> Upload your finished worksheet as a single pdf file on moodle before the next class session in order to get participation credit.
> Try to keep your books closed. Discuss with your fellow students to come to an answer. Show your work.

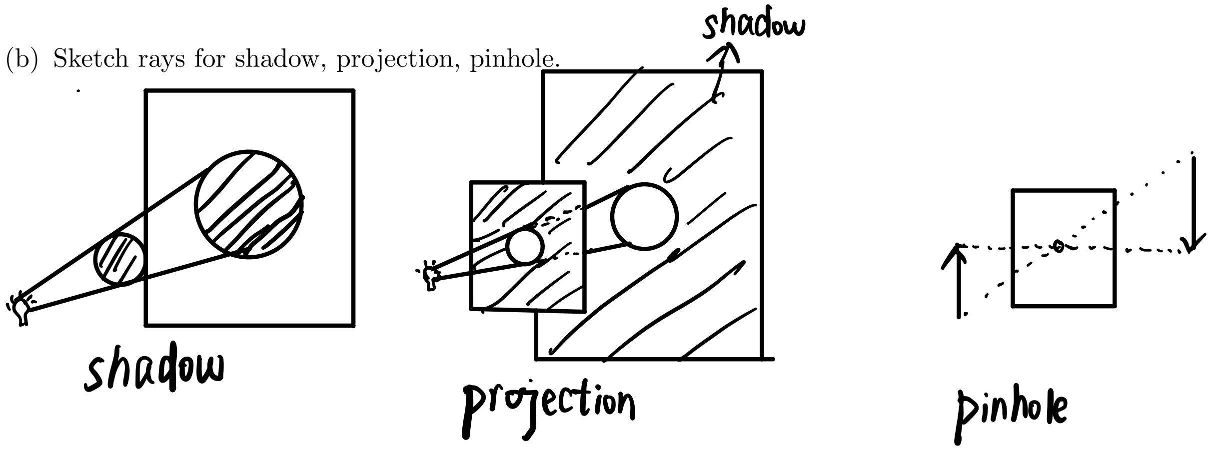
Name:

1. Ray Optics

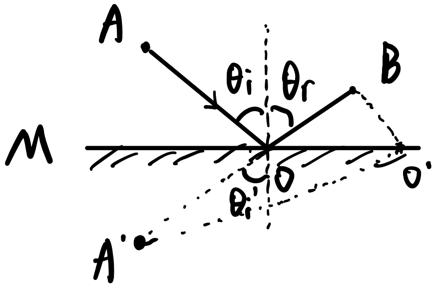
(a) Describe Fermat's principle.

Light travels between two points along the path that requires the least time, as compared to other nearby paths

(b) Sketch rays for shadow, projection, pinhole.



(c) For a reflection from a mirror, the angle of incidence equals the angle of reflection. Sketch and argue this law based on Fermat's principle.

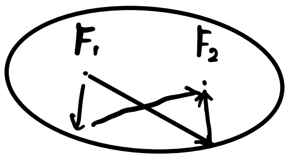


A. B are two random points on same side of the mirror. M. A and A' are symmetric about M. A'OB is shorter than any A'O'B

$\theta_i = \theta_i' = \theta_r$.

(d) In your experiment you want to collect light from your source with a small volume S in your detector in point P. What optical element (mirror) do you use to collect the light efficiently?

Elliptical Mirror

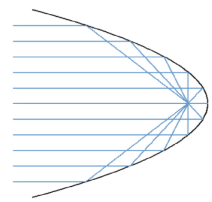


Focus all light from F_1 to F_2 after one reflection event

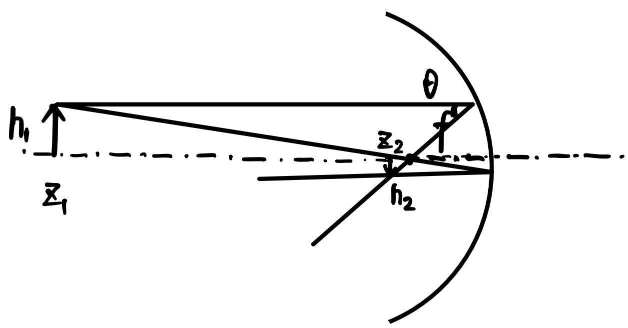
Think about it in terms of focal spots. Sketch.

(e) You want to collect sunlight and focus it in a heat absorber for solar energy applications. What optical element (mirror) do you use. Sketch.

Parabolic Mirror : Focus parallel light to focal point.



(f) You have an object ↑ at a distance z_1=300 mm from a spherical mirror with a radius r=100 mm. Where is the image formed. What is the magnification? If your object is 20 mm tall, do you get a good image? Sketch.



$f = \frac{1}{2} r = 50mm$

$\frac{1}{z_1} + \frac{1}{z_2} = \frac{1}{f}$.

$z_1 = 300mm$ so $z_2 = 60mm$.

$Mag = -\frac{z_2}{z_1} = -\frac{1}{5}$ (or simply $\frac{1}{5}$)

$h_1 = 20mm$, $h_2 = 4mm$

$\theta \approx \arctan\left(\frac{h_1 + h_2}{z_2}\right) = \arctan(0.4)$

Paraxial approximation ($\sin\theta \approx \theta \approx \tan\theta$) is not well satisfied

→ Not a good image

2. Wave optics

(a) In the Fresnel approximation a light wave is described by

$$U(r) = \frac{A_o}{z} exp[-ikz] exp[-ik\frac{x^2+y^2}{2z}] \quad (1)$$

i. Under which boundary conditions is the Fresnel approximation applicable?

$z^2 \gg x^2+y^2$ or $\theta^2 = \frac{x^2+y^2}{z^2} \ll 1$

Close to the axis and far from the source.

Remark: $z^2 \gg x^2+y^2$ and $z \gg \sqrt{x^2+y^2}$ actually are two different scale requirements for x, y, z

(For some of you using $z \gg \sqrt{x^2+y^2}$ instead of $z^2 \gg x^2+y^2$)

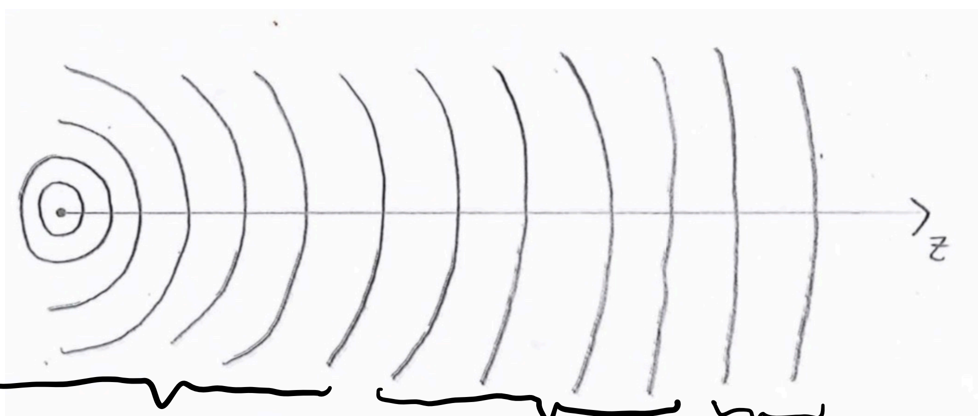
ii. Discuss the different terms in U(r) as a function of z.

$\frac{A_0}{z}$: Amplitude: decay with distance at the speed of $1/z$

$exp[-ikz]$: planar wave

$exp[-ik\frac{x^2+y^2}{2z}]$: parabolic wave

iii. Sketch the wavefront as function of z.



$\underbrace{\hspace{3cm}}$ spherical wave

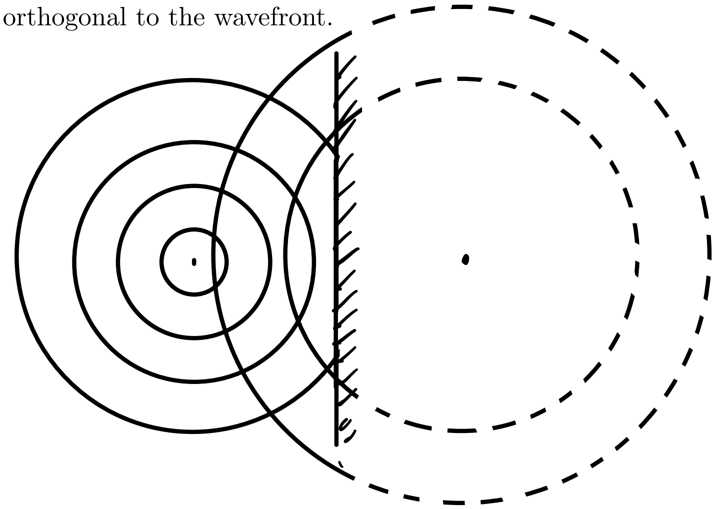
$\underbrace{\hspace{3cm}}$ parabolic wave

condition: $z^2 \gg x^2+y^2$

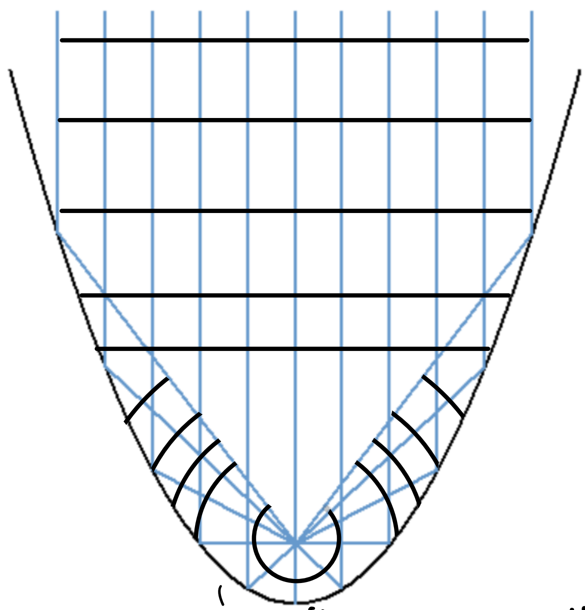
$\underbrace{\hspace{1cm}}$ planar wave

condition: (optional) $k \cdot \frac{x^2+y^2}{2z} \ll 1$ or $z \cdot \lambda \gg x^2+y^2$ (λ is wavelength)

(b) Sketch the wavefront of a spherical wave reflecting from plane mirror. Remember that the optical rays are orthogonal to the wavefront.



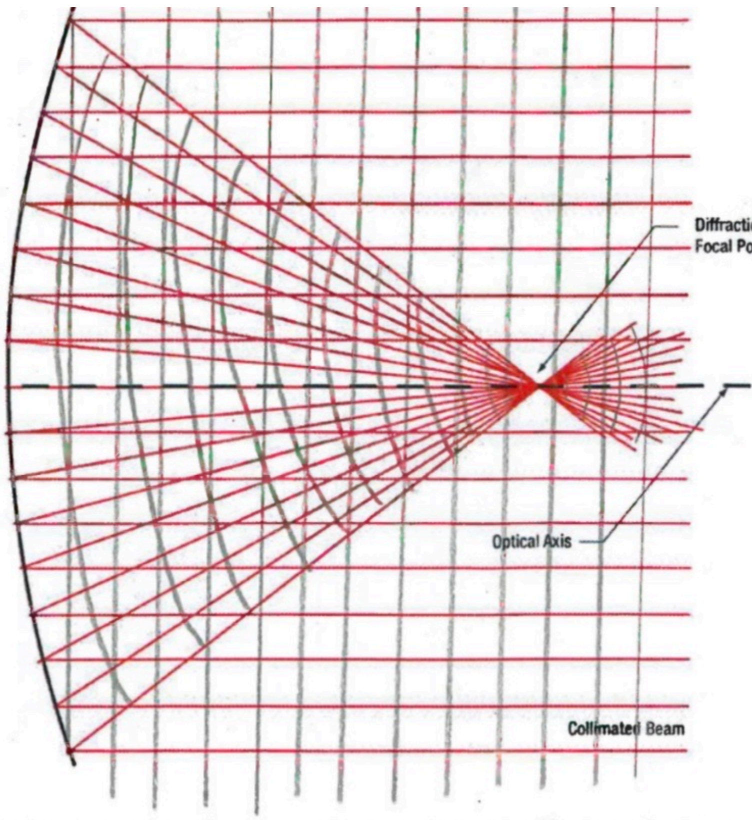
(c) Sketch a plane wave from a parabolic mirror. Compare to a spherical mirror. What is the difference?



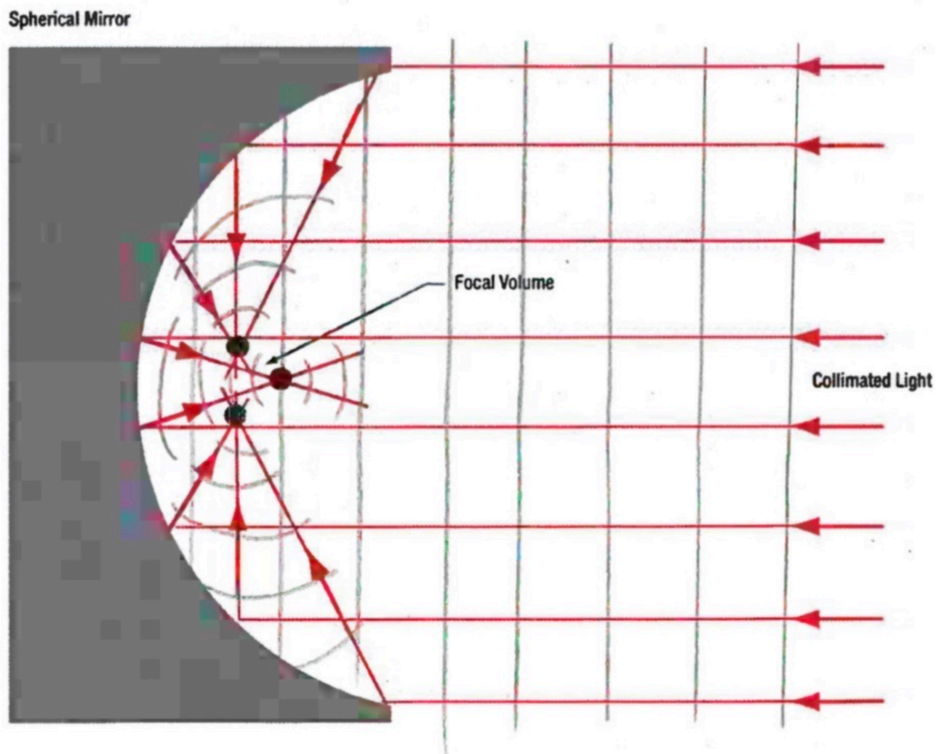
Remark:

Use wave front that's perpendicular to the propagation direction to dipict the process. Important thing to know is that after reflection and before focus. waves are converging spherical wave.

The End.



A parabolic mirror only has one focal point. Hence the wavefronts form a parabolic shape that slowly shrink and close in on the focus.



However, for a spherical mirror, the focal point at r/2 is only valid for paraxial rays. There exist other focal points for rays that hit the mirror far from the optical axis.

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