**TORQUE AND ROTATIONAL MOTION**

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| **BIG IDEA 3: The interactions of an object with other objects can be described by forces.** |
| **3.F.1.1:** The student is able to use representations of the relationship between force and torque. **[SP 1.4]** |
| **3.F.1.2:** The student is able to compare the torques on an object caused by various forces. **[SP 1.4]** |
| **3.F.1.3:** The student is able to estimate the torque on an object caused by various forces in comparison to other situations. **[SP 2.3]** |
| **3.F.1.4:** The student is able to design an experiment and analyze data testing a question about torques in a balanced rigid system. **[SP 4.1, 4.2, 5.1]** |
| **3.F.1.5:** The student is able to calculate torques on a two-dimensional system in static equilibrium, by examining a representation or model (such as a diagram or physical construction). **[SP 1.4, 2.2]** |
| **3.F.2.1:** The student is able to make predictions about the change in the angular velocity about an axis for an object when forces exerted on the object cause a torque about that axis. **[SP 6.4]**: |
| **3.F.2.2:** The student is able to plan data collection and analysis strategies designed to test the relationship between a torque exerted on an object and the change in angular velocity of that object about an axis. **[SP 4.1, 4.2, 5.1]** |
| **3.F.3.1:** The student is able to predict the behavior of rotational collision situations by the same processes that are used to analyze linear collision situations using an analogy between impulse and change of linear momentum and angular impulse and change of angular momentum. **[SP 6.4, 7.2]** |
| **3.F.3.2:** In an unfamiliar context or using representations beyond equations, the student is able to justify the selection of a mathematical routine to solve for the change in angular momentum of an object caused by torques exerted on the object. **[SP 2.1]** |
| **3.F.3.3:** The student is able to plan data collection and analysis strategies designed to test the relationship between torques exerted on an object and the change in angular momentum of that object. **[SP 4.1, 4.2, 5.1, 5.3]** |
| **BIG IDEA 4: Interactions between systems can result in changes in those systems.** |
| **4.A.1.1** The student is able to use representations of the center of mass of an isolated two-object system to analyze the motion of the system qualitatively and semiquantitatively. **[SP 1.2, 1.4, 2.3, 6.4]** |
| **4.D.1.1:** The student is able to describe a representation and use it to analyze a situation in which several forces exerted on a rotating system of rigidly connected objects change the angular velocity and angular momentum of the system. **[SP 1.2, 1.4]** |
| **4.D.1.2:** The student is able to plan data collection strategies designed to establish that torque, angular velocity, angular acceleration, and angular momentum can be predicted accurately when the variables are treated as being clockwise or counterclockwise with respect to a well-defined axis of rotation, and refine the research question based on the examination of data. [**SP 3.2, 4.1, 4.2, 5.1, 5.3]** |
| **4.D.2.1:** The student is able to describe a model of a rotational system and use that model to analyze a situation in which angular momentum changes due to interaction with other objects or systems. **[SP 1.2, 1.4]** |
| **4.D.2.2:** The student is able to plan a data collection and analysis strategy to determine the change in angular momentum of a system and relate it to interactions with other objects and systems. **[SP 4.2]** |
| **4.D.3.1:** The student is able to use appropriate mathematical routines to calculate values for initial or final angular momentum, or change in angular momentum of a system, or average torque or time during which the torque is exerted in analyzing a situation involving torque and angular momentum. **[SP 2.2]** |
| **4.D.3.2:** The student is able to plan a data collection strategy designed to test the relationship between the change in angular momentum of a system and the product of the average torque applied to the system and the time interval during which the torque is exerted. **[SP 4.1, 4.2]** |
| **BIG IDEA 5: Changes that occur as a result of interactions are constrained by conservation laws.** |
| **5.E.1.1:** The student is able to make qualitative predictions about the angular momentum of a system for a situation in which there is no net external torque. **[SP 6.4, 7.2]** |
| **5.E.1.2:** The student is able to make calculations of quantities related to the angular momentum of a system when the net external torque on the system is zero. **[SP 2.1, 2.2]** |
| **5.E.2.1:** The student is able to describe or calculate the angular momentum and rotational inertia of a system in terms of the locations and velocities of objects that make up the system. Students are expected to do qualitative reasoning with compound objects. Students are expected to do calculations with a fixed set of extended objects and point masses. **[SP 2.2]** |