

Pre-Content/content Post-Content	Learning outcomes/Objectives	
	General	Specific
<u>Pre Content</u> Force, acceleration, velocity, angular velocity, three equations of motion, kinetic energy, linear momentum. <u>Content</u> Centre of mass, centre of gravity, linear momentum, vector product, angular velocity, torque, mechanical advantage, moment of inertia, conservation of angular momentum, rotational kinetic energy and rolling motion. <u>Post Content</u> Numerical problems on: centre of mass, vector product, equilibrium and moment of inertia.	Students will be able to: analyse physical significance of center of mass in the study of motion of a rigid body. understand and apply vector product. explain moment of inertia in detail. study rotational dynamics and kinematics in detail.	Students will be able to: - define rotational motion. - define center of mass of a rigid body and discuss its significance. - derive formulae to depict motion of center of mass. - differentiate between center of mass and center of gravity. - write an expression for the linear momentum of a system of particles. - understand vector product. - apply vector product to define and calculate angular momentum and torque. - differentiate between angular momentum and torque. - derive the formula for mechanical advantage by applying concept of equilibrium of forces. - define moment of inertia. - calculate moment of inertia for various rigid bodies by applying theorem of parallel and perpendicular axes. - state and prove law of conservation of angular momentum. - derive expression for rotational kinetic energy of a rigid body. - explain rolling motion for a rigid body.

Home Work /Assignments:

- NCERT exercise discussed in the class is given as the home task.
- Assignment worksheets are given at the end of the chapter.

Teacher's Activity	Student's Activity	Teacher's observation and Remedial
Teacher will help students recall translational and circular motion and then explain the rotational motion. define and discuss the need of defining centre of mass of a rigid body. help students to derive the formula for calculating centre of mass. explain the difference between centre of mass and centre of gravity. write an expression for linear momentum of a single particle.. Introduce the concept of vector product and apply it to define torque and angular momentum. Annexure 6(A) demonstrate an activity to explain the concept of mechanical advantage. define moment of inertia as an important quantity in rotational motion. state theorem of parallel and perpendicular axes to calculate moment of inertia of various rigid bodies. Annexure 6(B) demonstrate an activity to understand law of conservation of angular momentum. guide students to derive an expression for rotational kinetic energy. guide students to derive the condition for rolling without slipping.	Students will comprehend rotational motion as an extension of circular motion. identify the physical significance of centre of mass to study the motion of a rigid body. calculate centre of mass for the given rigid bodies. list examples where centre of mass does not coincide with its centre of gravity. extend the expression for the system of "n" particles. differentiate between torque and angular momentum and apply formula for vector product to calculate the both. Annexure 6(a) perform an activity to understand mechanical advantage. identify that moment of inertia is analogous to mass in rotational motion. apply the theorem of parallel and perpendicular axes to calculate moment of inertia of given rigid bodies. Annexure 6(b) perform an activity to comprehend law of conservation of angular momentum. derive and apply the formula for rotational kinetic energy to solve numerical problems. follow the steps of derivation and solve conceptual problems on the same.	

Teaching Aids: Active inspire, ICR, equipment installed in the Science park

Methodology/Innovative: Enquiry, Discussion, Demonstration and experimentation.

Interdisciplinary Links: Mathematics, Dance and Acrobat.

Annexure 6(A), 6(a) - Let us Reduce the Effort

Subject	Physics
Class	XI
Chapter/Unit	Dynamics of Rotational Motion
Topic	Principle of Levers
Time	10 minutes
Nature of Activity	pair

What will I learn (Learning Outcome)?

To conclude that for a first class lever, mechanical advantage can be equal to unity, less than unity or more than unity. They will hence establish a relation between length of effort arm and load arm in order to apply least effort to lift a given amount of load (i.e. mechanical advantage greater than unity).

Skills: Analyzing and Creating

What I have to do?

To verify that effort moves farther than load for mechanical advantage to be more than Unity.

What do I require?

A 30 cm range ruler, pen/pencil, a book.

What do I need to know?

A lever is a simple machine which makes our mechanical work easier. It has a fulcrum, load and effort. The mechanical advantage of the lever is the ratio of output force (Load) to input force (Effort). It can also be calculated as ratio of the length of the lever on the applied effort side of the fulcrum to the length of the lever on the load force side of the fulcrum. A lever reaches equilibrium when the forces applied to each of its arms, in respect to its fulcrum, are the same.

➤ **Teacher's Activity**

Teacher will

1. make pair and explain the responsibility of each member in the pair
2. discuss the concept of equilibrium of a rigid body and types of levers (First Class, Second Class and Third Class) on the basis of placement of fulcrum
3. guide students on how to perform the activity.

How will I proceed?

➤ **Student's Activity**

1. keep a pen on the table and then keep ruler above it such that it makes an angle of 90° with the pen (like making a sign of $\perp$).
2. On one of the extreme end (call it end L at 30 cm mark) of the ruler keep a book.
3. keep the pen at the midpoint of the ruler (i.e. at 15 cm) and try to lift the book by applying force from the other extreme end of the ruler (end E at 0 cm mark).
4. Repeat step 3 for two different positions of the pen - at the mark 5 cm and 25 cm respectively. Observe the difference in amount of force applied in each case.

What have I observed?

S. No.	Position of pen	Effort Applied - More or Less
1	5 cm	
2	15 cm	
3	25 cm	

What have I learnt?

The lifting of the load was easiest when the Effort Arm is _____ as compared to Load Arm.

What am I curious to learn?

- We use following levers in our day-to-day life:-

Hockey Stick, Tweezers, Fishing Rod, Nut crackers, Wheel barrows, Door, Bottle opener, Crowbars, Scissors, Pliers and See saw

Let us identify the placement of load, fulcrum and effort along with the direction of force (effort as well as load) in each of the above mentioned levers.

Let me evaluate myself

1. What is meant by a rigid body?

2. What is meant by the translational equilibrium and rotational equilibrium of a rigid body?

3. Using a lever, Joe is able to lift a 10,000 N car off of the ground with a force of 1000 N. What is the mechanical advantage of the lever?

4. A pair of scissors is an example of a lever. Where should the material to be cut, is placed so as to reduce the efforts: - near the fulcrum or away from the fulcrum? Explain your answer.

5. A worker needs to haul a cart full of heavy boxes onto the deck of a house. He notices two ramps are set up, one being twice the length of the other one. Will the work done be same in both cases? If not then which one should he choose in order to reduce the amount of work he needs to do? Give reason for your answer.

Annexure 6(B), 6(b) - Let us rotate

Subject	Physics
Class	XI
Chapter/Unit	Dynamics of Rotational Motion
Topic	Conservation of Angular Momentum
Time	10 minutes
Nature of Activity	Individual

What will I learn (Learning Outcome)?

To verify the law of conservation of angular momentum experimentally.

Skills: Analyzing and Creating

What I have to do?

To demonstrate that as the moment of inertia of a rotating body increases, its angular velocity decreases, if the net external torque is zero..

What do I require?

A chair/stool with wheels and two dumbbell weights of 1 kg each.

What do I need to know?

According to the principal of conservation of momentum, in the absence of any external torque, the product of Moment of Inertia and Angular Velocity remains constant. This means to increase the angular speed of rotation, one must control the Moment of Inertia; i.e. as moment of inertia will decrease, speed of rotation will increase OR as moment of inertia will increase, speed of rotation will decrease. Further Moment of inertia is directly proportional to the mass of the body and the square of the radius of gyration.

➤ **Teacher's Activity**

Teacher will

1. discuss the law of conservation of angular momentum
2. guide students on how to perform the activity.

How will I proceed?

➤ **Student's Activity**

1. Sit on the chair/stool having wheels and hold the weights in the hands
2. Stretch the hands so that the weights are at a farthest position from the body.
3. Give yourself a rotation by pushing the ground.
4. Now slowly bring the weights closer to the body.
5. Observe - what happens to the speed of rotation of the chair as the weights are brought closer?

What have I observed?

S. No.	Position of weights	Speed of rotation (increases/decreases)
1	Closest to the body	
2	Farthest to the body	

What have I learnt?

As weights are brought closer to the chair, speed of rotation _____ and radius of gyration _____ which further _____ Moment of Inertia of the body.

What am I curious to learn?

Gyroscope is a device consisting of a wheel or disc mounted so that it can spin rapidly about an axis which is itself free to alter in direction. The orientation of the axis is not affected by tilting of the mounting, so gyroscopes can be used to provide stability or maintain a reference direction in navigation systems, automatic pilots, and stabilizers.

Let us find out if the law of conservation of angular momentum is also applicable on a gyroscope. Take a gyroscope and sit on a stool having wheels with feet not touching the ground. Then I can ask my friend to rotate the gyroscope very fast and leave. What do I observe? Can I explain my observation?

Let me evaluate myself

1. State the law of conservation of angular momentum.

2. If angular momentum of a rigid body is conserved, then what must be true about its initial and final angular momentum?
 - a) Initial angular momentum is greater than final angular momentum.
 - b) Initial angular momentum is less than final angular momentum.
 - c) Initial angular momentum is equal to final angular momentum.
 - d) Initial angular momentum is greater than zero, and final angular momentum is less than zero.
3. Derive the relation between angular momentum, moment of inertia and angular speed of a rigid body.

4. An acrobat/ballet dancer stretches her hands while dancing. What happens to her angular speed? Explain the reason for the change.

5. Why does a spring board diver, while jumping into a swimming pool, curls himself in such a way that his feet and head are driven close to each other.

