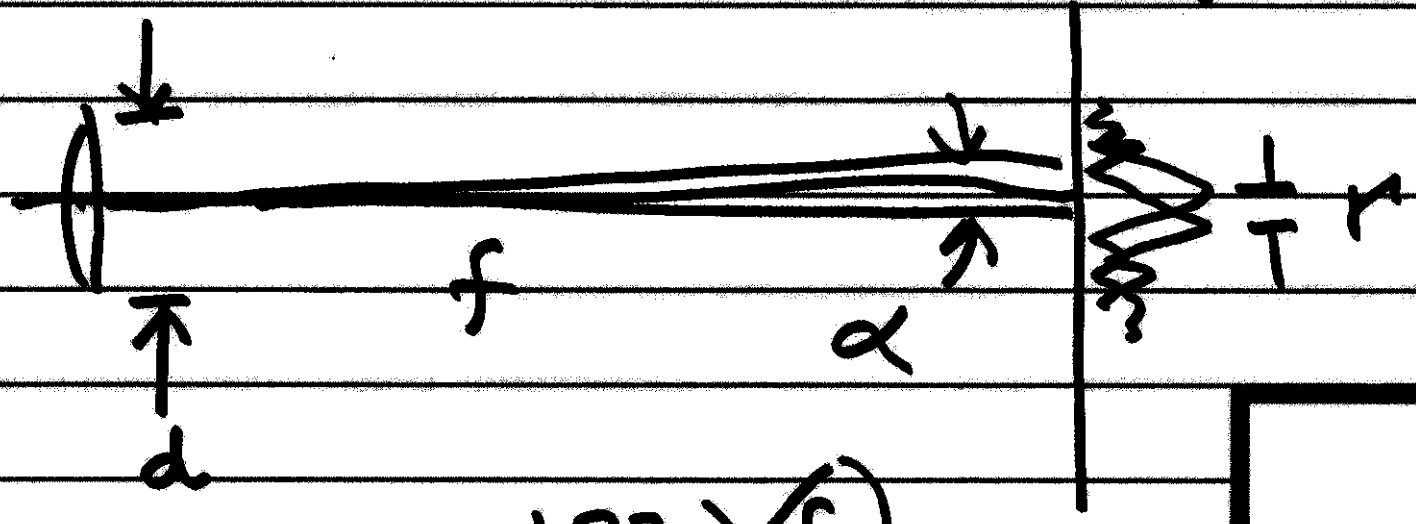


$$\alpha = \frac{1.22 \lambda}{d}$$

Rayleigh Criterion

$$\frac{r}{f} = \frac{1.22 \lambda}{d}$$

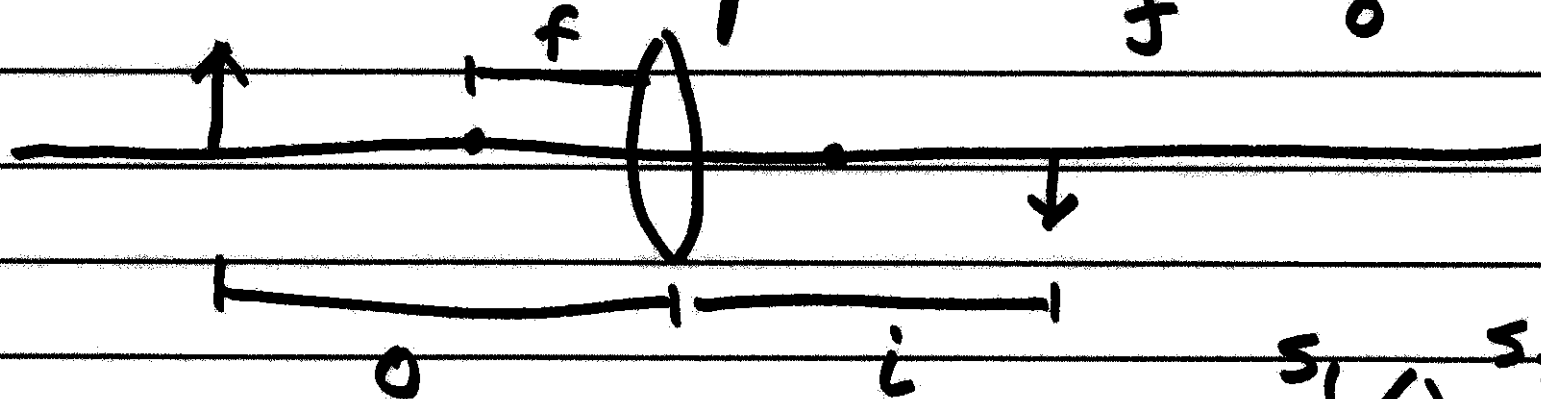


$$r = \frac{1.22 \lambda f}{d} \quad f/\#$$

Thin lens assumption

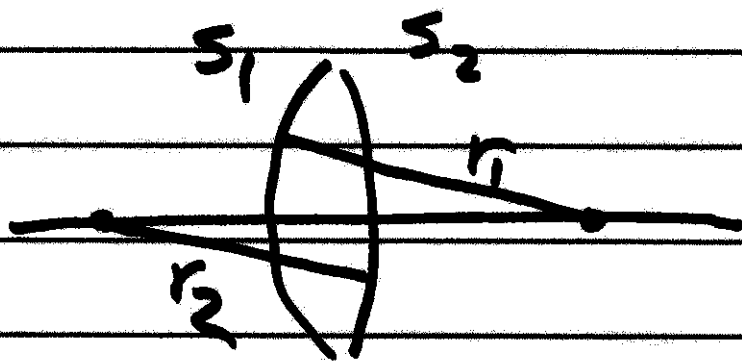
$$\frac{1}{f} = \frac{1}{o} + \frac{1}{i}$$

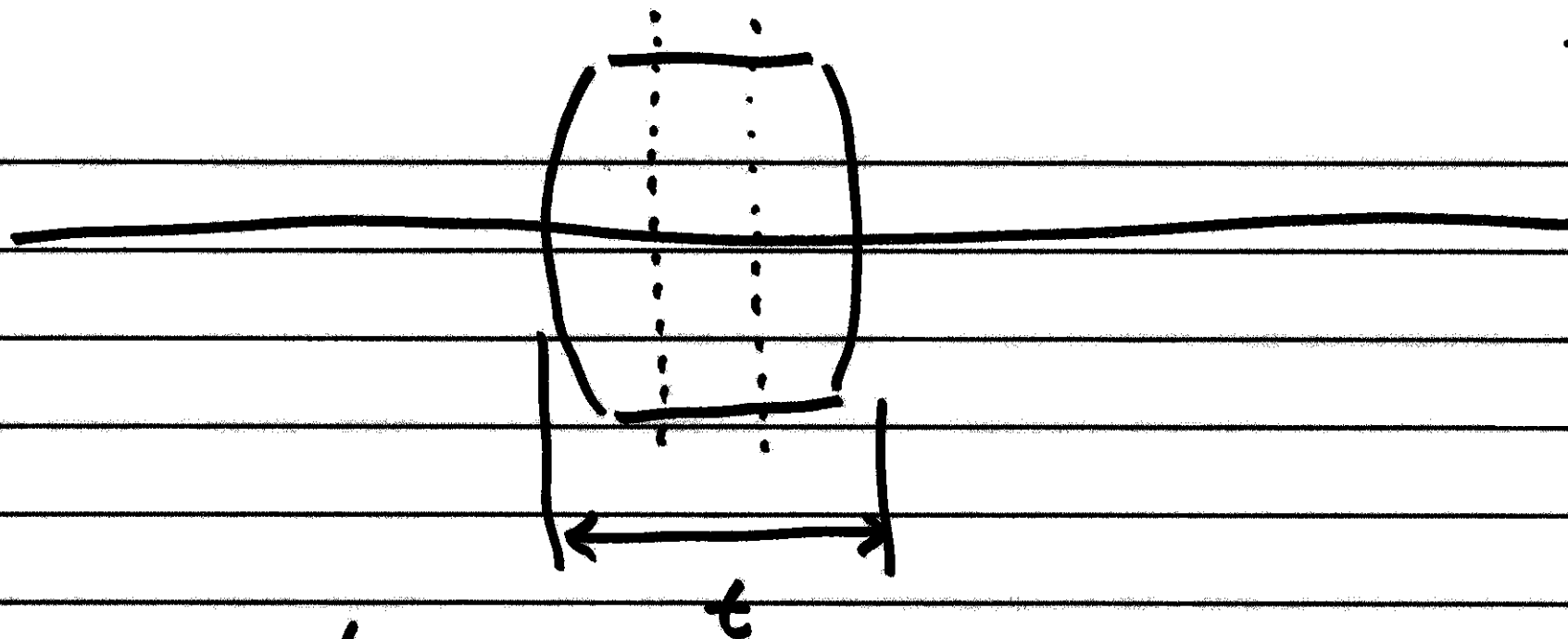
3-2



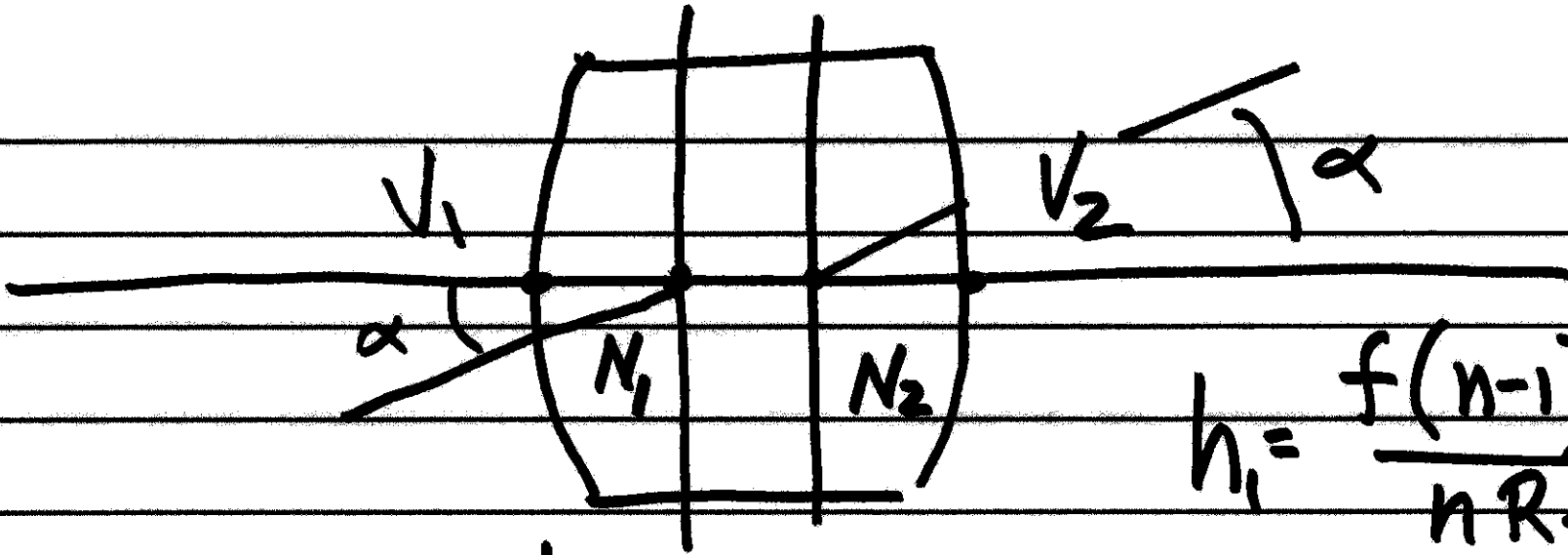
lens maker's equations

$$\frac{1}{f} = (n-1) \left( \frac{1}{r_1} + \frac{1}{r_2} \right)$$

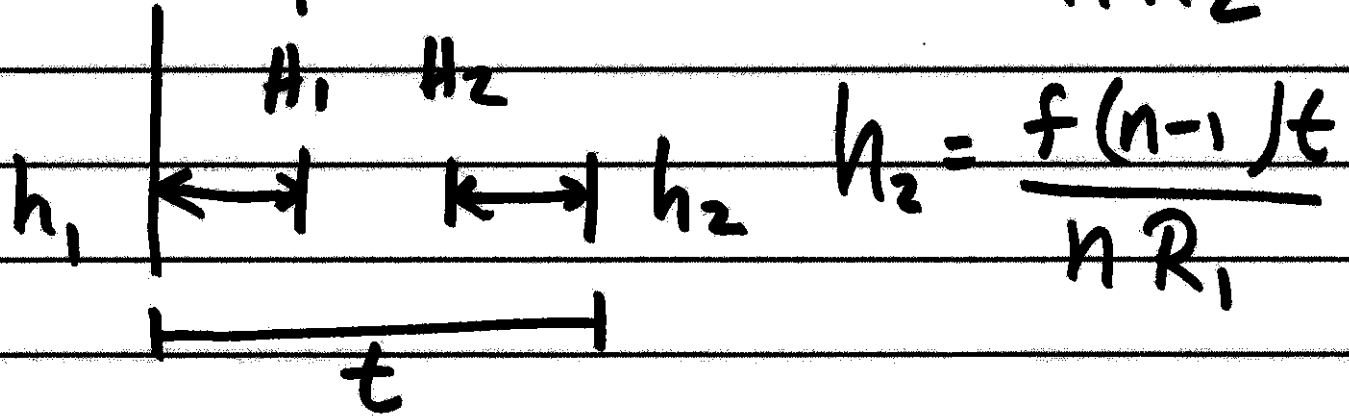




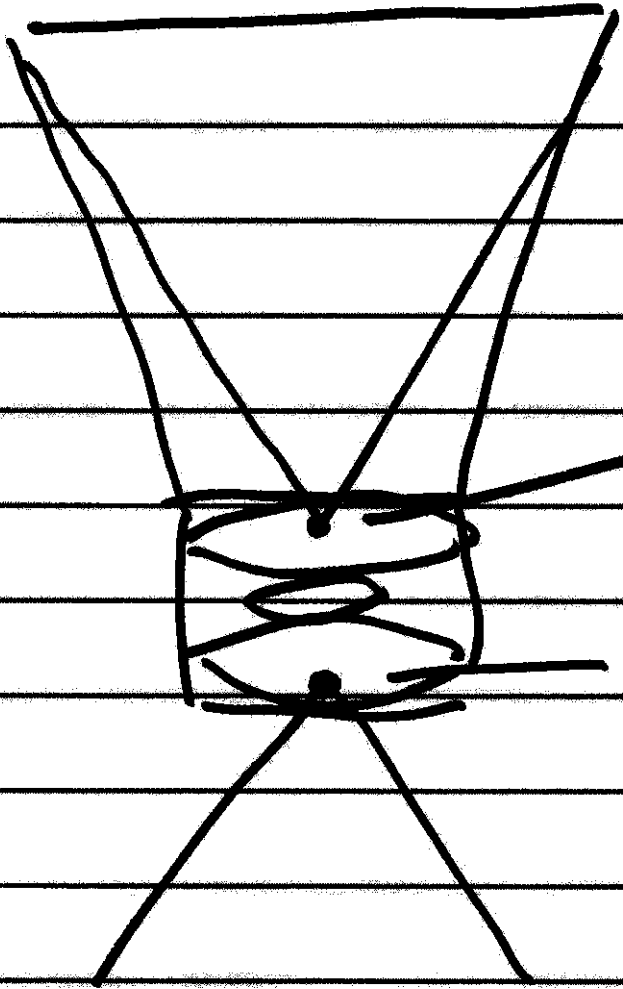
$$\frac{1}{f} = (n-1) \left( \frac{1}{r_1} + \frac{1}{r_2} - \frac{(n-1)t}{nr_1r_2} \right)$$



$$h_1 = \frac{f(n-1)t}{nR_2}$$

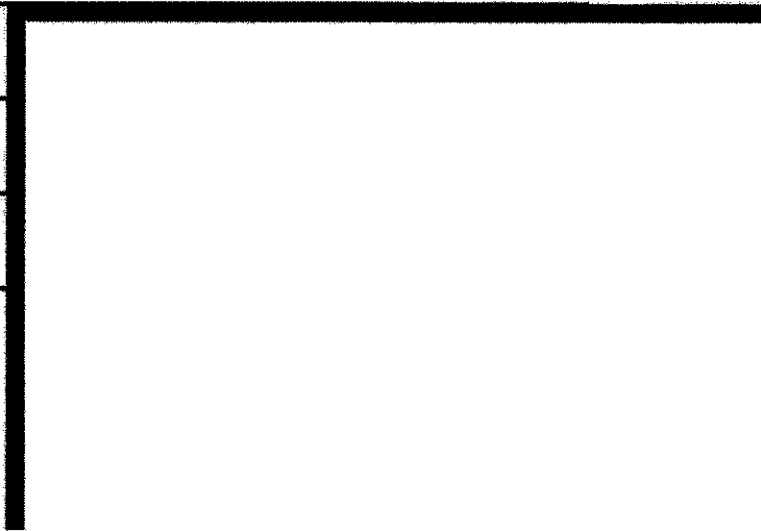


$$h_2 = \frac{f(n-1)t}{nR_1}$$

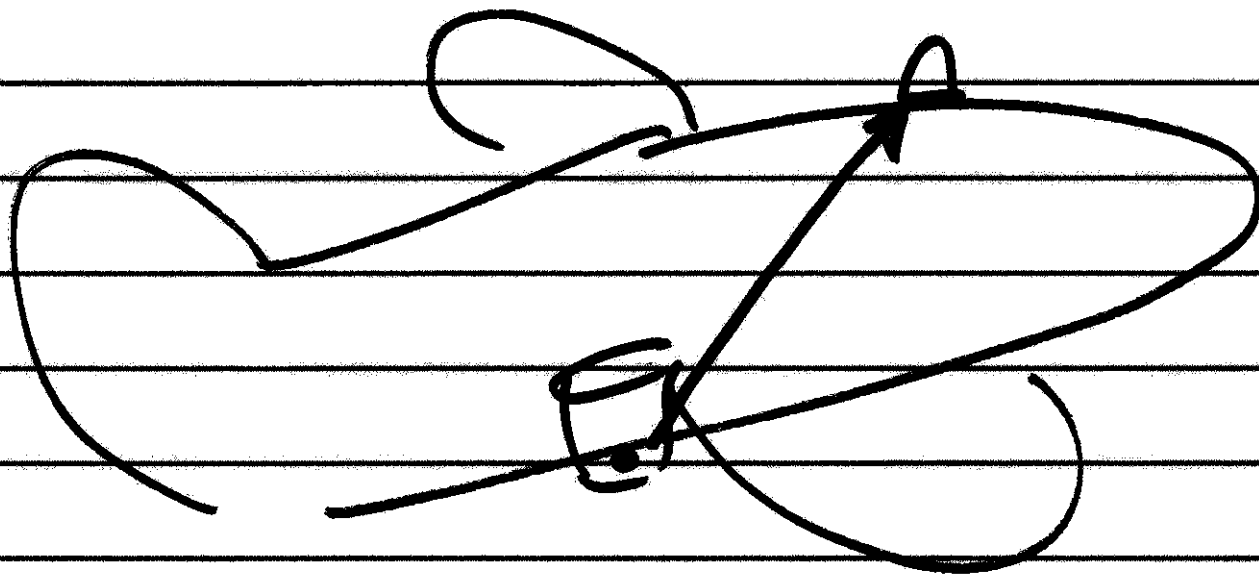


rear or exit node

front or entrance node



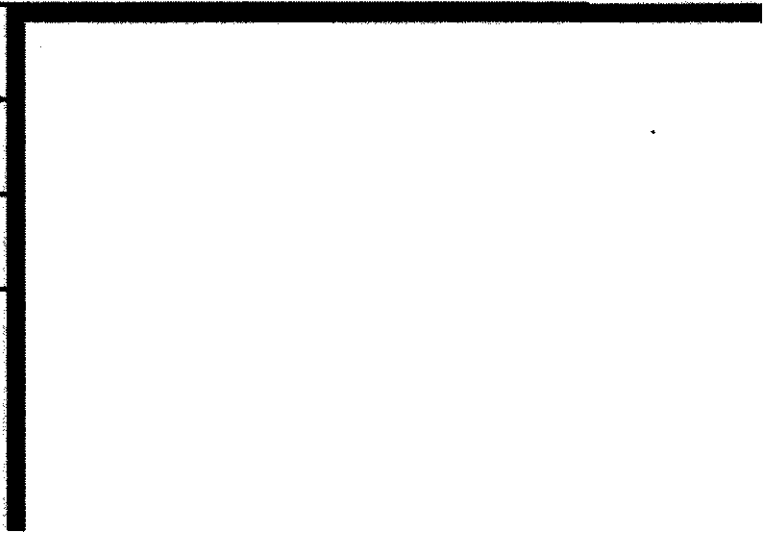
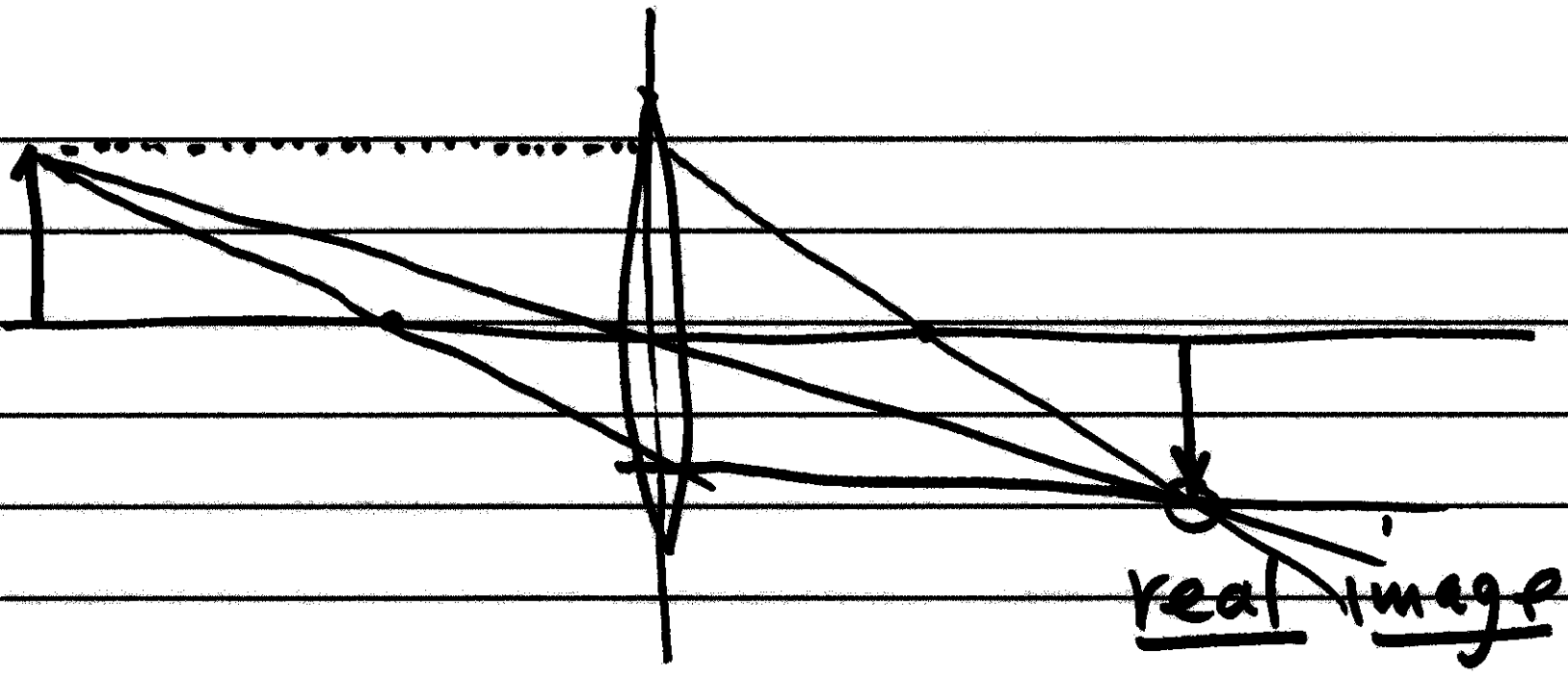
3-6



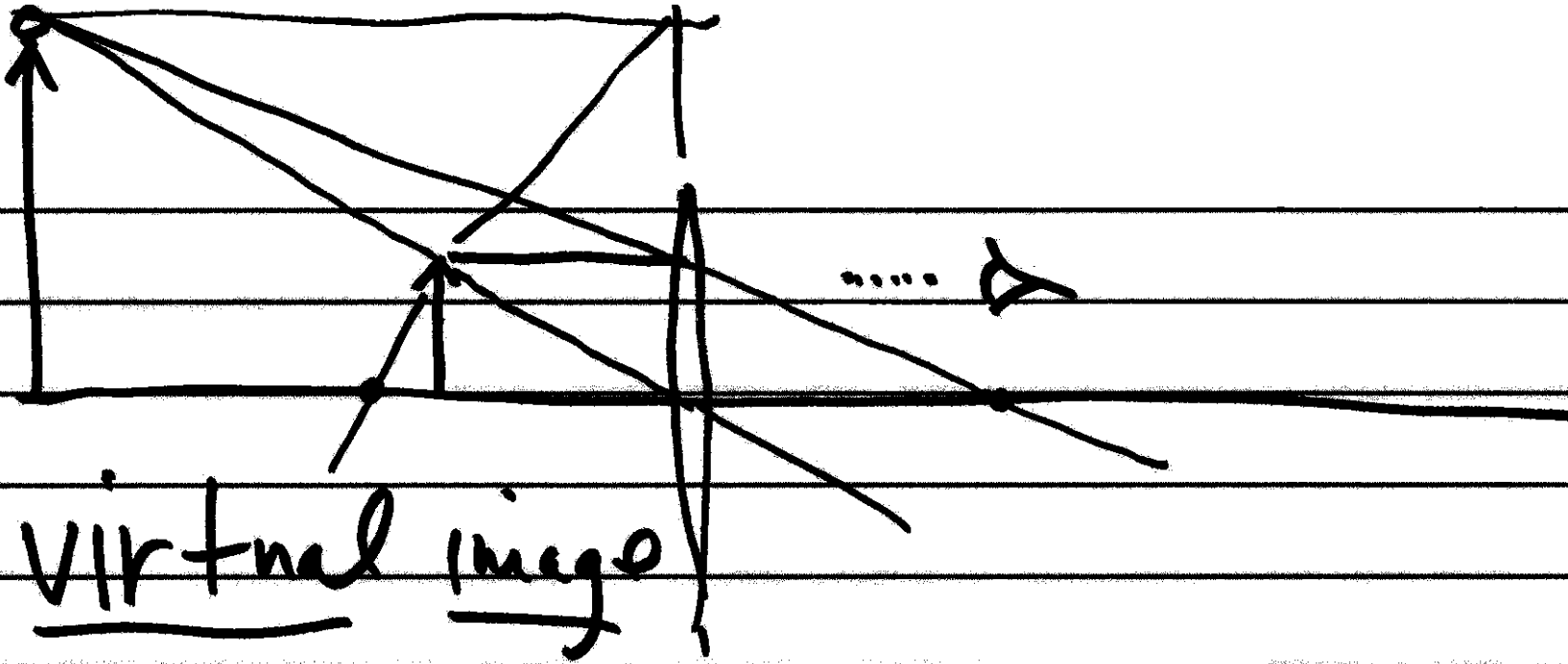
## 3 Rules

1. ray enters from left parallel to optical axis, emerges through opposite focal point
2. ray through the center of lens is undeviated
3. ray through the near focal point emerges parallel to optical axis

3-8



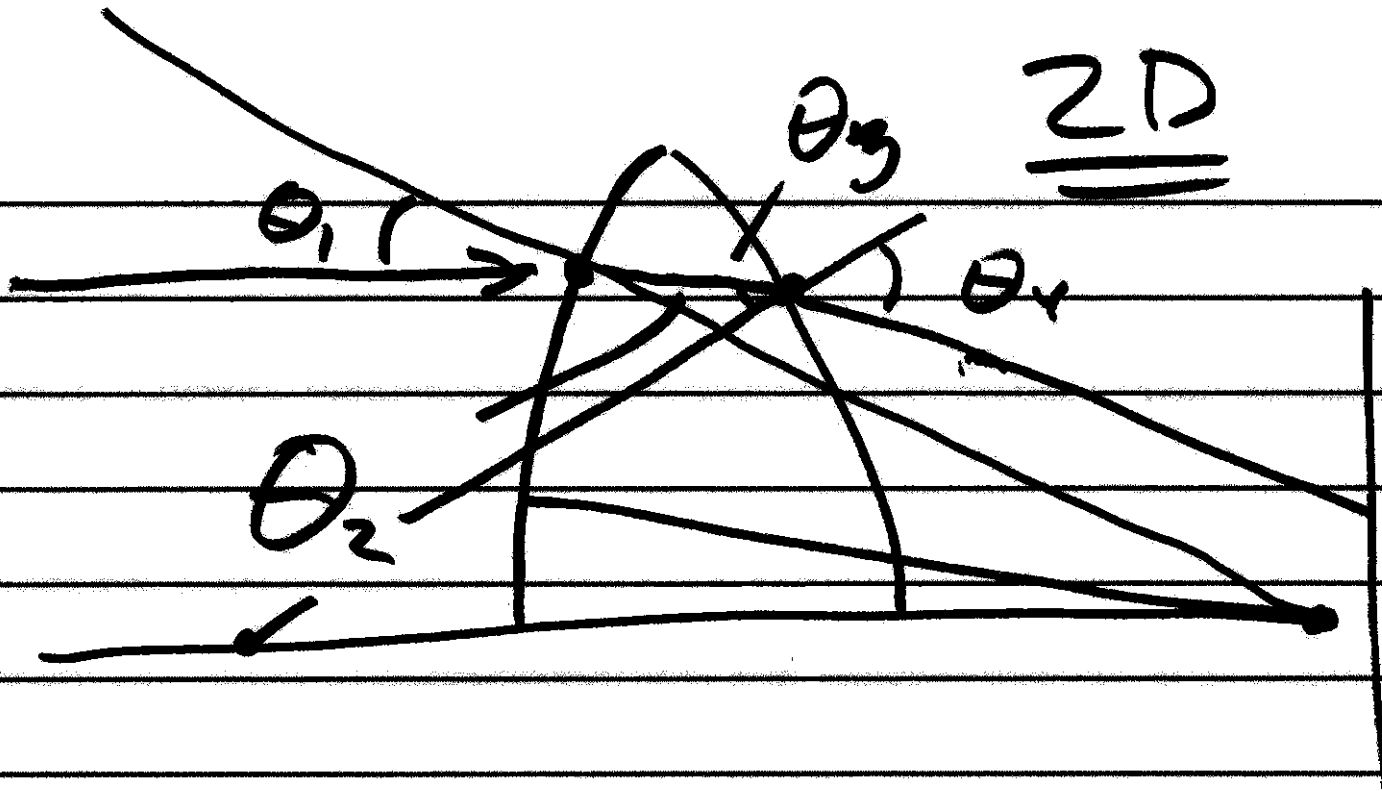




Virtual image

3-10

2D

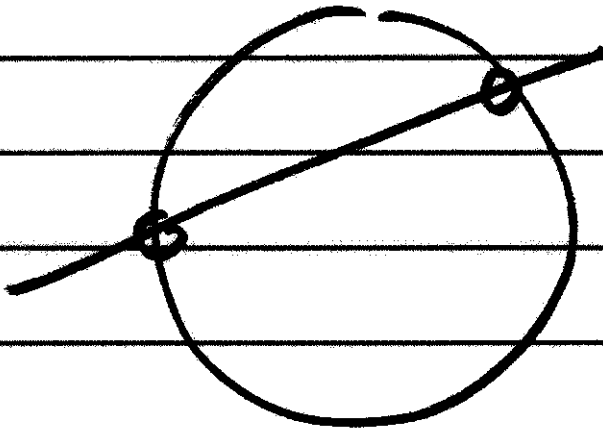


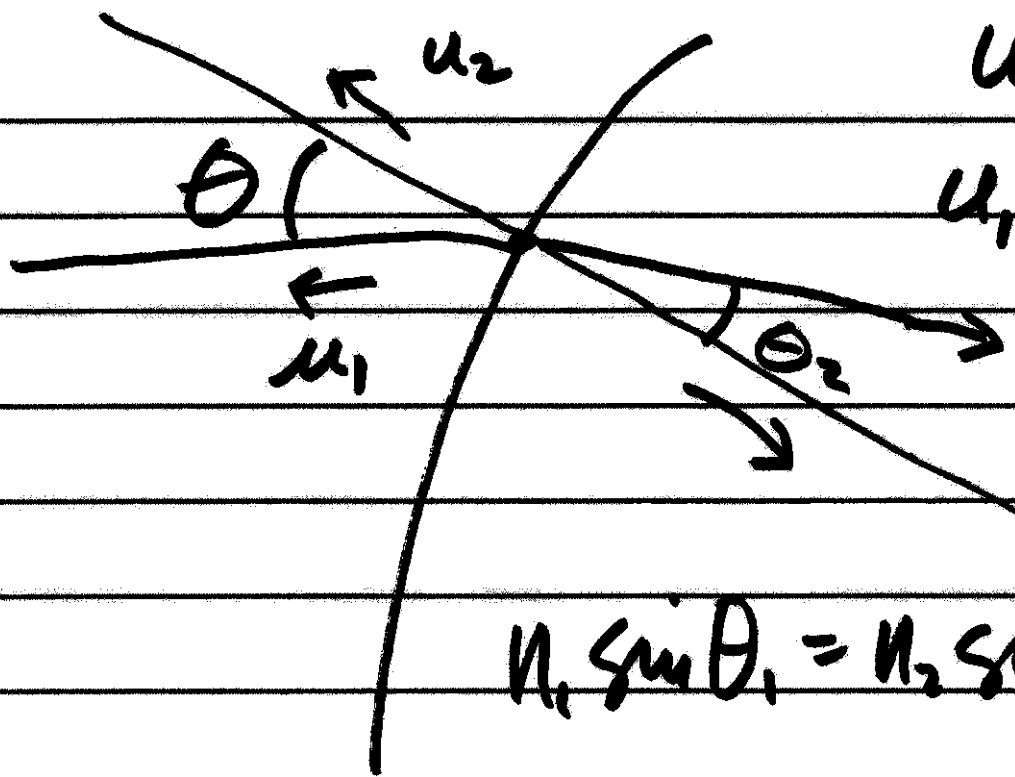
→  $y = mx + b$  ..... ↗

$$r^2 = (x - x_c)^2 + (y - y_c)^2$$

$$Ax^2 + Bx + C = 0$$

$$\frac{-B \pm \sqrt{B^2 - 4AC}}{2A}$$





$$u_1 \cdot u_2 = \cos \theta$$

$$u_{1x} \cdot u_{2x} + u_{1y} \cdot u_{2y}$$

$$\Delta x = \sin \alpha z$$

$$\Delta y = \cos \alpha z$$

$$u_1 \sin \theta_1 = u_2 \sin \theta_2 \quad \text{keyc}$$

Slope from  $\Delta x, \Delta y$

$$\alpha z = \tan^{-1} \left( \frac{\Delta x}{\Delta y} \right)$$



$$\alpha z_{\text{norm}} = \theta_2$$

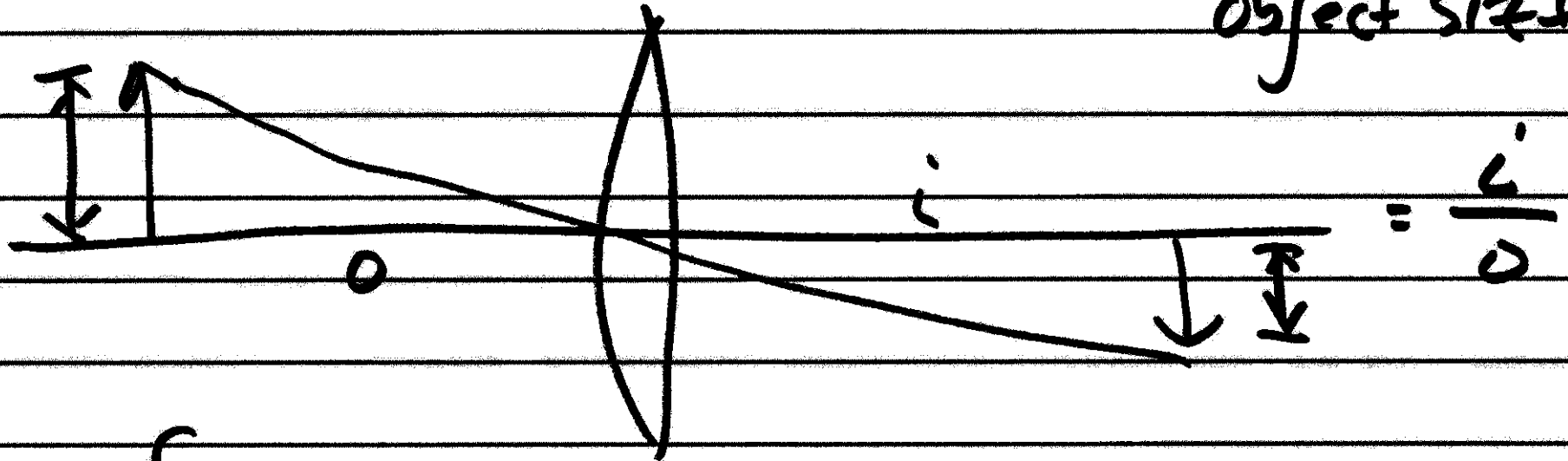
Magnification

3-13

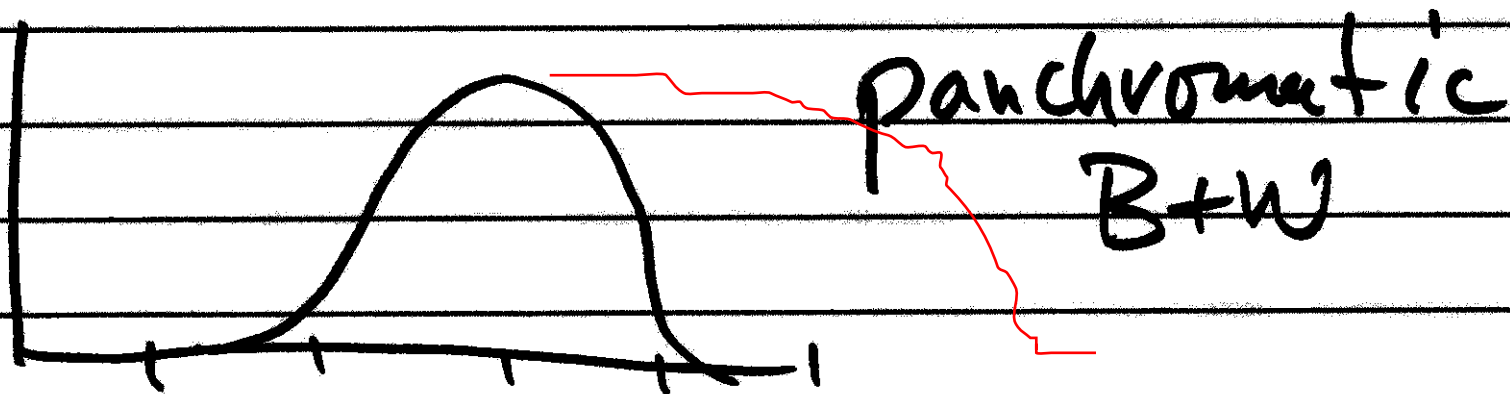
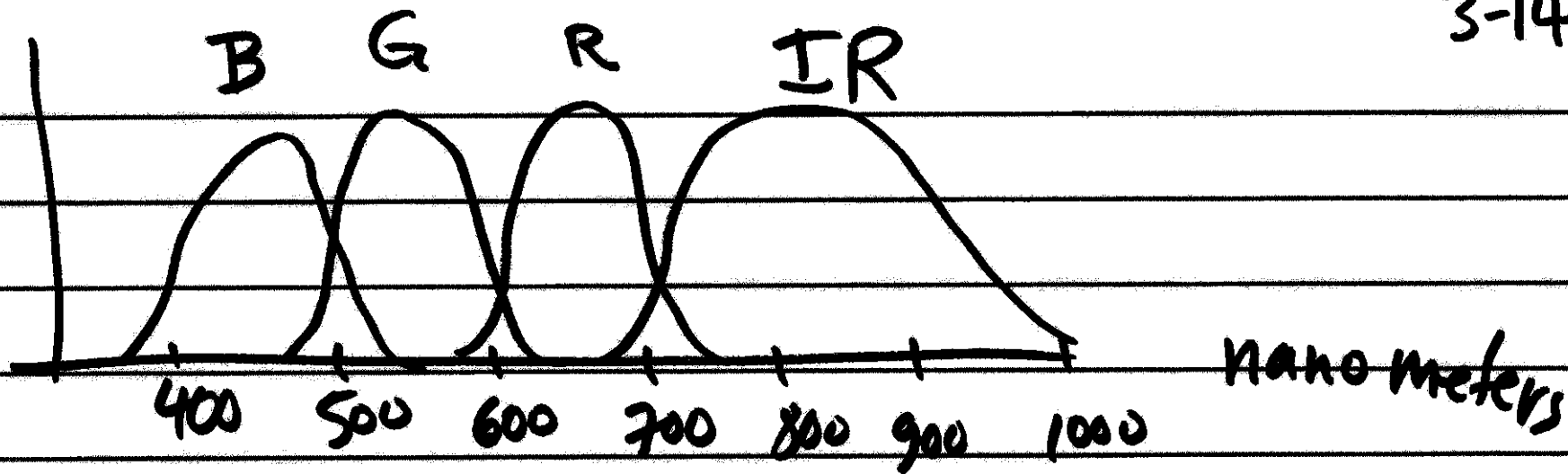
$$M = \frac{y - y_i}{x - x_i}$$

Scale

$$= \frac{\text{Image size}}{\text{Object size}}$$



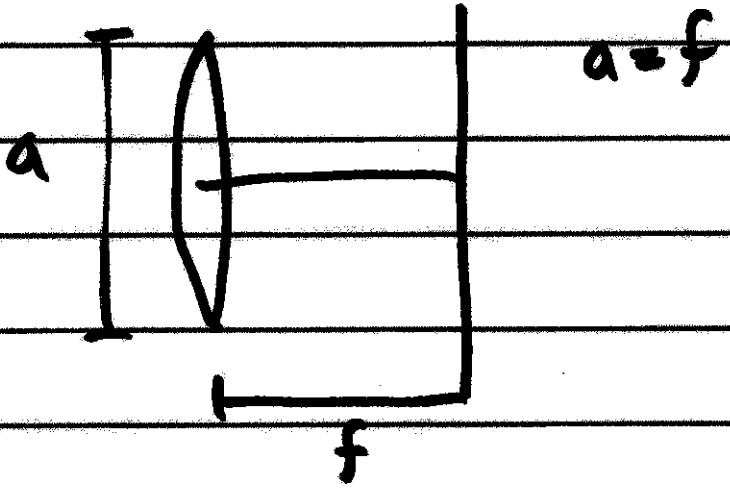
$$\frac{f}{H}$$



yellow  
(-blue)

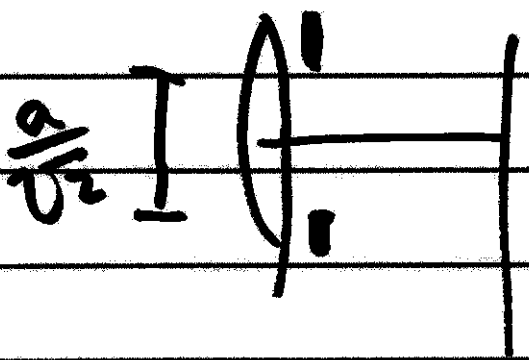
haze reduction

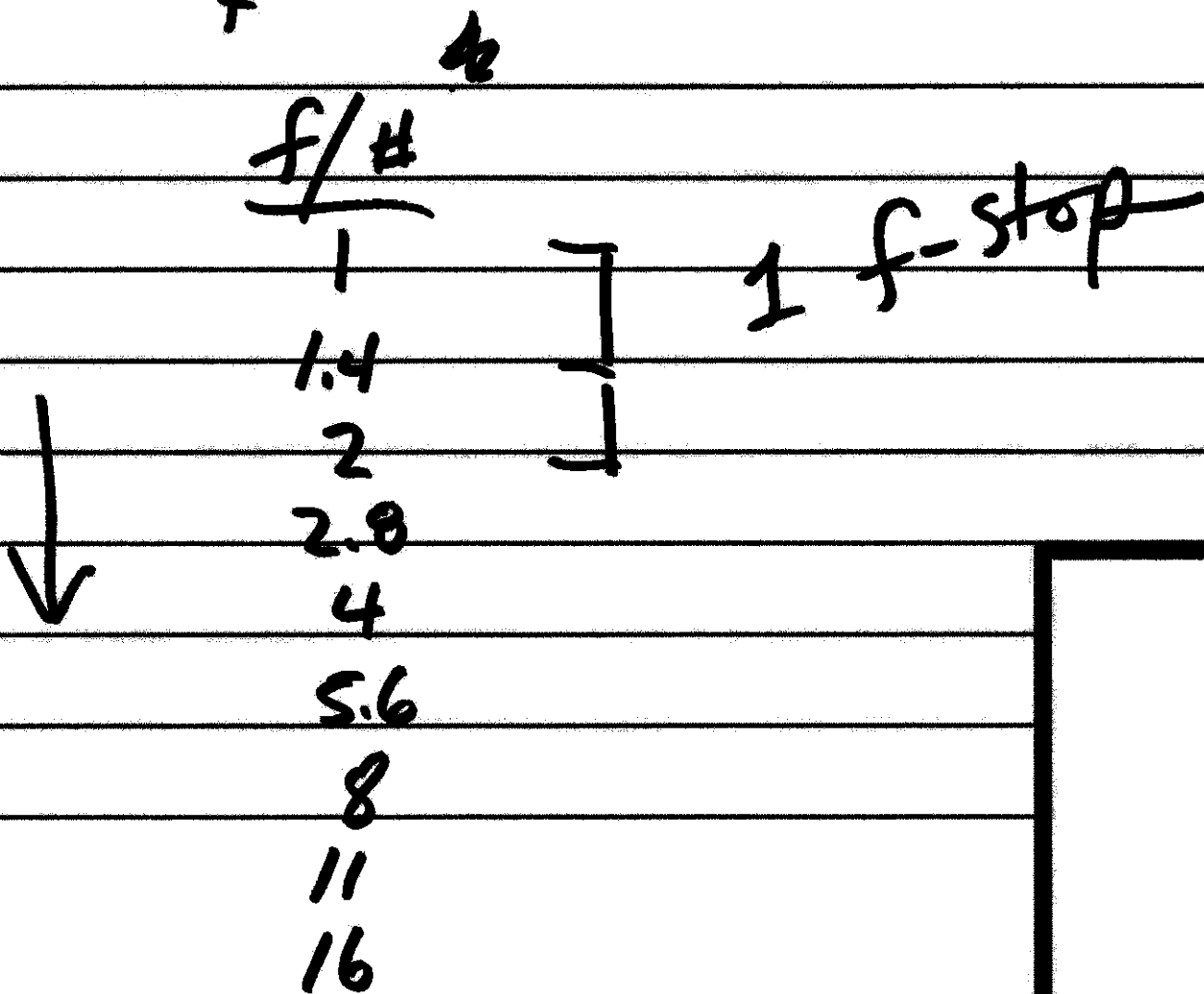
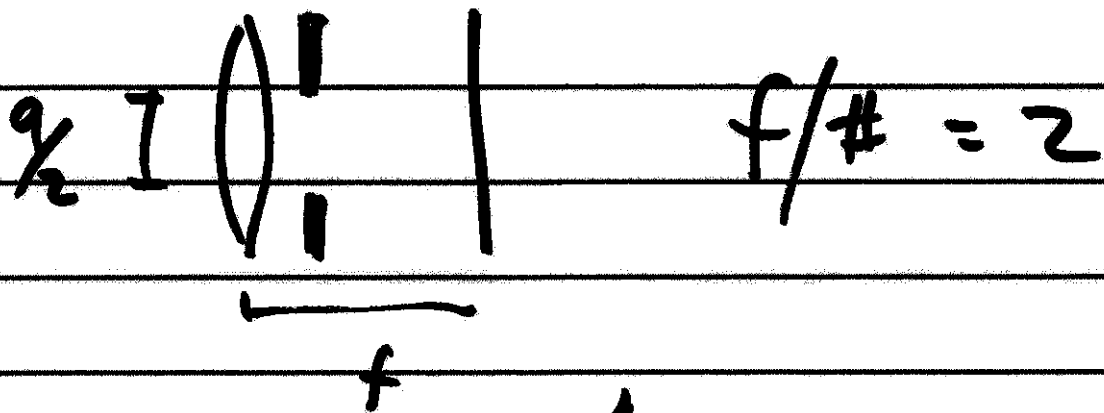
$$\frac{f}{d} = f/\# : \frac{\text{focal length}}{\text{diameter of a perture}}$$



$$f/\# = 1$$

$$f/\# = 1.4$$



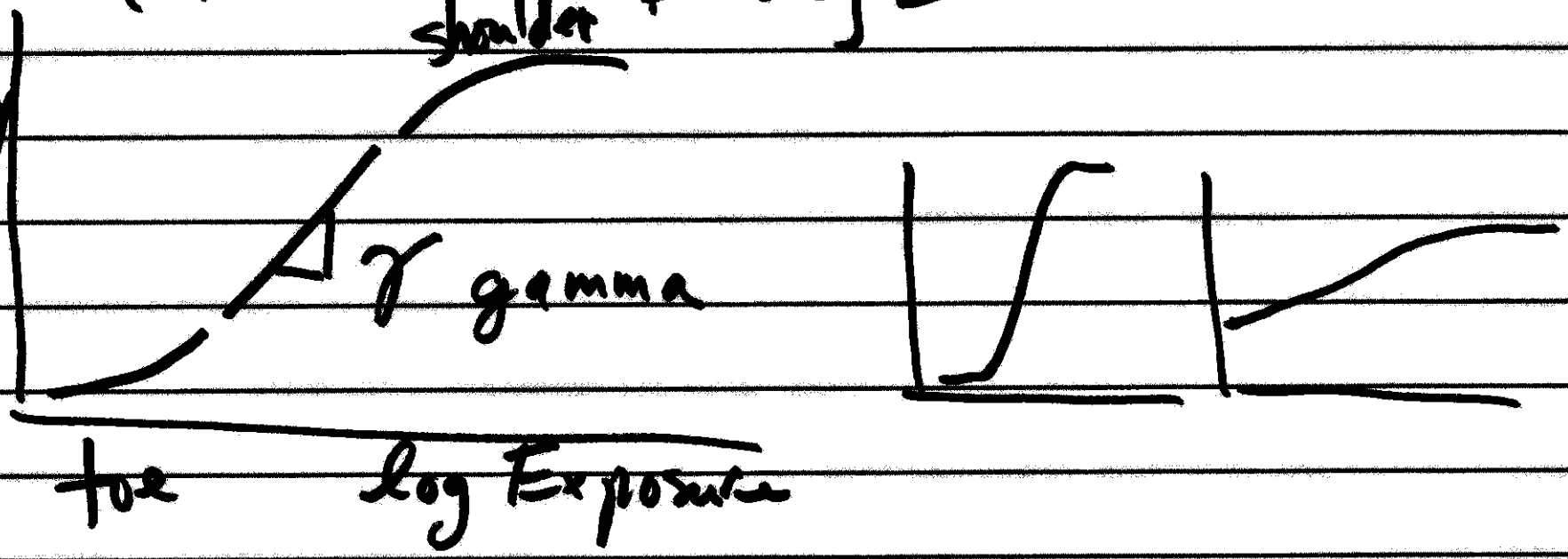




Film

shoulder  $D-\log E$

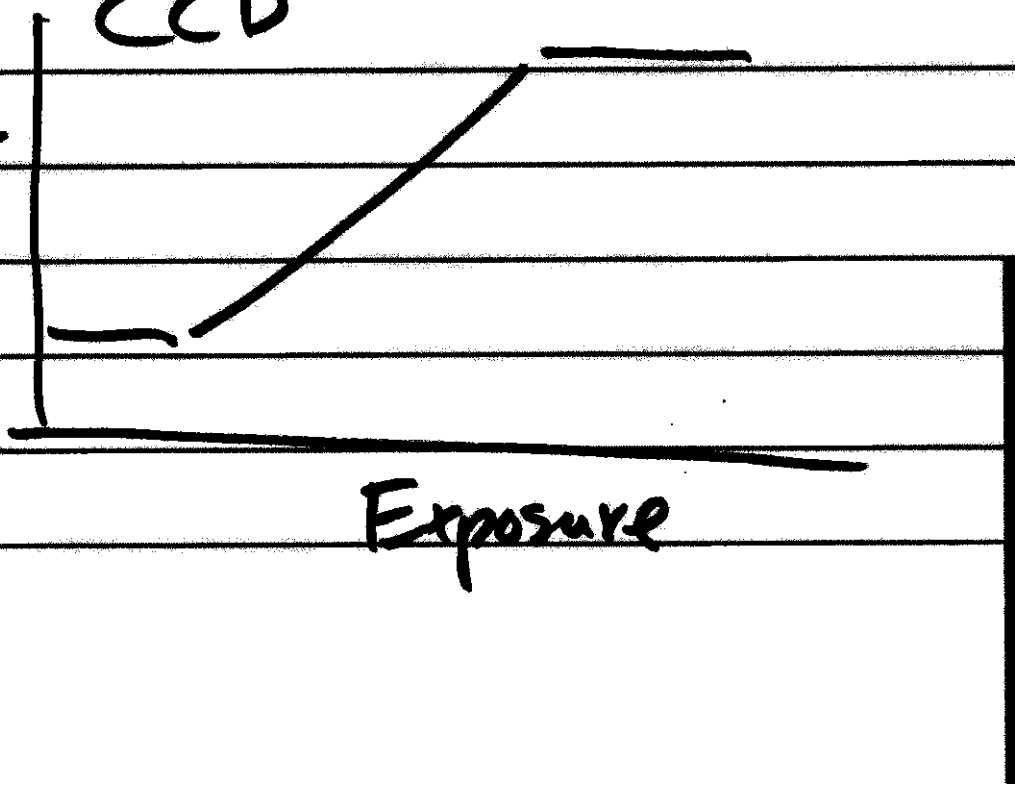
density



toe log Exposure

CCD

Signal  
toolt



Exposure

# CCD benefits

linear

high dynamic range

geometrically stable

Quantum Efficiency

QE

⋮