Mean: \( \bar{X} = \frac{\sum x_i}{N} \)

Standard Deviation: \( \sigma = \sqrt{\frac{\sum (x_i - \bar{X})^2}{N-1}} \)

uncertainty on one measurement

Standard Deviation of the mean:

\( \sigma_{\bar{X}} = \frac{\sigma}{\sqrt{N}} \)

uncertainty on the mean value of \( N \) measurements.

Propagation: If \( F = F(x, y, \ldots) \) then

\( \Delta F = \sqrt{\left( \frac{\partial F}{\partial x} \Delta x \right)^2 + \left( \frac{\partial F}{\partial y} \Delta y \right)^2 + \ldots} \)

Special Case: \( F = xy \). Thus

\( \left( \frac{\Delta F}{F} \right) = \sqrt{\left( \frac{\Delta x}{x} \right)^2 + \left( \frac{\Delta y}{y} \right)^2} \)
Special Case: \[ F = x + y \]. Then
\[ \Delta F = \sqrt{(\Delta x)^2 + (\Delta y)^2} \]

Snell’s Law:
\[ n_1 \sin \theta_1 = n_2 \sin \theta_2 \]

Total Internal Reflection: (possible when \( n_1 > n_2 \))
\[ \sin \theta_c = \frac{n_2}{n_1} \]

Thin Lens:
\[ \frac{1}{s} + \frac{1}{s'} = \frac{1}{f} \]

Principle Ray Diagram.
Converging Lens: $F > 0$
Diverging Lens: $F < 0$.

Virtual Image: $s' < 0$, image is located on the input side of the lens.

Real Image: $s' > 0$, image is located on the output side of the lens.

Malus' Law: 

\[
\frac{I}{I_0} = \cos^2(\theta), \quad \theta = \text{angle between} \ \vec{E} \ \text{and} \ \text{polarizer direction.}
\]

Brewster's Angle: The angle at which $p$-wave polarized light does not reflect.

\[
\tan \theta_B = \frac{n_2}{n_1}
\]
Michelson Interferometer.

\[ \Delta m = \frac{2 (x_2 - x_1)}{\lambda} \]

For the sodium lamp, \( \Delta \lambda = \frac{\lambda^2}{2 \, d_0} \)

\( d_0 \) = distance between maximum fringe visibility.

Any 2-beam interference:

\[ I = I_0 \cos^2 \left( \frac{\Delta \phi}{2} \right) \]

\( \Delta \phi = \) phase difference

Single Slit Diffraction:

zeros occur where \( b \sin \theta = m \lambda \)

\( b = \) slit width

\( \theta = \) angle from normal.
Double Slit Diffraction:

1st diffraction at zero

Ratio of slit spacing to slit width = \frac{3}{3} = 3

in this case.

Slit width is still \( b \sin \theta = m \lambda \)

or \( b = \frac{\lambda}{\sin \theta} \) for \( m = 1 \).

Multiple Slit Diffraction: Secondary Maxima Appear

4 secondary maximum \Rightarrow 3 slits

Still missing maximum (\( \Theta \)),

so slit spacing = 3 \times \text{slit width.}
Diffraction Grating

Grating Equation:
\[ a \sin \theta = n \lambda \]

\( a = \) grating spacing.

This tells us where observable maxima will occur.

Hydrogen Atom.

\[ \Delta E = (-13.6 \text{ eV}) \left( \frac{1}{n^2} \frac{1}{n'^2} \right) \]

\[ \frac{1}{\lambda} = R \left( \frac{1}{n^2} \frac{1}{n'^2} \right) \]

\( R = \) Rydberg Constant.