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Fidget Spinner & Physics

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Abstract: *Fidget spinner is a mechanical model of heaven which spins so perfectly and magically on the top of finger of a person. Fidget spinner have attracted an acute mass in pop culture. These are available in many shapes, designs and colors in the market. Fidget spinners help the people to reduce their stress and anxiety. To some extent fidget spinners are useful in treating people with ADHD, anxiety, autism and other mental or psychological disorders. Fidget spinner was the most popular toy among many other toys in early 2017. In this paper we will discuss how fidget spinner really works and what the physics behind its mechanism is. We will discuss how we can find out the spin time and moment of inertia of fidget spinner and how this pocket sized gadget obeys the rules of Sir Isaac Newton.*

Keywords: *Fidget spinner, spinning, ball bearings, friction, spin time, Stress and anxiety, ADHD*

I. INTRODUCTION

Today life is running at much faster pace. People are getting much more technically busier than ever as the time progress on. Everyone in this fast running world wants to relax for some time and want some space from their busy and hectic schedule. An amazing toy fidget spinner can help people to relax and give people little distraction from their busy lives.

A. What is Fidget Spinner?

Fidget spinner is a small jiggle toy that usually used to reduce tension, nervousness, worries and anxiety [1]. A fidget spinner is a small pocket sized gadget that comprises of a ball bearing in the middle of multi lobed flat structure prepared from metal or plastic. It is called fidget spinner because it can spin and help you to get distraction from the random thoughts of the world around you. Fidget spinner is designed in such a way to rotate around its axis with slight efforts. Fidget spinners are available in various sizes, structures and are fabricated from various different materials. Fidget Spinner helps to treat undesirable behaviors like biting nails, smoking, scratching nose, licking lips etc. Fidget spinners help to calm you down instead of biting your nails or licking nails. Using fidget spinner, many people have efficaciously treated their undesirable habits. Fidget spinner is prevalent among people with Attention Deficit Hyperactivity Disorder (ADHD), autism. Fidget spinners are well known to relief mild to moderate stress and anxiety. But if someone has severe anxiety, that person might not be benefited to calm down using fidget spinner. Ronald Rotz and Sarah D. Wright have explained how fidgeting of a fidget spinner can prevent the distractions [2]. Fidgeting a spinner may prevent your attention from being engaged with obsessive and unhealthy feelings like what you are living for, why other person is more attractive than you, what other people thinks about you, why other person is more successful as compared to you etc. There are many reasons why this toy has attracted so many people. It was very popular among all other toys in early 2017. It is a small gadget that is usually held on hand. This toy stays like a propeller and spins on the top of our finger. It's like a stress or anxiety relieving therapy to watch a fidget spinner while spinning. People with stressful jobs got attracted by fidget spinners so much that they used to carry these gadgets to their work places and offices. These gadgets are best to get distracted from smart phones and helpful to improve concentration, focus and attention of the people. It's really a fun to watch a small fidget gadget dancing on our finger. Once you get your hands on a fidget spinner and you spin it, it seems like it is alive.

B. History of Fidget Spinner

Fidget spinner is a popular toy with full craze among the people; however it was actually invented in early 1990's. Fidget spinner was invented by a lady named as Catherine Hettinger [3]. There was some inspiration behind the invention of fidget spinner. Catherine Hettinger was actually suffering from a disorder, Myasthenia gravis. This disorder makes it difficult to reach from brain to muscles of the body. People who have this disorder face problems to move arms. Myasthenia gravis disorder inspired Catherine Hettinger to invent fidget spinner. Catherine and her daughter decided to invent a toy with which they can play together. Then she designed a small plastic toy which looked alike a hat and would spin and balance on the top of finger. This history of fidget spinners clearly shows the motive behind the invention of fidget spinner. After that many people invent their versions of fidget spinners, but different from the spinner invented by the Catherine [4]. The current basic fidget spinners have 2 or 3 blades or wings. These latest spinners have ball bearings in the middle which help the spinner to spin for much longer time. These fidget spinner has really hit

the market with a fire. There are so many creative and adorable designs and colors of spinners available to attract the fidget spinner lovers. Catherine Hettinger as the inventor of original fidget spinner should be enjoying high life but this inventor is not making money of her brilliant creations [5]. She held the patent on her creation for 8 years and surrendered it in 2005 because she could not afford the fee to renew the patent of her incredible invention. Over the decades later, in 2016 present generation of fidget spinner became popular. These gadgets are different from the Hettinger's invention, even Hettinger agrees with it. These new Fidget spinners depend upon complete mechanism for the movement.

C. Basic Structure and Design Of Fidget Spinner

Fidget spinner is a toy like a top but it rotates on the hand rather than floor. These are designed in such a way that it is possible to make it spin even with the little efforts. A fidget spinner has three basic parts wings, ball bearings and button or central pad, which are explained below:

- 1) *Wings or Blades:* Wings are that part of fidget spinner which has to abricate and finish with great care. Wings of fidget spinners are made of plastic and have a canter of poise.
- 2) *Ball Bearings:* Ball bearings are known has heart of a fidget spinner. A bearing is a point of contact between wings and button. Most of the fidget spinners have ball bearings exactly in the center and some can hold it to spin the fidget spinner. Actually center of a fidget spinner consists of a number of little balls sandwiched between two circular rings called "Inner race" and "Outer Race". Ball bearings are available in various types, sizes and class. The spin of a fidget spinner can be smooth and long depends on the type of bearing used in fabrication of a fidget spinner. Ball bearings reduce the friction and allow the fidget spinner to spin freely for longer time. Thus with the help of good bearings fidget spinners spins perfectly and for long span of time. A regular bearing used for fidget spinners is ceramic bearing. Ball bearings can vary to change the time of spin, vibration and sound.
- 3) *Circular Pad or Button:* Button is that part of a fidget spinner which is fixed at the center of it. To make a fidget spinner start spinning we have to hold the button and flick the wings of spinner with our finger . Button of a fidget spinner is usually round in shape and is carved beautifully.



Fig.1. A basic three lobbed fidget spinner at rest (left) and while spinning (right)

D. Principle Behind The Fidget Spinner

As we have discussed those ball bearings are the key to this spinning gadget and we know that frictional force is the resistance to motion that arises when an object moves relative to another object. These ball bearings diminish this frictional force and allow the fidget spinner to spin freely for a long time[6]. To better understand the principle on which spinning of a fidget spinner depends, let us try a little experiment. To understand principle behind the fidget spinner let us slide a block of wood on the floor and do the same with the marbles. We will observe that marbles will go farther as compared to wooden block. That's because friction related to rolling motion is less than the friction associated with the sliding motion. Same is the principle related to spinning of fidget spinner. To rotate an object we need to apply torque on that object. In a fidget spinner we hold the center of one ball bearing and outer bearing spins around which makes the outer parts of fidget spinner to spin. According to Doherty, a physicist at Exploratorium in San Francisco, "One flick of the fidget spinner with a finger or a rapid twist of wrist sets the fidget spinner in motion and it keeps on going because of low friction. ". Spinning of fidget spinner also depends upon its shape. If the ball bearing is at the center of fidget spinner then one person can make it to spin by just one push on the outer part. According to Doherty, center of mass of an object should be at the center, where center of mass of a body is the point at which whole mass of the body is concentrated and center of

mass is a point at which one can balance the object. If the fidget spinner has protrusions so that ball bearings is not at the center of mass of fidget spinner then one can make fidget spinner to spin with the flick of wrist. The ball bearings on the outside of fidget spinner are there for weight.

II. FIDGET SPINNERS WITH DIFFERENT DESIGNS AND FEATURES

A fidget spinner is not just a toy but also a stress relieving tool, a treatment for ADHD and a distraction from undesirable behaviors like biting nails, licking lips etc. Fidget spinners have taken over the market of handheld toys. A lot of people weather they are kids or adults desires to have this new pocket sized gadget. Now life of most of us is so much busier than ever. Because of our busy and hectic schedules we don't have time to relax. These small gadgets help us to relax for some time even at our work places and offices. We can relax for few minutes while watching fidget spinners dancing on top of our finger. Fidget spinners make some twirling sound when they spin, which is so enthralling. This enthralling feeling is what makes us feel stress free and tranquil. The rate of popularity of these hand held toys is rising at very fast pace. According to the reports of studies, these gadgets are in high demand. Every manufactureris motivated to create a fidget spinner with unique look and different features from others. To make fidget spinners of different sizes, shapes and colors a lot of imagination is required. There are various fidget spinners available in the market with different and fancy designs and adorable looks [7]. Before discussing the types of fidget spinners, we will discuss what is so special about a fidget spinner that makes it so fascinating for kids as well as adults? There are many fidget spinners that are being designed with different quality materials and features. Fidget spinners are available in wide ranges of and affordable prices. But it should be remembered that you get only what you pay for. Low-priced spinners and high quality spinners differ from each other in many features and these differences can be felt by anyone.

A. The Features Which Make The High Quality Spinners Better Than Cheaper Spinners Are

- 1) *Spin Time of a Fidget Spinner:* There are many fidget spinner lovers who are just enthusiastic about the time span of spin of fidget spinner. For those fidget spinner lovers' time of spin matters a lot and is very essential. However this is not a common case with every fidget spinner lovers. People, who have a lot of interest in spin time of a fidget spinner, usually go for best quality of fidget spinners with ceramic ball bearings. These spinners are fabricated from finest metals. These kinds of fidget spinners can be balanced on the top of finger for longer time span of spin. Because of longer spin time for fidget spinner lovers get pleasure by watching spinning of spinner for longer time. Time for a longer spin of a spinner can be about 1-2 minutes. A fidget spinner cannot spin for more than 2 minutes unless it is designed by suing high end skills whereas cheaper spinners can't be designed with such quality materials so their spin time is very short.
- 2) *Excellence of Spins of a Fidget Spinner:* High quality spinners are designed in such a fine way they have very smooth and perfect spins. These smooth spins of a f High quality spinners are fabricated by using R188 bearings. These R188 bearings are recognized to produce smoothest spins. However no such ball bearings are used for low prices fidget spinners. Cheaper spinners are designed with te bearings which have no comparison with R188 ceramic ball bearing.
- 3) *Durability of a Fidget Spinner:* High quality expensive spinners are designed by using high quality material which makes them durable and these spinners last longer as compared to the low priced fidget spinners. However fidget spinners need to be taken care of in order to make them last for long. So lots of high quality spinners are designed with caps which don't allow the dirt to get into the bearings so that they can last for longer.
- 4) *Fidget Spinners with Unique Designs:* Fidget spinners with unique designs make them more attractive. Innovation and creativity that is being used in designing these fidget spinners is just great which make spinner fascinating for kids. There are so many spinners with adorable designs and colors are available in the market. Even the adorable designs of a spinner attract those people who hate spinners.

B. Some Types of Fidget Spinners

- 1) *Fidget Spinners with Bluetooth Speakers and Light:* Fidget spinners with Bluetooth speakers and light are just great. They also have a switch and a USB charging design. These types of spinners are recognized as multipurpose fidget spinners. These fidget spinners are very handy and great for releasing the stress and to help the people with ADHD. For the fans of fancy fidget spinners these kinds of spinners are best choice. Fidget spinners with light and blue tooth speakers entices the kids very much.



Fig. 2. Fidget spinner with light and speaker

- 2) *Fidget Spinners with Spikes*: Fidget spinner with try spikes are very common and makes very fine spins. These spikes enhance the quality as well as give spinners an attractive looks. Fidget spinners with blades looks almost same as the spinners with spikes.



Fig. 3. Fidget spinner with spikes

- 3) *Fidget Spinners with Marbles*: Fidget spinners with marbles are ideal for the kids as these kinds of spinners would encourage their concentration and attention. Designs of these spinners are full of creativity.



Fig. 4. Fidget spinners with marbles

- 4) *Fidget Spinners with Zip Ties*: These kinds of fidget spinners consist of two bars with a bearing in the center and other bearings on each side of spinner. These kinds of fidget spinners look unique and stand out from rest of the spinners available in the market. Fidget spinners with zip ties have perfect balance and can spin for longer time.



Fig. 5. Fidget spinners with zip ties

There are also other types of fidget spinners with lot of varying designs. One person can choose according to his taste. But I think only one type of fidget spinner is not enough for the fidget spinner lovers.

III. FIDGET SPINNERS AND PHYSICS

A. Fidget Spinner and Sir Isaac Newton's Laws

The science of fidget spinner starts earlier even before fidget spinner always start whirling. Even when the spinner is not spinning, it epitomizes the fundamental theories of physics [8]. Sir Isaac Newton was really genius. He predicted enough how the things like a spinner works. Let's discuss now how a fidget spinner spins on the top of finger by following the Newton's law side by side.

- 1) *What Makes The Spinner to Spin?* According to Newton's first law of motion an object won't accelerate until and unless it is acted upon by any external unbalanced force. If we take the case of fidget spinner, it must be twisted in order to spin. There is a ring in the middle of fidget spinner that holds little ball bearings. These bearings connect the inner parts and outer parts of the fidget spinner. Surface area in contact between the inner and outer rings is not as much; this is an attempt to reduce friction. When someone hits the spinner so that it can start spinning then Newton's first law take a hold again. Fidget spinner keeps on spinning until the unbalanced force of friction eventually takes the hold. If there were no force of friction like resistance by wind, the fidget spinner would go on spinning forever. It is great to look at an immobile spinner but to rotate it we have to apply a torque on spinner. The torque depends upon the amount of force applied on an object and how far away from the rotational axis the force is exerted and how much of force is at right angle to the limbs of fidget spinner. One need to push it with lot of energy as far from the center as probable and at least distance one need to push slightly in the desired direction.
- 2) *What Makes The Fidget Spinner to Stay Upright?* A fidget spinner also follows the law of conservation of angular momentum. An object will move on with a constant linear velocity until an external unbalanced force acts on the body. In similar ways rotational velocity will remain constant until an unbalanced torque acts on the body, If the spinner is spinning in the in an ideal world then the only force acting on the body will be gravity. As spinner is symmetrical so gravity does not exert any unbalanced force on spinner and this makes the spinner to spin in the exactly same direction without leaning.
- 3) *What Makes Spinner to Revolve in a Circle?* The fidget spinner keeps on spinning in same direction. As we have discussed earlier that fidget spinner follows the law of conservation of angular momentum. In order to change the angular momentum, we need to apply torque of a force pushing. If spinner is spinning on an uneven or rough surface like a pencil eraser, top of the finger then fidget spinner will tilt slightly. This actually un-aligns the center of mass of fidget spinner and axis of rotation of fidget spinner. Because of which gravity will pull the center of spinner and which will cause an unbalanced torque and this will lead to change in angular momentum. This change in angular momentum will make the spinners to shake but it will not fall over. This is called Precession.

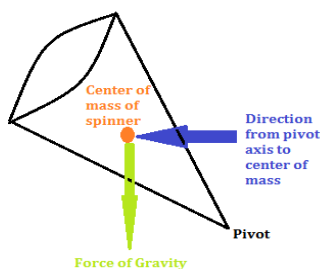


Fig. 6. Precession in fidget spinners

To better understand it let us discuss right hand rule. Point fingers of your right hand in the form of pivot to center of mass so that fingers of right hand can curve towards the force of gravity and thumb will point in the direction of torque. The direction of angular momentum as shown in the above fig is same as the direction of angular velocity shown in fig below.

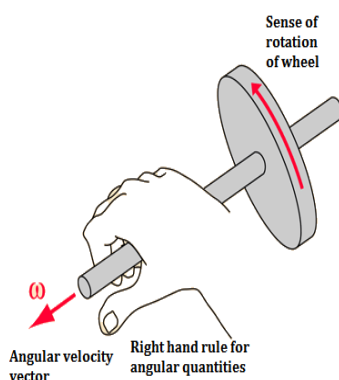


Fig. 7. Right Hand Rule for angular quantities

If you wrap the axis of rotation by the right hand as shown in above finger, so that fingers will turn in the direction of rotation then thumb will give you the direction of angular velocity. As discussed above if the angular momentum of fidget spinner changes because of unbalance torque application. This will lead to change in the direction of center of rotation. By using right hand rule again and again we can observe that it will make a circle. If we attempt to make spinner to spin vertically instead of horizontally by rotating the wrist, it will create a big change in angular momentum of fidget spinner and as we push the fidget spinner it pushes on us. This shows that a fidget spinner obeys the Newton's third law.

- 4) *What Make It to Stop?* As ball bearing of fidget spinner is not friction less this frictional force oppose the motion of spinner. There are other external forces like friction force of air, force of gravity which oppose the motion of a spinner and slows down the whirling of fidget spinner and ultimately when frictional force take a hold, the spinner will stop.
- 5) *Fidget Spinner and Newton's Second Law:* According to Newton's 2nd law, acceleration of an object produced by the net force on that object is directly proportional to magnitude of net force and direction of acceleration is same as the direction of force and is directly proportional to mass of the object. So if we have a big sized spinner then more force will be required to make it move and also it will move for long time. If we increase the weight of spinner its acceleration will also increase. We can prove it by a simple experiment. Let's take a spinner and put it on the table. Put your one finger on the center point of spinner to hold it steady and make it spin using other hand and with the help of your another friend note down the time period of spin of that spinner on your data sheet. Repeat it 3-4 times and calculate the average of your readings. Now tape the coin of same size on the top of each arm of spinner and note down the spin time 3-4 times and calculate the average of readings in this case also. You will observe that spinner with additional mass of coins will spin for longer time as compared to spinner without coins. This shows how a fidget spinner goes with Newton's second law.

B. Fidget Spinner and Rolling Friction

Fidget spinners are basically ball bearings with low friction [9]. When two things move over one another, friction prevents them from sliding easily. If someone tries to slide a wooden block over the floor then wooden block will ultimately stop sliding because

of the friction between wooden block and floor. But if someone rolls a wooden ball instead of wooden block over the same floor, the wooden ball will go farther as compared to the wooden block. This is because rolling friction is much frailer in comparison to sliding friction. Because in the case of rolling friction contact between the wooden ball and floor is comparatively insignificant.

Most of the fidget spinners have ball bearings exactly in the center, which some one can hold to make fidget spinner spin. The center of spinner consists of a number of little balls sandwiched between two circular rings called “Inner Race” and “Outer Race”. Without balls inner and outer race would spin against each other only for less time until sliding friction wins over their motion. But because of the tiny balls between the inner and outer race, there will be rolling friction rather than sliding friction, which make them to spin for much longer time.

C. Spin Time of a Fidget Spinner

A fidget looks like a plastic bauble in which ball bearing is hidden within the body of spinner around which the entire mechanism revolves. Now here we have question that how to know that how long a spinner can spin? To know about the spin time of a fidget spinner, all we need is angular acceleration of that fidget spinner. Before it we should first discuss about fundamental rotation kinematics. Let us suppose a rotating object; we can measure the angular position of that object at any point. Let the angular position of that rotating object is ‘ θ ’.

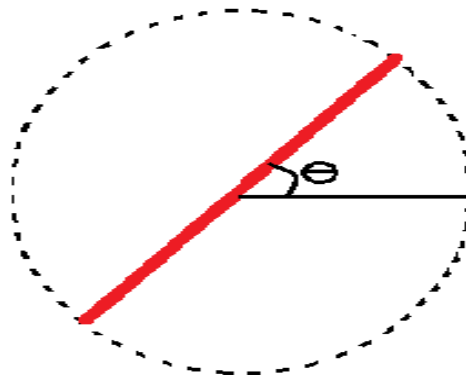


Fig.8. Rotating object with angular position

If the object is continuously rotating then angular position will change and change in ‘ θ ’ will give us angular velocity. Let ‘ ω ’ is the angular velocity of that rotating object and can be represented as:

$$\omega = \frac{\Delta\theta}{\Delta t} \dots\dots\dots (1)$$

Change in angular velocity will give us the angular acceleration as we know angular acceleration is rate of change of angular velocity. Let ‘ α ’ is the angular acceleration and is represented by:

$$\alpha = \frac{\Delta\omega}{\Delta t} \dots\dots\dots (2)$$

If we know the initial angular velocity of the rotating object and by assuming final velocity of the object as 0 rad/sec then $\Delta\omega = 0 - \omega_i$, we can calculate the spin time of that rotating object. Angular acceleration $\alpha = \frac{-\omega_i}{\Delta t}$,

$$\text{Therefore spin time } \Delta t = \frac{-\omega_i}{\alpha} \dots\dots\dots (3)$$

Thus calculate the spin time of a fidget spinner; we need to know the value of angular acceleration of that fidget spinner. We can calculate the angular acceleration by measuring the change in angular velocity of the fidget spinner. But this is not so easy task to measure the change in angular velocity of a fidget spinner. It is not easy to capture the video of spinning fidget spinner as it spin so fast [10]. Rhett Allain an Associate professor, Southeastern Louisiana University, used a laser to measure to measure the change in angular velocity of spinner. The experimental setup which he set to measure the change in angular velocity of fidget spinner is shown in fig below. In this setup laser light falls on a light sensor. During spinning fidget spinner occasionally blocks the sensor and interrupt the laser. Spin rate of fidget spinner was determined by the no of time sensor was blocked so these values were recorded by light sensor.

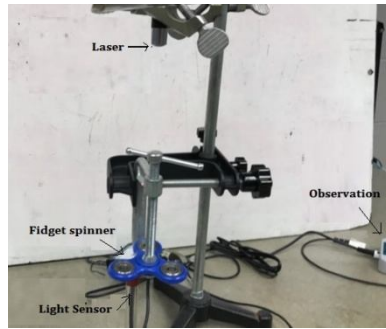


Fig. 9. Experimental setup to measure the change in angular velocity using laser

RhettAllain from his observations plotted a graph between angular velocity and time which looks fairly linear and slope of this straight line gave the angular acceleration for that fidget spinner. According to the observations of Allain spin time of that particular spinner that used in the setup was found to be around 104 sec.

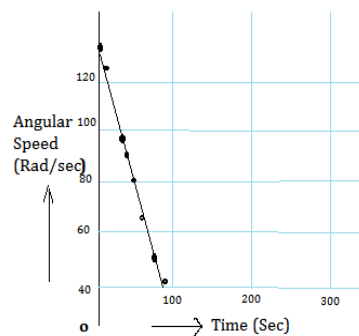


Fig. 10. Graph between angular velocity vs. time to find the angular acceleration

D. Moment of Inertia of a Fidget Spinner

In the previous article we have discussed that how to find out the spin time of a fidget spinner. Now we will discuss how to find out the moment of inertia of a fidget spinner [11]. For this we need to measure the mass and size of the fidget spinner. As we know moment of inertia of a body is given by:

$$I = \sum_i m_i R_i^2 \dots\dots\dots (4)$$

It is not easy to find out the moment of inertia of a spinner as it does not have any mathematical figure. To measure the moment of inertia of a fidget spinner Allain used a physical pendulum. We are familiar with the basic pendulum, that's a small mass swinging from a cord. Time period of oscillation of a simple pendulum is given by:

$$T = 2 \pi \sqrt{\frac{L}{g}} \dots\dots\dots (5)$$

Where L = Length of the cord

And g = acceleration due to gravity (9.8 N/ Kg)

If the cord of a basic pendulum is replaced by any rigid thing like stick then we will have a physical pendulum. In that case time period of oscillation is given by:

$$T = 2 \pi \sqrt{\frac{I}{mgL}} \dots\dots\dots (6)$$

Where I = Moment of Inertia about the axis of rotation,

L = Distance between axis of rotation and center of mass

And m= mass of the object.

So moment of inertia of an object can be finding out by using above equation (6) by hanging that object with the physical pendulum. But if moment of inertia of an object through another axis has to be find out. Then theorem of parallel axis will be used, which state that if we know moment of inertia of an object about an axis that runs through its center of mass, then moment of inertia through another axis will be given by:

$$I_{\text{parallel}} = I_s + md^2 \dots\dots\dots (7)$$

Where m= mass of an object,

D = distance between center of mass axis to another new axis.

To measure the moment of inertia of fidget spinner Allain tied a spinner of mass of just 1 gm. to stick and attached this stick to the rotation sensor so as to record the time period of oscillation and angle of stick as shown in fig below:

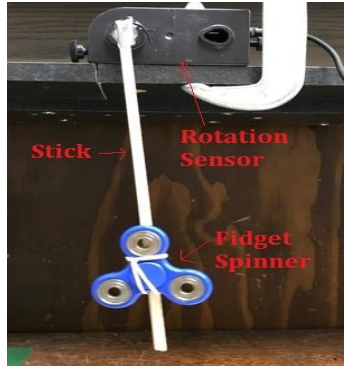


Fig. 11. Fidget spinner hanged with a stick and then to rotation sensor to find out time period of oscillation and angle of stick.

To find the moment of fidget spinner Allain used the time period of a physical pendulum and applied the theorem of parallel axis and gave the following relation:

$$\frac{T^2 mgL}{4\pi^2} = I_s + mL^2 \dots\dots\dots (8)$$

From the above relation Allain not just measured the one time period of oscillation, instead he measured the time period with spinner at some distance L, then changed the distance and measured the new time period. Like this he recorded many readings and plotted a graph as shown below and found the moment of inertia of a fidget spinner. During the observation he ignored the mass of stick and rubber band which he used to secure the spinner with the stick. From his observations Allain calculated moment of Inertia of a fidget spinner around $5.4 \times 10^{-5} \text{ Kg- m}^2$.

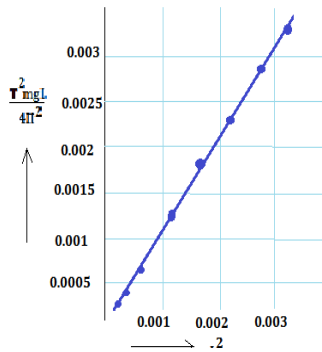


Fig. 12. Graph plotted to find moment of inertia of a fidget spinner

IV. CONCLUSION

In this paper, I have concluded that the most popular toy fidget spinner of early 2017 is totally dependent upon the fundamental laws of physics. Fidget spinner is in complete agreement with laws of Sir Isaac Newton. High quality ball bearings of a fidget spinner make it to spin perfectly according to the predictions of Sir Isaac Newton. This paper have shown that how a fidget spinner follows the law of conservation of momentum and energy. The spin time and moment of inertia of a spinner can be measured by using simple laws of physics. When you spin this small pocket sized gadget, it seems like it comes alive, like it combats any motion to try to give it. The cause is physics. So the magical spin of a fidget spinner which has made a lot of people crazy about it is full of physics. It's really a fun to watch the rules of physics dancing on the top of our finger in the form of a fidget spinner. Whether you love it or hate it you should try it once.



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