify, and its source code is open and published under the very permissive LGPL license. The data you produce with FreeCAD is fully yours, and can be recovered without FreeCAD. FreeCAD is also fundamentally a social project, as it is developed and maintained by a community of developers and users united by their passion for FreeCAD.

FreeCAD is an open-source parametric 3D modeling application, made primarily to design real-life objects. Parametric modeling describes a certain type of modeling, where the shape of the 3D objects you design are controlled by parameters. For example, the shape of a brick might be controlled by three parameters, such as height, width and length. In FreeCAD, as in other parametric modelers, these parameters are part of the object, and stay modifiable at any time, after the object has been created. Some objects can have other objects as parameters, for example an object can be modelled which takes the brick as input, and creates a column from it. FreeCAD is also multiplatform (it runs exactly the same way on Windows, Mac OS and Linux platforms).

The official website of FreeCAD is at [http://www.freecadweb.org](http://www.freecadweb.org)

## 2. Installation Procedure

Installation Procedure of FreeCAD software has been described in Fig.2.1-Fig.2.16.

1. Type FreeCAD in Google.

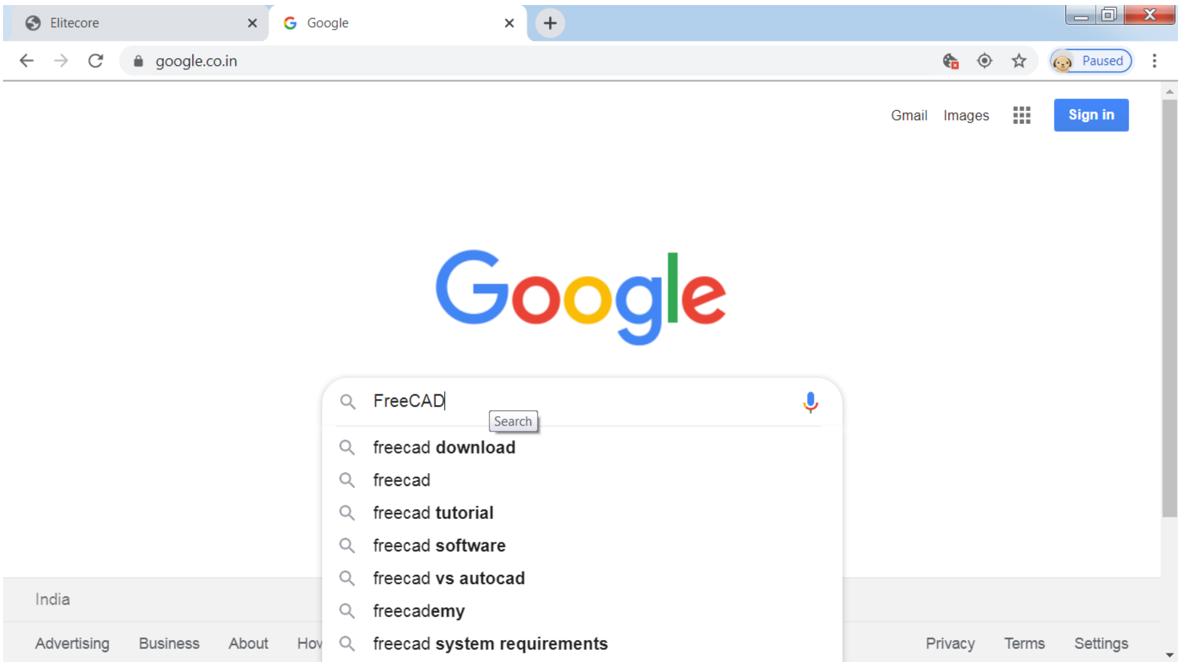



Fig. 2.1

2. Click on FreeCAD:  your own 3D parametric modeler.

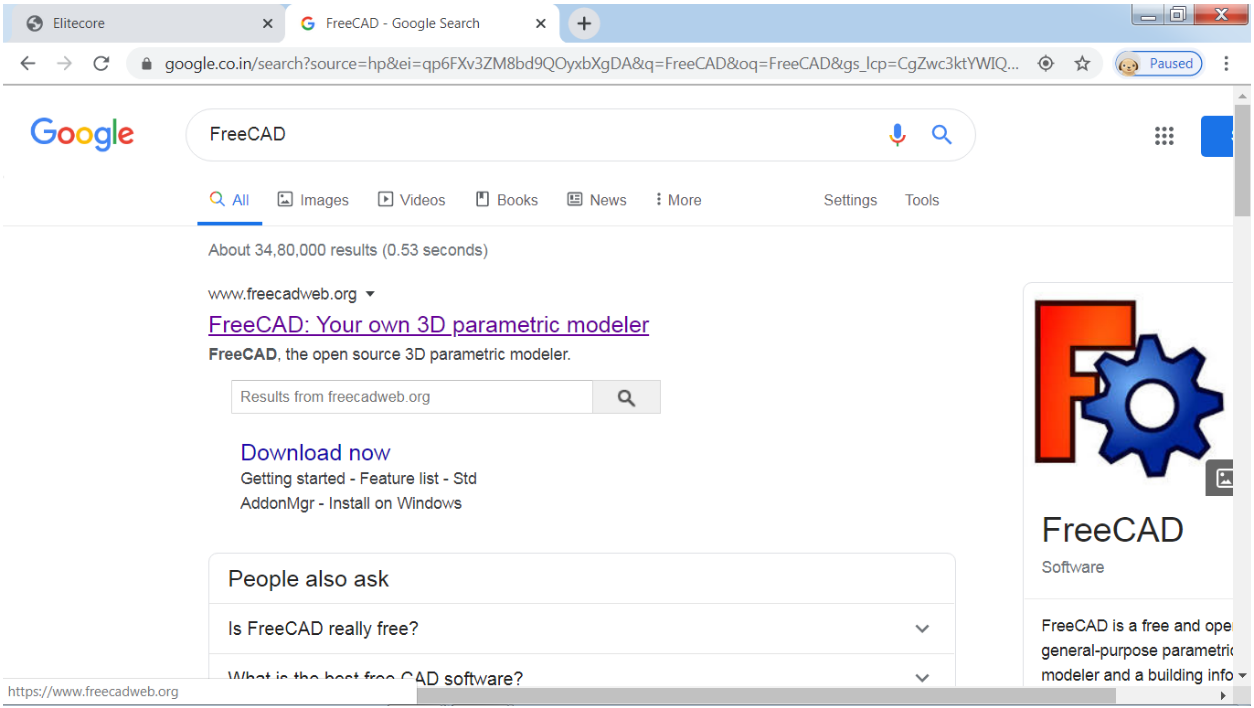



Fig.2.2

3. You will reach to this page,

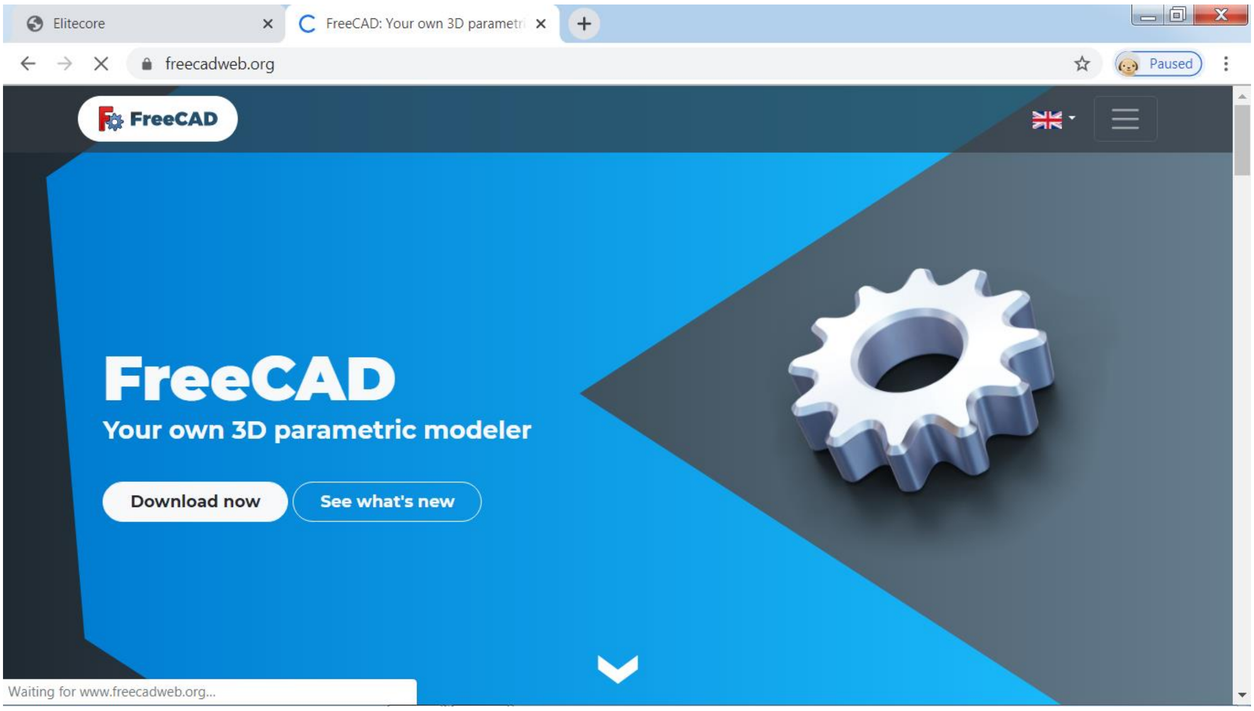



Fig. 2.3

4. Click at proper option (generally windows).

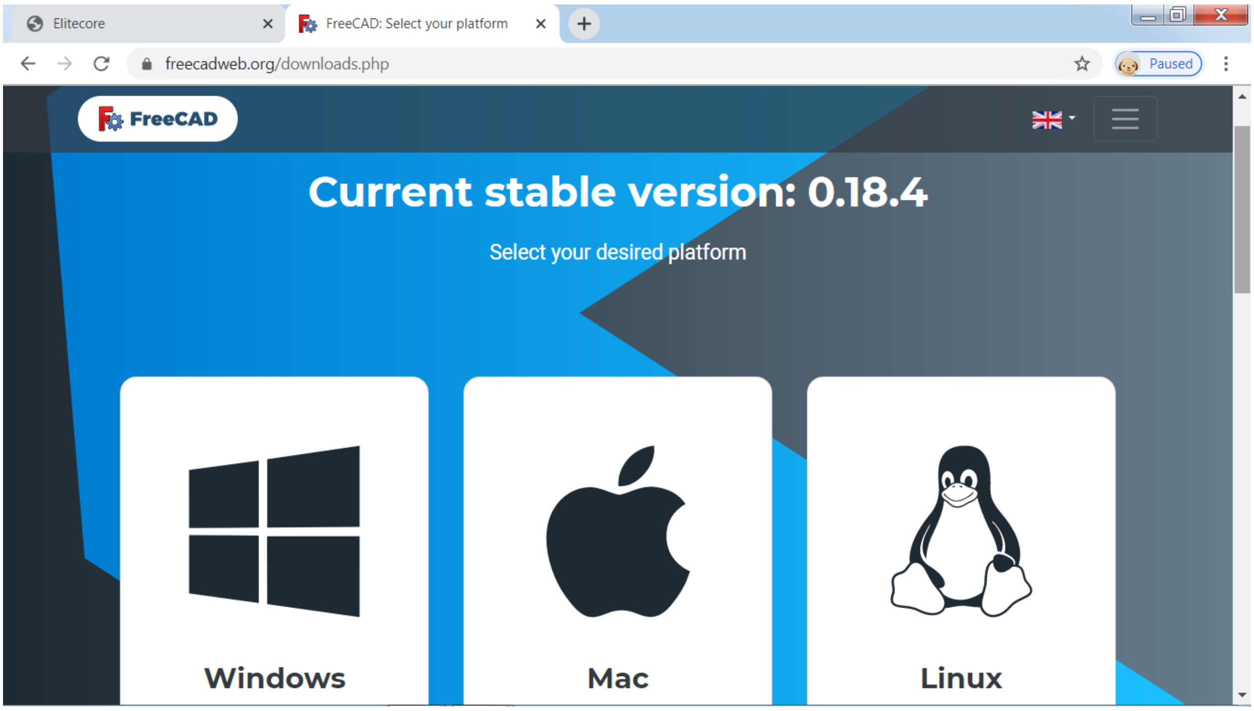



Fig. 2.4

5. Select 32 bit or 64 bit as required.

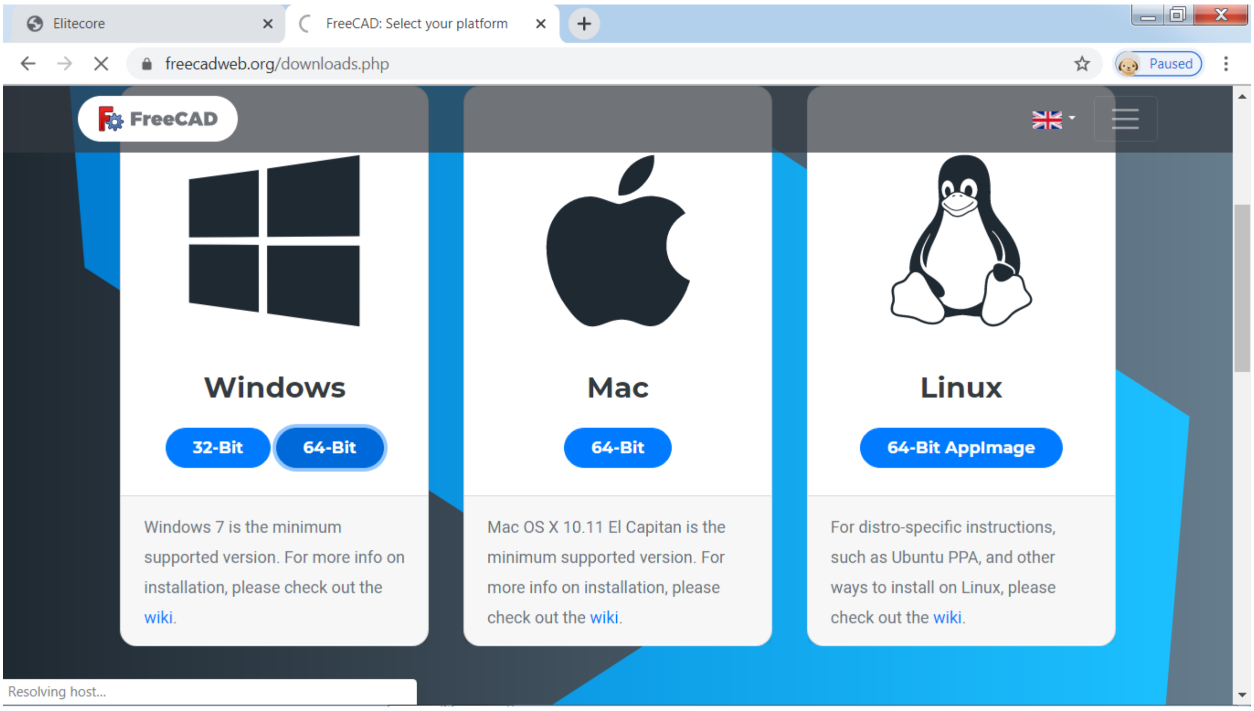



Fig. 2.5

6. It will be downloaded (as shown below).

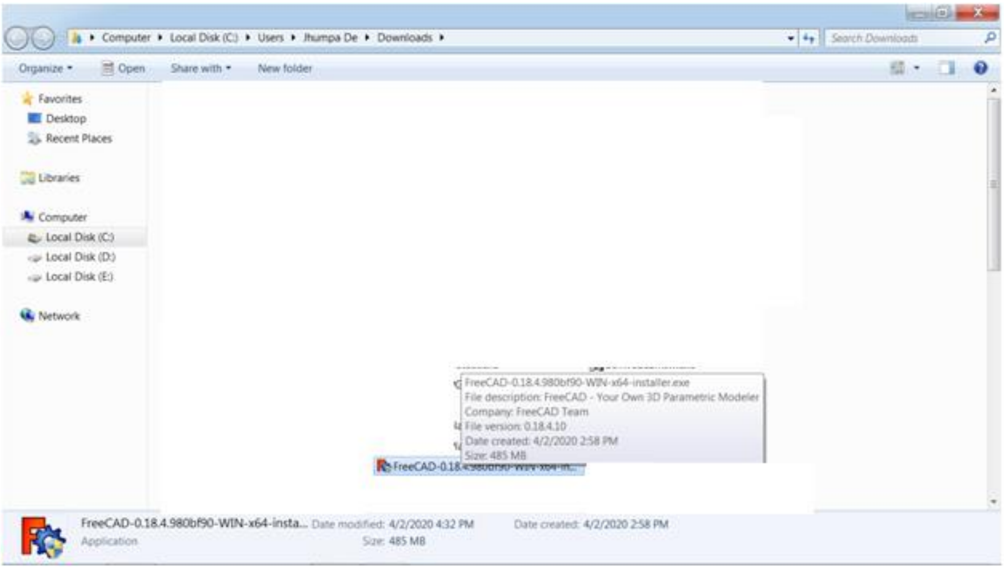



Fig. 2.6

7. Click on "FreeCAD-0.18.4.980bf90-WIN-x64-installer.exe" to run the program.

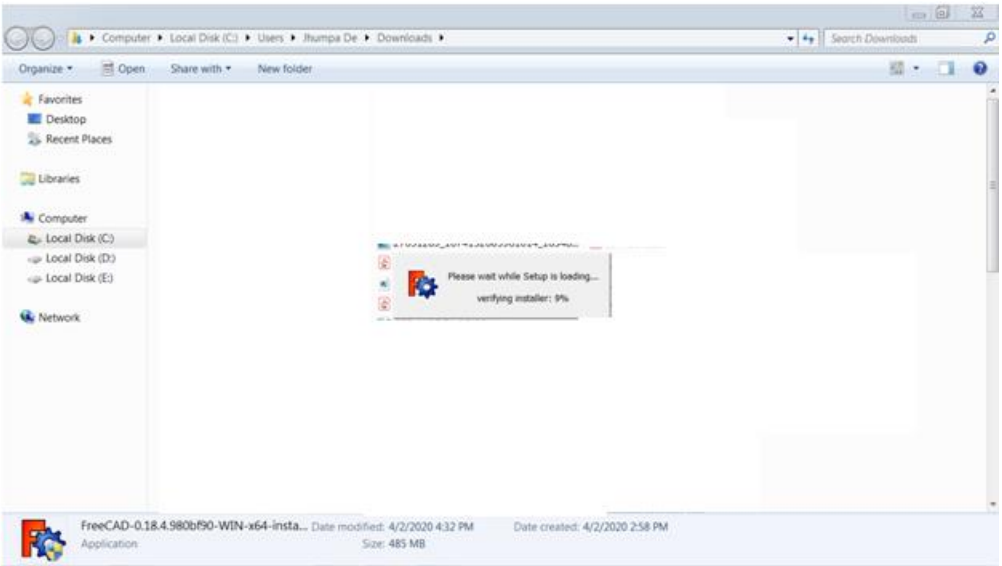



Fig. 2.7

8. Run the set up file (.exe)

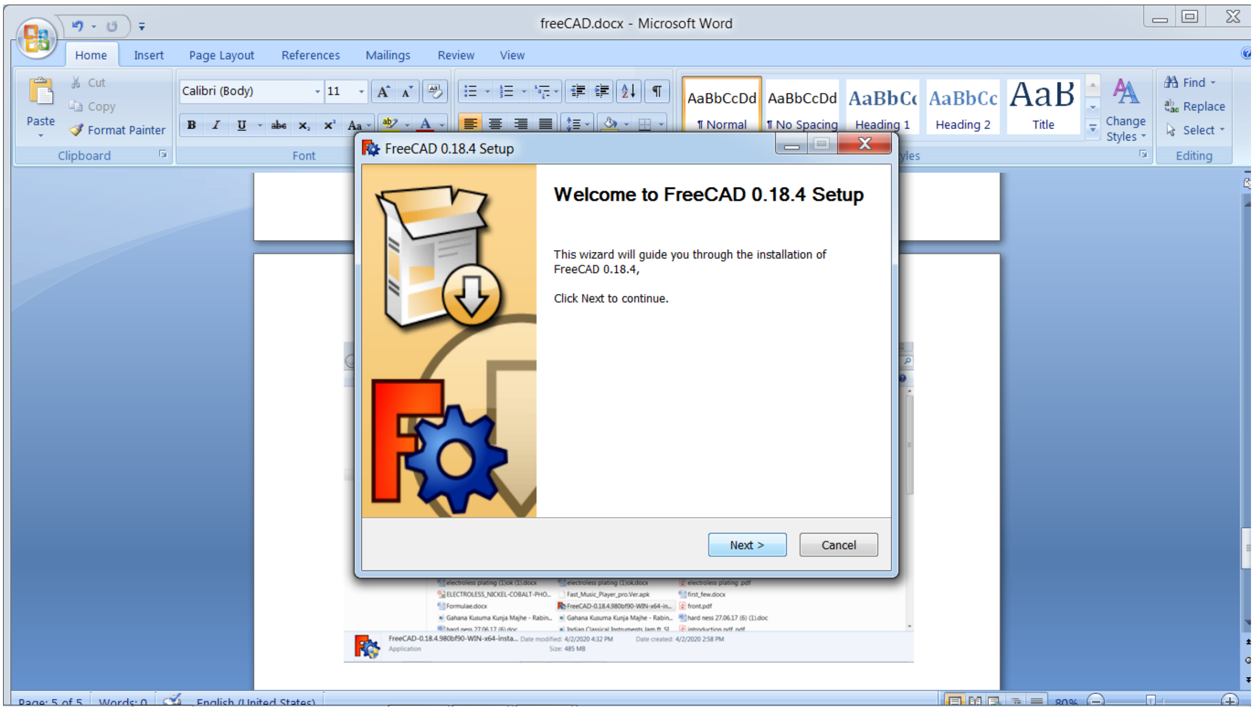



Fig. 2.8

9. After clicking ‘next’ in the above page , click ‘next ‘ again.

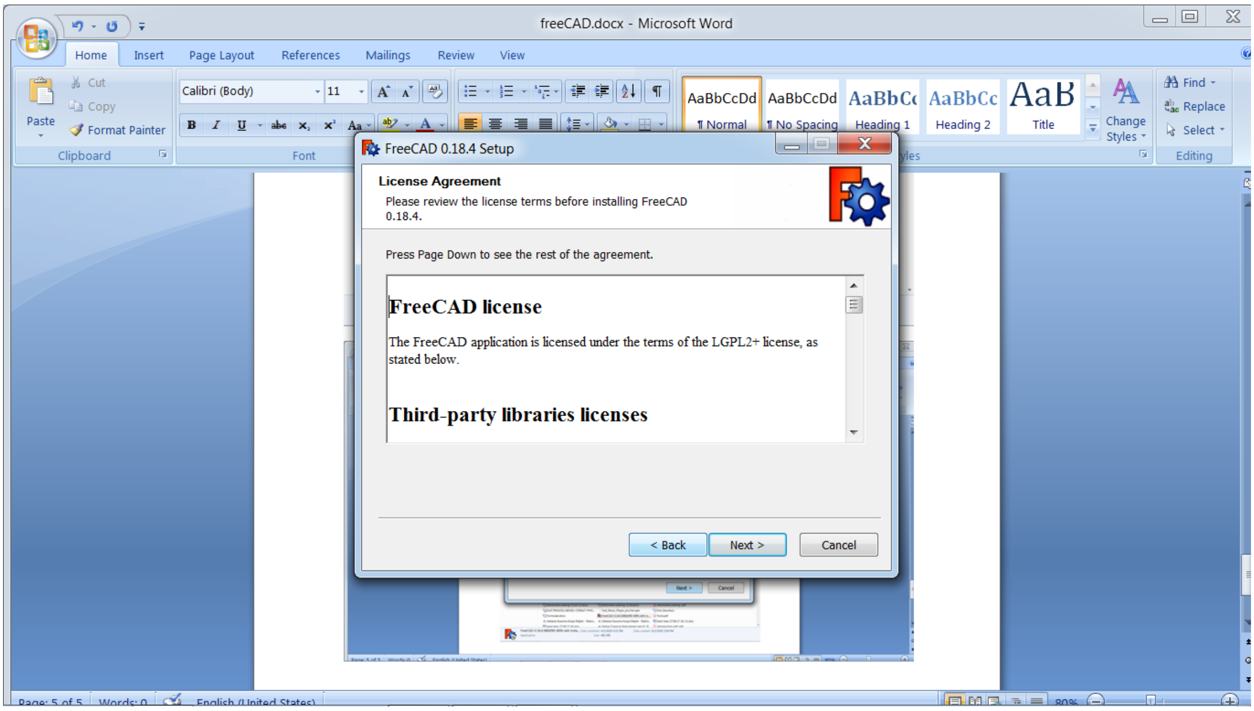



Fig. 2.9

10. Then click ‘next’ again.

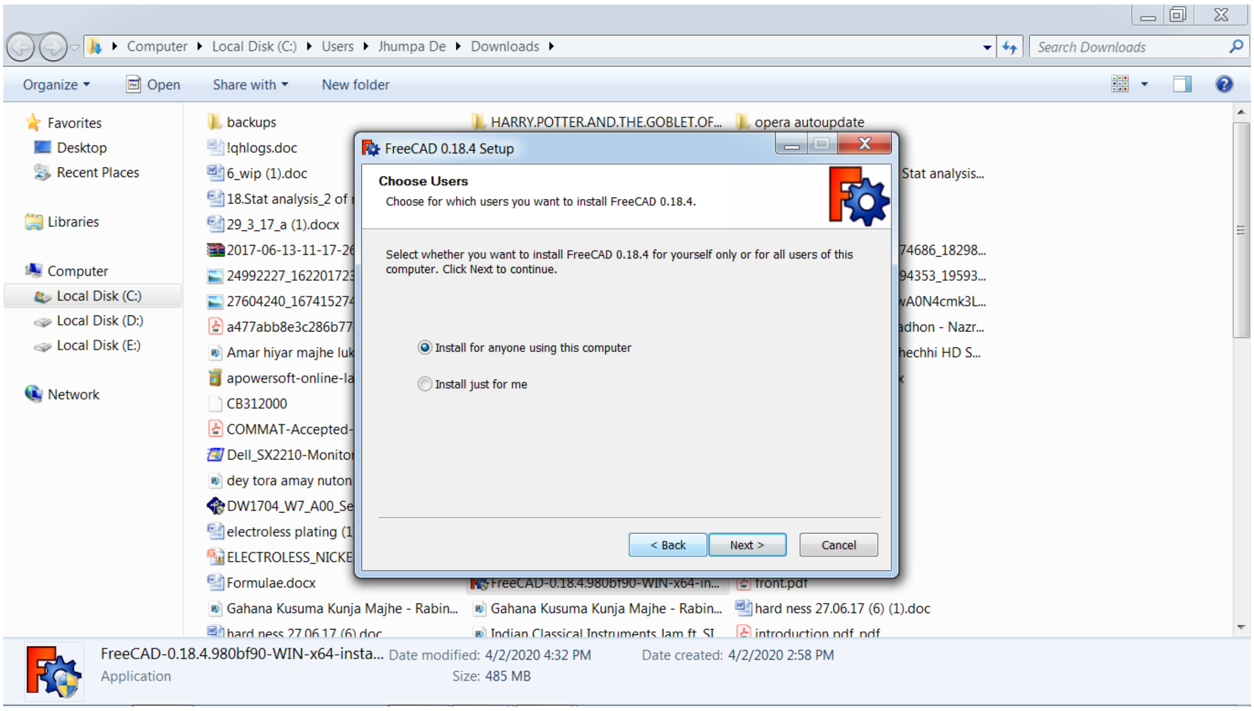



Fig. 2.10

11. Click at ‘next’ to continue.

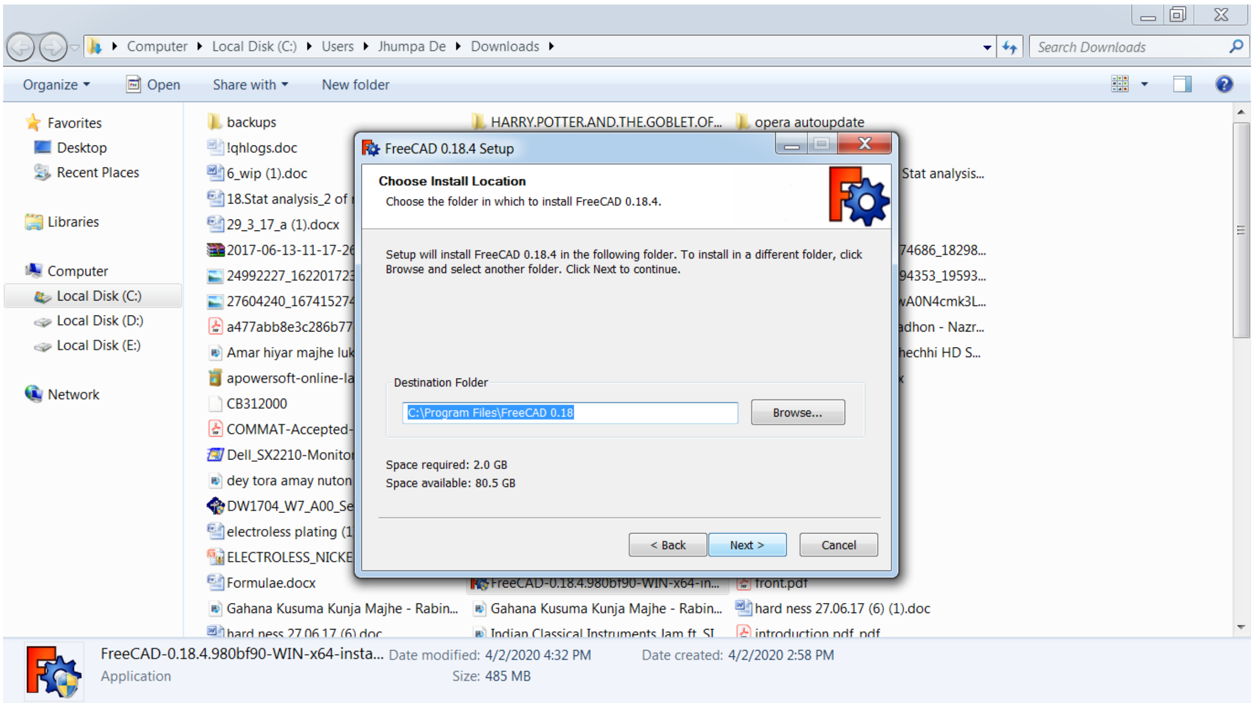



Fig. 2.11

12. Click ‘next’ to continue.

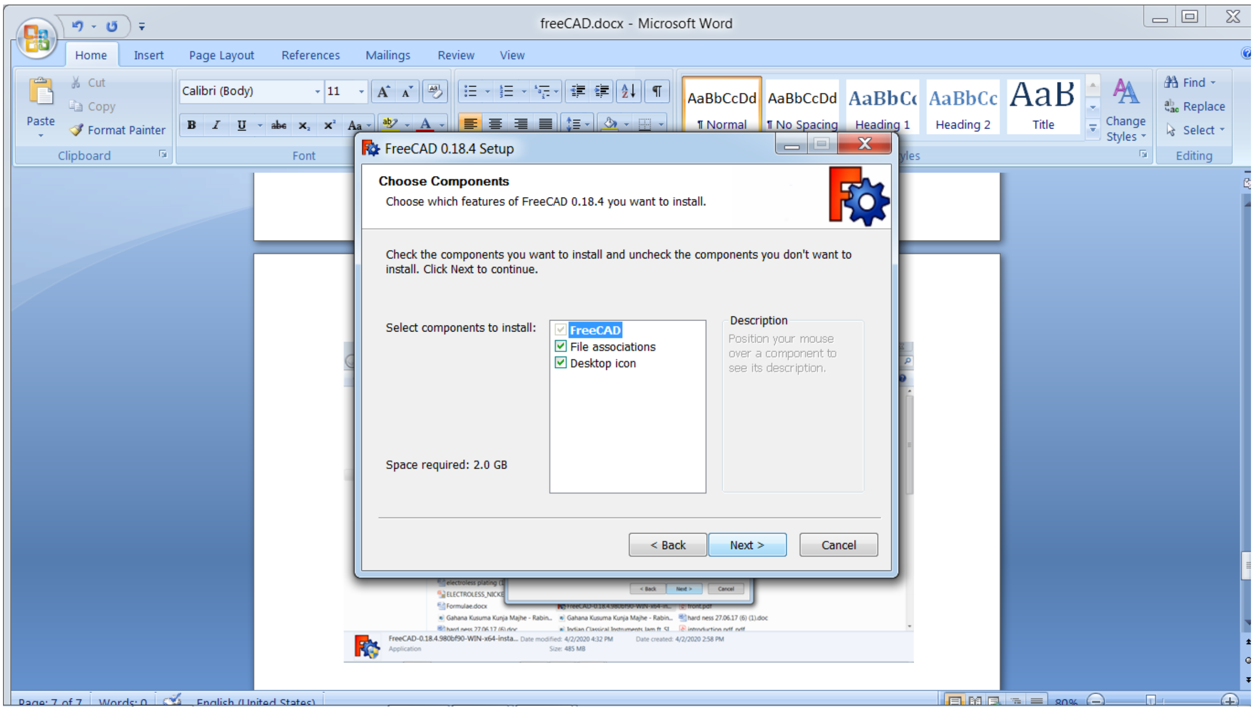



Fig. 2.12

13. Click ‘next’ to continue.

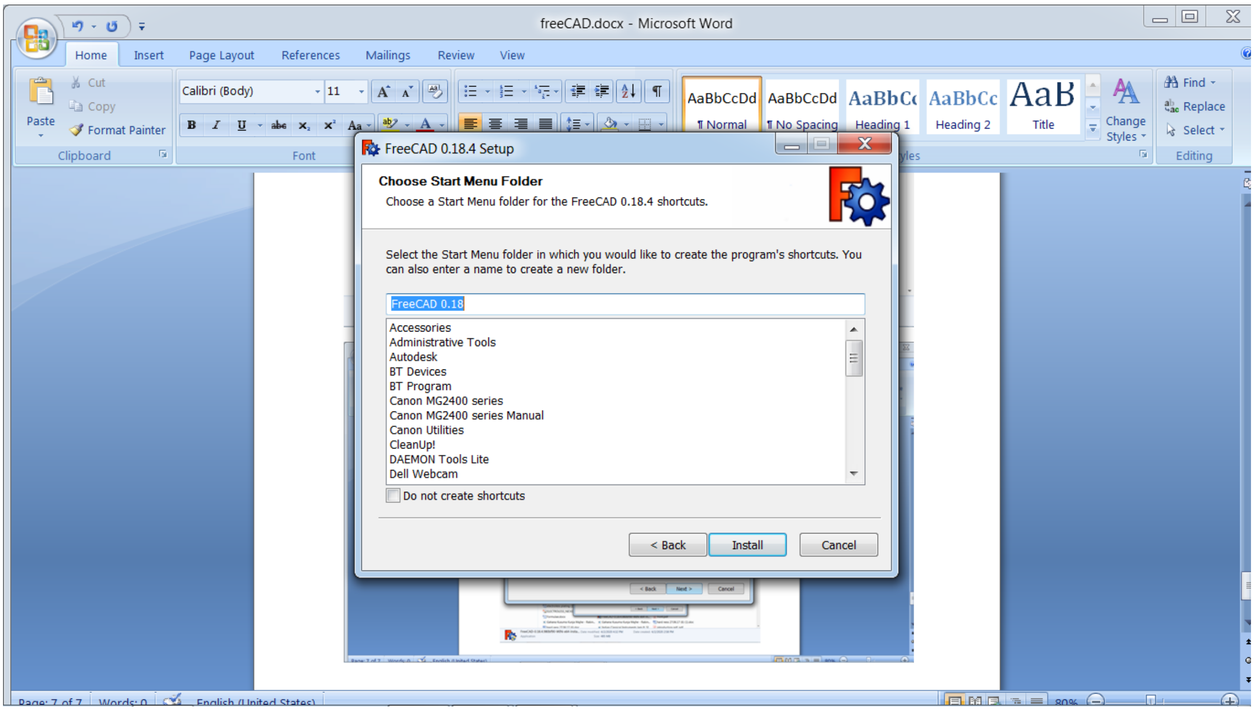



Fig.2.13

14. Click ‘next’ to continue.

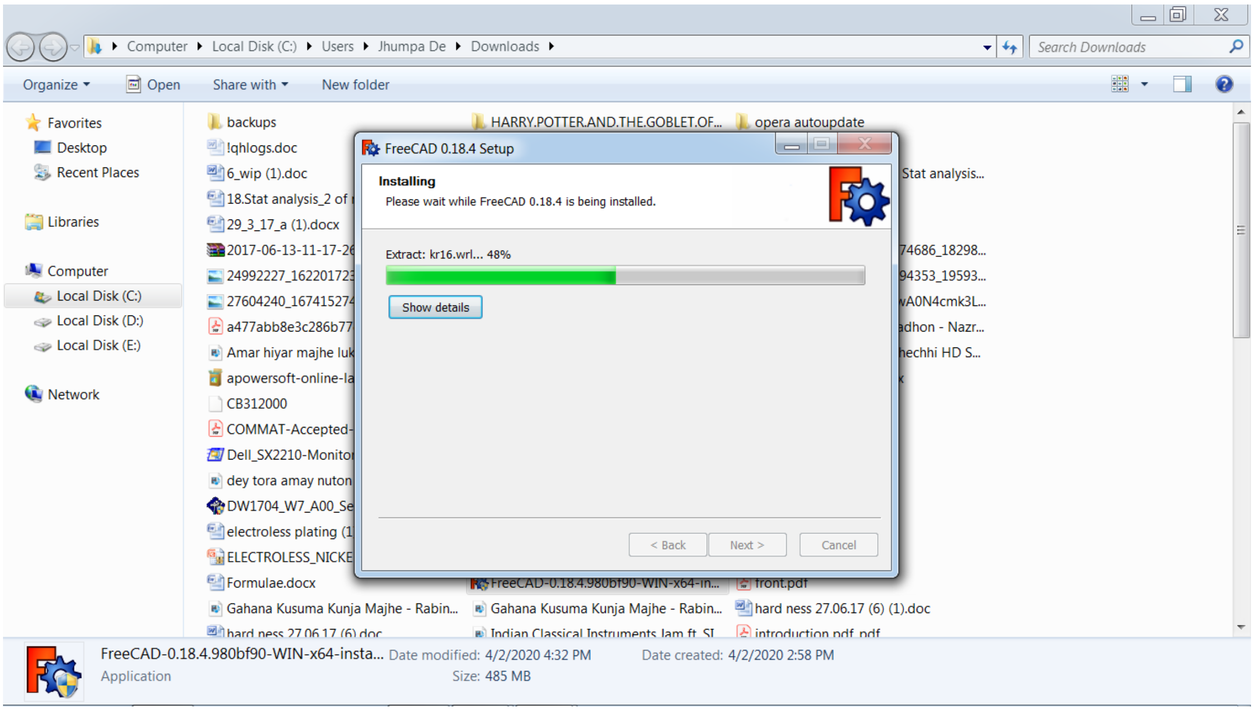



Fig.2.14

15. Click ‘finish’ to complete the installation procedure.

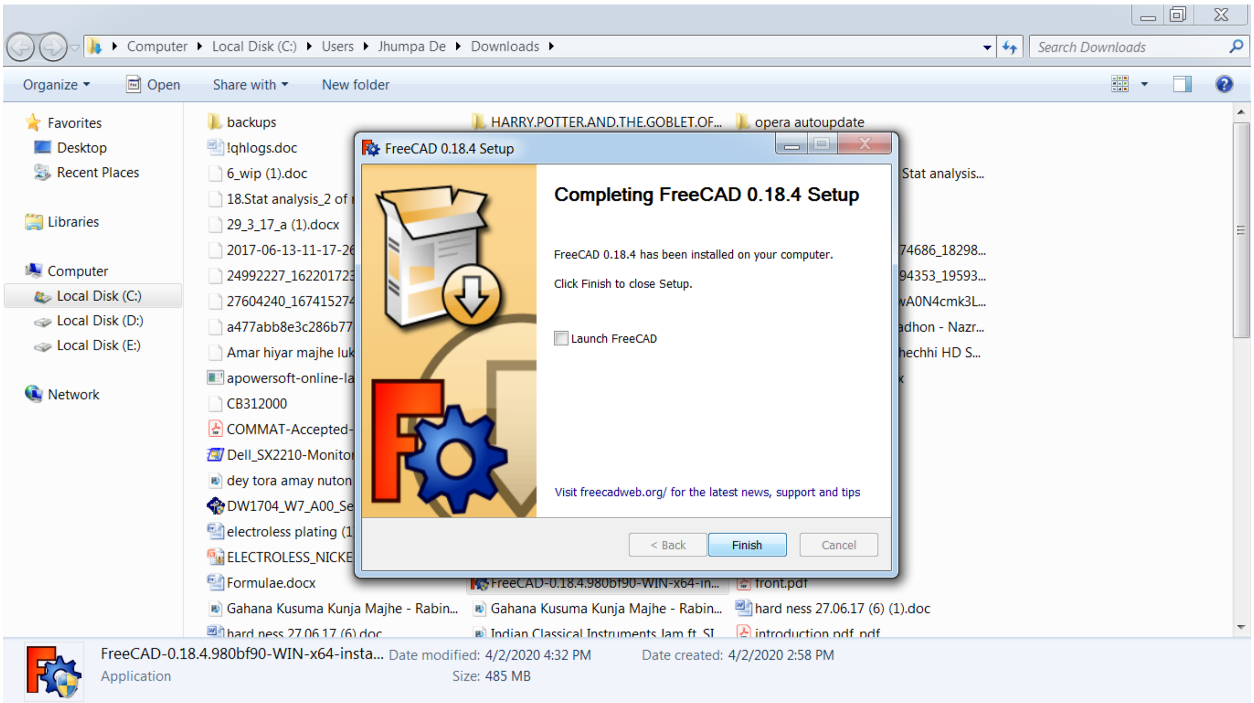



Fig. 2.15

16. Click on the FreeCAD icon on desktop.

Fig.2.16

17. The FreeCAD page will  be opened. After installations images are shown in Fig. 2.17-2.19.

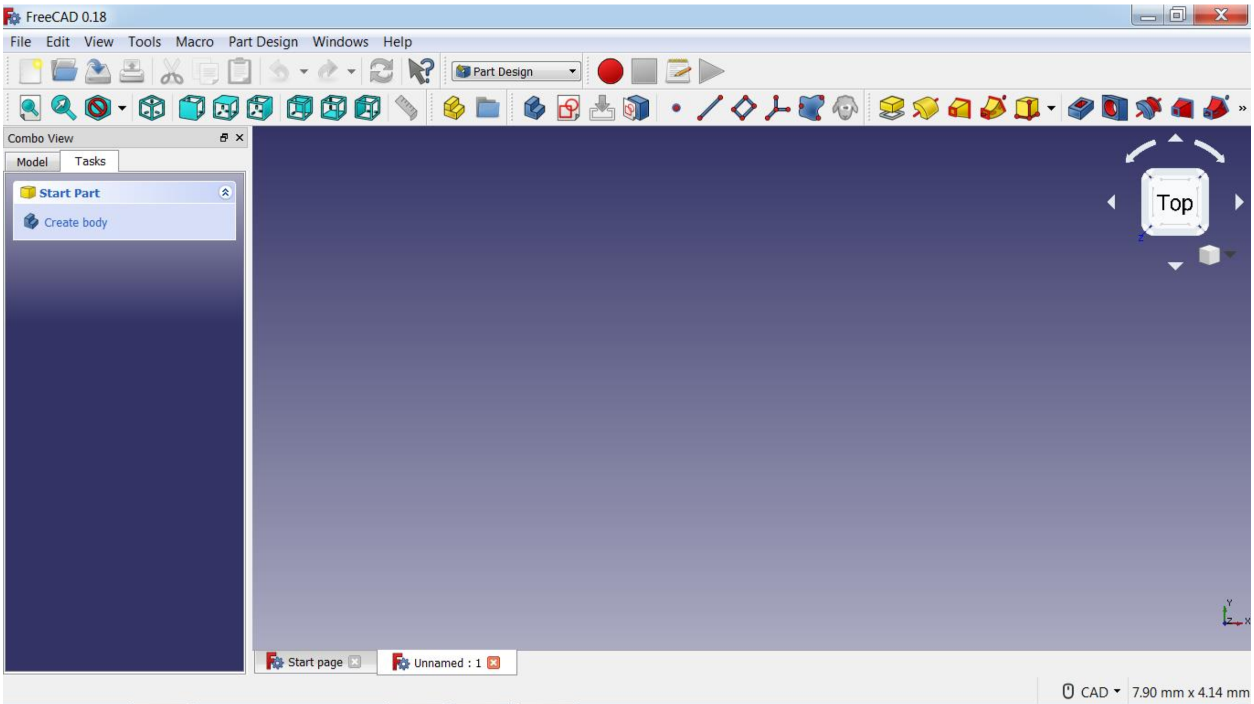



Fig. 2.17

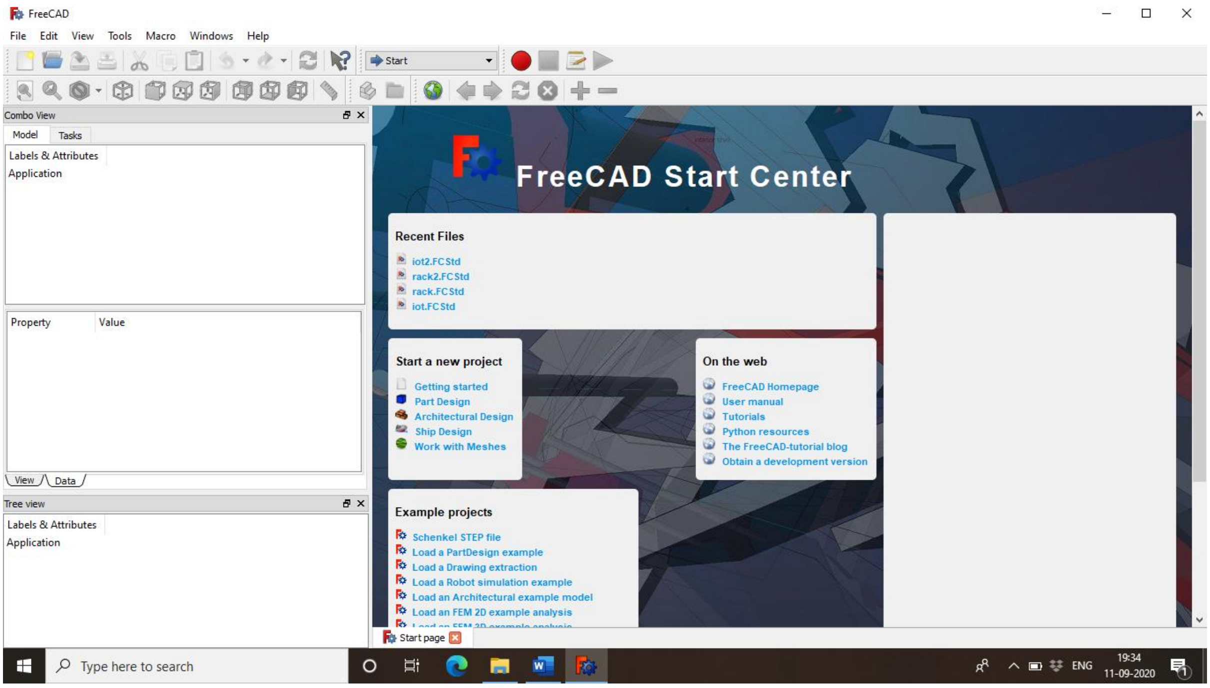



Fig.2.18

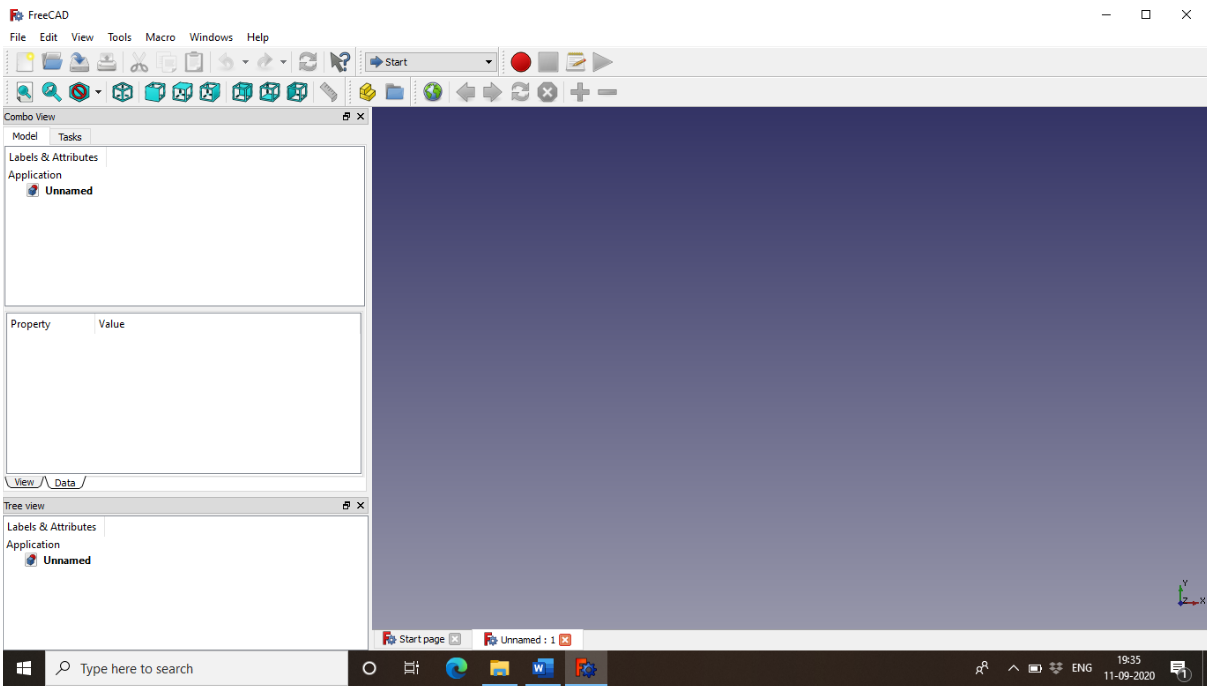



Fig. 2.19

3. **Setting preferences for units**

   The procedure for setting of unit systems has been explained through Fig. 3.1-3.3.

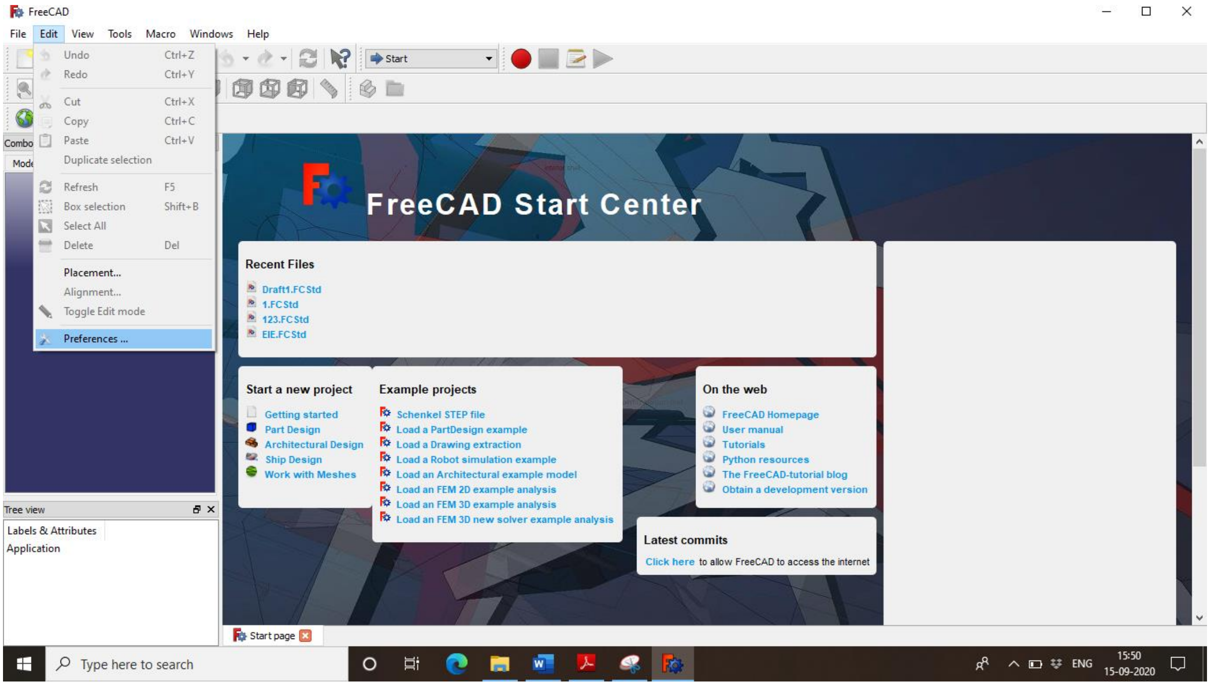

FreeCAD
File
Edit
View
Tools
Macro
Windows
Help
Undo Ctrl+Z
Redo Ctrl+Y
Cut Ctrl+X
Copy Ctrl+C
Paste Ctrl+V
Duplicate selection
Refresh F5
Box selection Shift+B
Select All
Delete Del
Placement...
Alignment...
Toggle Edit mode
Preferences ...
Start
FreeCAD Start Center
Recent Files
Draft1.FCStd
1.FCStd
123.FCStd
EIE.FCStd
Start a new project
Getting started
Part Design
Architectural Design
Ship Design
Work with Meshes
Example projects
Schenkel STEP file
Load a PartDesign example
Load a Drawing extraction
Load a Robot simulation example
Load an Architectural example model
Load an FEM 2D example analysis
Load an FEM 3D example analysis
Load an FEM 3D new solver example analysis
On the web
FreeCAD Homepage
User manual
Tutorials
Python resources
The FreeCAD-tutorial blog
Obtain a development version
Latest commits
Click here to allow FreeCAD to access the internet
Tree view
Labels & Attributes
Application
Start page
Type here to search
ENG
15:50
15-09-2020

Fig. 3.1

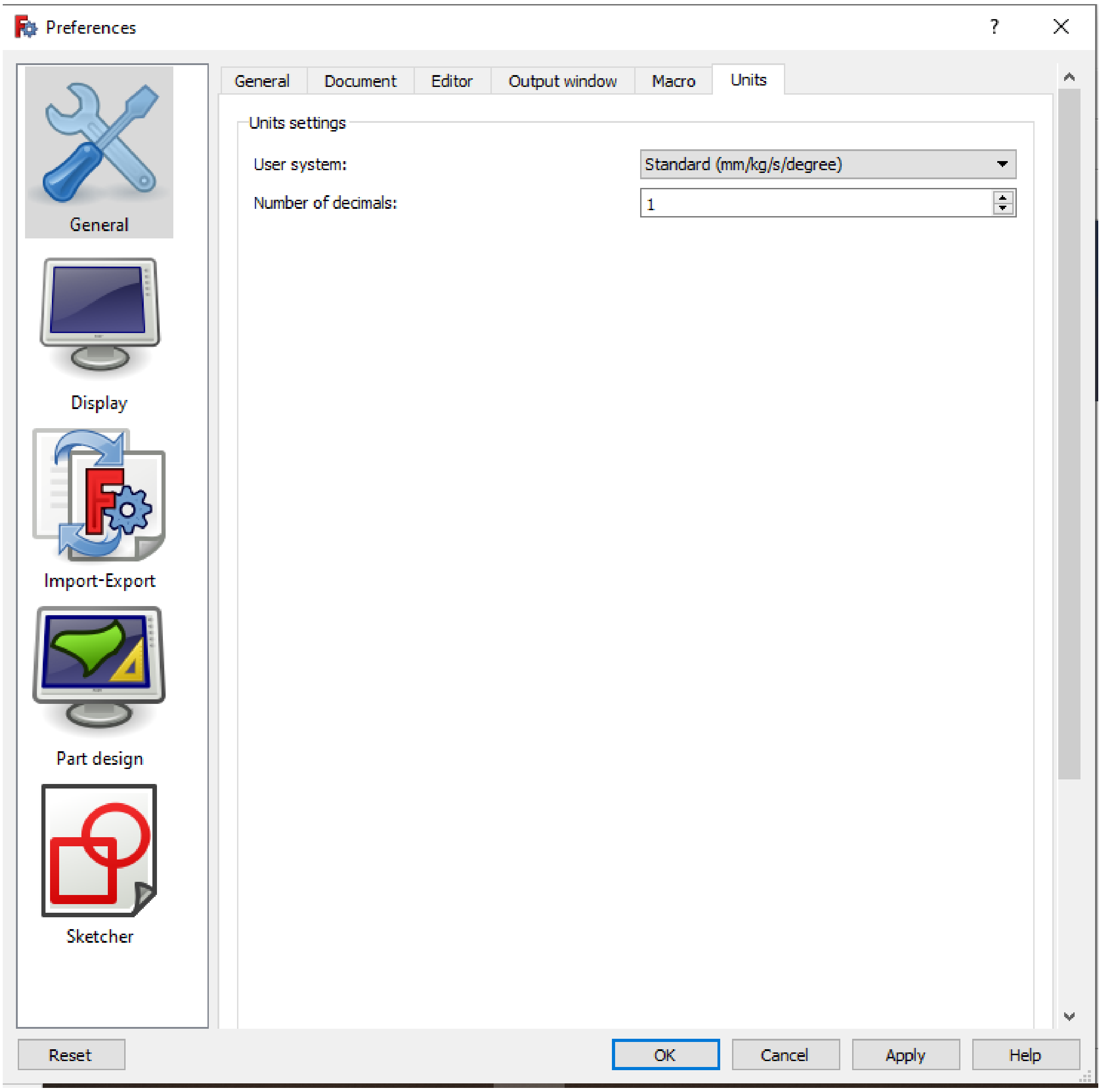

Preferences
General
Display
Import-Export
Part design
Sketcher
General
Document
Editor
Output window
Macro
Units
Units settings
User system:
Standard (mm/kg/s/degree)
Number of decimals:
1
Reset
OK
Cancel
Apply
Help

Fig. 3.2

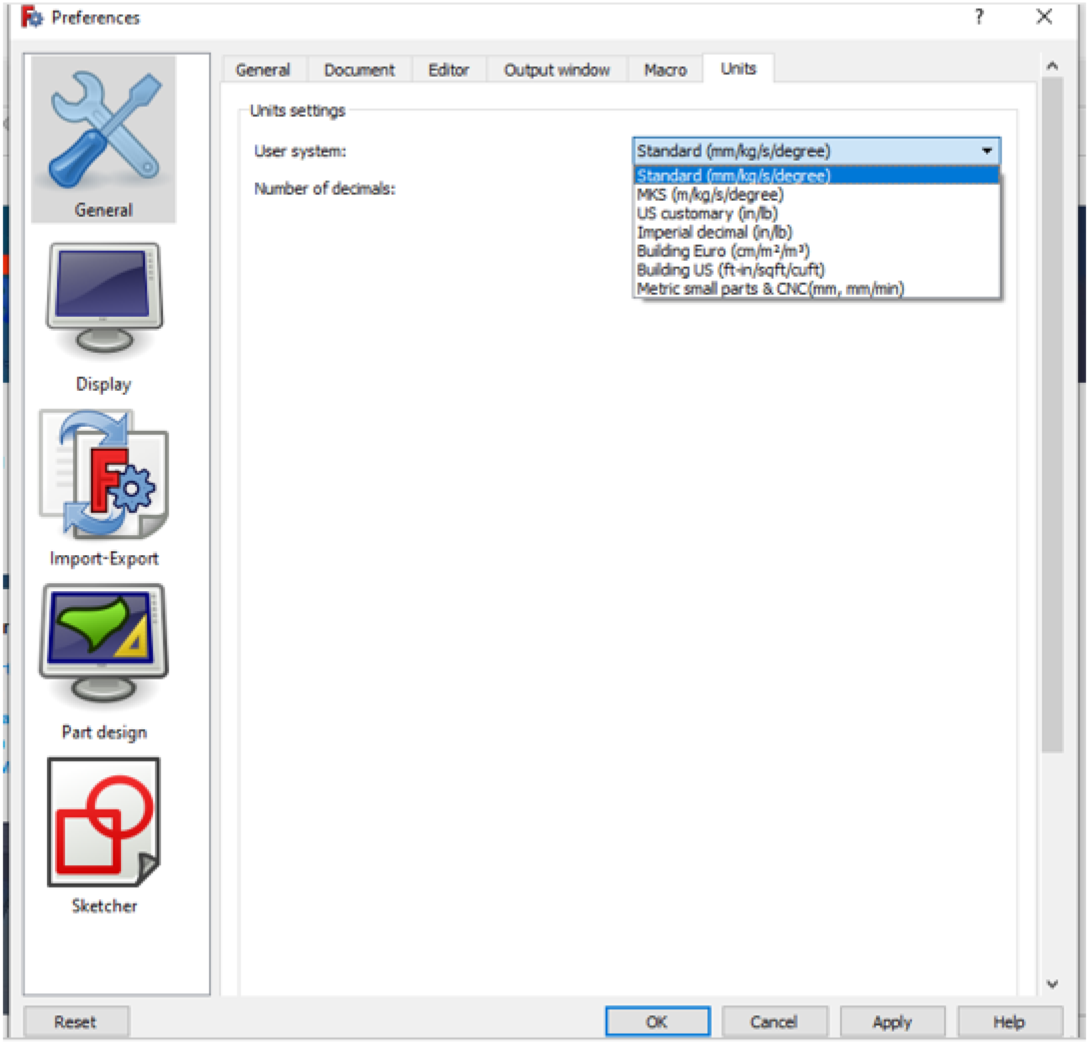



Fig. 3.3

**4. Installing additional content**

As the FreeCAD project and its community grows quickly, and also because it is easy to extend, external contributions and side-projects made by community members and other enthusiasts begin to appear everywhere on the internet. There is an effort going on to gather all these interesting additions in one place, on the FreeCAD github page.

i. A Parts library, which contains all kinds of useful models, or pieces of models, created by FreeCAD users that can be freely used in your projects. The library can be used and accessed right from inside your FreeCAD installation.

ii. A collection of addons, most of them additional workbenches, that extend the functionality of FreeCAD for certain tasks. Instructions for installing are given on each separate addon page.

iii. A collection of macros, which are also available on the FreeCAD wiki along with documentation about how to use them. The wiki contains many more macros.

a) Download the addons-installer.FCMacro file from https://github.com/FreeCAD/FreeCAD-addons by clicking it, then right-clicking the "RAW" button, and choosing "Save as".

b) Place the macro in your FreeCAD Macros destination path. The FreeCAD Macros destination path is indicated at the bottom of the **Execute macro** dialog in FreeCAD.

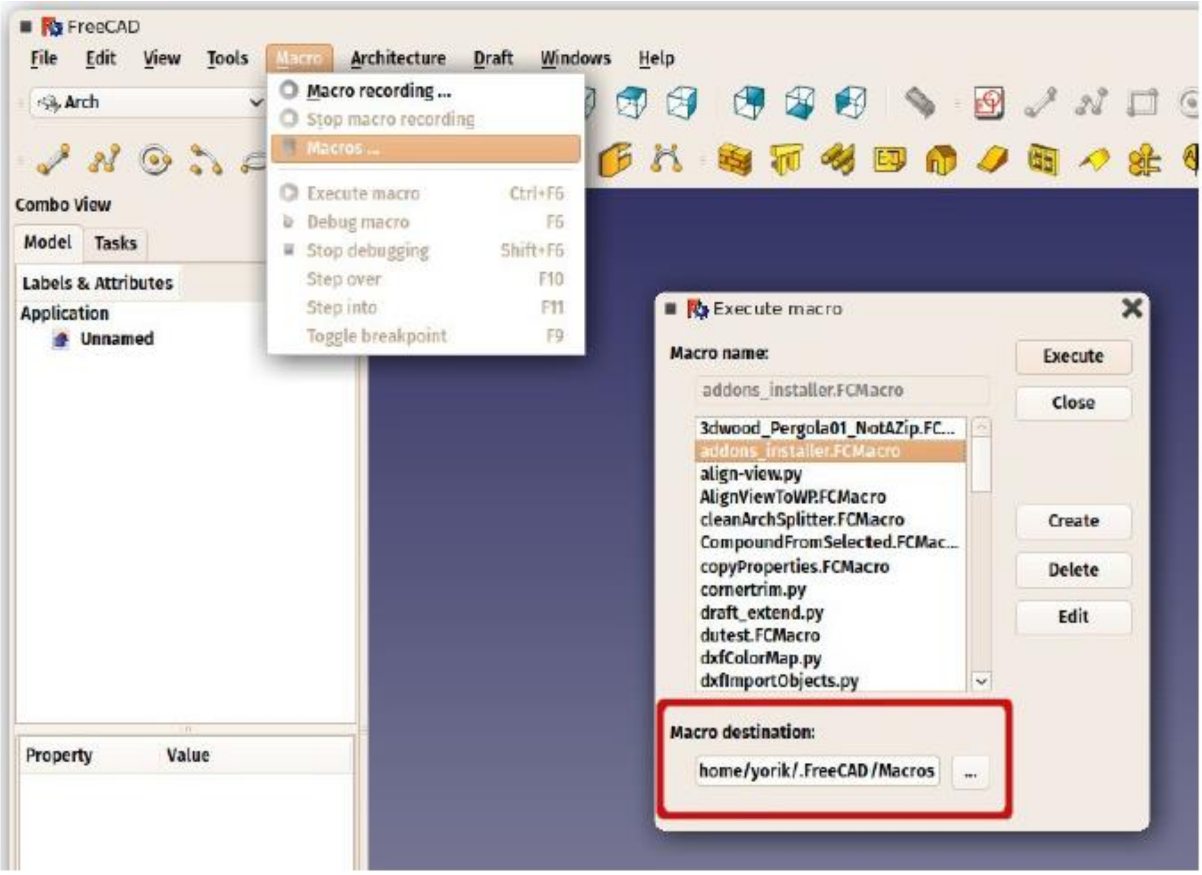



Fig. 4.1

c) Close and reopen the **Execute macro** dialog, and start the **addons_installer.FCMacro**. The installer will launch, from where you can install, update and uninstall any of the addons:

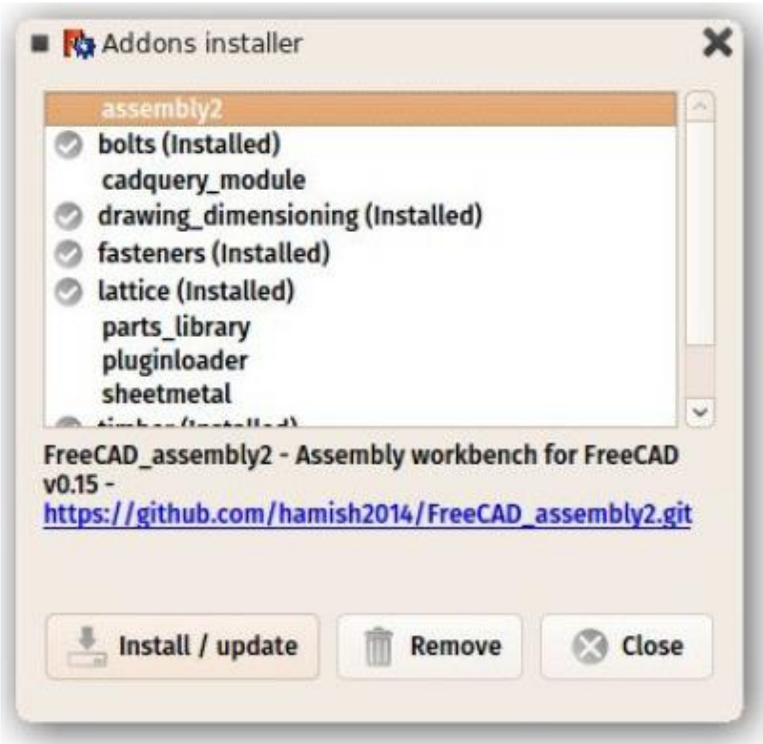



Fig.4.2

FreeCAD github page: https://github.com/FreeCAD

Follow the steps to get draw_dimensioning workbench from Fig. 4.3-4.13:

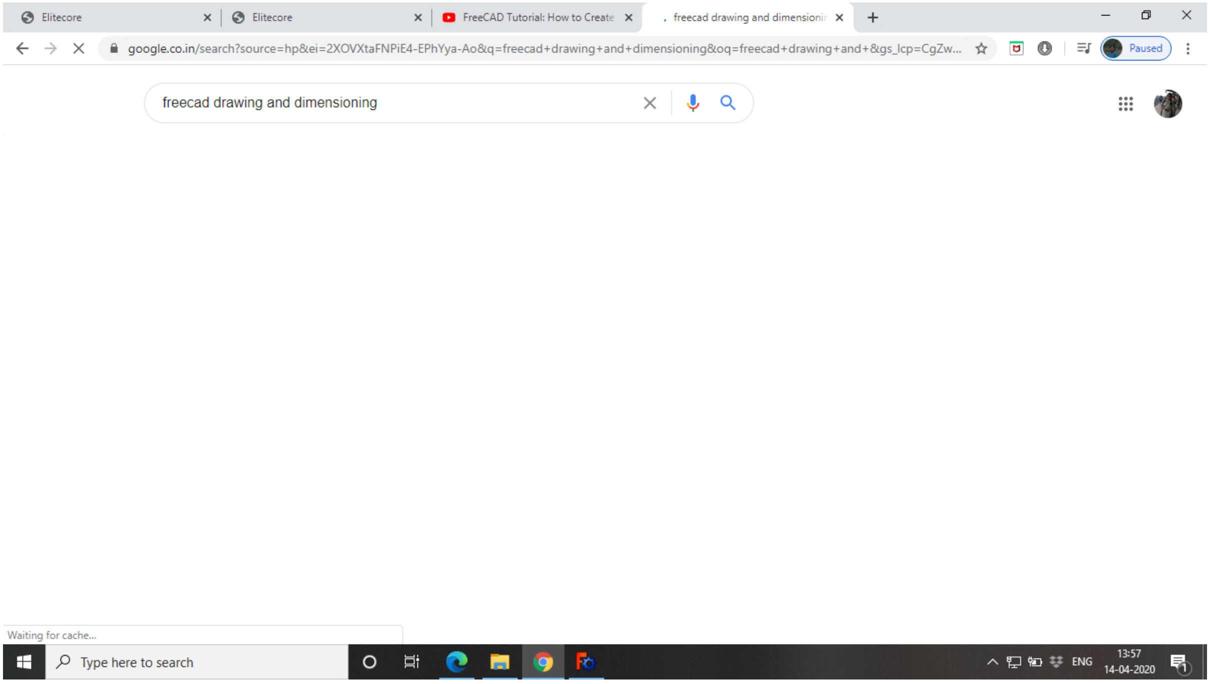



Fig.4.3

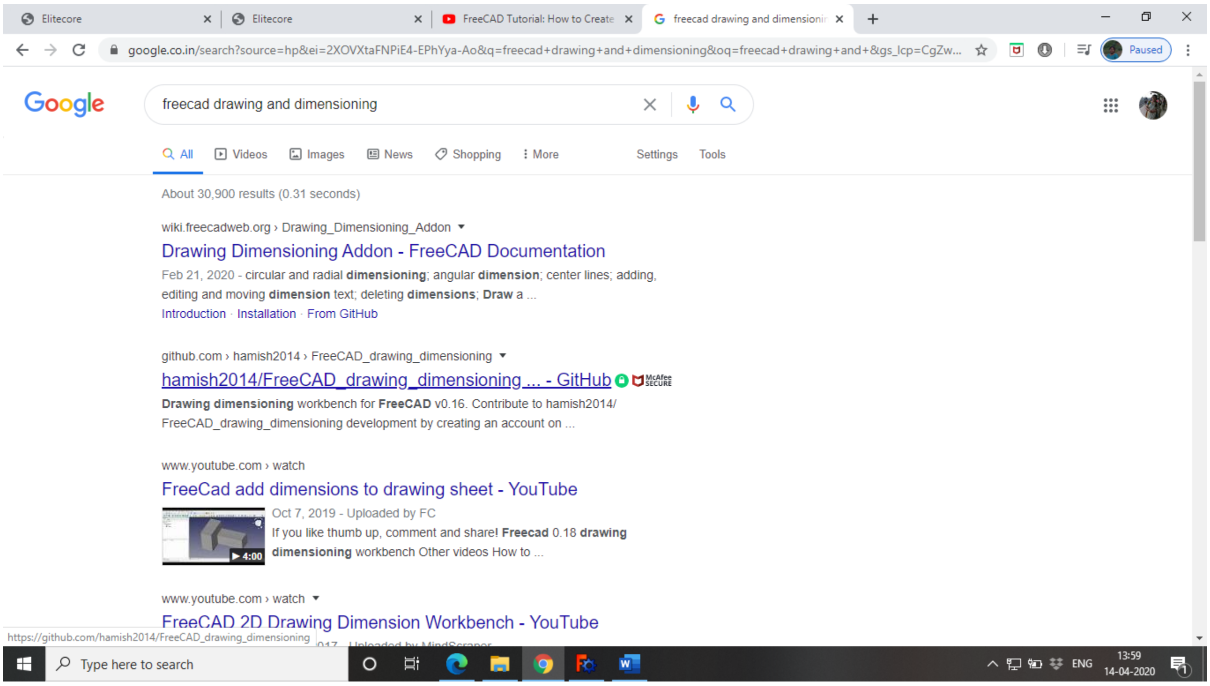



Fig. 4.4

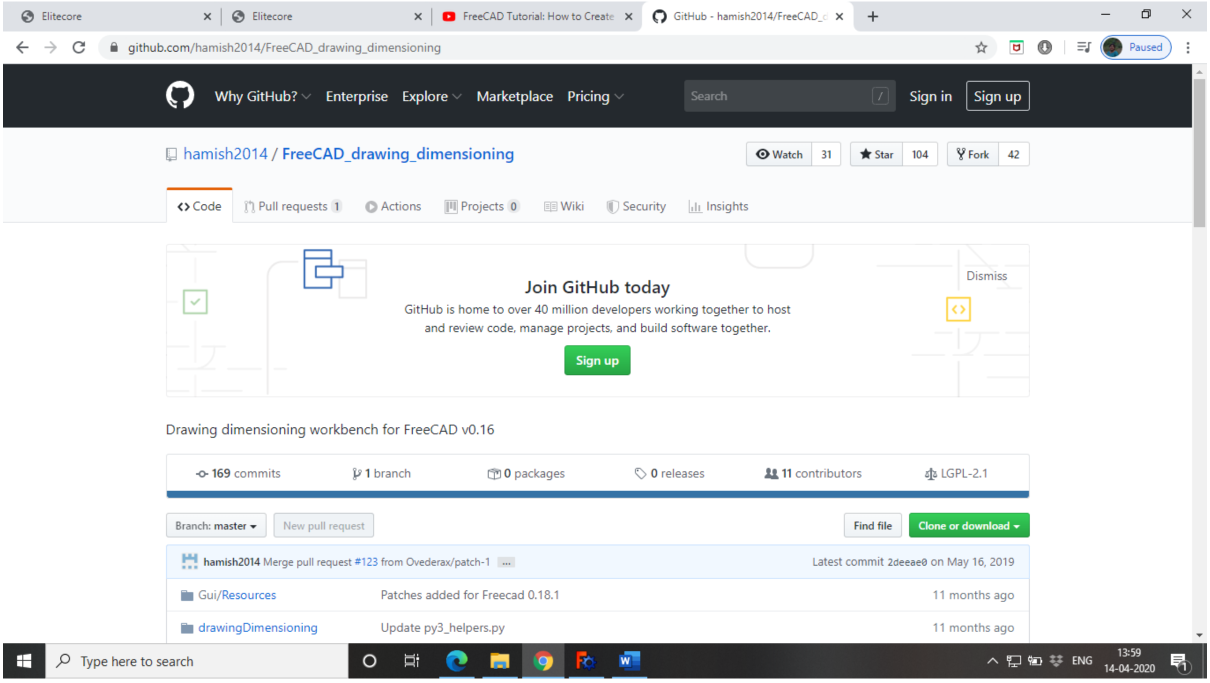

github.com/hamish2014/FreeCAD_drawing_dimensioning
hamish2014 / FreeCAD_drawing_dimensioning
Join GitHub today
GitHub is home to over 40 million developers working together to host and review code, manage projects, and build software together.
Sign up
Drawing dimensioning workbench for FreeCAD v0.16
169 commits
1 branch
0 packages
0 releases
11 contributors
LGPL-2.1
Gui/Resources
Patches added for Freecad 0.18.1
drawingDimensioning
Update py3_helpers.py

Fig. 4.5

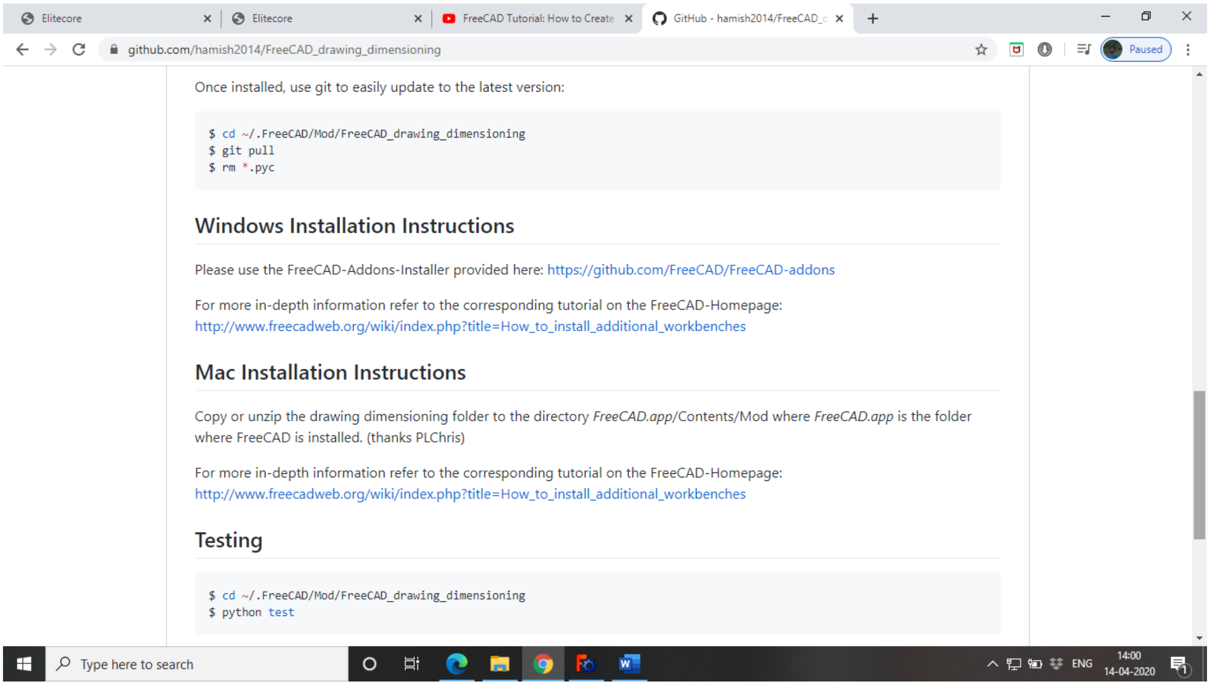

Once installed, use git to easily update to the latest version:
$ cd ~/.FreeCAD/Mod/FreeCAD_drawing_dimensioning
$ git pull
$ rm *.pyc
Windows Installation Instructions
Please use the FreeCAD-Addons-Installer provided here: https://github.com/FreeCAD/FreeCAD-addons
For more in-depth information refer to the corresponding tutorial on the FreeCAD-Homepage:
http://www.freecadweb.org/wiki/index.php?title=How_to_install_additional_workbenches
Mac Installation Instructions
Copy or unzip the drawing dimensioning folder to the directory FreeCAD.app/Contents/Mod where FreeCAD.app is the folder where FreeCAD is installed. (thanks PLChris)
For more in-depth information refer to the corresponding tutorial on the FreeCAD-Homepage:
http://www.freecadweb.org/wiki/index.php?title=How_to_install_additional_workbenches
Testing
$ cd ~/.FreeCAD/Mod/FreeCAD_drawing_dimensioning
$ python test

Fig. 4.6

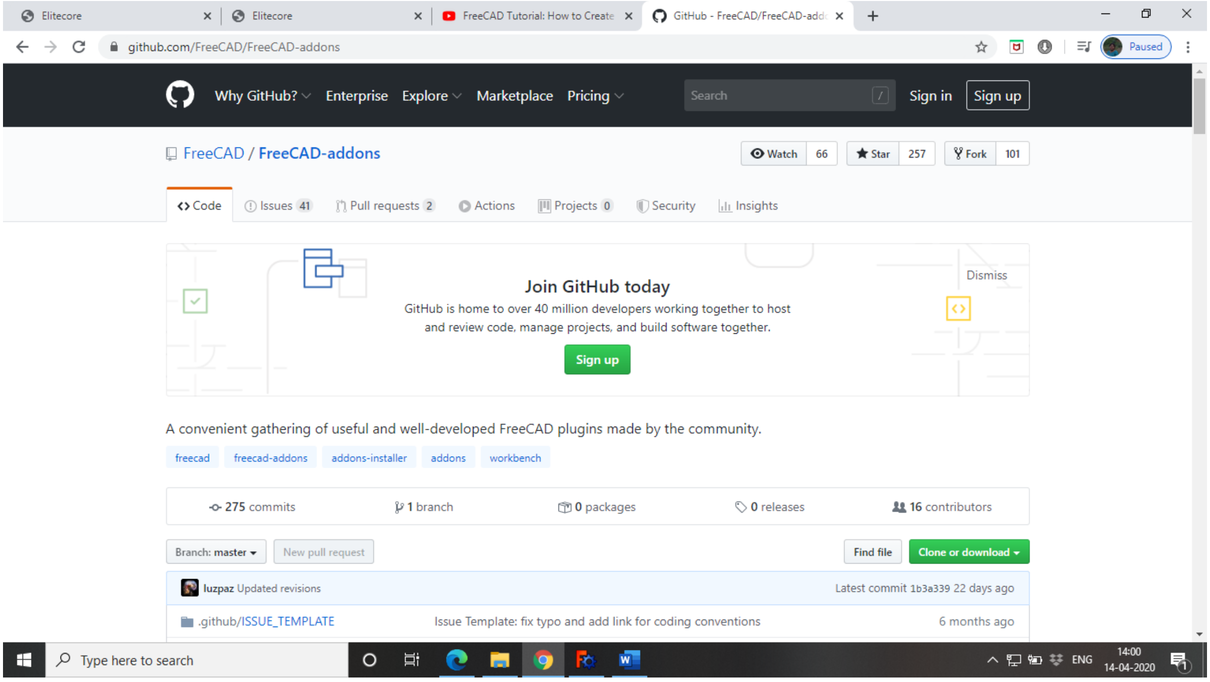


Fig. 4.6

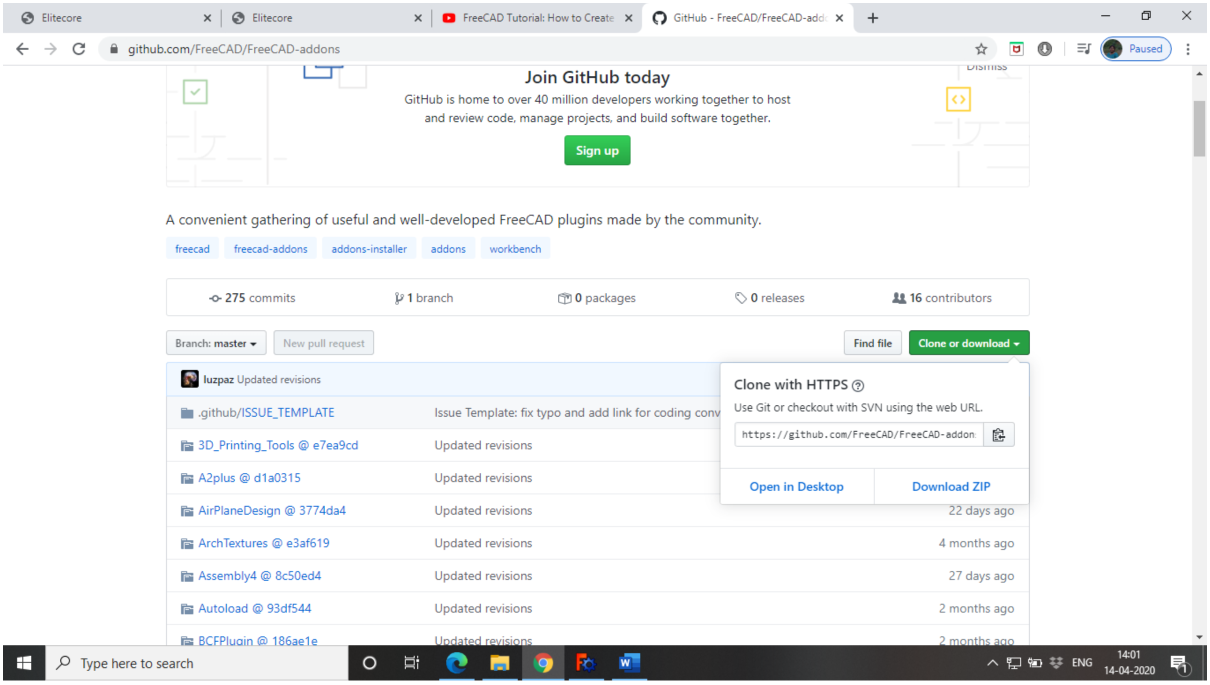


Fig. 4.7

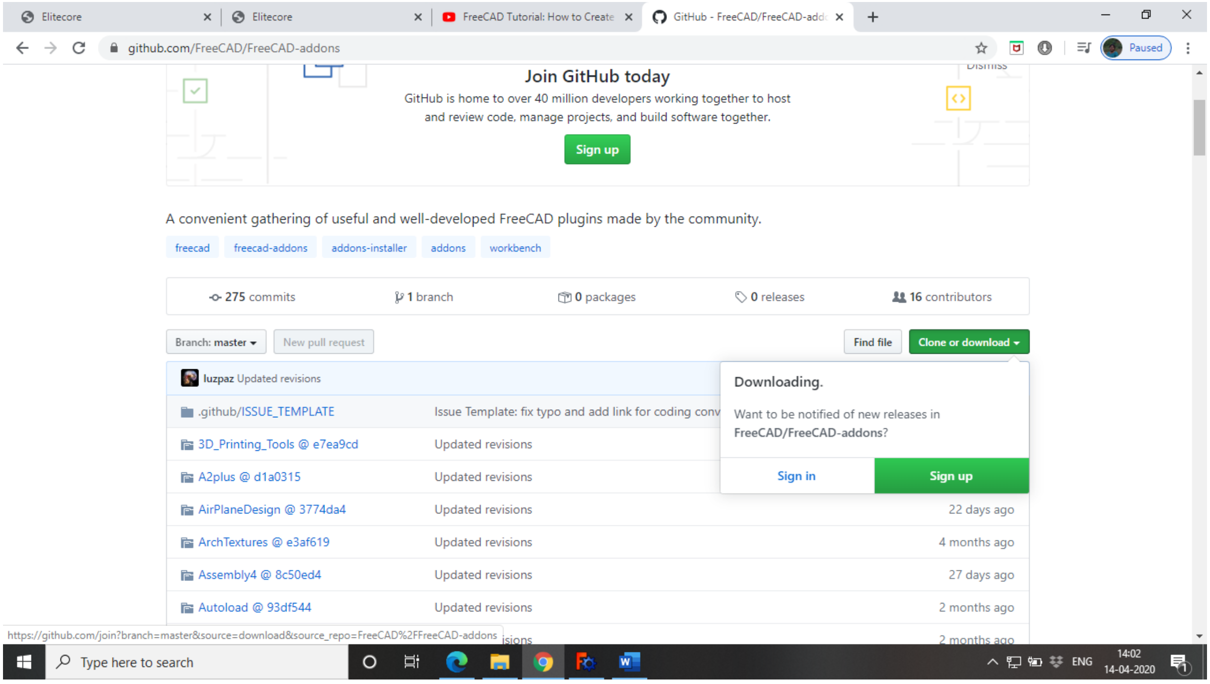


Fig. 4.7

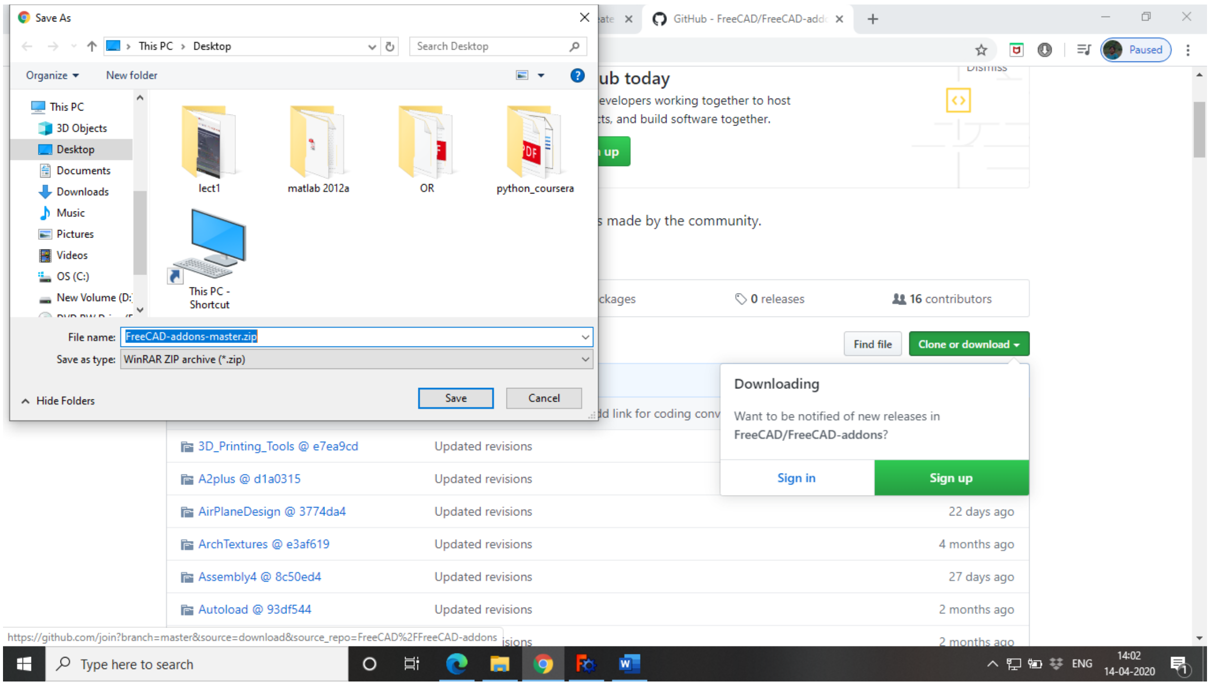


Fig. 4.8

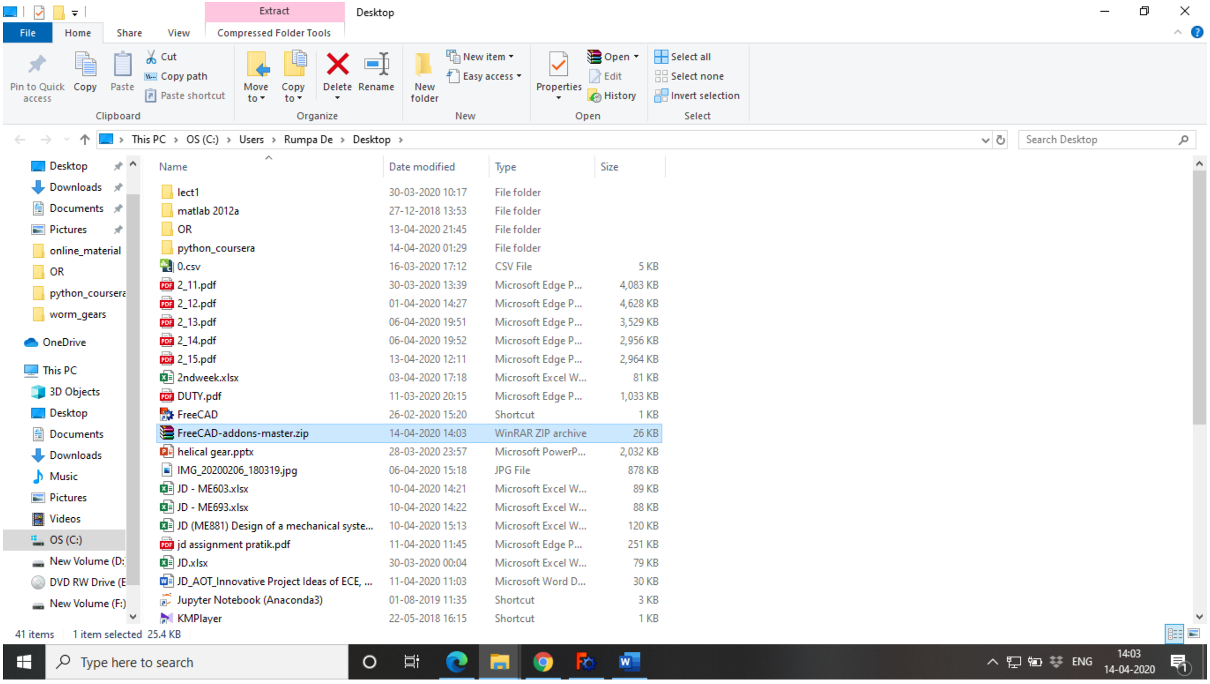



Fig. 4.9

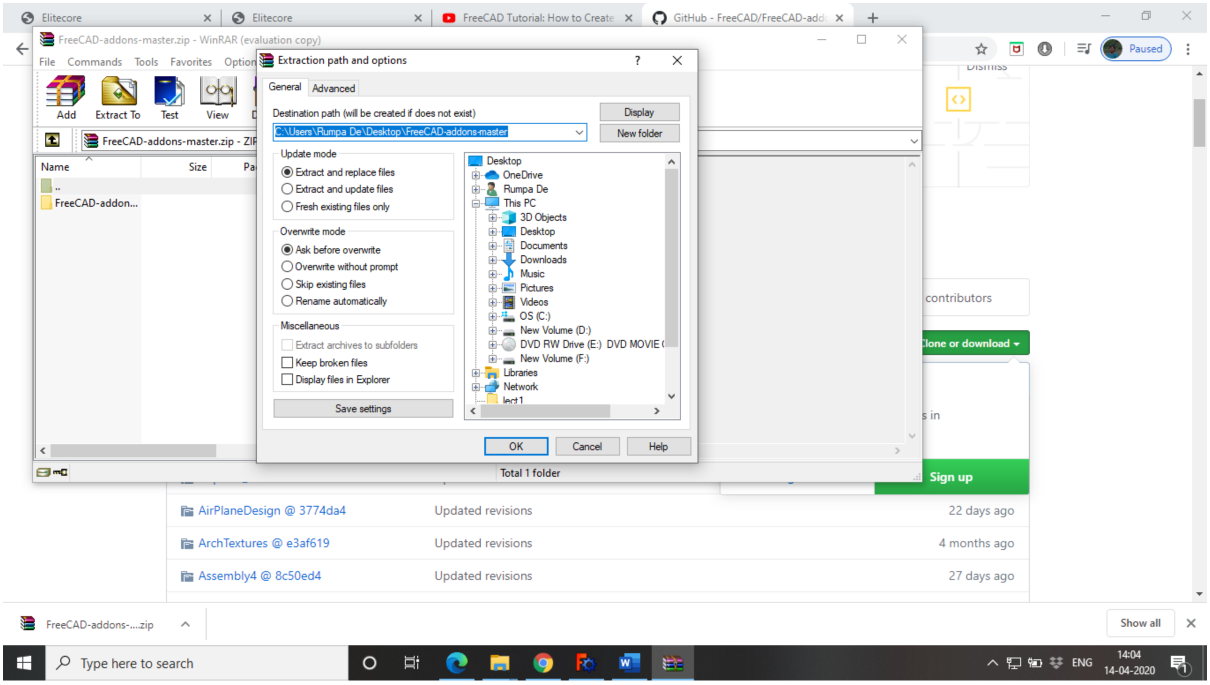



Fig.4.10

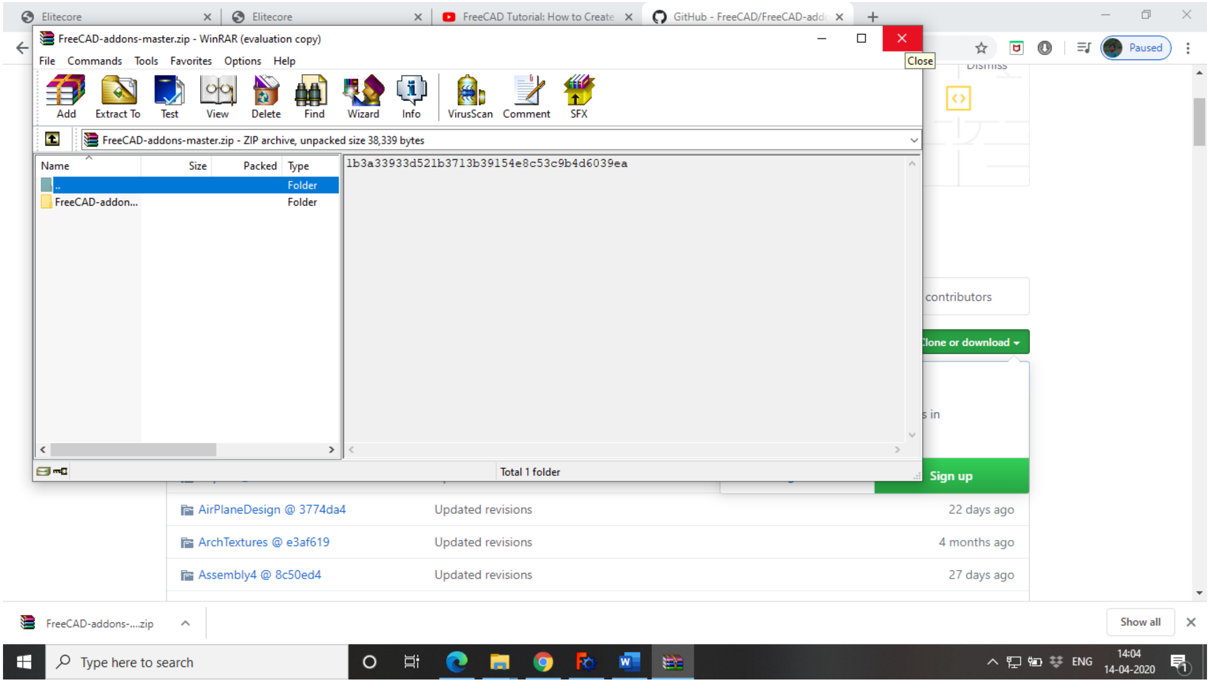


Fig.4.11

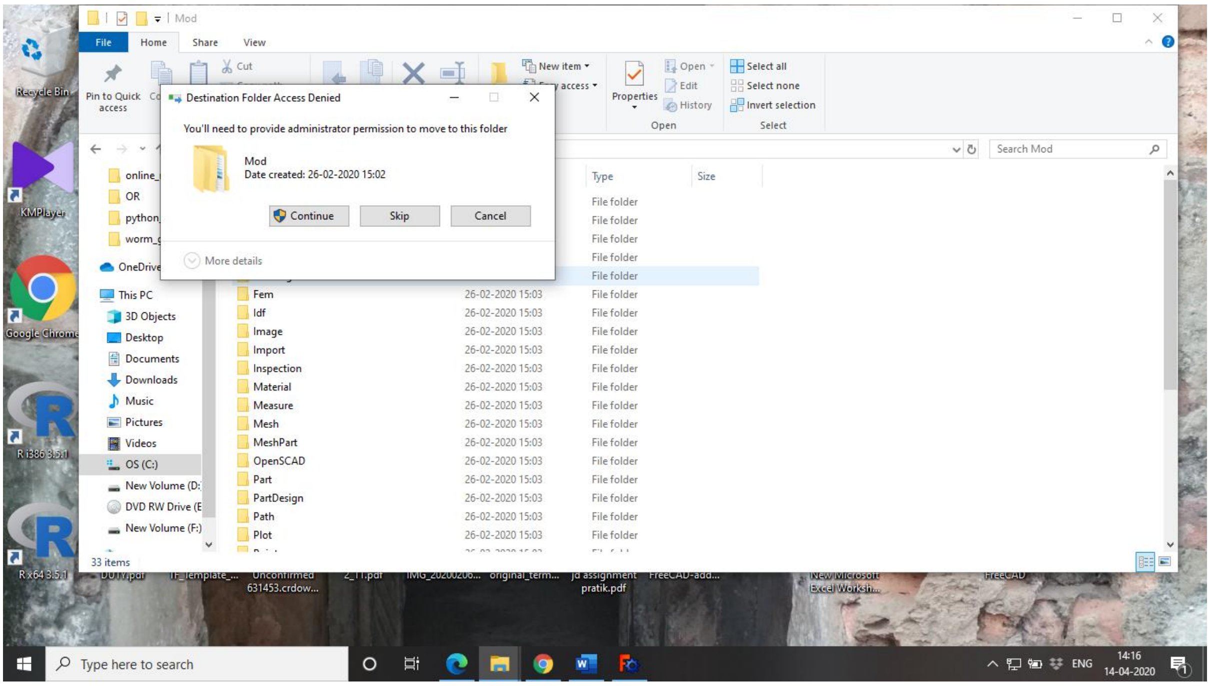


Fig.4.12

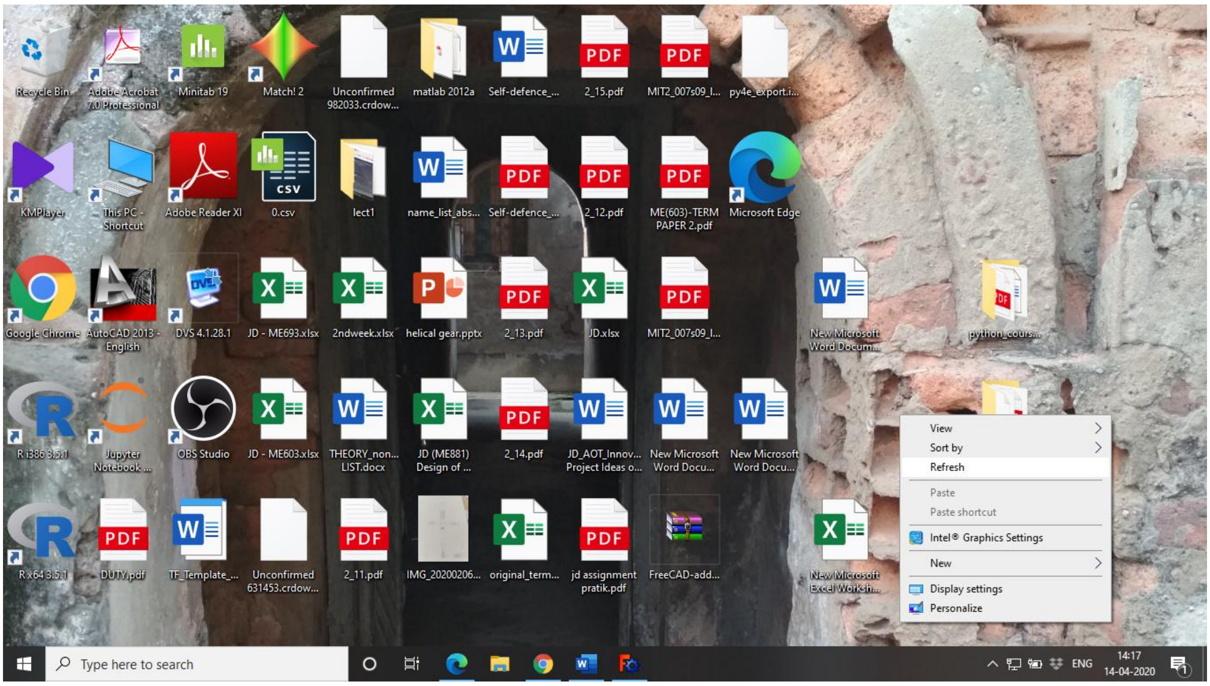


Fig. 4.13

After completing step from Fig.4-4.13, you may get the required work bench. If you steel don't get it in start , then follow these procedure from Fig. 4.14 to 4.18.

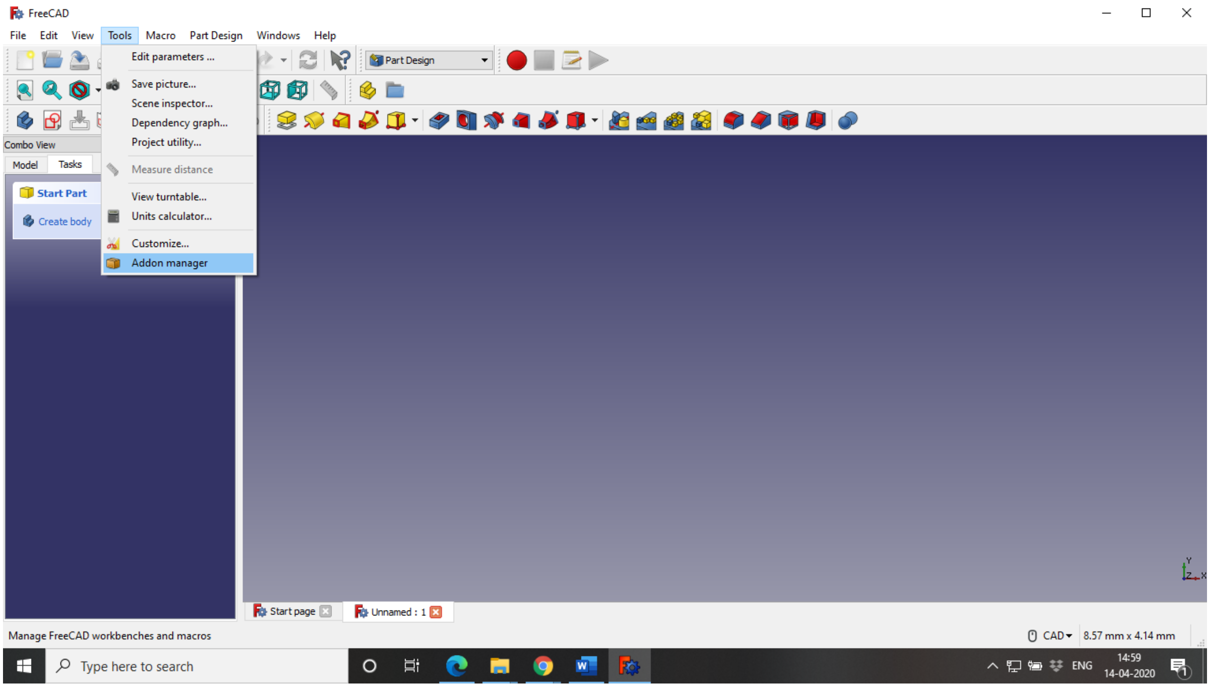


Fig.4.14

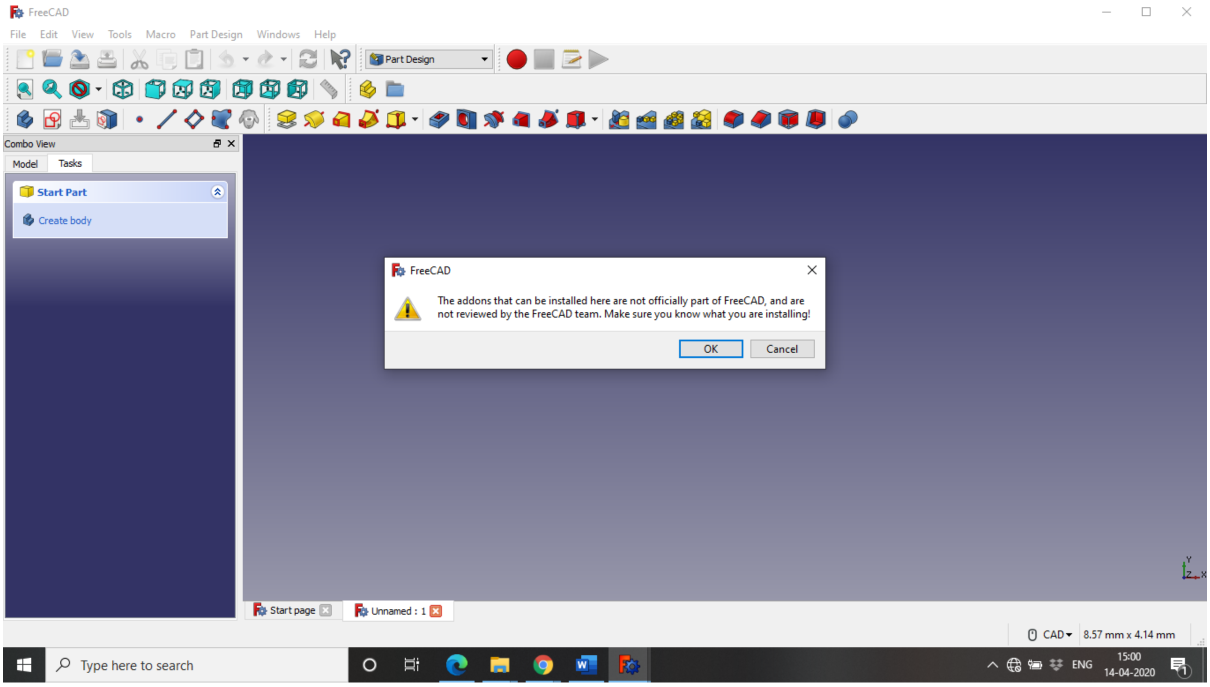



Fig.4.15

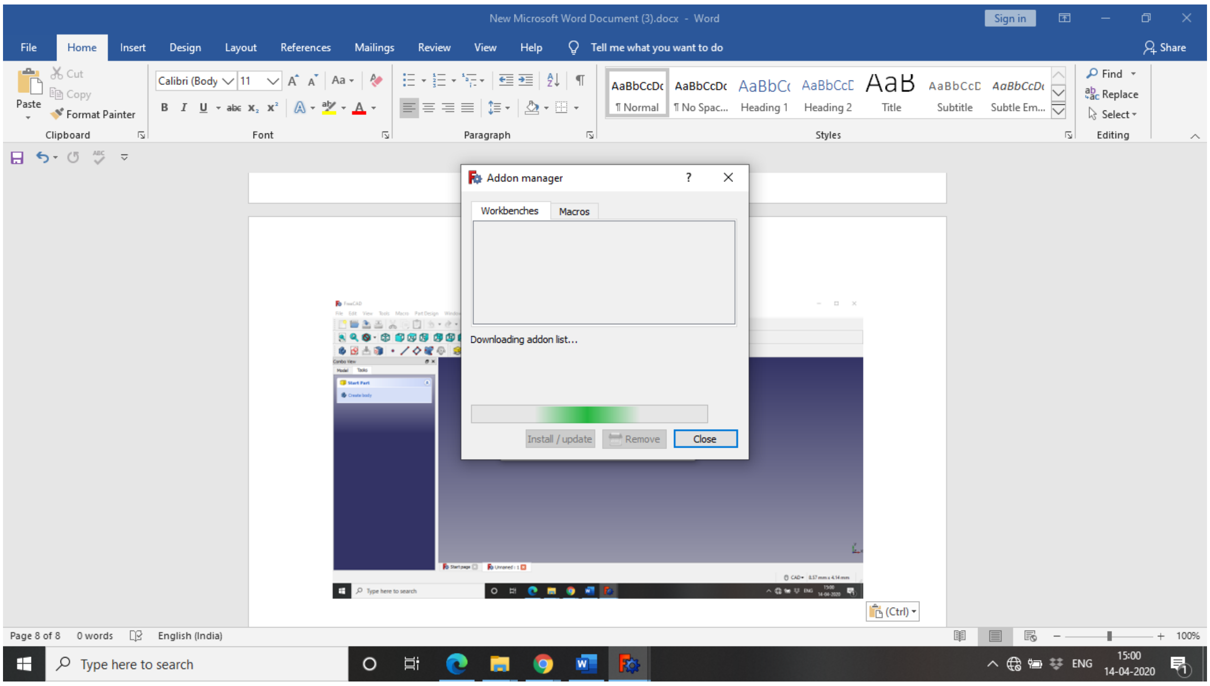



Fig.4.16

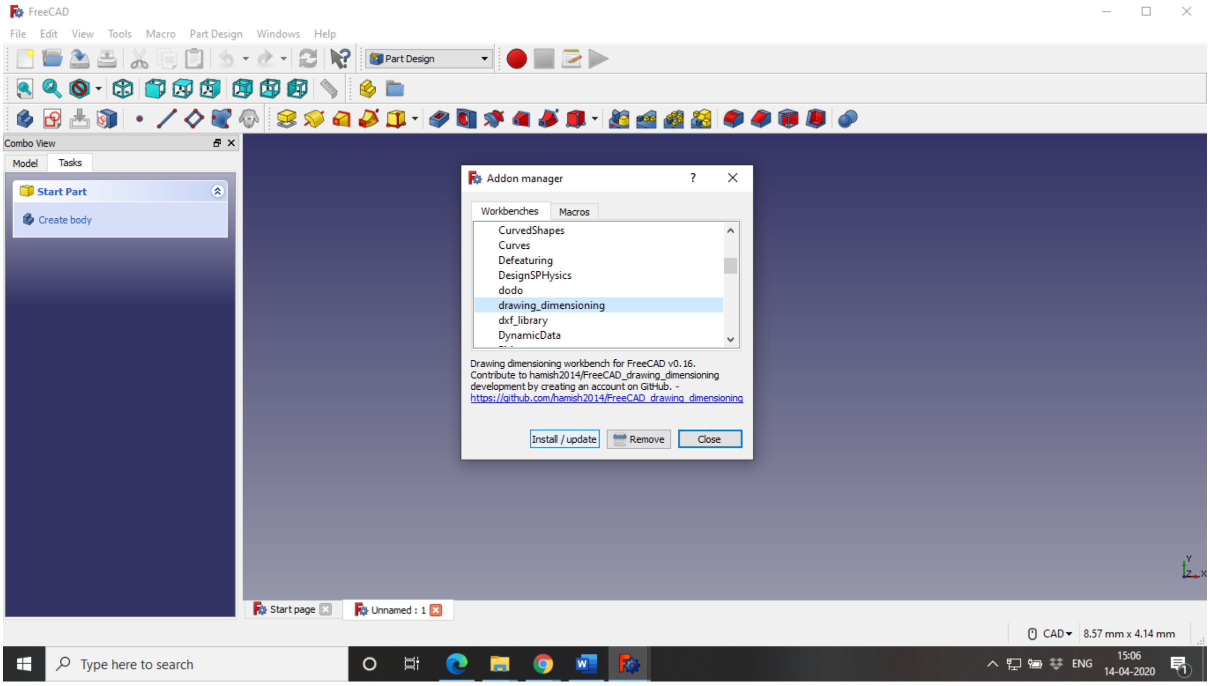



Fig.4.17

After these use refresh and click on FreeCAD icon to get drawing and dimensioning work bench.

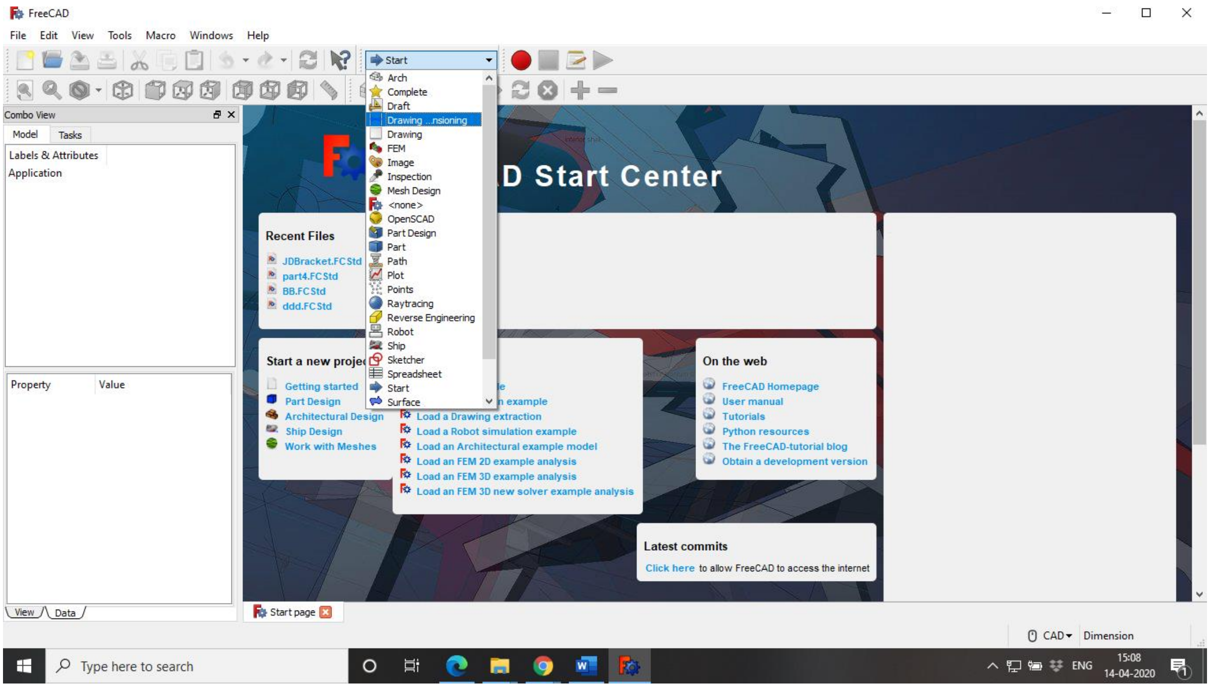



Fig. 4.18

## 5. The FreeCAD interface

FreeCAD uses the Qt framework to draw and manage its interface. This framework is used in a wide range of applications, so the FreeCAD interface (Fig.5.1) is very classical and presents no particular difficulty to understand. Most buttons are standard and will be found where you expect them (File -> Open, Edit -> Paste, etc). Here is the look of FreeCAD when you open it for the first time, just after installing, showing you the start center:

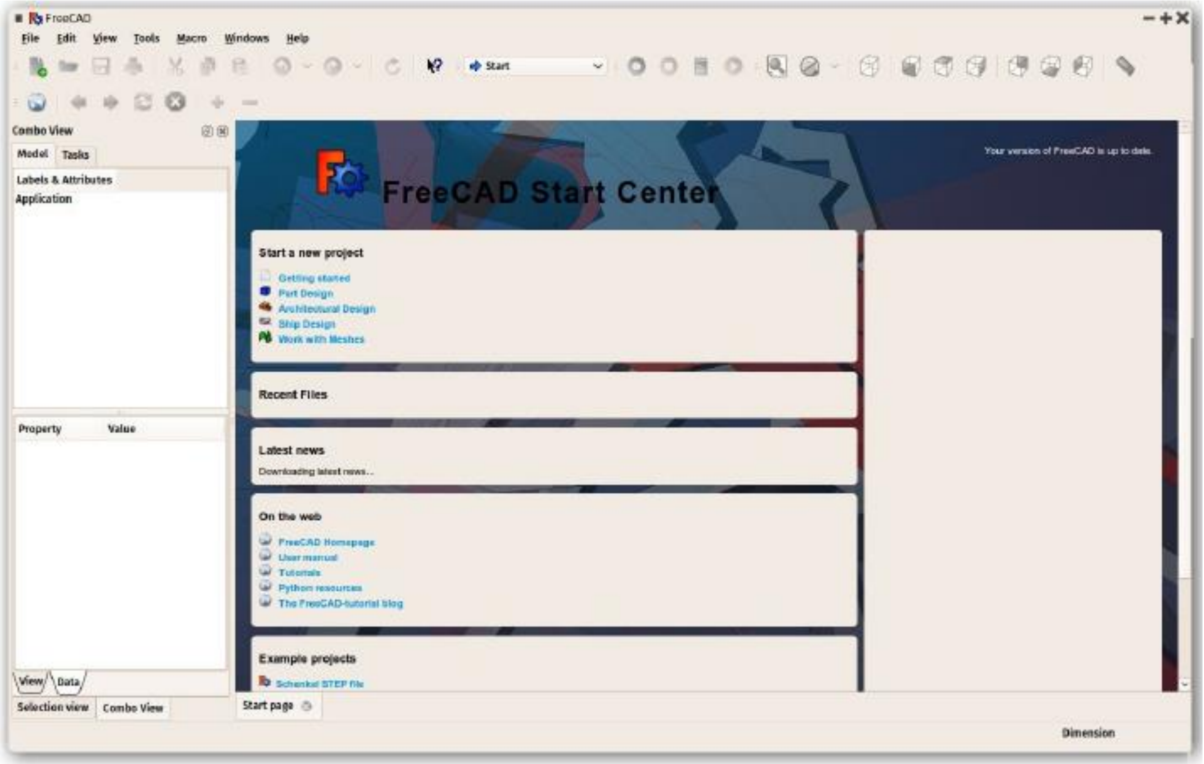



Fig. 5.1

The start center is a convenient "welcome screen", that shows useful information for newcomers, like the latest files you have been working on, what's new in the FreeCAD world, or quick info about the most common Workbenches. It will also notify if a new stable version of FreeCAD is available. Close the Start Page tab (click on the tab x near the bottom) and create a new document (Ctrl-N) (Fig. 5.2):

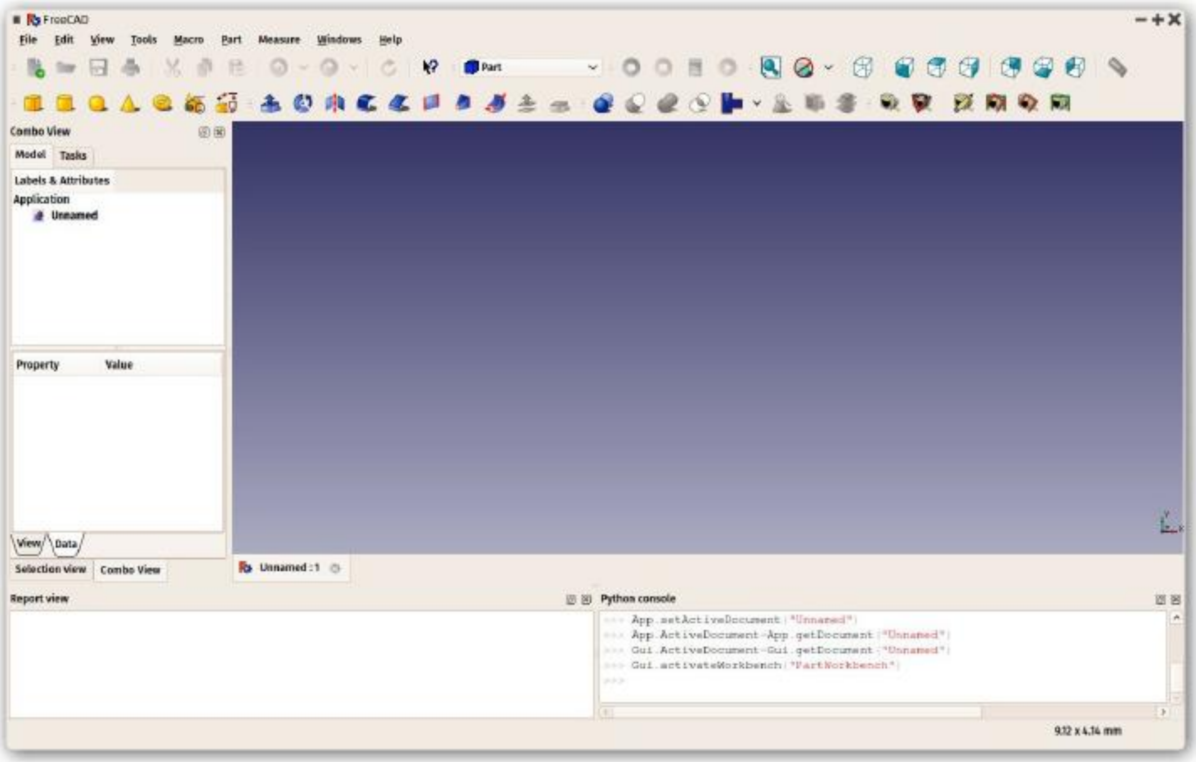


Fig. 5.2

## 5.1. Workbenches

Workbenches are group of tools (toolbar buttons, menus, and other interface controls) that are grouped together by specialty. The most important control of the FreeCAD interface is theWorkbench selector, which is used to switch from one Workbench to another shown in Fig.5.3-5.4 :

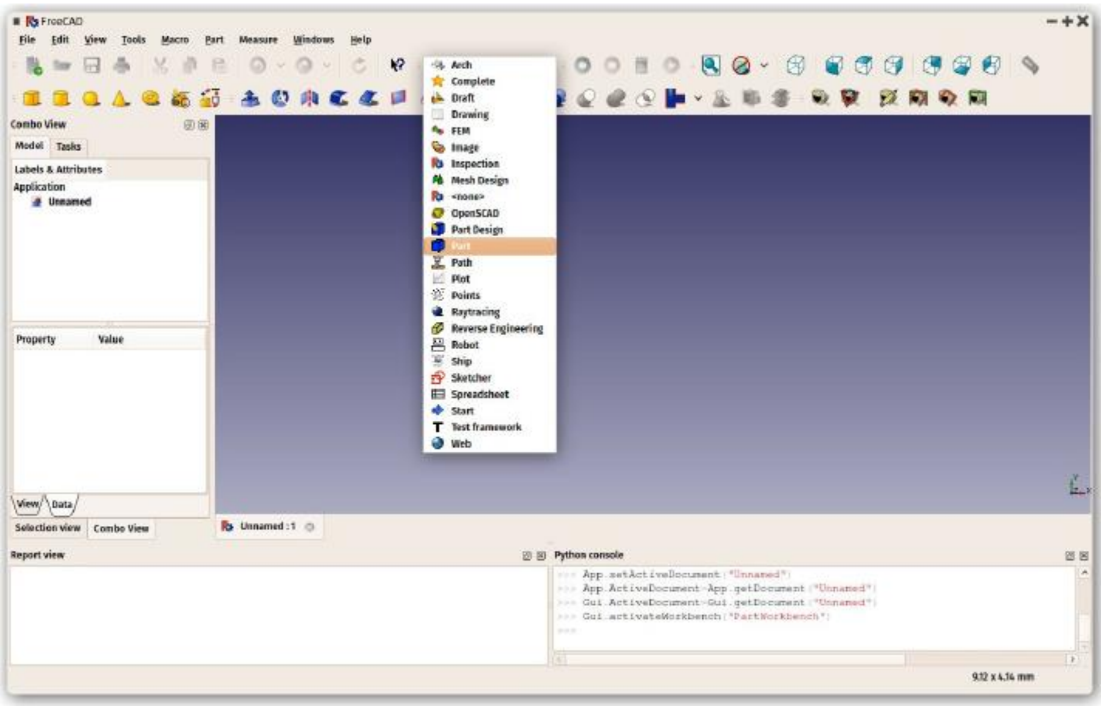


Fig.5.3

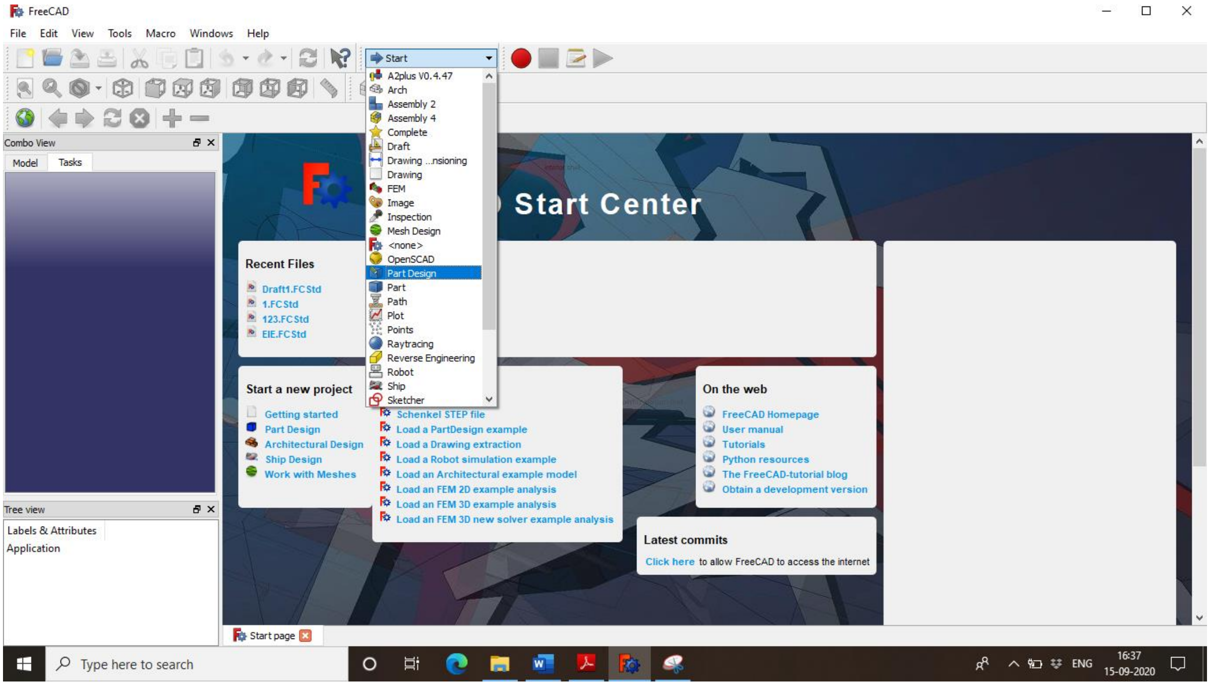



Fig.5.4

### 5.2. Tools of different workbenches:

**Part**

The Part Workbench provides basic tools (Table 1) for working with solid parts: primitives, such as cube and sphere, and simple geometric operations and boolean operations. Being the main anchor point with OpenCasCade, the Part workbench provides the foundation of FreeCAD's geometry system, and almost all other workbenches produce Part-based geometry.

Table 1: Tools in Part Workbench

| Tool | Description | Tool | Description |
|---|---|---|---|
| Box | Draws a box | Cone | Draws a cone |
| Cylinder | Draws a cylinder | Sphere | Draws a sphere |
| Torus | Draws a torus (ring) | Create Primitives | Creates various other parametric geometric primitives |
| Shape Builder | Create more complex shapes from primitives | Fuse | Fuses (unions) two objects |
| Common | Extracts the common (intersection) part of two objects | Cut | Cuts (subtracts) one object from another |
| Join Connect | Connects interiors of walled objects | Join Embed | Embeds a walled object into another walled object |
| Join Cutout | Creates a cutout in a wall of an object for another walled object | Extrude | Extrudes planar faces of an object |
| Fillet | Fillets (rounds) edges of an object | Revolve | Creates a solid by revolving another object (not solid) around an axis |
| Section | Creates a section by intersecting an object with a section plane | Section Cross | Creates multiple cross sections along an object |
| Chamfer | Chamfers edges of an object | Mirror | Mirrors the selected object on a given mirror plane |
| Ruled Surface | Create a ruled surface between selected curves | Sweep | Sweeps one or more profiles along a path |
| Loft | Lofts from one profile to another | Offset | Creates a scaled copy of the original object |
| Thickness | Assign a thickness to the faces of a shape | | |

## Draft

The Draft Workbench provides tools (Table 2) to do basic 2D CAD drafting tasks using lines, circles, rectangle etc. and a series of generic handy tools such as move, rotate or scale. It also provides several drawing aids, such as grid and snapping.

Table 2: Tools in Draft Workbench

| Tool | Description | Tool | Description |
|---|---|---|---|
| Line | Draws a line segment between 2 points | Wire | Draws a line made of multiple line segments (polyline) |
| Circle | Draws a circle from center and radius | Arc | Draws an arc segment from center, radius, start angle and end angle |
| Ellipse | Draws an ellipse from two corner points | Polygon | Draws a regular polygon from a center and a radius |
| Rectangle | Draws a rectangle from 2 opposite points | Text | Draws a multi-line text annotation |
| 1.00 Dimension | Draws a dimension annotation | BSpline | Draws a B-Spline from a series of points |
| Point | Inserts a single point | Shape String | The ShapeString tool inserts a compound shape representing a text string at a given point in the current document |
| Facebinder | Creates a new object from selected faces on existing objects | Bezier Curve | Draws a Bezier curve from a series of points |
| Move | Moves or copies objects from one location to another | Rotate | Rotates objects by a certain angle around a point |

| | | | |
|---|---|---|---|
| Offset | Offsets an object to a certain distance | Trimex | Trims, extends or extrudes an object |
| Upgrade | Turns or joins objects into a higher-level object | Downgrade | Turns or separtes objects into lower-level objects |
| Scale | Scales objects in relation to a point | Shape2D View | Creates a 2D object which is a flattened view of another object |
| Draft2Sketch | Converts a Draft object to a Sketch and vice-versa | Array | Creates a polar or rectangular array from an object |
| PathArray | Creates an array from an object by placing copies along a path | Clone | Creates linked copies of objects |
| Mirror | Mirrors objects across a line | | |

**Sketcher**

The Sketcher Workbench contains tools (Table 3) to build and edit complex 2D objects, called sketches. The geometry inside these sketches can be precisely positioned by the use of constraints. They are meant primarily to be the building blocks of PartDesign geometry, but are useful everywhere in FreeCAD.

Table 3: Tools in Sketcher Workbench

| Tool | Description | Tool | Description |
|---|---|---|---|
| Point | Draws a point | Line by 2 points | Draws a line segment from 2 points |
| Arc | Draws an arc segment from center, radius, start angle and end angle | Arc by 3 points | Draws an arc segment from two endpoints and another point on the circumference |
| Circle | Draws a circle from center and radius | Circle by 3 points | Draws a circle from three points on the circumference |
| | Draws an ellipse by center point, major radius point and | Ellipse | Draws an ellipse by major diameter (2 |

| | | | |
|---|---|---|---|
| center | minor radius point | by 3 points | points) and minor radius point |
| Arc of ellipse | Draws an arc of ellipse by center point, major radius point, starting point and ending point | Polyline | Draws a line made of multiple line segments. Several drawing modes available |
| Rectangle | Draws a rectangle from 2 opposite points | Triangle | Draws a regular triangle inscribed in a construction geometry circle |
| Square | Draws a regular square inscribed in a construction geometry circle | Pentagon | Draws a regular pentagon inscribed in a construction geometry circle |
| Hexagon | Draws a regular hexagon inscribed in a construction geometry circle | Heptagon | Draws a regular heptagon inscribed in a construction geometry circle |
| Octagon | Draws a regular octagon inscribed in a construction geometry circle | Slot | Draws an oval by selecting the center of one semicircle and an endpoint of the other semicircle |
| Fillet | Makes a fillet between two lines joined at one point | Trim | Trims a line, circle or arc with respect to a clicked point |

| | | | |
|---|---|---|---|
| External Geometry | Creates an edge linked to external geometry | Construction Mode | Toggles an element to/from construction mode. A construction object will not be used in a 3D geometry operation and is only visible while editing the Sketch that contains it |
| Coincident constraint | Affixes a point onto (coincident with) one or more other points. | Point On Object constraint | Affixes a point onto another object such as a line, arc, or axis. |
| Vertical constraint | Constrains the selected lines or polyline elements to a true vertical orientation. More than one object can be selected before applying this constraint. | Horizontal constraint | Constrains the selected lines or polyline elements to a true horizontal orientation. More than one object can be selected before applying this constraint. |

| | | | |
|---|---|---|---|
| | | | constraint. |
| Parallel constraint | Constrains two or more lines parallel to one another. | Perpendicular constraint | Constrains two lines perpendicular to one another, or constrains a line perpendicular to an arc endpoint. |
| Tangent constraint | Creates a tangent constraint between two selected entities, or a co-linear constraint between two line segments. | Equal Length constraint | Constrains two selected entities equal to one another. If used on circles or arcs their radii will be set equal. |
| Symmetric constraint | Constrains two points symmetrically about a line, or constrains the first two selected points symmetrically about a third selected point. | Lock constraint | Constrains the selected item by setting vertical and horizontal distances relative to the origin, thereby locking the location of that item |
| Horizontal Distance constraint | Fixes the horizontal distance between two points or line endpoints. If only one item is selected, the distance is set to the origin. | Vertical Distance constraint | Fixes the vertical distance between 2 points or line endpoints. If only one item is selected, the distance is set to the origin. |
| Length constraint | Defines the distance of a selected line by constraining its length, or defines the distance between two points by constraining the distance between them. | Radius constraint | Defines the radius of a selected arc or circle by constraining the radius. |
| Internal Angle constraint | Defines the internal angle between two selected lines. | Snell's Law constraint | Constrains two lines to obey a refraction law to simulate the light going through an interface |
| Internal Alignment constraint | Aligns selected elements to selected shape (e.g. a line to become major axis of an ellipse) | Map sketch to face | Maps a sketch to the previously selected face of a solid |
| Merge | Merge two or more sketches | Mirror | Mirrors selected elements of a sketch |

**Part Design**

The Part Design Workbench contains advanced tools to build solid parts. It also contains all the tools from the sketcher. Since it can only produces solid shapes, it is the main workbench to use when designing parts to be manufactured or 3D-printed, as you will always obtain a printable object. The tools of Part Design workbench have been shown in Table 4.

Table 4: Tools in Part Design Workbench

| Tool | Description | Tool | Description |
|---|---|---|---|
| Pad | Extrudes a solid object from a selected sketch | Pocket | Creates a pocket from a selected sketch. The sketch must be mapped to an existing solid object's face |
| Revolution | Creates a solid by revolving a sketch around an axis | Groove | Creates a groove by revolving a sketch around an axis |
| Fillet | Fillets (rounds) edges of an object | Chamfer | Chamfers edges of an object |
| Draft | Applies angular draft to faces of an object | Mirrored | Mirrors features on a plane or face |
| Linear Pattern | Creates a linear pattern of features | Polar Pattern | Creates a polar pattern of features |
| Scaled | Scales features to a different size | MultiTransform | Allows creating a pattern with any combination of the other transformations |
| Shaft wizard | Generates a shaft from a table of values and allows to analyze forces and moments | Involute Gear wizard | Allows you to create several types of gears |

**Arch**

The Arch Workbench contains tools to work with BIM projects (civil engineering and architecture). It also contains all the tools from the Draft workbench. The main use of the Arch Workbench is to create BIM objects or give BIM attributes to objects built with other workbenches, in order to export them to IFC. The tools of Arch Workbench have been shownin Table 5.

Table 5: Tools in Arch Workbench

| Tool | Description | Tool | Description |
|---|---|---|---|
| Wall | Creates a wall from scratch or using a selected object as a base | Structure | Creates a structural element from scratch or using a selected object as a base |
| Reinforcement Bar | Creates a reinforcement bar in a selected structural element | Floor | Creates a floor including selected objects |
| Building | Creates a building including selected objects | Site | Creates a site including selected objects |
| Window | Creates a window using a selected object as a base | Section Plane | Adds a section plane object to the document |
| Axes | Adds an axes system to the document | Roof | Creates a sloped roof from a selected face |
| Space | Creates a space object in the document | Stairs | Creates a stairs object in the document |
| Panel | Creates a panel object from a selected 2D object | Frame | Creates a frame object from a selected layout |
| Equipment | Creates an equipment or furniture object | Set Material | Attributes a material to selected objects |
| Schedule | Creates different types of schedules | Cut Plane | Cut an object according to a plan. |
| Add Component | Adds objects to a component | Remove Component | Subtracts or removes objects from a component |
| Survey Mode | Enters or leaves surveying mode | | |

**Drawing**

The Drawing Workbench handles the creation and manipulation of 2D drawing sheets, used for displaying views of your 3D work in 2D. These sheets can then be exported to 2D applications in SVG or DXF formats, to a PDF file. The tools have been shown in Table 6.

Table 6: Tools in Drawing Workbench

| Tool | Description | Tool | Description |
|---|---|---|---|
| A3 New sheet | Creates a new drawing sheet | Insert view | Inserts a view of the selected object in the active drawing sheet |
| Annotation | Adds an annotation to the current drawing sheet | Clip | Adds a clip group to the current drawing sheet |
| Browser preview | Opens a preview of the current sheet in the browser | Ortho Views | Automatically creates orthographic views of an object on the current drawing sheet |
| Symbol | Adds the contents of a SVG file as a symbol on the current drawing sheet | Draft View | Inserts a special Draft view of the selected object in the current drawing sheet |
| Export | Saves the current sheet as a SVG file | | |

**Other built-in workbenches**

Although the above summarizes the most important tools of FreeCAD, many more workbenches are available. Such as, the Mesh Workbench allows to work with polygon meshes. Although meshes are not the preferred type of geometry to work with in FreeCAD, because of their lack of precision and support for curves, meshes still have a lot of uses, and are fully supported in FreeCAD. The Mesh Workbench also offers a number of Part-to-Mesh and Mesh-to- Part tools.

The Raytracing Workbench offers tools to interface with external renderers such as povray or luxrender. Right from inside FreeCAD, this workbench allows you to produce high-quality renderings from your models.

The Spreadsheet Workbench permits the creation and manipulation of spreadsheet data, that can be extracted from FreeCAD models. Spreadsheet cells can also be referenced in many areas of FreeCAD, allowing to use them as master data structures.

The FEM Workbench deals with Finite Elements Analysis, and permits the performing of pre- and post-processing FEM calculations and to display the results graphically.

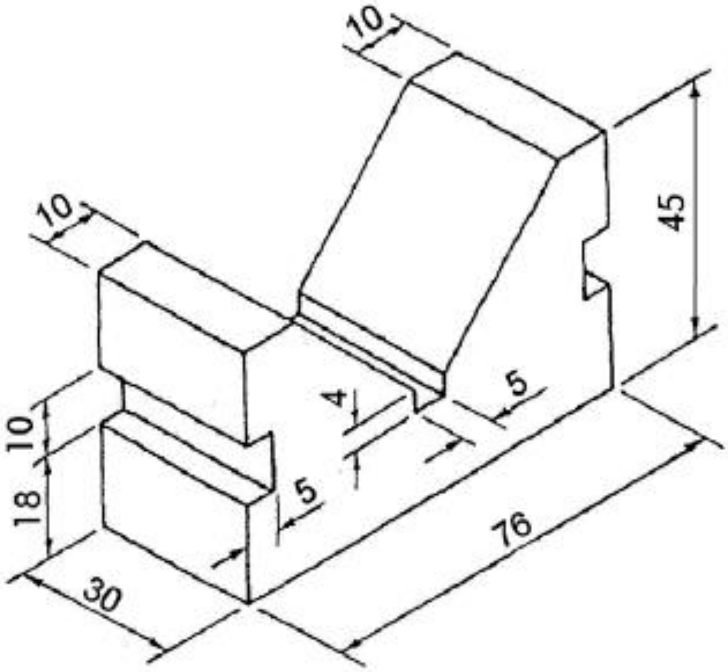
**External workbenches**

A number of other very useful workbenches produced by FreeCAD community members also exist. Although they are not included in a standard FreeCAD installation, they are easy to install as plug-ins. They are all referenced in the FreeCAD-addons repository. Among the most developed are:

- The Drawing Dimensioning Workbench: This offers many new tools to work directly on Drawing Sheets and allow you to add dimensions, annotations and other technical symbols with great control over their aspect.
- The Fasteners Workbench offers a wide range of ready-to-insert fasteners objects like screws, bolts, rods, washers and nuts. Many options and settings are available.
- The Assembly2 Workbench offers a series of tools to mount and work with assemblies.

## Assignment-1

1. Do the following Part modelling and drafting using FreeCAD.

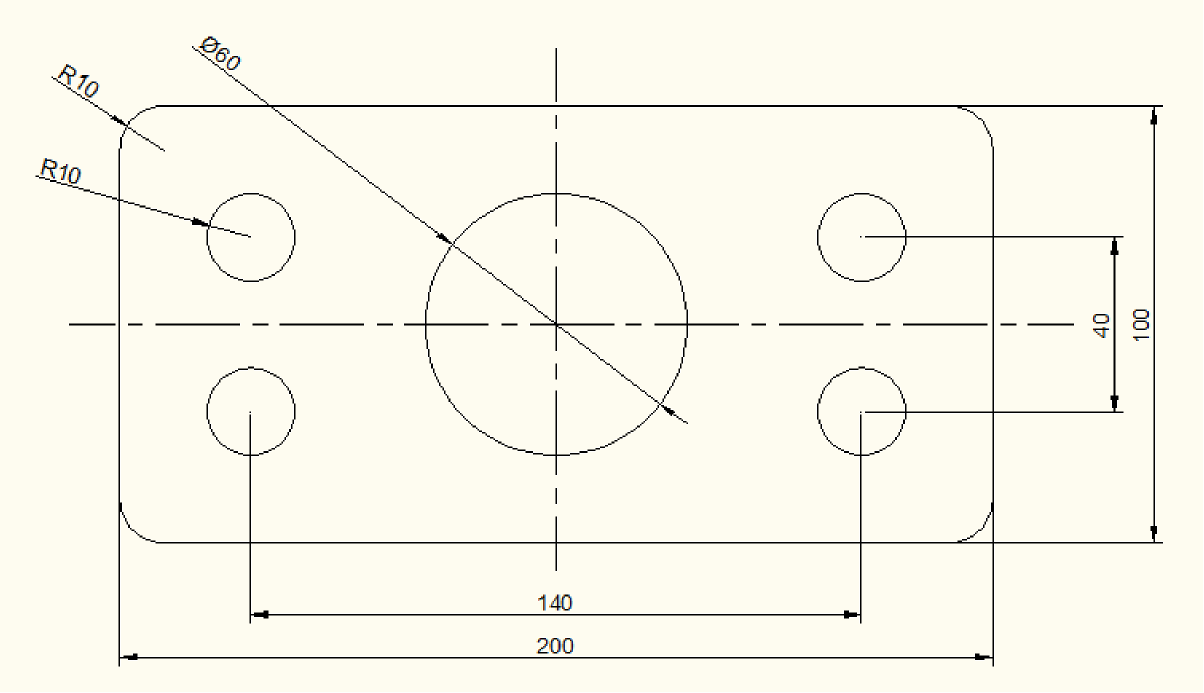



All dimensions are in mm.
Fig. A01

**Drawing Name: V Block** **No: FCAD/1/A01**

## Assignment-2

2. Do the following Part modelling and drafting using FreeCAD. Take thickness as 10 mm.



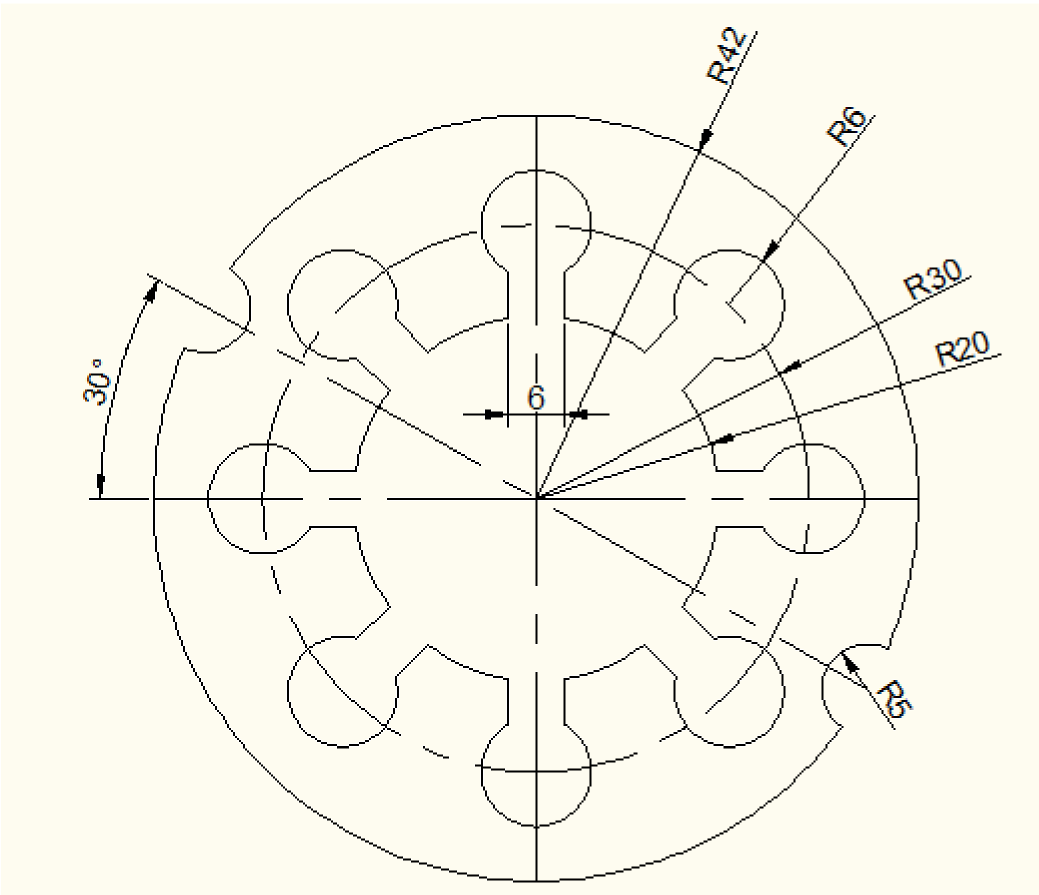

All dimensions are in mm.

Fig. A02

**Drawing Name: Drill template** **No: FCAD/1/A02**

# Assignment-3

3. Do the following Part modelling and drafting using FreeCAD. Take thickness as 10 mm.

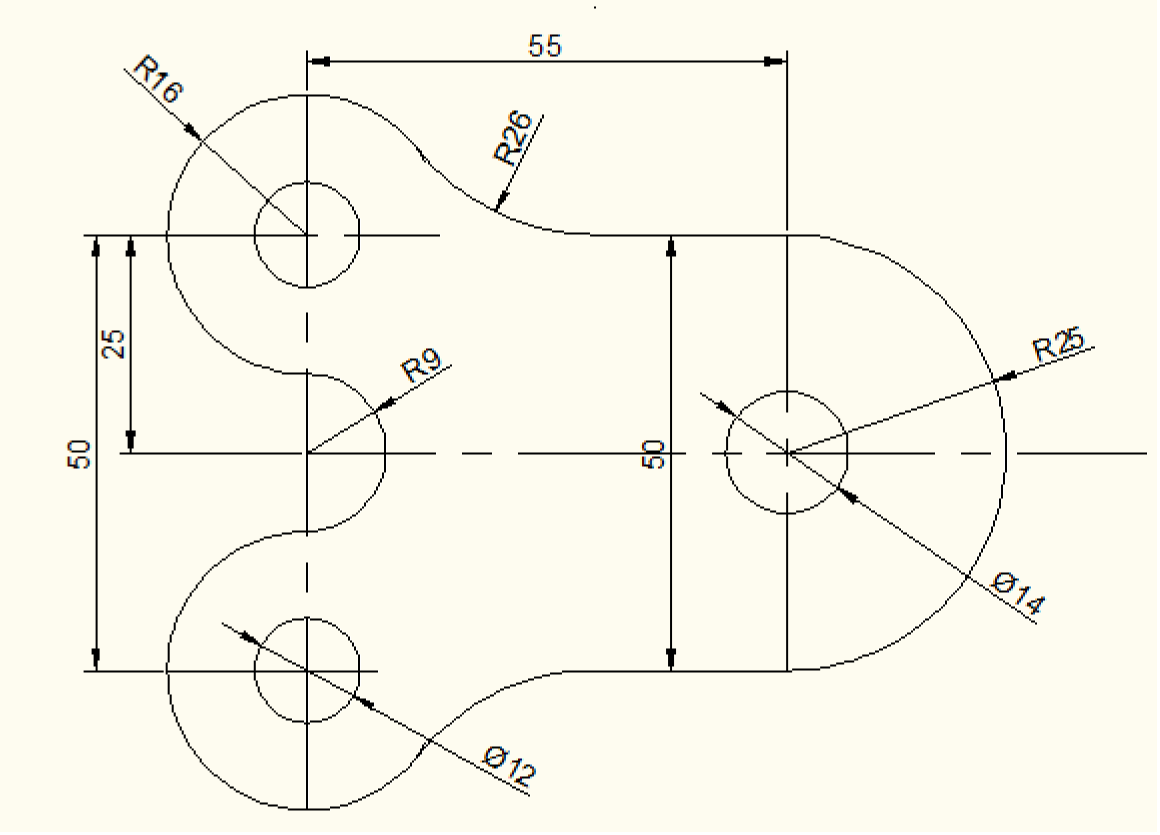



All dimensions are in mm.
Fig. A03

**Drawing Name: Template2** **No: FCAD/1/A03**

# Assignment-4

4. Do the following Part modelling and drafting using FreeCAD. Take thickness as 10 mm.



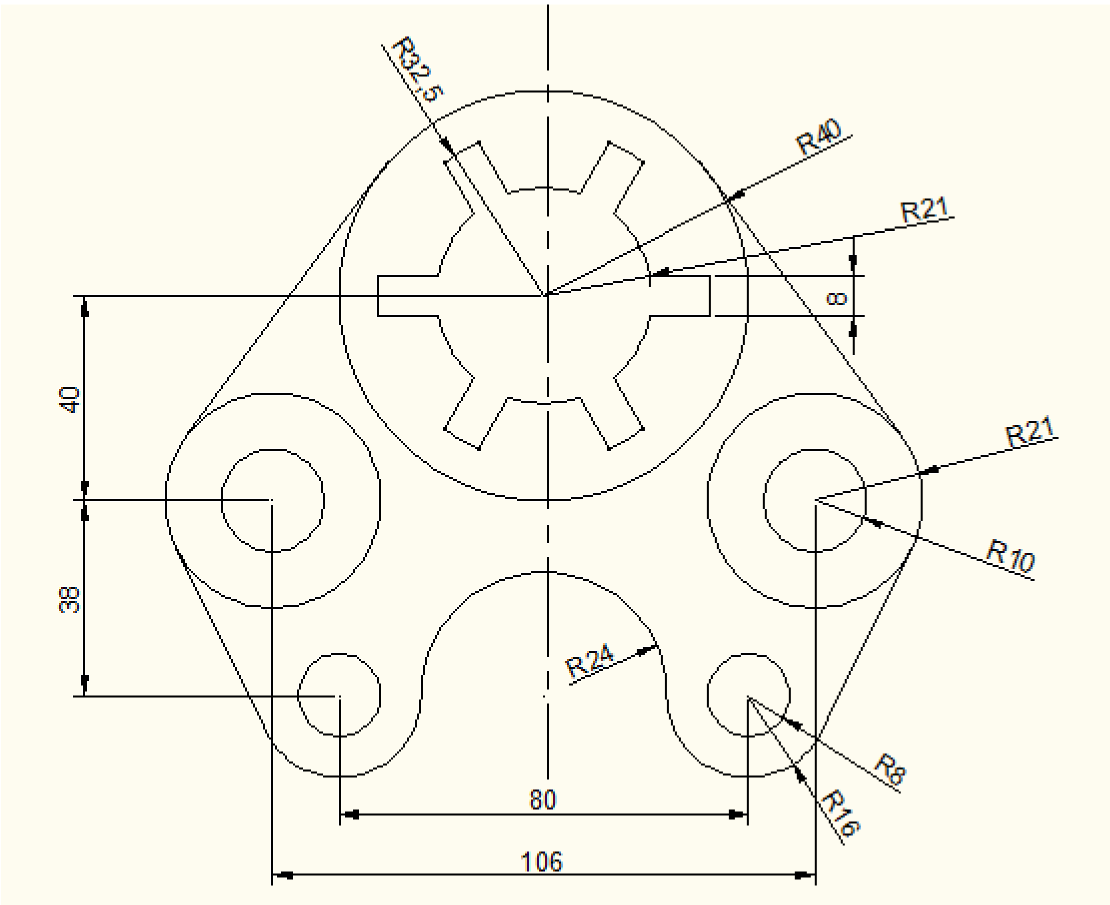

All dimensions are in mm.

Fig. A04

**Drawing Name: Template 3** **No: FCAD/1/A04**

# Assignment-5

5. Do the following Part modelling and drafting using FreeCAD. Take thickness as 10 mm. Then height of cylindrical portions above base is 20 mm.



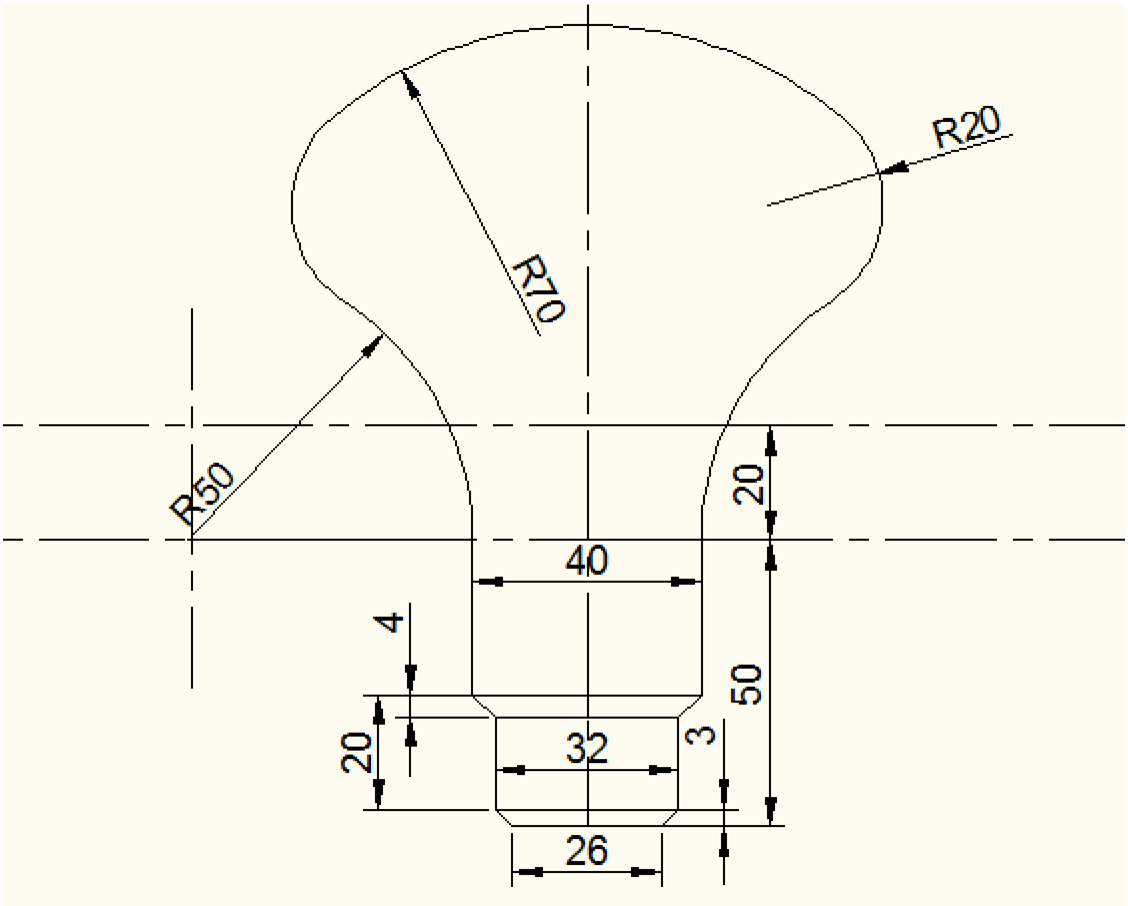

All dimensions are in mm.

Fig. A05

**Drawing Name: Gasket** **No: FCAD/1/A05**

## Assignment-6

6. Do the following Part modelling and drafting using FreeCAD.




All dimensions are in mm.
Fig. A06

**Drawing Name: Electric Bulb** **No: FCAD/1/A06**