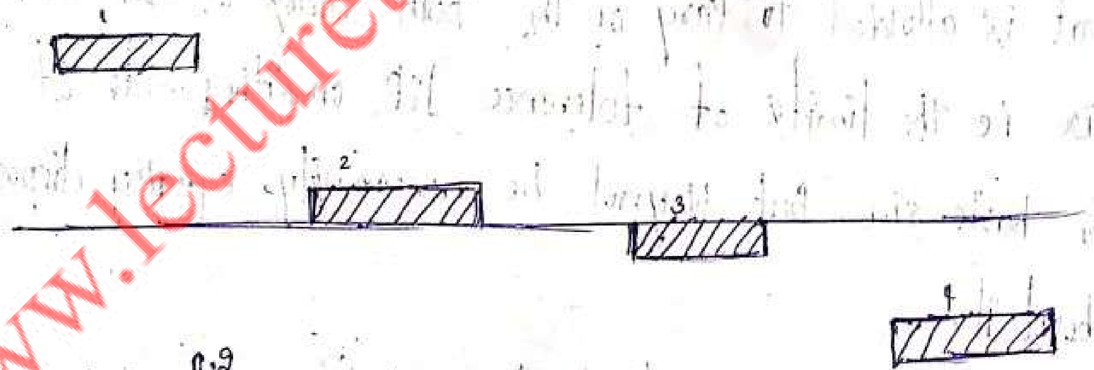
System of Writing tolerances :—

1. uni lateral system
2. Bilateral system

1. unilateral system —

In this system the dimensions of the part is allowed to vary only on one side of the basic size i.e tolerance lies wholly on one side of the basic size either above or below it.



1 — $20.0^{+0.2}_{+0.1}$

2 — $20.0^{+0.02}_{-0.00}$

3 — $20.0^{+0.00}_{-0.02}$

4 — $20.0^{-0.01}_{-0.02}$

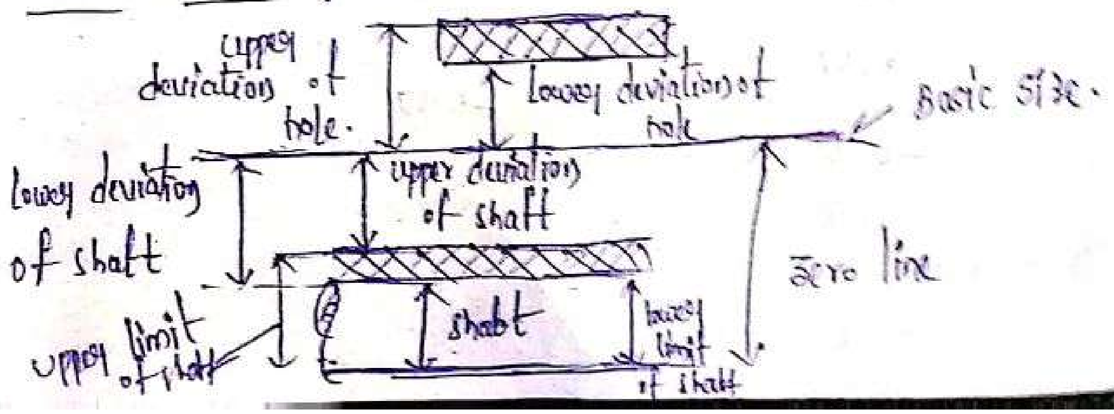
unilateral system is preferred by most manufacturer especially when precision fits are required. because

1. It is easy and simply to determine deviation
2. Another advantage of this system is that Go gauge ends can be standardized as the holes of different tolerance grades as the same lower limit and all the shafts have same upper limit
3. This form of tolerance greatly assists the operator when machining of making parts

2. Bilateral system —

In this system the dimension of the part is allowed to vary on the both sides of the basic size i.e the limits of tolerance lie on either side of the basic size. but may not be necessarily equally disposed about it.

Conventional diagram of limits and fits :—



Terminology for limits & fits

i) shaft – The term shaft refers ~~to~~ not only to diameter the circular shaft but also to any external dimensions of a component.

ii) ~~hole~~ hole – the term hole refers not only to diameter of a circular hole but also any ~~exter~~ internal dimensions of a component

iii) Basic (or) nominal size – It is a standard size of a part with reference to which the limits of variations of a size are determined.

(iv). Actual size – Actual size is the dimension as measured on the Manufactured product.

v) Zero line – It is the straight line drawn horizontally to represent the basic size

vi) Deviation – It is the algebraic difference between the size and corresponding basic size

vii) upper deviation – It is the algebraic difference of the upper limit of the size and the corresponding basic size

viii) lower deviation – It is the algebraic difference of ~~the~~ b/w The lower limit of the size and corresponding basic size.

The upper deviations for a shaft is denoted by 'es'
" " " " a hole " " 'ES'

lower deviation it is designated by 'ei' for shaft
" " " " 'EI' for hole.

the Tolerance is designated as 'IT' (international Tolerance)

Fundamental deviation —

the fundamental deviation is that one of the two deviations which is nearest to zero line either for a hole or a shaft the fundamental deviations are designated by capital letters i.e A, B, C - - - Z, ZA, ZB, ZC and excluding a few alphabeats I, L, O, Q, W, for a shaft it is designated by small letters i.e a, b, c, - - - - z, za, zb, zc

Basic shaft :- The basic shaft is the shaft whose upper deviations is zero. It is denoted by 'h'

Basic hole :- It is defined as the ~~bsh~~ hole as the lower limit of the hole. is some deviation is zero. i.e lower limit of the hole as basic size. It is denoted by 'H'

Tolerance zone:- It is the zone bounded by the two limits of a part

Tolerance grade:- It is an indication of the degree of accuracy of a Manufacturer. and it is designated (or) represented as 'IT' followed by number.

→ It is varies from IT01, IT1, --- ----IT16

→ The larger the number larger will be Tolerance and the accuracy will be less Then cost less

Types of fits:-

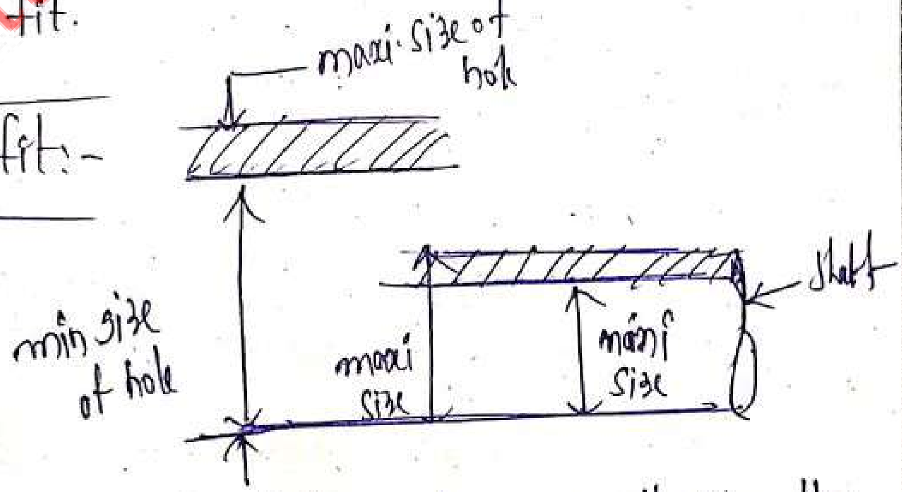
these fits are classified into three types

i) clearence fit

ii) Interference fit

iii) Transition fit.

(i) clearence fit:-



In the clearence fit the shaft is always smaller than the hole i-e the largest permissible shaft diameter is smaller Than the diameter of the smallest hole.

So that the shaft can rotate (or) slide with different degrees of freedom. it is further classified as

(a) slide fit

(b) easy slide fit

(c) running fit

(d) slack running fit

(e) loose running fit.

Maximum clearance — the diff b/w the Maximum size of hole to Minimum size of the shaft

Minimum clearance — the diff b/w the Minimum size of the hole to Maximum size of the shaft

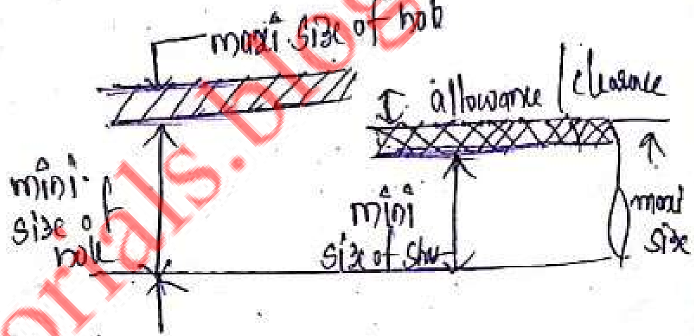
ii) Interference fit :-

1) The limits shown on a drawing for the mating hole and shaft are for the hole $50.000^{+0.046}_{-0.000}$ mm, for shaft $50.000^{-0.010}_{-0.029}$ mm state the type of fit and find the allowance. What is the gratest possible amount of clearence or interference.

Sol →

Given hole $50.000^{+0.046}_{+0.000}$ mm , shaft $50.000^{-0.010}_{-0.029}$ mm

50.000 , 50.046   49.99 , 49.971



Maxi metal limit of hole = 50.000 mm

Max metal limit of shaft = 49.99 mm

The type of fit is clearence fit

Mini clearence = mini size of hole − Maxi size of shaft

= 50.000 − 49.99

= 0.01 mm

Maxi clearence = Maxi size of hole − Mini size of shaft

= 50.046 − 49.971 = 0.075 mm

Allowance = maxi metal limit of hole − maxi metal limit of shaft

= 50.0 − 49.99 = 0.01 mm

② the limits for a hole and a shaft Combination are for hole $80.000^{+0.035}_{-0.000}$ mm for shaft $80.000^{+0.093}_{+0.071}$ mm state the type of fit and find the allowance what is the greatest possible amount of clearence (or) interferance.

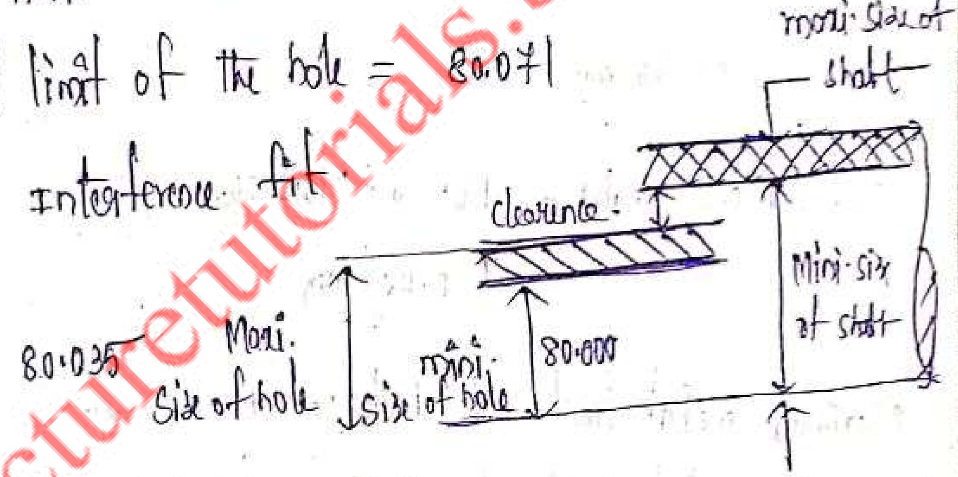
Sol → Given hole – $80.000^{+0.035}_{-0.000}$ shaft – $80.000^{+0.093}_{+0.071}$

80.035 , 80.000 80.093 , 80.071

Mini. metal limit of the hole = 80.035

Maxi metal limit of the hole = 80.071

It is a interference fit.



Allowance – Maxi. metal limit of Shat – maxi. metal of hole

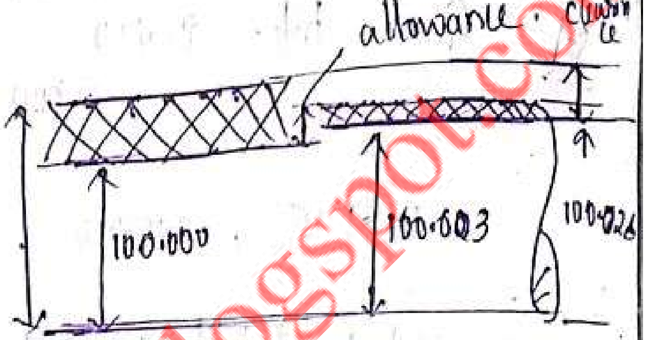
= 80.093 – 80.00

= 0.093

greatest interference = allowance

③ Maximum metal limit for the shaft is 100.026 mm, minimum Maximum metal limit for the hole is 100.000 mm, minimum metal limit for the hole is 100.036 mm, ~~determine~~ minimum metal limit for the shaft is 100.003 mm determine the Type of fit and find the allowance, Tolerance for shaft & hole

Sol →



Tolerance of hole

$= 100.036 - 100.000$

$= 0.036$ mm

Tolerance of shaft $= 100.026 - 100.003$

$= 0.023$ mm

Maximum metal limit of hole = 100.000 mm

Maximum metal limit of shaft = 100.026 mm

↑ It is Interference fit when Maximum metal limits of both shaft & hole are considered.

Minimum metal limit of hole = 100.036

Maximum metal limit of shaft = 100.003

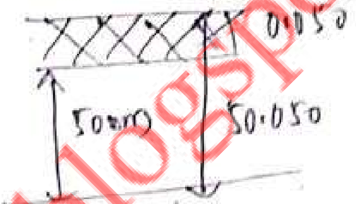
↑ It is clearance fit when Minimum metal limits of both shaft & hole are considered.

allowance – Maximum metal limit of shaft – maximum metal limit of hole

$= 100.026 - 100.00$

$= \underline{0.026}$

(4) A 50mm diameter is made to rotate in the bush the tolerance for both shaft and bush are 0.050 mm determine the dimensions of shaft and bush, give an allowance of 0.075 mm with a hole basis system.



Sol

For a hole basis system lower limit of hole is fixed = basic size.

= 50.000 mm

upper limit of hole = lower limit + Tolerance

= 50.000 + 0.050

= 50.050 mm

Higher limit of shaft = lower limit of hole – allowance

= 50.000 – 0.075

= 49.925 mm

lower limit of shaft = Upper limit of shaft – tolerance

= 49.925 – 0.050

= 49.875 mm

→ The tolerance value is calculated using the following

IT_5 to IT_{16}: → $i = [0.453\sqrt[3]{D} + 0.001D]$ microns

Where, D – Diameter of the part in mm, and

0.001D is the linear factor

and 'D' is calculated by $D = \sqrt{D_{max} \times D_{min}}$

→ For IT01, $i = 0.3 + 0.008D$

→ For IT0, $i = 0.5 + 0.012D$

→ For IT1, $i = 0.8 + 0.020D$

<u>Various diameter steps</u>:–

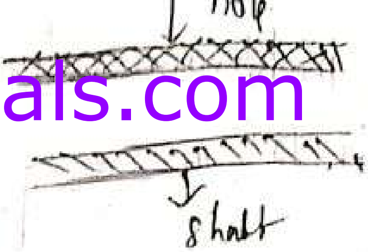
1–3, 3–6, 6–10, 10–18, 18–30, 30–50, 50–80, 80–120, 120–180, 180–250, 250–315, 315–400, 400–500, 500–630, 630–800, 800–1000

① Design the general type of go and no-go gauges as per the British system for a 40mm shaft and hole pair designated as 40 H8d9. Given that $i = 0.453\sqrt[3]{D} + 0.001D$, $IT_8 = 25 \times i$ and also $IT9 = 40 \times i$, upper deviation of shaft $-16D^{0.44}$ with their tolerances. Sketch the hole and shaft

Sol → Given 40 step diameter falls under 30–50mm

Diameter $D = \sqrt{D_{max} \times D_{min}}$

$= \sqrt{30 \times 50}$



$D = 38.72\,mm$

Fundamental Tolerance $i = 0.453\sqrt[3]{D} + 0.001D$

$i = 1.571$ microns.

For hole quality $H_8 = 25 \times i$

$= 25 \times 1.571$

$= 39.28$ microns.

For the hole the fundamental deviation is zero

the lower limit of the hole $= 40\,mm$

upper limit of the hole $= 40 +$ Tolerance

$= 40 + 0.039$

$= 40.039\,mm$

For shaft quality

the fundamental Tolerance is $d_9 = 40 \times i$

$= 40 \times 1.571$

$= 62.84$ microns

For the shaft the fundamental deviation is given by

$= -16D^{0.44}$

$= -16 \times 38.72^{0.44}$

$= -79.96$ microns $\Rightarrow -0.079\,mm$

The limit for the shaft are as follows

upper limit of shaft $= 40 -$ fundamental deviation

$= 40 - 0.079$

$= 39.921$ mm

lower limit of the shaft $= 40 - [0.079 + \text{tolerance}]$

$= 40 - [0.079 + 0.062]$

$= 39.859$

Tolerance of shaft $=$ upper limit of shaft $-$ lower limit of shaft

$= 39.921 - 39.859$

$= 0.062$

(2) Design and sketch the hole and shaft system of a $32H_7m_8$ and multiplication factors for the hole and shaft Tolerances are 16 and 25 and the upper deviation of the shaft is $-16D^{0.44}$

Sol → Given 32 mm diameter falls under 30-50 mm

Diameter $D = \sqrt{D_{max} \times D_{min}} = \sqrt{50 \times 30}$

$= 38.72$ mm

Fundamental Tolerance $i = 0.453\sqrt[3]{D} + 0.001D$

$= 1.57$ microns.

For Hole quality $H_7 = 16 \times i$

$= 16 \times 1.57 \Rightarrow 25.12 \Rightarrow 0.025$ (micron → mm)

Scanned by CamScanner

lower limit of hole = 32 mm

The fundamental deviation of hole is 0

upper limit of hole = 32 + 0.025

= 32.025 mm

For shaft quality $m_8 = 25 \times i$

Fundamental Tolerance $= 25 \times 1.571 = 39.28$ microns

$= 0.039$ mm

For shaft the fundamental deviation is given by

$= -16D^{0.44}$

$= -16 \times 38.72^{0.44}$

$= -79.94$ microns

$= -0.079$ mm

upper limit of shaft $= 32 - 0.079$

$= 31.921$ mm

lower limit of shaft $= 32 - [0.079 + 0.039]$

$= 31.882$

Tolerance of shaft = upper limit − lower limit

$= 31.921 - 31.882$

$= 0.039$ mm

Line standard:

→ When the length being measured is expressed as the distance between the two lines. This is known as line standard.

→ A scale is quick and easy to use over a wide range of dimension.

→ The line standards are not accurate as end standards and can't be used for close Tolerance Measurements.

→ A steel scale can be read to about ±0.2 mm of truth value

→ The scale graduations are not subjected to ~~whole~~ wear although significance whole on leading, end leads to under sizing.

→ The scales are subjected to parallax error of reading. They may be +ve or −ve reading.

→ Errors due to inaccuracy of graduations engraved on the scale are possible.

→ A scale doesn't provide a built in measuring datum

End standards:-

→ When the length being measured is expressed as the distance b/w the two surfaces or ends. This known as End standards

→ They are time consuming to use and prove only 1 dimension at a time

→ End standards are highly accurate and well suitable for close tolerance measurement i.e 0.0005 mm can be obtained.

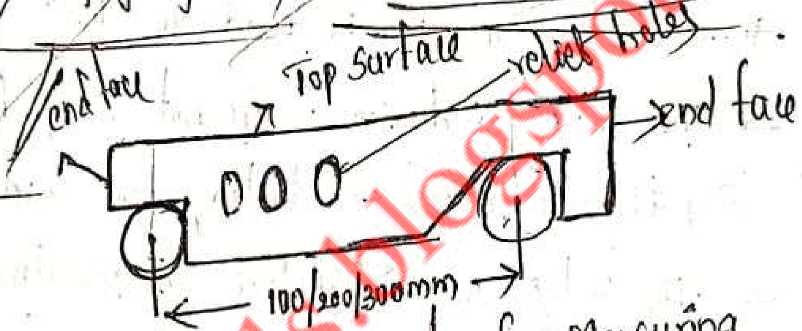
→ They are subjected wear on their measuring surfaces also wringing of slip gauges lead to damage.

→ The parallax error is not associated with such type of measurement because the distance is measured b/w two flat surfaces.

→ They have a built in measuring datum as their measuring faces are flat and parallel.

Gauge Blocks / slip gauges / Johnson's gauge / Jo gauge

gage blocks



Sine bars

→ 'sin' bar is the most accurate instrument for measuring accurate straight rectangular angles. it consists of a bar made up of high quality steel and having two accurately lapped cylinderical ~~flex~~ plugs or rollers at the ends. the rollers are so fixed that when the sin bar is placed on the surface plate the surface of the bar is exactly parallel to surface plate. the various parts of the sin bar are hardened before grinding and lapping.

If a sin bar is to be accurate then the following property must exist.

→ the distance b/w centers must be precisely known

→ The axis of rollers must be parallel to each other.

→ The upper surface of the sin bar must be flat and parallel.

→ The Rollers must be of identical diameters and ground to within a close tolerance.

Sources of errors and sin bars

→ Constant angle error.-
This is caused if the working surface and the cylinder axis are not parallel.

→ progressive angle error -
This is due to the error in cylinder centre distance

→ Gauge block Tolerance &
accumulation is also source of progressive error.

Bevel protractor:-

A circle can be devided into 360 equal angles each angle is called a degree.
A circle is 360° for calculation a degree is devided into 60 parts called 'minitues' and a minitue is devided into 60 sub parts. called "seconds"

The Bevel protractor is used to establish and test angles to very close tolerances.

It reads upto 5 min. (05) 1/20 and can be used completely through 360°. The bevel protractor consists of a beam graduated dial and blade which is corected to swivel plate by Thumb nut and clamp

When the edges of the beam and blade are parallel a small line on the swivel plate coincides with the zero line on the graduated dial. and when any measurement of angle below the beam and the blade of 90° (or) under desired the reading may be obtained direct from the position of the line on the swivel plate with regard to the graduation Number on the dial

Since the spaces both on the Mainscale and the vernier scale are numbered both to the right and to the left from zero any angle can be measured the readings can be Taken either to the right or to the left According to the direction in which the zero on the mainscale is moved.

The Bevel protractor vernier scale indicates every 5 minutes (or) $\frac{1}{20}°$ each space on the vernier scale is 5' less than 2 spaces on the main scale.

24 spaces on the vernier scale equal in extreme length 23 double degrees on a main scale Thus the difference b/w the spaced occupied by 2° on a main scale and the space of the vernier scale is equal to one 24th of 2° or one 12th of 1° or 5 minutes

Angle Gauge :-

An angle gauge is a hardened steel block approximately 75mm long, 16mm wide which has two lapped flat working faces lying at a very precise angle to each other. They are supplied in a sets of 13 and can be wrung together (Sedhan) to forms desired angles.

The arrangement allows angles in 3 sec step to be obtained and thus no required angle expressed in ~~bo~~ whole seconds can be more than 1.5 sec in nominal error. An additional block of 9° is also available so that a 90° angle having an angle can be built up.

Two diff grades are available A & B. The only difference in a, B type 0.05 when 9° is excluded and thus consists of only 12 gauges.

Sine Centers :-

Sine center basically a sine bar with blocks holding centers which can be adjusted and rigidly clamped in any position. The sine centers are used for inspection of conical objects b/w ~~with~~ centers. These are used upto inclenation of 60°. The rollers are clamped firmly to the body without any play.

Autocollimator :-

It is an optical instrument for noncontact Measurement of angles They are typically used to align components and Measure deflections in optical or Mechanical systems an auto collimator works by projecting an image on to a target mirror and Measuring the deflections of the return image against a scale either visually or by means of electronic detector a visual ~~vision~~ auto collimator can measure angles as Small as 1 arc second i.e 4.85 micro radians while an electronic autocollimator can have upto 1000 time more resolution

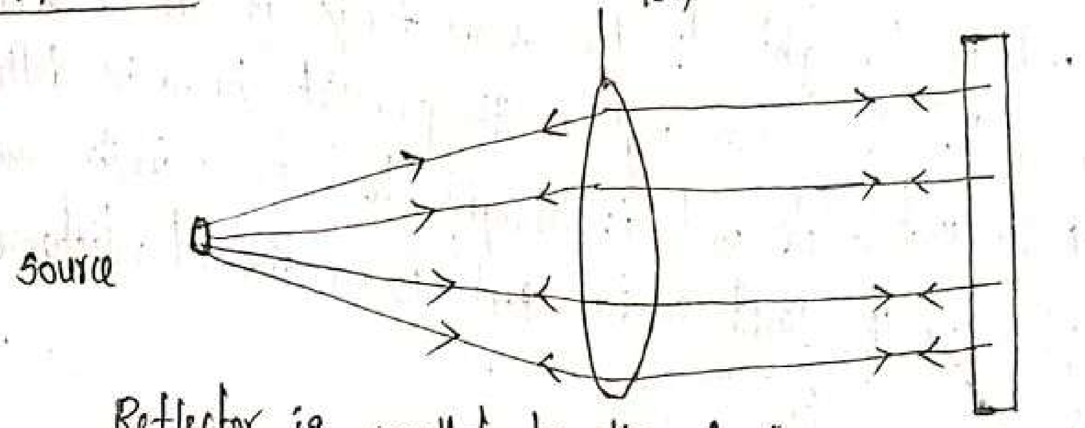
Principle :-

→ When a beam of rays coming out from a monochromatic source of light are made parallel by placing a collimating lens and if These parallel rays are made to fall on reflector The rays reflect back and travels in the Same path and converges at the source Through The lens

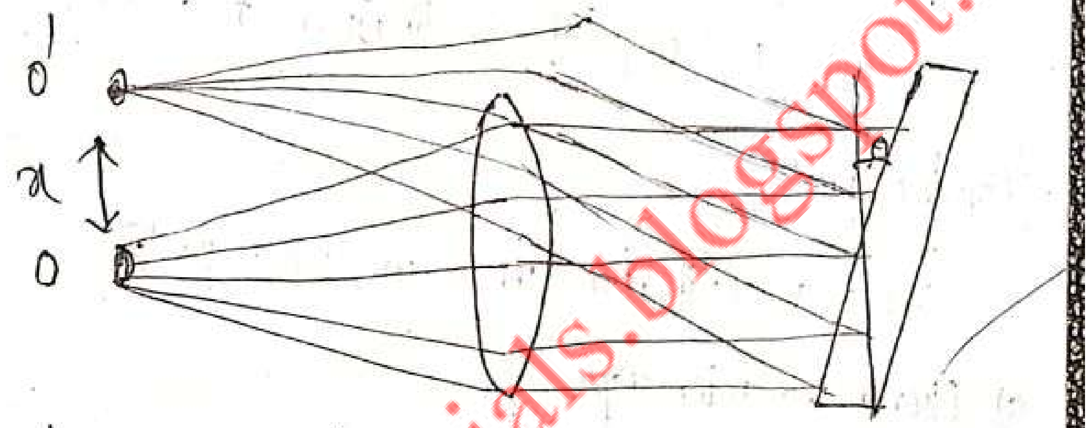
→ If the reflector is twilted by an angle 'θ' then the reflected rays make an angle '2θ' and converges at point 'O''

→ $O, O' = 2\theta f$ where f – focal length i.e the distance between The Source and Collimator.

Application:-



Reflector is parallel to the lens.



Application

→ Measurement of straightness and flatness
→ precise angular indexing in conjuction with polygons
→ Comparative measurement using master angles
→ Essement of squareness and parallelism of components
→ Measurement of small linear dimensions.

Working of collimator:—

If a light source is placed in the focus of a collimating lens it is projected as a parallel beam of light if this beam is made to straight a plane reflector is kept normal to the optical axis. when perfectly back along its own path and is brought to the same focus if the reflector is tilted to a small angle θ. The parallel beam is deflected twice that angle and is brought to a focus in the same plane as the light source but to one side at a distance 'x'. $x = 2f\theta$.

where f - focal length

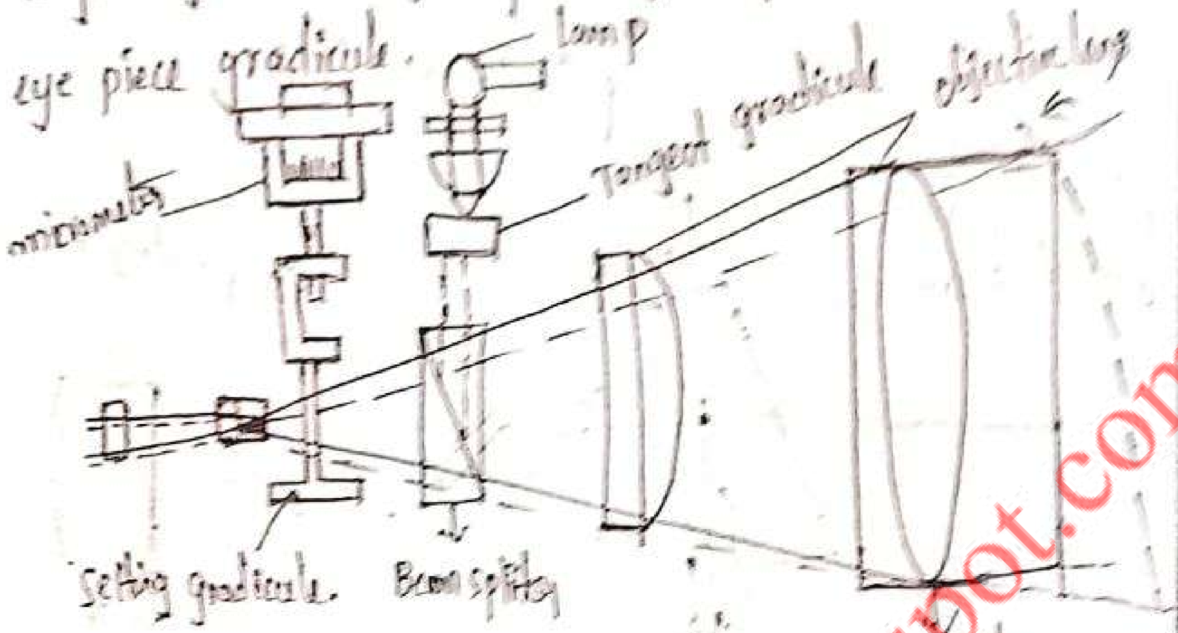
θ - angle of inclination of reflecting mirror

Construction:-

In a autocolimator there are ~~three~~ parts.

a) Micrometer microscope
b) lighting unit
c) collimating lens

a 45° transferent beam spliter ~~replace~~ reflects the light from the gradicule towards the object i.e collimating lens the image seen after reflection in the external reflector whose angular variation are being measured is ~~found~~ formed by the light from the objective lens this slight passes through the beam spliter and the image is pickedby the microscope for simentaneous measurements in two planes at right angles a micrometer is fitted to the longest ... the



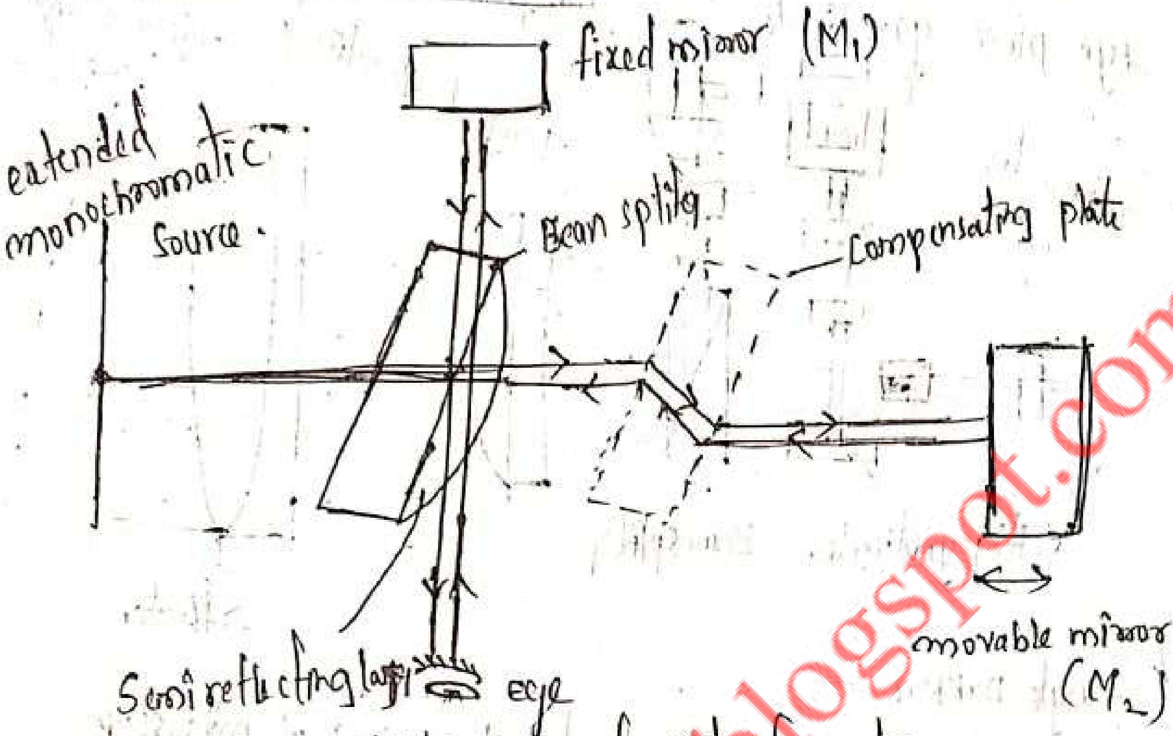
Angle Dakkor:-

→ This is a type of auto collimator it consists of microscope objective lens and two scales engraved on a glass screen which is placed in the focal plane of objective lens one of the scales called datum scale is horizontal and fixed

→ It is engraved across the centre of the screen and is always visible in the microscope eye piece

→ Another scale is an illuminated vertical scale fixed across the centre of the screen and the reflected image of the illuminated scale is received at right angles to this fixed scale and the two scales in the position intersects each other thus the reading on the illuminated scale. measures angular deviations from one axis at 90° to the optical axis

Michelson's Interferometer:-



→ This is the oldest type of interferometer

→ It utilizes monochromatic light from an extended Source

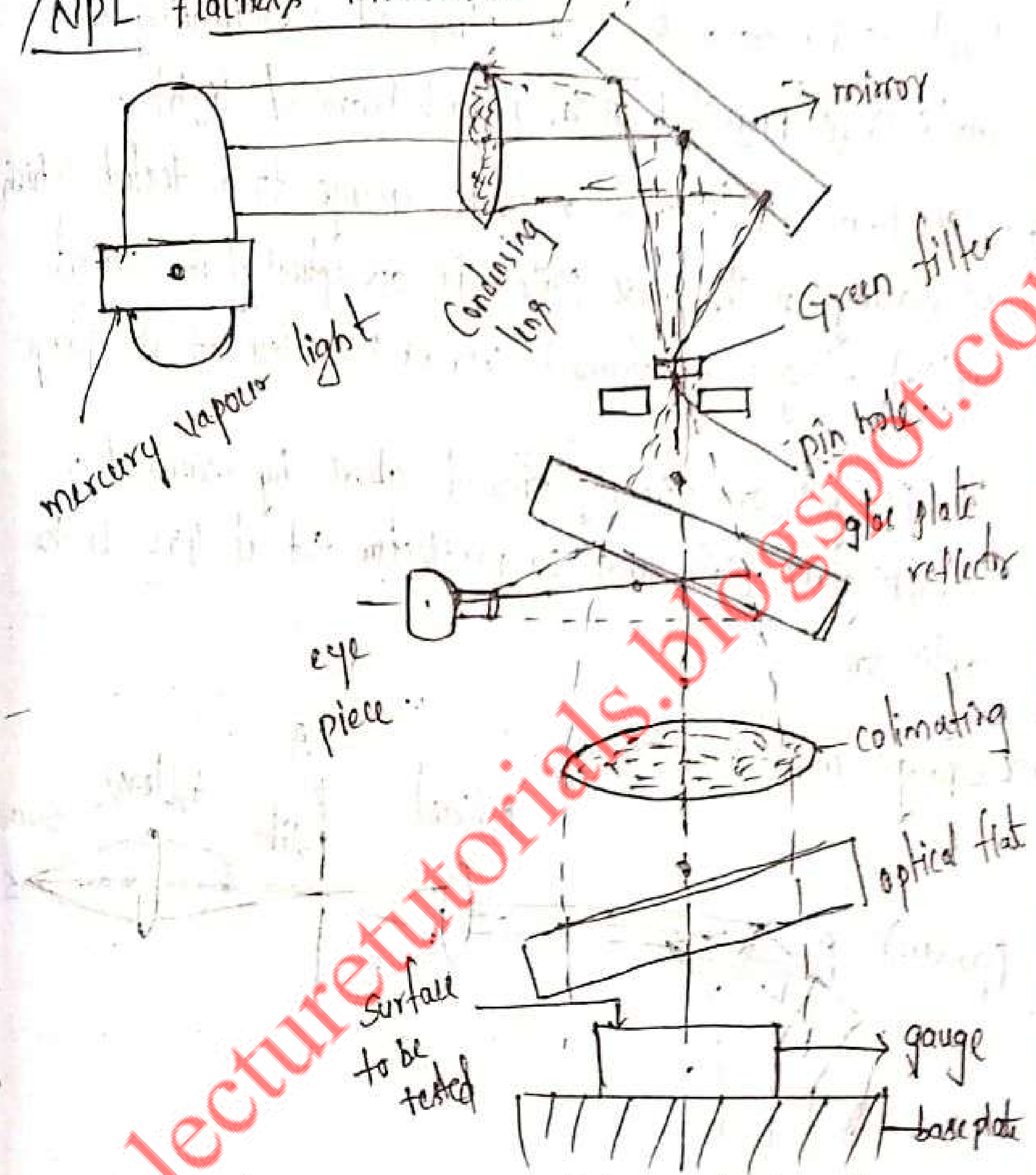
→ the Monochromatic light falls on a beam splitter consisting of Semi reflecting layer

→ the light ray is devided into two parts i.e one is transmitted through compensating plate to the mirror M_1 and the other is reflected to the Beam splitter to mirror M_2

→ From both these mirrors the rays are reflected back and this reunite at the semireflecting surface. and they are transmitted to the eye and the fringes can be observed.

→ mirror M_2 is fixed and M_1 is free (or) Movable i.e it is attached to the object whose dimension is to be measured.

NPL flatness interferometer:-



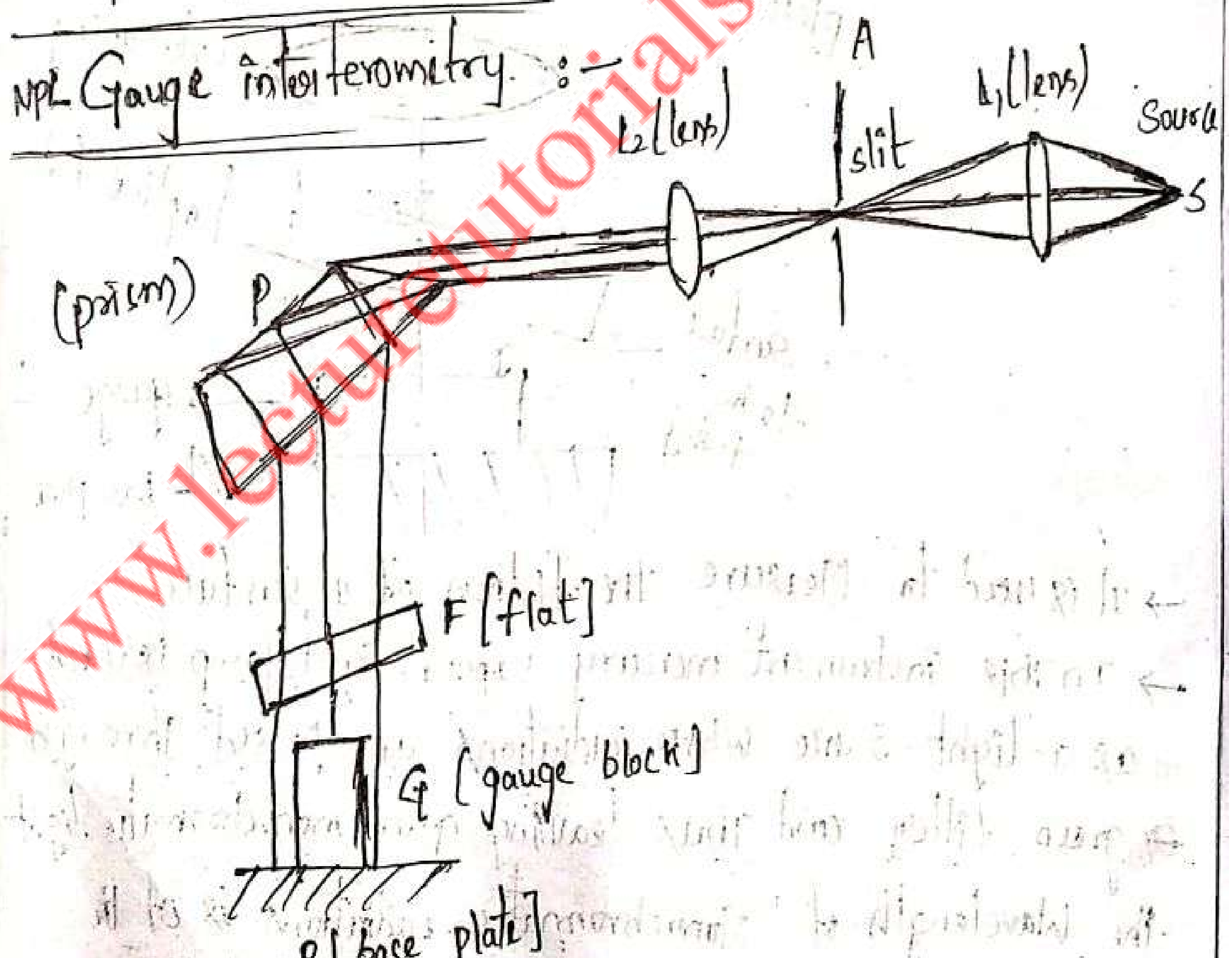
→ It is used to Measure the flatness of a surface
→ In this instrument mercury vapour light/lamp is used as a light source whose radiations are passed through ~~a~~ green filter and thus leaving green monochromatic light the wavelength of monochromatic radiations is of the order of 0.0005mm [i.e 0.5 micrometer/ μm]

→ This method in the light from a pin hole is ordinary to obtain an intense point of source of monochromatic light which is in the focal plane of a collimating lens and is thus projected as the parallel beam of light.

→ The beam is directed on to the gauge to be tested which is wrung on the base plate via an optical flat so that optical fringes are formed across the face of the gauge.

→ The fringes are directly viewed above by means of a thick glass plate that semi reflector set at 45°c to the optical axis.

NPL Gauge interferometry :-



It is also called Gauge-interferometer

→ It is used to determine the actual dimension (or) absolute length of the gauges

→ The light from the sources falls on the slit 'A' through the lens 'L_1'

→ After collimation by lens 'L_2' it goes through constant deviation prism 'p' whose rotation determine wavelength pass passed through reference flat 'F' to upper surface of the gauge block 'G' and base plate 'B' to which it is wroung

→ light is reflected back in mirror 'p' and its pattern are observed through a telescope

→ This instrument should be used in standard conditions of temperature and pressure.

Interferometer :-

→ These are optical instruments used for measuring flatness and determining the length of slip gauges they ~~have~~ are based upon the interference principle and employ wavelength of light as their measuring units

→ the interferometers makes use of some type of beam divider. That splits an incoming ray into two parts

→ these two parts of the ray travel along different paths until they are recombine usually in the same beam divider.

→ ~~In~~ interferometers, the lay of optical flat can be controlled and the fringes can be oriented to the best advantage.

→ ~~An~~ arrangement to view the fringes directly from top and above the fringes is also incorporated.