# Using MEMS Accelerometers in AP Physics C: Measurement Principles and Data Analysis Considerations

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## Summary

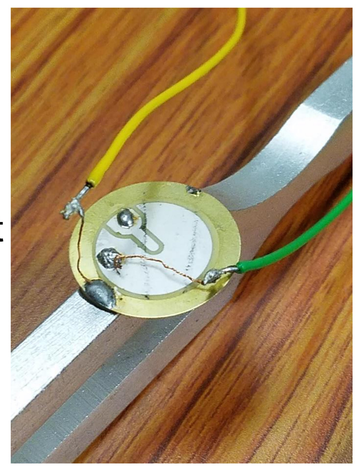
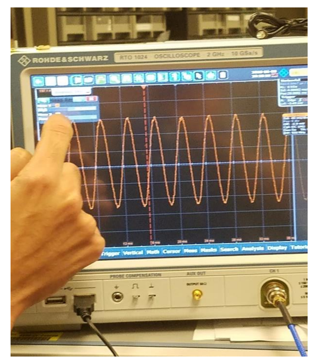
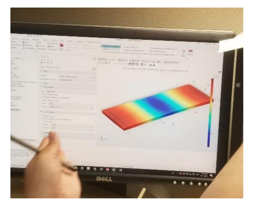
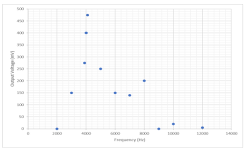
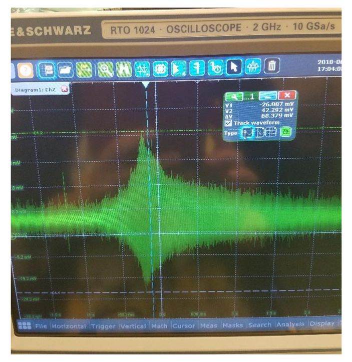
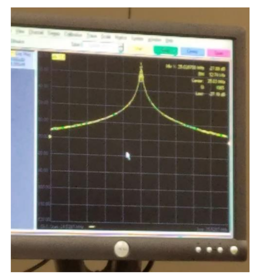
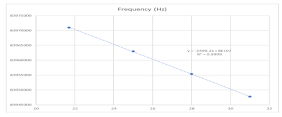
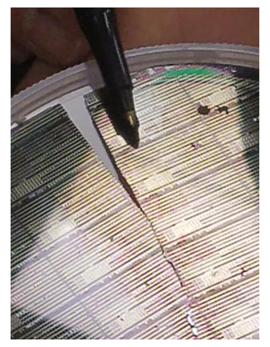
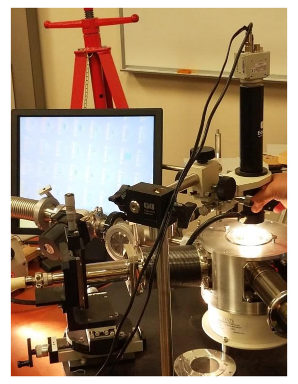
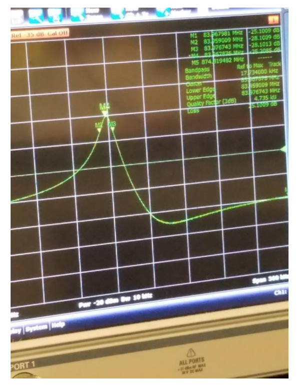

- The Internet of Things (IoT) is a fast-growing and opportunity-rich area of research and development
- UCF's CoMET (Collaborative Multidisciplinary Engineering design experiences for Teachers) program sponsored by NSF's RET (Research Experience for Teachers) provides teachers from a variety of STEM subjects an opportunity to learn and experience some of the integral parts of IoT technology: sensors, hardware, networking and software/programming
- Sensors: MEMS (Microelectromechanical systems) offer incredible capabilities in modern devices and a better understanding of them leads to both excellent "real-world" examples in physics courses and an increased number of measurement possibilities
- Hardware: FPGA (Field-Programmable Gate Arrays) offer a cost-effective flexibility in rapidly designing and testing devices as compared to ASIC (Application-Specific Integrated Circuits); Introduction to Logic Circuit design

Networking/Software: Introduction to some of the communication methods and protocols needed for IoT applications; Introduction to basic computer logic and programming, including C and Java programming languages

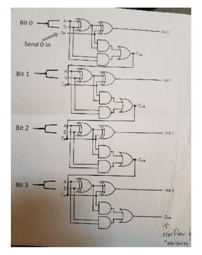
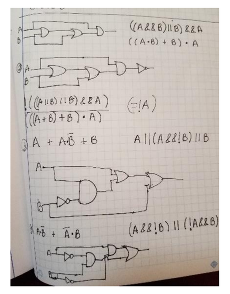

## Research Activities

- MEMS Resonators
  - Lots of physics ☺
    - Resonance!
    - Q-factor and why I shouldn't skip teaching it!

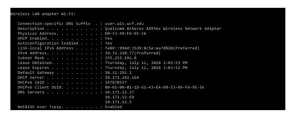
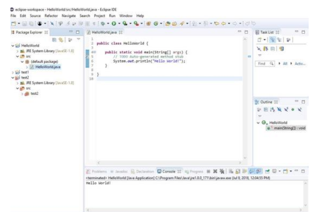
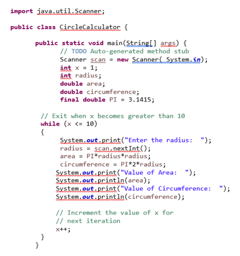
    Some MEMS devices
    - Accelerometers
      - Piezoelectric
      - Capacitive
    - Gyroscopes
      - Coriolis force application
    - Magnetic field sensors
    - Microphones
    - Pressure sensors
    - Temperature Sensors
  - Design/Simulation/Testing
  - Fabrication – lots of chemistry!

- Hardware
  - Intro to FPGA
  - Logic Gates and Circuits

- Networking/Software
  - So many protocols!!!
  - Programming – extremely useful for physics ☺

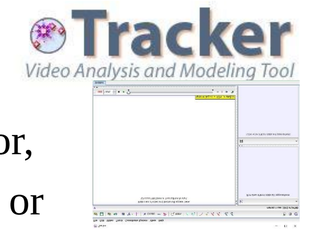
## Lesson Plan

Goals:
- Introduce students to MEMS sensors using accelerometers
- Examine data collection and analysis/manipulation methods for kinematic data in context of calculus relationships (slopes/derivatives; areas under curves/integrals)
- Introduce students to Python programming and simple numerical integration techniques so that students can
  - Relate discrete numerical methods to analytical calculus
  - Describe how "drift" may result in determination of position from inertial measurements.

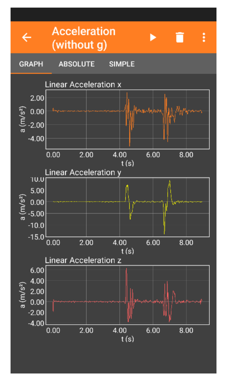
(Day 1) Class Discussion about how we measure kinematic variables:
- Elicit student ideas
- Brainstorming and Quick Research in small groups
- Informal 3-5 minute whiteboard presentations on accelerometer types
- Calculus and Kinematics class exercises

(Days 2 and 3; whiteboard presentation Day 7) Measuring Kinematic Data Activity
- Students will design and conduct an investigation using various means to determine displacement and acceleration of an object.
- They will compare displacements and accelerations

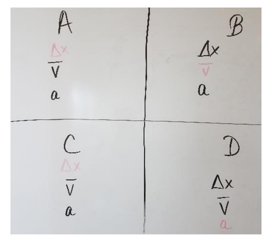
from data acquired through (1) video analysis, (2) a Vernier motion detector, (3) photogates, and (4) Vernier's low-g accelerometer, PocketLab Voyager or smartphone accelerometer measurements.

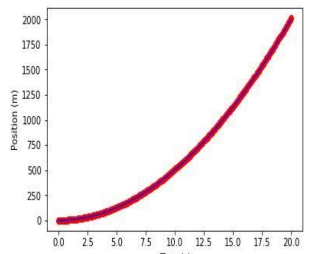




- Students will analyze data and submit an informal group report.
- On the day the report is due, students will participate in a whiteboard presentation activity.

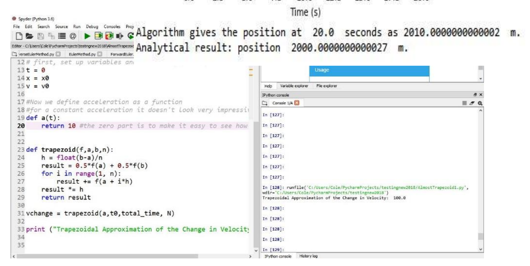


(Days 4-6) Introduction to Numerical Integration
Using the Python (free, open source) programming language, students will learn basic numerical integration techniques and examine/compare errors in results.

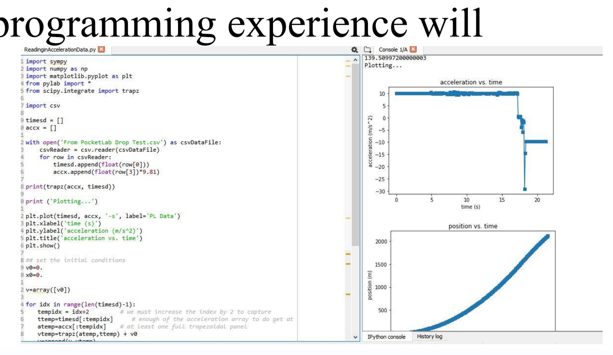


- Sample programs will be modeled and discussed in class
- Students will complete short programming exercises related to

Euler methods and trapezoidal methods.



Ideally, the end goal is to use numerical integration techniques to integrate data produced by the accelerometer part of the experiment, but this may be too difficult to implement without spending more time than available. Students' previous programming experience will determine if we attempt to do this.



## Lessons Learned

Technical/Skills
- Lots of physics-related MEMS examples to tie-in throughout curriculum
- Refresh of very rusty C and Java programming skills
- Basics of networking and hardware introduction – mainly learned how much there is to know
- Use of Raspberry Pi – hope to use in classes

Education/Teaching
- Medium-difficulty scaffolding as important as building easy-level supports
- Learning information without context is difficult and frustrating
- Importance of resonance – plan to emphasize for future physics classes
- Usefulness of basic programming skills – plan to incorporate more Python programming in AP Physic C (maybe other classes too if successful)

## Implementation Strategy

The lesson will be delivered near the beginning of first quarter for AP Physics C.
- Elicit prior knowledge
- Cooperative learning and group problem solving
- Student-designed experimental procedures
- Summarizing and Compare/Contrast
- Reflections on learning
- Individual practice and exercises

Formative Assessments – informal during class discussions, groupwork and group whiteboard presentations

Summative Assessment – Lab Report; Group Whiteboard Presentation of Lab Analysis; Student submission of programming exercises

Additionally, I plan to incorporate MEMS sensors into the rest of the AP Physics C curriculum throughout the year:
- 2nd Quarter: MEMS Gyroscopes
- 3rd Quarter: revisit capacitive and piezoelectric accelerometers and explore the electric principles behind the transduction mechanisms
- 4th Quarter: MEMS magnetic field sensors

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