Physics aspects in dance

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Certificate

This is to certify that this project entitled "Physics aspects in dance" is a Bonafede record of the project (code- BH6BP02B18) done by Athulya R Nadh (SB21BHA004) under our guidance towards partial fulfillment of the requirement of the award of degree of Bachelor of Arts in Bharathanatyam of University of Mahatma Gandhi during the year 2024.

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Declaration

I hereby declare that this project report entitled "Physics aspects in Dance" submitted to department of Bharatanatyam, St. Teresa's College(autonomous), Ernakulam, affiliated to M G University, Kottayam is a record of original work done by me under the guidance of Arunima JR assistant professor, department of Bharatanatyam.

The information and data given in the report is authentic to best of my ability and knowledge.

The project report is not submitted to any other institution or university for the award of any degree, diploma and fellowship.

Athulya R Nadh

17th April 2024

Ernakulam

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INTRODUCTION

Dance is highly physical activity that engages the entire body, promoting cardiovascular health, strength and flexibility. The constant movement and mascular engagement in dance contribute to improved muscle tone, endurance and overall physical fitness.

The science of dance reveals the profound impact of movement of the human mind and body from its cognitive benefits, emotional expression and stress reduction to it's physiological advantages in improving fitness and promoting cardiovascular health, dance serves as multifaceted avenue for enhancing overall well being.

Dance and science are so much related to each other as scientific exploration in the field of dance continues, we gain a deeper understanding of it's transformation potential and it's capacity to enrich lives . Dance as in art form gives us a divine pleasure but as we dive deep into its movements we could find relation between dance and physics. It is fact that science is truth which prevail and it is the evident truth because of which the world is existing. It always remains constant. Theories and innovation might differ by the change of

time and generation but the core principles remains the same. It permeats nearly every aspect of our lives. Almost core movements of dances whichever dance form it might be Ballet, Classical , Hip hop, Jazz etc all of them could be very much be allied to physics.

The physics aspects which can be majorly related to dance are force, gravity, momentum, friction, torque, Gravitational acceleration , Newton's third law of motion and other points staying balanced on the foot. Balance while turning, physics of jumps aspects of sound and art of balance

* *Gravity: Gravity is the force by which a planet or body draws object towards it's centre. The force of gravity which keeps our body on the ground. In this aspect the mass is signified as dancer's body.*

* *Momentum :The ability to keep increase or developing the force that makes something more faster. In simple words the power when a body is moving, meaning how force it can have on another body.*

* *Friction: The extend force that opposes the relative motion of two contact area. In simple words rubbing one surface or thing against another.*

** Torque : Torque is the measure of force that can cause an object to rotate about an axis. It can be defined as the rotation equivalent of linear line.*

** Newton's first law of motion: An object at rest remains at rest and object in motion remains in motion at constant speed and in line unless acted on by unbalanced force (Inertia)*

**Newton's second law of motion: A large force acting on an object with larger mass require motion force. Net force is equal to mass time acceleration.*

** Newton's third law of motion: Every action has an equal an opposite reaction.*

** Sound: Sound is a type of vibration when an object vibrates it causes movement in surroundings air molecules which close them causing them to vibrate as well.*

**Acceleration : Any process where the velocity changes in terms of speed and direction.*

2. Shiva Nataraja Pose statue at CERN - Geneva, Switzerland

Conseil Européen pour la Recherche Nucléaire or European Organization of Nuclear Research. Is the most respected centre of scientific research. It operates largest particle physics laboratory in the world . This organization has a Nataraja pose statue in front of the organization. Nataraja pose is the brilliant invention which combine single Shiva's role as creator preserver and destroyer of Universe.

The metaphor of cosmic dance unifies ancient mythology, religious art and modern physics.

Shiva in his dynamic pose holds damru in right hand which is believe as creation and in left hand he holds fire which signifies destruction. The pose conveys the never ending cycle of time. So the creation and destruction and balanced on cosmic pose. So, the idea of creation and destruction is mentioned in particle physics. In physics, particles are constantly created and destroyed in sub atomic level. So this shows how rich our culture is considered around the world and when we dive deep into aspects of dance we could see how much our art is relevant in physics.

3. GRAVITY AND IT'S RELATION IN DANCE

Before the invention of gravity by Issac Newton's , gravity was invented much before Maharshi Baskaracharya. In the text it is clearly mentioned that "earth has an attraction power, so it attracts all the heavy object toward it.

Later when Newton invented the gravity, his theory states that any particles of matter in the universe attracts any other with the force varying directly as the product of the masses are inversely to the distance between them. In other words gravity is the force that attracts a body toward centre of earth or any other physical body having mass in other words it is fundamental interaction which causes mutual attraction between all the things that have mass. The force of attraction between earth and body on its surface changes according to the mass of the body.

The dancer standing on the floor has the ground reaction force from the earth which produced by gravity earth pulling dancer into the floor. This derivation comes from "Third law of action and reaction".

3.1 CENTRE OF GRAVITY IN DANCE

All objects behave as through their mass and is concentrated at point called centre of gravity. It is an imaginary point around which the dancer's body weight evenly distributed.

The centre of gravity of the human body can change considerably because of segments of the body when move their masses with joints rotation. This is concept of critical understanding balance and stability and how gravity effects the technique of dance.

The direction of force of gravity through body is downwards towards the centre of earth through centre of gravity. This line of gravity is important to understand and visualize when determining a persons ability to successfully maintain balance. When the line of gravity Falls outside the base of support a reaction is needed to balance.

For the dancer to maintain balance, arms and leg position are used to hold centre of gravity . If the centre of gravity is not in line the dancer may tend to topple.

The best way to of demonstrating Centre of gravity is definitely the Natyarambha position where hands outstretched in sama pada or in araimandi (where both the both knees are pointed towards either sides). In this position a dancer's body is fully balanced. Here the dancer is directly over the contact with the floor. The centre of gravity is where an object is placed on all sides.

In our body centre of gravity is slightly higher than our waist because there is more weight in the top of our body than bottom half of body.

In dance triangles are considered the most strongest shape to balance on all sides because any added force is evenly spread throughout all the sides. - The best example of this is sitting in araimandi position. If we notice , there forms a triangular gap when new sit in proper araimandi position.

A wide base of support is the foundation of stability. When a vertical line from the centre of gravity through the wide base of support balance is achieved.

The net effect of gravity on an dancer is the same as if it were only acting and not all parts of object.

3.2 ASPECT OF FREE FALL AND WEIGHTLESSNESS IN DANCE

When a body is allowed to fall from a certain height it falls to the earth due to force of gravity. This is free fall. In a person it is a sensation experienced by an individual where there is no external force excerted on ones body.

During free fall the only force acting on the body is force due to gravity which is acting upward it feels weightlessness. Hence it is the situation in which an object moves only under the influence of gravity. The phenomenon of zero gravity, when a dancer experiences free fall , in other words weightlessness is a condition experience while in free fall.

For example:when we are sitting in a chair, then we are applying force on the chair, it is giving a reaction force but for freely falling or jumping there is no reaction force against gravity.

In Bharatanatyam this phenomenon can seen more in

**Utplavana adavus*

**Utplavana bhedas -Alakam, Kartari, Ashvotplavanam, Motitha, Kripalakam*

**Bhramari- Utpluta bhramari and aakasha bhramari*

It can be also majorly seen in dance forms like Kathak, Chaau, Garbha, Ballet etc..

3.3 STAYING BALANCED

While staying balanced on the floor , Centre of Gravity remains directly above the area of contact with the floor.

This is point where the forces acting on one side is equal to those acting on the other side.

In Bharatanatyam staying balance can be more challenging in some of the adavus like

**Kudhithamettu adavu : Where toes are mainly used . In this adavu mainly we stay on toes in araimandi or half sitting position and releases to the normal position of feet. Not exactly similar but in ballet the dancer stays on top of the foot for a long time.*

**Mandi adavu : In this adavu we sit on toes , heel lifted up balancing the position maintaining erect position and striking slowly in floor with knees.*

To maintain balance keep centre of gravity over the support base of feet toe or heel.

4. ASPECT OF FRICTION IN DANCE

Friction is another important factor of dance. The friction between dancers feet and floor is an example of a horizontal ground reaction force. For a dancer to move forward, the dancer pushes, backward into the floor.

Providing that there is enough friction between the dancer's foot and floor, the horizontal ground reaction, force of friction then pushes the mass forward, but it is no different to jump on ground and the ground reaction force, pushes daner to air. Similarly when we need to stop moving or change direction the friction from the floor is needed .

This can phenomena can majorly seen in ballet, in bharatanatyam it can be seen in theiyya theiyee adavu and chakra bhramari. Friction can also be seen in Mohiniyattam.

5. ASPECT OF MOMENTUM IN DANCE

Momentum can be defined as mass in motion, all the objects have mass so if an object is moving then it has momentum. In the terms of equation the momentum of an object is equal to the mass of an object times the velocity of of an object

Mass ×Velocity or m×v

Momentum makes an connection between the dancer and the audience through the palpable feeling of movement in a shared space. The dancer and audience alike absorb the evolving kinetic energy just like the exhaustion, which become element during the performance. Only the rhythm and speed limits in the momentum in the structural dimension. The pure physical sweat inducing choreography can create magic.

5.1 Angular Momentum

Angular momentum is the rotational analog of linear movement. It is important physical quantity because it is conseved quantity.

While we do twerls we could notice we usually move our hands outwards and inwards. When we start spinning we create a momentum so as to reduce the radius of the body. So we get to do the spins easily . So we could conserve angular momentum.

If before or during the action the dancer gives the muscular impulse to change direction then he or she might begins to generate rotation movement that causes to rotate on herself acquiring angular momentum.

So, it is the magnitude of object of angular momentum which gives an indicattion of how hard is to bring to a stop.

We could see angular momentum majorly in kathak, ballet, garbha spin, in bharatanatyam we could be see angular momentum in bhramaris and in utpavana adavu.

5.2 The physics of jumps

The gravitational force depends on mass

More massive -greater gravitational pull

Momentum also depends upon the mass, the greater force, the harder it's to stop moving at particular speed.

On jumping from considerable height one achieve higher velocity before landing . Hence, it is the momentum directly proportional to both mass and velocity.

Utplavana bhedas in Bharatanatyam are the great example of momentum phenomena

6. ASPECT OF ACCELERATION IN DANCE

Acceleration is any process where the velocity changes. Since velocity is speed of direction, there are only two ways to accelerate : by changing the speed and change the direction. It is one of the several components of kinematics, the study of motion. Acceleration are vector quantity.

In dancers, purpose of acceleration is important, as the dancer increases the speed of dance, being able to accelerate quickly and greatly aids a dancer because it allows us to get into more favourable position in our performance.

Acceleration changes velocity over change in time.

The concept of Energy

If a dancer is moving and has a velocity it immediately mean it has energy. For the dancer to be moving around in space. He/she has to have energy in the body. Now this energy comes from force internally and externally .

Acceleration -> Energy -> Force - > Velocity ->

6.1 GRAVITATIONAL ACCELERATION

Gravitational acceleration is the acceleration of an object in free fall within a vacuum. It is described as the object receiving an acceleration due to force of gravity on it . It represented by 'g'

Anything you drop speeds up at the same rate anything thrown straight up slows down at same rate. Same happens when you jump at a speed rate you will land on the earth at same rate of speed.

All jumps involve vertical acceleration and force. In order for a dancer to jump they must exert a force downwards against the floor, which is greater than the weight. To increase the force created by a dancer, many vertical jumps are done. These jumps create a parabolic path.

In Utplavana adavus and bhedas we could see such parabolic path.

7. NEWTON'S LAW OF MOTION

Newton's law of motion are three laws of motion that describes the relationship between the motion of the object and forces acting on it.

7.1 First law of motion (Inertia)

The object at rest remains at rest and object in object in motion remains in motion.

For the dancer to move we need some force to act on the dancers body for it move. It also states that object tend to resist changes in their state of motion. An object in motion stays in motion and an object at rest will tend to stay at rest unless acted upon a force .

For example: A scatter gliding on ice will continue with the same speed and in same direction barring and external force action. Similarly, the body of the dancer who dances scattered chasses around the floor will want to retain the motion unless internal or muscular force can overcome the inertia. And either transition to another step change direction or stop.

7.2 Newton's second law of motion (Acceleration)

A force acting on an object with larger mass require motion force. Net force is equal to mass time acceleration.

Newton'slaw precisely explains how much motion a force creates. The acceleration (the tendency of the object change speed or direction) an object experience is proportional to objects mass

Force= Mass × Acceleration (f=ma)

Example :When a ball is thrown , kicked or struck, it tends to travel in the direction of applied force of action, similarly the greater the amount of force applied the greater the speed ball has.

Similarly when a dancer improves legs strength through training while maintaining same body mass. In that case they will have an increased ability to accelerate the body using legs resulting in better agility and speed. This also relates to ability to rotate segment.

7.3 NEWTON'S THIRD LAW OF MOTION

Newton's third law of motion states that every action has an equal and opposite reaction.

In the third law the forces are not acting alone but occure in equal and opposite pairs between interacting bodies .

Example : The force created by legs pushing against the ground reaction forces in which the ground reaction forces in which ground pushes back and allows the dancer to move across the floor (as the earth is much massive than the dancer, the dancer accelerates and moves rapidly while earth does not accelerate or move at all.

This action and reaction also occures when we try to stand on our toes. By pushing through the calf muscles to the floor, the ground reacts on our bodies with equal and opposite force causing us to get up on the toes much like ballerina and in bharatnatyam we could see in kudhithamettu adavu Or sitting in muzhumandi.

8. TECHNIQUE OF TORQUE IN DANCE

Torque is rotational force. It can also be said a twisting force that tend to cause rotation. It is the measure of the force that the cause an object to rotate about an axis.

In dance force is the foot pushing off the ground and the axis in body, when we look the science behind the dance it allows the break down of fundamentals of physics concept that allows dancer to excute the perfect turn.

To maintain that hold in your core maintain releve straighten leg, shoulders down, having long neck, keep your pace high, connected to knee, keep hip level.

The art of rotating entire body weight is the technique garnered over the years are just way to manipulate existing phenomenon such as in physics and biomechanics, to the dancers advantage, producing effortless stunning result.

Usually in bhramaris let's take chakra bhramari as an example we begin stance with one foot forward and one foot back , legs slightly bent, body balanced in middle, then the dancer pushes the foot kept in front creating momentum and giving enough speed .

The more torque the dancer can produce more force that can put in the bhramaris , chakkars or spin irrespective of the dance form we are doing allowing to turn multiple times before friction slows down.

8.1 Balance in turning

** While taking turns we have keep our eye contact stick to one position to distinct "physics domains here".*

** slow turn :maintain static balance*

Fast turn : rotation axis shouldn't wobble.

**Not all position are statically balanced. It an be held in turn*

For example: garuda mandalam turn

**Centrifugal forces exert a torque, throwing the dancer off balance.*

**Maintain centre of gravity to balance effectively.*

9. ASPECT OF SOUND IN DANCE

Sound is a type of vibration. When an object vibrates or sound is created by an object a to and fro motion is created this movement in surrounding spread in air molecules which close them causing them to vibrate. The frequency determines the shrillness and pitch of the sound. If the frequency of vibration is higher then then sound is shrill and has higher pitch. If the frequency of vibration is lower, we say sound has lower pitch it produces bass sound. This phenomenon can be explained using two musical instruments which used in Bharatanatyam and other classical dance forms too

Nattuvangam

The nattuvangam is the cymbals, the sound is produced by striking the one cymbal on the other at various angles represent different sound of the dancers feet when they make contact with the ground.

For example : striking on the ground with the flat foot creates sound and placing the heel on the ground creates no sound. The cymbals are made up of iron and brass, which creates 428Hz to 500Hz . It creates a shrill sound. It creates high pitch and hence the frequency of vibration is higher.

Mridangam

It is the double sized drum whose body is made up using hollowed piece of jackfruit wood about an inch thick .The aperture of drum are coverd with skin of goat,buffalo and laced to each other with leather straps along with the length of drum. Mridangam has many membrane and patterns and sound waves. The wave length frequency found on mridangam is high.

Mridangam size varies but most of them are 60cm in length with 16cm diameter vanthalai and 18cm diameter thoppi.

The frequency range of mridangam is about 261.6Hz to 311.1Hz or 466.2 Hz in texture. It has sustained character of notes.

When we strike mridangam the sound that we hear is not only the membrane, but of the body. The size or mass of the mridangam is also one of the important factor for sound it produce. The frequency and the pitch is low ,hence it creates a bass sound.

10. ASPECT OF FORCE IN DANCE

The force applied to dance to accentuate the weight attack, strength and flow of a dancer movement (sharp, strong, light, heavy, bound , free flow etc.) In other words, the dancer pushing the floor with strength against the floor to move their body upwards . The energy of force come from muscle contraction

Example: sitting in araimandi position

Forces come to play including friction and gravity. Once the dance loses contact with floor, the dancer centre of gravity will follow a parabolic trajectory.

The forces in dance

**Gravity force-which constantly at work pushing us towards the floor.*

* *Muscular force- utilized by engaging various muscle to move body*

**Centrifugal force- which is created on the outside turn.*

**Centrpetal force – which is created in inside turn.*

11. Conclusion

There are interesting parallels between some ideas of current interest in the dance and those of modern physics

Understanding the technique of science on dance could help dance effectively and prevent injuries. If points such as centre of gravity is not kept in mind can cause problems such as:

**Uneven weight distribution of weight can cause injuries in ankle*

**Misalignment of lower and upper body can effect personal balance*

**Misalignment of joint may cause knee, hip may cause loss of balance and ligament tear.*

It is interesting to see that almost all dance aspects of dance and physics concept overlaps. It was over all wonderful experience doing this.

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