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Rotatory motion, also referred to as rotational motion, is a type of motion in which an object moves in a circular path around a fixed point called the axis of rotation. All points on the object move in circles around the axis line, and the object rotates in either a clockwise or anti-clockwise direction. This can be seen in the examples: 1. Spinning top: Here, the axis of rotation is the line passing through the point of contact of the top with the ground. The top spins around this axis. 2. Rolling wheel: In this case, the axis of rotation is the line passing through the center of the wheel. The wheel rolls around this axis. Have you ever wondered how the world spins around you? Rotational motion examples are all around us, from the simple act of spinning a top to the complex movements of planets in our solar system. Understanding these examples not only piques your curiosity but also deepens your appreciation for physics and its role in everyday life.Rotational motion appears in various forms throughout the world. Understanding these types provides insights into how objects move around an axis. Here are two significant examples:Simple harmonic motion (SHM) refers to oscillations around a central point. A few everyday instances include:Pendulum clocks: The swinging of a pendulum creates periodic motion, demonstrating SHM.Mass on a spring: When you pull and release a mass attached to a spring, it moves back and forth in SHM.These examples highlight how forces act on objects to create rhythmic motions that repeat over time.Circular motion involves an object moving along a circular path. Key examples include:Earth's rotation: Earth rotates around its axis once every 24 hours, creating day and night.Car tires: Tires roll in circular paths as cars drive, maintaining contact with the ground while rotating.These instances show how circular motion governs many aspects of our daily lives, influencing everything from transportation to natural phenomena.Rotational motion plays a significant role in various aspects of daily life and technology. Understanding these applications can deepen your appreciation for the physics behind everyday phenomena.Rotational motion is crucial in machinery, influencing how machines operate efficiently. Here are some examples:Gears: Gears transfer rotational motion between different parts of machines, enabling movement in devices like clocks and engines.Motors: Electric motors convert electrical energy into rotational motion, powering everything from household appliances to vehicles.Turbines: Wind turbines harness wind energy by rotating blades, generating electricity through their rotational motion.Machines rely on this type of motion for effective operation, showcasing its importance across industries.You encounter natural rotational motions frequently in the environment. Consider these instances:Planets: The rotation of planets around their axes creates day and night cycles. For example, Earth's rotation takes approximately 24 hours.Earth's Orbit: Earth orbits the Sun due to gravitational forces, completing one full revolution every year.Ocean Currents: The Coriolis effect causes ocean currents to rotate due to Earth's rotation, affecting climate patterns globally.These examples illustrate how rotational motion governs natural processes essential for life on Earth.Rotational motion plays a crucial role in understanding how objects move in circular paths. By examining key concepts and mathematical representations, you can gain deeper insights into this fundamental aspect of physics.Understanding rotational dynamics involves several core concepts:Torque: Torque is the measure of the force that causes an object to rotate around an axis. Greater torque results from either stronger forces or longer distances from the pivot point.Moment of Inertia: Moment of inertia quantifies how mass is distributed relative to an axis of rotation. Objects with greater moment of inertia require more torque to change their rotational speed.Angular Momentum: Angular momentum refers to the momentum associated with rotating bodies. It remains constant unless acted upon by external torques, illustrating conservation principles.These concepts are essential for analyzing various examples, such as a spinning basketball or a merry-go-round.Mathematical equations illustrate rotational motion clearly:Torque (τ) can be expressed as:[τ = r times F]where (r) is the distance from the pivot and (F) is the applied force.The equation for moment of inertia (I) varies based on shape:[I = frac{1}{2} m r^2]To find angular velocity (ω), use:[ω = frac{θ}{t}]where (θ) represents angular displacement and (t) indicates time taken.These formulas help quantify and analyze real-world scenarios involving rotational motion, like wheels turning or planets orbiting stars.Understanding rotational motion can be challenging, and several common mistakes often arise. Here are some key errors to avoid:Confusing linear and rotational quantities: Many people mix up concepts like linear velocity with angular velocity. Linear velocity refers to how fast an object moves along a path, while angular velocity relates to the rate of rotation around an axis.Neglecting the significance of torque: Torque is crucial for understanding how forces cause rotation. Without recognizing its role, you might overlook why certain objects rotate faster or slower than others.Overlooking moment of inertia: Moment of inertia isn't just about mass; it's also about how that mass is distributed relative to the axis of rotation. Failing to consider both aspects leads to misunderstandings in predicting an object's rotational behavior.Ignoring angular momentum conservation: Angular momentum remains constant unless external forces act on it. Forgetting this principle can lead you astray when analyzing systems involving rotating bodies.Misunderstanding circular motion types: Circular motion includes uniform (constant speed) and non-uniform (changing speed) circular motions. Confusing these types can affect your grasp of related phenomena, like centripetal force.By being aware of these mistakes, you'll strengthen your understanding of rotational motion and improve your ability to analyze real-world scenarios effectively. When an object rotates or spins about its axis, it is said to be exhibiting rotatory motion. Some examples of rotary or rotatory motion include the motion of a spinning top, rotation of the earth and other planets, movement of hands of a clock, etc. Examples of Rotary Motion 1. Rotation of Earth As the name itself suggests, the motion of the earth and other planets about their respective axis is an example of rotatory motion. This spinning of the celestial bodies about their central position is a result of inertia. 2. Wheels of a Moving Vehicle The wheels of a vehicle rotate with respect to the axle. This rotation of the wheels helps to move the vehicle in the forward or reverse direction. The motion of the wheels demonstrates the rotatory motion, whereas the motion of the car is the result of the conversion of rotational motion into linear motion. 3. Fan Blades The blades of a fan are attached to a central hub, which is further connected to a motor present inside the internal circuitry of the appliance. When the electric current is supplied to the electrical circuit of the fan, the motor gets activated. The motor then translates electrical energy to mechanical energy, thereby causing the blades of the fan to spin and exhibit rotatory motion. 4. Helicopter Rotor Blades The rotary blades present on the top of a helicopter rotate about a central point with the help of a combination of multiple rotary motors. This rotatory motion of the helicopter wings helps in the generation of aerodynamic lift force that is sufficient enough to balance the weight of the helicopter, overcome the aerodynamic drag, and lift it in the air. 5. Spinning Top A spinning top is a toy that is externally wrapped with a thread and consists of a pointed tip. The movement of a spinning top is one of the best examples of rotatory motion. When the spinning top is placed on a surface such that only its pointed end is in contact with the ground and the thread is pulled with force, the top spins about its own axis till the energy possessed by the top gets consumed thoroughly. 6. Ferris Wheel A Ferris Wheel is a major attraction of any funfair or carnival. It is an amusement ride that consists of a huge metallic wheel. The rim of the Ferris Wheel consists of a number of cabins to carry the people in it. When the motor connected to the ride is supplied with power, the wheel rotates about its central point. Hence, the movement of a Ferris Wheel clearly demonstrates rotatory motion in real life. 7. Gears A gear is a mechanical part that consists of cut teeth on its outer surface. The application of gears can be seen in a number of mechanical and automobile machines such as bicycles, cars, watches, etc. The main task of gear is to rotate and translate one form of motion into the other. Hence, a gear is said to be exhibiting rotatory motion. 8. Clock Ticking The minute, hour, and second hand of a clock rotate in a circular direction, keeping the pinpoint as the centre or the axis of rotation. Hence, the hands of a clock are said to be exhibiting rotatory motion. 9. Blender A blender is one of the most common examples of rotary motion in real life. When the power switch of a blender is pressed, the motor present inside the internal circuitry of the appliance helps the blades rotate and display rotary motion. 10. Drill Machine The motion of the drill bit attached to the tip of the drill machine is a prominent example of rotatory motion. The drill bit moves or rotates in a circular direction about its axis and forms a hole in the surface. It is also an example of the conversion of rotatory motion to rectilinear motion because the bit rotating about its own axis eventually tends to move forward in a linear direction. When an object rotates or spins about its axis, it is said to be exhibiting rotatory motion. Some examples of rotary or rotatory motion include the motion of a spinning top, rotation of the earth and other planets, movement of hands of a clock, etc. Examples of Rotary Motion 1. Rotation of Earth As the name itself suggests, the motion of the earth and other planets about their respective axis is an example of rotatory motion. This spinning of the celestial bodies about their central position is a result of inertia. 2. 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We can not explain the concepts of wobbling or precession by using fixed axis hypothesis for rotational motion.(wikipedia) Here in this article about rotational motion I am assuming that you are comfortable in describing motion in physics. In addition to this you are also aware of types of motion in physics.. After completing this lesson you would be able to explain Rotational motion and know the difference between rotational motion and circular motion. We will also look at rotational motion examples from activities around us in our daily life. Till now in our study of force and laws of motion we have always analyzed motion of an object by considering it as a particle even when the size of the object is not negligible. In this process we represent object under consideration as a point mass and shape and size of the object remains irrelevant while discussing the particular problem under consideration. Here in the study of rotational mechanics, this point mass or point particle model is inadequate for problems involving rigid body motion i.e. rigid body undergoing both translational motion and rotational motion. One more reason for not considering the body as particle is that all the particles of the body do not undergo same linear displacement. As an example consider the motion of a wheel, we cannot consider a wheel as a single particle because different parts of the wheel in motion has different velocities and acceleration. Here in rotational mechanics, we will consider rigid bodies and their motion. Rigid bodies have definite shape and size and they are capable of having both rotational and translational motion. What is a rigid body? The rigid body is a body with a perfectly defined and unchanging shape that is no matter how the body moves, the distance between any two particles within the body remains constant. Although the way we define rigid body gives us the definition of an idealized rigid body and real materials always deforms on the application of force and this idealized rigid body assumption can be used freely for the substances where deformation is negligibly small and can be neglected. Motion of a rigid body in general can be considered to consist of a translation of center of mass of the body plus rotation of the body about an axis through the center of mass as shown below in the figure: Figure: Motion of a rigid body having transnational motion and rotational motion about center of mass along path \(AB\). You could notice the change in angular position of Point \(P\) in between two positions of the moving body. Get rotational motion formulas list by following this link. Rotational motion Examples We see rotational motion examples in our daily life. Some of the examples of rotational motion are Rotation of earth about its own axis create the cycle of day and night. Motion of wheel, gears, motors, etc is rotational motion. Motion of the blades of the helicopter is also rotatory motion. A door, swiveling on its hinges as you open or close it. A spinning top, motion of a Ferris Wheel in an amusement park. Examples Of Rotational Motion If you want to learn more about rotational dynamics and clear your concepts further then there is a very good book by MTG Interactive Physics: Rotational Dynamics where you can clear your concepts further and gain knowledge accordingly.For those of you who are interested in video tutorials can look at this video course by udemyMastering Rotational Kinematics and DynamicsIn this course, you can learn concepts like Angular variables, Concept of Angular Velocity and Acceleration, Rolling, Rotation and Torque, Mechanics of a Rolling Mass on an Inclined Plane, Physics behind a YOYO and other such related concepts. What I like about this course is how the instructor builds concepts of rotational mechanics as he takes the course further. There are enough solved examples for students which help them improve their problem-solving skills. Also Read Rotational motion is the motion of an object rotating about a fixed axis. Some of the examples of rotational motion are the Earth's rotation about its axis, a rotating merry-go-round and the rotational wheels of a car. Circular motion is a special type of rotational motion. In kinematics, you studied 1 and 2-D motion of objects, where objects move from one place to another. Now, we will call that motion, translational or linear motion to distinguish it from the rotational motion. Rotating rigid body When studying the rotational motion of objects, we consider the objects as rigid bodies. What is a rigid body?. A rigid body is a solid object, where the distance between any two points in the object is constant. Any external force acting on a rigid body does not deform the object so that the distance between any two points remains the same. But, in reality, there is no ideal rigid body exists as all objects undergo deformation when a force is applied on them. In most cases, the deformation is so small, we can ignore them and consider the objects as rigid bodies. In the figure below, a rotating rigid body is shown. To study the rotational motion of the rigid body, we consider it as a collection of large number of small objects, called point objects. When the rigid body rotates, all the point objects rotate about an invisible line, called the axis of rotation of the body. So, the point objects are in circular motion on different circles. For a point object, the radius of the circle is the distance of it from the axis of rotation. In the figure, the circular motion of two point objects are shown. Point objects closer to the axis of rotation moves slower than those far away from it. For example, in a merry-go-round, a person sitting farther from the center (through which the axis of rotation passes) moves faster than the one closer to it. Angular displacement Angular displacement of an object is how much angle, the object has rotated and in what direction. The direction can be clockwise, counterclockwise or something else. Definition of angular displacement Consider a point object in a rigid body that is at a distance r from the axis of rotation of the rigid body. When the rigid body rotates, the point object move on a circle of radius r. If the point object moves a distance, $\Delta \ell$ on the circle, then its angular displacement, $\Delta \theta$ is defined as, $\Delta \theta=\dfrac{\Delta \ell}{r}$ If you take any point on the rigid body, all of them have the same angular displacement. So, $\Delta \theta$ is the angular displacement of the rigid body. Angular displacement is a vector as it has a direction. The SI unit of angular displacement is radian (rad.). The common unit of angular displacement or angle is degree ($^\circ$). We can find a relation between the radian and degree as follows. When a point object makes one complete rotation, its angular displacement is $\Delta \theta= 360^\circ$. And, the distance traveled by the point object in one complete rotation is equal to the circumference of the circle. That is, $\Delta \ell = 2\pi r$. Substituting these in $\Delta \theta=\Delta \ell/r$, we get $360^\circ=\dfrac{2\pi r}{r}\:rad.$ Canceling out the r's, $360^\circ=2\pi\:rad.$ or $\boxed{180^\circ=\pi\:rad.}$ This is the conversion factor between degrees and radians. Angular velocity Angular velocity is the rate of change of angular displacement. It is a measure of how fast an object is rotating. If $\Delta \theta$ is the angular displacement of an object in a time interval, Δt, then the angular velocity of the object is $\omega=\dfrac{\Delta \theta}{\Delta t}$ We use the greek letter omega (ω) for angular velocity. Unit of angular velocity is $rad./s.$ Angular velocity is a vector. The magnitude of angular velocity is called angular speed. Direction of angular velocity, $\vec \omega$ is determined by a rule called the right hand rule. It states that when you curl your fingers of the right hand around the rotation axis and point in the direction of rotation, then the thump points in the direction of the angular velocity. In the figure below you can see the rotating direction of a disc and the direction of its angular velocity. Direction of angular velocity. Angular velocity and linear velocity In translational motion, you studied about the velocity, v, and now in rotational motion, we have angular velocity, ω. To distinguish one from the other, we call the velocity, v as linear velocity. The two velocities are related as you will see below. Let us again consider a point of object of a right body. Assume in a small time interval, Δt, the point object travels a distance, $\Delta \ell$ on its circular path. So, the angular displacement of the point object is $\Delta \theta =\dfrac{\Delta \ell}{r}$ Dividing by Δt, $\dfrac {\Delta \theta}{\Delta t}=\dfrac{1}{r} \dfrac{\Delta \ell}{\Delta t}$ Left hand side is the angular velocity of the point object or the rigid body, ω. And on the right hand side, $\Delta \ell/\Delta t$ is nothing but the linear velocity, v of the point object. So we have, $\omega =\dfrac{v}{r}$ (or) $\boxed{v=r\omega}$ The angular velocity and linear velocity are related by this equation. Note that the angular velocity of all the points of a rigid body is the same, but the linear velocity is different at different points as they are at different distance, r from the axis of rotation. Angular speed, period and frequency of a rigid body The time for one full rotation of a rigid body is called the period, T of rotation. In one full rotation, a point object of a rigid body travels a distance equal to the circumference of the circle. Therefore, the linear speed of the point object can be written as $v=\dfrac{2\pi r}{T}$. Substituting, $v=r\omega$, we get, $r \omega =\dfrac{2\pi r}{T}$. Canceling the r's, $\omega=\dfrac{2\pi}{T}$ The reciprocal of period is the frequency of rotation, that is, $f=1/T$. Substituting this in the equation, we get, $\boxed{\omega=2\pi f}$ So, from the frequency of rotation of a rigid body, you can find its angular speed. Angular acceleration Angular acceleration is the rate of change of angular velocity. When there is a change in angular velocity of an object, there is an angular acceleration. We use the letter, alpha (α) for angular acceleration. The angular acceleration of a rigid body is $\alpha=\dfrac{\Delta \omega}{\Delta t}$. where $\Delta \omega$ is the change in angular velocity of the rigid body in a time interval, Δt. The SI unit of angular acceleration is $rad./s.^2$. Centripetal and tangential acceleration of a point object When a rigid body rotates with a constant angular speed, then the speed (the linear speed) of each point object of the rigid body is constant. In this case, the point objects are in uniform circular motion. So, they have centripetal acceleration. The centripetal acceleration of a point object moving on a circle of radius r is $a_c=\dfrac{v^2}{r}$ Substituting, $v=r\omega$, and simplifying, we get $\boxed{a_c=r\omega^2}$ If the angular speed of the rigid body is not constant, then the speed (the linear speed) of the point objects are not constants. So, the objects will be in non-uniform circular motion. An object in non-uniform circular motion has another acceleration in addition to the centripetal acceleration. That acceleration is called the tangential acceleration. The tangential acceleration of an object is $a_{tan}=\dfrac{\Delta v}{\Delta t}$ Note that when v is constant, $a_{tan}=0$ and there will only be the centripetal acceleration. From the equation, $v=r\omega$, we can write, $\Delta v=r\Delta \omega$. Substituting this in the previous equation, $a_{tan}=r\dfrac{\Delta \omega}{\Delta t}$ Since, $\Delta \omega/\Delta t=\alpha$, we get, $\boxed{a_{tan}=r\alpha}$ The direction of tangential acceleration is tangent to the circle as shown in the figure above. Note that the tangential acceleration is same as the acceleration in a translation motion. So, we call this as linear acceleration. Since there are two accelerations for the point object in non-uniform circular motion, the net acceleration, $\vec a_{net}$ of the object is the vector sum of the two accelerations: $\vec a_{net} = \vec a_c+\vec a_{tan}$ If you add the two vectors, you will get the direction of the net acceleration, $\vec a_{net}$ as shown in the figure above. And, you will get the magnitude of the net acceleration, $a_{net}=\sqrt{a_c^2+a_{tan}^2}$ Rotational kinematics We used the 1-D kinematic equations to describe the translational or linear motion of objects. From these equations, we can obtain another set of equations to describe the rotational motion of objects. To get the equations, we need to substitute the following in the 1-D kinematic equations: $\Delta x=r \Delta \theta$, $v=r\omega$, and $a=r\alpha$ After the substitution, you can cancel out the r's in the equations and you will get the following equations, $\omega=\omega_0+\alpha t$ $\Delta \theta=\dfrac{1}{2}(\omega_0 +\omega)t$ $\Delta \theta=\omega_0 t+\dfrac{1}{2}\alpha t^2$ $\omega ^2=\omega_0^2+2\alpha \Delta \theta$ These equations are called the rotational kinematic equations. In the equations, ω_0 is the initial angular velocity of the rigid body, ω is the velocity at time, t, you can also call this the final angular velocity, and $\Delta \theta$ is the angular displacement at time t. Note that $t=0$ is the initial time as in the 1-D kinematic equations. It is important to note that the rotational kinematic equations are valid when the angular acceleration, α is constant. This is because the 1-D kinematic equations are valid for constant linear acceleration. Torque You know that in translational motion, a force accelerates an object. That is, a force is required for linear acceleration of an object. Now the question is what is needed for an angular acceleration of an object?. For that also a force is required. But not all forces can produce an angular acceleration. When a force is applied on a rotating object, the angular acceleration of a rotating object depends on three factors, (i) magnitude of the force, (ii) the direction of the force and (iii) the point of application of the force. A physical quantity that takes into account all these aspects is called, torque. So, a torque plays the role of force in rotational motion. To define torque, let us consider an object in the shape of a beam as shown in the figure below. Assume the object can rotate freely about the axis of rotation as in the figure. And, you are applying a force, $\vec F$ on the object to rotate it as shown. The magnitude of torque, τ exerted on the object by the force is defined as $\tau=rF\sin \theta$ where r is the distance between the axis of rotation (also called pivot) and the point where the force is applied; and θ is the angle between the force and a line joining the pivot and the point of application of the force. Now, draw a perpendicular line from the pivot to the force vector (you can extend the force line if needed). The length of this line is $r_\perp$, which is called the lever arm or the moment arm. From the right angled triangle in the figure above, we can write, $r_\perp = r \sin\theta$ So, the torque can also be written as $\tau=r_\perp F$ Torque is also called moment or moment of force. A net torque on an object rotates the object in rest or changes the angular velocity if the object is already in rotational motion. Direction of torque Torque is a vector. Its direction is determined by another right hand rule: stretch your fingers in the direction from the pivot to the point where the force is being applied, then swirl your fingers in the direction of the force, now the thumb points to the direction of the torque. Sign convention for torques When you apply a torque on an object, it tends to rotate the object. A torque can rotate an object either in the clockwise or in the counter clockwise direction. So, if there are more than one torque acting on an object, we need a sign convention to add them to find the net torque. We use the following sign convention. If a force tends to rotate the object in the counter clockwise direction, then the torque by that force is positive, and the torque is negative, if the force tends to rotate the object in the clockwise direction. Torque on a rotating point object Again, consider a point object in a rigid body. To rotate the point object, you need to apply a force on the object. But only the force or force component tangent to the circle can rotate the object. Calculating the torque on the object, $\tau=rF$. where r is the radius of the circle. Since the force ccelerate the object tangentially, we have $F=ma_{tan}=mr\alpha$ Substituting this in the torque equation, $\tau=mr^2\alpha$. This is the equation for the torque on a point object. Torque on a rotating rigid body We have the torque acting on a rotating point object. By using that we can find the torque on a rotating rigid body. Again, assume the rigid body is made up of a large number of point objects. And, there are n number of point objects. When the rigid body rotates, all point objects rotate with same angular acceleration, but on circles of different radii. Let $m_1, m_2, m_3, ..., m_n$ are the masses of the point objects and $r_1, r_2, r_3, ..., r_n$ are the radii of their circular paths. Now, if you add the torque on all point objects, you will get the torque on the rigid body. The torque on the rigid body is therefore, $\tau=m_1r_1^2\alpha+m_2r_2^2\alpha+...m_nr_n^2\alpha$ $\tau=(m_1r_1^2+m_2r_2^2+...m_nr_n^2)\alpha$ or $\tau=I\alpha$ where $I = m_1r_1^2+m_2r_2^2+...m_nr_n^2$ I is called the moment of inertia of the rigid body about the axis of rotation. Moment of inertia The moment of inertia of a rigid body depends on the mass, shape and the axis of rotation. With the use of calculus, we can find the moment of inertia of rigid bodies of different shapes. The moment of inertia of objects of different shapes and axis of rotation are given in the table below. M in the table is the mass of the object Object Axis of rotation Moment of inertia Uniform sphere Through center $\dfrac{2}{5}MR^2$ Solid cylinder Through center $\dfrac{1}{2}MR^2$ Hollow cylinder Through center $\dfrac{1}{2}M\left(R_1^2+R_2^2\right)$ Long uniform rodor cylinder Through center $\dfrac{1}{12}Ml^2$ Long uniform rodor cylinder Through one end $\dfrac{1}{3}Ml^2$ Thin hoop Through center MR^2 Thin hoop Through central diameter $\dfrac{1}{2}MR^2+\dfrac{1}{12}Mw^2$ Rectangular plate Through center $\dfrac{1}{12}M\big(l^2+w^2\big)$ Rotational kinetic energy An object in rotation has kinetic energy, like an object in translational motion. To find the kinetic energy of a rotating object, we use the same strategy that we used to find the torque on a rigid body. Assume the rigid body is made up of large number of point objects. As the body rotates each point object rotates with same angular velocity but with different linear velocities because of different radius. Total kinetic energy of the body is the sum of the kinetic energies of the point objects. Therefore, $KE_{rot}=\dfrac{1}{2}m_1v_1^2+\dfrac{1}{2}m_2v_2^2+...+\dfrac{1}{2}m_nv_n^2$. where ω is the angular velocity of the rigid body. Substituting $v=r\omega$, we have $KE_{rot}=\dfrac{1}{2}m_1r_1^2\omega^2+\dfrac{1}{2}m_2r_2^2\omega^2+...+\dfrac{1}{2}m_nr_n^2\omega^2$. $KE_{rot}=\dfrac{1}{2}(m_1r_1^2+m_2r_2^2+...+m_nr_n^2)\omega^2$. or $KE_{rot}=\dfrac{1}{2}I\omega^2$ where I is the moment of inertia of the object about the axis of rotation. With this equation, you can find the rotational kinetic energy of a rotating rigid body. Kinetic energy of a rolling object If an object undergoes both rotational and translational motion on a surface, then we call that rolling motion. If you ride a bike, the wheels of the bike are in rolling motion as they rotate about their axle and also translate from one place to another. A rolling object has both translational and rotational kinetic energy. Further, if you roll an object, it will rotate about its center of mass. Therefore, total kinetic energy of a rolling object is $KE=\dfrac{1}{2}mv^2+\dfrac{1}{2}I_{cm}\omega^2$ where I_{cm} is the moment of inertia of the object about its center of mass. Work and power in rotational motion Work in rotation Torque does work on a rotating object in the same way a force does work on an object that makes linear displacement. To derive the equation for work by torque, we consider a wheel with a rope around its rim. And assume, you are pulling the rope with a force of magnitude F, so that the wheel moves a distance d. Now the work done by the force is $W=F\, d$. Since the distance d with the rotating angle, $\Delta \theta$ of the wheel by $d=r\Delta \theta$ Substituting this in the above equation, you get $W=F\, r \Delta \theta$ $F\, r$ is nothing but the torque on the wheel, so we can write $W=\tau \Delta \theta$ Thus, if a torque on an object rotate the object, a work is done on the object by the torque. Power in rotation You learned that power is the amount of work done per unit time. If W is the amount of work done in a time Δt, then the power generated is $P=\dfrac{W}{\Delta t}$ Substituting, $W=\tau \Delta \theta$, $P=\tau \dfrac{\Delta \theta}{\Delta t}$ Since $\dfrac{\Delta \theta}{\Delta t}=\omega$, the power generated by torque is $P=\tau \omega$ Angular momentum Angular momentum in rotational motion is analogous to the linear momentum in translational motion. Angular momentum (L) of a rotating object is defined as, $L=I\omega$ where I is the angular momentum about the axis of rotation of the object. Unit of angular momentum is $kg.m^2/s$. Since the angular momentum is proportional to the angular velocity, its direction is same as the angular velocity. Torque and angular momentum We have the relation between the torque and the angular acceleration of a rigid body, $\tau=I\alpha$. $=I\dfrac{\Delta \omega}{\Delta t}$ $=\dfrac{\Delta (I\omega)}{\Delta t}$ $\tau=\dfrac{\Delta L}{\Delta t}$ (or) $\tau=\dfrac{\Delta L}{\Delta t}$ i.e., the torque is just the rate of change of angular momentum. When you compare the angular momentum with linear momentum, you see that force is the rate of change of linear momentum, and torque is the rate of change of angular momentum. Conservation of angular momentum You learned in linear momentum that when there is no net external force acting on a system (an isolated system), the linear momentum is conserved. Angular momentum is also conserved when there is no net torque acting on a rigid body as you see below. We have, $\tau=\dfrac{\Delta L}{\Delta t}$ Putting, $\tau=0$, $\dfrac{\Delta L}{\Delta t}=0$ $\Delta L=0$ or $L=$ constant That is the angular momentum is constant when there is no net torque acting on an object. i.e., the angular momentum of a rotating object or a system is conserved. So, if L_1 and L_2 are the initial and final angular momenta of a rotating object or a system, then $L_1=L_2$ Have you ever wondered how everyday objects spin and twirl around? Examples of rotational motion are all around you, playing a crucial role in both nature and technology. From the simple act of riding a bicycle to the complex movements of celestial bodies, rotational motion is an integral part of our world.Rotational motion appears in various aspects of daily life. You can see it in simple activities as well as complex systems. Here are some key examples:Bicycle Wheels: As you ride a bike, the wheels rotate around their axle, propelling you forward.Earth's Rotation: The Earth spins on its axis every 24 hours, causing day and night.Spinning Tops: When you spin a top, it rotates around its center until friction slows it down.Planets Orbiting the Sun: Planets travel in elliptical paths due to gravitational forces while rotating on their axes.Understanding these examples illustrates how rotational motion plays a crucial role in both natural phenomena and human-made devices.Rotational motion appears in various natural phenomena. Understanding these examples highlights its significance in the environment around you.Planetary rotation refers to the spinning of celestial bodies on their axes. Earth rotates once every 24 hours, creating day and night. Other planets exhibit similar behavior; for instance:Jupiter spins rapidly, completing a rotation in about 10 hours.Venus rotates very slowly, taking approximately 243 Earth days for one complete turn.Such rotations affect climate patterns and gravitational forces across the solar system.Ocean currents are large-scale water movements influenced by Earth's rotation. The Coriolis effect causes currents to curve rather than flow straight. For example:The Gulf Stream moves warm water from the Gulf of Mexico towards Europe.The Antarctic Circumpolar Current circulates around Antarctica, connecting all major oceans.These currents play a crucial role in regulating global temperatures and influencing weather patterns.Rotational motion appears prominently in various technologies, showcasing its vital role in modern mechanics. Below are key examples that highlight this concept.Electric motors rely on rotational motion for operation. They convert electrical energy into mechanical energy. When electric current flows through the motor's coils, it generates a magnetic field that causes the rotor to spin. This spinning action drives countless applications, such as:Household appliances: Fans and washing machines.Transportation: Electric vehicles and trains.Industrial machinery: Conveyor belts and pumps.These examples illustrate how essential rotational motion is for functionality across different devices.Gyroscopes utilize rotational motion to maintain orientation and stability. They consist of a spinning wheel or disk mounted so that its axis can freely turn in any direction. As it spins, the gyroscope resists changes to its orientation due to angular momentum. Common applications include:Aerospace navigation: Airplanes use gyroscopes for flight stability.Smartphones: Many smartphones feature gyroscopes for screen orientation adjustments.Robotics: Robots employ gyroscopic sensors for balance control.These uses demonstrate how rotational motion contributes significantly to technology by enhancing precision and reliability.Rotational motion is evident in various sports, showcasing its impact on performance and technique. Here are some key examples.In javelin throw, athletes utilize rotational motion to maximize distance. They spin their bodies while holding the javelin, generating strong centrifugal force that propels the projectile forward. The rotation helps create speed and momentum, critical for achieving optimal results.Technique: Athletes often perform a series of spins before releasing the javelin.Physics: The angle of release and spin affects trajectory and distance.In gymnastics, rotations appear prominently during routines like floor exercises and vaults. Gymnasts execute flips and twists through controlled rotational motion, allowing them to perform complex maneuvers seamlessly.Aerial Skills: Skills like the double backflip involve significant body rotation mid-air.Landing Precision: Successful landings depend on controlling rotational velocity throughout the move.These examples illustrate how essential rotational motion is across different sports disciplines, enhancing athletic performance and precision. Rotational motion is a fascinating concept prevalent throughout our natural world. From the smallest subatomic particles to the vast cosmic dance of planets and stars, revolving circular motion is everywhere we look. A classic example can be seen in the graceful pirouettes of ice skaters. As they spin across the ice, figure skaters maintain an incredible rotational velocity through a delicate balance of precisely coordinated limb and core movements. By pulling in their arms and tilting their bodies at just the right angles, skaters are able to spin faster and faster while retaining impeccable form. This rotational versatility stems from an application of our understanding of fundamental physics principles like angular momentum and centrifugal force. Their mastery of these concepts allows skaters to turn and twirl with fluid beauty on the ice. Understanding Rotational Motion in Physics Rotational motion describes how objects rotate. It is governed by the principles of kinematics. Kinematics is a branch of physics that deals with the motion of objects without considering the forces involved. It focuses on variables such as change in position, velocity, acceleration, and time, which can be applied to both linear and rotational motion. When studying rotational motion, we delve into the realm of rotational kinematics. Rotational kinematics explores the relationships between various rotational motion variables. It's important to note that velocity, acceleration, and displacement are vector quantities, meaning they have both magnitude and direction. Key Rotational Motion Variables The essential rotational motion variables include: Angular velocity Angular acceleration Angular displacement Time Understanding Angular Velocity, \(\omega\) Angular velocity represents the rate of change of angle with respect to time. It is calculated using the formula $$ \omega = \frac{\theta}{t} $$ where angular velocity is measured in radians per second (\(\mathrm{\frac{rad}{s}}\)). The derivative of this equation gives us $$\omega = \frac{\mathrm{d}\theta}{\mathrm{d}t},$$ which defines instantaneous angular velocity. Understanding Angular Acceleration, \(\alpha\) Angular acceleration is the rate of change of angular velocity over time. It is determined by the formula $$ \alpha = \frac{\omega}{t} $$ where angular acceleration is measured in radians per second squared (\(\mathrm{\frac{rad}{s^2}}\)). The derivative of this equation gives us $$\alpha = \frac{\mathrm{d}\omega}{\mathrm{d}t},$$ which defines instantaneous angular acceleration. Understanding Angular Displacement, \(\theta\) Angular displacement is the result of angular velocity multiplied by time. It is calculated using the formula $$ \theta = \omega t $$ where angular displacement is measured in radians (\(\mathrm{rad}\)). Understanding Time, \(t\) Time is simply time. It is represented as $$ \mathrm{time} = t $$ and is measured in seconds (\(s\)). Relationship Between Rotational Kinematics and Linear Kinematics Before diving deeper into rotational kinematics, it is important to understand the relationship between kinematic variables. This relationship can be seen when comparing the variables in the table below: Variable Linear Linear SI units Angular Angular SI units Relationship acceleration $$a$$ $$\frac{m}{s^2}$$ $$\alpha$$ $$\mathrm{\frac{rad}{s^2}}$$ $$\begin{aligned}a &= \alpha r \\ \alpha &= \frac{a}{r}\end{aligned}$$ velocity $$v$$ $$\frac{m}{s}$$ \(\omega\) $$\mathrm{\frac{rad}{s}}$$ $$\begin{aligned}v &= \omega r \\ \omega &= \frac{v}{r}\end{aligned}$$ displacement $$x$$ $$m$$ \(\theta\) $$\mathrm{rad}$$ $$\begin{aligned}x &= \theta r \\ \theta &= \frac{x}{r}\end{aligned}$$ time $$t$$ $$s$$ \(t\) $$\mathrm{s}$$ $$t = t$$ Note that \(r\) represents the radius and time is the same in both linear and angular motion. As a result, equations of motion can be written in terms of linear and rotational motion. However, it is important to understand that although equations are written in terms of different variables, they are of the same form because rotational motion is the equivalent counterpart of linear motion. Remember these kinematic equations only apply when acceleration, for linear motion, and angular acceleration, for rotational motion, are constant. Rotational Motion Formulas The relationship between rotational motion and rotational motion variables is expressed through three kinematic equations, each of which is missing a kinematic variable. $$\omega=\omega_{o} + \alpha{t}$$ $$\Delta{\theta} =\omega_o{t}+\frac{1}{2}{\alpha}t$$ $$\omega^2={\omega_{o}}^2 +2{\alpha}\Delta{\theta}$$ where \(\omega\) is final angular acceleration, \(\omega_0\) is the initial angular velocity, \(\alpha\) is angular acceleration, \(t\) is time, and \(\Delta{\theta} \) is angular displacement. These kinematic equations only apply when angular acceleration is constant. Rotational Kinematics and Rotational Dynamics When discussing rotational kinematics, it is essential to also delve into rotational . Rotational focuses on the motion of an object and the forces that induce rotation. In rotational motion, torque is the force responsible for this rotation. Newton's Second Law for Rotational Motion To understand Newton's second law in the context of rotational motion, we must first define torque. Torque Torque, denoted by \(\tau\), is the force applied to an object that causes it to rotate about an axis. Torque is represented by \(\tau\) and is defined as the amount of force applied to an object that will cause it to rotate about an axis. The equation for torque, similar to Newton's second law \(F=ma\), is expressed as $$\tau = I \alpha$$ Here, \(I\) represents the moment of inertia and \(\alpha\) denotes angular acceleration. Torque is the rotational equivalent of force. It is important to note that the moment of inertia quantifies an object's resistance to angular acceleration, with formulas varying based on the object's shape. When a system is at rest, it is in rotational equilibrium. Rotational equilibrium occurs when a system's motion and internal energy remain constant over time. For equilibrium, the sum of all forces must be zero, and in rotational motion, the sum of all torques must equal zero: $$ \sum \tau = 0 $$ If torques act in opposite directions, they can cancel out, resulting in a zero sum. Torque and Angular Acceleration The relationship between angular acceleration and torque is captured in the equation \(\tau={I}\alpha \), which can be rearranged to solve for angular acceleration as \(\alpha=\frac{\tau}{I} \). This shows that angular acceleration is directly proportional to torque and inversely proportional to moment of inertia. Rotational Motion Examples When tackling rotational motion problems, the five rotational kinematic equations come in handy. By understanding the connection between rotational motion, kinematics, and linear motion, we can work through examples to enhance our comprehension. Before solving a problem, remember these steps: Read and identify given variables. Determine the problem's requirements and needed formulas. Apply formulas and solve. Use visuals if necessary. Example 1 Let's apply rotational kinematic equations to a bicycle wheel. A bicycle wheel, initially at rest, is set into motion reaching an angular velocity of \(4.0\,\mathrm{\frac{rad}{s}}\) after \(2.0\,\mathrm{s}\). Calculate the wheel's angular acceleration. Based on the problem, we are given the following: Initial velocity Final velocity Time As a result, we can identify and use the equation, \(\omega=\omega_{o} + \alpha{t} \) to solve this problem. Therefore, our calculations are: $$\begin{aligned}\omega &= \omega_{o} + \alpha{t} \\\omega-\omega_{o} &= \alpha{t} \\\alpha &= \frac{\omega-\omega_{o}}{t} \\\alpha &= \frac{4.0\,\frac{rad}{s}- 0}{2.0\,s} \\\alpha &= 2.0\,\frac{rad}{s^2}\end{aligned}$$ The angular acceleration of the wheel is \(2.0\,\mathrm{\frac{rad}{s^2}}\). Example 2 Next, let's calculate the rotational dynamics of a ceiling fan. Given a ceiling fan that starts from rest and achieves an angular velocity of \(20\,\mathrm{\frac{rad}{s}}\) after \(4\,\mathrm{s}\), calculate its angular acceleration and displacement. We use the equation: \(\alpha = \frac{\omega - \omega_{o}}{t} \) Substitute the values: \(\alpha = \frac{20\,\mathrm{\frac{rad}{s}} - 0}{4\,\mathrm{s}} = 5\,\mathrm{\frac{rad}{s^2}} \) Thus, the angular acceleration of the ceiling fan is \(5\,\mathrm{\frac{rad}{s^2}}\). To find the fan's angular displacement, use the equation: \(\Delta{\theta} = \omega_{o}t + \frac{1}{2}\alpha t^2 \) Substitute the values: \(\Delta{\theta} = 0 \times 4\,\mathrm{\frac{rad}{s}} + \frac{1}{2} \times 5\,\mathrm{\frac{rad}{s^2}} \times (4\,\mathrm{s})^2 = 40\,\mathrm{rad} \) Therefore, the angular displacement of the ceiling fan is \(40\,\mathrm{rad}\). Example 3 For our last example, consider the torque required to accelerate a flywheel. A flywheel with a moment of inertia of \(50\,\mathrm{\frac{kg}{m^2}} \) experiences an angular acceleration of \(3.2\,\mathrm{\frac{rad}{s^2}} \). Calculate the torque required to produce this acceleration. Given the following information: Angular acceleration Moment of inertia By applying the torque equation derived from Newton's second law, our calculations are as follows:\begin{align}\tau &= {I}\alpha \\\tau &= \left(50\,\mathrm{\frac{kg}{m^2}}\right)\left(3.2\,\mathrm{\frac{rad}{s^2}}\right) \\\tau &= 160\,\mathrm{N\,m}\end{align} The torque required to rotate the flywheel about an axisis \(160\,\mathrm{N\,m} \). In summary, rotational motion encompasses the movement of objects along a circular path and is characterized by several key concepts. These include the types of rotational motion—such as fixed-axis rotation and the combination of rotational and translational movements—and the core variables like angular velocity, angular displacement, and angular acceleration. The principles of rotational kinematics help in understanding the relationships between these variables, which can be analogously linked to linear motion equations. Furthermore, rotational dynamics focuses on the forces and torques that govern rotational behavior, adhering to Newton's Second Law. When the net torque on a system is zero, it achieves rotational equilibrium, showcasing the balance of forces in rotational dynamics. When an object rotates or spins about its axis, it is said to be exhibiting rotatory motion. Some examples of rotary or rotatory motion include the motion of a spinning top, rotation of the earth and other planets, movement of hands of a clock, etc. Examples of Rotary Motion 1. Rotation of Earth As the name itself suggests, the motion of the earth and other planets about their respective axis is an example of rotatory motion. This spinning of the celestial bodies about their central position is a result of inertia. 2. Wheels of a Moving Vehicle The wheels of a vehicle rotate with respect to the axle. This rotation of the wheels helps to move the vehicle in the forward or reverse direction. The motion of the wheels demonstrates the rotatory motion, whereas the motion of the car is the result of the conversion of rotational motion into linear motion. 3. Fan Blades The blades of a fan are attached to a central hub, which is further connected to a motor present inside the internal circuitry of the appliance. When the electric current is supplied to the electrical circuit of the fan, the motor gets activated. The motor then translates electrical energy to mechanical energy, thereby causing the blades of the fan to spin and exhibit rotatory motion. 4. Helicopter Rotor Blades The rotary blades present on the top of a helicopter rotate about a central point with the help of a combination of multiple rotary motors. This rotatory motion of the helicopter wings helps in the generation of aerodynamic lift force that is sufficient enough to balance the weight of the helicopter, overcome the aerodynamic drag, and lift it in the air. 5. Spinning Top A spinning top is a toy that is externally wrapped with a thread and consists of a pointed tip. The movement of a spinning top is one of the best examples of rotatory motion. When the spinning top is placed on a surface such that only its pointed end is in contact with the ground and the thread is pulled with force, the top spins about its own axis till the energy possessed by the top gets consumed thoroughly. 6. Ferris Wheel A Ferris Wheel is a major attraction of any funfair or carnival. It is an amusement ride that consists of a huge metallic wheel. The rim of the Ferris Wheel consists of a number of cabins to carry the people in it. When the motor connected to the ride is supplied with power, the wheel rotates about its central point. Hence, the movement of a Ferris Wheel clearly demonstrates rotatory motion in real life. 7. Gears A gear is a mechanical part that consists of cut teeth on its outer surface. The application of gears can be seen in a number of mechanical and automobile machines such as bicycles, cars, watches, etc. The main task of gear is to rotate and translate one form of motion into the other. Hence, a gear is said to be exhibiting rotatory motion. 8. Clock Ticking The minute, hour, and second hand of a clock rotate in a circular direction, keeping the pinpoint as the centre or the axis of rotation. Hence, the hands of a clock are said to be exhibiting rotatory motion. 9. Blender A blender is one of the most common examples of rotary motion in real life. When the power switch of a blender is pressed, the motor present inside the internal circuitry of the appliance helps the blades rotate and display rotary motion. 10. Drill Machine The motion of the drill bit attached to the tip of the drill machine is a prominent example of rotatory motion. The drill bit moves or rotates in a circular direction about its axis and forms a hole in the surface. It is also an example of the conversion of rotatory motion to rectilinear motion because the bit rotating about its own axis eventually tends to move forward in a linear direction. When an object rotates or spins about its axis, it is said to be exhibiting rotatory motion. Some examples of rotary or rotatory motion include the motion of a spinning top, rotation of the earth and other planets, movement of hands of a clock, etc. Examples of Rotary Motion 1. Rotation of Earth As the name itself suggests, the motion of the earth and other planets about their respective axis is an example of rotatory motion. This spinning of the celestial bodies about their central position is a result of inertia. 2. Wheels of a Moving Vehicle The wheels of a vehicle rotate with respect to the axle. This rotation of the wheels helps to move the vehicle in the forward or reverse direction. 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It is also an example of the conversion of rotatory motion to rectilinear motion because the bit rotating about its own axis eventually tends to move forward in a linear direction. A rotational motion, also known as rotatory motion, is a type of motion in which all points of a rigid body maintain a constant distance from an imaginary axis and rotate in circular paths about a common axis with a common velocity. An object can undergo translational and rotational motion at the same time. Earth rotating about its axisSubatomic particles rotating in a cyclotronA skater exhibiting rotation during her routineA wheel rolling down a hillA football spinning in its trajectoryA phonograph's turntable rotating about a pinA potter's wheel rotating about its center The following are examples of rotational motion, although they may not seem so. The reason is that the angle through which the objects rotate is slight and does not complete a full circle. Children playing on a see-sawOpening a doorTurning a wrenchA pendulum swinging about its pivot point Rotational Motion Examples Angle of Rotation An object rotating about an axis is defined by its angle of rotation, θ. Its analogy is similar to distance in linear motion. It tells us how much the object has spun. It is a time-dependent variable that is convenient to measure. Its unit is degree or radian. When the object completes one rotation, the angle it describes is 360˚ or 2π radian. Angular Velocity The angular velocity, ω, is defined as the rate at which the object spins. It is analogous to linear velocity. It is given by the change in the angle of rotation divided by the change in time. \[\omega =\frac{\Delta \theta}{\Delta t} \] It has a unit of radians per second or rad/s. Angular Acceleration The rate at which the angular velocity changes is called angular acceleration, similar to acceleration in linear motion. It is denoted by the symbol α and, mathematically, given by \[\alpha = \frac{\Delta \omega}{\Delta t} \] It has a unit of radians per second squared or rads/s2. The sign of α depends on whether ω increases or decreases with time. If ω is increasing with time, then α is positive. If ω is decreasing with time, then α is negative. Let us examine how the quantities θ, ω, and α are related. Using rotational kinematics, the relationship among these physical entities is given by \[\omega = \omega_o + \alpha t \] Where ωo is known as the initial angular velocity. It is the velocity of the rotating object at time t = 0. Rotational Motion Torque Torque is the angular version of force. It is the turning efficiency of the force. For example, we apply torque to operate a merry-go-round. Force is generally applied on the lever arm to rotate an object about its axis. Mathematically, torque is given by the following equation: \[\tau = rF \cos \theta \] Where, τ: Torque F: Force applied r: Distance of the applied force from the rotation axis or the length of the lever arm θ: Angle of rotation The unit of force is Newton or N, and the unit of distance is meter or m. Therefore, the unit of torque is Newton·meter or N·m. Newton's second law for rotational motion states that every object will move with a constant angular velocity unless acted upon by a torque. Tangential Velocity and Tangential Acceleration A rotating object also has a tangential velocity and a tangential acceleration. Tangential velocity is the instantaneous linear velocity of the object. The relationship between tangential velocity v and angular velocity ω is given as follows: \[v = \omega r \] This equation says that the tangential speed v is proportional to the distance r from the center of rotation. Consider an object rotating about its axis that passes through the center, like a CD. A point closer to the center will have a lower tangential velocity than a distant point. The distant point makes a longer arc length simultaneously with the closest point. Both these points will have the same angular velocity. The rate of change of tangential velocity gives the tangential acceleration a. The relationship between tangential acceleration and angular acceleration is as follows: \[\alpha = \frac {a}{r} \] The magnitudes of tangential acceleration and angular acceleration are directly proportional to each other. The higher the angular acceleration, the greater the tangential acceleration, provided the object's radius remains constant. Problem 1. How much torque does a person produce if he applies an 8 N force 2 m away from the rotation axis, perpendicularly to the lever arm? Solution Given F = 8 N r = 2 m θ = 0˚ The torque is given by τ = r F cos θ or, τ = 2 m * 8 N * cos 0 or, τ = 16 N·m Problem 2. An object's angular velocity changes from 5 rad/s clockwise to 10 rad/s clockwise in 4 s. What is its angular acceleration? Solution Given ω1 = 5 rad/s ω2 = 10 rad/s t = 4 s The angular acceleration is given by α = (ω2 – ω1)/t or, α = (10 rad/s – 5 rad/s)/4s or, α = 1.25 rad/s Q.1. How does one convert from rotational to linear motion? Ans. Rotational motion can be converted into linear motion by using a screw. Q.2. What causes rotational motion in an electric motor? Ans. A current-carrying wire wound into a coil experiences a force in a magnetic field that makes it rotate. Article was last reviewed on Saturday, April 8, 2023 Perhaps you think of your movements in the world, and the motion of objects in general, in terms of a series of mostly straight lines: You walk in straight lines or curved paths to get from place to place, and rain and other things fall from the sky; much of the world's critical geometry in architecture, infrastructure and elsewhere is predicated on angles and carefully arranged lines. At a glance, life may seem far more rich in linear (or translational) motion than in angular (or rotational) motion. As with a lot of human perceptions, this one, to the extent each persons experiences it, is hugely misleading. Thanks to how your senses are structures to interpret the world, it is natural for you to navigate that world in terms of forward and back and right and left and up and down. But were it not for rotational motion – that is, motion about a fixed axis – there would be no universe or at least not one hospitable or recognizable to physics buffs. Okay, so things spin around as well as shift about generally. What of it? Well, the big takeaways about rotational motion are that: 1) It has mathematical analogs in the world of linear or translational motion that make studying either one in the context of the other extremely useful, as it shows how physics itself is "set up"; and 2) the things that set rotational motion apart are very important to learn. Rotational motion refers to anything spinning or moving in a circular path. It is also called angular motion or circular motion. The motion may be uniform (i.e., the velocity v doesn't change) or non-uniform, but it has to be circular. The revolution of the Earth and other planets around the sun may be treated as circular for simplicity, but planetary orbits are actually elliptical (slightly oval) and therefore not an example of rotational motion. An object can be rotating while also experiencing linear motion; just consider a football spinning like a top as it also arcs through the air, or a wheel rolling down the street. Scientists consider these kinds of motion separately because separate equations (but again, tightly analogous) are required to interpret and explain them. It's actually useful to have a special set of measurements and calculations to describe rotational motion of those objects as opposed to their translational or linear motion, because you often get a brief refresher in things like geometry and trigonometry, subjects it is always good for the science-minded to have a firm handle on. While the ultimate non-acknowledgment of rotational motion might be "Flat Earthism," it is actually pretty easy to miss even when you're looking, perhaps because many people's minds are trained to equate "circular motion" with "circle." Even the tiniest slice of the path of an object in rotational motion around a very distant axis – which would look like a straight line at a glance – represents circular motion. Such motion is all around us, with examples including rolling balls and wheels, merry-go-rounds, spinning planets and elegantly twirling ice-skaters. Examples of motions that may not seem like rotational motion, but in fact are, include see-saws, opening doors and the turn of a wrench. As noted above, because in these cases the angles of rotation that are involved are often small, it's easy to not filter this in your mind as angular motion. Think for a moment about the motion of a cyclist with respect to the "fixed" ground. While it's obvious that the wheels of the bike are moving in a circle, consider what it means for the cyclist's feet to be fixed to the pedals while the hips remain stationary atop the seat. The "levers" in between are executing a form of complex rotational motion, with the knees and ankles tracing out invisible circles with different radii. Meanwhile, the whole package might be moving at 60 km/hr through the Alps during the Tour de France. Hundreds of years ago, Isaac Newton, perhaps the most high-impact math and physics innovator in history, produced three laws of motion that he based largely on the work of Galileo. Since you are studying motion formally, you might as well be familiar with the "ground rules" governing all motion and who discovered them. Newton's first law, the law of inertia, states that an object moving with constant velocity continues to do so unless disturbed by an external force. Newton's second law proposes that if a net force F acts on a mass m, it will accelerate (change the velocity of) that mass in some way: F = ma. Newton's third law states that for every force F there exists a force –F, equal in magnitude but opposite in direction, so that the sum of the forces in nature is zero. In physics, any quantity that can be described in linear terms can also be described in angular terms. The most important of these are: **Displacement.** Usually, kinematics problems involve two linear dimensions to specify position, x and y. Rotational motion involves a particle at a distance r from the axis of rotation, with an angle specified in reference to a zero point if needed. **Velocity.** Instead of velocity v in m/s, rotational motion has angular velocity **ω** (the Greek letter omega) in radians per second (rad/s). Importantly, however, a particle moving with constant ω also has a tangential velocity **vt** in a direction perpendicular to r. Even if constant in magnitude, **vt** is always changing because the direction of its vector continually changes. Its value is found simply from vt = ωr. **Acceleration.** Angular acceleration, written **α** (The Greek letter alpha), is often zero in basic rotational motion problems because **ω** is usually held constant. But because **vt**, as noted above, is always changing, there exists a **centripetal acceleration ac** directed inward toward the rotation axis and with a magnitude of \(a_c=\frac{v_t^2}{r}\) **Force.** Forces that act about an axis of rotation, or "twisting" (torsional) forces, are called torques, and are a product of the force F and the distance of its action from the axis of rotation (i.e., the length of the lever arm): \(\tau=F\times r\) Note that the units of torque are Newton-meters, and the "×"here signifies a vector cross product, indicating that the direction of **τ** is perpendicular to the plane formed by F and **r.** **Mass.** While mass, m, factors into rotational problems, it is usually incorporated into a special quantity called the moment of inertia (or second moment of area) I. You'll learn more about this actor, along with the more fundamental quantity angular momentum L, soon. Because rotational motion involves studying circular paths, rather than using meters to describe the angular displacement of an object, physicists use radians or degrees. A radian is convenient because it naturally expresses angles in terms of π, since one complete turn of a circle (360 degrees) equals 2π radians. Commonly encountered angles in physics are 30 degrees (π/6 rad), 45 degrees (π/4 rad), 60 degrees (π/3 rad) and 90 degrees (π/2 rad). Being able to identify the axis of rotation is essential in understanding rotational motions and solving associated problems. Sometimes this is straightforward, but consider what happens when a frustrated golfer sends a five-iron twirling high into the air toward a lake. A single rigid body con rotate in a surprising number of ways: end-over-end (like a gymnast doing 360-degree vertical spins while holding a horizontal bar), along the length (like the drive shaft of a car), or spinning from a central fixed point (like the wheel of that same car). Typically, the properties of an object's motion change depending on how it is rotated. Consider a cylinder, half of which is made of lead and the other half of which is hollow. If an axis of rotation were chosen through its long axis, the distribution of mass around this axis would be symmetrical, though not uniform, so you can imagine it spinning smoothly. But what if the axis were chosen through the heavy end? The hollow end? The middle? As you just learned, spinning the same object around a different axis of rotation, or changing the radius, can make the motion more or less difficult. A natural extension of this concept is that similarly shaped objects with different distributions of mass have different rotational properties. This is captured by a quantity called the **moment of inertia I,** which is a measure of how hard it is to change an object's angular velocity. It is analogous to mass in linear motion in terms of its general effects on rotational motion. As with elements in the periodic table in chemistry, it's not cheating to look up the formula for I for any object; a handy table is found in the Resources. But for all objects, I is proportional to both mass (m) and the square of the radius (r2). The biggest role of I in computational physics is that it offers a platform for computing angular momentum L: \(L=I\omega\) The law of conservation of angular momentum in rotational motion is analogous to the law of conservation of linear momentum and is a critical concept in rotational motion. Torque, for example, is just a name for the rate of change of angular momentum. This law states that the total momentum L in any system of rotating particles or objects never changes. This explains why an ice skater spins so much faster as she pulls in her arms, and why she spreads them out to slow herself to a strategic stop. Recall that L is proportional to both m and r2 (because I is, and L = I**ω**). Because L must remain constant, and the value of m (the skater's mass doesn't change during the problem, if r increases, then the final angular velocity **ω** must decrease and conversely. Beck, Kevin. "Rotational Motion (Physics): What Is It & Why It Matters" sciencing.com, . 28 December 2020. APA Beck, Kevin. (2020, December 28). Rotational Motion (Physics): What Is It & Why It Matters. sciencing.com. Retrieved from Chicago Beck, Kevin. Rotational Motion (Physics): What Is It & Why It Matters last modified August 30, 2022. When an object rotates or spins about its axis, it is said to be exhibiting rotatory motion. Some examples of rotary or rotatory motion include the motion of a spinning top, rotation of the earth and other planets, movement of hands of a clock, etc. Examples of Rotary Motion 1. Rotation of Earth As the name itself suggests, the motion of the earth and other planets about their respective axis is an example of rotatory motion. This spinning of the celestial bodies about their central position is a result of inertia. 2. Wheels of a Moving Vehicle The wheels of a vehicle rotate with respect to the axle. This rotation of the wheels helps to move the vehicle in the forward or reverse direction. The motion of the wheels demonstrates the rotatory motion, whereas the motion of the car is the result of the conversion of rotational motion into linear motion. 3. Fan Blades The blades of a fan are attached to a central hub, which is further connected to a motor present inside the internal circuitry of the appliance. When the electric current is supplied to the electrical circuit of the fan, the motor gets activated. The motor then translates electrical energy to mechanical energy, thereby causing the blades of the fan to spin and exhibit rotatory motion. 4. Helicopter Rotor Blades The rotary blades present on the top of a helicopter rotate about a central point with the help of a combination of multiple rotary motors. This rotatory motion of the helicopter wings helps in the generation of aerodynamic lift force that is sufficient enough to balance the weight of the helicopter, overcome the aerodynamic drag, and lift it in the air. 5. Spinning Top A spinning top is a toy that is externally wrapped with a thread and consists of a pointed tip. The movement of a spinning top is one of the best examples of rotatory motion. When the spinning top is placed on a surface such that only its pointed end is in contact with the ground and the thread is pulled with force, the top spins about its own axis till the energy possessed by the top gets consumed thoroughly. 6. Ferris Wheel A Ferris Wheel is a major attraction of any funfair or carnival. It is an amusement ride that consists of a huge metallic wheel. The rim of the Ferris Wheel consists of a number of cabins to carry the people in it. When the motor connected to the ride is supplied with power, the wheel rotates about its central point. Hence, the movement of a Ferris Wheel clearly demonstrates rotatory motion in real life. 7. Gears A gear is a mechanical part that consists of cut teeth on its outer surface. The application of gears can be seen in a number of mechanical and automobile machines such as bicycles, cars, watches, etc. The main task of gear is to rotate and translate one form of motion into the other. Hence, a gear is said to be exhibiting rotatory motion. 8. Clock Ticking The minute, hour, and second hand of a clock rotate in a circular direction, keeping the pinpoint as the centre or the axis of rotation. Hence, the hands of a clock are said to be exhibiting rotatory motion. 9. Blender A blender is one of the most common examples of rotary motion in real life. When the power switch of a blender is pressed, the motor present inside the internal circuitry of the appliance helps the blades rotate and display rotary motion. 10. Drill Machine The motion of the drill bit attached to the tip of the drill machine is a prominent example of rotatory motion. The drill bit moves or rotates in a circular direction about its axis and forms a hole in the surface. It is also an example of the conversion of rotatory motion to rectilinear motion because the bit rotating about its own axis eventually tends to move forward in a linear direction. 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