Journal of Physics Special Topics

An undergraduate physics journal

S3_6 Spinning Around

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November 16, 2017

Abstract

We explore the changing velocity of a pole dancer's spin using a pole which rotates as the performer spins. Assuming the motion is frictionless we find that an initial leg whip perpendicular to the pole lasting π radians results in a velocity of 0.484 rev s^{-1}. By pulling the outstretched leg in to the pole the velocity increases massively to 7.74 rev s^{-1}.

Introduction

In pole fitness a spinning pole has an outer cylinder which rotates around an inner cylinder so that the pole moves with the performer. This set up is virtually frictionless and it's possible to continue spinning for a long time without slowing down. In this paper we look at the change of angular velocity of a climbing spin on the pole. In this move the pole dancer's leg whip creates the torque which drives the spin. In an ideal scenario, to generate the maximum angular momentum, this leg is perpendicular to the pole as it is whipped around as shown in Figure 1.

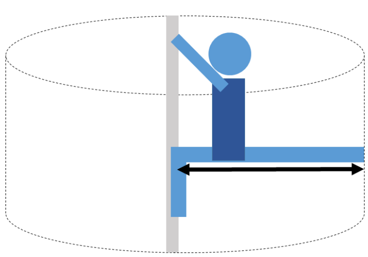

Figure 1: Diagram showing the leg whip for a climbing spin where the arrows show the moment arm r.

Theory

We study the motion of the climbing spin by first finding the angular velocity ω after the leg whip then at the maximum angular velocity with the leg pulled in to the pole. The equation for constant angular acceleration used is Eq. 1 where the initial velocity ω_0 is zero [1]

$$\omega^2 = \omega_0^2 + 2\alpha\Delta\theta. \tag{1}$$

The variable $\Delta\theta$ is the angle passed through by the outstretched leg and α is angular acceleration. We find the acceleration of the whip using Eq. 2 rearranged for α:

$$\tau_{net} = I\alpha, \tag{2}$$

and using the definition of torque τ (the force F times the radius of the axis of rotation r) and the moment of inertia I. We estimate the moment of inertia for the pole dancer by modelling the leg whip as a cylinder as shown in Figure 1 which gives I as mr^2. Combining the two previous equations we reach Eq. 3 which is

$$\omega = \sqrt{2\tau_{net}\Delta\theta/I} = \sqrt{2F\Delta\theta/mr}, \tag{3}$$

where F is the force of the leg whip.

The maximum angular velocity of the pole dancer is found by using the conservation of angular momentum L, given in Eq. 4,

$$L = mr_i^2\omega_i = mr_f^2\omega_f, \tag{4}$$

where r_i and r_f are the initial and final radii and ω_i and ω_f are the initial and final velocities. The mass m is constant and disappears when the equation is rearranged for ω_f.

Results

Neglecting drag, the force contributing to the torque of the spin is equivalent to the weight of the dancer's leg. This is because the leg is perpendicular to the axis of rotation and so $\sin\theta$ is zero. The weight of the leg is approximated by using that a leg is approximately 18% of the mass of a woman's body [2]. We assume the pole dancer's mass m is 60 kg which gives us a leg mass of 10.8 kg, or leg weight F of approximately 106 N. The moment arm r is estimated as 1.2 m and the angle travelled through in the leg whip as π (180 degrees). Using Eq. 3 we find the angular velocity of the leg whip to be 3.04 rad s^-1 or 0.484 rev s^-1.

We find the maximum velocity of the spin where the pole dancer's leg is pulled into the pole and we estimate the new moment arm r_f to be 0.3 m. We rearrange Eq. 4 for ω_f and use ω_i as 3.04 rad s^{-1} and the initial moment arm r_i as 1.2 m. The new velocity of the pole dancer is 48.6 rad s^{-1}, which is 7.74 rev s^{-1} which is 16 times the revolutions per second for the initial leg whip. This is much higher than we expected and in reality the velocity would not reach such high velocities due to friction and taking into account the mass of the pole. In addition a perfect spin would have to be performed to reach this velocity. These factors have all been neglected in this ideal scenario.

Conclusion

We found the changing angular velocity of a spinning climb on a spinning pole using the torque used to drive the spin and constant angular acceleration equations. By modelling the pole dancer's movement around the pole as a cylinder with constant mass along the moment arm, the moment of inertia could be estimated. Using this we found the angular velocity reached as 3.04 rad s^{-1} or 0.484 rev s^{-1}. Through the pole dancer pulling their leg close to the pole we found the maximum angular velocity reached was 48.6 rad^{-1} or 7.74 rev s^{-1} which would be unlikely to reach in reality but makes sense with our assumptions.

References

[1] Tipler, P. (2008). Rotation and Angular Momentum. In: Marshall, C. *Physics For Scientists and Engineers.* Basingstoke: W.H. Freeman and Company. p317, p354.

[2] Plagenhoef, S. (1983). Anatomical Data for Analyzing Human Motion. *Research Quarterly For Exercise and Sport.* 54.