**Traffic, Traffic Lights, and Autonomous Vehicles**

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| **Lesson Plan for Grades: High School (10th-12th Grade)**  **Length of Lesson: 2-3 Class periods** |
| **Authored by:** UT Environmental Science Institute (Erick Jones)  **Date created:** 12/01/2018 |
| **Subject area/course:**   * Physics, Economics |
| **TEKS/SEs:**  **§112.38. Integrated Physics and Chemistry**  (4) Science concepts. The student knows concepts of force and motion evident in everyday life. The student is expected to:   * (A) describe and calculate an object's motion in terms of position, displacement, speed, and acceleration; |

**Questions to Answer (Objectives)**

1. How do human reactions times compare to autonomous reaction times?
2. How does traffic design take stopping distance into accounts?
3. How do supply and demand principles affect traffic?
4. How many cars can roads and highways handle at a given time?
   1. At different speeds? Following distances?
5. What can be done to reduce the number of roads and highways needed?

**Lesson Plan Outline**

1. **Determining Reaction Times** (30-45 minutes)
   1. Give an overview of why Autonomous Vehicles will have fast reaction times, due to various sensors and computer processing ***(Engagement)***
   2. Encourage students to design experiments that measured their reaction times. ***(Exploration)***
      1. Ruler experiment
      2. Reaction Experiment online (<https://faculty.washington.edu/chudler/java/redgreen.html>)
   3. Give feedback on how to get more accurate results ***(Explanation)***
      1. Discuss how their ruler experiment can be improved
      2. Or discuss how the online reaction test works.
   4. Compared their results to empirical results ***(Elaboration)***
      1. Have them google what the reaction times are in practice
      2. <https://copradar.com/redlight/factors/>
   5. Give prizes to the winning groups who were closest to the empirical results ***(Evaluation)***
   6. ***Sources and Materials***
      1. <http://www.nanosonic.com/wp-content/uploads/2017/07/Module-1_Lesson-4_Traffic-Congestion_Lesson-Plan_HS.pdf>
      2. Ruler for dropping
      3. Computers for online based reaction times.
2. **Stopping Distances** (30-45 minutes)
   1. Present the problem of how to design traffic signals and why it is important (**Engagement)**
      1. <https://www.traffic-signal-design.com/traffic_signal_design_process.htm>
   2. Go over d = v22 – v12 / 2\*(mu)\*g and how different (mu) – coefficient of frictions affect stopping distances (**Exploration)**
   3. Have the students calculate how long should a light be before it turns yellow for streets of a certain speed? **(Exploration)**
      1. Keep in mind reaction times and the stopping distance equation
   4. Give feedback on how to get more accurate results ***(Explanation)***
      1. Discuss how what reaction times to use and other safety factors.
   5. Compared their results to empirical results ***(Elaboration)***
      1. Have them google what the traffic times are in practice
      2. <https://gizmodo.com/how-long-a-yellow-light-should-be-1647634895>
      3. Discuss flaws in current yellow light design **(Engagement)**
   6. Compare their results to empirical results (**Elaboration)**
      1. Determine what results should be the best as a group
   7. Give prizes to the winning groups who were closest to the best empirical results ***(Evaluation)***
   8. Sources and Materials
      1. <http://www.nanosonic.com/wp-content/uploads/2017/07/Module-1_Lesson-2_Stopping-Distance-and-Crash-Avoidance_LAB_HS.pdf>
      2. Pen and Pad
      3. Computer for Googling
3. **Basic Supply and Demand** (30-45 minutes)
   1. Explain Supply and Demand with simple examples (**Engagement)**
      1. <http://familymint.com/blog/a-really-simple-way-to-explain-supply-demand-to-kids#.XAlfaWhKhPY>
      2. <https://www.youtube.com/watch?v=GqeRnxSuLFI>
   2. Get students to understand how incentives work by playing a game where they buy and sell energy. (**Exploration)**
      1. Play the game in the sources section
      2. Discuss the results of the first game (**Explanation)**
         1. Why did some people make out better
   3. Add a tax to the game to see how outside influences affect decisions. (**Elaboration)**
   4. Go over the results of the game and reward winners (**Evaluation)**
   5. Sources and Materials
      1. <https://www.cmu.edu/gelfand/education/k12-teachers/succeed/decision-making-lesson-plans/supply-demand.html>
      2. Deck of Cards
      3. Pen and Paper to keep track of transactions
4. **Traffic** (30-45 minutes)
   1. Run a simple experiment where students move in a circle to see why traffic jams start. (**Engagement)**
      1. Have the students move in a circle without touching and observe the phantom traffic jams that pop up
      2. Modify the experiment where the students have to communicate by putting their hand on the other student’s shoulder.
      3. Discuss whether one way was better and correlate that with real life traffic (**Explanation)**
   2. Calculate what the following distance of a car is given reaction times and stopping distances. (**Exploration)**
      1. Using the stopping distances and reaction times from the previous activities calculate how close cars should be to each other
   3. Compare the calculated following distances to empirical results. (**Elaboration)**
      1. Find empirical results and discuss if they are good metrics
   4. Give the group with the closest results to the best empirical results a prize (**Evaluation)**
   5. Using the calculated following distances calculate how many cars go pass a given point on a highway at a given time (exclude the time it takes a car to go by) (**Elaboration)**
      1. Encourage them to realize a given point represents one lane of traffic
   6. Sources and Materials
      1. <http://jliszka.github.io/2013/10/01/how-traffic-actually-works.html>
      2. Pen and paper and old results
5. **Road/Highway Capacity (30-45 minutes)**
   1. Refresh the students on all the things they have learned in this lesson plan (**Engagement)**
   2. Continue the reasoning of how many cars can clear a lane in an hour but calculate for decreasing following times. (**Exploration)**
      1. Calculate how long it takes a car to clear a point from bumper to bumper (16ft to 20ft car) at various speeds
      2. <https://en.wikipedia.org/wiki/Family_car>
   3. Ask how you could reduce the number of lanes needed. Inform the students of the peak number of cars at a given time in Austin (74,500 cars) (**Elaboration)**
      1. Less cars, smaller cars, more motorcycles
      2. Shorter following distances
      3. Faster average speeds
      4. <https://www.austinchamber.com/upload/files/2016-mobility-report.pdf>
   4. From the given answers ask how these things could be implemented. (**Explanation)**
      1. For less cars remind students of the lessons on supply and demand
      2. Shorter following distances. Remind how AVs have faster reaction times.
      3. Faster average speeds, again faster reaction times and think about highway speed limits. Ask why they are what they are.
   5. Have the students work in teams design a city where they have to move traffic from 5 population centers. **(Exploration)**
      1. Break up the city population by demographic maps.
         1. <http://www.austintexas.gov/page/demographic-maps>
         2. Population: 20% North, 50% South, 10% West, 15% East, and 5% downtown
         3. Jobs: 25% North, 25% South, 25% West, 15% East, 10% Downtown
         4. Each sector has 4 population hubs on the middle of each side and on directly in the center
         5. Downtown only has a population hub in the center
         6. Lay down minimal roads needed all 2 lane roads (see below)

20 Thousand Commuters

25% of jobs

10 Thousand Commuters

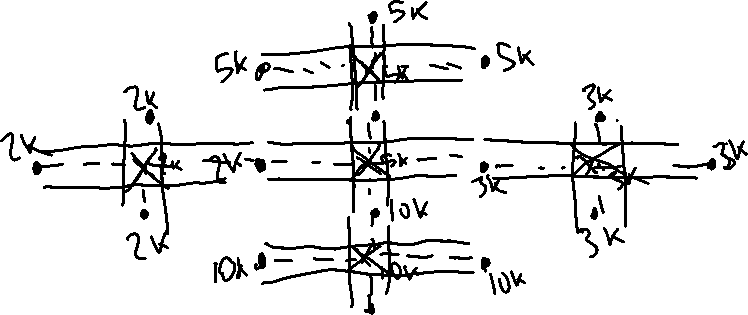
25% of jobs

5 Thousand Commuters

10% of jobs

15 Thousand Commuters

15% of jobs



50 Thousand Commuters

25% of jobs



* + 1. Set the basic rules for the project
       1. You can go to job hub by bike if it is adjacent to you otherwise you need a car
       2. Set the peak to 100,000 job commuters at a time.
          1. Mention the peak *cars* is only 74,500
       3. Each area has a certain amount of people that go to different areas
          1. North: ¼ go West, ¼ go Downtown, ½ stay
          2. South: 1/5 go West, 1/10 go downtown, 1/5 go north
          3. West: All stay West
          4. East: All stay East
          5. Downtown: all stay Downtown
    2. The problem is to build the minimal amount of lanes to let everyone get to the job center in the appropriate area in less than 30 minutes travel time
       1. Have to figure out how many travelers will travel on each stretch of road
       2. Then decide if you want to expand the lanes of each road at certain points or build completely new highways
       3. Can also try to modify how commuters get around, but have to justify it
          1. i.e. Encouraging more bikers by building bike lanes, or penalizing driving a car
  1. Discuss the different methods and determine the feasibility of them all (**Elaboration)**
     1. Have the groups compare their cities
     2. Have them discuss how the different cities would feel culturally
  2. Have the students vote on which group should win based on their solution, the teacher has veto power and ensures each group has a feasible solution. The winning group receives a prize (**Evaluation)**
  3. Sources and Materials
     1. Butcher Paper

**Electromagnetic Questions (Next Lesson Plan)**

1. How do the sensors work?
   1. LIDAR
   2. RADAR
2. What are the limitations of the sensors?
3. How do communicating cars work?
4. Computational Power Needed to Process
5. What could be done to reduce sensors or computational requirements?