NAME OF PRACTICAL

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Category

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Atul Singh Arora: *Name of Practical,* Category, *Every honest researcher I know admits he's just a professional amateur. He's doing whatever he's doing for the first time. That makes him an amateur. He has sense enough to know that he's going to have a lot of trouble, so that makes him a professional.*

— Charles F. Kettering (1876-1958) (Holder of 186 patents)

ACKNOWLEDGEMENTS

I express my sincere gratitude to our instructors, Mr. Instructor and , for bringing the subject to life and helping us discover, in depth, the science behind the procedures.

I also thank Vivek Sagar (MS11017) for his contribution to this report as my lab-partner, who made the task of performing experiments immensely comfortable and productive at the same time.

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ACRONYMS

1 CHARGE TO MASS RATIOE/M

January 8 and 15, 2012

1.1 AIM

To determine the charge to mass ratio (e/m) of an electron by the helical method (long solenoid).

1.2 APPARATUS

e/m by Helical Method apparatus (we used the one by SIBA India), connecting wires

1.3 CATHODE ANODE

Cathodes are defined to be where a reduction takes place (chemically). Thus in accordance with the image appended, the anode is where the conventional current starts from and moves towards the cathode. For an electron, it starts from the cathode and moves towards the anode.

1.4 THEORY

Our objective here, as described earlier, is to determine the charge to mass ratio. For this, we shall describe here, an apparatus, without developing a motivation for doing the same.

First, consider a vacuum tube; in one edge, say the starting edge (there's a screen at the other edge), we place a cathode and a perforated anode and apply a constant potential difference between them (the polarity is implied from the definition of cathode), such that the electrons move away from the starting edge. Now we can evaluate the speed of the electrons that pass through the anode by invoking the work energy theorem as follows:

$$\frac{1}{2}mv^2 = eV \tag{1}$$

where the symbols have their usual meaning, viz. m is mass of electron, v is speed of electron at the instant described, V is the potential applied across the anode and cathode, and e is the charge of one electron. Refer to the diagram for direction conventions assumed. If we try to turn on the apparatus at this stage, we should just see a spot, we assume to be the centre of the screen (this may not necessarily happen experimentally, but can be adjusted; however for simplicity, we will discuss that later)

Now the next step is introducing a differential velocity component (do not confuse this with infinitesimal) along the X direction. This is done by applying an alternating electric field as shown in the figure. When the electrons reach the plane A, they would have a certain distribution of velocity components along the X direction. It is important to realize here that the distribution of electrons along the X axis will be fairly small, because the velocities are not large enough to cause enough spatial deviation, in the small time corresponding to the length of the accelerating plates. This condition can be achieved by making the speed of the electrons sufficiently large with respect to the length of the alternating electric field plates. Yet, when observed on the screen, a line would be obtained (it's length would depend on the strength of the alternating electric field) as the electrons get displaced along (or against) the X axis, as they're displaced by L' along the Z axis, because of the initial velocity.

With that said, it is now that we introduce a uniform magnetic field B along the Z axis. We are certainly introducing certain errors by doing so, as the magnetic field in the experiment is present everywhere in the tube, when it's turned on. However, to simplify, we account for it's effect after the electrons have passed the plane A. Now most electrons would have a non-zero velocity component along the X axis, viz. a direction perpendicular to the uniform magnetic field. Thus, we can evaluate the radius of the acceleration of the electron with velocity v_x can be evaluated as

$$\frac{m_e v_x^2}{r} = e v_x B \tag{2}$$

$$\Rightarrow \omega = \frac{v_x}{r} = \frac{m_e B}{m} = \frac{2\pi}{T} \tag{3}$$

$$\Rightarrow T = \frac{2\pi}{eB} \tag{4}$$

Using the formula for a solenoid and taking $\theta_1 = \theta_2 = \theta$ tending to zero in the following

$$B = \mu_0 N I (\cos\theta_1 - \cos\theta_2)/2L \tag{5}$$

where the symbols have their usual meanings and θ is the corresponding angle (loosely speaking, s.t. for the angle tending to zero, it results in an ideal, infinite length solenoid)

Using this and equating T to the time $t = l/v_z$ (time taken by the electron to travel the distance l, as given in the diagram), we get the following working formula.

$$\frac{e}{m} = \frac{V}{2I^2}\left(\frac{4\pi L}{\mu_0 N l \cos\theta}\right)^2 \tag{6}$$

where for our setup, we have $N = 980$ (the number of turns), $L = 43$ cm, $l_x = 13.5$ cm, $l_y = 11$ cm.

1.5 OBSERVATIONS AND CALCULATIONS

Observations have been appended at the end of this experiment.

1.6 PROCEDURE

1. Placed the solenoid in the wooden bracket such that its axis lies in the east-west direction (although this is not very important, since the magnetic field would change at most by about 2%). Mounted the CRT inside the solenoid at the centre. The power unit should be kept as far away as possible to avoid stray magnetic field. [1]
2. Connected the CRT with it's power-supply using the 8 wire plug into the octal base provided
3. Connected the solenoid with the DC power terminals colourwise.
4. Turn off the magnetic field by using the corresponding knob.
5. Plug the supplies to the mains, and switch it on. Leave it for about three minutes for the CRT to warm up.
6. Adjust the accelerating voltage to get a spot. Adjust the focus and intensity to get a finer and clearer spot. Note the accelerating voltage.
7. Apply an AC voltage to the Y or X plates by means of the DEF volt control. Do note that you need to turn on the deflection plate to centre the position of the spot, while the DEF knob is at zero. Otherwise the control for centring doesn't work.
8. Now adjust the deflection to about 2 cm.
9. Now put the DC in the forward direction. Turn on the solenoid current and increase the DC voltage till the line reduces to a point. (you are increasing the magnetic field)
10. Reverse the DC voltage using the other knob and again find a DC voltage to get a point. Note both currents
11. Repeat the same with Y or X plates (depending on which you did first)
12. Use the formula derived earlier and plug in the value of the slope of the V vs I^2 graph.

1 The procedure is highly influenced from the Lab Manual for PHY212, 2013

1.7 RESULT

The expected e/m ratio is 1.66×10^{11} C/Kg. Experimentally, we obtained 1.66×10^{11} C/Kg and 1.57×10^{11} C/Kg for the X with a 7% standard error and Y with a 9% standard error.

1.8 PRECAUTIONS

Precautions have been embedded place-wise in the procedure.

2 FRANK HERTZ

February 16, 2013

2.1 AIM

To experimentally verify that atomic energy levels are discrete, using the frank-hertz setup.

2.2 APPARATUS

Frank Hertz Apparatus, An Oscilloscope, a few connecting wires and a camera or tracing paper

2.3 THEORY

2.3.1 *Rationale Behind the Experiment*

This experiment is very fascinating, for it experimentally, using a rather naive method, proves the atomic energy levels are discrete.

The basic idea is to bombard atoms with progressively higher energy electrons, and measure the current of these electrons. When the electrons have specific, discrete energy values, they collide plastically with the atoms and the current drops. If we plot the energy of the electrons against the current obtained, the difference in energy between two consecutive valleys (in the graph), will give the energy difference between two atomic states.

2.3.2 *Experimental Setup*

The detailed setup of the experiment is beyond the scope of this report. However, to a first approximation, the setup can be understood in terms of a triode as given in Figure 1. An electrode is heated by flow of electric current. This thermal energy, acquired by the electrons, if exceeds the binding energy of the electron with the metal, results in ejection of electrons from the metal surface. (Of course there would be a distribution of thermal energy, however, here we are not getting into the quantitative details) There's another electrode, called the grid, which is at a higher potential with respect to the cathode (the first electrode, which releases electrons). This potential is maintained to a desired value by a variable potential source. Most electrons, get through the grid, and gain an energy equivalent to eV where e is the charge of an electron, and V is the potential difference between the electrodes. So far so good. Now we introduce a third electrode. The magnitude of potential difference between the grid and the cathode is greater than that between the grid and the third electrode (call it V_2), viz. $|V| > |V_2|$. Consequently, the current that flows through the third electrode, will be constituted by electrons that have an energy greater than eV_2. The entire setup is enclosed within a vacuum tube, with Argon atoms.

Now we vary V to increase the maximum kinetic energy and measure the current I through the third electrode. The current is expected to increase in a known fashion (precise details are not relevant at the moment) in the absence of Argon. In the presence of Argon, the current drops periodically to a minima, at constant voltage differences.

2.4 OBSERVATIONS AND CALCULATIONS

Observations have been appended at the end of this experiment.

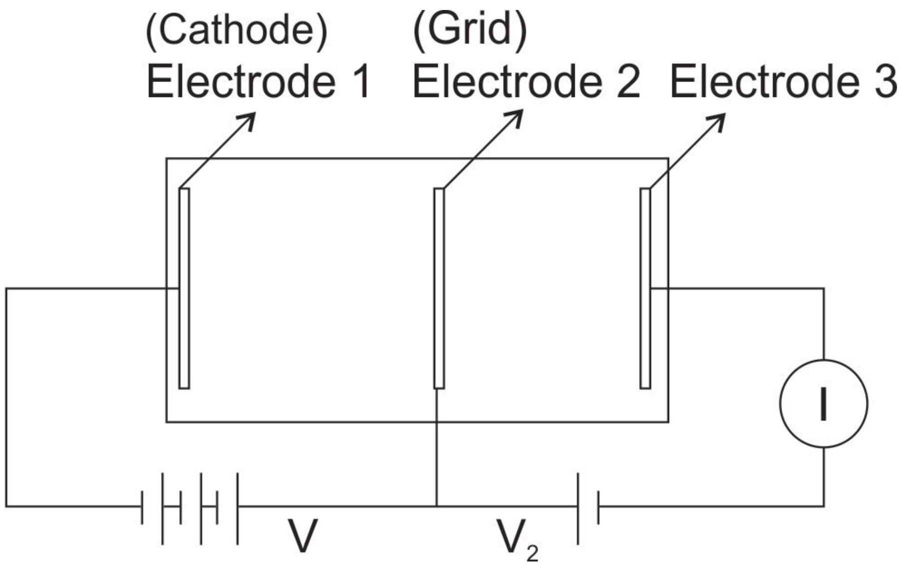

Figure 1: Simplified schematic of the Setup

2.5 PROCEDURE

The procedure has been influenced heavily by the one given in the Physics Lab Manual, provided to us, during the course, PHY212, 2013.

1. Before switching on the power, it was made sure that the control knobs are at their minimum and the current multiplier knob is set to 10^{-7}.
   a) Manual
   b) The Manual mode was selected using the Manual-Auto switch.
   c) Turned the display selector to V_{G_1K} and adjusted the corresponding knob to read 1.5V on the display
   d) Next, V_{G_2A} was selected and set to 7.5V
   e) Now, the V_{G_2K} knob was turned and the variation of the current (these correspond to V and I discussed in the theory) noted, with increase in voltage from zero.
   f) The graph for the same is plot and average distance between two successive maxima (or minima) is calculated. This gives the first excitation potential for Argon.
   g) Automatic
   h) Scanning mode was selected by turning the Manual-Auto switch to auto.
   i) The instruments X, Y, G sockets were put in the corresponding sockets of the CRO.
   j) The scanning range switch of the CRO was set to X-Y mode/external X.
   k) Switched on the scanning knob of the instrument and the waveform observed.
   l) The X-gain and -gain were adjusted to obtain a clear waveform and the Y amplitude within the screen range.
   m) The horizontal distance was again measured between the peaks.

2.6 RESULT

The expected value of the first excitation energy of Argon is $11.83eV$. Experimentally, from the manual mode, the same was found out to be $11.7 \pm 0.4eV$, and from the auto mode, it was found out to be $12eV$. Figure 2 shows the graph corresponding to the manual mode.

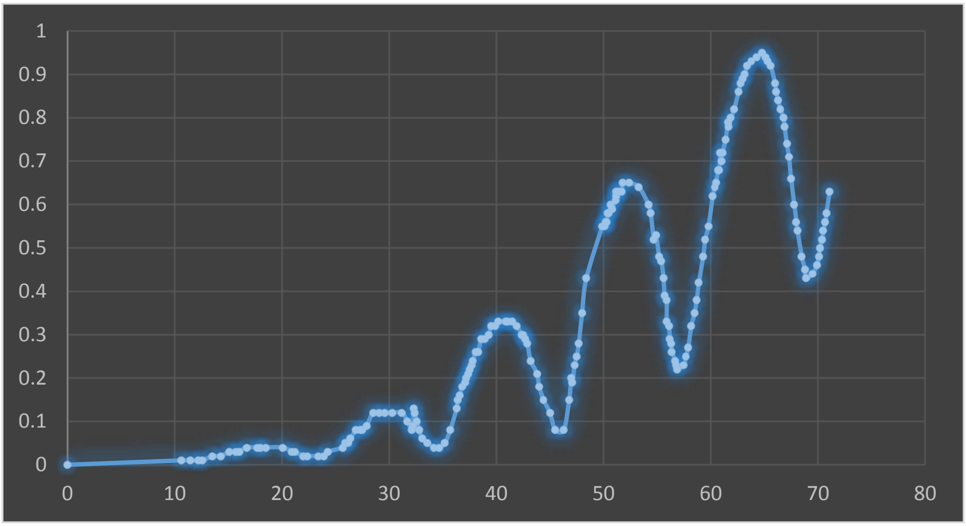

Figure 2: Graph for the Manual Mode

3 HYDROGEN BALMER SERIES AND RYDBERG CONSTANT

Feb 19 and 26, 2013

3.1 AIM

To experimentally measure the Balmer series line of the Hydrogen spectrum and calculate Rydberg's constant, R from the result.

3.2 APPARATUS

Hydrogen Discharge tube, Diffraction grating, Spectroscope

3.3 THEORY

3.3.1 *Motivation*

The Spectrum of hydrogen is spread over a large range in the electromagnetic spectrum. The visible part is known as the Balmer series, given by the formula

$$\frac{1}{\lambda} = R\left[\frac{1}{4} - \frac{1}{n^2}\right] \tag{7}$$

where n is an integer > 2. The general formula for the Hydrogen Spectra is given by

$$\frac{1}{\lambda} = R\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right] \tag{8}$$

where $n_f > n_i$. This reduces to the previous formula for $n_f = 2$. This equation was derived by Rydberg as a phenomenological description. The same equation was derived by Bohr, from more basic principles of physics, using quantization ideas from Plank and Einstein, and certain other bold assumptions (no radiation for specific orbits and angular momenta) to conclude the following

$$R = \frac{me^4}{8\epsilon_0^2 h^3 c} \tag{9}$$

where m and c are mass and charge of the electron

3.3.2 *Experimental Setup*

The setup is fairly straight forward. We have a Hydrogen discharge tube (source of Hydrogen spectrum) placed in front of a [[telescope device]] with a diffraction grating in between. This grating results in splitting of the spectrum spatially. We measure the positions of these split lines to find their wavelengths and plot the corresponding quantities to find the value of R.

3.3.3 *Useful Results*

To calculate λ, we use the relation $d \sin\theta = m\lambda$ with $m = 1$.

R in SI units is $1.09 \times 10^7 m^{-1}$

The wavelengths of the Balmer series are 656.28 nm, 486.13 nm, 434.05 nm and 410.17 nm, for $n = 3, 4, 5$, and 6 respectively.

3.4 OBSERVATIONS AND CALCULATIONS

Please refer to Figure 3.

3.5 PROCEDURE

The procedure has been influenced heavily by the one given in the Physics Lab Manual, provided to us, during the course, PHY212, 2013.

1. Focussed the telescope to infinity (Took the telescope outside the dark room for this, focussed at something outside the window)
2. Placed the light source about 1 cm from the collimator slit. The slit was left barely open.
3. Looked through the eye piece and adjusted it to ensure the cross wire is aligned well and visible. Do NOT move the telescope's focus
4. Rotated the telescope arm to align directly with the collimator.
5. Turned on the light source and viewed the slit of the collimator
6. Focussed the collimator to obtain a sharp image of the slit.
7. Now placed the diffraction grating in the corresponding mount, at right angles to the axis formed by the collimator and the telescope
8. Looked straight through the telescope to continue seeing the direct image of the slit. Ensure at this stage that the image is getting formed at the centre.

9. Used the cross wire to measure the left and right edge of the slit
10. Rotated the arm of the telescope to left or right, and observed the coloured spectrum. The contrast of the lines can be increased at the cost of brightness by adjusting the slit width. This may be done to identify the first order lines. Higher order lines come at higher angular deviations.
11. Noted the position of the three Balmer lines corresponding to $n_i = 5, 4$ and 3.

3.6 RESULT

The expected value of the Rydberg constant $R = 1.09 \times 10^7 m^{-1}$. Experimentally this was determined to be $1.00 \times e^7$ with $R^2 = 0.9213$ for the straight line fit.

	MSD (Left)	VSD(Left)	Angle (Left)	MSD (Right)	VSD (Right)	Angle (Right)	Corrected Angle	
Left for centre	295.5	0	295.5	115.5	0	115.5	295.5	
Right for centre	295	59	295.0295	115	58	115.029	295.02925	
Mean for centre (calculated)							295.264625	
Blue (absolute)	309	0	309	129	0	129	309	
Red (absolute)	314.5	12	314.506	134.5	7	134.5035	314.50475	*
Green (absolute)	311.5	50	311.525	131.5	48	131.524	311.5245	*
Green II (absolute)	312	31	312.0155	131.5	48	131.524	311.76975	*
Blue							13.735375	
Green							14.5245	
Green II							14.76975	
Red							17.50475	

297 * The readings other than blue, were taken with respect to this

	Wavelength in cm	Wavelength in nm	1/lambda	(1/4 - 1/(n^2))	Expected	Expected Angle
Blue	4.02062E-05	402.06	2487181	0.222222222	410	14.01205171
Green	4.24678E-05	424.68	2354726			
Green II	4.3169E-05	431.69	2316475	0.21	434	14.85058324
Red	5.09329E-05	509.33	1963367	0.1875	486	16.67890632

Lines per inch	15000	
Separation between lines	6.66667E-05	inches
d	0.000169333	cm

Rydberg's Constant 1.00E+07 ± 7.87E+05 1/m

R^2= 0.9213

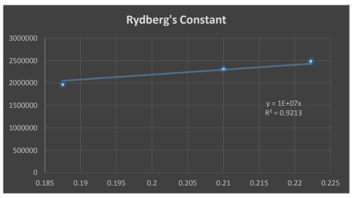

Figure 3: Observations for Frank-Hertz

4 QUINCKES METHOD

March 19 and 26, 2013

4.1 AIM

TODO: Find out the precise aim

To determine the magnetic susceptibility of an Mn^{2+} solution.

4.2 APPARATUS

U-tube, Mn^{2+} solution (to make the solution: Volumetric Flasks, foil paper, weighing balance), Magnetic Field Sensor, Magnetic Field Producer

4.3 THEORY

4.3.1 *The Rationale*

4.4 OBSERVATIONS AND CALCULATIONS

4.5 PROCEDURE

4.6 RESULT

COLOPHON

This document was typeset using the typographical look-and-feel `classicthesis` developed by André Miede, for LaTeX.
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