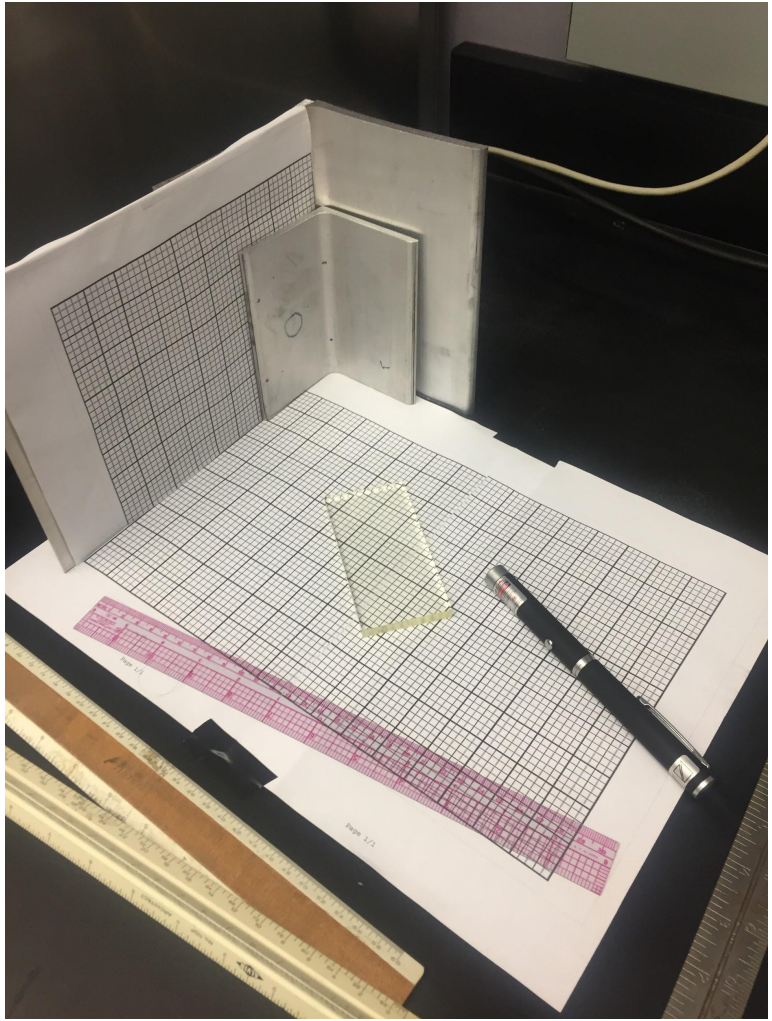
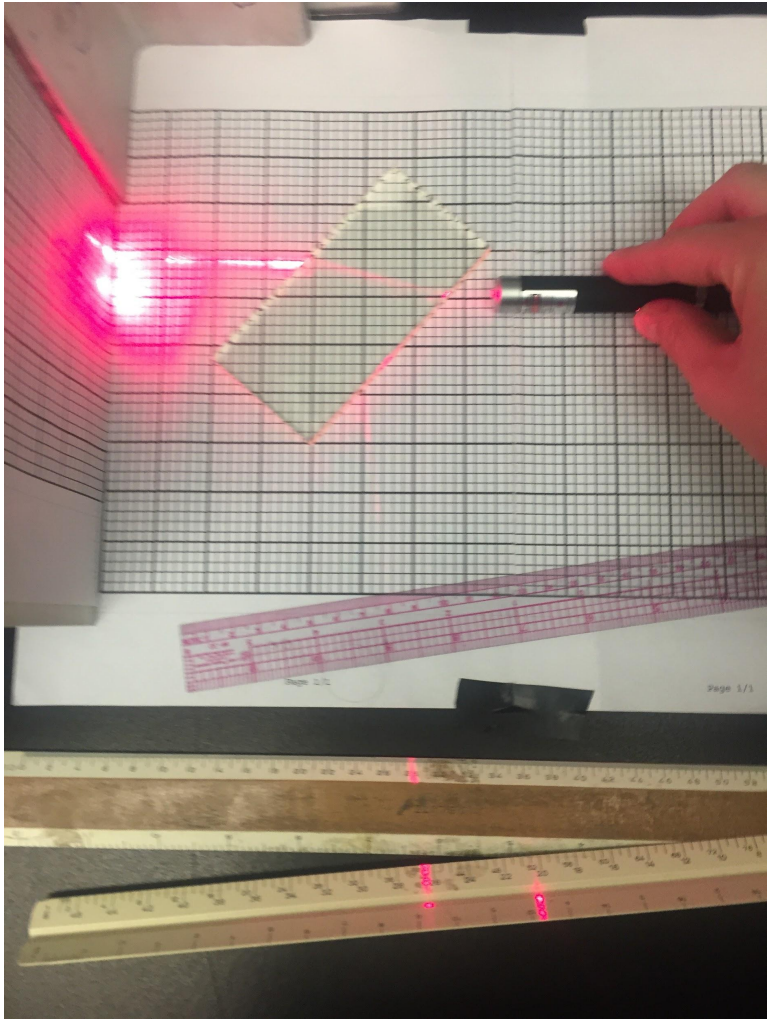
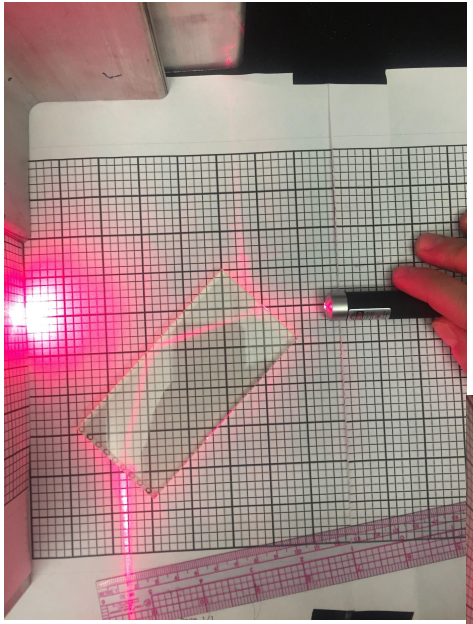
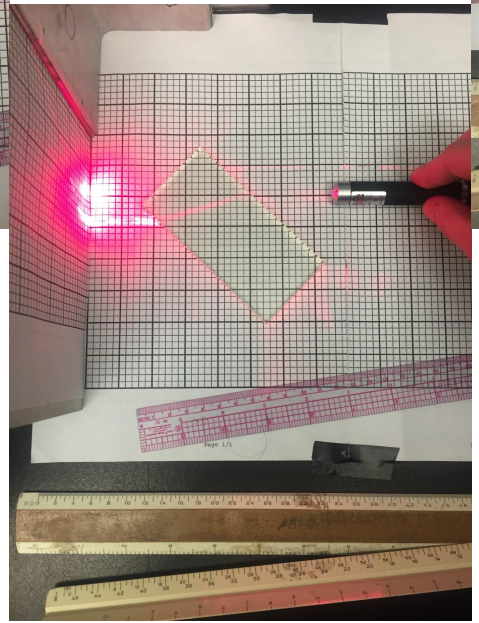
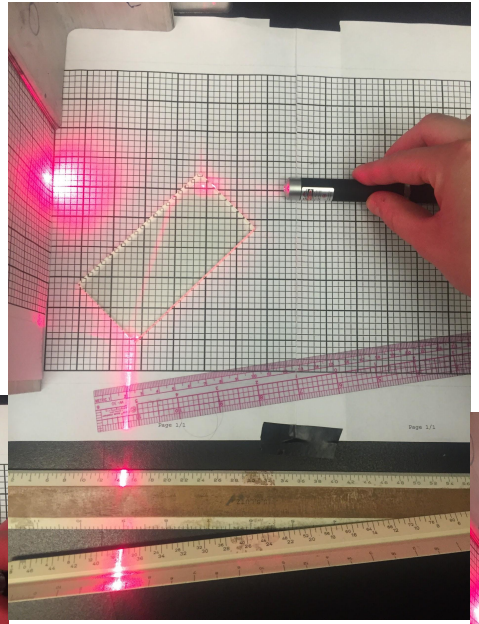
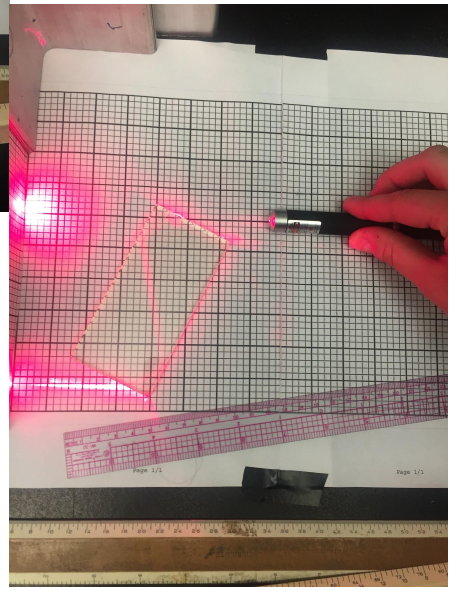




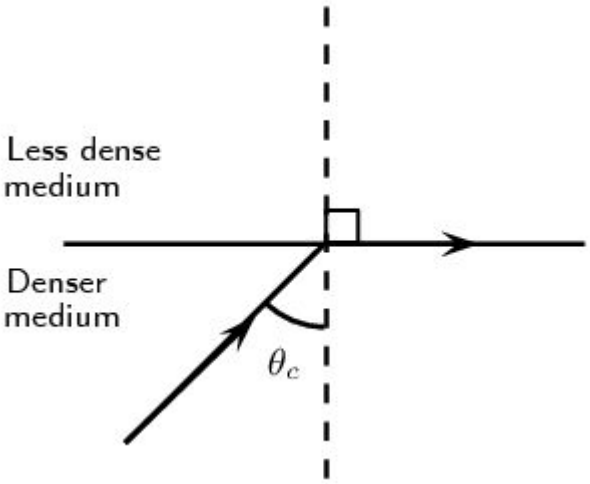


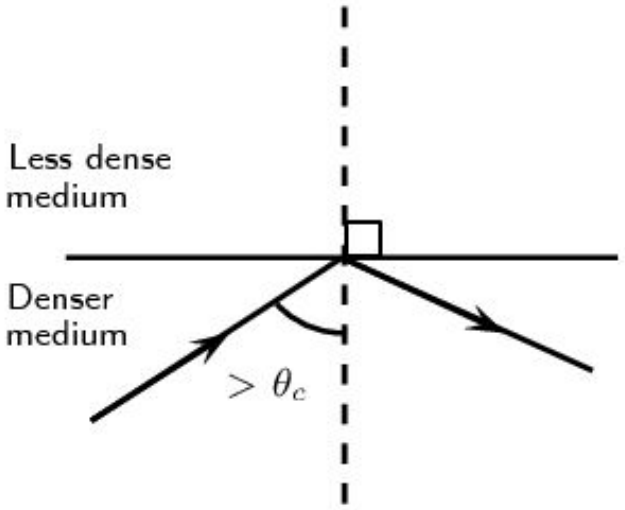






The Critical Angle



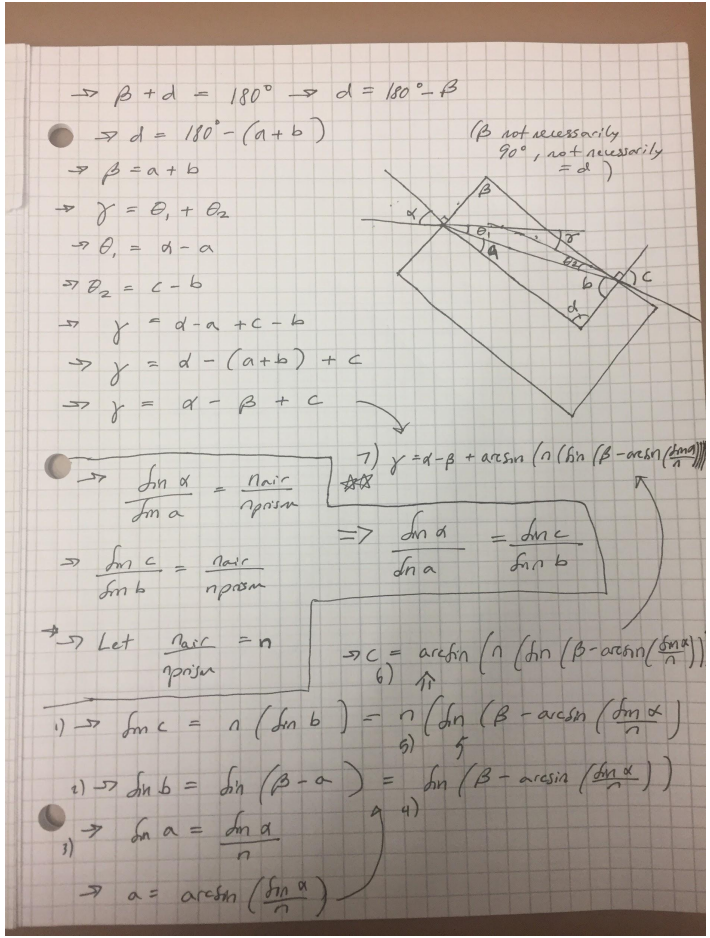


https://www.siyavula.com/read/science/grade-11/geometrical-optics/05-geometrical-optics-07

Index of Refraction (1)

$\gamma = \alpha - \beta + \arcsin(n(\sin(\beta - \arcsin((\sin\alpha)/n))))$

$n = \sqrt{(\sin^2\alpha + \sin^2(\gamma + \alpha))}$



$\rightarrow \alpha = \gamma + c$

$\rightarrow \gamma = \alpha - c$

$\rightarrow \alpha - c + b = \gamma$

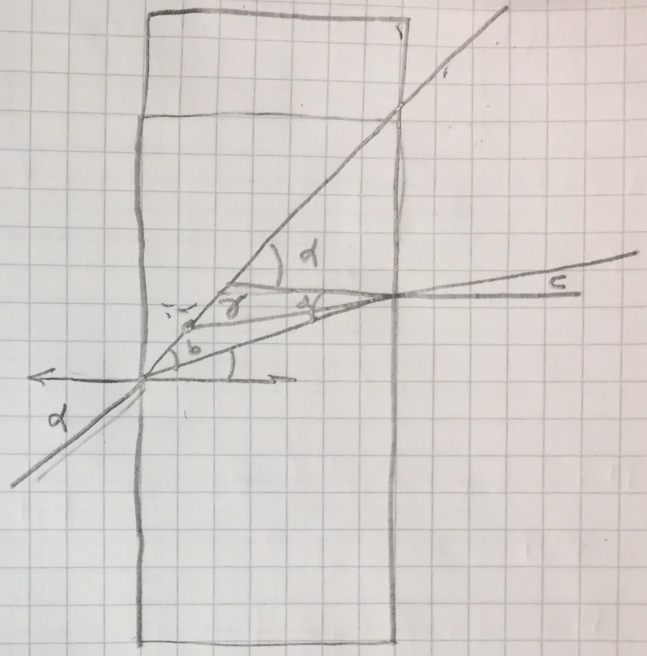
$\rightarrow \gamma = \alpha + b - c$

$\rightarrow \alpha = b + \alpha$

$\rightarrow \dfrac{\sin \alpha}{\sin(\alpha - b)} = n = \dfrac{\sin c}{\sin \alpha}$

$\rightarrow \dfrac{\sin \alpha}{\sin c} = \dfrac{\sin(\alpha - b)}{\sin \alpha} = \dfrac{\sin(b + \alpha - b)}{\sin \alpha} = 1$

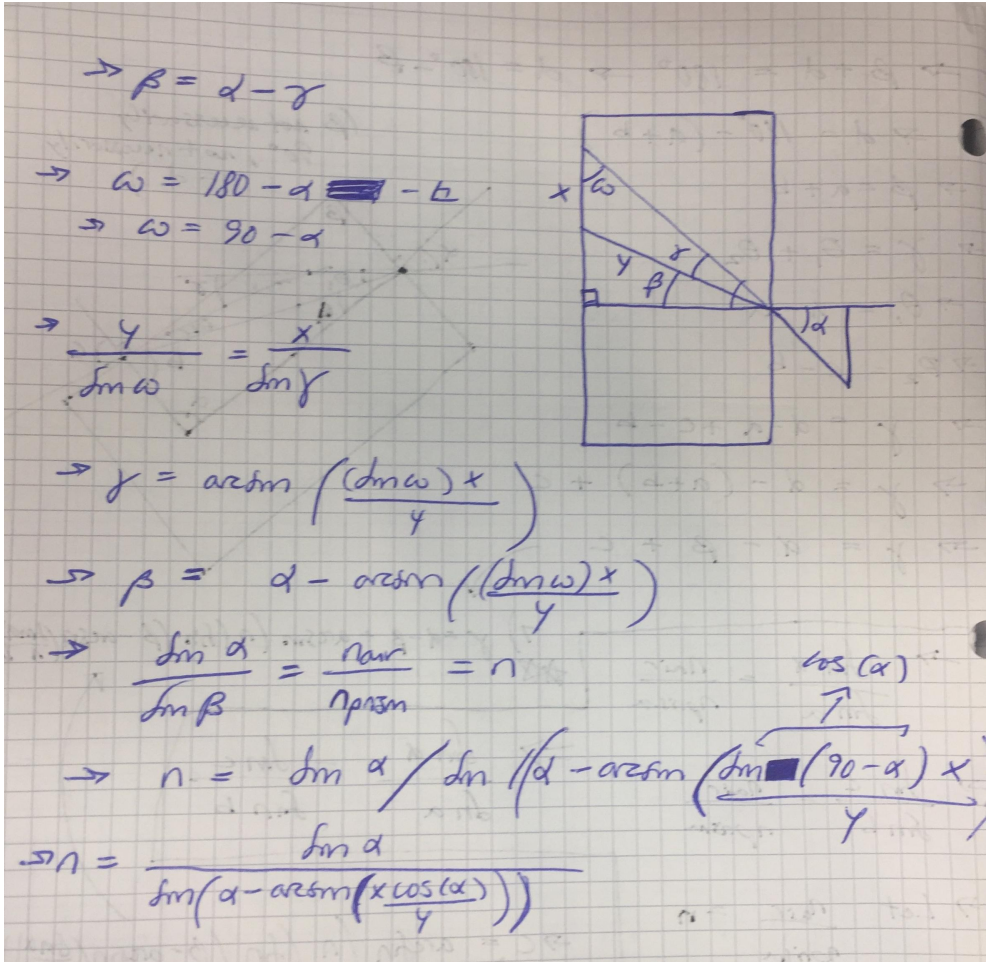
$\rightarrow \alpha = c \quad \because \gamma = 0$



The index cannot be calculated using the first equation when the laser is shone through the body of the prism rather than across the angle

Index of Refraction (2)

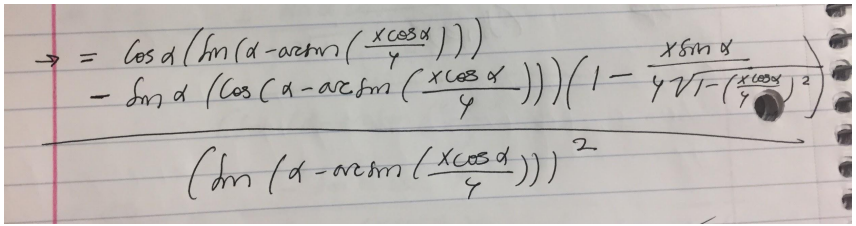
- n = (sin α)/(sin(α - arcsin(x(cosα)/y)))
- n = (sinα)/(sinβ)

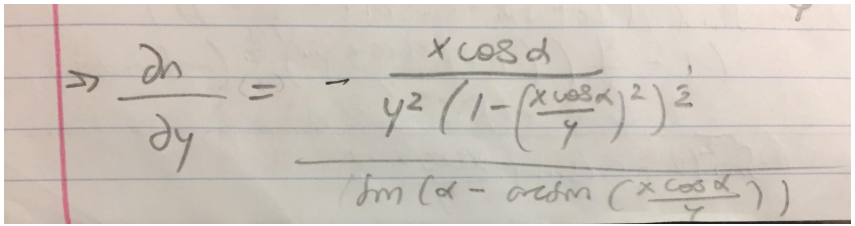


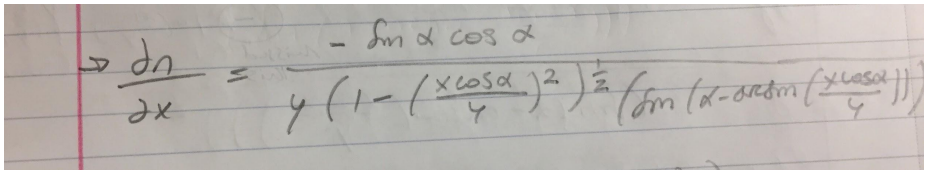
Measurements and Equations (2)

https://docs.google.com/spreadsheets/d/1Txx-vV3wgf3GK_qlBFUmlLhNHIcuCy1psQFxUU7tCow/edit#gid=1868993415

- $n = (\sin\alpha)/(\sin(\alpha - \arcsin(x(\cos\alpha)/y))$
- $n = (\sin\alpha)/(\sin\beta)$
- $\delta n(\alpha,x,y) = \sqrt{((\partial n/\partial\alpha)\delta\alpha)^2 + ((\partial n/\partial x)\delta x)^2 + ((\partial n/\partial y)\delta y)^2}$
- $\partial n/\partial\alpha =$



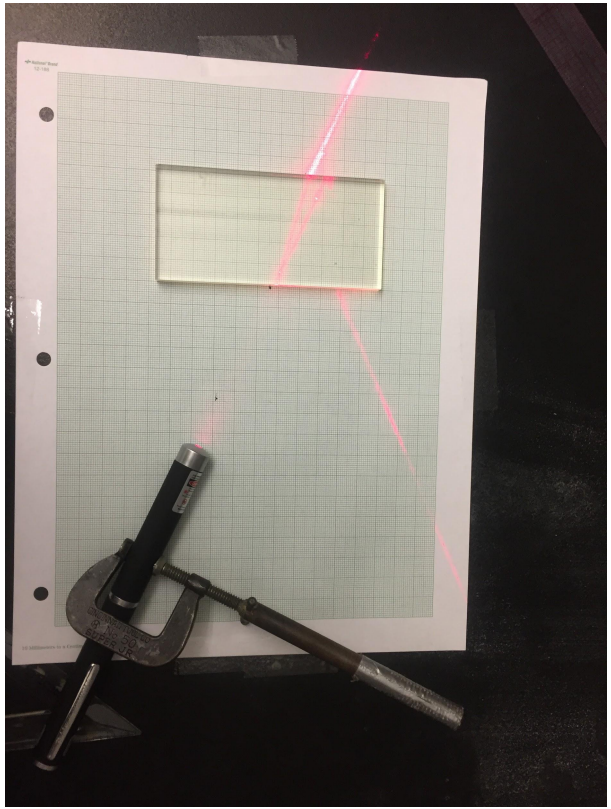


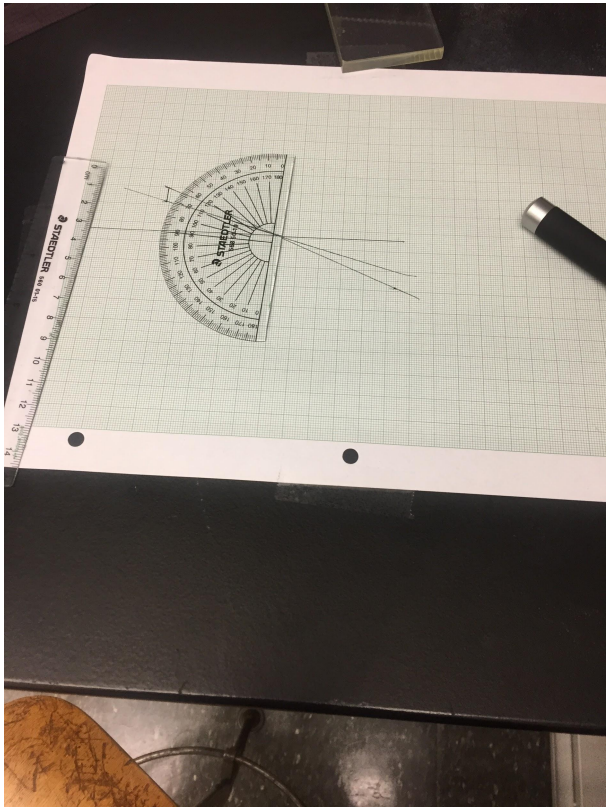


Original Measurement Approach

- Measuring while the laser was on
- Using original graph paper as reference
- Taking whole laser width as systematic error with additional random error
- Taking each measurement of 4 values as a set
- Problems:
  - Beam lifted up and put down to be able to see angles - eventually propped it up instead
  - Laser wouldn’t stay on
  - Prism and laser easily inadvertently moved
  - Protractor placed on top of prism - additional error from perspective
  - Small protractor, beam covers multiple degrees
  - Beam refracted through transparent ruler and protractor
  - Estimated error of +/- .2 for n

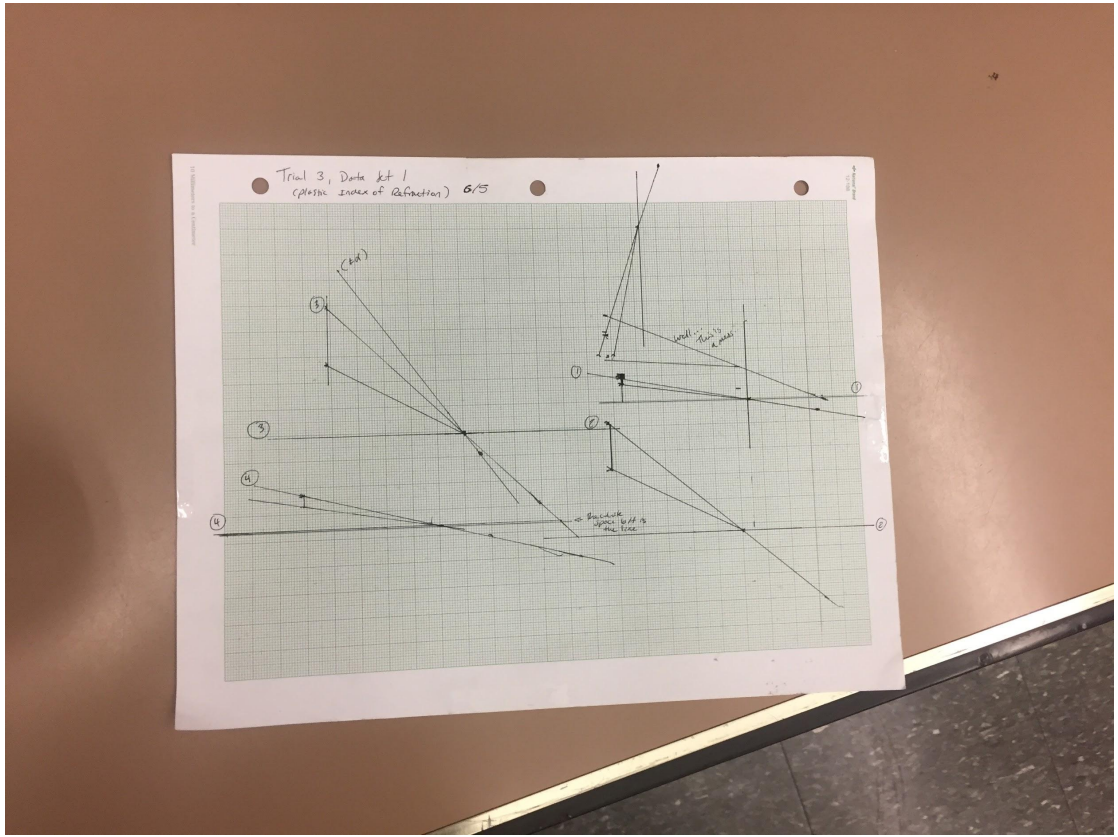
New Approach





New Approach

- Marking the location of the beam and measuring afterwards
- Using more precise graph paper
- Estimating the position of the edge of the laser beam (set 1) and then the center of the laser beam (set 2) as the point of measurement
- Taking each measured value independently
- Problems:
  - Protractor
  - Lines and points contribute to possible systematic error
  - Still error of .06+ for n
  - Data doesn't agree -> error underestimated

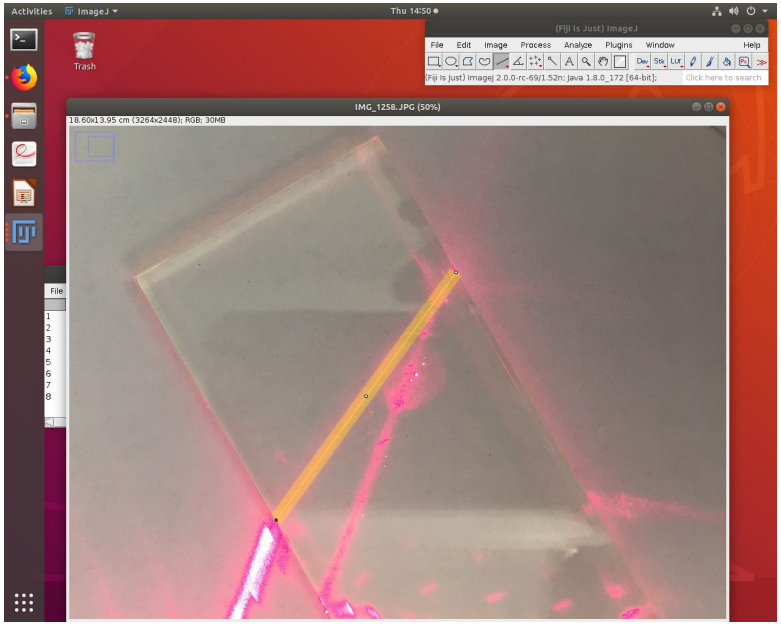


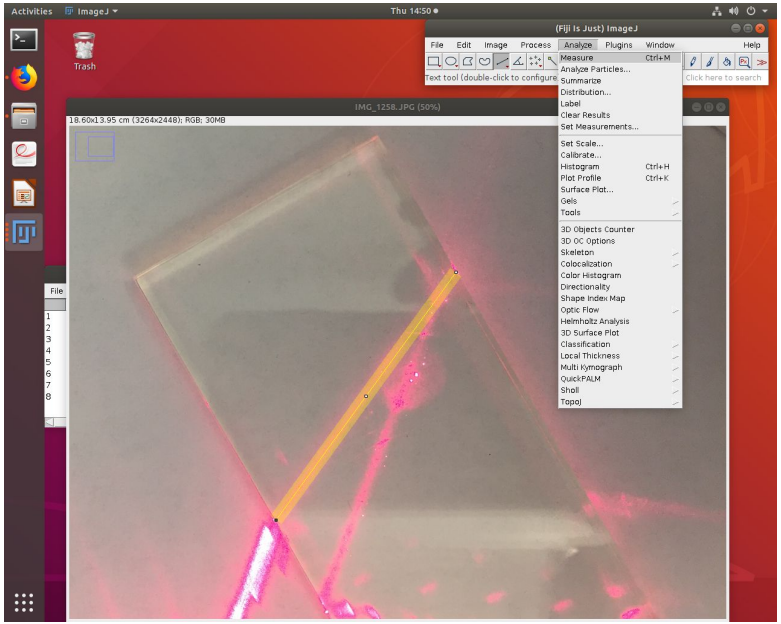
https://docs.google.com/spreadsheets/d/1Txx-vV3wgf3GK_qlBFUmlLhNHIcuCy1psQFxUU7tCow/edit#gid=1346628582 - Spreadsheet

Possible Image Analysis Software

- ImageJ - Free Image Analysis Software https://imagej.nih.gov/ij/features.html
- “Measure area, mean, standard deviation. Measure lengths and angles. Use real world measurement units such as millimeters. Generate histograms and profile plots”
- Fiji - ImageJ Package http://fiji.sc/
- Same measurement features as ImageJ -Tested this week
- Digimizer - not free https://www.digimizer.com/features.php
- ‘Define unit of measurement, measure distances and lengths of line segments or path, measure angles, locate middle of line segment, measurements on perpendicular lines, fit line’
- Adobe Photoshop - https://helpx.adobe.com/photoshop/using/measurement.html
- “Using the Photoshop Measurement feature you can measure any area defined with the Ruler tool or with a selection tool, including irregular areas selected with the Lasso, Quick Select, or Magic Wand tools. You can also compute the height, width, area, and perimeter, or track measurements of one image or multiple images”

ImageJ


Activities
ImageJ
Thu 14:50
Trash
(Fiji Is Just) ImageJ
File Edit Image Process Analyze Plugins Window Help
IMG_1258.JPG (50%)
18.60x13.95 cm (3264x2448); RGB; 30MB


Activities
ImageJ
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(Fiji Is Just) ImageJ
File Edit Image Process Analyze Plugins Window Help
Measure Ctrl+M
Analyze Particles...
Summarize
Distribution...
Label
Clear Results
Set Measurements...
Set Scale...
Calibrate...
Histogram Ctrl+H
Plot Profile Ctrl+K
Surface Plot...
Gels
Tools
3D Objects Counter
3D OC Options
Skeleton
Colocalization
Color Histogram
Directionality
Shape Index Map
Optic Flow
Helmholtz Analysis
3D Surface Plot
Classification
Local Thickness
Multi Kymograph
QuickPALM
Sholl
Topoj
IMG_1258.JPG (50%)
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ImageJ

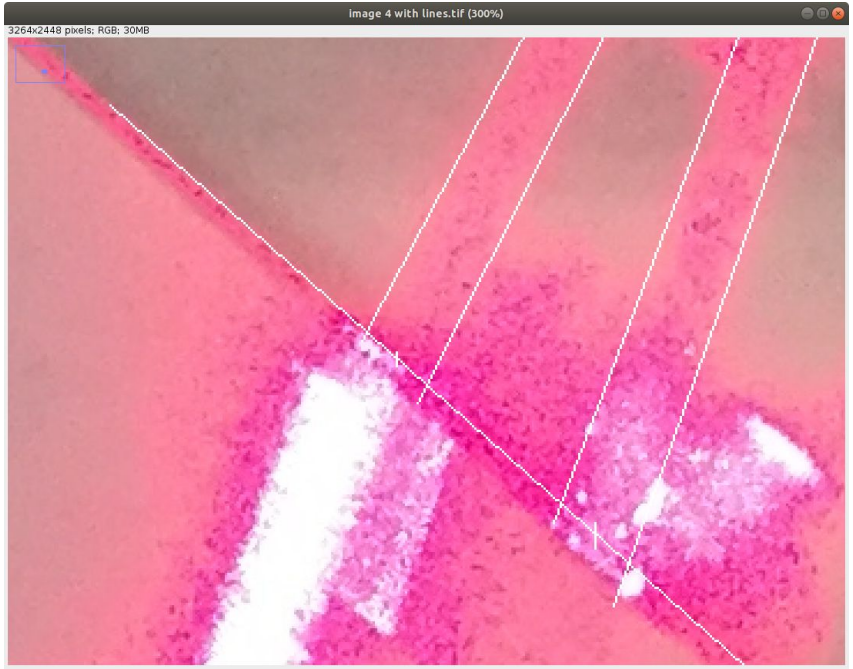
image 4 with lines.tif (300%)
3264x2448 pixels; RGB; 30MB

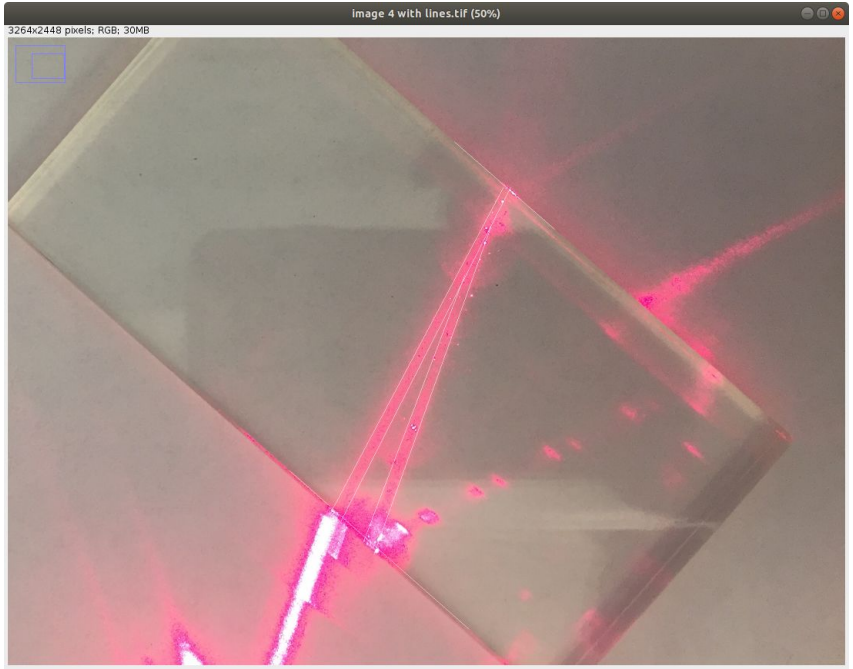
image 4 with lines.tif (50%)
3264x2448 pixels; RGB; 30MB