Nelson 7.1

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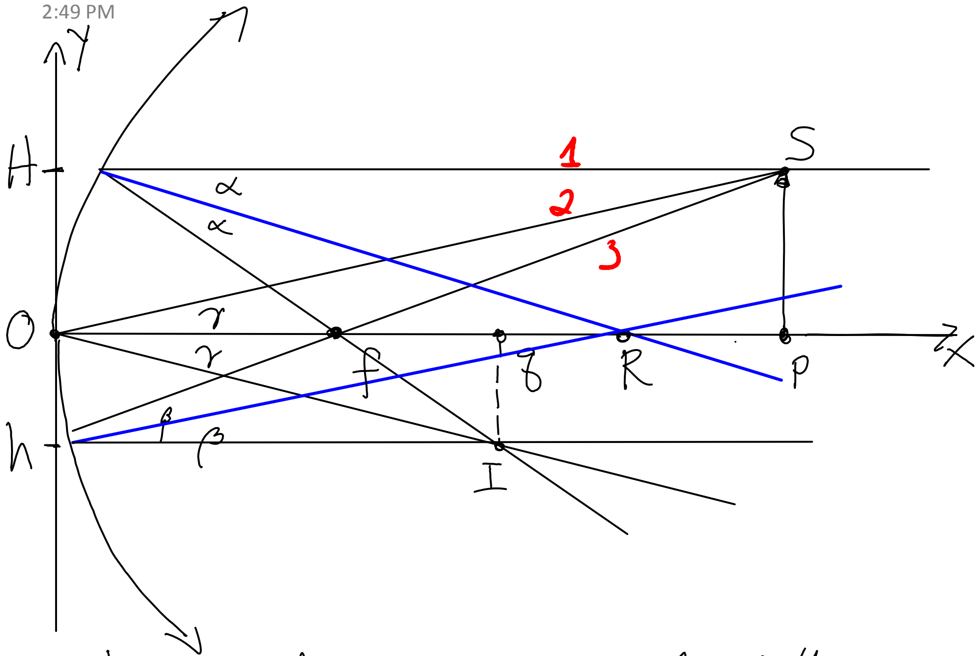

1st mark all distances & angles of the 3 principal rays and use the points S, I, O to mark the source, image & origin.

$$\tan\alpha = \frac{H}{R}, \tan(2\alpha) = \frac{H}{f} = \frac{2\tan\alpha}{1-\tan^2\alpha}$$

$$y_{\alpha S}(x) = H$$

$$y_{\alpha R}(x) = \frac{-H}{R}x + H$$

$$y_{\alpha I}(x) = -\frac{H}{f}x + H$$

$$\tan\gamma = \frac{H}{p} = \frac{h}{q}$$

$$y_{\gamma I}(x) = -\frac{H}{p}x = -\frac{h}{q}x$$

$$y_{\beta I}(x) = -h$$

set $Y_{\alpha I}(x_h) = -h = -\frac{H}{f}x_h + H$

set $Y_{\alpha I}(x_h) = -h = -\frac{H}{f}x_h + H$

$$-h - H = -\frac{H}{f}x_h$$

$$\frac{fh}{H} + f = x_h$$

set $Y_{\gamma I}(x_h) = -h = -\frac{H}{P}x_h$

$$x_h = +\frac{hP}{H}$$

for them to converge

$$\frac{fh}{H} + f = \frac{hP}{H}$$

$$\frac{h}{H} = \frac{q}{P}, \quad f = \frac{1}{2}R$$

$$\frac{Rq}{2P} + \frac{1}{2}R = \frac{q\cancel{P}}{\cancel{P}}$$

$$\frac{1}{2}R\left(1 + \frac{q}{P}\right) = +q$$

$$\boxed{\frac{2}{R} = \frac{1}{q} + \frac{1}{P}}$$

Nelson 7.2

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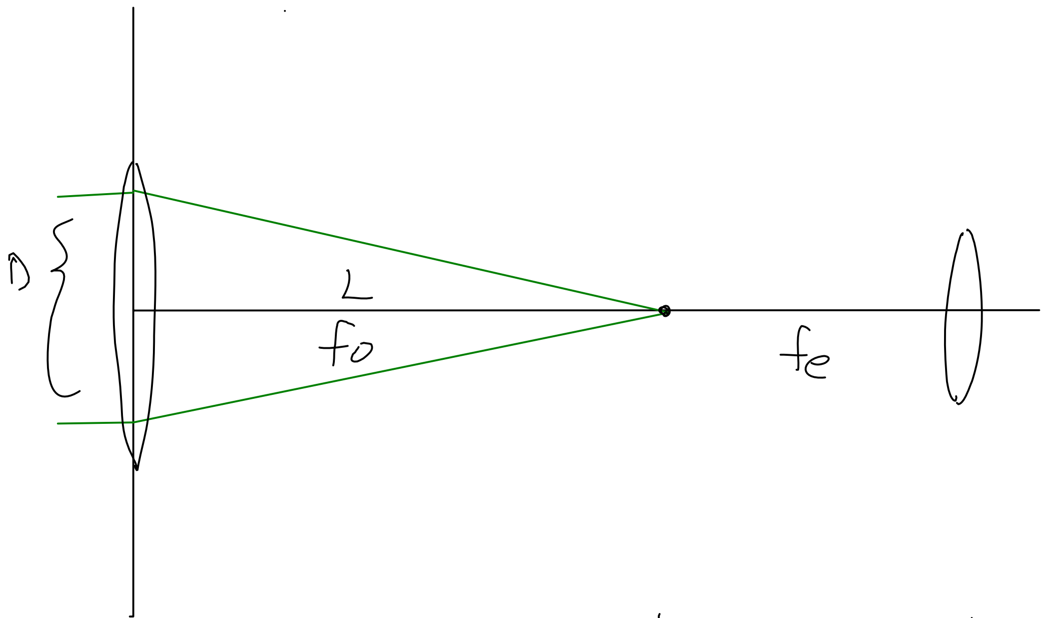

The diffraction limit can be estimated by

$$\frac{D}{L} = \frac{\lambda}{d}$$

D = diameter of telescope
L = focal length
$\lambda \cong 500\,nm$.

$$d = \frac{500 \times 10^{-7}\,cm \cdot \cancel{50}0\cancel{cm}}{\cancel{5}\,\cancel{cm}}$$

$$\boxed{= 5 \times 10^{-4}\,cm}$$

$$M = \frac{f_o}{f_e} = 10 \rightarrow \boxed{f_e = 5\,cm}$$

Crawford 9.32

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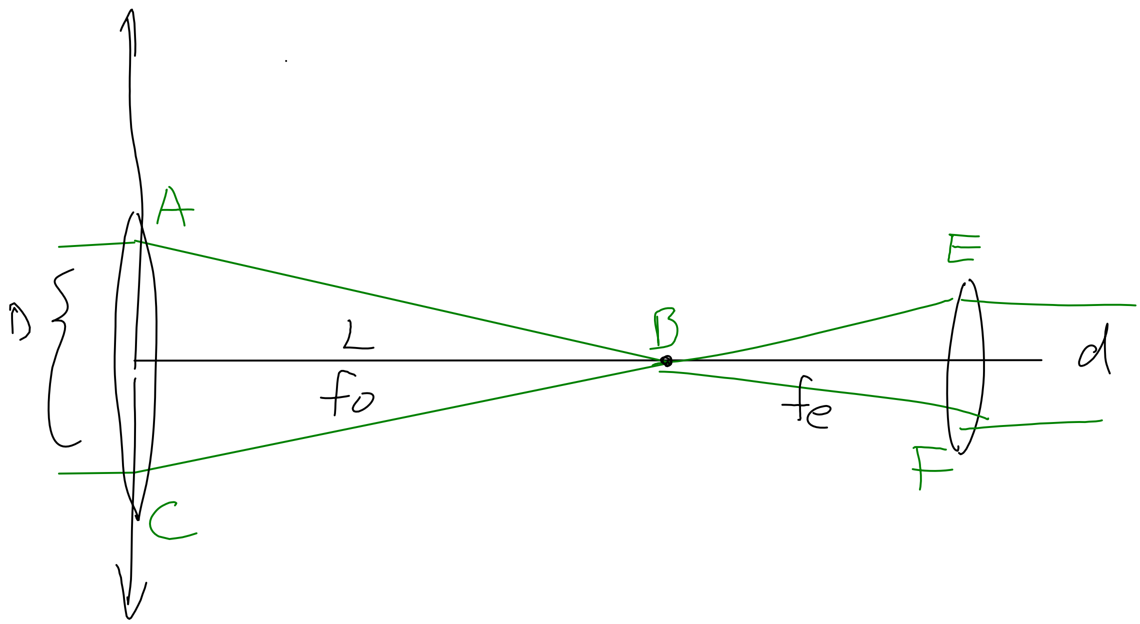

$\triangle ABC \cong \triangle BEF$

$$\frac{D}{f_o} = \frac{d}{f_e}$$

$$D = \frac{d\, f_o}{f_e}$$

d = diameter of pupil since all ray from telescope are parallel
Anything larger will not be seen by the naked eye.

Crawford 9.60

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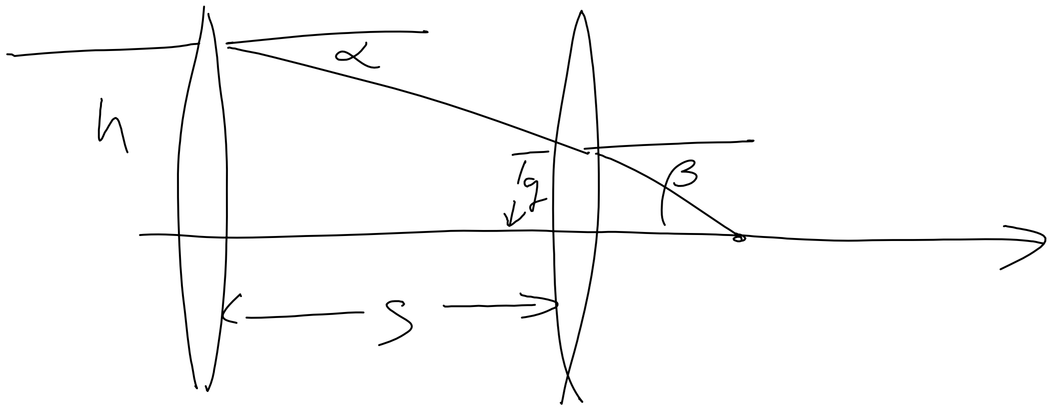

$$\alpha \simeq \frac{h}{f_1}$$

$$\beta \simeq \frac{g}{f_2}$$

$$\frac{h}{F} = \tan(\alpha+\beta).$$

$$\simeq (\alpha+\beta)$$

$$F = \frac{h}{\frac{h}{f_1} + \frac{g}{f_2}} = \frac{\cancel{h}}{\frac{\cancel{h}}{f_1} + \frac{\cancel{h}\left(1-\frac{s}{f_1}\right)}{f_2}}$$

$$g = h\left(1 - \frac{s}{f_1}\right)$$

$$\boxed{F = \frac{1}{\frac{1}{f_1} + \frac{1}{f_2} - \frac{s}{f_1 f_2}}}$$

$$\boxed{\bar{F} = \frac{1}{\frac{1}{f_1} + \frac{1}{f_2} - \frac{S}{f_1 f_2}}}$$

for 1-convergent & 1-divergent

$f_2 \to -f_2$

$$\boxed{\bar{F} = \frac{1}{\frac{1}{f_1} - \frac{1}{f_2} + \frac{S}{f_1 f_2}}}$$

if $f_2 = f_1$

$$\boxed{\bar{F} = \frac{f_1^2}{S}}$$

Andersen 3.5 a

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positronium muonium

$\overset{\circ}{e^+}$ $\overset{\circ}{e^-}$ $\overset{\circ}{p}$ $\overset{\circ}{\mu^-}$

Positronium

$$E = -\frac{\mu(Ze^2)^2}{2n^2\hbar^2}$$

$$\mu = \frac{m_0^2}{2m_0} = \frac{1}{2}m_0$$

$$E = -\frac{m_0}{4}\frac{e^4}{n^2\hbar^2}$$ $r_n = 2r_{n\,Hydro} = 1.06\,\text{Å}$

$$= +\frac{1}{2}E_{n\,Hydrogen}$$

muonium

$$\mu = \frac{207 m_0\, 1836 \cancel{m_0}}{2043\cancel{m_0}}$$

$$= 186\ m_0$$

$$\boxed{E_n = 186\,E_{n\,Hydrogen}}$$

$$\boxed{r_n = \frac{1}{186} r_{n\,\text{Hydrogen}}.}$$

Andersen 3.6

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1^{st} excited state is $n=2$
transition to $n=1$ state

Energy emitted $= W = E_2 - E_1$

$$\mu = \frac{208 m_p m_\mu}{208 m_p + m_\mu}$$

$$= \frac{(208)(1836)(207) m_0^{\cancel{2}}}{\cancel{m_0}((208)(1836) + (207))}$$

$$= 206.89 m_0 \approx m_\mu$$

due to the fact that $m_{pb} >> m_\mu$.

$Z_{pb} = 82$

$$E_N = +(82)^2 (207)(E_N \text{ Hydrogen})$$

$$W = \frac{3}{4}(E_1) = \frac{3}{4}(82)^2(207)(13.6 \text{ eV})$$

$$\boxed{= 14.2 \text{ MeV}}$$

b) $W_{meas} = 5.963 \text{ MeV}$

b) $W_{meas} = 5.963\,\mathrm{MeV}$

i) size of nucleus

$$r_0 \sim \frac{0.53\,\text{Å}}{(207)(82)} = 3\,\mathrm{fm}$$

radius of nucleus $r_A = A^{1/3} r_{proton}$

$r_{proton} = 1\,\mathrm{fm}$

$r_{208} \sim 6\,\mathrm{fm} > r_0$

effective charge Z is less while the muon is in the nucleus.

ii) S & P orbital are describe by different wave functions

P-orbitals are non-spherical which results in a diff. energy. See an undergraduate or google Hydrogen wave func.

iii) Pb_{208} - muon relativistic?

From eq. 3.24 of Andersen

$$\frac{1}{2}\mu v^2 = \frac{Ze^2}{2r}$$

for the hydrogen atom, let's try

for the hydrogen atom, let's try to find v.

$$v_n^2 = \frac{Ze^2}{r_n \mu}$$, where n is the discrete E states

$$r_n = \frac{n^2 \hbar^2}{\mu Z e^2}$$

$$v_n^2 = \frac{Ze^2}{\frac{n^2\hbar^2}{\cancel{\mu} Z e^2}\cancel{\mu}}$$

$$= \frac{Z^2}{n^2}\frac{e^4 c^2}{\hbar^2 c^2}$$

$$\alpha = \frac{e^2}{\hbar c}$$

$$v_n^2 = \frac{Z^2}{n^2}\alpha^2 c^2$$

$$\beta_n = \frac{v_n}{c} = \frac{Z}{N}\alpha$$

for hydrogen atom ground state

$$\boxed{\beta = \alpha}$$ ← easy way to remember Bohr atom.

$$\bar{V}_e = \frac{1}{137}c$$ non-rel.

For Pb208 - muonic atom groundstate

For Pb_{208} - muonic atom groundstate

$$\beta = \frac{82}{137} \alpha$$

$\bar{v}_{\mu} \approx 0.6\, c \rightarrow$ relativistic

classical treatment cannot be accurate at this "speed".