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Subject :- Physics (classical Mechanics)

Title :- Inertial Force (Equation)

Abstract:-

In this research I have given Formulas and Properties of Inertial force, law of required force for change in state of rest, state of motion with uniform velocity, state of motion with uniform angular velocity and law of required force for change in direction in straight line.

Introduction:-

Inertia

First of all its principle was proposed by Galileo. He divided Inertia into three parts.

1. Inertia of rest
2. Inertia of motion
3. Inertia of direction

According to Galileo, "Inertia of an object is those features in which an object opposes its state of rest or its uniform velocity."[1]

According to Newton, " Every object maintain its state of rest or its uniform motion unless any external unbalance force is applied to change its state."[1]

There scientists gives hypothesis of Inertia only. They do not give any equation of Inertial force.

Research Methodology (Process) And Diagram :-

Inertia force

When an object is in a state of rest or move with uniform velocity, then an force acts on it. Therefore, an object can't change its state. This force is called Inertial force.

When any body(object) moves with uniform angular velocity in any axis of rotation or any point as centre, then a force act on an body(object) which opposes change its state. This force is called Inertial force.

Types of Inertial forces

4. Rest inertial force
5. Motion inertial force
6. Direction inertial force
7. Gyration inertial force
8. Circular or elliptical inertial force

1. Rest Inertial Force

When any object is in a state of rest then a force acts on it due to inertia, which opposes change in its state of rest . This force is called Rest Inertial Force. Due to this force when any object is in a state of rest then it remains in this state unless any external force act on it.

When any object is in a state of rest than Rest Inertial Force acting on it is proportionally to its Inertial mass. I.e.

$$\mathbf{F_R \propto m}$$

$$\mathbf{F_R = k_R m \ (N)}$$

Where k_R is a proportionally constant. Which is know as Rest Inertial Constant. Its value always be 1. This constant is always equal for all masses of any object which are in a state of rest.

Proof :-

∵ Inertia is directly proportional to mass. I.e.

Inertia ∝ mass[1]

∵ Rest Inertial Force depends on inertia.

∴ Rest Inertial Force is directly proportional to inertia. I.e.

$$F_R \propto \text{Inertia} \propto \text{mass}$$

$$F_R \propto \text{mass}$$

$$F_R \propto m$$

$$F_R = k_R m \ (N)$$

2. Motion Inertial Force

When any object moves with uniform velocity in a straight line then a force acts on it due to inertia, which opposes change in its state of motion of uniform velocity. This force is called Motion Inertial Force.

Due to this force when any object is in state of motion with uniform velocity, then it remains in this state unless any external force act on it.

When any object is moving from a uniform velocity to a straight line then Motion Inertial Force acting on it is proportionally to multiplication of its inertial mass and velocity. I.e.

$$F_M \propto mv$$

$$F_M = k_M mv \text{ (N)}$$

Where k_M is proportionally constant. Which is know as Motion Inertial Constant. It value is 1. This constant is equal for all masses of any object which are move in a uniform velocity.

Proof :-

∵ Inertia is directly proportional to mass. I.e.

Inertia ∝ mass

∵ Motion Inertial Force depends on inertia.

∴ Motion Inertial Force is directly proportional to inertia. I.e.

$$F_M \propto \text{Inertia} \propto \text{mass}$$

$$F_M \propto \text{mass}$$

$$F_M \propto m. \qquad \text{..............(1)}$$

Now, an object is move in straight line with uniform velocity. Hence, velocity is also applied force on object. Therefore it can't change its state. So velocity is also directly proportional to the inertia. I.e.

$$\text{Inertia} \propto \text{velocity}. \qquad \text{..............(2)}$$

Hence, Motion Inertial Force is also depend on Inertia. So, this force will directly proportional to inertia. I.e.

$$F_M \propto \text{Inertia}$$

$$F_M \propto mv. \qquad \text{..........(from 1 and 2)}$$

$F_M = k_M mv$ (N)

3. Direction Inertial Force

When an object is moving with uniform velocity in a straight line and if an external force forces it to change its direction then the object puts a force in opposition to that change due to inertia, which is called Direction Inertial force. Due to this force when any object moves in straight line with uniform velocity then object can't change its direction unless any external force act on it.

When any object is moving from a uniform velocity to a straight line then Direction Inertial Force acting on it is proportionally to multiplicaton of its momentum and [1+cos(180-θ)]. I.e.

$F_D \propto mv[1+\cos(180-\theta)]$

$F_D = k_D\, mv[1+\cos(180-\theta)]$ (N). $(\theta \leq 180^0)$

Where k_D is a proportionality constant. Which is know as Direction Inertial Constant. It value is 1 and it is equal for all masses of any object which are move in straight line with uniform velocity.

Proof :-

Hence, where an object move in a straight with uniform velocity then

Inertia $\propto$ mv

$\because$ Direction Inertial Force depends on inertia.

Hence, Direction Inertial Force is directly proportional to inertia. I.e.

$F_D \propto$ inertia $\propto mv$

$F_D \propto mv$ ....(1)

Hence the value of [1+cos(180-θ)] in crease then Direction Inertial Force is also increases. I.e.

$F_D \propto [1+\cos(180-\theta)]$ ....(2)

$\therefore F_D \propto mv[1+\cos(180-\theta)]$. ....(From 1 and 2)

$F_D = k_D\, mv[1+\cos(180-\theta)]$ (N)

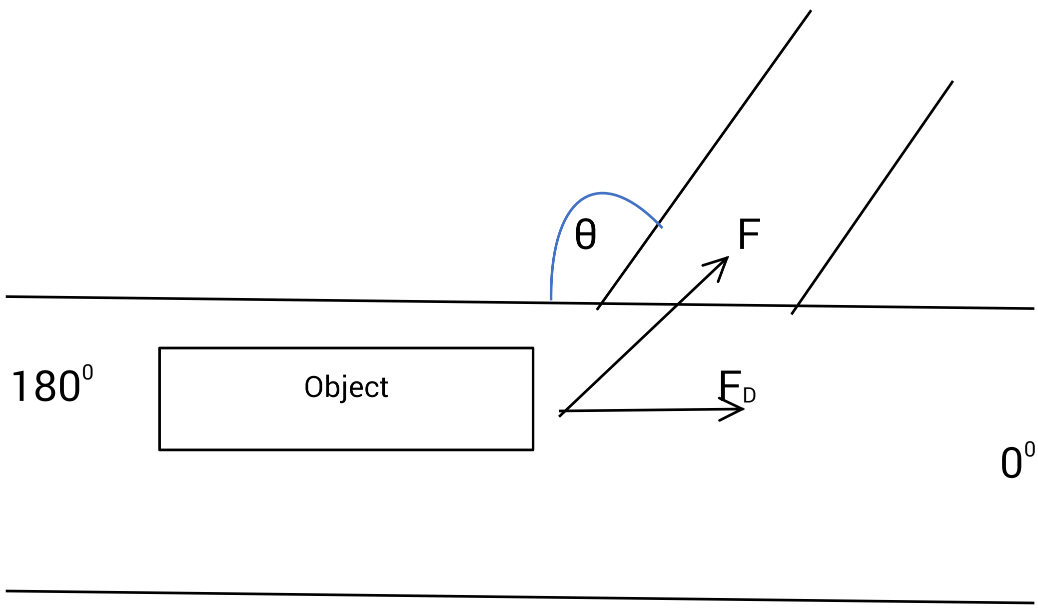
1. When object move in 180^0 angle, then

$F_D = mv[1+\cos(180-\theta)]$ (N) .... $(k_D=1)$

$F_D = mv[1+\cos(180-180^0)]$ (N)

$F_D = mv(1+1)$ (N)

$F_D = 2mv$ (N)



2. When object move in 150^0 angle, then

$F_D = mv[1+\cos(180-\theta)]$ (N) .... (k_D=1)

$F_D = mv[1+\cos(180-150^0)$ (N)

$F_D = mv(1+0.86)$ (N)

$F_D = 1.86mv$ (N)

3. When object move in 120^0 angle, then

$F_D = mv[1+\cos(180-\theta)]$ (N) .... (k_D=1)

$F_D = mv[1+\cos180-120^0)$ (N)

$F_D = mv(1+0.5)$ (N)

$F_D = 1.5mv$ (N)

4. When object move in 90^0 angle, then

$F_D = mv[1+\cos(180-\theta)]$ (N) .... (k_D=1)

$F_D = mv[1+\cos(180-90^0)]$ (N)

$F_D = mv(1- 0)$ (N)

$F_D = mv$ (N)

5. When object move in 0^0 angle, then

$F_D = mv[1+\cos(180-\theta)]$ (N) .... (k_D=1)

$F_D = mv[1+\cos(180-0^0)$ (N)

$F_D = mv(1- 1)$ (N)

$F_D = 0$ (N)

4. Gyration Inertial Force

When a rigid body(object) move with uniform angular velocity in axis of rotation then a force acts on it due to inertia, which opposes change in its state of gyration motion of uniform angular velocity. This force is called Gyration Inertial Force.

Due to this force when any body(object) is in state of gyration motion with uniform angular velocity then it remains in its state unless any external force act on it.

When any body(object) is moving from uniform angular velocity then gyration inertial force acting on it is proportionally to its angular momentum. I.e.

$$F_G \propto J$$

$$F_G = k_G J \text{ (N)}$$

Where k_G is Gyration inertial constant. Its value is 1 and it is equal for all particles of a body.

Proof :-

Hence, the value of moment of inertia of a body(object) increases then a body(object) also opposes its changes in rotational motion. Therefore, it can't change in gyration motion.

Hence, moment of inertia is directly proportional to gyration inertial force. I.e.

$$F_G \propto I \quad \text{.......................} \quad (1)$$

Hence, body(object) move with uniform angular velocity, so angular velocity also force on body(object). Therefore, it can't change in gyration motion.

∴ Angular velocity of an object is directly proportional to gyration inertial force. I.e.

$$F_G \propto \omega \quad \text{.........................} \quad (2)$$

From (1) and (2)

$$F_G \propto I\omega$$

$F_G \propto J$ ……………………………….. (hence, $J= I\omega$)

$F_G= k_G J$ (N)

Suppose body(object) is moving with gyration motion in which mass of any particle is m_1 and its linear velocity is v_1, distance from axis of rotation of particle is r_1 and angular velocity be ω then angular momentum of particle is-

$J_1= m_1 r_1 v_1$

$J_1= m_1 r_1^2 \omega$...........[1]

Now, Gyration Inertial force acting on particle-

$F_G \propto J_1$

$F_G= k_G m_1 r_1^2 \omega$ (N)

Suppose, any rigid body(object) having mass M which is moving axis of rotation. To gyration inertial force about a axis of rotation S of body(object). Suppose body(object) is formed from many small – small particles in which these masses are m_1, m_2, m_3,……….. respectively. Distance of particles from axis of rotation are r_1, r_2 ,r_3, …….. respectively , linear velocity of these particles are v_1, v_2, v_3, ……. Respectively and angular velocity of total body(object) is ω then gyration inertial force act on these particles will $k_G m_1 r_1^2 \omega$, $k_G m_2 r_2^2 \omega$, $k_G m_3 r_3^2 \omega$……. Respectively. Hence, the gyration force on whole body

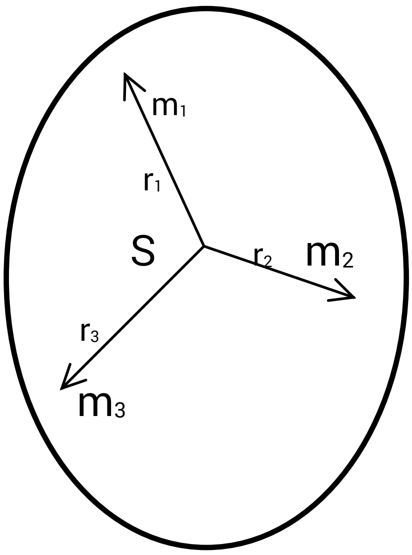
$F_G= k_G m_1 r_1^2 \omega + k_G m_2 r_2^2 \omega + k_G m_3 r_3^2 \omega +$…………….

$= k_G \omega[m_1 r_1^2 + m_2 r_2^2 + m_3 r_3^2 +$……….]

$= k_G \omega \Sigma m r^2$.

$= k_G \omega I$

$F_G = k_G J$ (N)



5. Circular or elliptical Inertial force

When any body(object) moves with uniform angular velocity in a circular or elliptical orbit around centre, then a force acts on body due to inertia, which opposes to change in its state of circular or elliptical motion of uniform angular velocity. This force is called circular or elliptical inertial force.

Due to this force when any body(object) is in state of circular or elliptical motion with uniform angular velocity then it remains in its state unless any external force act on it.

When any body(object) is moving in a circular or elliptical orbit with uniform angular velocity around a centre, then circular or elliptical inertial force acting on it is proportionally to its angular momentum. I.e.

$$F_C \propto J$$

$$F_C = k_C J \ (N)$$

Where k_c is circular or elliptical inertial constant. It's value is 1 and it is equal for all particles of a body .

Proof :-

Hence, the value of moment of inertia of a body(object) increases then a body(object) also opposes its changes in Circular or elliptical motion. Therefore, it can't change in Circular or elliptical motion.So, moment of inertia of a body(object) is directly proportional to the circular or elliptical inertial force of a body(object). I.e.

$$F_C \propto I \qquad \ldots\ldots\ldots\ldots\ldots\ldots. \qquad (1)$$

∵ a body(object) is move with uniform angular velocity; so angular velocity also applied force on body(object). Therefore, it can't change in circular or elliptical motion, so angular velocity will also directly proportional to circular or elliptical inertial force. I.e.

$$F_C \propto \omega \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (2)$$

From (1) and (2)

$$F_C \propto I\omega$$

$$F_C \propto J \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \qquad (\because J = I\omega)$$

$$F_C = k_C J \ (N)$$

Suppose object is moving with circular or elliptical motion in which mass of any particle is m_1 and its linear velocity is v_1, distance from centre of particle is r_1 and angular velocity be ω then angular momentum of particle is-

$$J_1 = m_1 r_1 v_1$$

$J_1 = m_1 r_1^2 \omega$..........[1]

Now, Circular or Elliptical Inertial force acting on particle-

$F_C \propto J_1$

$F_C = k_C m_1 r_1^2 \omega$ (N)

Suppose, any rigid body(object) having mass M which is moving around a point's as a centre. To Circular or Elliptical inertial force about a centre S of object. Suppose body(object) is formed from many small – small particle in which its masses are m_1, m_2, m_3,.......... respectively. Distance of particles from centre are r_1, r_2 ,r_3, ... respectively , linear velocity of these particles are v_1, v_2, v_3, ... Respectively and angular velocity of total body is ω then Circular or Elliptical inertial force act on these particles will $k_C m_1 r_1^2 \omega$, $k_C m_2 r_2^2 \omega$, $k_C m_3 r_3^2 \omega$....... Respectively. Hence, the circular or elliptical force on whole body

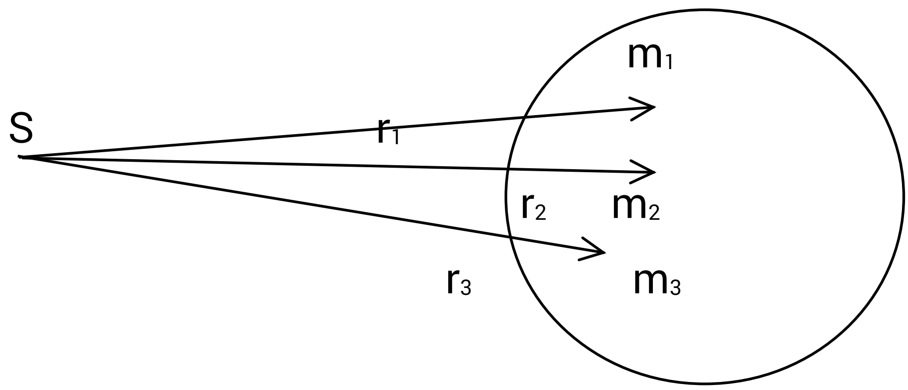
$$F_C = k_C m_1 r_1^2 \omega + k_C m_2 r_2^2 \omega + k_C m_3 r_3^2 \omega + \ldots\ldots\ldots\ldots$$

$$= k_C \omega [m_1 r_1^2 + m_2 r_2^2 + m_3 r_3^2 + \ldots\ldots\ldots]$$

$$= k_C \omega \Sigma m r^2$$

$$= k_C \omega I$$

$$F_C = k_C J \text{ (N)}$$

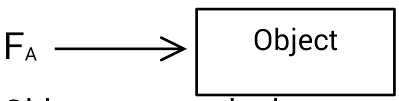


Law of Required force for change in state

Here, state change means that any body or object or particles of body in a state of rest then it bring to motion state and If object or body or particles are move with uniform velocity or uniform angular velocity in state of motion then it bring to be state of rest.

- ***Required force for change in state of rest***

When any object is in a state of rest then it is required to change its state by applying force which is more than Rest Inertial force. If the force which is applied on object is less than Rest Inertial force then object can't change its state. I.e.



Object come to be in state of motion, when

$F_A > F_R$ (N)

$F_A > k_R m$ (N)

$F_A > m$ (N) ………………………. ($k_R = 1$)

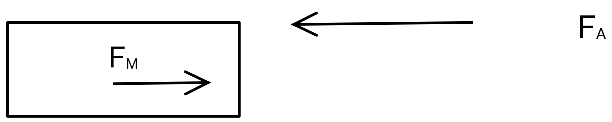
Where F_A = External force

So, required force for change in state of rest of object

$F = F_A$ (N)

- ***Required force for change in state of motion***

When any object moves in straight line with uniform velocity then it is required to change its state of motion by applying force which is equal to or more than Motion Inertial force. If force is applied on object is less than motion inertial force than object can't change its state. I.e.



Object come to be in state of rest, when

$F_A \geq F_M$ (N)

$F_A \geq k_M m v$ (N)

$F_A \geq mv$ (N) ……………………….. $(k_M=1)$

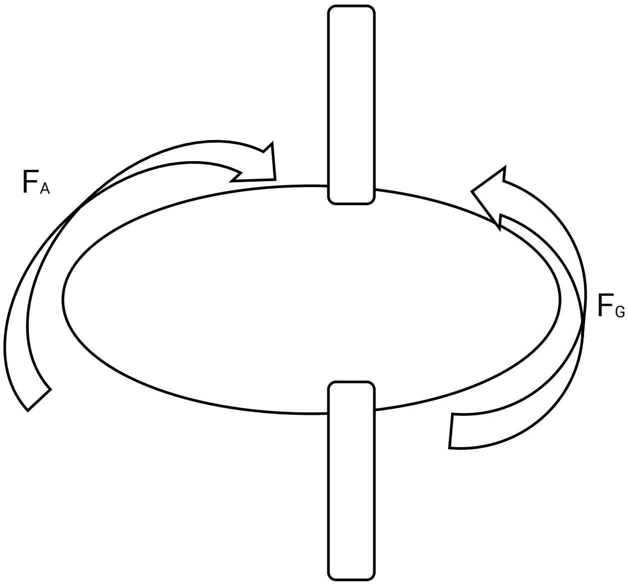
Where F_A = External force

So, required force for change in state of motion of object

$F=F_A$ (N)

- ***Require force for change in state of gyration motion***

When any body (object) moves with uniform angular motion then it is require to change its state by applying force which is equal to or more than gyration inertial force. If force is applying on body (object) is less than gyration inertial force then body (object) can't change its state. I.e.



Body(object) come to be in state of rest, when

$F_A \geq F_G$ (N)

$F_A \geq k_G J$ (N)

$F_A \geq J$ (N) ……………………….. $(k_G=1)$

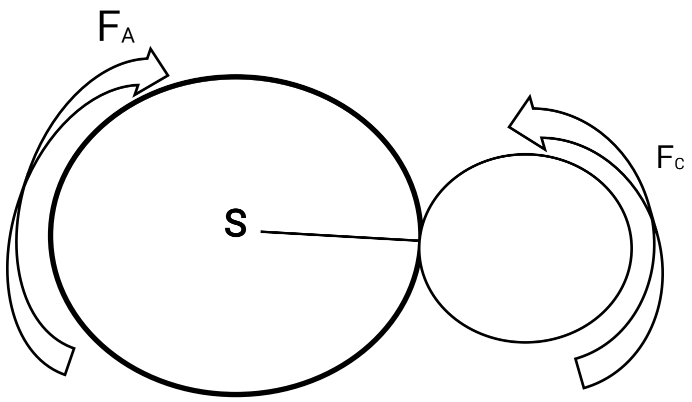
Where F_A = External force

So, required force for change in state of gyration motion of body(object)

$F=F_A$ (N)

- **Required force for change in circular or elliptical motion state**

When any body (object) moves with uniform angular velocity around centre in circular or elliptical orbit than it is required to change its motional state by applying force which is equal to or more than circular or elliptical inertial force. If force is applied on body (object) is less than circular or elliptical inertial force then body(object) can't change its motional state. I.e.



Body(object) come to be in state of rest, when

$F_A \geq F_C$ (N)

$F_A \geq k_C J$ (N)

$F_A \geq J$ (N) ……………………….. (k_C=1)

Where F_A = External force

So, required force for change in state of circular or elliptical motion of body(object)

$F=F_A$ (N)

- ***Required force for change in direction***

When object moves in a straight line with a uniform velocity then it is required to change its direction by applying force which is more than direction inertial force. If force applied on object is less than direction inertial force than object can't change its direction. I.e.

Object can change its direction, when

$F_A > F_D$ (N)

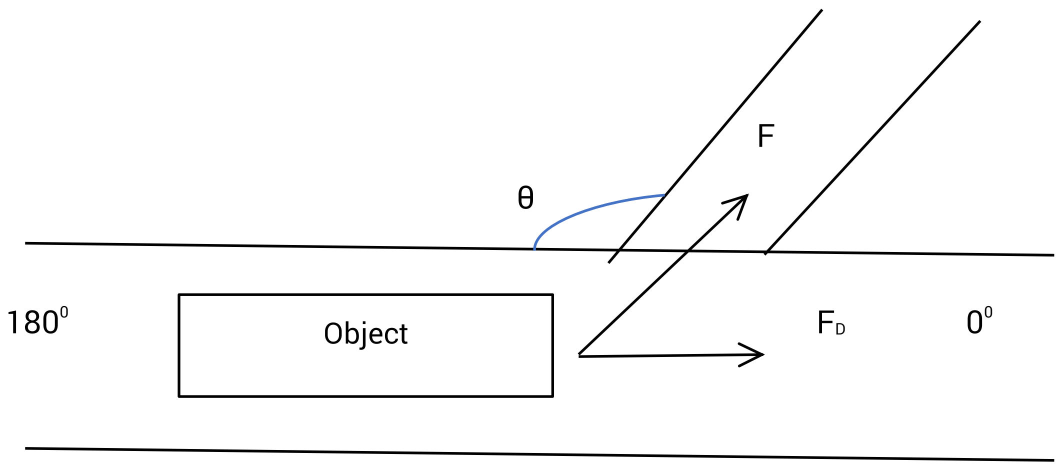
$F_A > k_D mv[1+\cos(180-\theta)]$ (N)

$F_A > mv[1+\cos(180-\theta)]$ (N) ……………………….. (k_D=1)

Where F_A = External force

So, required force for change in direction of object

$$F = F_A \text{ (N)}$$



Properties of Inertial force

1. Hence inertia or moment of inertia is an intrinsic characteristics of an object, body or particles of body[19]. So inertial force is an intrinsic force of an object, body or particles of body.
2. This force opposes to change in state of an object or body or particles of body.
3. It always opposes to external applied force on an object or body or particles of body.
4. Any object or body or particles of body uses the same force as its inertial force in opposes to external force.

Conclusion:-

- In this research I have given Formulas and Properties of Inertial force, law of required force for change in state of rest, state of motion with uniform velocity, state of motion with uniform angular velocity and law of required force for change in direction in straight line.

- We can count Inertial force act on any object and required force for change in its state from this formula.

References:-

1.[1]This line or sentences has taken from book of physics of Mittal Publishing. Its author is Kumar Mittal.