q-p plot: $\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$

$$q = \frac{1}{\frac{1}{f} - \frac{1}{p}} = \frac{f}{1 - \frac{f}{p}}$$

① $p = \infty$, $q = f$

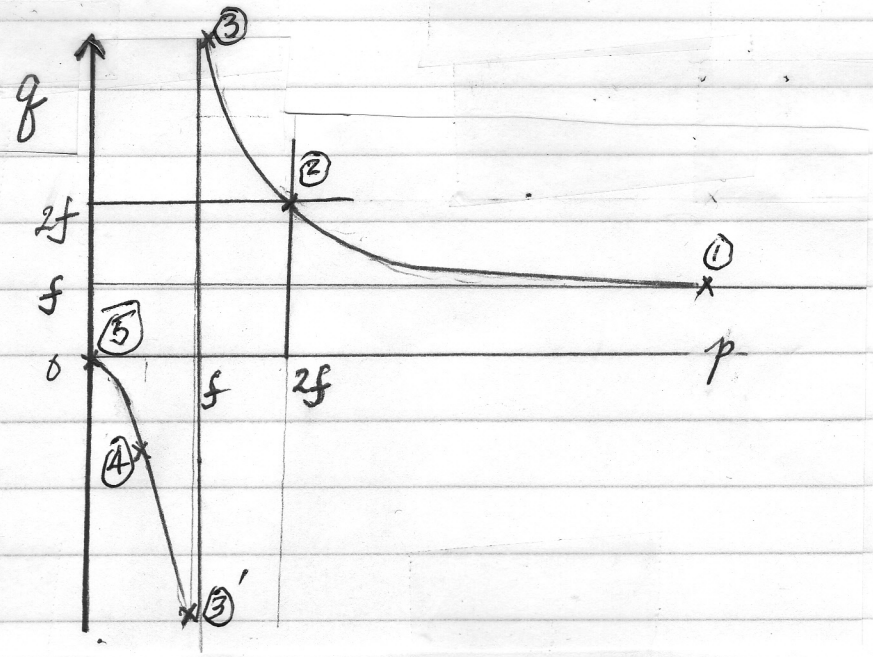
② $p = 2f$, $q = \frac{f}{1 - \frac{1}{2}} = 2f$

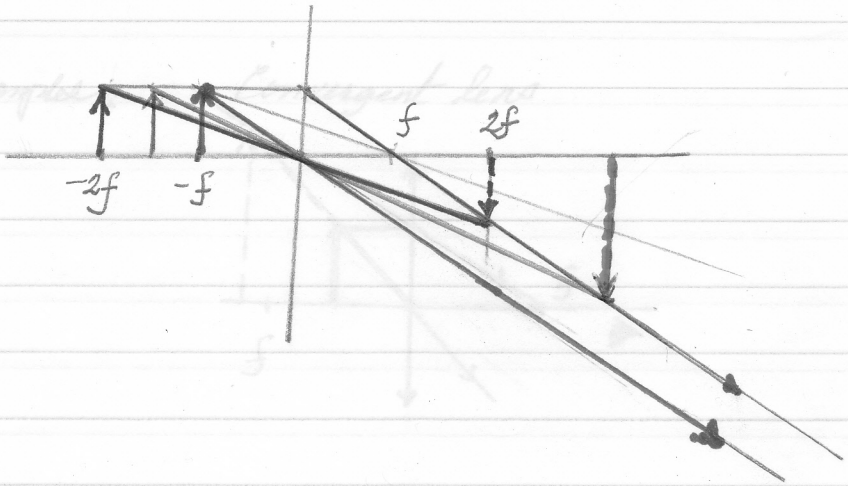
③ $p = f + \epsilon f$, $\frac{f}{p} = \frac{f}{f(1+\epsilon)} \approx 1 - \epsilon$, $q = \frac{f}{1 - (1-\epsilon)} = \frac{f}{\epsilon} \to +\infty$

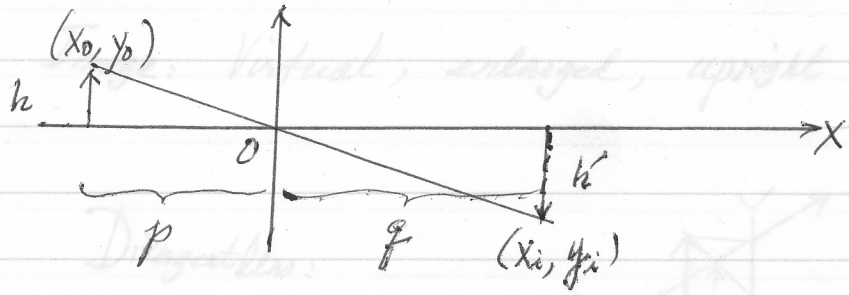
③′ $p = f - \epsilon f$, $q = \frac{f}{-\epsilon} \longrightarrow -\infty$

④ $p = \frac{f}{2}$, $q = \frac{f}{1-2} = -f$

⑤ $p = 0$, $q = \frac{1}{\frac{1}{f} - \frac{1}{p}} = \frac{p}{\frac{p}{f} - 1} = \frac{p}{-1} = 0$







Object: $p = |x_0| > 0$, $h = y_0$

Image: $q = x_i$, $h' = |y_i|$

$$M = \frac{y_i}{y_0} = -\frac{q}{p}$$

Properties of image:

$$\frac{h'}{h} = \begin{cases} >1 & \text{enlarged} \\ <1 & \text{reduced} \end{cases}; \quad y_i: \begin{cases} <0 & \text{inverted} \\ >0 & \text{upright} \end{cases}$$

$$q: \begin{cases} >0, & \text{in front of the lens, real image} \\ <0, & \text{behind the lens, virtual image} \end{cases}$$

Examples: Convergent lens

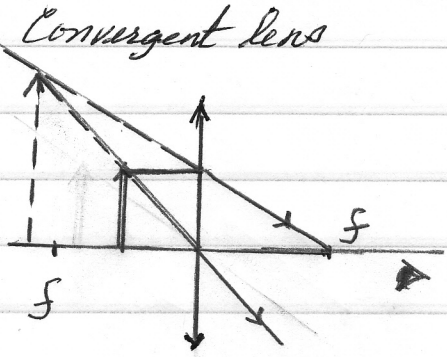


Image: Virtual, enlarged, upright

Divergent lens:

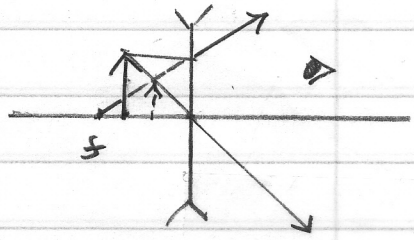
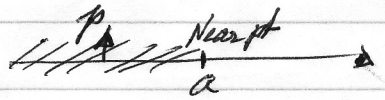


Image: Virtual, reduced, upright

Near sighted:

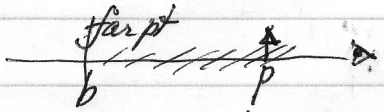


Cannot see clearly beyond the near point a.

Correction: Bring distant object image to a.

Verify: Lens needed has $f < 0$

Far sighted:



Cannot see clearly closer than far point b.

Correction: Bring close object image to far point

Verify Lens needed has $f > 0$.