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Palash's Spinning Effect: A Study of Rotational and Translational Motion

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Abstract: ***This paper presents a detailed study of the relationship between rotational and translational motion, termed as Palash's Spinning Effect. The study involves a series of experiments and mathematical proofs to demonstrate this phenomenon. The findings suggest that as long as a spinner has translational velocity, it will also have some angular velocity. This effect implies a relation between the motion as: - " rotational motion favours translational motion, and its vice versa is also true [translational motion favours rotational motion]". Example: Like a car's wheel rotating on road makes the car move translationally in forward or backward direction, depending on the direction of motion of the wheel.***

Keywords: Rotational Motion, Translational Motion, angular Velocity, Physics, Spinning Effect, Inertia

1. Purpose

The purpose of this study is to explore and explain the phenomenon of rotational motion favouring translational motion and vice versa, termed as Palash's Spinning Effect.

2. Significance

This study contributes to the understanding of the relationship between rotational and translational motion, providing insights that could be useful in various applications in physics and engineering.

3. Experiment showing effect

To perform the experiment, we require only two instruments that are as follows: -

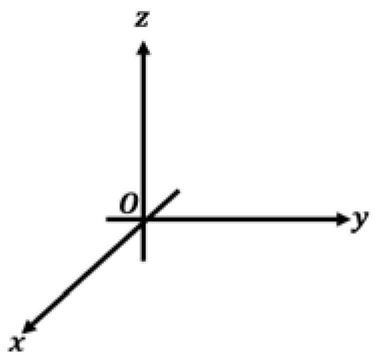
- Non rigid/Rigid platter (card sheet) with a huge surface area
- A solid cylindrical spinner with a long spinning tip

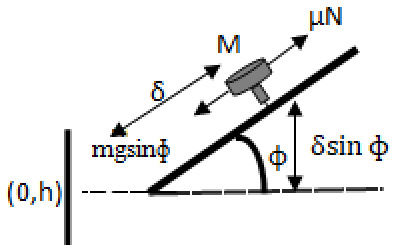
The experiment goes as follows, take the spinner and make it spin on the surface of the platter in the first step, next holdthe platter in a horizontal plane initially with hands, letting the spinner spin on board. After a small time, interval, when the spinner's angular velocity has diminished by its initial amount, start oscillating the platter in such a fashion that the spinner will move around the surface of platter in an elliptical trajectory. When this happens a very interesting thing is been seen, the spinner that was going to arrive at rest has regain its angular velocity and it continue keeps spinning and moving in the elliptical trajectory as long as you keep oscillating the plate. Which states that when you move the platter, you give the spinner a translational velocity and it regains its rotational velocity. The spinner keeps spinning infinitely unless you stop oscillating the platter. After the platter is stopped oscillating, the spinner comes to rest after some time. The objective of this effect is to show that the spinner can spin forever till the platter is raised by some angle from the horizontal.

To really know what is actually the physics behind this effect and to show the real reason of this bizarre phenomenon, in the rest of the paper, I would present a complete mathematical proof for why this phenomenon takes place.

The complete mathematical proof: -

Let us first take a look at what the setup of this experiment looks like with a help of an FBD diagram -





ϕ is the angle made by the platter with x axis.
h is the height from the ground.
M is the mass of the spinner

Now, at a specific point (distance δ from the end tip of platter), the spinner has energy -

$$E = \frac{1}{2}M\upsilon^2 + \frac{1}{2}I\omega^2 + Mg(h + \delta.\sin\phi) \ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

This is the energy the spinner has when it has a translatory velocity υ and angular velocity ω.

Now as we know that the energy is always conserved, so the rate of change of energy with respect to time is zero.

Now differentiating the equation 1 with respect to time: -

$$\frac{dE}{dt} = \frac{1}{2}M\frac{d\upsilon^2}{dt} + \frac{1}{2}I\frac{d\omega^2}{dt} + Mg\frac{dh}{dt} + Mg\frac{d\,\delta\sin\phi}{dt} = 0$$

$$\frac{1}{2}M(2\upsilon.a) + \frac{1}{2}I(2\omega.\alpha) + Mg(\upsilon\sin\phi + \delta\cos\phi\frac{d\phi}{dt}) = 0$$

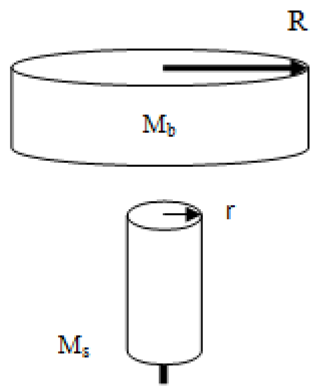
$\frac{dh}{dt}$ = 0as the value of height h is kept constant during the experiment, and $\frac{d\delta}{dt}$ = υ as this term is instantaneous velocity of the spinner at that point.

$\frac{d\phi}{dt}$ is the change of angle of inclination with time.

$$M\upsilon a + I\omega\alpha + Mg(\upsilon\sin\phi + \delta\cos\phi\frac{d\phi}{dt}) = 0$$

$$I\omega\alpha = -[M\upsilon a + Mg(\upsilon\sin\phi + \delta\cos\phi\frac{d\phi}{dt})]$$

Now considering the specifications of the spinner, writing the moment of inertia for the next equation: -



$$(\mathbf{M})_{\text{total}} = \sum_{i=s}^{b}(M)_i = \mathbf{M_b + M_s}$$

Both the physique in the figure are solid cylinders with one having radius R and mass M_b and another having radius r and a mass M_s.

Therefore, the moment of inertia of the spinner is going to be: −

$$I = [Mb\frac{R^2}{2} + Ms\frac{r^2}{2}]$$

$$\left[Mb\frac{R^2}{2} + Ms\frac{r^2}{2}\right].\omega.\alpha = -\left\{M\upsilon a + Mg\left(\upsilon\sin\phi + \delta\cos\phi\frac{d\phi}{dt}\right)\right\} \quad \ldots\ldots\ldots 2$$

Now simplifying the equation and taking value of omega: −

$$[Mb\frac{R^2}{2} + Ms\frac{r^2}{2}].\omega.\alpha = -M\upsilon\,(a + g.\sin\phi + \frac{g\,\delta\cos\phi}{\upsilon}.\frac{d\phi}{dt})$$

$$\frac{1}{2}[MbR^2 + Msr^2].\omega.\alpha = -M\upsilon\,(a + g.\sin\phi + \frac{g\,\delta\cos\phi}{\upsilon}.\frac{d\phi}{dt})$$

$$\omega.\alpha = \frac{-M\upsilon\,(a + g.\sin\phi + \frac{g\,\delta\cos\phi}{\upsilon}.\frac{d\phi}{dt})}{[Mb.R^2 + Ms.r^2]}$$

$$|\omega| = \frac{M\upsilon\,(a + g.\sin\phi + \frac{g\,\delta\cos\phi}{\upsilon}.\frac{d\phi}{dt})}{\alpha\,[Mb.R^2 + Ms.r^2]}$$

Now as the change of angle of inclination with time is negligibly small:

$$\frac{g\,\delta\cos\phi}{\upsilon}.\frac{d\phi}{dt} \approx 0$$

$$|\omega| = \frac{M\upsilon(a + g.\sin\phi)}{\alpha[Mb.R^2 + Ms.r^2]}$$

→ *Magnitude of the angular velocity of the spinner*

From here we obtain a very important relation as -

$$|\omega| \propto \upsilon$$

which states that as long as the spinner has translational velocity, it will also have some angular velocity.

Now using *Newtons laws* to derive an equation for the translational velocity from the FBD diagram, to see how the magnitude of angular velocity is affected with the change in angle ϕ.

$$Mg.\sin\phi - \mu N = M\frac{d\upsilon}{dt}$$

$$(N = Mg.\cos\phi)$$

$$Mg.\sin\phi - \mu.Mg.\cos\phi = M\frac{d\upsilon}{dt}$$

$$g\,[\sin\phi - \mu.\cos\phi] = \frac{d\upsilon}{dt}$$

$$\int_0^{\upsilon} d\upsilon = g\,[\sin\phi\int_{t1}^{t2} dt - \mu.\cos\phi\int_{t1}^{t2} dt]$$

$$\upsilon = g\Delta t\,[\sin\phi - \mu.\cos\phi] \quad \ldots\ldots\ldots\ldots\ldots\ldots 3$$

$$\upsilon = g\Delta t\,[\sin\phi - \mu.\{1 - 2.\sin^2\frac{\phi}{2}\}]$$

OR

$$\upsilon = g\Delta t\,[\sin\phi - \mu.\sqrt{1 - \sin^2\phi}]$$

equation 3 is 2^{nd} important equation for the translational velocity

$$\upsilon = g\Delta t\sin\phi\,[1 - \mu\cot\phi] \quad \ldots\ldots\ldots\ldots\ldots\ldots 4$$

Now:

$$\sin\phi \in [-1, 1]$$
$$\cos\phi \in [-1, 1]$$

Therefore, from equation 4, the range of angle of inclination is: −

$$0 < \phi \leq \frac{\pi}{2}$$

Therefore, the equation is defined only for the angle of inclination ranging from (0, π/2]. and this is true as seen from the experiment, as the spinner shows this effect only for the value of angles in the interval, and at angle 0 it shows normal rotation.

Therefore, we conclude that the angular velocity $\omega \propto v$ and, from equation 3 we can see that the spinner's translational motion is affected by the variation of angle of inclination ϕ. *So, the spinner will keep spinning, if there be some angle of inclination.*

4. Conclusion

The study demonstrates the relationship between rotational and translational motion, termed as Palash's Spinning Effect. The findings suggest that as long as a spinner has translational velocity, it will also have some angular velocity. This contributes to our understanding of these fundamental concepts in physics.

References

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[3] Law of conservation of energy.
[4] Images from Getty Images, and 3d co - ordinate system from Google.