Boğaziçi University

Introductory Phys Labs

THE BALMER LINES OF HYDROGEN AND RYDBERG CONSTANT

PHYS 202

Boğaziçi University, Physics Department

THEORY

What is diffraction grating?

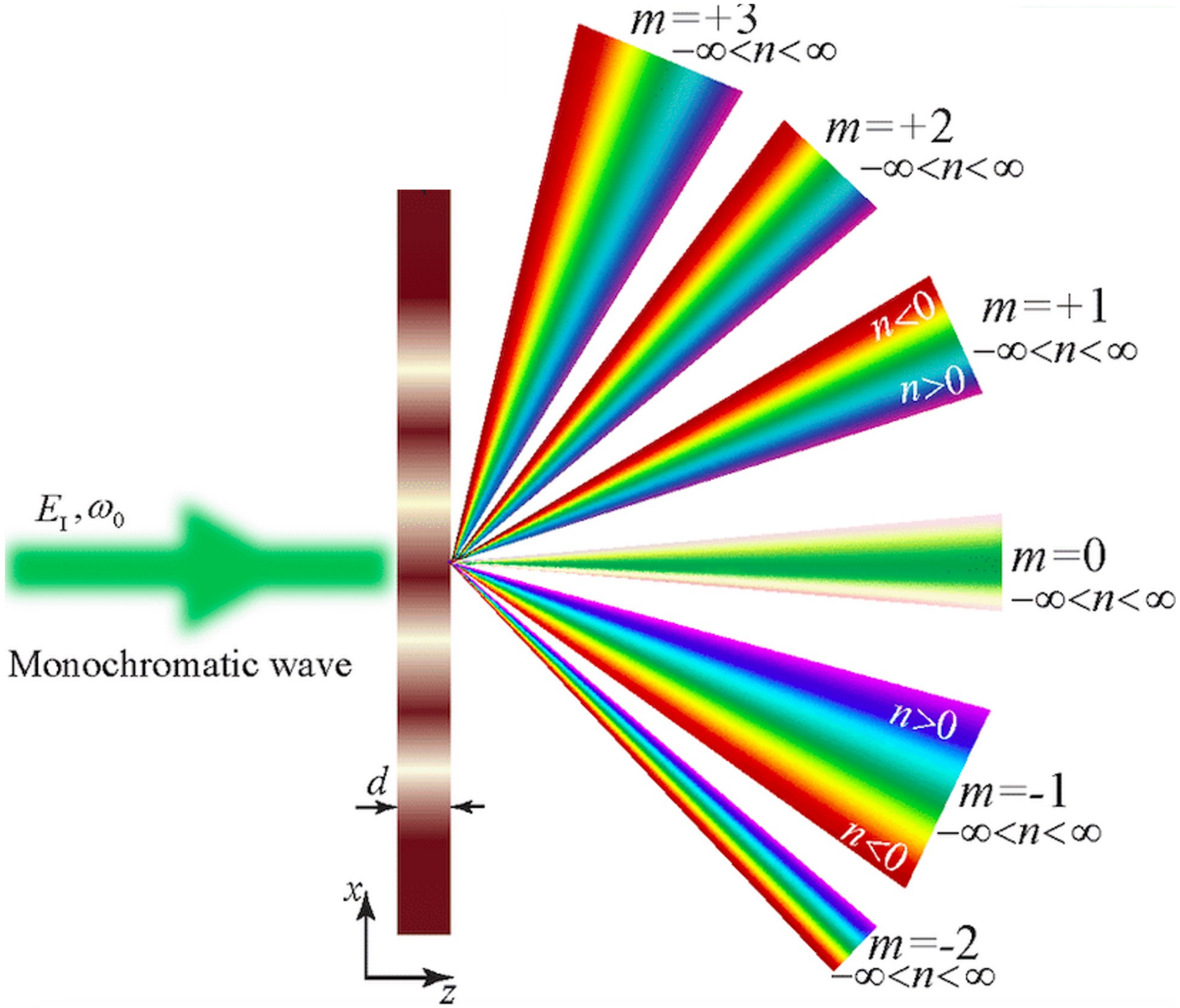
Diffraction grating is an optical device, composed of many equally separated thin slits, that diffracts the incoming light. The angle of diffraction can be determined by the formula

$$m.\lambda = d.\sin\theta$$

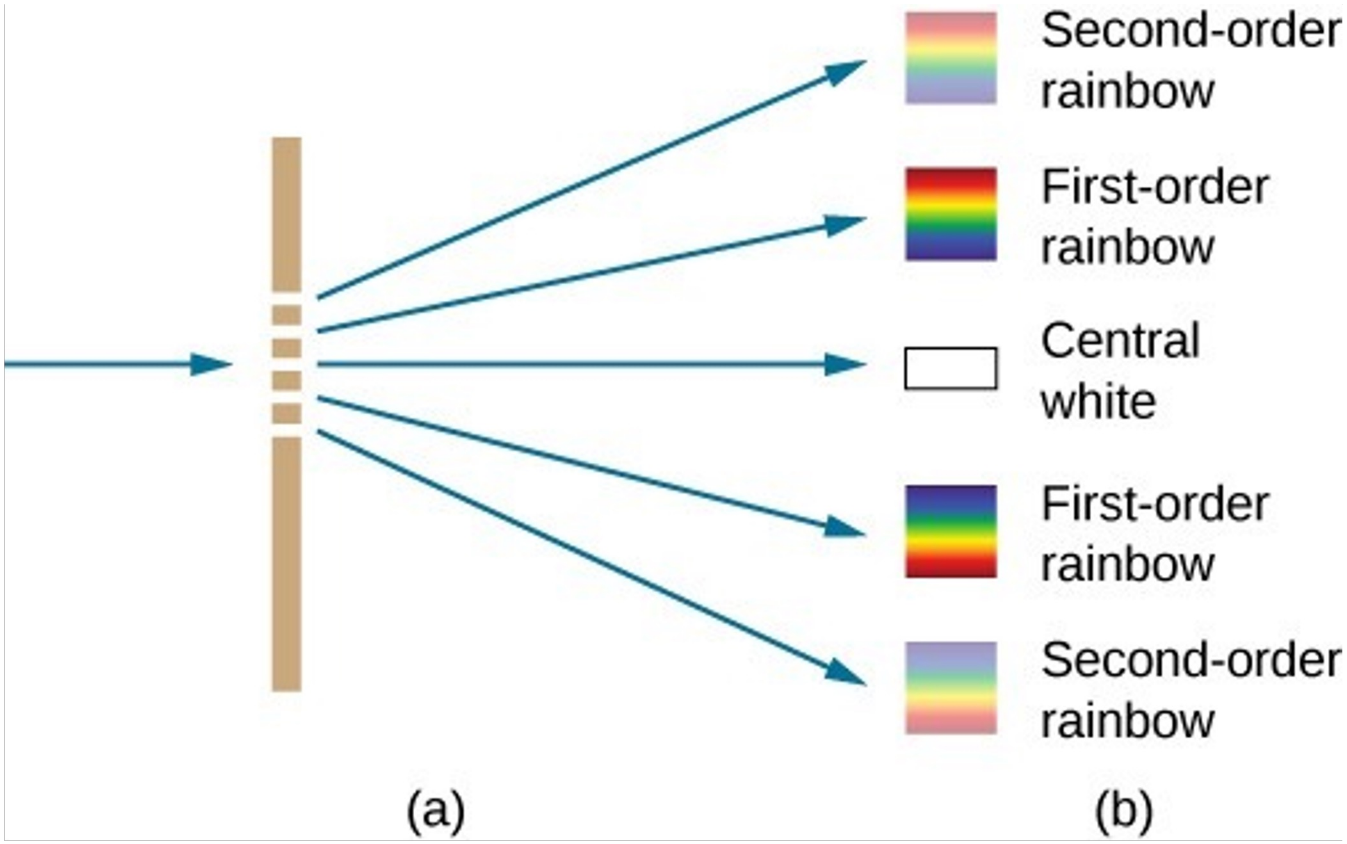
,where

- **d is the separation between successive slits,**
- **λ is the wavelength of incoming light,**
- **m is the order of the spectrum.**

Diffraction of white light:

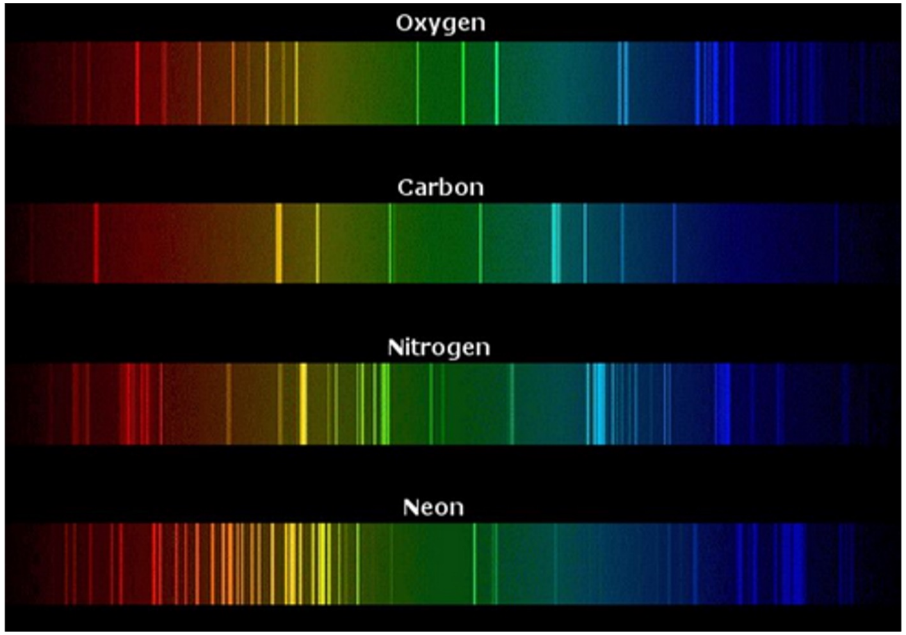


First order (m = 1) diffraction lights are brighter than others. We will use them throughout the experiment.



Emission in an Atom

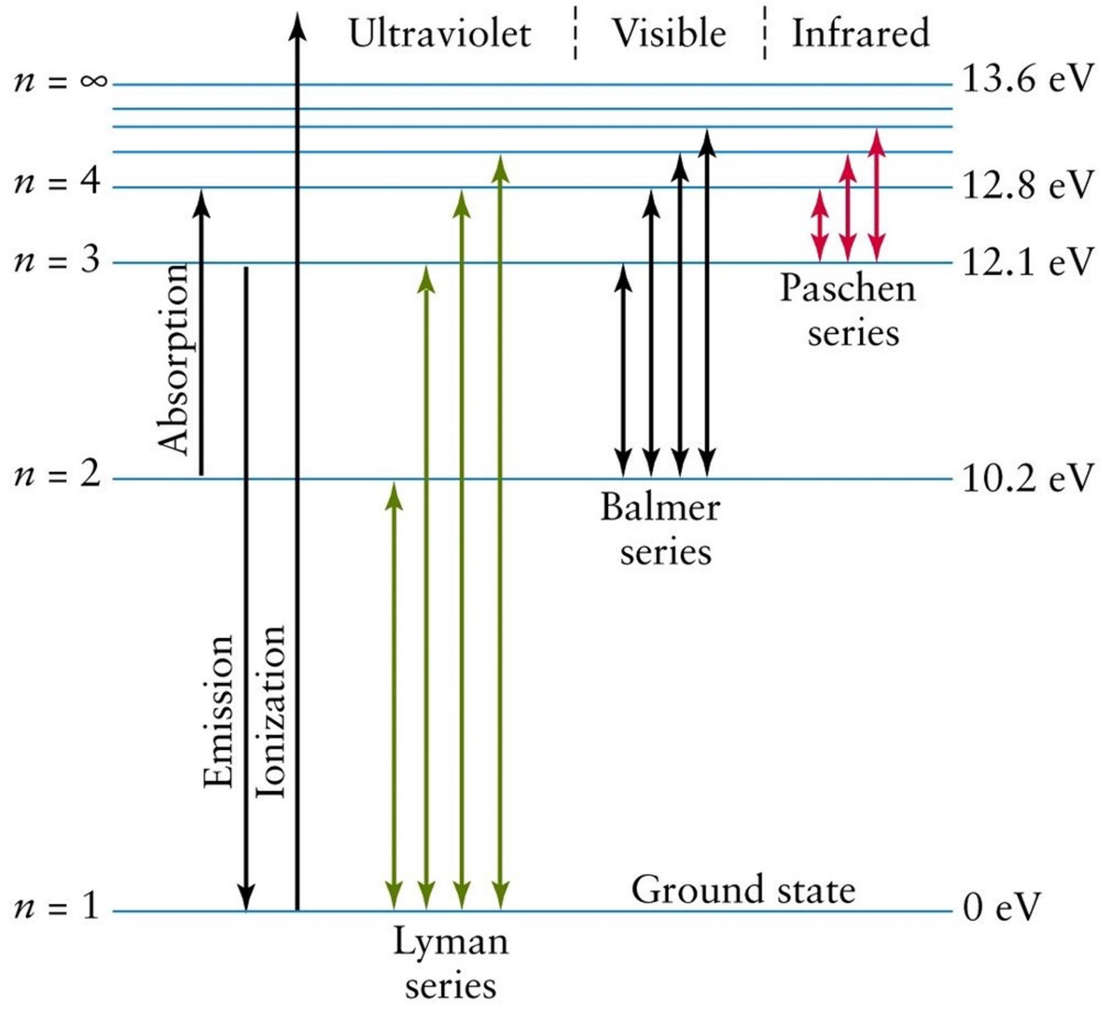
If an atom is given energy through heating or applying voltage, some of its electrons become excited to higher states. After the excitation, the atom gives its excess energy via emitting a photon. The energy of the photon equals to the energy difference of initial and final states of the electron. Since the energy levels unique, each atom has a distinct emission spectra.



Emission in Hydrogen Atom

Emission spectra of Hydrogen atom have special names depending on the final state of the electron. For n = 1, it is called Lyman series.

Balmer series, n = 2, is a special case, since the photons are in the visible range of the spectrum.



Balmer Series:

Four lines from Balmer series falls to visible range in the spectrum. As seen in the figure, red, blue/green and two violet lines are the emission spectra of ni = 3, 4, 5, 6 to nf = 2.

The formula for wavelength is

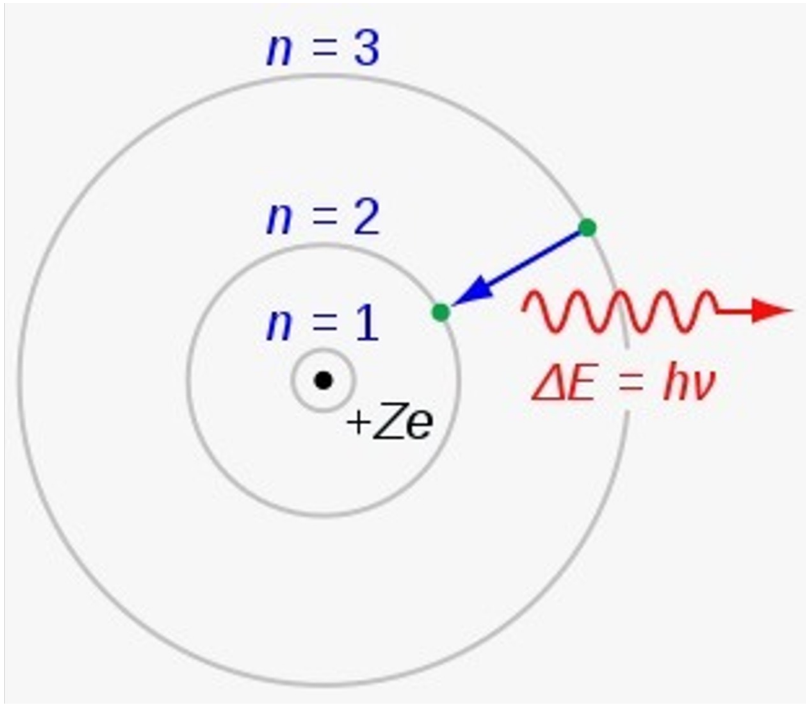
$$\frac{1}{\lambda} = R.(\frac{1}{n_f^2} - \frac{1}{n_i^2})$$

R is the Rydberg constant.

Bohr Atom Model:

The Bohr model is a relatively primitive model of the hydrogen atom, compared to the valence shell atom model.

The Rydberg formula, which was known empirically before Bohr's formula, is seen in Bohr's theory as describing the energies of transitions or quantum jumps between orbital energy levels.



Rydberg Constant

The aim of this experiment is to find Rydberg constant experimentally.

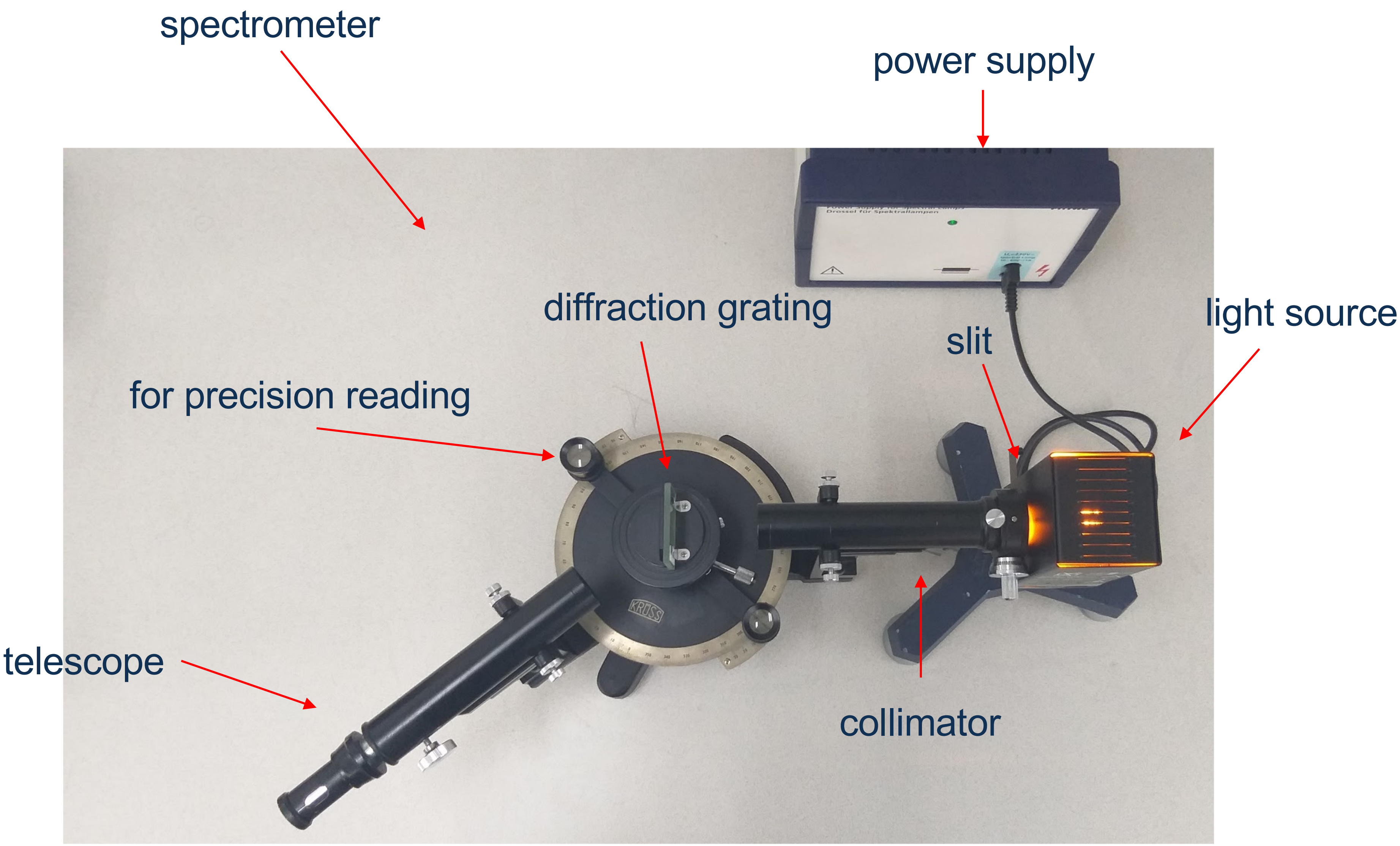
Theoretical formula for the constant is

$$R = \frac{m.e^4}{8.\epsilon_0^2.h^3.c}$$

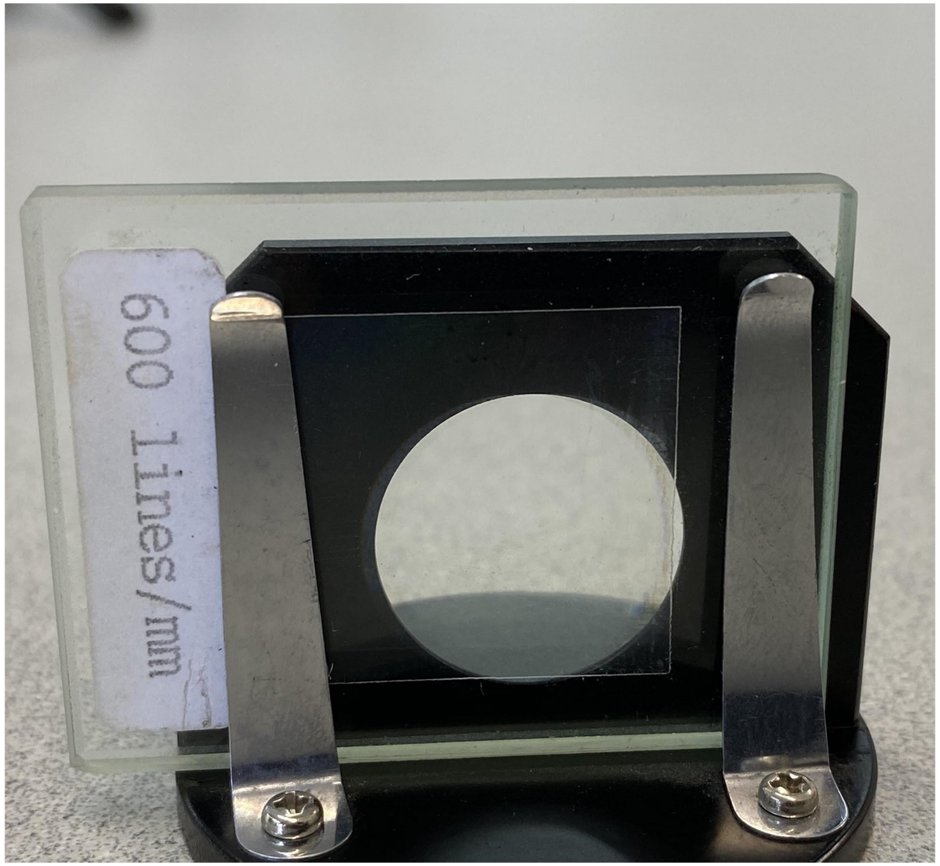
where

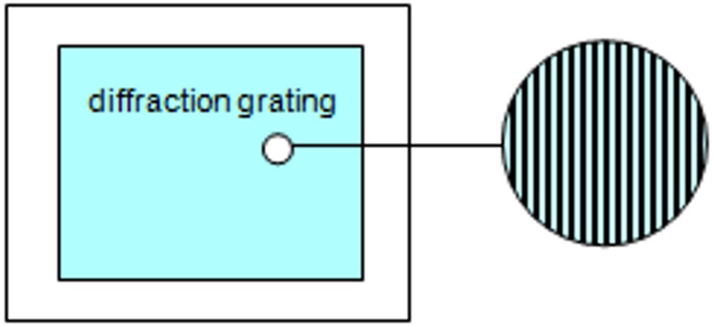
- m is the mass of electron,
- e is the charge of electron,
- h is the Planck constant,
- c is the speed of light and
- ϵ is vacuum permittivity.

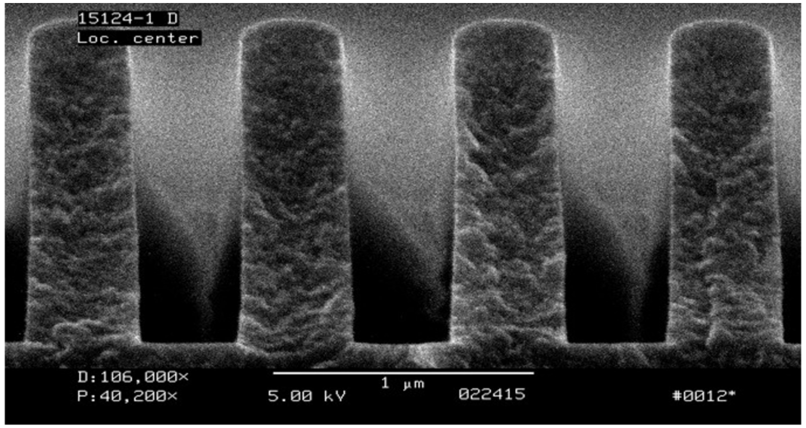
APPARATUS


spectrometer
power supply
diffraction grating
slit
light source
for precision reading
telescope
collimator

Diffraction Grating







EXPERIMENT

- Read the angles for red, green(blue) and violet light from both left and right side of the spectrometer.

- Take the average of left and right angle values for each.

- Use the angles and diffraction grating constant given to calculate the wavelengths for red, green(blue) and violet lights.

Table 1: Angle Measurements

Color of Line	Angle from Left (θ_L)	Angle from Right (θ_R)	Average Angle (θ_{avg})
Red			
Blue-Green			
Violet			

$$m.\lambda = d.\sin\theta$$

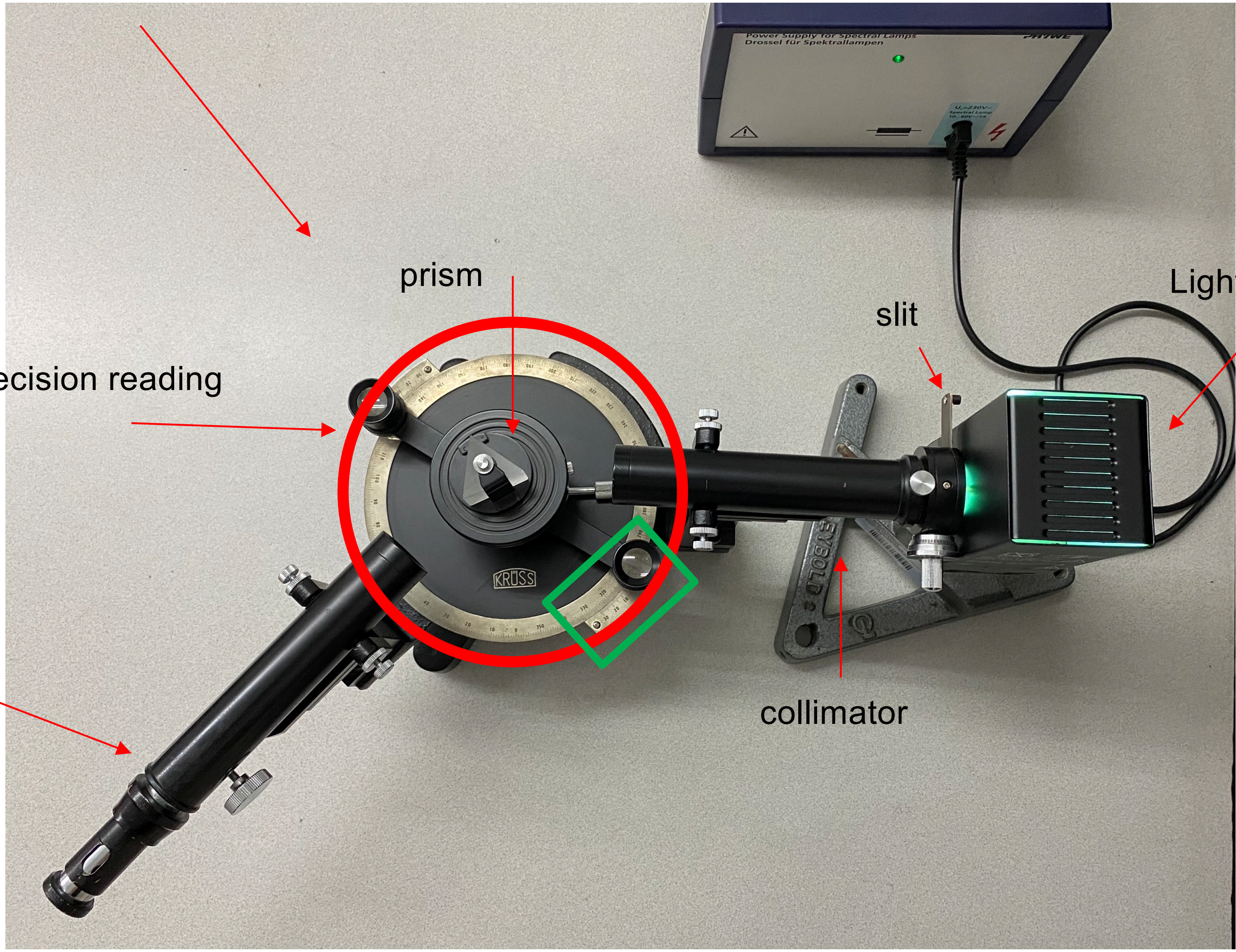
With the appropriate initial and final states for red, green and violet light, calculate the Rydberg constant using wavelengths and states. Calculate the average Rydberg constant.

Table 3: Wavelengths and Rydberg Constant

Color of Line	Measured Wavelength (nm)	Calculated Rydberg Constant(m^{-1})
Red		
Blue-Green		
Violet		

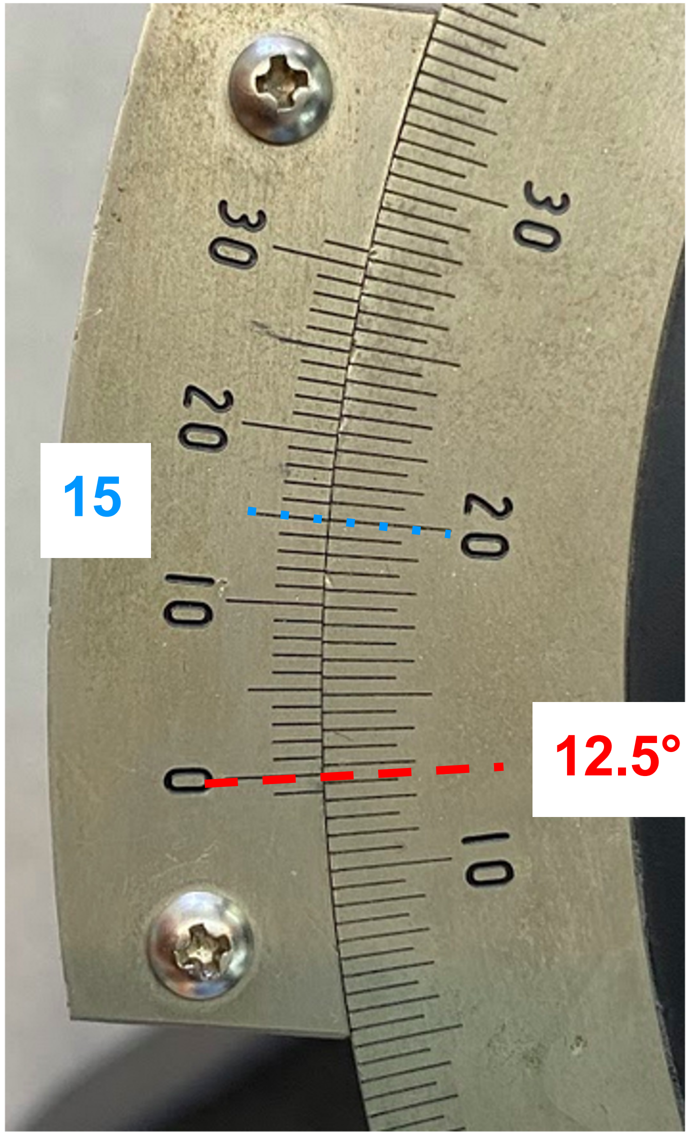
$$\frac{1}{\lambda} = R.(\frac{1}{n_f^2} - \frac{1}{n_i^2})$$

SPECTROMETER



Reading the Angle:

Find the intersection point of zero value of the outer scale and inner scale. Then, pick the value on the inner scale that intersection point passes. Note this angle value up to 1 significant figure after the decimal point. In this figure the value is 12.5°.
Then, find the line on the outer scale that exactly matches with the line in the inner scale. Read the value from outer scale. In this figure, 15 of the outer scale is the exact match.



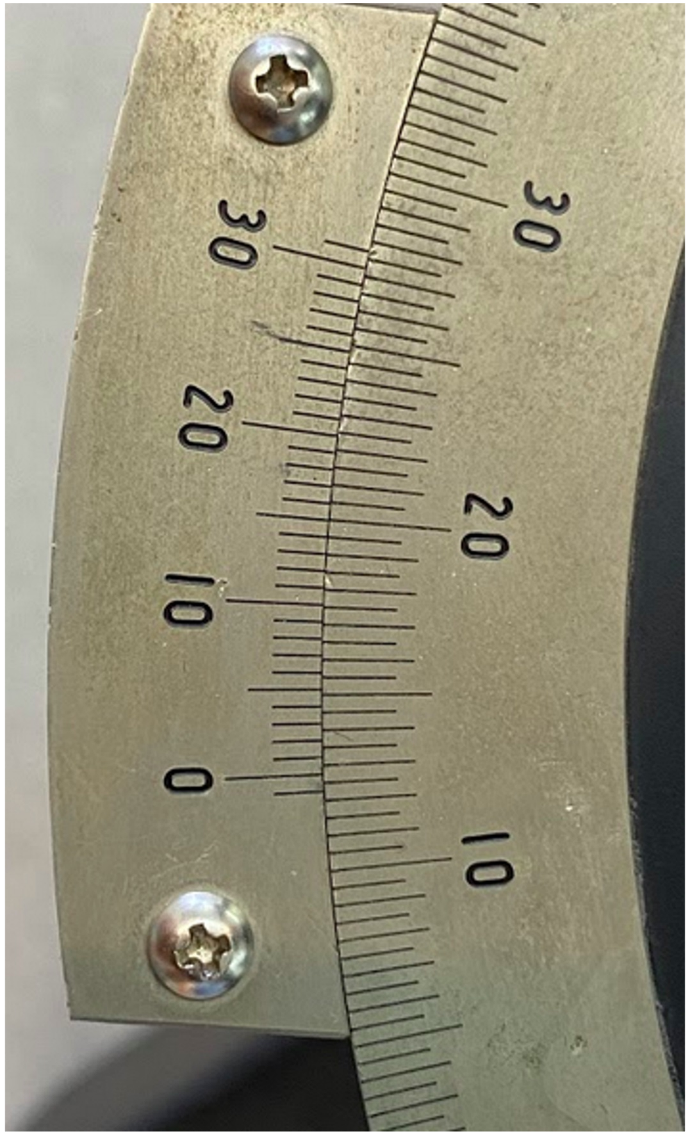
Reading the Angle:

Note this values as 12.5°(15).

The outer scale divides 0.5° to 30 (or 1° to 60). So any reading x from outer scale means x/60 degree angle.

The final reading for this image is

$$12.5^\circ + \frac{15}{60} = 12.75^\circ$$



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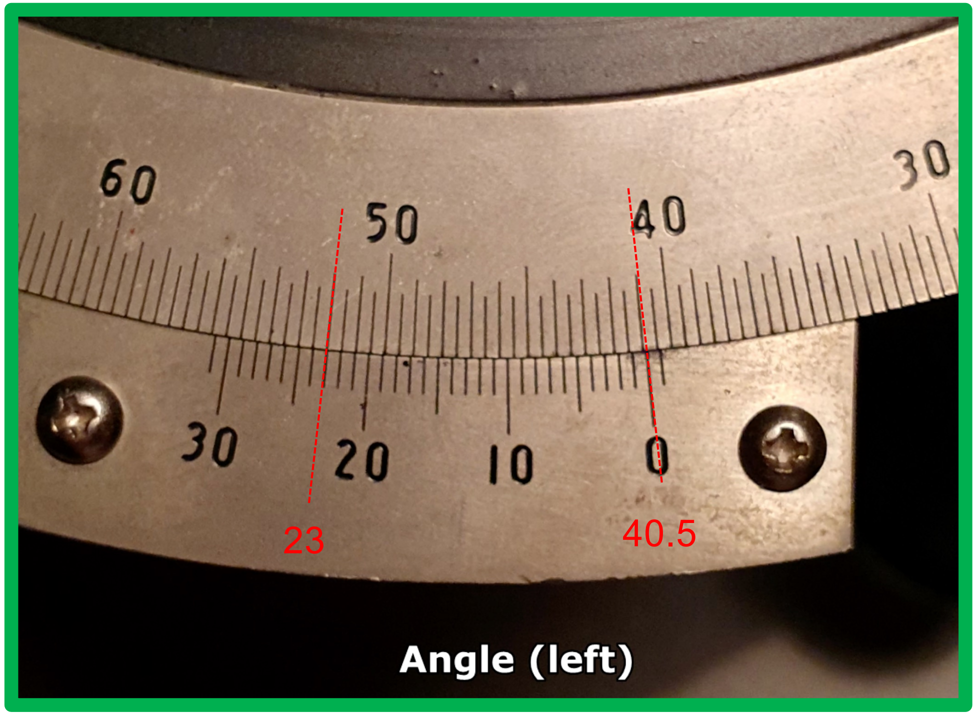
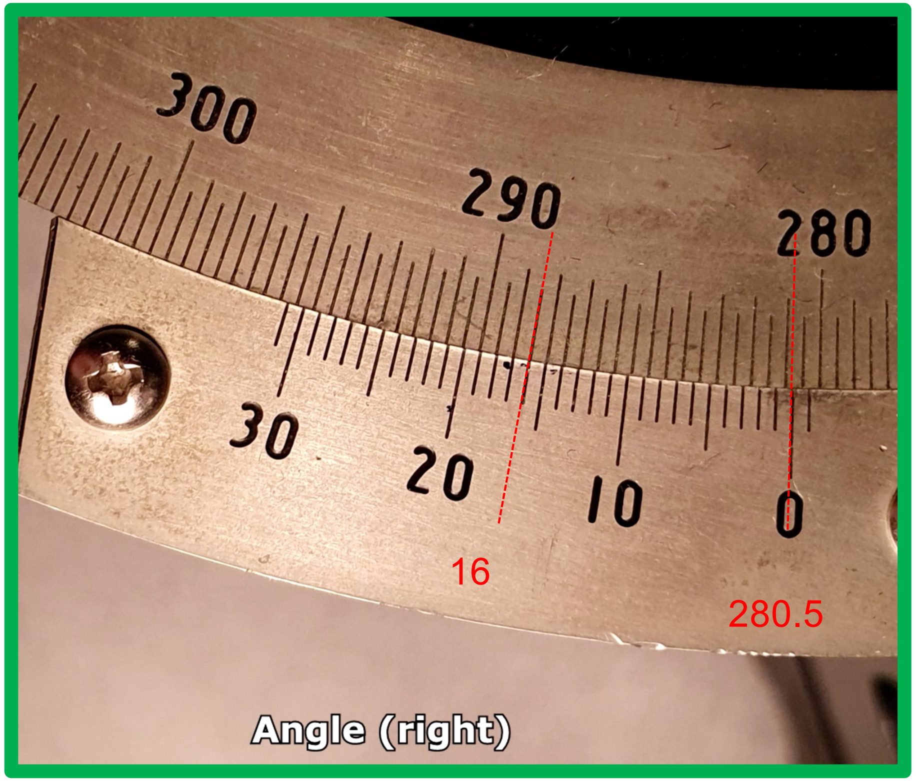
SPECTROMETER





40.5(23)°
30 0.5°
23 x
x=0.38° (2 SF)
40.88° (2 SF after decimal point)

280.5(16)°
30 0.5°
16 x
x=0.27° (2 SF)
280.77° (2 SF after decimal point)

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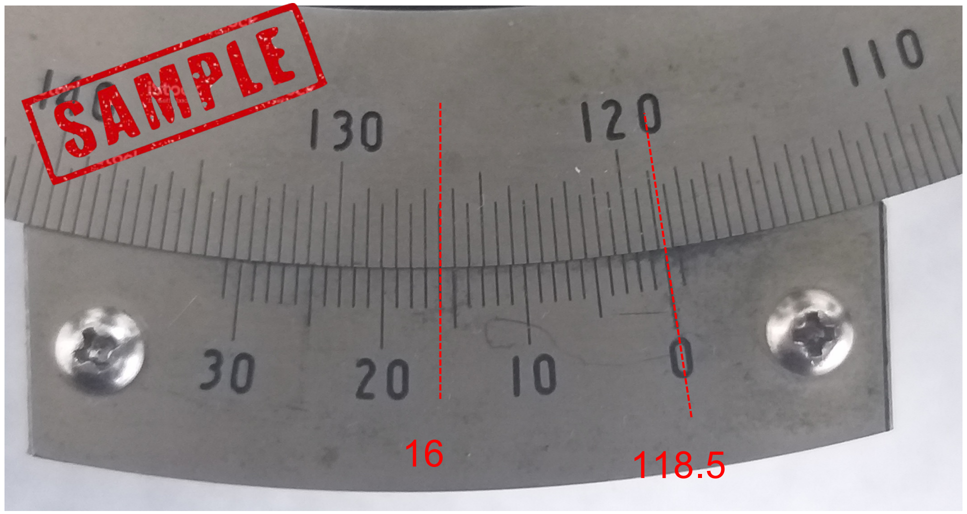
WHITE LIGHT REFLECTION – demonstration 0 ° – 0 ° match

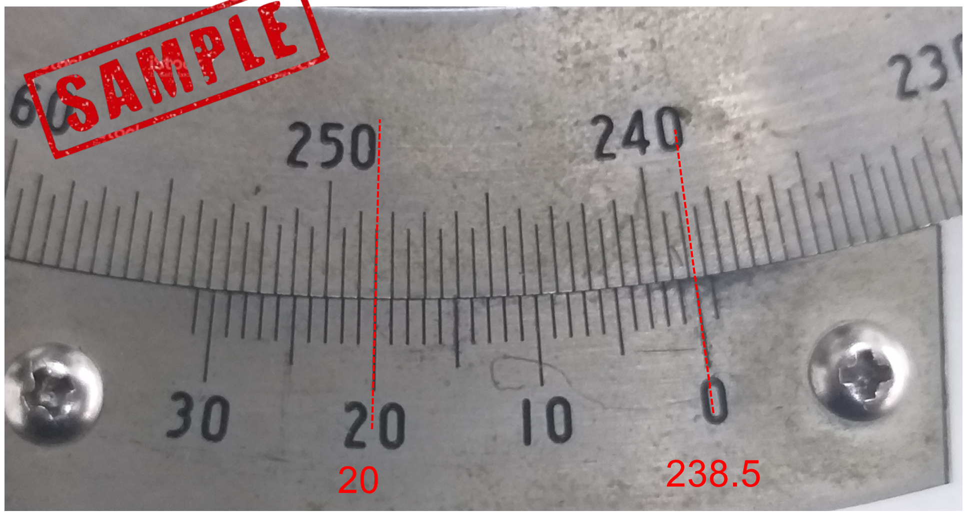
58.5(12)°
30 0.5°
12 x
x=0.20° (2 SF)
58.70° (2 SF after decimal point)

298.5(15)°
30 0.5°
15 x
x=0.25° (2 SF)
298.75° -> 360.00° – 298.75°
= 61.25° (2 SF after decimal point)

(58.70°+61.25°)/2= 59.98° = α

WHITE LIGHT REFLECTION – demonstration 0 ° – 180 ° match





118.5(16)°
30 0.5°
16 x
x=0.27° (2 SF)
118.77° (2 SF after decimal point)

238.5(20)°
30 0.5°
20 x
x=0.33° (2 SF)
238.83° (2 SF after decimal point)

(238.83°-118.77°)/2= 60.03° = α