

Lecture # 33

Applied Optics

2

Interference

f number - focal length/lens diameter (adjusted by diaphragm)
depth of field - range of object distances to achieve focusing

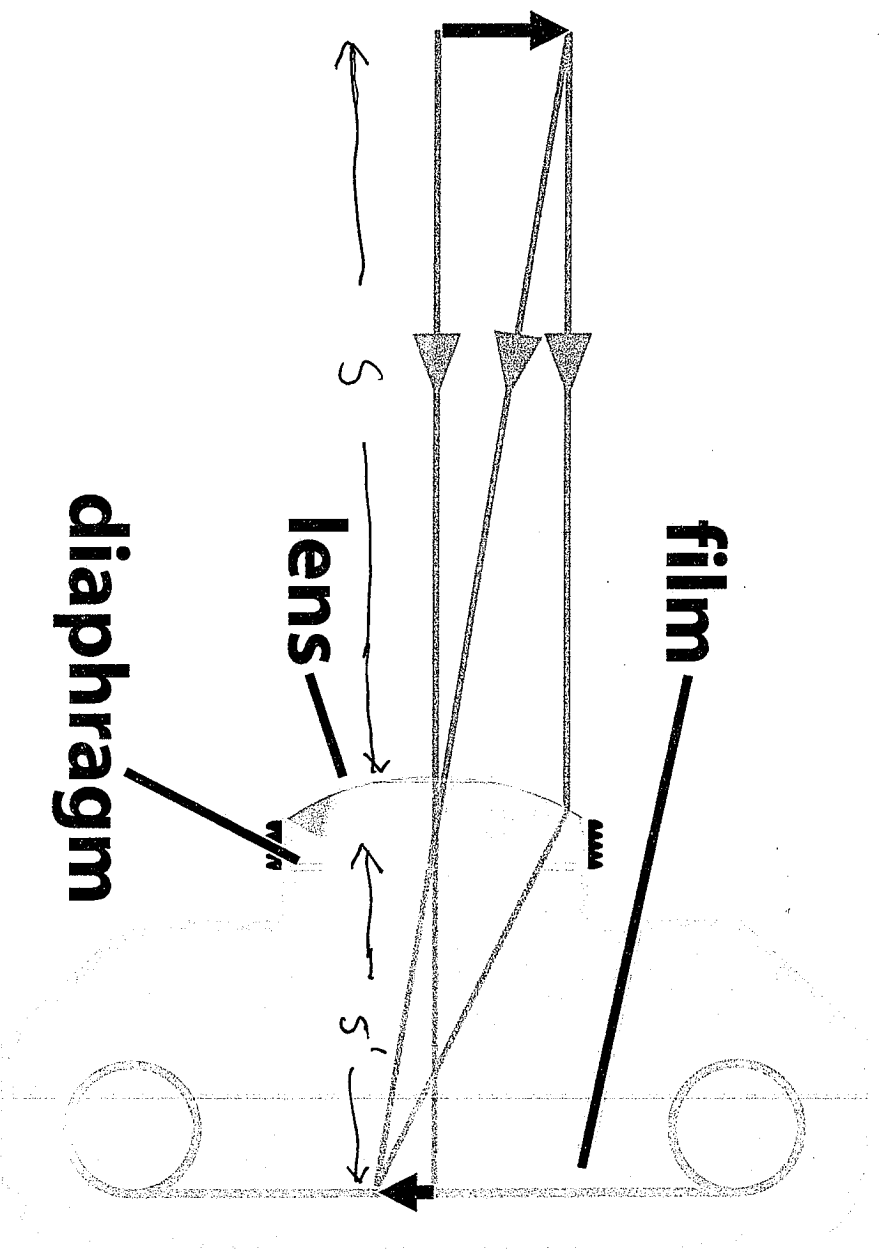


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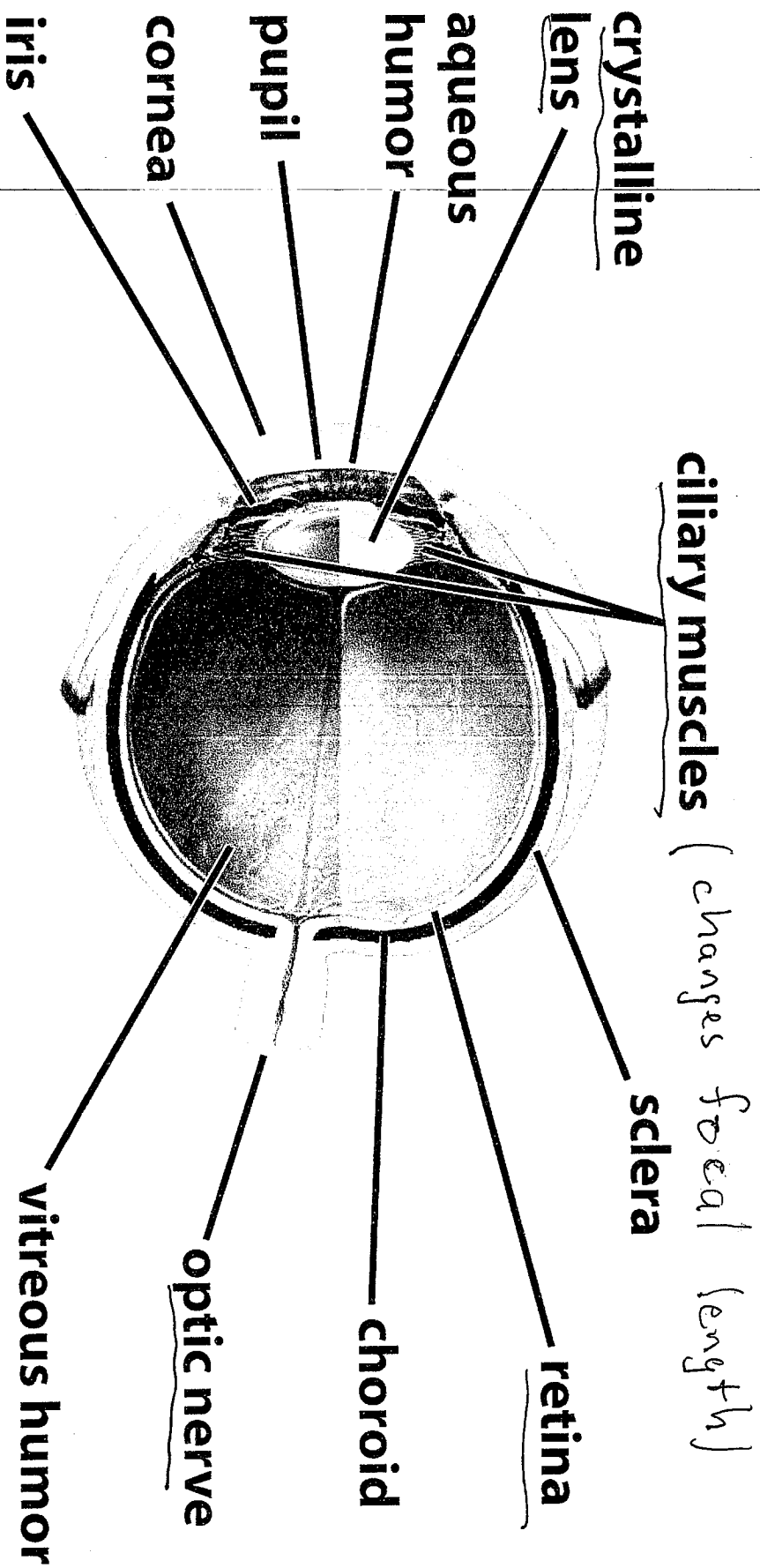
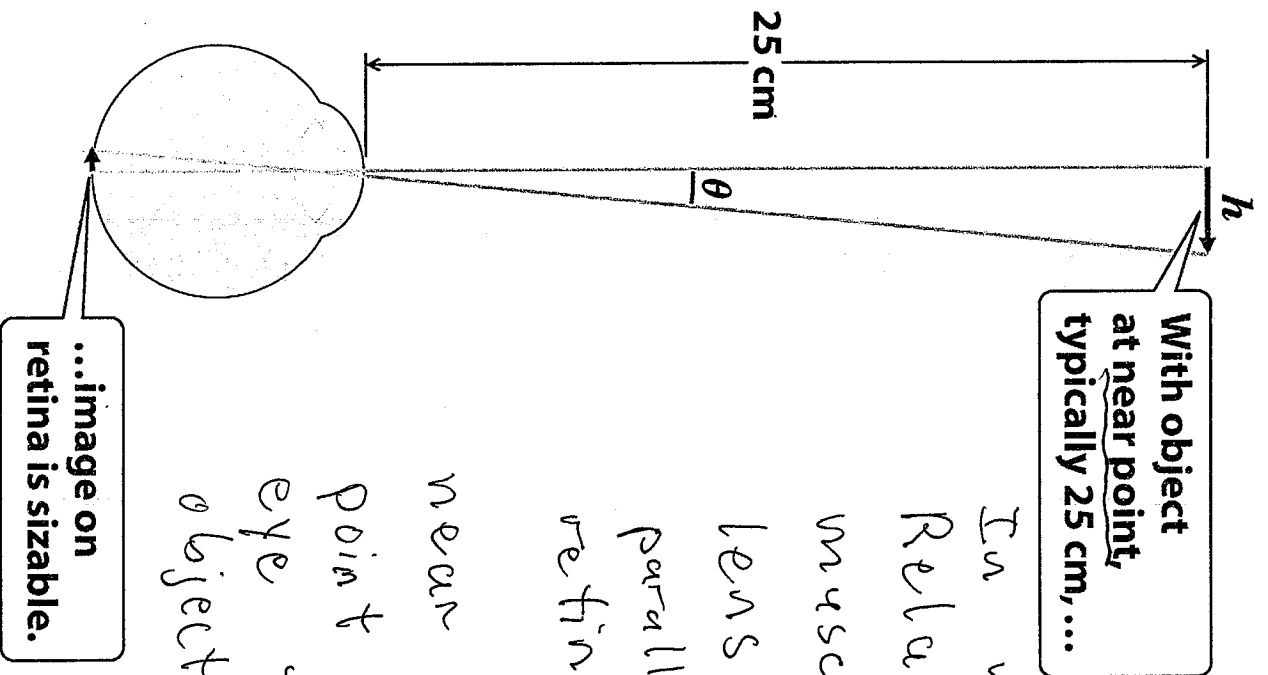


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Normal Eye



In normal eye
Relaxed ciliary
muscles allows
lens to focus
parallel light on
retina

near point. Closest
point that allows
eye to focus on
object

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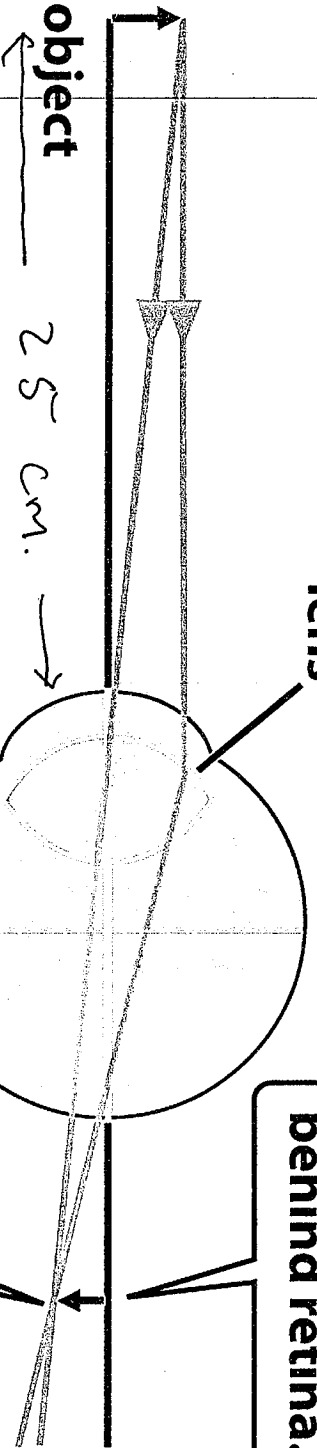
FAR-sightedness (near point > 25 cm)

(a)

"contracted" lens

Image forms behind retina.

To correct farsightedness...



(a) $f = 25 \text{ cm}$

(b) $f = 50 \text{ cm}$

(c) $f = 100 \text{ cm}$ (b)

...a converging eyeglass or contact lens shifts image to retina.

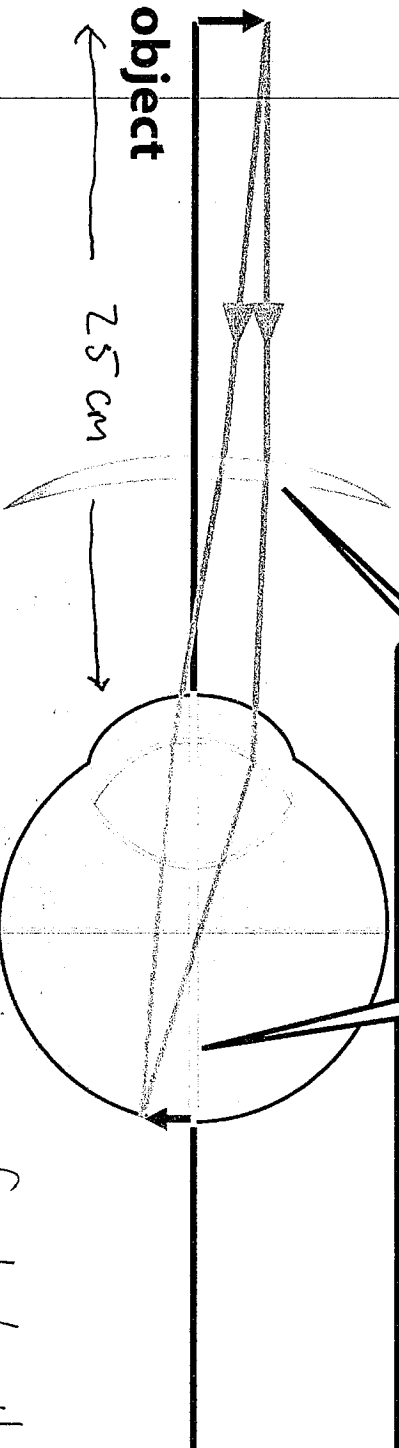
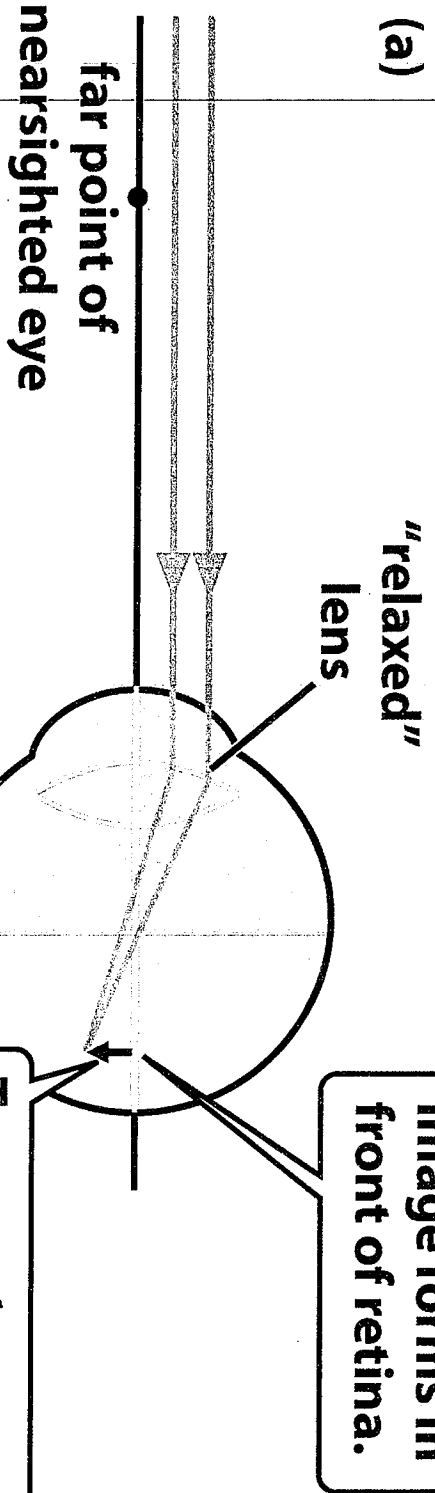


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If near point 50 cm, what is focal length of lens?

Near sightedness



(a) $f = -5\text{m}$

(b) $f = -10\text{m}$

(b)

(c) $f = -50\text{mm}$

(d) $f = -2\text{m}$

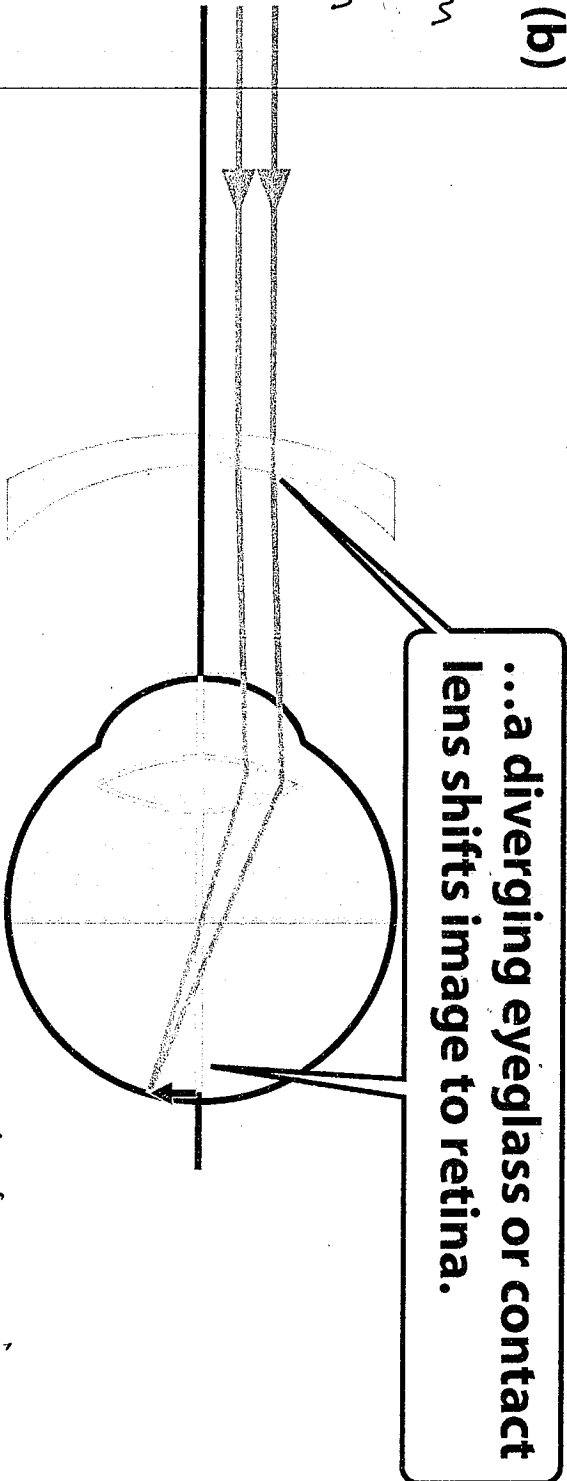


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If Far point is what focal length of lens?

10.1m, 5.

Magnifier

Eye sees object, of height h_1 at 25 cm, with angular width

$$\theta \equiv \Delta\theta_{25} = \frac{h}{25}$$

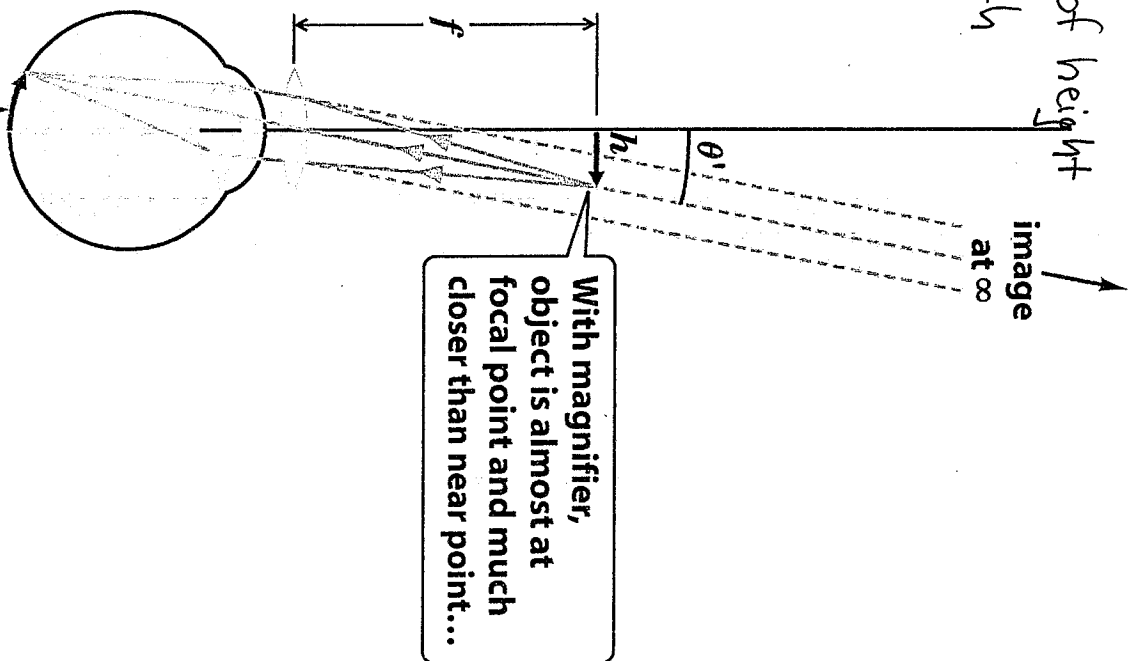
If object placed near focal point of lens, virtual image at infinity subtends angle

$$\theta' \equiv \Delta\theta_{\text{image}} = \frac{h}{f}$$

Angular Magnification

$$M \equiv \frac{\Delta\theta_{\text{image}}}{\Delta\theta_{25}} = \frac{h/f}{h/25} = \frac{25}{f}$$

$$\text{True Magnification for sight} = \frac{25}{f}$$

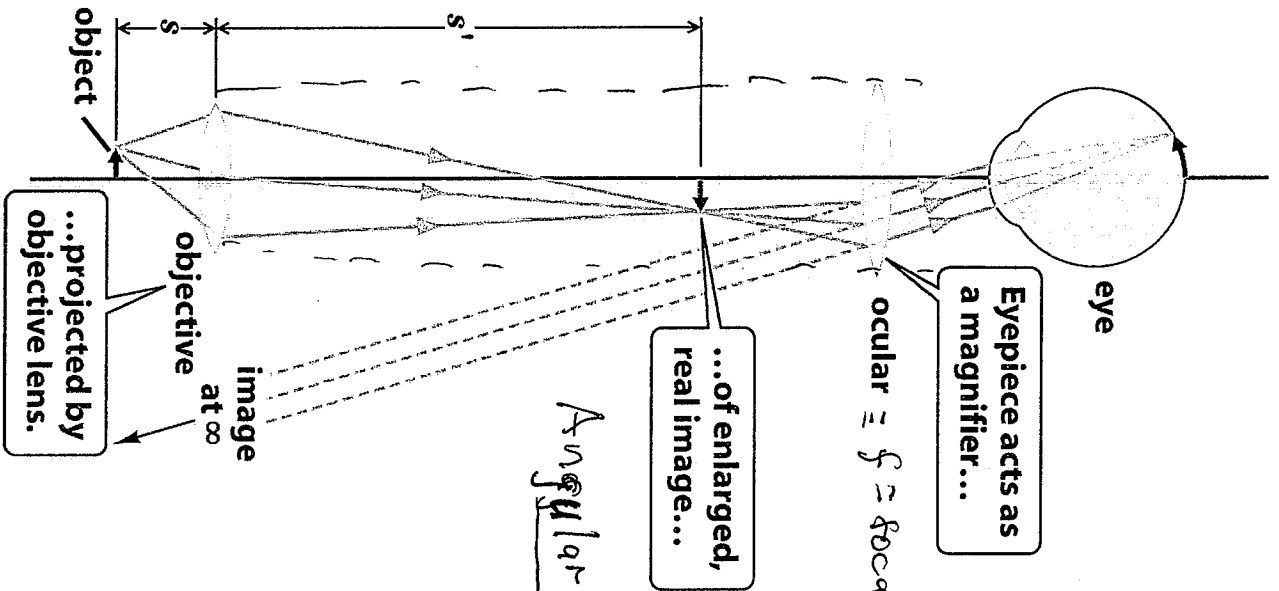


With magnifier, object is almost at focal point and much closer than near point...

...so that image on retina is enlarged.

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Microscope



ocular = f = focal length

...of enlarged, real image...

Angular Magnification

$$M_{\text{ang}} = \frac{-s'}{s} \approx \frac{25}{f}$$

Telescope

Angular Magnification

$$M_{\text{mag}} = \frac{\theta'}{\theta} = \frac{FP/FB}{FP'/f_{\text{obj}}} = \frac{f_{\text{obj}}}{FB} = \frac{f_{\text{obj}}}{f_{\text{ocular}}}$$

$FB = f_{\text{ocular}}$

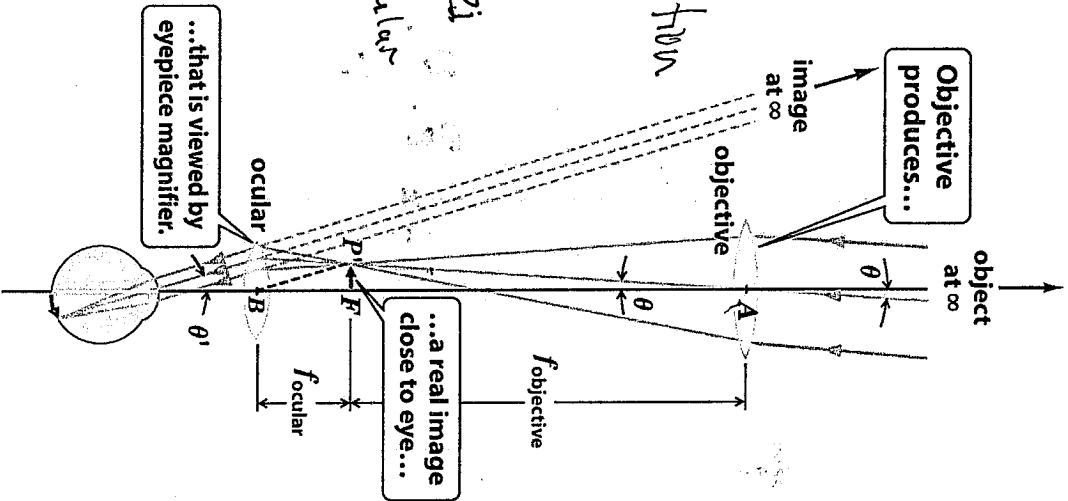


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Handwritten notes:
 $M = \frac{\theta'}{\theta} = \frac{f_{\text{obj}}}{f_{\text{ocul}}}$
 ... a real image close to eye ...
 ... that is viewed by eyepiece magnifier ...

Handwritten initials: J.D.

Mirror Telescope

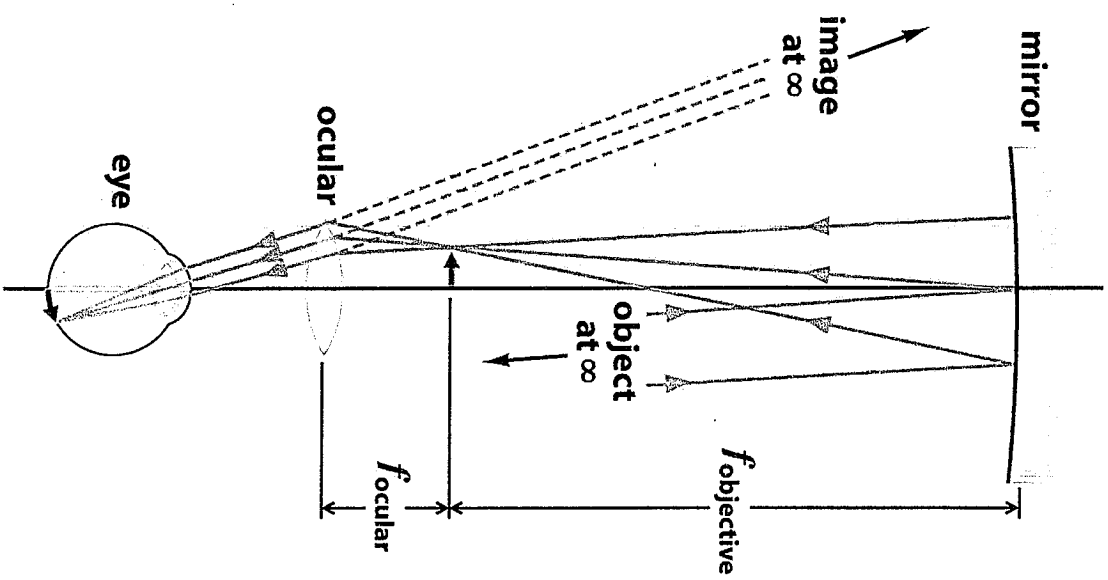


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$$M_{ang} = \frac{f_{obj}}{f_{ocular}}$$

Consider two beams
with electric field

$$\vec{E}_1 = \vec{E}_0 \cos(\omega t - kr + \phi)$$

$$\vec{E}_2 = \vec{E}_0 \cos(\omega t - kr - \phi)$$

The intensity of \vec{E}_1 is proportional
to $|\vec{E}_0|^2$; $I_1 = \alpha |\vec{E}_0|^2$ ($I = \frac{\vec{E} \times \vec{B}}{\mu_0}$)

and intensity of \vec{E}_2 is also
proportional to $|\vec{E}_0|^2$

specifically $I_2 = \alpha |\vec{E}_0|^2$

$$\left(\alpha = \frac{c \epsilon_0}{2} \right) = \left(\frac{\epsilon_0}{\mu_0} \right)^{1/2} / 2 \quad c = \frac{1}{\sqrt{\epsilon_0 \mu_0}}$$

Thus $I_1 + I_2$

Now consider the intensity of

$$\vec{E}_{12} = \vec{E}_1 + \vec{E}_2 = \vec{E}_0 \cos(\omega t - kr + \phi) + \vec{E}_0 \cos(\omega t - kr - \phi)$$

What is the intensity of \vec{E}_{12}

(1) $2|\vec{E}_0|^2 \alpha$, (2) $|\vec{E}_0|^2 \alpha$, (3) $4|\vec{E}_0|^2 \alpha$

(4) 0 (5) $0 \leq I_{12} \leq 4\vec{E}_0^2 \alpha$

$$\vec{E}_1 + \vec{E}_2$$

$$= \hat{E}_0 \cos(\omega t - kr + \phi) + \hat{E}_0 \cos(\omega t - kr - \phi)$$

$$= \hat{E}_0 \left\{ \begin{array}{l} \cos(\omega t - kr) \cos \phi - \sin(\omega t - kr) \sin \phi \\ \cos(\omega t - kr) \cos \phi + \sin(\omega t - kr) \sin \phi \end{array} \right\}$$

$$= 2 \hat{E}_0 \cos(\omega t - kr) \cos \phi$$

$$I_{12} = 4 \hat{E}_0^2 \cos^2(\omega t - kr) \cos^2 \phi$$

$$= 4 \hat{E}_0^2 \frac{1}{2} \cos^2 \phi$$

$$\overline{I_1} = \frac{\hat{E}_0^2}{2}, \quad \overline{I_2} = \frac{\hat{E}_0^2}{2}$$

$$\overline{I_{12}} = 2 \hat{E}_0^2 \cos^2 \phi$$

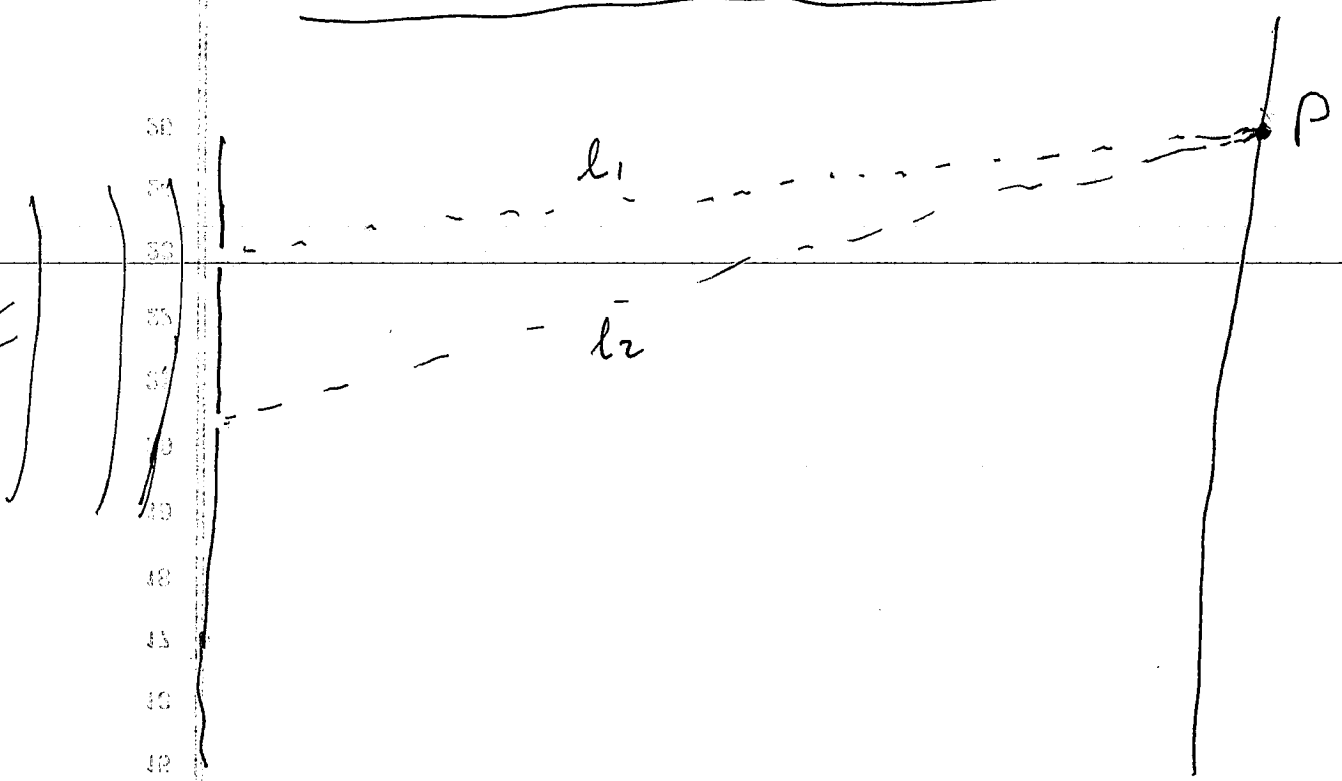
$$\phi = (n + \frac{1}{2})\pi, \quad 0 \leq 2 \hat{E}_0^2 \cos^2 \phi \leq 4 \left(\frac{\hat{E}_0^2}{2} \right), \quad \phi = n\pi$$

$\phi = n\pi$ constructive interference

$\phi = (n + \frac{1}{2})\pi$ destructive interference

Interference from two slits

CHEMISTRY
 PHYSICS
 HONORS IN 1955



Young's Slit Experiment

$$E_{12} = E_0 \cos(\omega t - k l_1) + E_0 \cos(\omega t - k l_2)$$

$$= E_0 \left[\cos(\omega t - k \frac{l_1+l_2}{2}) - k \frac{l_1-l_2}{2} \right] + \cos(\omega t - \frac{k l_1+l_2}{2} + \frac{k l_1-l_2}{2})$$

$\underbrace{\hspace{10em}}_A \qquad \qquad \qquad \underbrace{\hspace{10em}}_{\phi = \beta} \qquad \qquad \qquad \underbrace{\hspace{10em}}_{\phi}$

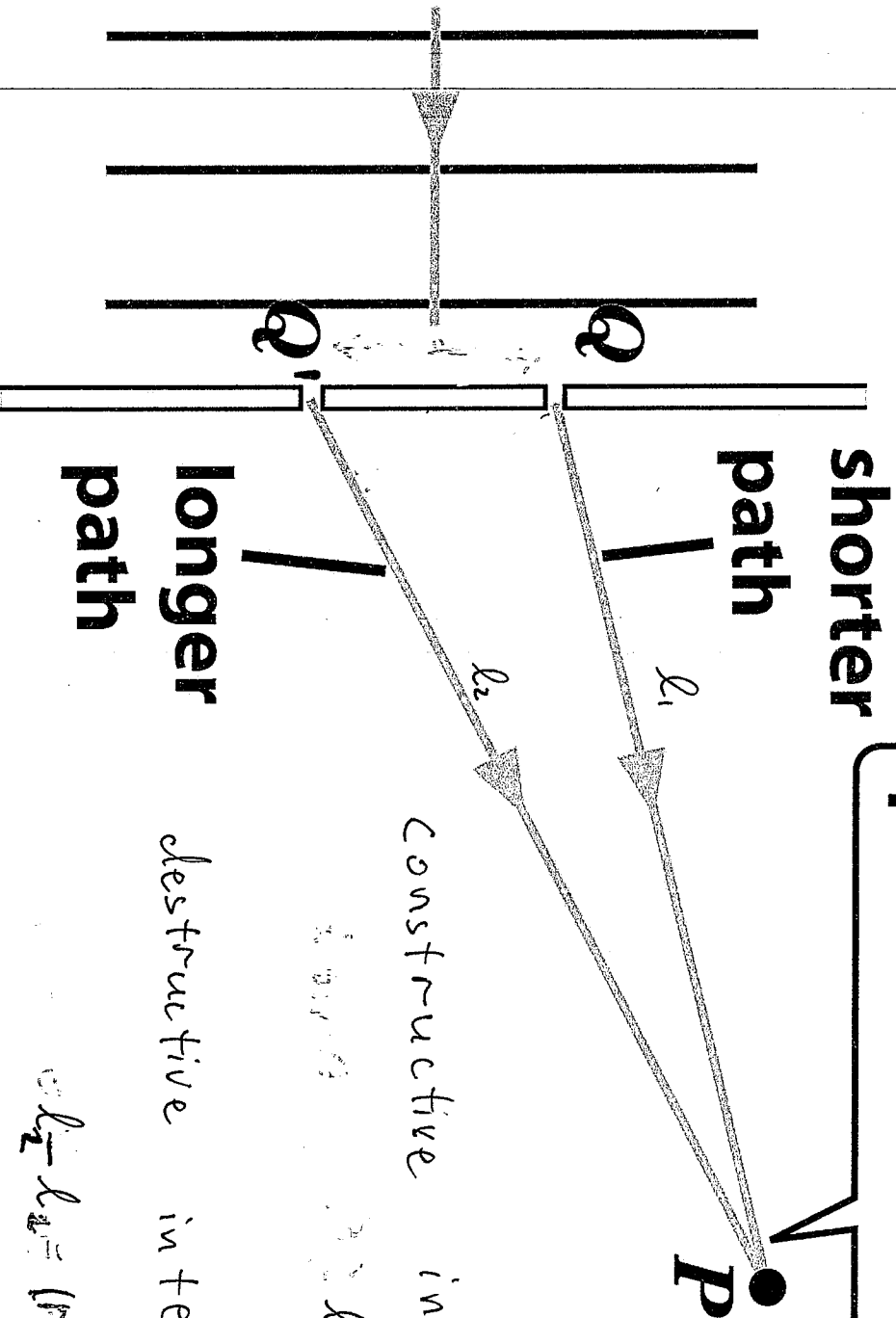
if $\phi \equiv k \frac{l_1-l_2}{2} = n\pi$; constructive interference

as $k = \frac{2\pi}{\lambda}$, $\frac{l_1-l_2}{\lambda} = n$

constructive interference $l_1-l_2 = n\lambda$

similarly; destructive interference if $\phi \equiv k \frac{l_1-l_2}{2} = (n + \frac{1}{2})\pi \Rightarrow l_1-l_2 = (n + \frac{1}{2})\lambda$

**Interference at P
is determined by
path difference.**



constructive interference

$$l_2 - l_1 = n\lambda$$

destructive interference

$$l_2 - l_1 = (n + \frac{1}{2})\lambda$$

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constructive
interference

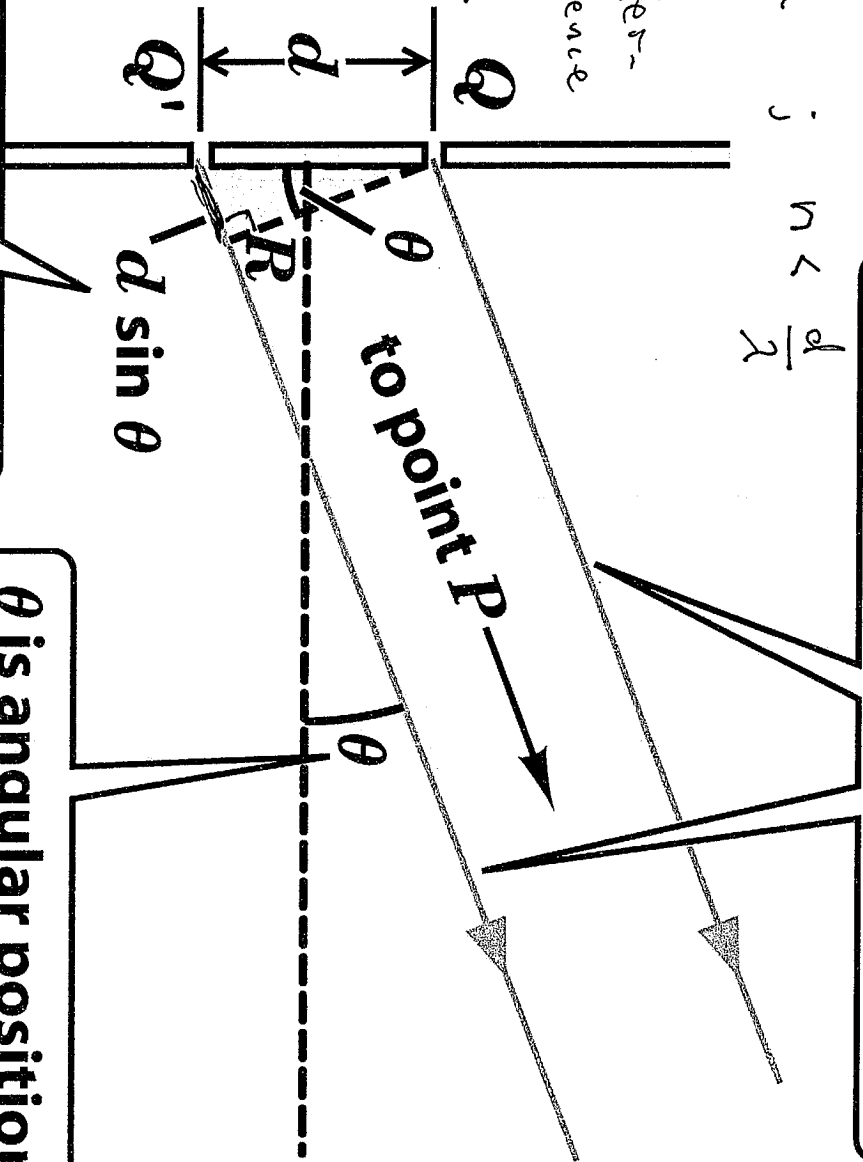
$$d \sin \theta = n \lambda ; n < \frac{d}{\lambda}$$

destructive
interference

$$d \sin \theta = (n + \frac{1}{2}) \lambda$$

$$n + \frac{1}{2} < \frac{d}{\lambda}$$

For a faraway point P , rays from slits are nearly parallel.



$d \sin \theta$ is path difference to P .

θ is angular position of point P with respect to midline.

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