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| **TEAM Lesson Plan Template** |
| Teacher: Dr. Jason Alexander |
| Subject/Grade: 8th grade science (or 7th grade mathematics) |
| Lesson Title: Centripetal Acceleration |
| **STANDARDS** | **Identify what you intend to teach.** State, Common Core, ACT College Readiness Standards and/or State Competencies; Enduring Understandings and Essential Questions. |
| (Mathematics: 7.RP.A.3 Use proportional relationships to solve multi-step ratio and percent problems.) 8.PS2.3 Create a demonstration of an object in motion and describe the position, force*(s acting on)*, and direction of the object.This lesson emphasizes:Engineering practice: Planning and carrying out InvestigationsCCC: Structure and FunctionLearning performance: Students will plan and carry out an investigation to describe the force acting on an object in motion highlighting structure and function of the system.  |
| **OBJECTIVE(s)/Sub-Objectives** | **Connect prior learning to new learning.** Clear, Specific, Observable, Demanding, High Quality, Measurable, Aligned to Standard(s), and Integrated with other subjects, build on prior student knowledgeStudent-Friendly (I Can Statement) |
| I can measure the time it takes a car to travel around a circle. I can calculate the centripetal acceleration of a car. I can calculate the force acting on a car to keep it traveling in a circle.  |
| **MATERIALS AND RESOURCES**  | **Content-related:** Clearly supports lesson objective(s); rigorous & relevant; Incorporates multimedia & resources beyond the textbook.  |
| **Materials** This activity requires a significant amount of space on a smooth flat surface. It is best done in a hallway, gym, or on a wide sidewalk. The amount of required space can be reduced by using shorter pieces of string, but a 6-inch radius is approximately the minimum practical length; Students will need room to kneel near the car while staying out of its path. It is helpful, but not necessary, to be able to tie a bowline knot. <https://www.youtube.com/watch?v=ALQzG-mx-qw>**Per group**: 1 constant velocity car with two C-cell batteries, about 1 meter of string, 1 meter stick, 1 pencil, 1 student worksheet, calculator, stopwatch. Also a table leg, ring stand, dowel, or another pencil to serve as the center of rotation. **Per class:** Projector and computer with internet access, white board with markers. **What if the technology is not working?** If the cars are not working, do the activity another day. **Routine for distributing materials:** Students should begin class in their groups. One member from each group should come forward to pick up worksheets and a car. Another member should pick up the meter stick.  |
| **ACCOMMODATIONS/ADAPTATIONS** | **Learning styles and interests.** Anticipate learning difficulties, regularly incorporate student interests & cultural heritage; differentiate instructional methods. |
| **Modifications/Plans for Diverse Learners *(NOTE: Clearly identify where you will use each of these in your lesson; do not just check the box!)*****Differentiation****\_\_x\_\_ Flexible Grouping** The radius measurement task, the time measurement task, operating the car, and recording results/arithmetic are each different and may be performed by different group members. **\_\_x\_\_ Process** It may be necessary to tie knots for some groups. Also, this activity invites several follow-on activities/questions from many different levels of Bloom’s Taxonomy. See the “early finishers” section below.**Accommodations****\_\_\_ Preferential Seating \_\_\_ Extended Time \_\_\_ Small Group \_\_\_ Peer Tutoring** **\_\_\_ Modified Assignments \_\_\_ Other** **Early Finishers:**  Plan and carry out an investigation to measure the magnitude of the center-directed force acting on the car directly using the scale. Ensure that the radius is approximately equal to the radius you used without the scale. Did you get the same value for magnitude of the force as you calculated in the first part of the activity?  |

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| **MOTIVATING STUDENTS/ANTICIPATORY SET** | **“Hook”: Engage students’ attention and focus on learning.** Personally meaningful and relevant. |
| Khan Academy video deriving formula for centripetal acceleration (almost 10 minutes): <https://www.khanacademy.org/science/ap-physics-1/ap-centripetal-force-and-gravitation/centripetal-acceleration-ap/v/visual-understanding-of-centripetal-acceleration-formula>Alternative: Ask the question: If a car does not change speed, can it undergo acceleration? Volunteer: Post the “I can” statements.  |
| **INSTRUCTIONAL PROCEDURES** | **Step-by-Step Procedures-Lesson Sequence: Basic to Complex.** Lesson includes visuals, modeling, logical sequencing and segmenting (beginning, middle, ending); essential information; concise communication; grouping strategies; differentiated instructional strategies to provide intervention & extension; seamless routines; varied instructional strategies; key concepts & ideas highlighted regularly. |
| ***Introductio*n**After showing the video or discussing the “speed/acceleration question,” have students count off and assign group roles. Have reader/recorders come collect materials and worksheets. Demonstrate each group role. Instruct them to complete the worksheet. **Middle**Monitor students as they complete the activity and record results on the worksheet. Ask questions to prompt them as necessary. If students finish early, prompt them with activities from the “early finishers” section of this plan. **End/Closure**:  Have students return their cars and string to a central location. Regain the whole group’s attention and discuss what was learned. Compare lengths of strings that groups used. If there is a long string and a short string, clearly different in length, have the groups announce the period of their cars and the magnitude of the acceleration that they calculated. **Motivating Students** \_x\_ Relate to Real World Most students are familiar with cars. This activity connects the motion of an actual to forces acting on the car.  \_x\_ Verbal Reinforcement The teacher will monitor students’ work throughout the activity to provide reinforcement. **Presenting Instructional Content** \_x\_ Lecture/notes There is a brief discussion at the beginning to discuss Newton’s 2nd law and ensure that students know the equation F = ma. \_x\_ Video (optional) may be omitted. \_x\_ Hands on \_x\_ Guided Practice The worksheet provides guided steps for students to complete the hands-on activity. ***Instructional strategies:******Input -* Hook (Set)** **Modeling and Guided Practice *–*** The worksheet lays out steps for students. The teacher will monitor their work and ask questions to prompt them if they are stuck.  **Check for Understanding (CFU) –** ***What am I doing for students that progress at different rates?*** Encourage students to help each other within their groups. If one group is significantly ahead of another, ask one group to help the other. If necessary, provide help with the algebra (“the algebra” here is essentially unit conversions and substituting values into formulas. These are not the main point of this activity). ***What do I do if they get it?*** If students handle the activity smoothly have them either 1) (short time available) repeat the activity with a different radius or 2) (longer time available) measure center-directed force directly with approximately the same radius. Compare the measured force to the calculated force. ***What do I do if they don’t get it?*** Use one of the following: Review the fact that acceleration is a change in velocity and that velocity involves speed and direction. Since the direction of the car’s motion is changing, then it must experience acceleration. Have the student hold the center of the string in their fingers rather than wrapping it around a table leg. Have the student hold her fingers still and let the car drive with the string tight. The car will move in a arc and the student can feel the force pulling on her fingers. Try that Khan Academy video again.  |
| **QUESTIONING/THINKING/PROBLEM SOLVING (embedded throughout)** | **Balanced mix of question types.** Utilizes Blooms Taxonomy/Webb’s Depth of Knowledge; high frequency; purposeful & coherent; require active responses; balance based on volunteers/non-volunteers, ability, & gender; lead to further inquiry & self-directed learning.  **Implement four types of thinking (Analytical, Practical, Creative, & Research-based) & Teach/Reinforce problem-solving types**. Provide opportunities for students to generate ideas & alternatives; analyze, evaluate & explain information from multiple perspectives& viewpoints. |
| **Questioning** These questions will occur throughout the activity as prompts based on groups’ or individual students’ progress. **Knowledge:**Are there batteries in the car? Is the switch set to On or Off?Are the lights on?  **Comprehension:** Did we calculate the car’s speed in this activity? What did we use instead of speed in this activity? **Application:**How do we convert centimeters to meters? How do we convert grams to kilograms? Why do we measure the time for 10 revolutions to calculate the period of the car? How could we calculate the speed of the car from the period? Have you seen a NASCAR race? What provides the centripetal force during one of these races? [ friction between the tires and the track, but also gravity – the curves are banked so that downhill is toward the center of the curve ] **Analysis:** The instructor in the video ( <https://www.khanacademy.org/science/ap-physics-1/ap-centripetal-force-and-gravitation/centripetal-acceleration-ap/v/visual-understanding-of-centripetal-acceleration-formula> ) came up with the formula $a\_{c}=\frac{V^{2}}{r}$, but the formula on our worksheet is $a\_{c}=\frac{4π^{2}r}{T^{2}}$. Are both of these correct? How can we convert from one to the other? [ This is really a math, not a science question. The applicable math standard is 7.RP.A.3 ] In an earlier activity, we measured the magnitude V of the car’s velocity. If we use this value of V in the formula $a\_{c}=\frac{V^{2}}{r}$, do we get the same value as we calculated with the formula $a\_{c}=\frac{4π^{2}r}{T^{2}}$ ? Why or why not? **Synthesis:**[Introduces CCC: cause and effect] What will happen if we use a longer string? Will the period increase or decrease? Will the magnitude of the acceleration increase or decrease? Plan and carry out an investigation to measure the center-directed force acting on the car directly using the scale. Ensure that the radius is approximately equal to the radius you used without the scale. Did you get the same value for magnitude of the force as you calculated in the first part of the activity?**Evaluation:** **Thinking**  \_x\_ **Practical** –Students have to tie knots, remain clear of the path of the car, choose a start point to count laps, and time the car’s travel. \_x\_ **Creative**– Students can suppose or predict what would happen to speed and acceleration if they use a longer or shorter string. \_x\_ **Analytical** – Students analyze the motion of the car and express the motion in a variety of units. They convert units and calculate values from formulas.  \_x\_ **Research-based** – Students observe the car’s motion and calculate acceleration even though speed does not change. This activity helps them explore the difference between speed and velocity. **\*What am I going to do to give Students an opportunity to?** **1. Generate variety of ideas:** **2. Analyze problems from multiple viewpoints:** **Problem Solving *Note: Teach 2 or more types of problem solving (NOTE: Clearly identify where you will use each of these in your lesson; do not just check the box!)*****\_x\_\_** **Observing and Experimenting** Students observe the motion of the car to gain data about acceleration that they use to calculate force acting on the car. **\_x\_\_ Predicting Outcomes** Students have the opportunity to predict what will happen with a longer or shorter radius. **\_x\_\_ Improving solutions** There are several variations of the activity that students should be encouraged to explore. As examples, there are good knots to use and other knots that are not so great. A smooth notch at the right height on a round stick (pencil) will keep the center of the string from sliding down the center pole. If more room is available, a longer string may be used. Groups can communicate so that one group uses a short string, another uses a medium-length string, and another uses a long string. They can compare force and acceleration for the different lengths. **\_x\_\_ Creating and Designing** Students who finish early may be challenged to measure force directly. They will have to come up with a procedure, and they will have to keep the radius (approximately) the same as when they calculated force.  |

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| **GROUPING** | **Maximize student understanding & learning** Varied group composition (race, gender, ability, & age); clearly understood roles, responsibilities & group work expectations; accountability for group & individual work; student opportunities for goal setting, reflection & evaluation of learning. |
| * Heterogeneous groups of three or four
* Roles. Reader/recorder, Driver, Timer, Measurer
* The teacher will have students count off in each group. The 1s become readers, the 2s drivers, etc. In a group of 3, the Reader/recorder becomes the Reader/recorder/Timer. The teacher will model each role.
* Transition. Students should begin class in their groups and remain in the groups throughout.
* Product. Students will complete a worksheet.
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| **ASSESSMENT** | **Formative and/or summative assessment.** A variety of assessments, including rubrics, measure achievement of objectives and informs instruction.  |
| ***Assessments: aligned with state stds; measurement criteria; measure student performance in more than 2 ways (project, experiment, presentation, essay, short answer, multiple choice test) (NOTE: Clearly identify where you will use each of these in your lesson; do not just check the box!)*****\_\_x\_ Teacher Made Test** A future test may ask students to “Describe the direction of acceleration for an object moving at a constant speed in a circle” or “If an object moves in a circle at a constant speed, what effect does centripetal acceleration produce?” **\_\_x\_ Worksheet** Students will submit the worksheet for assessment. *\****Students should achieve \_\_\_\_\_% mastery of this objective: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_** |
| **CLOSURE** | **Reflection/Wrap Up.** Summarizing, reminding, reflecting, restarting, connecting. |
| * ***Review/Summary: wrap up what has been learned and accomplished in the lesson (even if they are in the middle of an exercise, it is still important to summarize to the point where they are now). Ideally involve students in this synthesis.***
* ***Preview for next lesson: link what they did to day with where they are going next.***
* ***Upcoming assignments: remind them of any upcoming assignments.***

***Today we…. Turn to your partner and…. Let’s review our I Can statements……*** **Here is your exit ticket for today**: **Follow-up Activities/Extension *These may be designed to create a longer or more intense lesson. For example, if the class is able to cover the material in a lesson much faster than expected, extensions may prove helpful. Extensions may also be useful in various parts of a lesson where the teacher (and class) decides they should spend more time on a skill or topic.******Reflection: You must reflect on every lesson you teach.*** |

**NOTES:**

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