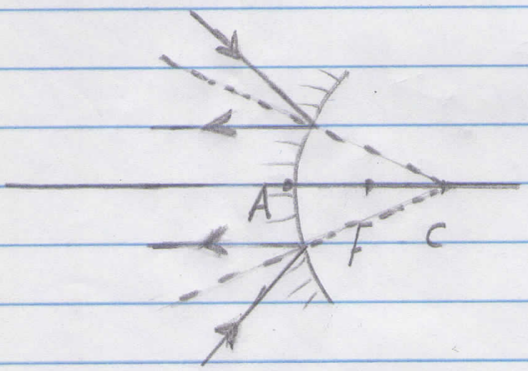
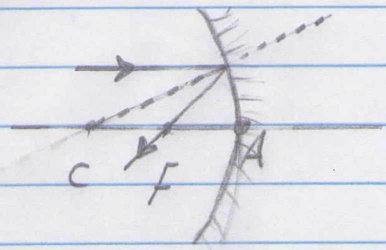
« Spherical Mirror »

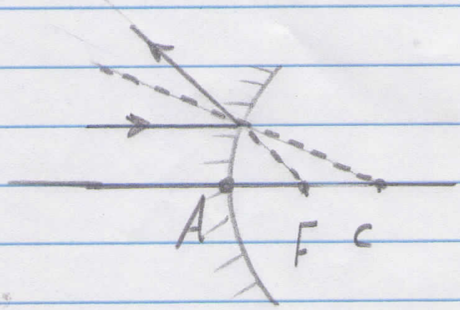
Mostly, spherical mirrors are preferable more than Spherical lens because of absence of chromatic abvration due to dispersion that always acompany to the refraction of white light, but their applications are not so broad as those of lenses because they do not ofer the Same posipilities of correction of other aberrations of image.

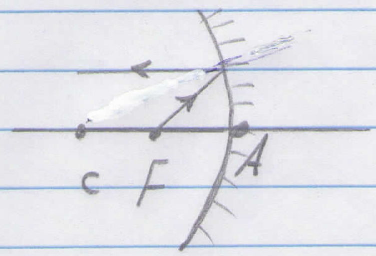
The law of reflection is more simple than the law of refraction then the study of image formation by mirrors is easier than that in the case of lenses.

many features are the Same in lenses and mirrors.









The focal length of the concave mirrors is alway positive (+ Ve)
The focal length of convex mirros is always negative (-ve)

" Mirror formulas "

In order to be to apply astander mirror formulas, we must apply the following Signs convention:-

1- Distances measured from left to right are positive (+), while those from right to left are negative (-).

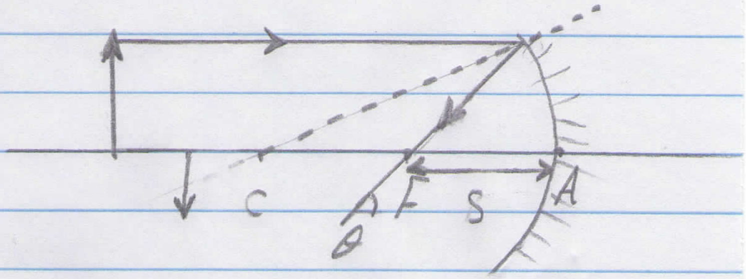
2- Incident rays travel from left to right and the reflected ray from the right to left.

3- The radius is measured from vertex to the center of curvature. This make r is negative from concave mirror and positive from convex mirror.

4- The focal length is measured from the focus to the vertex This is make the focal length positive for concave mirror and negative for convex mirror.

5- Object and image distance are measured from object and image to the vertex.

i.e S and S` are positive at the left of the vertex and negative to the right of The vertex.

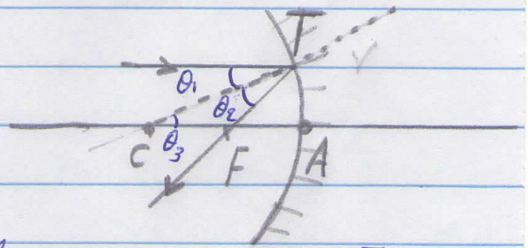


H.W :- what is meant by primary and Secondary focal point of concave and convex mirror.? explain your ansuve by digram.

---

prove that :- The focal length of Spherical mirror equal Half of the radius of curvature.

Sol :- Δ CFT :-



$\theta_1 = \theta_2$ and $\theta_3 = \theta_1 \Rightarrow \therefore \theta_3 = \theta_2$

This mean that the Δ CFT is isosceles i.e $CF = FT$.
as we deal with paraxial ray then :-

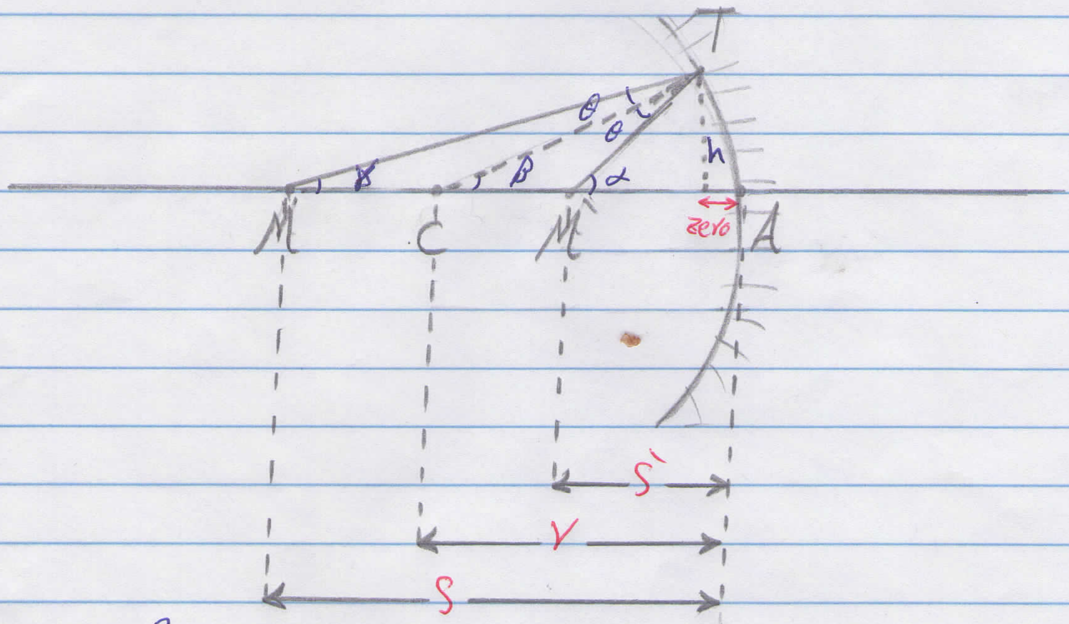
$FT = FA$

$\therefore CF = FA \Rightarrow$ i.e $CA = 2FA$

$CA = r$, $FA = f \Rightarrow \therefore r = 2F$
if the mirror is concave then $F = \frac{r}{2}$ θ
if the mirror is convex $F = \frac{r}{2}$

State mirror formula prove it using oblique ray method.

Sol:-



$$\frac{1}{S} + \frac{1}{S`} = -\frac{2}{r}$$

$\triangle MM`T$

$\alpha = 2\theta + \gamma \qquad \Rightarrow 2\theta = \alpha - \gamma$ —— ①

$\triangle MCT$

$\beta = \theta + \gamma \qquad \Rightarrow \theta = \beta - \gamma$ —— ②

from 1 and 2 $(\ \beta - \gamma = \alpha - \gamma)$

$2\beta = \alpha - \gamma$

as we deal with paraxial ray.

$\sin\theta \cong \tan\theta = \theta$

$\sin\alpha \cong \tan\alpha = \alpha$

$\sin\beta \cong \tan\beta = \beta$

$\sin\gamma \cong \tan\gamma = \gamma$

$2 \tan \beta = \tan \alpha - \tan \gamma$

$2 \frac{h}{CA} = \frac{h}{MA} + \frac{h}{M'A} \Rightarrow \frac{2}{CA} = \frac{1}{MA} + \frac{1}{M'A}$

$-\frac{2}{r} = \frac{1}{s'} + \frac{1}{s}$ for concave mirror

for convex mirror $+\frac{2}{r} = \frac{1}{s} + \frac{1}{s'}$

1- If the object at ∞ :-

$\frac{1}{s} + \frac{1}{s'} = -\frac{2}{r} \Rightarrow \frac{1}{\infty} + \frac{1}{s'} = -\frac{2}{r}$

$\frac{1}{F} = -\frac{2}{r}$ as $s' \cong F = F'$

2- If the object at the focus point:-

$\frac{1}{s} + \frac{1}{s'} = -\frac{2}{r} \Rightarrow \frac{1}{F} = \frac{1}{\infty} = -\frac{2}{r}$

$\frac{1}{F} = -\frac{2}{r}$ as $s' \cong F' = F$

$M = \frac{y'}{y} = -\frac{s'}{s}$

Example:- object 2 cm high, is stuated 10 cm in front of concave mirror, radius 16 cm. Find :- 1) The focal length of the mirror.
2) The position of the image
3) lateral magnification.

Sol:-

$$f = \frac{-r}{2} = -\frac{-16}{2} = +8$$

$$\frac{1}{S} + \frac{1}{S'} = \frac{1}{f} \Longrightarrow \frac{1}{10} + \frac{1}{S'} = \frac{1}{8}$$

$$\frac{1}{S'} = \frac{1}{8} - \frac{1}{10} \Longrightarrow \frac{1}{S'} = \frac{5-4}{40} \Longrightarrow \therefore S' = 40 \text{ cm}$$

$$M = -\frac{S'}{S} = \frac{y'}{y} = -\frac{40}{10} = -4$$

$$-4 = \frac{y'}{2} \Longrightarrow y' = -8$$

"power of mirror"

let:- $P = \dfrac{1}{f(m)}$

$V = \dfrac{1}{S(m)}$ $\qquad V' = \dfrac{1}{S'(cm)}$

$K = \dfrac{1}{r(m)}$

$$V + V' = P = -2K$$

$$M = \frac{y'}{y} = -\frac{S'}{S} = -\frac{V}{V'}$$

lens it's power is (+ 3.5 D), Find its focal length.

Sol:-

$P = \frac{1}{f(m)} \Rightarrow f = \frac{1}{3.5} \times 100 = 28.5$ cm

---

Example:- An object is located (20 cm) in front of convex mirror of radius (50 cm) calculate:- 1) the power of the mirror 2) the position of image.

Sol:-

$P = -2K \Rightarrow -2 \frac{1}{r(m)} = \frac{-2}{0.5} = -4\ D$

$V = \frac{1}{0.2} = +5D \Rightarrow P = V + V' = -4 - 5 =$

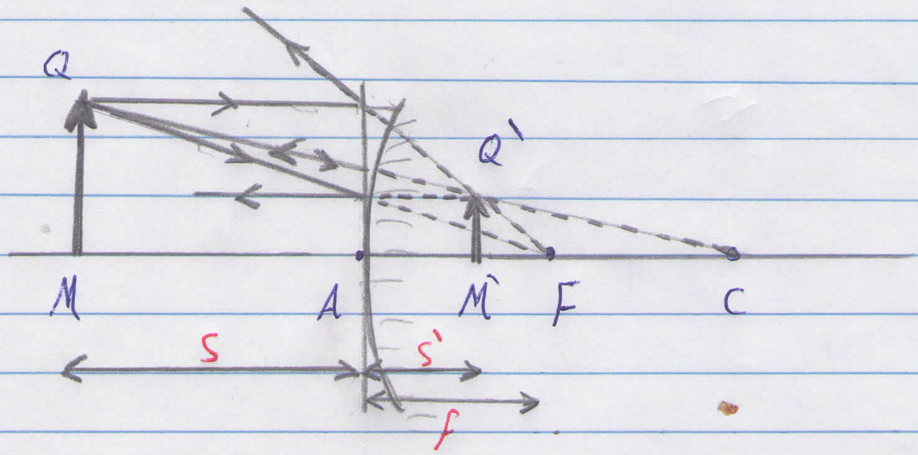
$V' = -9$

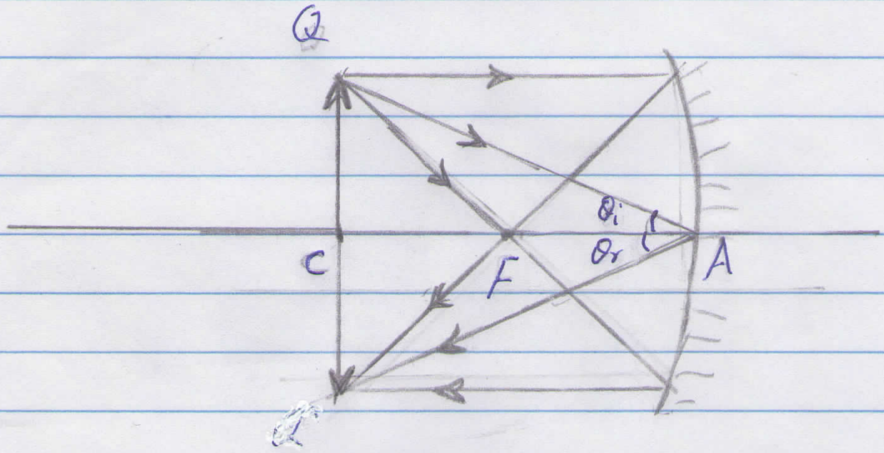
$S' = \frac{1}{V'} = -11.10$

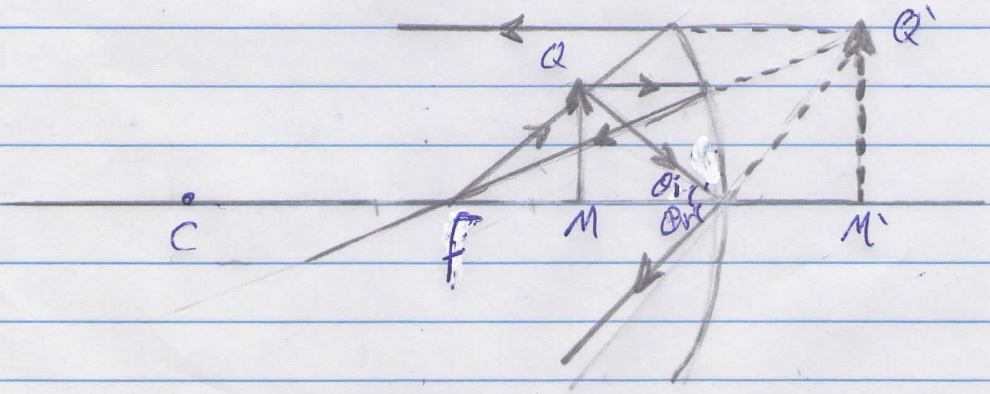
$M = -\frac{V}{V'} = -\frac{5}{-9} = 0.55$

The power is (-4 D) and the image is vertual and erect it is located 11.10 cm to the right of the mirror and has magnification (0.55).

«Image formation using parllel ray»







Example:- object (2 cm) stuated (10 cm) in front of concave mirror, radius (16 cm). find :- 1) the focal length of the mirror.
2) The position of the image.
3) The lateral magnification.

Sol:-

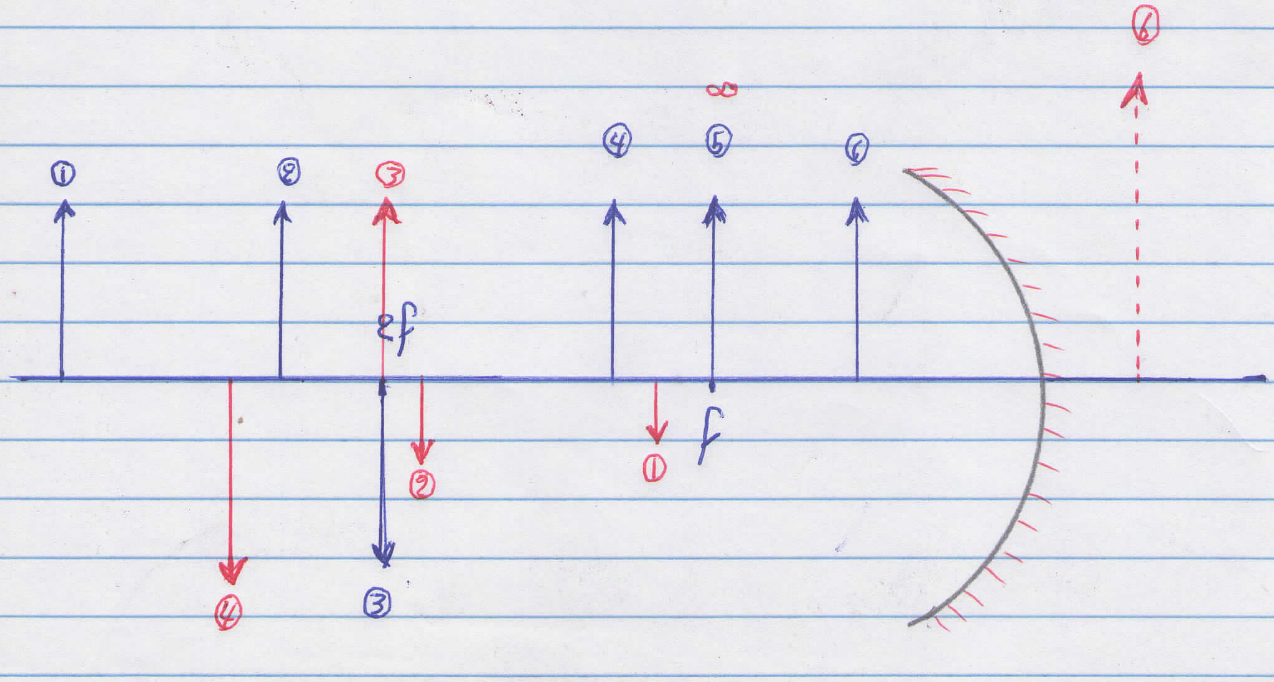
$$F = -\frac{r}{2} = -\frac{-16}{2} = +8$$

$$\frac{1}{S} + \frac{1}{S'} = \frac{1}{F} \Rightarrow \frac{1}{10} + \frac{1}{S'} = \frac{1}{8}$$

$$\frac{1}{S'} = \frac{1}{8} - \frac{1}{10} \Rightarrow \frac{1}{S'} = \frac{5-4}{40} \Rightarrow \therefore S' = 40 \text{ cm}$$

$$M = -\frac{+S'}{S} = \frac{y'}{y} = -\frac{40}{10} = -4$$

$$-4 = \frac{y'}{2} \Rightarrow y' = -8$$



Example:- A concave mirror of radius zero on object located 12 cm to the left of the vertex if the high of the object is 3 cm. find :- 1) the focal length of the mirror.
2) the position of the image.
3) the length of the image.

Sol:-

$F = -\frac{r}{2} = -\frac{-20}{2} = 10$ cm

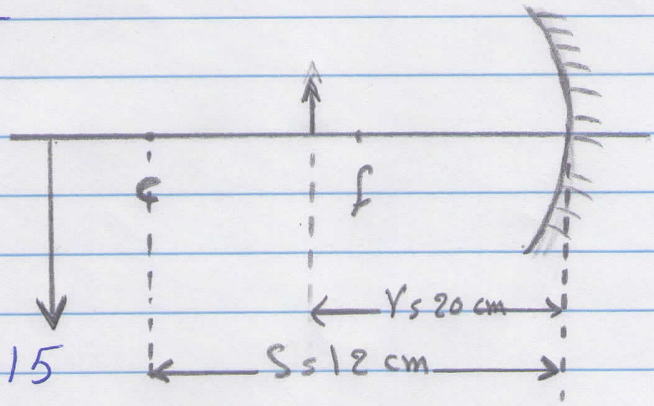
$\frac{1}{S} + \frac{1}{S'} = \frac{1}{F} \Rightarrow \frac{1}{12} + \frac{1}{S'} = \frac{1}{10}$

$\frac{1}{S'} = \frac{1}{10} - \frac{1}{12} \Rightarrow \frac{1}{S'} = \frac{6-5}{60}$

$\frac{1}{S'} = \frac{1}{60} \Rightarrow S' = 60$ cm

$M = -\frac{S'}{S} = -\frac{60}{12} = -5$

$M = \frac{y'}{y} \Rightarrow -5 = \frac{y'}{3} \Rightarrow y' = -15$



Example:- concave mirror r = 30 cm, find the position of object in front of the mirror to obtain image,
i) real and magnified 3 times.
ii) virtual and magnified 3 times.

Sol:-
I) as the image is real and magnified 3 times:-

$M = -3 = -\frac{S'}{S} \Rightarrow S' = 3S$

$F = -\frac{r}{2} = -\frac{-30}{2} = 15$ cm

$$\frac{1}{S} + \frac{1}{S'} = \frac{1}{F} \Longrightarrow \frac{1}{S} + \frac{1}{3S} = \frac{1}{F}$$

$$\frac{3+1}{3S} = \frac{1}{15} \Longrightarrow 3S = 60 \Longrightarrow S = 20 \text{ cm}$$

ii) As the image is virtual and magnified 3 times:-

sol:-

$$M = +3 = -\frac{S'}{S} \Longrightarrow S' = -3S$$

$$\frac{1}{S} + \frac{1}{S'} = \frac{1}{F} \Longrightarrow \frac{1}{S} + \frac{1}{-3S} = \frac{1}{F}$$

$$\frac{3-1}{3S} = \frac{1}{15} \Longrightarrow 3S = 2 * 15 \Longrightarrow S = \frac{30}{3} = 10 \text{ cm}$$

"Aberration"

aberration

monochromatic aberration	chromatic aberration
lens and mirror	lens only
	due to dispersion

1) spherical aberration.
2) Coma.
3) Astigmatism.
4) field of curvature.
5) Distortion.

(Aberration):- are errors in an image that occur because of imperfection in the optical system.
Aberration result when the optical system misdirect some objects rays.

(chromatic aberration):-
This type of aberration occur with lens only. light wich have many colours like white light and each colour has it's own focus. So each colour has refractive index (Dispersion).
Then from point object of white light, there are many image with different colours lay on the optical axis.
There is no chromatic aberration with mirror because, there is no refraction.

we have Seen earliar that in paraxial ray tracing the angle that the rays sebtend with the optical axis are assumed to be Small (no longer than a few degrees) in this case we have consider :-

$$\sin\theta \cong \tan\theta \cong \theta$$

However, the angle can be larger in case like this the sin of angle:-

$$\sin\theta = \theta - \frac{\theta^3}{3!} + \frac{\theta^5}{5!} - \frac{\theta^7}{7!} + \cdots$$

If we are assume that $\sin\theta = \theta$, then we have first order optics (first order aberration) or Gaussian optics.

If the next term $\frac{\theta^3}{3!}$ is considerd then :-

$$\sin\theta = \theta - \frac{\theta^3}{3!}$$ we have 3rd order optics (aberraition)

Third order aberration Some time is called Sedial aberration.

« Spherical aberration »

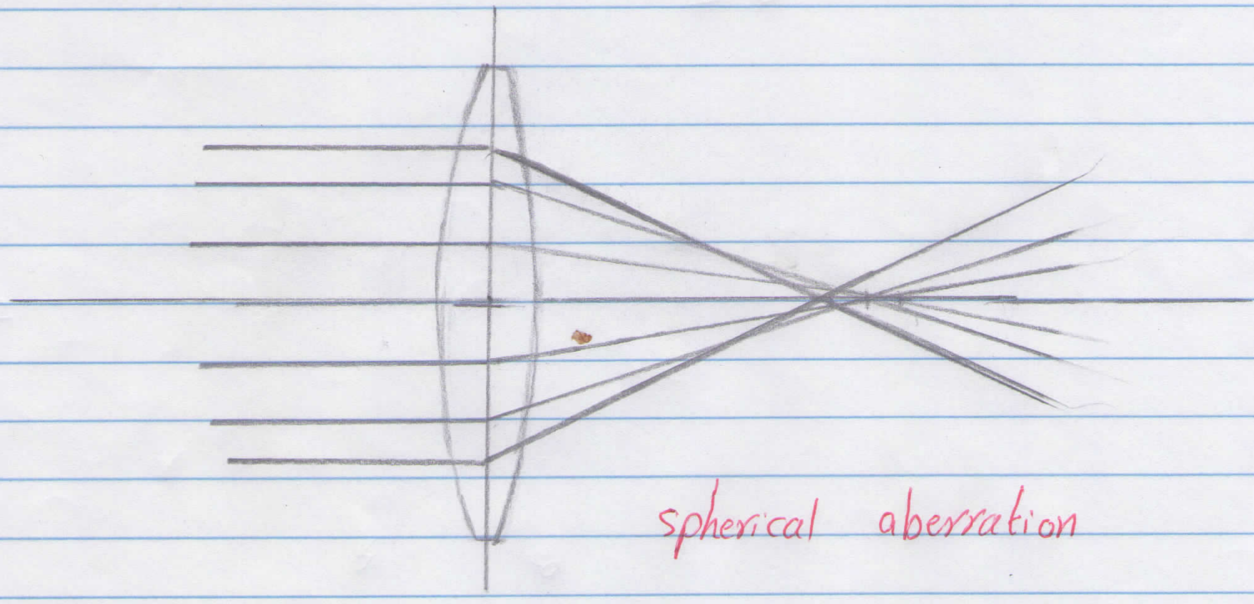
(Spherical aberration on axis aberration) :-

as the paraxial rays confinment, a sharp image of objects at any distance may be formed on a Screen, Since bandles of parallel rays close to the axis and making Small angles with the optical axis are brought to a sharp focus in the focal plane.

If however, the one object point do not come to a focus at a common point and we have undesirable effect Known as Spherical aberration.

Rays passing through points on lens or mirror farther away from axis are refracted or reflected more than those closer to the axis.

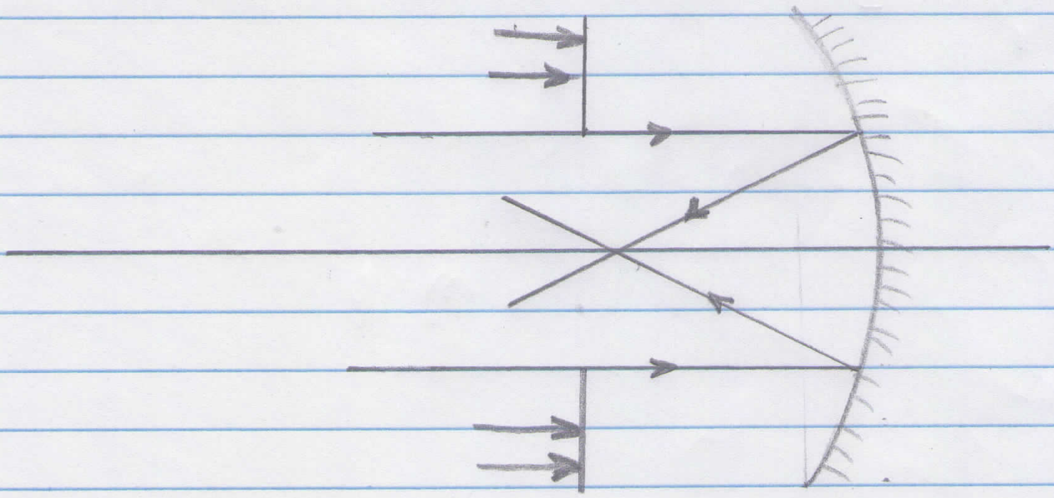
The result is distribution of foci along the optical axis.



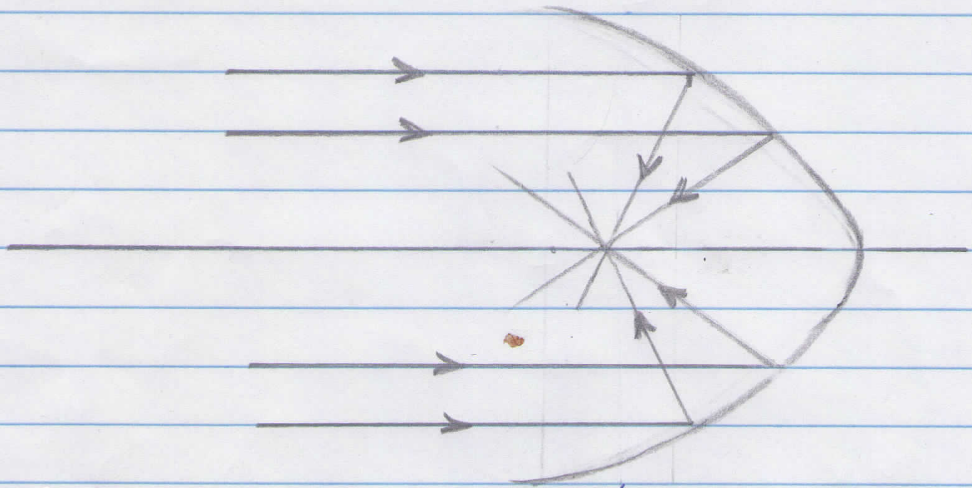
spherical aberration

Correction of mirror Spherical aberration :-

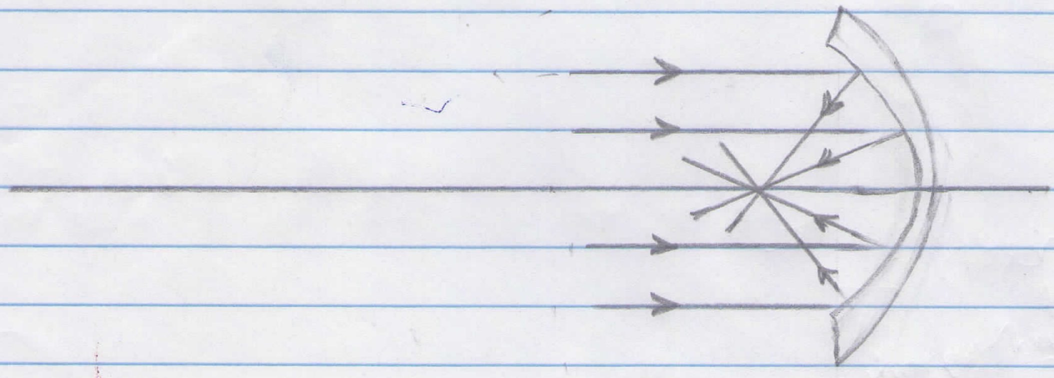
1) By using mask (stop) to limited the paraxial rays only.



2) By using paraboloid mirror, but this type increase astigmatisim.



3) By using Mangen mirror wich is decreased stigmatisim also:



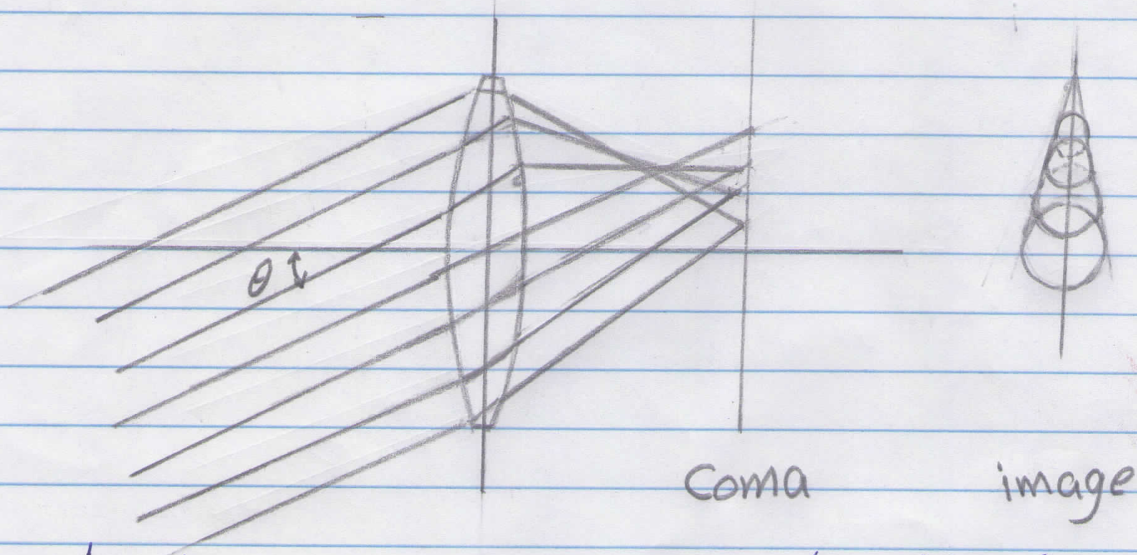
Correction of lens spherical aberration :-

1) By bending the lens to the best form (increasing the radius of curvature).
2) By multiple lenses spherical aberration can be canceled by over correcting Some elements.

3) By using lens with gradding refractive index wich have high n in the center and decreases closer the edges of the lens.
4) By using mask (stop).

Coma of axis aberration:-

coma is an aberration wich causes rays from off axis point of light in the object plane to create trailling " comet like " blur directed away from the optical axis.



when an object is imaged by a lens that suffer from coma, rays that pass through the periphery of the lens from a large image than the ray that pass through the lens closer to the axis.
Correcting for coma requires that the different images are made to overlap.

In effects the image formed by the paraxial and peripheval rays need to experience different degrees of magnification. coma can be minimized by curefully specfying the radii of curvature of the two side of the a single lense or by using combination of optical elements.
when an optical system has no spherical aberration or coma, it called "aplanatic system".

"Astigmatism"

(Astigmatism) :- Defect of image occurs when an object point lies in Some distance from the axis of lens or mirror.
Rays that are emitted from on object point form a right circular cone as they travel towards lens

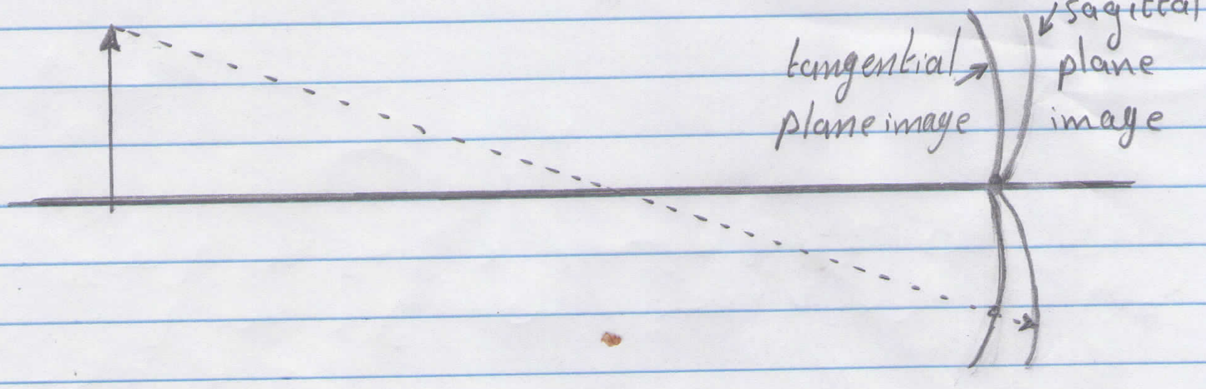
"Astigmatism"

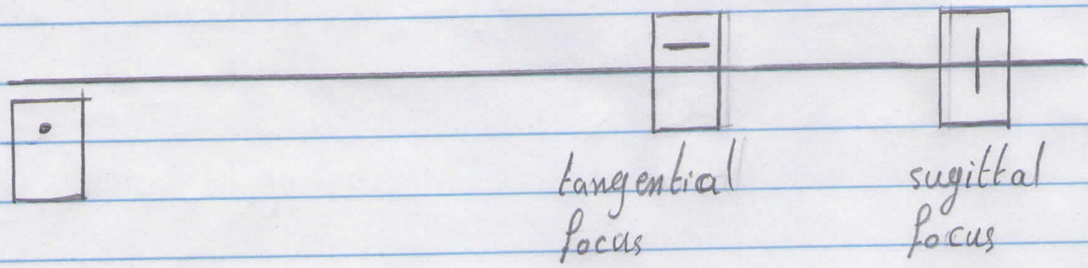
(Astigmatism) :- Defect of image occurs when an object point lies Some distance from the axis of mirror or lens.
With stigmatism the image of a point object is not point image in steade it is two focal line.
when an incident rays making an angle θ with the axis of the mirror or lens, the result is that in steade of point image two mutually perpendicular line of images are formed.
The effect is known as stigmatism.
when rays that are emitted from an object point form a circular cone as they travel towards the lens or mirror.
If the object on the axis, the rays form a circle on the Surface of the mirror or lens.
when the object point is located off-axis the cone of rays form an ellipse on the Surface of the lens or mirror.
- The ray in the tangential plane which contain the plane of incidence which (the point object and the optical axis)
- The other rays in sagittal plane oriented perpendicular to the tangential plane.

Because of the different rays in which they intersect the lens or the mirror, the rays in the tangential plane and the rays in sagittal plane experience different focal length to the Same lens or mirror.
- The effictive lens that the rays in the tangential plane experience has a higher power.

Because of this, the ray in the tangential plane focus closer to the lens or the mirror that the Sagitial plane rays.
location of the image point for the tangential and Sagittal

ray coincide on the optical axis and they diverges for a points farther from the optical axis.



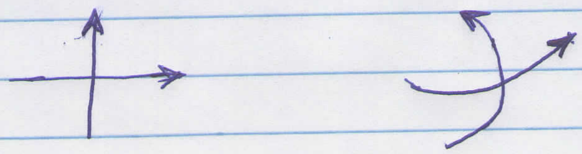


"feild curvature"

In this type aberration a plane object is imaged on curvature, rather than on plane. This is a problem with cameras, cinama and slide projector. In this aberration, the image is not blurred. The curved image field can be flattened by using retraction of lenses.

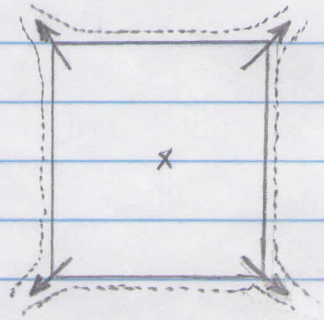
If two lenses are used, their indices of retraction n_1, n_2 and their focal length (f_1 and f_2) must meet the following condition.

$$n_1 f_1 + n_2 f_2 = 0$$

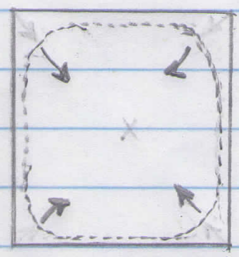


„Distortion„

when the image is suffered from distortion, the image points are displaced radially from the positions predicted when paraxial rays are traced through the optical system.
The image points may be displaced either towards or away from the optical axis, The various parts of object experience different magnification. with distortion the image is not blurred.
In pincushion distortion the magnification increase in the edage of the image



pencushion distortion stretches the image of square at the corners.



Barrel Distorshion stretches the corners of the an image of square toward the center

In the barrel distorshions the magnification decreases along the indicated directions
The image of Square suffering from barrel distortion would be characterized by retraced corners.