<table>
<tr><td>PRINCETON
INDEPENDENT SCHOOL DISTRICT</td><td colspan="3">Campus: Princeton H.S.</td></tr>
<tr><td>Author(s): Kyle Lamothe</td><td colspan="3">Date Created / Revised: 15 Dec 2018</td></tr>
<tr><td>Six Weeks Period: 4th</td><td colspan="3">Grade Level & Course: AP Physics</td></tr>
<tr><td>Timeline: 24 Days</td><td colspan="2">Unit Title: Unit 6.2 Rotational Kinematics & Dynamics</td><td>Lesson # 1</td></tr>
<tr><td>Stated Objectives: TEK # and SE</td><td colspan="3">§112.64. Advanced Placement (AP) Physics
(b) Content Requirements. Content requirements for Advanced Placement (AP) Physics are prescribed in the College Board Publication Advanced Placement Course Description: Physics, published by The College Board.
Source: The provisions of this §112.64 adopted to be effective September 1, 1998, 22 TexReg 7647.

<u>Cutnell & Johnson Book chapter 5, 8, 9.</u>

AP Physics Syllabus (course approved syllabus)
I. Newtonian Mechanics
E. Circular Motion and Rotation
1. Rotational Kinematic Ch 8
2. Torque Angular momentum and its conservation Ch 9

http://phyz.org/hewittdrewit/romo.html</td></tr>
<tr><td colspan="4">See Instructional Focus Document (IFD) for TEK Specificity</td></tr>
<tr><td>Key Understandings</td><td colspan="3">1. Circular motion and gravitation
• Angular measure
• Angular speed and velocity
• Uniform circular motion and centripetal acceleration
• Angular acceleration

2. Rotational Motion and Equilibrium
• Rigid bodies, translations and rotations
• Torque, equilibrium and stability
• Rotational dynamics
• Rotational work and kinetic energy
• Angular momentum</td></tr>
<tr><td>Misconceptions</td><td colspan="3"></td></tr>
<tr><td>Key Vocabulary</td><td colspan="3">Angular speed, angular velocity, centripetal acceleration, torque, equilibrium, angular momentum</td></tr>
<tr><td>Suggested Day 5E Model</td><td colspan="2">Instructional Procedures
(Engage, Explore, Explain, Extend/Elaborate, Evaluate)</td><td>Materials, Resources, Notes</td></tr>
<tr><td>Day 1 Wednesday Jan 10th</td><td colspan="2">Objective: Introduce rotational motion and angular displacement</td><td>1 piece of string for each student (3-4” each)</td></tr>
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	Quick teaser of what this unit will answer: Why does sticking arms out helps you balance? Why is it more difficult to swing a baseball bat from the handle than the barrel? Why do figure skaters pull their arms in to spin faster? How do cats always land on their feet? Why doesn't the leaning tower of Pisa fall? What is a radian? Distribute pieces of string. Have them draw a line that is the same length as the string. Now move on end of the string through an angle that matches the length of the string. Introduce Angular displacement emphasizing measurement in radians. Draw out radian circle identifying common angles. Relate one radian to the distance of radius. Relate radius to circumference. as in video Radian animation Rotation introduction worksheets Homework is to check your in class work with the solutions that are to be shared on G classroom Give practice in converting from revolutions≫radians and rad≫ revs. What is the angular displacement of sec hand, minute hand, hour hand during 1 hour? possible extra practice: Page 234: 1,2,3, 9, 10,	Rotation 1 Slides
Day 2 Thursday Jan 11th	Objective: Practice calculating rotational kinematic equations. Mythbusters Square wheels watch a few moments from mythbusters Review Homework: Have one student work one of the previous days homework problems on the board. PHET Ladybug Revolution/physicsclassroom.com interactive Angular Kinematics TechLab (30 minutes) based on ladybug revolution: angular kinematics Ladybug Revolution Clicker Questions Slides (10 minutes) Demo: Roll office chair (small radius) next to bike wheel (big radius) at same translational velocity. Ask the students What is the same about both? (translational velocity) What is different? (Angular velocity) Why? (different wheel size) Solve 1 or 2 example problems with same process as 1 dimensional kinematics Rotational Kinematics Practice Consider sharing solutions online use page stephen murray rotation worksheet for homework possible extra practice Page 235 #7, 15, 236 # 20 a) b) 21, 22, 24, 25 a) 30.	• Laptop Carts
Day 3 Friday Jan 12	Objective: Review Rotational Kinematics Bellringer: A Satellite follows a circular path with a constant speed around a planet. Choose which quantities are constant vs which are constantly changing and which quantities are zero and which are greater than zero: Linear velocity, angular velocity, angular acceleration, centripetal acceleration -Introduce rolling motion	• **Rotation Day 3** •

	-Show animation of rolling motion show path/velocity/acceleration of c of mass and point P http://dynref.engr.illinois.edu/rko.html Allow students to work in groups and work through the following: Page 225: Check your understanding 7-9 TIPERS B1-01 Graphs of Angular Velocity & Angular Acceleration B6-RT06: Spheres Rolling- Radius Example 8 61 (challenge, but good) Page 237 # 57, 53 Take two quarters and lay them on a table. Press down on one quarter so it cannot move. Then, starting at the 12:00 position, roll the other quarter along the edge of the stationary quarter, as the drawing suggests. How many revolutions does the rolling quarter make when it travels once around the circumference of the stationary quarter? Surprisingly, the answer is *not* one revolution.  *(Hint: Review the paragraph just before Equation 8.12 that discusses how the distance traveled by the axle of a wheel is related to the circular arc length along the outer edge of the wheel.)*	
Day 4 ***Tuesday*** ***Jan 16th*** ***Students needed more time to review before quiz***	Objective: to introduce torque with center of mass/ center of gravity Review Ratio question Quiz or Quiz Corrections Find Center of gravity in various objects. After watching a demonstration of someone juggling, I ask for volunteers to explain in their own words the concept of center of mass in the parabolic motion of objects being juggled. Using a juggling example to explain the concept of center of mass provides a very powerful (and fun) visualization. I often have students who can juggle. Tennis ball thrown vs. wrench thrown. Ask what is different? What is the same? (C of Mass parabolic path) Youtube High Jump center of mass (just show part with animation of center of mass) https://www.youtube.com/watch?v=RaGUW1d0w8g https://www.youtube.com/watch?v=_DzgPB9646k (possible demo, have everyone stand against the wall and try to stand on tiptoes or back against the wall and try to bend over and touch your toes) Bottle flip demo Ask why do things tip over? Why is the leaning tower of Pisa not the Fallen Rock Pile of Pisa? Today we will answer that. https://www.youtube.com/watch?v=pjK_3RuiCXk tipping point Closing Task: Center of Mass questions (need 10 minutes of review)	C of Gravity Slides

Day 5 ***Wed Jan 17***	Bellringer: What are the worst spots on a door to put a doorknob? Why? Quiz Corrections (15 minutes) Homework Corrections CYU 3,4,5,7,8,14,16 in groups	•
Day 6 Thursday Jan 18	Torque Mass Meterstick Balance Lab 1-6 (conceptual) then lecture through the basics of torque with example calculations including rotational equillibrium Get a ruler; push it in the middle. Ask how hard do I have to push to get it to turn? I don't have to push super hard, just away from the center. The center of mass/gravity will be important in our understanding of torque. Define torque as any force that causes rotation. Use interactive lecture to introduce Problem (20 minutes) Have demo set up to model a human bicep as an arm holds a book. Have students guess the tension in the bicep. Are the forces balanced? Will the downward force=the upward? then introduce that the placement of the force matters, it must be away from the center of mass. Solving procedures CPO torque powerpoint (15 minutes) Use sample question for review over torque and equilibrium. Students work to put the problem on work for evaluation and review. Students check their answer and get feedback on problems Introduce Torque=Force*Lever Arm Push door @ different spots @ different angles Homework: Finish up lab report individually Objective: Forces @ an angle & torque	• Torque Day 6 Slides meitersticks, slotted masses, • Lab stand, lever, hanging mass, string, spring scale
Day 7 ***Friday Jan 19***	Have students hold backpacks and change angle of metersticks and identify which angle is the hardest to hold (and thus which angle is the best to use for torque) Demo rolling Spool Trick. Students predict which way the spool will roll if you pull at different angles. Spool Trick Handout (or Conceptual Physics 11-2) (consider scrapping spool trick part of handout, just have spool trick as intro) Draw & Calculate lever arm. Work a few examples on board, give students time to complete problems on handout. Show solutions at the end of class. (on p. 3 of spool trick handout) *****You can either draw a force vector triangle or distance vector triangle .	printed Handouts Torque Day 7,8 Have demo of sign hanging from angle on CPO stand
Day 8	Revisit Spool Trick Handout. Emphasize method of calculating torque: 1. extend line of action	Torque Day 7,8

	2. Draw a right angle, then draw a perpendicular from line of action to the fulcrum. page 268 #3,6. Page 243 Example 3 & 4 Check Your Understanding 1,4, & ***(note to self for next year, work thru a beam held up by 2 strings before introducing vector components)*** Have students draw forces and then components of a beam held up by a cable suspending a sign. Torque at angle practice Ladder, hanging sign from rod Homework Torque 1	
Day 9	Students read bottom of p. 242- the reasoning strategy on 243, Let the steps guide our thinking for beam held up vertically with 2 strings (no horizontal component) Read 244 answer "what might help us to choose our axis?" Sign Torque also pg 270 # 18,	•
Day 10	Bellringer: CYU # 5 on p. 247 Open up blue books to p. 243, read as a class all 6 steps. Work dog on beam example on Rotational Equilibrium practice or alternate link for rotational equillibrium Have students practice example of dog and cat on beam where supports aren't on the ends of the beam. Check work then introduce 2-D static of rope/cable holding up a sign from a beam. Assign the rest of the handout as practice	•
Day 11	Handout 3 from AP Physics 1 Curriculum Module Formative assessment on Torque and Rotational Kinematics	•
Day 12	RK & Torque Quiz	
Day 13	Objective: to introduce rotational inertia and what makes things more difficult to spin Predict which will hit ground fastest: pvc pipe tipped over, or pvc pipe with weight at the top tipped over? Hand out metersticks have students rotate them while holding them at different points. Ask why is it more difficult to rotate it at different points? Does the mass change?	• Rotation Day 13 2 broom handles, 4clamps

	Where can you hold the broom/meterstick in order to spin it the easiest? Prediction: Observations: Follow Up: Why was it easiest to spin the meterstick/broom at those points? A friend says: Rotational inertia is just a fancy name for an object's mass when the object is rotating. If the object has more mass, ti has more rotational inertia, and if it has less mass, it has less rotational inertia-end of story. Nothing else matter." In what ways, if any do you agree with your friend? In what ways, if any do you disagree? The moment of inertia (The rotational inertia changes) inertia=sluggishness=amount of mass….more mass…more resistance to change. More mass: more resistant to change in rotation CYU # 10 Activity 5 & 6 Determining Rotational Inertia of standard shapes Closing Task: I will hold a ruler at different points and demonstrate how I can change the rotational inertia without changing mass.	
Tuesday ***Day 14***	Ring & Hoop Race Show F=ma ≫ t=Ia derivation on board Either Mcgraw Hill or C&J powerpoint on Moment of Inertia/Rotational Inertia. Example 10 p. 255 Assign 1 practice problem # 31, give 6 minutes to complete, project solution Work example of finding angular acceleration with multiple torques and multiple object like in khan academy video. Khan Academy for reference Starting at 9:00 for a reference. PreLab Homework TIA (Extra practice #'s p. 268 # 12 & 13, 31, 32, 35, 37, 40 page 271)	
Wednesday ***Day 15***	Review Homework Determination of Rotational Inertia Lab https://docs.google.com/document/d/1yO8sc49cuCPkgup7tchB3MblX4wn4YFJ33SnER7W5mk/edit Purpose: Design an experiment to determine the relationship between torque exerted on an apparatus and rotational inertia of the apparatus.	
Thursday ***Day 16***	Finish Lab Groups share results & calculations	• pvc pipe, pvc pipe connectors, end caps, ring stands, rope, hanging masses, metersticks, stopwatch

Friday ***Day 17***	Selected problems & solutions Complete Lab write-up. Include the purpose, independent & dependent variables, how you will change independent, how you will measure the dependent variable, what you had to keep constant. Show work to determine the Tension in the string (in terms of the acceleration of the falling mass) (include free body diagram) Thus far we have ignored the pulley (for good reason), but the string not only rotates the apparatus, but also rotates the pulley. If the rotational inertia of the inertia were a bit larger, how might it effect our results? Graph Torque vs Rotational Inertia What type of relationship can you conclude from the graph? Bonus Graph Torque vs angular acceleration and determine the meaning of the slope and/or the y-intercept.	
Day 18 ***Monday***	Groups share graphs from Labs Roll basketball as demo of translational & rotational motion Predict, which wins the race, hoop, marble, box that slides without rolling Crash Course Rotational Energy Hoop vs Box vs Marble have students find RKE Introduce RKE TIPERS B6-RT08: Spheres Rolling- Rotational Kinetic Energy TIPERS B6-QRT29: Solid sphere rolling along a track location at height RKE Lab Prep (work through 1st page and assign page 3-4 for homework)	• RKE Pre-Lab
Day 19 ***Tuesday***	Using Rotational Kinetic Energy For the Ball on a Ramp Lab Appendix E RKE Lab students let a ball roll down a ramp and off a tabletop, measuring where the ball lands, to figure out what fraction of the system's initial potential energy converts to rotational kinetic energy instead of translational kinetic energy. Students can design the experiment using available materials and making decisions about what measurements to take, which calculations are pertinent, and how many trials are advisable.	• Ramps, marbles, tennis balls, meterstick
Day 20 ***Wednesday***	Smarter Every Day RKE Motorcross Finish Lab	
Day 21 ***Thursday***	Bellringer: Today we'll introduce a new concept with momentum, but first let's contrast energy and momentum. Create a venn diagram of energy & momentum. (Include what energy can describe and what momentum can describe) Group Share: What did you do to figure out how much of the initial potential energy became rotational kinetic energy?	• Angular Momentum Day 1

	Introduce Angular Momentum Rotating Stool Handout Rotating Stool, Angular Momentum of a point mass Have one student stand on spinning platform holding a book/notebook in each hand. Have another student spin her/him while holding arms out. After one rotation have the student bring hands with notebook/book into body. Observe velocity increase. Ask students what happen. Review drawing pos time graphs & angular momentum of point mass hitting a rod Introduce Angular momentum formula. Show quick youtube video of angular momentum. such as https://www.youtube.com/watch?v=iWSu6U0Ujs8 Angular momentum is conserved. Emphasize Systems and Impulse Show linear momentum elastic collision to show momenta of 1 & 0 before and -1 and unknown after. Ask students what the unknown momentum must be (2) as analogy for bike wheel on stool demo. Now get student on spinning platform with bike wheel. Spin wheel and have student try to turn wheel over. https://www.youtube.com/watch?v=_XgYTP0kB7A Direct Measurement marble hitting block of wood Closing Task: p. 265 # 17 & 20 p. 269 # 17, 18 Closing Task: Ice skater spinning with outstretched arms. When he pulls limbs in he spins faster. Is there any external force? Does angular momentum change? Why does his angular velocity increase?	
Day 22 Friday	determine whether linear and angular momentum are conserved and if linear momentum can transfer into angular momentum like linear kinetic energy can transfer into rotational kinetic energy Marble Block Direct Measurement Video	• **Split up data collection between groups
Day 23	Show veritasium prediction of bullet block, have student groups write CER for prediction. Show result Handout example data sheet from direct measurement lab and draw conclusions about differences between linear & angular momentum. Pass out Rotation Review for students to begin to work through (still needs to add RKE example)	• Big dry erase boards or butcher paper for writing Angular Momentum Slides
Day 24	Pass out 2017 # 3 Free Response question, rubric, & student sample responses. Give students 25 minutes to score sample responses & discuss reasonings. (consider giving entire time for student review) Allow remainder of class for students to work on finishing review	

Accommodations for Special Populations	**Accommodations for instruction will be provided as stated on each student's (IEP) Individual Education Plan for special education, 504, at risk, and ESL/Bilingual.**