KENT STATE UNIVERSITY

Conceptual Chemistry

Laser Hair Analysis as a Forensic Investigation Tool

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Conceptual Chemistry

Conceptual Chemistry is a graduate course designed for grade school and middle school teachers to assist in their understanding of chemistry and to provide concrete ideas that they can take back to their classrooms to teach their students.

Conceptual Chemistry

Participants in this course receive:

- Free tuition and five graduate credit hours from the College of Education of Kent State University. *($2,425 value)*
- Over $850 worth of materials and supplies to take back to the classroom.

Conceptual Chemistry

Support for *Conceptual Chemistry* and the development/production of this material was provided by a grant under the federally funded *Improving Teacher Quality State Grants Program*, administered by the **Ohio Board of Regents.**

Spectroscopy

Spectroscopy
The investigation into the nature of matter using electromagnetic radiation.

Most Common Types
Infrared, ultraviolet, visible, NMR, X-ray and microwave.

Activity Objectives

Key Concepts

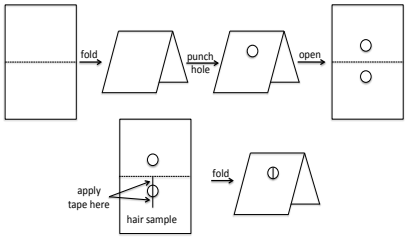
- Molecular Spectroscopy
- Electromagnetic Radiation
- Quantitative Analyses
- Forensic Science
- Having fun with science!

Safety

- Never look directly into a laser beam.
- Never direct laser beams at others.
- Never reflect laser beams off mirrors or other reflective materials.

Laser Hair Analysis

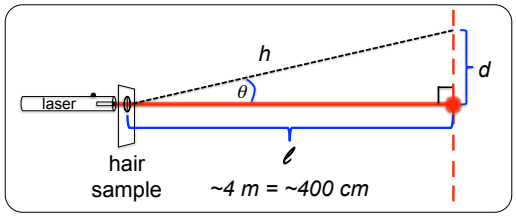
1. Make a hair sample holder using the notecard and single-hole punch.



2. Tape the hair sample vertically in the holder.

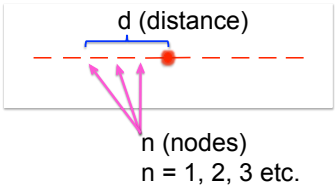
Laser Hair Analysis

3. Tape 3 sheets of 8½" x 11" printer paper together and tape them on a whiteboard.
4. Place the whiteboard ~4 m (400 cm) away from the hair sample. Record this distance, ℓ.



Laser Hair Analysis

4. Shine a red laser pointer light onto the hair sample and view the image on the paper:

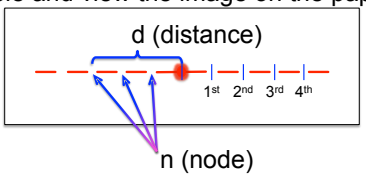


n (nodes)
n = 1, 2, 3 etc.

See actual sample images on next slide.

Laser Hair Analysis

5. Shine a red laser pointer light onto the hair sample and view the image on the paper:

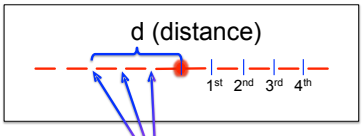


n (node)
n = 1, 2, 3 etc.

6. Use a pen to place a small line in the middle of the center spot and each node to the left and right of the center spot.

Laser Hair Analysis

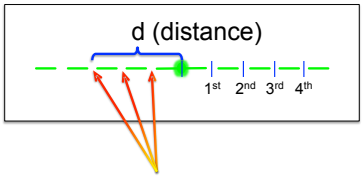
7. Use a meter stick or ruler to measure the distance from the center spot to the nodes in centimeters, ± 0.01 cm.



n (node)
n = 1, 2, 3 etc.

Laser Hair Analysis

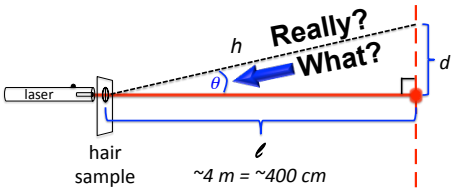
8. Repeat the process using a *green* laser pointer.



n (node)
n = 1, 2, 3 etc.

Calculations

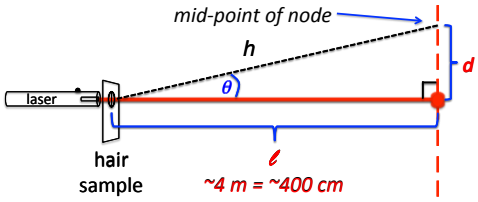
9. Calculate the hair width as follows:



$$w_{hair} = \frac{n\lambda}{\sin\theta}$$

where:
n = node number
λ = laser wavelength
red = 650 nm
green = 532 nm

Small Angle Approximation

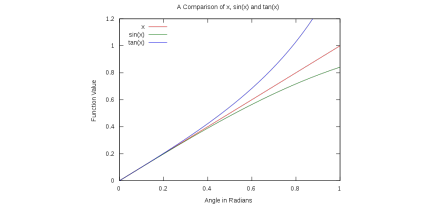


For angles less than 20°:

$$\sin\theta = \frac{d}{h} \approx \tan\theta = \frac{d}{\ell} \approx \theta$$

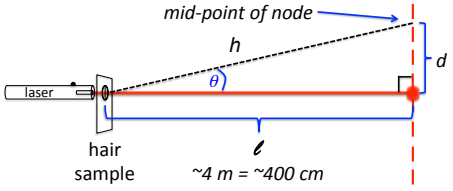
Laser Hair Analysis

Small angle approximation (for ∠'s < 20°):



$$\sin\theta = \frac{d}{h} \approx \tan\theta = \frac{d}{\ell} \approx \theta$$

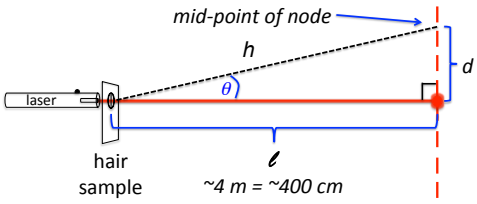
Laser Hair Analysis



$$w_{hair} = \frac{n\lambda\ell}{d}$$

where:
n = node number
λ = wavelength of light
d = distance to node
ℓ = dist. from hair to screen

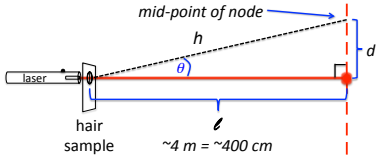
Laser Hair Analysis



$$w_{hair} = \frac{n\lambda\ell}{d}$$

ℓ = 435.30 cm
n = 3, d = 15.00 cm
λ = 650 nm (red laser)

Laser Hair Analysis

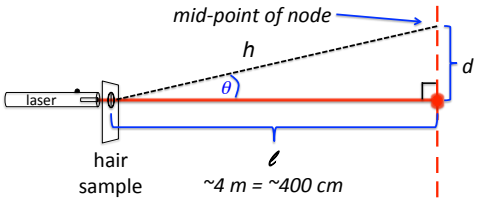


$$w_{hair} = \frac{(3)(650\text{ nm})(435.30\text{ cm})}{(15.00\text{ cm})} = 5.66 \times 10^4\text{ nm}$$

3 sig. figs.

$$5.66 \times 10^4\text{ nm} \times \frac{1\ \mu\text{m}}{1000\text{ nm}} = 56.6\ \mu\text{m}$$

For High School or College

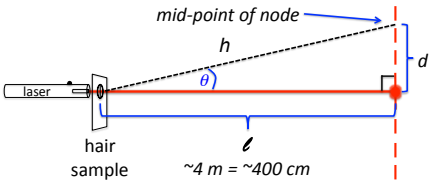


arctangent

$$\tan\theta = \frac{d}{\ell} \qquad \theta = \tan^{-1}\left(\frac{d}{\ell}\right)$$

$$w = \frac{n\lambda}{\sin\theta}$$

Laser Hair Analysis

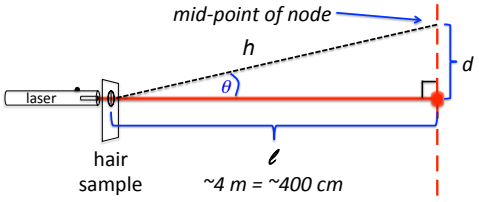


If d = 15.00 cm & red laser (650 nm)

$$\theta = \tan^{-1}\left(\frac{15.00\text{ cm}}{435.30\text{ cm}}\right) = 1.974$$

$$w = \frac{3(650\text{ nm})}{\sin(1.974)} = 5.66 \times 10^4\text{ nm} \times \frac{1\ \mu\text{m}}{1000\text{ nm}} = 56.6\ \mu\text{m}$$

Laser Hair Analysis

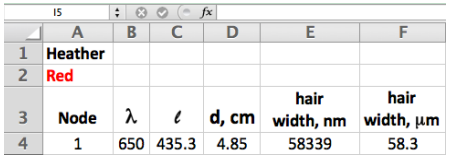


If d = 15.00 cm & red laser (650 nm)

56.6 μm

average human hair = 17 – 180 μm

Excel Calculations



	A	B	C	D	E	F
1	Heather					
2	Red					
3	Node	λ	ℓ	d, cm	hair width, nm	hair width, μm
4	1	650	435.3	4.85	58339	58.3

hair width, nm: =A4*B4*C4/D4

hair width, μm: =E4*1000

Results

Heather

Red

Node	λ	ℓ	d, cm	hair width, nm	hair width, μm
1	650	435.3	4.85	5.83E+04	58.3
2	650	435.3	9.80	5.77E+04	57.7
3	650	435.3	15.00	5.66E+04	56.6
4	650	435.3	19.70	5.75E+04	57.5
5	650	435.3	25.10	5.64E+04	56.4
6	650	435.3	29.60	5.74E+04	57.4
				Average =	57.3
				σ =	0.73

1.54% difference!

Green

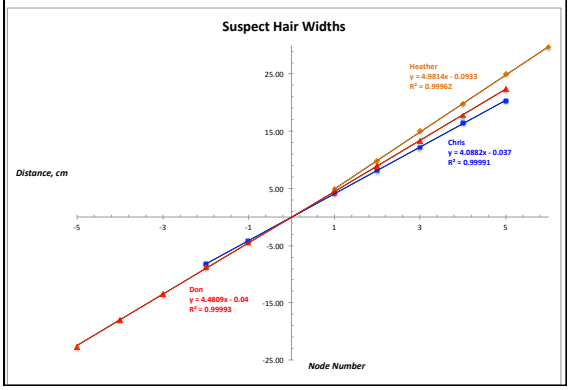
Node	λ	ℓ	d, cm	hair width, nm	hair width, μm
1	532	435.3	4.00	5.79E+04	57.9
2	532	435.3	7.90	5.86E+04	58.6
3	532	435.3	11.90	5.84E+04	58.4
4	532	435.3	16.10	5.75E+04	57.5
5	532	435.3	19.90	5.82E+04	58.2
6	532	435.3	23.90	5.81E+04	58.1
7	532	435.3	27.80	5.83E+04	58.3
8	532	435.3	31.70	5.84E+04	58.4
				Average =	58.2
				σ =	0.34

laser variance ± 10 nm

1.54% (red)

1.88% (green)

Results



Graph Results

Don

Graph results

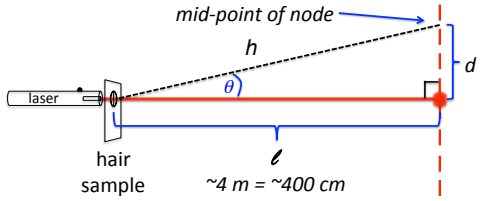
slope	4.48 *cm/node*	slope	3.62 *cm/node*
y-int	-0.0400	y-int	0.125
r^2	*0.99997*	r^2	*0.99997*
hair width	**70.8 μm**	**hair width**	**71.6 μm**
		Difference	1.21%

Data Average

Average = 71.3 μm	**Average = 71.4 μm**
σ = *0.87*	**σ =** *1.02*
	Difference = 0.13%

Overall Method Comparison 0.582%

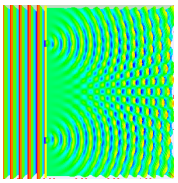
Laser Hair Analysis



$$\lambda_{green} = \frac{d_{green}}{d_{red}} \cdot \lambda_{red} \qquad \lambda_{red} = \frac{d_{red}}{d_{green}} \cdot \lambda_{green}$$

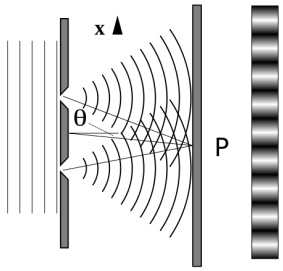
Why This Works

- Light behaves as waves.
- When an obstacle is encountered the beam splits.
- The waves *scatter* and *interference* patterns result.



http://weelookang.blogspot.com/

Interference



Diffraction Pattern

$$w_{slit} = \frac{n\lambda}{\sin\theta}$$

Where:

n = node number

λ = wavelength of light

θ = angle of diffraction

Conclusions

- Both red and green lasers gave excellent results. ± 0.13% - 2.78%, σ < 1.00 μm
- Graphing vs. averages, <1% difference
- Differences were within the laser variance!
- Suspects were easily identified!
- Numerous teaching topic can be covered with one activity: measurement, error analysis, trigonometry, quantum theory, wave theory, etc.

References

1. http://www.optics.rochester.edu/workgroups/berger/EDay/EDay2008_Diffraction.pdf
2. Hecht, Eugene, Optics, 2nd Ed, Addison Wesley, 1987.
3. http://www.wikihow.com/Measure-Hair-Thickness
4. http://stemak.org/sites/default/files/Measuring%20the%20diameter%20of%20a%20hair%20using%20a%20laser.pdf
5. http://io9.com/measure-the-width-of-your-hair-with-a-laser-pointer-1605161189