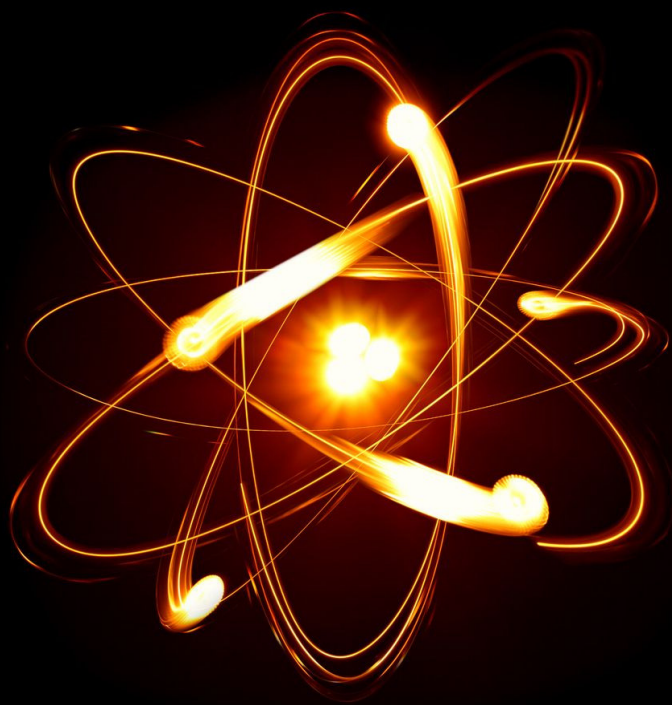


E C H O



THE PHYSICS SOCIETY

2020



St. Stephen's College, Delhi



THE PHYSICS SOCIETY

From the Editors

Behind The Scenes of Echo

“It gives me immense pleasure and satisfaction to finally pen down the editorial for the Physics Journal, **Echo** 2019-20.”

The process of putting up this journal has been a bumpy road which started from deciding to replace the journal with a blog and ended up working day and night to collect and edit articles within two small weeks and here we are with this short yet interesting collection of articles ranging from research papers and poems to personal reflections .With all its ups and downs , this journey has been very enriching for me and my co-editor Reuel and we are glad that we were able to take the tradition of society journal forward.

You might find this short collection of articles interesting and informative , you might relate to the poems at a personal level , you might find the journal ends as soon as it begins, but for us it is a product of a lot of work put up in asking for articles, sorting them out, compiling it all and putting them together and all this happening between the 8 to 5 classes of our really hectic second year.

This journal is not only the result of the efforts of the editors; I thank all the people who have contributed articles to the journal. I would thank the President and Vice President of the Physics Society for constantly pushing us to make it happen . I would also thank our Staff Advisor Dr. Harish Kumar for his guidance and support.

This journal represents a blurry reflection of the creative sides of the physics students. I hope the we have more articles from students next time and the reflection gets clearer.

Happy Reading!

From the Staff Advisor	1
Trajectories of Spheres in viscid fluids	2
A message to Oneself	6
कदम	7
Time - Frequency representations in gravitational waves analysis	9
Convolutional Neural Networks	12
Microgravity Experiments	15

C O N T E N T S

“The whole purpose of education is to turn mirrors into windows.”

Sydney J. Harris

The Physics Society of St. Stephen's college believes in this very idea. It is a platform through which they interact with scientists, academicians, or even to their fellow colleagues on topics from diverse fields. The purpose of these interactions is not limited to mere introducing them to the advance research topics/fields rather the emphasis is on concepts so that they can see the picture more clearly, which by now was not so clear. The society was created with the idea to involve students in activities which are outside their curriculum so as to explore and expand their horizons. Started primarily with the Feynman club, Problem solving club, Astronomy club etc. it has expanded over the years in order to include new fields and the necessity to explore the interdisciplinary nature of subjects. This is possible only because of the love, passion and enthusiasm of the students for the society and it in turn comes from the impacts of these events in their professional and academic spheres. This is the space where the students are free, unbounded from the boundaries of classrooms and the demands of the examination system, to refuel their scientific interests and chalk out their future endeavors. The Physics Society achieved all these after a very well thought and much deliberated process such that the time and resources of the society will be utilized efficiently.

The Physics Society Journal is another stage through which the students can express their thoughts (philosophical or scientific), interests, and their understanding of a particular phenomenon. In some sense it is more powerful than other activities because it is something that is penned down and will be a part of the department library. In the past it has been discontinued for a small period of time but it comes again as an important and regular feature of the society. I hope the students will keep this part of the society alive as it deserved to be.

I wish to congratulate every member of the physics department, students as well as my colleagues, who have helped and contributed to the activities of the society. I congratulate the members of the Physics Society who put in so much hard work to organize various events and also bring this journal in shape and in stream. I wish them the best.

Dr. Harish Kumar Yadav
Staff Advisor

Trajectories of Spheres in Viscid Fluids

Rohit Vasav*

Department of Physics,
St. Stephen's College, Delhi University,
New Delhi - 110007, India

Gaurav Dar†

Department of Physics ,
Birla Institute of Technology and Science,
Sancoale, Goa-403726, India

In this paper, we have discussed the equations which govern the motion of a spherical projectile in a viscid fluid, rotating about an arbitrary axis in the presence of an arbitrary flowing wind. The forces acting are: 1. Gravity, 2. Translational Drag Force, 3. Rotational Drag Torque and 4. Lift Force (Magnus Force). The problem has been coded in Python and some examples of model trajectories are presented which could be applied to ball games such as tennis, soccer, baseball or cricket.

I. INTRODUCTION

The simplest approach to finding the trajectory of a projectile is usually to ignore all atmospheric effects (air resistance, lift and drag), effectively treating it as a vacuum, and assuming only the effects of a constant gravitational force which acts vertically downwards. The motion is well understood this way and the trajectory comes out to be a parabola.

Once the effects of the Drag and Magnus forces are factored in, the equation of motion are no longer simple. These equations are no longer easy to solve and don't give an analytic solution due to their non-linear nature. In this case, the only method to simulate an answer comes from computational methods and numerical analysis.

In this paper, we will assume a rigid, smooth and spinning spherical body moving through a continuous, viscid fluid of constant density and composition like air at low altitudes. The inherent symmetry of the system simplifies the problem and let us simulate the motion of most sports and real-world objects.

II. MAGNUS FORCE

If a sphere is moving through a fluid, such as air, it is subject to a Drag Force \vec{F}_D , which, by symmetry, is in the opposite direction to the motion. If the sphere is spinning it is also subject to a second force, the Lift or Magnus Force \vec{F}_L . **Figure 1** shows a schematic diagram of a sphere moving to the right with a velocity \vec{V} relative to the fluid, and spinning in an anti-clockwise sense with angular velocity $\vec{\omega}$ about an axis perpendicular to \vec{V} .

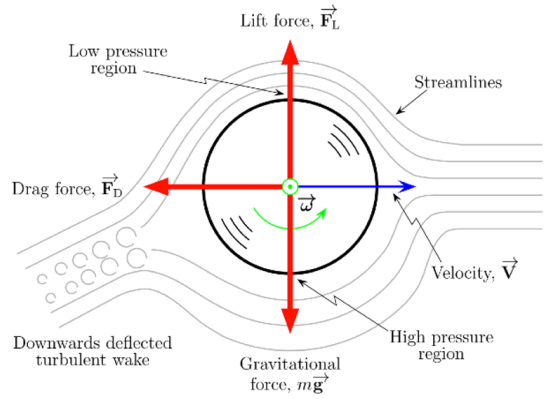


FIG. 1. Forces on a Rotating Sphere

III. AIR DRAG AND RESISTANCE

A. Translational Air Drag



FIG. 2. Drag Force on a particle

If the projectile has a velocity \vec{V} relative to air, the drag force \vec{F}_D , is assumed to be in the direction opposite to \vec{V} and proportional to V^2 where $V = |\vec{V}|$. The drag force is usually written as:

$$\vec{F}_D = -\frac{1}{2}\rho AC_D V^2 \hat{V} \quad (1)$$

where ρ is the density of the fluid, A is the projection area of the projectile and C_D is the dimensionless Drag Coefficient.

The Reynolds number of any moving system is defined by $\text{Re} = \frac{Vd}{\nu}$. Here d is a characteristic size of the object

* rohitnegism@gmail.com

† gdar@goa.bits-pilani.ac.in

(the diameter in the case of a spherical projectile) and ν is the kinematic viscosity of the medium. For air at 25°C, the value of $\nu = 1.562 \times 10^{-5}$. It is found that the drag coefficient is only a function of Reynold's Number[1].

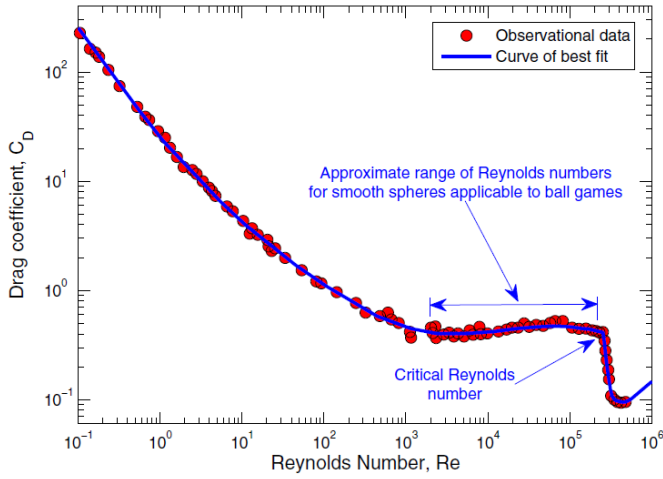


FIG. 3. Variation of Drag Coefficient with Reynold's Number (experimental data) [2]

By fitting a curve to this experimental data of **Figure 3**, the following equation for the Drag Coefficient is obtained [1].

$$C_D = \frac{24}{Re}(1 + 0.15Re^{0.5} + 0.017Re) - \frac{0.208}{1 + 10^4 Re^{-0.5}} \quad (2)$$

This expression is valid in a wide range of values of the Reynold's number, and for small Reynold's numbers ($Re \rightarrow 0$) is transformed to the well-known linear Stokes drag.

B. Rotational Drag Torque

The drag torque acting on a sphere rotating around its diameter can be calculated by taking an infinitesimal point on the surface of the sphere, calculating the drag force on it by using (1), and then integrating over the entire surface of the sphere to get the drag torque. Its value is given by the formula[1]:

$$\vec{\tau}_D = -C_\omega \rho \omega^2 r^5 \hat{\omega} \quad (3)$$

where $\omega = |\vec{\omega}|$, r is the radius of the sphere, ρ is density of the fluid and C_ω is the dimensionless rotational drag coefficient, whose value is $C_\omega = \frac{4\pi}{3} C_D$.

IV. LIFT FORCE

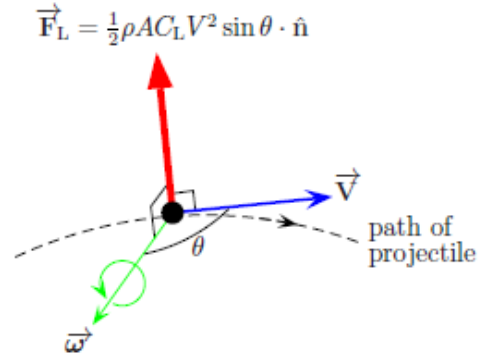


FIG. 4. Lift Force on a spinning particle

For spins perpendicular to the projectile velocity it is usually assumed, on the basis of experimental evidence, that the Lift or Magnus force is proportional to V^2 and to act at right angles to both \vec{V} and $\vec{\omega}$. The sense of direction of the lift force is given by $\vec{\omega} \times \vec{V}$. In this situation, the lift force[2] is usually written as:

$$\vec{F}_L = \frac{1}{2} \rho A C_L V^2 (\hat{\omega} \times \hat{V}) \quad (4)$$

Experiments have found the following relationship for the lift force, \vec{F}_L , to apply for golf balls[2], but the results can be applied to a various other spherical systems:

$$C_L = \frac{0.028992}{\rho A V^2} (1 - e^{-2.48 \times 10^{-4} \omega}) \quad (5)$$

V. EFFECT OF WIND

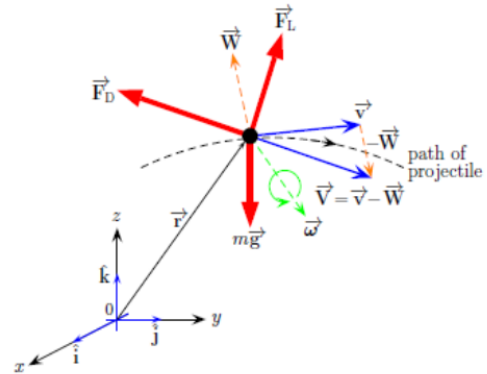


FIG. 5.

If a wind \vec{W} is blowing relative to velocity \vec{V} of the projectile as shown in **Figure 5**, then the Drag and Lift Force depend on the relative velocity ($\vec{V} - \vec{W}$) of the projectile.

Hence, then the Drag and Lift Forces would become:

$$\vec{F}_D = -\frac{1}{2}\rho AC_D|\vec{V} - \vec{W}|(\vec{V} - \vec{W}) \quad (6)$$

$$\vec{F}_L = \frac{1}{2}\rho AC_L|\vec{V} - \vec{W}|\frac{\vec{\omega} \times (\vec{V} - \vec{W})}{\omega} \quad (7)$$

VI. EQUATIONS OF MOTION

Applying Newton's Second Law, the equations of motion comes out to be:

$$m\ddot{x} = -\frac{1}{2}\rho A|\vec{V} - \vec{W}|(C_D(v_x - W_x) - C_L\left(\frac{\omega_y(v_z - W_y) - \omega_z(v_y - W_y)}{\omega}\right)) \quad (8)$$

$$m\ddot{y} = -\frac{1}{2}\rho A|\vec{V} - \vec{W}|(C_D(v_y - W_y) - C_L\left(\frac{\omega_z(v_x - W_x) - \omega_x(v_z - W_z)}{\omega}\right)) \quad (9)$$

$$m\ddot{z} = -\frac{1}{2}\rho A|\vec{V} - \vec{W}|(C_D(v_z - W_z) - C_L\left(\frac{\omega_x(v_y - W_y) - \omega_y(v_x - W_x)}{\omega}\right)) - mg \quad (10)$$

Applying the equations for drag torque, we get:

$$I\omega_{\dot{D}x} = -\rho C_\omega|\vec{\omega}_0 - \vec{\omega}_D|(\omega_{0x} - \omega_{Dx})r^5 \quad (11)$$

$$I\omega_{\dot{D}y} = -\rho C_\omega|\vec{\omega}_0 - \vec{\omega}_D|(\omega_{0y} - \omega_{Dy})r^5 \quad (12)$$

$$I\omega_{\dot{D}z} = -\rho C_\omega|\vec{\omega}_0 - \vec{\omega}_D|(\omega_{0z} - \omega_{Dz})r^5 \quad (13)$$

VII. MODEL TRAJECTORIES

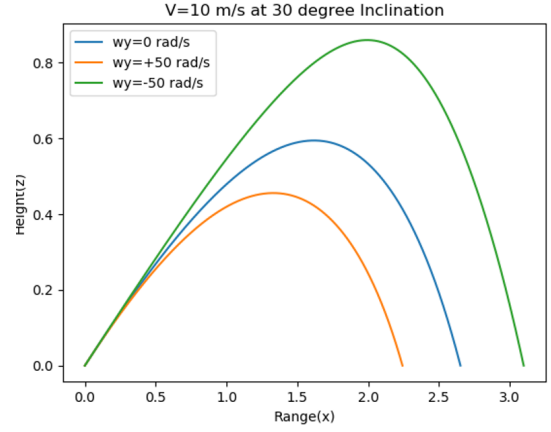


FIG. 6. Table Tennis ball. Diameter = 40 mm, Mass = 2.7 gm. It is seen that different spins gives different ranges, leading to a variety of strokes.

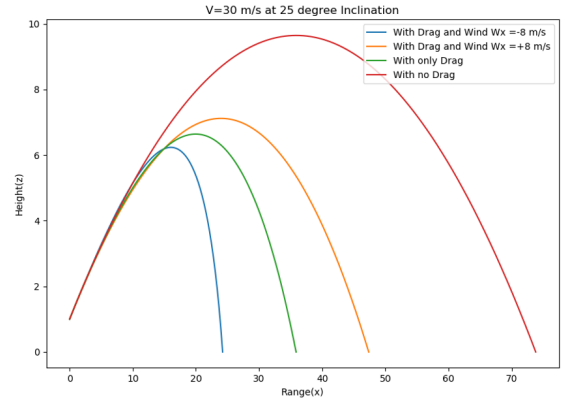


FIG. 7. Cricket Ball hit at a height of 1 metre. Diameter=7.15 cm, Mass=160 gm. The range changes according to the wind direction. Drag force reduces the range to almost half of the ideal case.

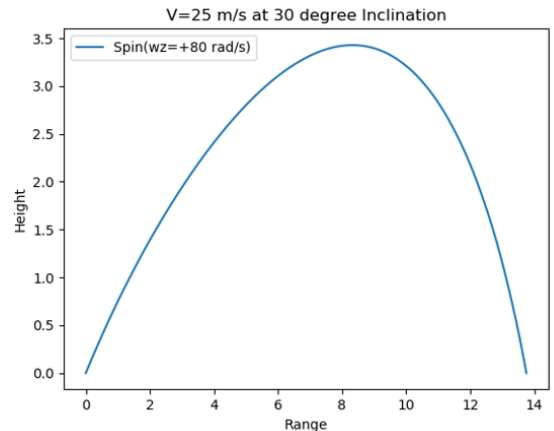


FIG. 11. Two-dimensional trajectory of a football (Diameter=22 cm, Mass=425 gm).

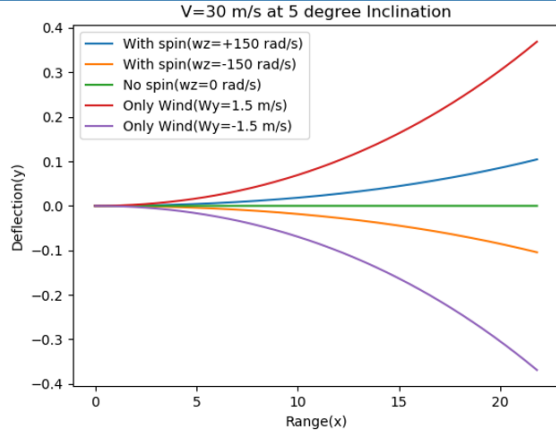


FIG. 8. Cricket Ball (see **Fig. 7**). Departure from straight line path (deflection along Y-direction) is seen.

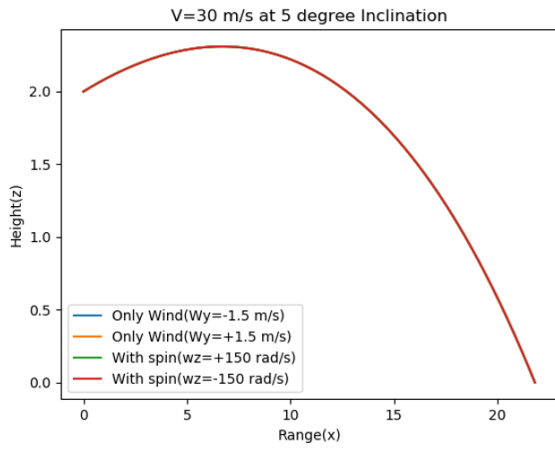


FIG. 9. The different cases of **Fig. 8** correspond to the same range.

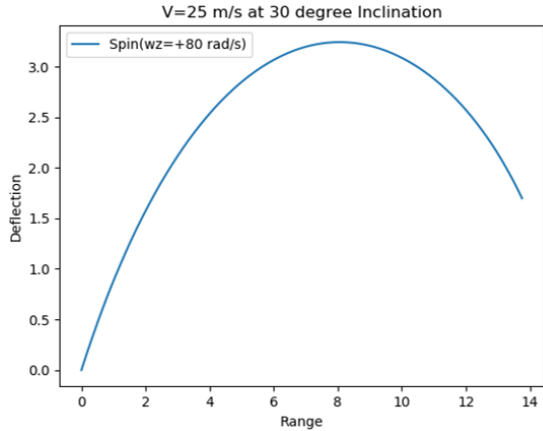


FIG. 12. Deflection produced in a football (see **Fig. 11**) due to a banana kick .

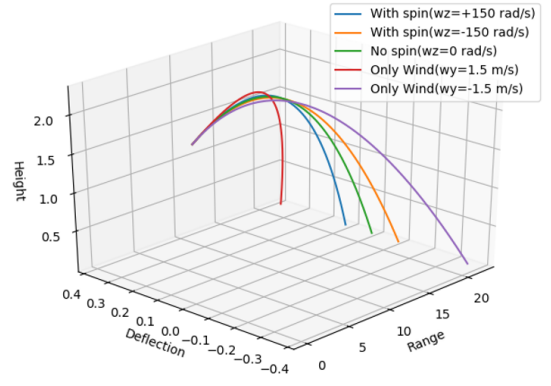


FIG. 10. Three-dimensional trajectories for **Fig. 8** and **Fig. 9**

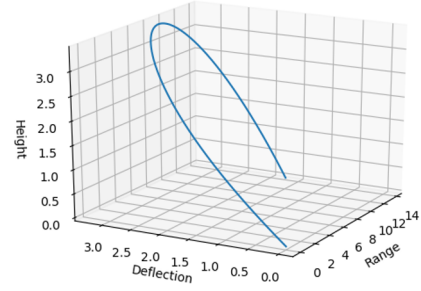


FIG. 13. Three dimensional trajectory of a banana shot combining **Fig. 11** and **Fig. 12**.

VIII. CONCLUSION

It is evident that the Magnus and the Drag force causes a significant amount of deviation from normal behaviour of a projectile. Depending on the spin of the ball, it can fall either much quickly, or it could cover more range. The effect of wind is also important because a helpful wind changes the path considerably, hence sports have to account for the flow of wind too, if the game is to be considered valid.

[1] N. Lukerchenko, Y. Kvurt, I. Keita, Z. Chara, and P. Vlasak, *Particulate Science and Technology* **30**, 55 (2012), <https://doi.org/10.1080/02726351.2010.544377>.

[2] G. Robinson and I. Robinson, *Physica Scripta* **88**, 018101 (2013).

Dear Aditya,

You must have come across the idea of 'passion', the ever so passionate never shut up about it. The idea of that 'one' thing, your true calling, the heart's desire, yadda yadda. Well, there might be some truth to it, but I don't think it as fancy as some people would lead you believe.

I was miserable doing Physics, so I decided to quit and that has made all the difference. Linguistics for me is the perfect blend of liking something and being good (enough) at it. I would very much like to think that I am passionate about it, but that doesn't mean I am 'so' madly in love with it that it's the only thing I want to be doing at all times. I really hate it every now and then; second guess my decisions; freak out; go numb. But then, ever so seldom, there are these brisk moments when I just cannot get enough of it. That one paragraph in a ten-page essay that blows your mind, that one lecture to buoy your spirits up so high, that one beautiful assignment amidst what seems like dull hundreds, those little packets of joy which someone appears to have carefully placed around for me to find. This is exactly what I had reading Physics as a high schooler, but missed big time as an undergrad, and this is all I need to feel connected to what I am doing right now; these ephemeral bouts of utter glee. Make no mistake, most of what I do is still quite tedious and above that, boring, but I would rather be bored doing linguistics than anything else, and this little fact is all there is to my passion, or perhaps passion in general.

So, don't be scared if your subject bores you to death, it's not so bad. The Star Wars movies are all boring and slow but they are still all worth it right? (except perhaps The Phantom "Jar-Jar" Menace). Still, if you can no longer take it, then change it, because 'nothing changes if nothing changes'. I know, change is scary and takes a lot of courage but it's still easier than living with regrets. So what if said change dooms you to a job less fancy, a career less Nobel. What would you rather be, excellent at a mediocre field or mediocre at an excellent field? The world doesn't need half-hearted Physicists anymore than you would want to be one. Anyways, remember these words in the beautiful voice of Emma Stone:

*"A bit of madness is key
To give us new colours to see
Who knows where it will lead us?
And that's why they need us"
So bring on the rebels
The ripples from pebbles
The painters, and poets, and plays
And here's to the fools who dream
Crazy as they may seem
Here's to the hearts that break
Here's to the mess we make*

**-Aditya Shekhawat
Batch of 2019**

KADAM...

-Vipin Chaudhary

अंजान थे जो कदम , अब राहे चुनने लगे हैं ।

कल कितने नासमझ थे हम , आज सही और गलत का फ़र्क समझने लगे हैं ।

शब्दों पे अटकते थे जो एहसास , वो कविता बनने लगे हैं ।

कोशिशों के अंकुर अब इरादों के वृक्ष बन गए हैं ।

अंजान थे जो कदम , अब राहे चुनने लगे हैं ।

याद हैं , वो कॉलेज का पहला दिन,

नए से बदलाव थे , मौसम भी कर रहा था रिम-झिम ।

उस दिन Assembly Hall से ज़िंदगी का एक नया सफर शुरू किया था,

Science Block की तरफ जाते हुए दिल 9 hertz की frequency से धड़क रहा था ।

चेहरे याद करने की कोशिश में , इन राहों पे खो जाने का डर साफ़ झलक रहा था ।

NPLT में उस corner वाली bench पे , कोई physoc के intros से बचने की कोशिश कर रहा था ।

हम भला कैसे भूल सकते हैं वो epsilon - delta की friendship,

तब शायद loose थी लिमिट की definition पे हमारी grip ।

Classes में बस यूँ ही खो जाया करते थे,

5:00 PM labs में हम अक्सर सो जाया करते थे ।

इसी बीच Physics से दोस्ती होने लगी थी,

वो हर रोज़ हमें गलतियाँ सुधारना सीखा रही थी ।

Maths के साथ मिलकर assumptions पे भरोसा करा रही थी,

अपने इस अनोखे अंदाज़ में Physics हमें काफी भा रही थी ।

कुछ ही दिनों में college अपना सा लगने लगा था,

वक़्त लिख रहा हमारा फ़साना था , अब लगता हैं की वो एक अलग ही जमाना था ।

KADAM...

-Vipin Chaudhary

छुपके lab के corner -door से ढाबा जाना हो या dark -room में बातें बनाना,
एक serious class में अपने benchmate को call करके उठाना हो, या Newton Tree के छाव में भरी दोपहरी गुज़ारना,
कितना याद आएगा यूँ हम सबका एक दूसरे को सताना ।

Chapel Lawns में सुनहरी सुबह हो , या दिसंबर में 'when चाय met exams ',
Second Year में हम कर रहे थे 'oscillations वाला dance '।

हाँ माना , सब कुछ सपनों के जैसा नहीं था,
कितनी दफा , DigiLog में हमारा circuit नहीं चला था ।

WLOG , Lab Reports में 'Manipulation ' एक सही तरीका था ।

Power की लुका-छुपी ने हमारा temperature raise और पानी का कम किया था ।

NPL में printer है, पुरे 373 रुपए खर्च करने के बाद पता चला था,
इन 3 सालों में बदल गया हम सब का जहाँ था ।

इस शहर में अपनों से दूर सपनों के लिए आये थे , अपने भी मिले और नए ख़्वाब भी,
हिम्मत भी मिली और नदी के उस तरफ जाने वाली नाव भी ।

मुश्किलों से लड़ना सीखा , तो समझ आया जीवन जीने का सलीका ।

हमारी कहानी में हज़ारों रंग थे , आखिर इतने खास मुसाफिर जो संग थे ।

मुमकिन नहीं था , मंज़िल को समझ पाना हमारे 'teachers ' के बिना,
दोराहो पे किस तरफ मुड़ना है, ये उनसे ही तो सीखने को मिला।

मगर, अब वक़्त घड़ी से तेज़ चलने लगा है,

सूरज की रौशनी और चाँद के सुकून की तरह सब अपना लगने लगा है ।

'रुकना' इस 'MCQ ' का option नहीं है , 3 सालों का ये exam अब पूरा होने चला है ।

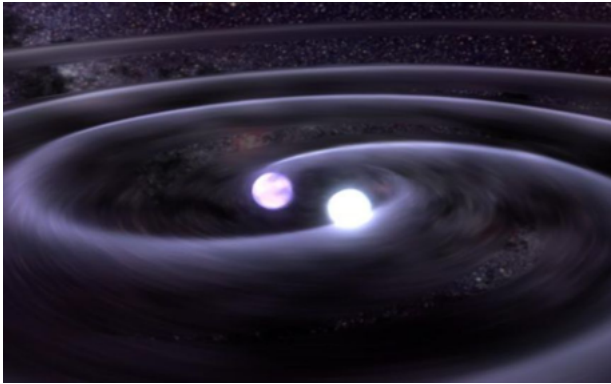
नयी उमीदों के साथ हम बढ़ तो चले हैं , पर हमारे कदम जब आएँगे यहाँ,

किस्से गुनगुनायेंगे आज के, आखिर ऐसे दिन अब मिल पाएँगे कहा ।

Time-Frequency representations in Gravitational Waves analysis

Debtroy Das - IIT Gandhinagar

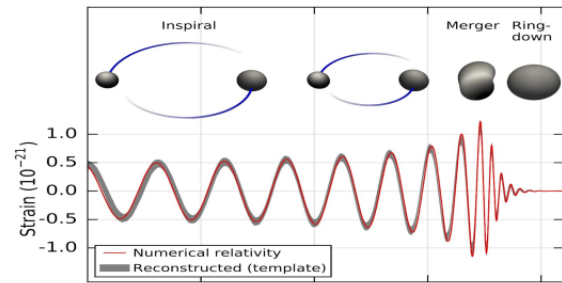
Einstein postulated gravitational waves in 1916 as a consequence of his theory of General Relativity, but no direct detection had been made for almost a century. In 2016, the Advanced LIGO (Laser Interferometer Gravitational-Wave Observatory) announced the first-ever direct detection of gravitational waves. The discovery caused a lot of excitement to both the general public and the scientific community and opened new areas of study in fields of physics. The LIGO team announced the detection of a second gravitational wave signal in June 2016 using the instruments that detected the signal on Dec. 26, 2015. The observatory announced the third detection in June 2017 and a fourth detection in September 2017. These four gravitational wave signals detected by LIGO were all created by colliding black hole pairs.



Study of gravitational waves is important for two primary reasons. Firstly, their detection is expected to open up a new window for observational astronomy since the information carried by gravitational waves is very different from that carried by electromagnetic waves. This new window will complement our view of the cosmos and will help us unveil the fabric of space-time around black-holes, observe directly the formation of black holes or the merging of binary systems consisting of black holes or neutron stars, search for rapidly spinning neutron stars, dig deep into the very early moments of the origin of the universe, and look at the very centre of the galaxies where supermassive black holes weighing millions of solar masses are hidden. Secondly, detecting gravitational waves is impor-

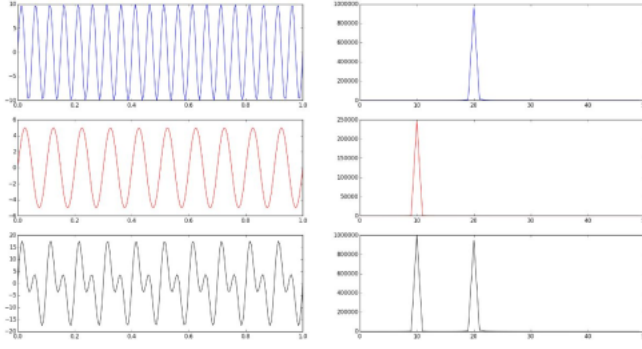
tant for our understanding of the fundamental laws of physics; the proof that gravitational waves exist will verify a fundamental prediction of general relativity. Also, by comparing the arrival times of light and gravitational waves, from, e.g., supernovae, Einstein's prediction that light and gravitational waves travel at the same speed could be checked. Finally, we could verify that they have the polarization predicted by general relativity.

These four gravitational wave signals detected by LIGO were all created by colliding black hole pairs.



After the detection, one should think about how to analyse the signal. GW signals are analysed primarily in 2 ways: by template matching and by time-frequency representations(TFR). I work on the TF analysis so I shall be talking about the same discussing various methods that are widely used and the challenges faced in the process and finally share some of the TFRs.

A signal can be expressed as a function of time or frequency. When studied as a function of time, one calls it time-domain analysis. And when studied as a function of frequency, one calls it frequency domain analysis. While analysing the signal in either one of these two domains, one loses resolution/ data of the other domain. For instance, in the time domain, one is unsure of the fact that which frequency components are present at a particular time; and in the frequency domain, one sees bars of frequency, without knowing when those frequencies occurred. And how do we jump from one domain to another is by use of Fourier transform. The figure below shows sinusoids and their combination and their corresponding Fourier transform.



Time-frequency analysis is devoted to the problem of identifying and quantifying the oscillatory components present in a signal. This is done by projecting the signal onto the time-frequency plane, which allows one to study its properties simultaneously in time and frequency domains. Such projections are called time-frequency representations (TFRs) and there are a number of different kinds, depending on the way in which the projection is carried out. Time-frequency analysis is especially useful for signals containing many components with time-varying amplitudes and/or frequencies, which is a very common scenario for real-life signals. Few of the well-known algorithms are Short-time Fourier Transform(STFT), Wavelet Transforms, Wigner Ville Distribution, etc. I shall be using STFT as the mother algorithm for all the TFRs discussed. STFT uses a window that is convolved with the signal and FT is executed.

$$\text{STFT}\{x(t)\}(\tau, \omega) \equiv G(\tau, \omega) = \int_{-\infty}^{\infty} x(t)w(t - \tau)e^{-j\omega t} dt$$

If we use a Gaussian window and take an STFT for a sine wave and of a wave whose frequency increases linearly with time(linear chirp), we see the following.

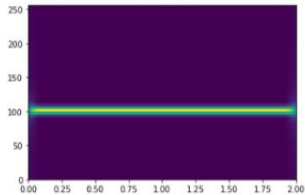


Figure 1: STFT of a signal containing a sine waves of frequency, $f_0 = 100\text{Hz}$

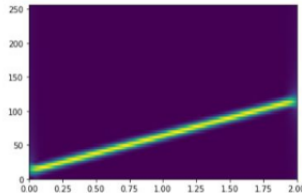
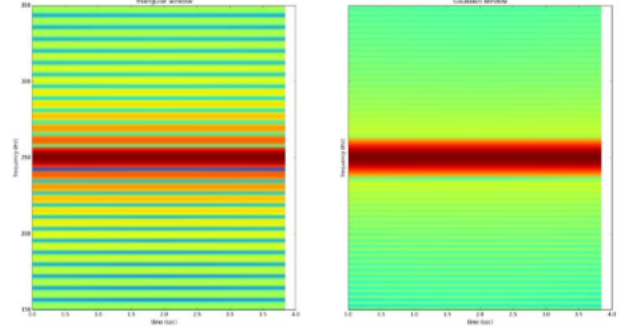


Figure 2: STFT of a signal containing a linear chirp

Now a curious mind shall question the role of the window and why do we use a Gaussian window. So we should choose a window which decays smoothly around its centre point that reduces the noise in the Fourier

domain. Also, the size of the window we use determines the frequency resolution. I shall demonstrate the impact the choice of the window does by comparing a triangular window and a gaussian window for a sine wave.



We can see that STFT gives us a blurred band instead of a single narrow line in the TFR even when we try it on a simple sine wave with no noise. WE see the same when other TF algorithms are used. This is due to Gabor inequality, which states that a signal can not be resolved infinitely in both time and frequency domain simultaneously. Due to the trade-off between frequency and time resolution, the TFRs obtained are smeared and to handle it, we employ reassignment methods, which uses time-varying features like Instantaneous frequency, Instantaneous phase, Instantaneous amplitude, etc. to reassign very crisply the TFRs. Hence we use methods like Synchrosqueezing and Synchroextracting which gives us a very good approximation of ideal TFR.

Synchrosqueezing is a special type of reassignment method that provides a way to construct concentrated time-frequency representation from the Windowed FT. The underlying idea is very simple, namely to join all WFT coefficients having the same instantaneous frequency (defined as the first derivative of the unwrapped-over-time WFT phase or by the equation) into one Synchrosqueezed WFT coefficient. In other words, we can say that synchrosqueezing is the reassignment operation done only on the frequency domain.

$$SST_x(t, \omega) \equiv \int S_x^g(\tau, \nu) \delta(\omega - \hat{\omega}(t, \nu)) e^{j\tau\omega} d\nu$$

The synchroextracting algorithm is similar to above with just a slight modification in the method of calculating instantaneous frequency based on the Auger Flandrin equations.

Where G_g is the STFT with Gaussian window and G_g' is the STFT with a derivative Gaussian window. This is a much more prone to noise algorithm, hence

should always be considered for TFR compared to Synchrosqueezing. We have shown some TFRs where we compare the STFT with the synchroextracted transform based on STFT. The signal used is a linear chirp and we have simulated some normal noise and added it to the chirp. In this case, the synchrosqueezed TFR is not fit for the generation of TFRs as it is not prone to noise.

We can see a much sharper TFR but the question one should ask is why do we put in so much effort to enhance the TFR. A much sharper TFR helps in improving accuracy in several calculations and analysis. As

mentioned earlier in the article, we use it to test Einstein's theory of General Relativity (GR). GR predicts a track along which the energy lies in the TFR. With a smudged TFR, we fail to accurately measure if the track is followed implying how accurate GR is. With a sharper TFR, we know if GR is followed or not and even if it is deviated by a very small amount we can detect it. This serves as a useful tool for several other astrophysical calculations. TFRs have applications in various other fields as well including lie detection, earthquake signal analysis and several medical purposes.

Convolutional Neural Networks

- Shraddha Jain
Batch of 2019

The title of course sounds like a weird amalgamation of Math, Biology and a tinge of Computer science, however, these networks have been one of the most influential contributions in the field of Machine learning. Ever wondered about how a computer can recognize a certain image of a dog as a dog, and not as a cat, or an elephant? As a child, you trained your brain to do so, but how does the computer do it? In the age where the field of machine learning is reaching new heights, there are various techniques and algorithms to train the computer for image detection. One such algorithm is the convolutional neural network, which interestingly has been inspired from the way the neural networks function in a human brain to process information.

The ConvNet algorithm has four steps:

- Convolution
- Addition of Non Linearity
- Pooling
- Classification of object

Convolution:

How we see an image is very different from how a computer sees it. For a computer, an image is just a matrix of numbers known as pixels. Convolution is basically addition of filters to the images by using a mathematical operation on the matrix. The basic function of convolution is to extract specific features from the image. For this, we use a smaller matrix known as 'filter' and slide it over the original matrix, and each time we slide this filter over, element wise multiplication is performed and the numbers are added up to produce one number, which is then stored in a new matrix called the 'Feature Map'. Hence, after one full cycle of "filtering" we produce a matrix with as many elements as the number of times the filter was run over the image matrix. One can use any filter he/she wants. For example, if I wish to extract circles from the original image, I will use a filter matrix that has high pixel values in the shape of a circle, so that when I run this filter over the image, I produce a new matrix with high pixel values only in the shape of a circle. Hence, the more number of filters we have, the better the algorithm is to recognize different patterns in images.

Addition of Nonlinearity:

Almost all real world systems are nonlinear. Hence we should train the program to recognize nonlinearity. One of the ways of adding non linearity could be by replacing all negative pixels by zero. Since convolution is a linear process, this step has to be performed after every convolution step.

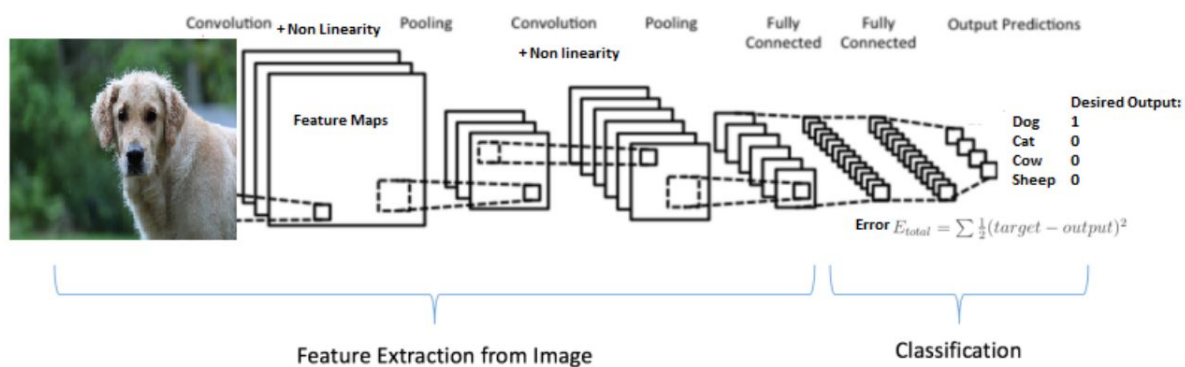
Pooling:

Pooling is a way to reduce the dimensionality of the matrix image, and yet retain the important and relevant information. It is done to reduce the data size, and hence minimize the complexity of the algorithm. There can be different types of pooling. For example, 'Max Pooling' would mean that we take the feature map, and let's say we choose to perform 2x2 max pooling. This would mean we take 2x2 smaller matrices within the feature map, and replace the 2x2 matrix by the maximum of the elements of that matrix. And this is done for the entire feature map. Similarly, 'Average Pooling' can also be performed. Together, the first three steps extract the relevant features from the image, introduce non linearity and reduce the feature dimension. It is important to note that these three steps can be performed multiple times. For example, when we perform convolution for the first time, we may extract some low level features like curves or lines. Then we use a second convolution layer (which uses the output of the first convolution layer as its input), to extract more complex features. Hence, the more times you perform convolution, the better features you will be able to extract. After these steps, what we have is basically a variety of feature maps representing different features from the image. So now, we need the computer to recognize that these features, when combined, represent a particular class of objects. This is done through the fully connected layer.

Fully Connected Layer:

This layer takes the output of the above mentioned steps as its input, and outputs a one dimensional array of size equal to the number of classes of objects the program has to choose from. For example, if we feed in an image of a dog to the program, then the size of the output array can be 4 (corresponding to dog, cat, cow, sheep) for example. Each element representing the probability of the image being one of these. If the output of

these fully connected layers is [0.75, 0.15, 0.6, 0.4], then we know that the image represents a dog. The name fully connected layer is because of the fact that each layer in this part of the algorithm is fully connected to the next layer. The way this layer works is that it looks at the output of the previous layer and determines which features most represent a particular class. For example, if the program is predicting a dog, it will have high pixel values in the feature maps corresponding to a paw or big nose etc. Consider that each of your feature maps as an input to this layer, and these are called nodes. Each of these nodes are connected to the next layer through some weightage. These weights are initially random. But we need more weightage for those features that a dog has uniquely. Since we are training our algorithm, we train it through “learning from one’s own mistakes” method. In the first time, we will get random probabilities for the example mentioned above. But we already know what the right output should look like [1, 0, 0, 0]. So, we feed in the desired output to the algorithm, and through a process called ‘Back Propagation’, the algorithm corrects its weights until the error is below a certain threshold. Once this error is almost negligible, we can say that our program can now recognize images of dogs. Similarly, we can train it for many other classes of objects.



References:

- ujjwalkarn.me/2016/08/11/intuitive-explanation-convnets/
- ujjwalkarn.me/2016/08/09/quick-intro-neural-networks/
- <https://adeshpande3.github.io/A-Beginner%27s-Guide-To-Understanding-Convolutional-Neural-Networks/>
- <https://towardsdatascience.com/a-comprehensive-guide-to-convolutional-neural-networks-the-eli5-way-3bd2b1164a53>

MICROGRAVITY EXPERIMENTS

-Deepanshu Bisht (1st physics)

The term microgravity suggests the idea of very less gravity- that 'force' which causes objects to fall with 9.8m/s^2 of acceleration on Earth. More clearly, the idea of microgravity revolves around weightlessness and that of microgravity experiments is to perform experiments with more or less an environment of weightlessness.

This brings us to the idea of weight. We humans can easily distinguish between freefall and sitting or standing. While in freefall, we feel 'weightless', which leads to the understanding that we feel our own weight only when something applies a force from below such as a chair or floor to keep us from falling below under gravity. Now if we go to the moon, its gravity attracts objects with less force(due to its smaller size!). Hence less normal force is needed to balance it and so we will feel less 'weighted'. The astronauts floating inside space stations constantly feel 'weightlessness' while floating. The situation is similar to falling on Earth. To see the parallel- Newton's thought experiment suggests taking a cannon to the top of a mountain, shooting it in such a way that its angle of inclination is zero. Increasing the initial velocity would increase the horizontal distance the projectile travels and eventually the cannonball would reach a velocity high enough, orbiting the Earth, because it falls in some time a height such that the Earth's curvature compensates it and it remains still at the same height from Earth's surface. Hence orbiting Earth continuously at the same height.

The International Space Station is exactly doing that now as you read this, at heights of 250 miles above Earth's surface and a speed of 7.66km/s needed to maintain the orbit(like the cannonball). Now although gravity is well within the ISS and is acting on every object there yet we can say the objects are in microgravity(or freefall) and floats. Another point of view is that if we choose the frame of reference attached to ISS, it is a non-inertial frame and hence everything within ISS also experience a pseudo force-The centrifugal force that balances the 'real' centripetal gravity of Earth and as there are no other forces, the objects behaves as if no force is acting on them.

This brings us to the exciting scope of doing experiments in microgravity, which is otherwise not available on Earth. However, NASA also does microgravity experiments by flying planes in parabolic arcs, creating microgravity for 20-25 seconds. But for longer experiments, space stations and shuttles are the only choice.

The list of experiments already performed and ongoing inside several space stations and shuttles is quite large but is not exhaustive. There is a vast scope for future microgravity experiments and this is just the beginning. Perhaps looking at some of them briefly will give us an interesting, fun insight into what is and can be microgravity research.

In 1992 and 1996 attempts were made by NASA and the Italian space agency jointly for a Tethered Satellite System(TSS). The plan was to deploy a satellite from a space shuttle in the ionosphere, it remaining tethered to the shuttle from a long cable extending 12.5 miles. Then dragging the satellite in space using the shuttle and the 12.5 mile cable between. The idea was to determine whether this mechanism can generate electric power, as it formed one part of a dynamo circuit in the Earth's magnetic field. In the 1992 mission, the cable could only be released 840ft due to a protruding bolt in the deployment mechanism causing failure. In the 1996 reattempt in 5 hours 12.24 miles cable was released but then it snapped, sending the satellite into a higher orbit. Fortunately the mission sent useful data till it was operational. Before snapping the TSS began generating 3500 volts and 0.5A current!

An interesting phenomenon that occurs differently in space is combustion. Understanding how fire spreads and behaves in space is crucial for the safety of astronauts and shuttles. On Earth, hot gases from the flame rise while gravity pulls cooler, denser air to the bottom of the flame. This creates both the shape of the flame, as well as the flickering effect (seen easily in a candle flame). In microgravity, however this flow doesn't occur. This reduces the variables in combustion experiments, making them simpler and creating spherical shaped flames in space. An experiment led by Principal Investigator Forman Williams revealed a never-before-seen two stage burning event. A heptane droplet of fuel extinguished two times. First the visible flame went out, yet it continued burning in what is called a cool flame(not visible). Then this also extinguished. This wasn't anticipated according to the theoretical models and numerical solutions for flames created after decades of studies. This experiment and other continued studies in microgravity on combustion will lead to better models. And in the long run, cleaner fuels, better mileage and reduced pollution are some real possibilities.

As of now, only NASA, Japanese space agency JAXA and European Space Agency ESA have conducted microgravity experiments in space. ISRO is planning to join the list soon by sending its much ambitious Gaganyaan mission by 2022. It is planned to be a crewed 7 day spaceflight in low-Earth orbit with 2-3 astronauts from India. Before this major launch, 2 non-crewed flights would also be launched separately for demonstration purposes. So for this mission ISRO has invited suggestions and ideas by India's top research institutes and organisations for the experiments to be done in the 7 days of the mission. And if all goes well, it would be pretty exciting to look at the fresh experiments and research contributed to the ever-flowing river of science by our country and all of the hard-working people involved.

Physics Society 2019-2020



OKAY, HOLD STILL.
AND REMEMBER, IF YOU
REALLY BELIEVE IN THE
LAWS OF PHYSICS,
YOU WON'T FLINCH.

