PHYSICS/AP PHYSICS 1
SYLLABUS
2017 – 2018[1] [2] [3]

The H.M. Jackson Way:
A rigorous and challenging curriculum
that prepares students for the future.

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- COLLEGE BOARD (AP PHYSICS 1): `https://apstudent.collegeboard.org/apcourse/ap-physics-1`
- DATE OF AP PHYSICS 1 (ALGEBRA-BASED) EXAM: Tuesday, May 8, 2018 (12 PM)

Course Description

The AP Physics 1 course will meet every day for normally 55 minutes. The AP College Board has designed the AP Physics 1 course as an equivalent to an algebra-based college-level physics class. At the end of the course, students will take the AP Physics 1 Exam, which will test students' knowledge of both the conceptual and mathematical formulations of the requisite concepts.

More specifically, students are expected to demonstrate their learning through the creation, interpretation, and analysis of data. Students will then be assessed through the production of their written work, tasks, laboratory reports, practicums, oral presentations, projects, tests/quizzes, and composition notebook. The composition notebook is used every day for classwork, notes, tasks, labs, practicums, etc. Therefore, to be successful in this course, it is necessary that students keep an organized and updated composition notebook.

[1] Adapted from Dolores Gende, College Board, & Andrew Sevald
[2] Last Modified: 2017/06/07 at 8:47am
[3] NB: this syllabus is subject to change

Text/Required Materials

- College Physics: A Strategic Approach (3rd Edition), Randall D. Knight (Professor Emeritus) and Brian Jones. (Required – Available on Moodle)

Topics (Brief)

31 Weeks of Instruction Before AP Exam: Tuesday, May 6, 2018 (12 PM)

- UNIT 1: **PHYSICS SKILLS** *(2 Weeks)*
  - *Graphing Skills; Laboratory Skills*
- UNIT 2: **KINEMATICS** *(3 Weeks)*
  - *Constant Velocity; Uniform Acceleration; Linear Motion; Projectile Motion*
  - *Textual Readings*
    - ***Knight**: Chapter 1 (1-1 through 1-5); Chapter 2 (2-1 through 2-8); Chapter 3 (3-1 through 3-7)* ***[62 pages]***
- UNIT 3: **DYNAMICS** *(3 Weeks)*
  - *Interactions: Forces; Newton's First Law; Newton's Third Law; Newton's Second Law*
  - *Textual Readings*
    - ***Knight**: Chapter 4 (4-1 through 4-7); Chapter 5 (5-1 through 5-8)* ***[44 pages]***
- UNIT 4: **CIRCULAR MOTION & GRAVITATION** *(2 Weeks)*
  - *Circular Motion; Gravitation*
  - *Textual Readings*
    - ***Knight**: Chapter 6 (6-1 through 6-6)* ***[20 pages]***
- UNIT 5: **ENERGY** *(4 Weeks)*
  - *Energy and Energy Transfer; Conservation of Energy*
  - *Textual Readings*
    - ***Knight**: Chapter 10 (10-1 through 10-6 and 10-8)* ***[22 pages]***
- UNIT 6: **MOMENTUM** *(3 Weeks)*
  - *Impulse and Momentum; Conservation of Momentum*
  - *Textual Readings*
    - ***Knight**: Chapter 9 (9.1 through 9.7)* ***[19 pages]***
- UNIT 7: **SIMPLE HARMONIC MOTION** *(3 Weeks)*
  - *Simple Harmonic Motion; Spring Mass Systems; Simple Pendulum*
  - *Textual Readings*
    - ***Knight**: Chapter 14 (14-1 through 14-5)* ***[16 pages]***
- UNIT 8: **TORQUE & ROTATIONAL MOTION** *(4 Weeks)*
  - *Rotational Kinematics; Torque; Rotational Dynamics; Rotational Kinetic Energy; Conservation of Angular Momentum*

  - *Textual Readings*
    - ***Knight**: Chapter 7 (7-1 through 7-7)* ***[26 pages]***

- UNIT 9: **MECHANICAL WAVES & SOUND** (*2 Weeks*)
  - *Transverse and Longitudinal Waves; Interference Sound; Standing Waves*
  - *Textual Readings*
    - ***Knight**: Chapter 15 (15-1, 15-2, 15-7); Chapter 16 (16-1 through 16-4 and 16-7)* ***[26 pages]***

- UNIT 10: **ELECTRIC CHARGE & ELECTRIC FORCE** (*2 Weeks*)
  - *Electric Force; Electric Current*
  - *Textual Readings*
    - ***Knight**: Chapter 20 (20-1 through 20-3)* ***[11 pages]***

- UNIT 11: **DC CIRCUITS** (*1 Week*)
  - *DC Circuits*
  - *Textual Readings*
    - ***Knight**: Chapter 22 (22-1 through 22-6); Chapter 23 (23-1 through 23-5)* ***[30 pages]***

- UNIT 12: **EXAM REVIEW** (*2 Weeks*)
  - *Preparation for AP Physics 1 Exam*
  - *Textual Readings*
    - *Practice Tests*

Required Materials

- Bound composition notebook (graph-paper is preferable)
- Pens/pencils,
- Scientific calculator (graphing calculator is preferable). **Note**: No personal communication devices can be used for calculator functions during tests and quizzes.

Grading Categories

Formative Assessments: 80%

- Quizzes
- Labs (Informal Lab Reports)
- Tasks (work assigned during class)
- Class Notes
  - Formative assessments demonstrate your learning progress and reflect the **most recent learning**.
  - Formative assessments **cannot be re-taken**.

Summative Assessments: 20%

- Unit Tests
- Lab Practicums (Formal Lab Reports)
  - Summative assessments demonstrate your learning at the **end of the unit of study**.
  - Summative assessments can be re-taken only once and only if you score an 85% or below and this grade will replace your original grade even if it your latest grade is lower.

Curve

Tests will be curved when necessary

Grading Scale

As	Bs	Cs	Ds/Fs
A = 93.0% – 100.0%	**B+** = 87.0% – 89.9%	**C+** = 77.0 – 79.9%	**D+** = 67.0 – 69.9%
A – = 90.0% – 92.9%	**B** = 83.0% – 86.9%	**C** = 73.0% – 76.9%	**D** = 60.0% – 66.9%
	B – = 80.0% – 82.9%	**C –** = 70.0% – 72.9%	**F** = 0.0% – 59.9%

Lab Journal Guidelines

Example of the elements that may be required for either a formal or informal lab report (or both):

(I) **Lab Investigation Question**

The problem or task to be investigated is written as a question by the student. It provides the overall direction for the laboratory investigation and must be addressed in the conclusion.

- If the investigation involves a prediction, the students know that:
  - A Hypothesis is a general belief, pattern, model, or rule developed from observations. Hypotheses can be used to develop predictions.
  - A Prediction is a statement that describes the outcome of a specific experiment (prior to conducting the experiment). Predictions must be based on the hypothesis being tested. The statement should be written as: IF (hypothesis) is true, AND (experiment), THEN (prediction).

(II) **Equipment & Equipment Setup**

- A list of all laboratory equipment used in the investigation
- A detailed and labeled diagram to illustrate the configuration of the equipment

(III) **Step-by-Step Procedure**

- Neatly explained in a numbered sequence
- Identify and name all experimental variables
- Briefly describe how the independent variable is controlled
  - **Hint**: your audience is not necessarily composed of Physics types! Someone who was not present during the lab should be able to understand how the experiment was performed and be able to reproduce the results by reading your procedure.

(IV) **Data**

- What data needs to be taken?
- How many trials do you have to include?
- How is data reported?
  - **Hint**: Be sure to clearly distinguish between measured quantities and calculated quantities. In this section you will only record your measurements.

(V) **Data Analysis**

- How do you interpret data?
- Include graphs and analysis of graphs as appropriate
- Show all calculations from graphs as appropriate.
- State the meaning of the slope and discuss the significance of the y-intercept when appropriate
- Calculations for any theoretical values should be neatly shown A sample calculation must appear describing the method of obtaining all derived values
- The comparison between experimental results and theoretical values should be done by finding percent errors
- If the results are obtained by two different ways, the comparison should be done by calculating percent differences

(VI) **Conclusions**

- Does the evidence support your claim? Explain why or why not.
- Discuss any questionable data or surprising results
- Explain the possible source of any error or questionable results
- Discuss the uncertainties in your measurements and how they affected the reliability of your results
- Suggest changes in experimental design that might test your explanations

Make-Up Work

- If you are absent, it is your responsibility to see me regarding missed work the day you return from your absence. Your grade will be assigned a **zero** until the work is completed.
- All make-up must be completed within the number of your absence.

Attendance/Tardies

We will follow the attendance policy of Jackson High School. This can be found in the Student Handbook, specifically the section on Student Responsiblities and Rights: `http://www.everettsd.org/domain/1493`.

Academic Honesty

We will follow the academic honesty policy of Jackson High School: `http://www.everettsd.org/domain/1493`.

Classroom Management: Behavioral Incidences

It is the right of all students to learn without disruptions. Guidelines outlined in the Student Rights and Responsibilities Handbook will be followed: http://www.everettsd.org/domain/1493.

- A 'behavioral incident' can be defined as *any event that interferes with the learning process, environment, or success of the class*. This definition follows from the policy of the Everett School District that all students have the right to learn without disruption. This can be found in the Student Handbook, specifically the section on Student Responsiblities and Rights: http://www.everettsd.org/domain/1493.
- The following is a general outline that we will adhere to, though it may be amended given the severity of the incident:

1st Incident (Any Combination of Steps Below)

(a) Verbal Warning and/or Student Conference

(b) 1 – 2 Detentions – Lunch and/or After-School (Parent Contact)

2nd Incident (Any Combination of Steps Below)

(a) Verbal Warning and Student Conference

(b) Parent Contact

(c) 1 –3 Detentions – Lunch and/or After-School (Parent Contact)

3rd Incident and Beyond (Any Combination of Steps Below)

(a) Student Conference and 1 –3 Detentions – Lunch and/or After-School (Parent Contact)

(b) Adminstator Referral

Note: *The severity of an infraction may require an automatic office referral. See Student Handbook for examples.*

Phone Use

Phones will be used for only academic purposes, as in video analysis.

7 Science Practices

The Science Practices describe the knowledge and skills that students should learn and demonstrate to reach a goal or complete a learning activity. (Note that Science Practices will be denoted by **"SP #.# "**.)

Science Practice 1: The student can use representations and models to communicate scientific phenomena and solve scientific problems

- **SP 1.1** The student can create representations and models of natural or manmade phenomena and systems in the domain.
- **SP 1.2** The student can describe representations and models of natural or manmade phenomena and systems in the domain.
- **SP 1.3** The student can refine representations and models of natural or manmade phenomena and systems in the domain.

- **SP 1.4** The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively.
- **SP 1.5** The student can reexpress key elements of natural phenomena across multiple representations in the domain.

Science Practice 2: The student can use mathematics appropriately

- **SP 2.1** The student can justify the selection of a mathematical routine to solve problems.
- **SP 2.2** The student can apply mathematical routines to quantities that describe natural phenomena.
- **SP 2.3** The student can estimate numerically quantities that describe natural phenomena.

Science Practice 3: The student can engage in scientific questioning to extend thinking or to guide investigations within the context of the AP course

- **SP 3.1** The student can pose scientific questions.
- **SP 3.2** The student can refine scientific questions.
- **SP 3.3** The student can evaluate scientific questions.

Science Practice 4: The student can plan and implement data collection strategies in relation to a particular scientific question

- **SP 4.1** The student can justify the selection of the kind of data needed to answer a particular scientific question.
- **SP 4.2** The student can design a plan for collecting data to answer a particular scientific question.
- **SP 4.3** The student can collect data to answer a particular scientific question.
- **SP 4.4** The student can evaluate sources of data to answer a particular scientific question.

Science Practice 5: The student can perform data analysis and evaluation of evidence

- **SP 5.1** The student can analyze data to identify patterns or relationships.
- **SP 5.2** The student can refine observations and measurements based on data analysis.
- **SP 5.3** The student can evaluate the evidence provided by data sets in relation to a particular scientific question.

Science Practice 6: The student can work with scientific explanations and theories

- **SP 6.1** The student can justify claims with evidence.
- **SP 6.2** The student can construct explanations of phenomena based on evidence produced through scientific practices.
- **SP 6.3** The student can articulate the reasons that scientific explanations and theories are refined or replaced.
- **SP 6.4** The student can make claims and predictions about natural phenomena based on scientific theories and models.
- **SP 6.5** The student can evaluate alternative scientific explanations.

Science Practice 7: The student is able to connect and relate knowledge across various scales, concepts and representations in and across domains

- **SP 7.1** The student can connect phenomena and models across spatial and temporal scales.
- **SP 7.2** The student can connect concepts in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.

Topics/Big Ideas/Learning Objectives/Science Practices/Textual Readings (Detailed)

31 Weeks of Instruction Before AP Exam: Tuesday, May 3, 2016 (12 PM)

Note that *Learning Objectives* are denoted by, for example, **"3.A.1.1"** and *Science Practices* denoted by, for example, **"SP 1.5"**.

Unit 1: Physics Skills

- Graphing Skills
- Laboratory Skills

Unit 2: Kinematics

- Reference Frames and Displacement
- Average Velocity and Instantaneous Velocity
- Motion at Constant Acceleration
- Falling Objects
- Adding Vectors by Components
- Projectile Motion: projectiles fired horizontally and at an angle
- Graphical Analysis of Motion

Textual Readings

- **Knight**: Chapter 1 (1-1 through 1-5); Chapter 2 (2-1 through 2-8); Chapter 3 (3-1 through 3-7) **[62 pages]**

BIG IDEA 3: The interactions of an object with other objects can be described by forces.
3.A.1.1: I can express the motion of an object using narrative, mathematical, and graphical representations. **[SP 1.5, 2.1, 2.2]**
3.A.1.2: I can design an experimental investigation of the motion of an object. **[SP 4.2]**
3.A.1.3: I can analyze experimental data describing the motion of an object and is able to express the results of the analysis using narrative, mathematical, and graphical representations. **[SP 5.1]**

UNIT 3: DYNAMICS

- Forces
- Free-Body-Diagrams
- Newtons Laws of Motion
- Mass and Weight
- Applications Involving Friction, Inclines

Textual Readings

- **Knight**: Chapter 4 (4-1 through 4-7); Chapter 5 (5-1 through 5-8) **[44 pages]**

BIG IDEA 1: Objects and systems have properties such as mass and charge. Systems may have internal structure.
1.C.1.1: I can design an experiment for collecting data to determine the relationship between the net force exerted on an object its inertial mass and its acceleration. **[SP 4.2]**
1.C.3.1: I can design a plan for collecting data to measure gravitational mass and to measure inertial mass and to distinguish between the two experiments. **[SP 4.2]**

BIG IDEA 2: Fields existing in space can be used to explain interactions.
2.B.1.1: I can apply $F = mg$ to calculate the gravitational force on an object with mass m in a gravitational field of strength g in the context of the effects of a net force on objects and systems. **[SP 2.2, 7.2]**

BIG IDEA 3: The interactions of an object with other objects can be described by forces.
3.A.2.1: I can represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation. **[SP 1.1]**
3.A.3.1: I can analyze a scenario and make claims (develop arguments, justify assertions) about the forces exerted on an object by other objects for different types of forces or components of forces. **[SP 6.4, 7.2]**
3.A.3.2: I can challenge a claim that an object can exert a force on itself. **[SP 6.1]**
3.A.3.3: I can describe a force as an interaction between two objects and identify both objects for any force. **[SP 1.4]**
3.A.4.1: I can construct explanations of physical situations involving the interaction of bodies using Newton's third law and the representation of action-reaction pairs of forces. **[SP 1.4, 6.2]**
3.A.4.2: I can use Newton's third law to make claims and predictions about the action-reaction pairs of forces when two objects interact. **[SP 6.4, 7.2]**
3.A.4.3: I can analyze situations involving interactions among several objects by using free-body diagrams that include the application of Newton's third law to identify forces. **[SP 1.4]**
3.B.1.1: I can predict the motion of an object subject to forces exerted by several objects using an application of Newton's second law in a variety of physical situations with acceleration in one dimension. **[SP 6.4, 7.2]**
3.B.1.2: I can design a plan to collect and analyze data for motion (static, constant, or accelerating) from force measurements and carry out an analysis to determine the relationship between the net force and the vector sum of the individual forces. **[SP 4.2, 5.1]**
3.B.1.3: I can re-express a free-body diagram representation into a mathematical representation and solve the mathematical representation for the acceleration of the object. **[SP 1.5, 2.2]**
3.B.2.1: I can create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively. **[SP 1.1, 1.4, 2.2]**
3.C.4.1: I can make claims about various contact forces between objects based on the microscopic cause of those forces. **[SP 6.1]**
3.C.4.2: I can explain contact forces (tension, friction, normal, buoyant, spring) as arising from interatomic electric forces and that they therefore have certain directions. **[SP 6.2]**

BIG IDEA 4: Interactions between systems can result in changes in those systems.
4.A.1.1 I can use representations of the center of mass of an isolated two-object system to analyze the motion of the system qualitatively and semi-quantitatively. **[SP 1.2, 1.4, 2.3, 6.4]**
4.A.2.1: I can make predictions about the motion of a system based on the fact that acceleration is equal to the change in velocity per unit time, and velocity is equal to the change in position per unit time. **[SP 6.4]**
4.A.2.2: I can evaluate using given data whether all the forces on a system or whether all the parts of a system have been identified. **[SP 5.3]**
4.A.2.3: I can create mathematical models and analyze graphical relationships for acceleration, velocity, and position of the center of mass of a system and use them to calculate properties of the motion of the center of mass of a system. **[SP 1.4, 2.2]**
4.A.3.1: I can apply Newton's second law to systems to calculate the change in the center-of-mass velocity when an external force is exerted on the system. **[SP 2.2]**
4.A.3.2: I can use visual or mathematical representations of the forces between objects in a system to predict whether or not there will be a change in the center-of-mass velocity of that system. **[SP 1.4]**

Unit 4: Circular Motion & Gravitation

- Kinematics of Uniform Circular Motion
- Dynamics of Uniform Circular Motion
- Newtons Law of Universal Gravitation
- Gravity Near the Earths Surface
- Satellites and"Weightlessness"
- Kepler's Laws

Textual Readings

- **Knight**: Chapter 6 (6-1 through 6-6) **[20 pages]**

BIG IDEA 1: Objects and systems have properties such as mass and charge. Systems may have internal structure.
1.C.3.1: I can design a plan for collecting data to measure gravitational mass and to measure inertial mass and to distinguish between the two experiments. **[SP 4.2]**

BIG IDEA 2: Fields existing in space can be used to explain interactions.
2.B.1.1: I can apply $F = mg$ to calculate the gravitational force on an object with mass *m* in a gravitational field of strength *g* in the context of the effects of a net force on objects and systems. **[SP 2.2, 7.2]**
2.B.2.1: I can apply $g = G\,M/r^2$ to calculate the gravitational field due to an object with mass *M*, where the field is a vector directed toward the center of the object of mass *M*. **[SP 2.2]**
2.B.2.2: I can approximate a numerical value of the gravitational field (*g*) near the surface of an object from its radius and mass relative to those of the Earth or other reference objects. **[SP 2.2]**

Unit 5: Energy

- Work
- Kinetic Energy and the Work-Energy Theorem
- Potential Energy: Gravitational and Elastic
- Mechanical Energy and its Conservation
- Power

BIG IDEA 3: The interactions of an object with other objects can be described by forces.
3.A.2.1: I can represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation. **[SP 1.1]**
3.A.3.1: I can analyze a scenario and make claims (develop arguments, justify assertions) about the forces exerted on an object by other objects for different types of forces or components of forces. **[SP 6.4, 7.2]**
3.A.3.3: I can describe a force as an interaction between two objects and identify both objects for any force. **[SP 1.4]**
3.A.4.1: I can construct explanations of physical situations involving the interaction of bodies using Newton's third law and the representation of action-reaction pairs of forces. **[SP 1.4, 6.2]**
3.A.4.2: I can use Newton's third law to make claims and predictions about the action-reaction pairs of forces when two objects interact. **[SP 6.4, 7.2]**
3.A.4.3: I can analyze situations involving interactions among several objects by using free-body diagrams that include the application of Newton's third law to identify forces. **[SP 1.4]**
3.B.1.2: I can design a plan to collect and analyze data for motion (static, constant, or accelerating) from force measurements and carry out an analysis to determine the relationship between the net force and the vector sum of the individual forces. **[SP 4.2, 5.1]**
3.B.1.3: I can re-express a free-body diagram representation into a mathematical representation and solve the mathematical representation for the acceleration of the object. **[SP 1.5, 2.2]**
3.B.2.1: I can create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively. **[SP 1.1, 1.4, 2.2]**
3.C.1.1: I can use Newton's law of gravitation to calculate the gravitational force the two objects exert on each other and use that force in contexts other than orbital motion. **[SP 2.2]**
3.C.1.2: I can use Newton's law of gravitation to calculate the gravitational force between two objects and use that force in contexts involving orbital motion **[SP 2.2]**
3.C.2.2: I can connect the concepts of gravitational force and electric force to compare similarities and differences between the forces. **[SP 7.2]**
3.G.1.1: I can articulate situations when the gravitational force is the dominant force and when the electromagnetic, weak, and strong forces can be ignored. **[SP 7.1]**

BIG IDEA 4: Interactions between systems can result in changes in those systems.
4.A.2.2: I can evaluate using given data whether all the forces on a system or whether all the parts of a system have been identified. **[SP 5.3]**

Textual Readings

- **Knight**: Chapter 10 (10-1 through 10-6 and 10-8) **[22 pages]**

BIG IDEA 3: The interactions of an object with other objects can be described by forces.
3.E.1.1: I can make predictions about the changes in kinetic energy of an object based on considerations of the direction of the net force on the object as the object moves. **[SP 6.4, 7.2]**
3.E.1.2: I can use net force and velocity vectors to determine qualitatively whether kinetic energy of an object would increase, decrease, or remain unchanged. **[SP 1.4]**
3.E.1.3: I can use force and velocity vectors to determine qualitatively or quantitatively the net force exerted on an object and qualitatively whether kinetic energy of that object would increase, decrease, or remain unchanged. **[SP 1.4, 2.2]**
3.E.1.4: I can apply mathematical routines to determine the change in kinetic energy of an object given the forces on the object and the displacement of the object. **[SP 2.2]**

BIG IDEA 4: Interactions between systems can result in changes in those systems.
4.C.1.1: I can calculate the total energy of a system and justify the mathematical routines used in the calculation of component types of energy within the system whose sum is the total energy. **[SP 1.4, 2.1, 2.2]**
4.C.1.2: I can predict changes in the total energy of a system due to changes in position and speed of objects or frictional interactions within the system. **[SP 6.4]**
4.C.2.1: I can make predictions about the changes in the mechanical energy of a system when a component of an external force acts parallel or antiparallel to the direction of the displacement of the center of mass. **[SP 6.4]**
4.C.2.2: I can apply the concepts of Conservation of Energy and the Work-Energy theorem to determine qualitatively and/or quantitatively that work done on a two-object system in linear motion will change the kinetic energy of the center of mass of the system, the potential energy of the systems, and/or the internal energy of the system. **[SP 1.4, 2.2, 7.2]**

BIG IDEA 5: Changes that occur as a result of interactions are constrained by conservation laws.
5.A.2.1: I can define open and closed systems for everyday situations and apply conservation concepts for energy, charge, and linear momentum to those situations. **[SP 6.4, 7.2]**
5.B.1.1: I can set up a representation or model showing that a single object can only have kinetic energy and use information about that object to calculate its kinetic energy. **[SP 1.4, 2.2]**
5.B.1.2: I can translate between a representation of a single object, which can only have kinetic energy, and a system that includes the object, which may have both kinetic and potential energies. **[SP 1.5]**
5.B.2.1: I can calculate the expected behavior of a system using the object model (i.e., by ignoring changes in internal structure) to analyze a situation. Then, when the model fails, the student can justify the use of conservation of energy principles to calculate the change in internal energy due to changes in internal structure because the object is actually a system. **[SP 1.4, 2.1]**
5.B.3.1: I can describe and make qualitative and/or quantitative predictions about everyday examples of systems with internal potential energy. **[SP 2.2, 6.4, 7.2]**
5.B.3.2: I can make quantitative calculations of the internal potential energy of a system from a description or diagram of that system. **[SP 1.4, 2.2]**
5.B.3.3: I can apply mathematical reasoning to create a description of the internal potential energy of a system from a description or diagram of the objects and interactions in that system. **[SP 1.4, 2.2]**
5.B.4.1: I can describe and make predictions about the internal energy of systems. **[SP 6.4, 7.2]**
5.B.4.2: I can calculate changes in kinetic energy and potential energy of a system, using information from representations of that system. **[SP 1.4, 2.1, 2.2]**
5.B.5.1: I can design an experiment and analyze data to examine how a force exerted on an object or system does work on the object or system as it moves through a distance. **[SP 4.2, 5.1]**
5.B.5.2: I can design an experiment and analyze graphical data in which interpretations of the area under a force-distance curve are needed to determine the work done on or by the object or system. **[SP 4.2, 5.1]**
5.B.5.3: I can predict and calculate from graphical data the energy transfer to or work done on an object or system from information about a force exerted on the object or system through a distance. **[SP 1.4, 2.2, 6.4]**

Unit 6: Momentum

- Impulse and Change in Momentum
- Conservation of Momentum
- Conservation of Energy and Momentum in Collisions (1 dimension)
- Conservation of Momentum in Collisions (2 dimensions: qualitative and semi-quantitative only)

5.B.5.4: I can make claims about the interaction between a system and its environment in which the environment exerts a force on the system, thus doing work on the system and changing the energy of the system (kinetic energy plus potential energy). **[SP 6.4, 7.2]**
5.B.5.5: I can predict and calculate the energy transfer to (i.e., the work done on) an object or system from information about a force exerted on the object or system through a distance. **[SP 2.2, 6.4]**
5.D.1.1: I can make qualitative predictions about natural phenomena based on conservation of linear momentum and restoration of kinetic energy in elastic collisions. **[SP 6.4, 7.2]**
5.D.1.2: I can apply the principles of conservation of momentum and restoration of kinetic energy to reconcile a situation that appears to be isolated and elastic, but in which data indicate that linear momentum and kinetic energy are not the same after the interaction, by refining a scientific question to identify interactions that have not been considered. Students will be expected to solve qualitatively and/or quantitatively for one-dimensional situations and only qualitatively in two-dimensional situations. **[SP 2.2, 3.2, 5.1, 5.3]**
5.D.1.3: I can apply mathematical routines appropriately to problems involving elastic collisions in one dimension and justify the selection of those mathematical routines based on conservation of momentum and restoration of kinetic energy. **[SP 2.1, 2.2]**
5.D.1.4: I can design an experimental test of an application of the principle of the conservation of linear momentum, predict an outcome of the experiment using the principle, analyze data generated by that experiment whose uncertainties are expressed numerically, and evaluate the match between the prediction and the outcome. **[SP 4.2, 5.1, 5.3, 6.4]**

5.D.1.5: I can classify a given collision situation as elastic or inelastic, justify the selection of conservation of linear momentum and restoration of kinetic energy as the appropriate principles for analyzing an elastic collision, solve for missing variables, and calculate their values. **[SP 2.1, 2.2]**
5.D.2.1: I can qualitatively predict, in terms of linear momentum and kinetic energy, how the outcome of a collision between two objects changes depending on whether the collision is elastic or inelastic. **[SP 6.4, 7.2]**
5.D.2.3: I can apply the conservation of linear momentum to a closed system of objects involved in an inelastic collision to predict the change in kinetic energy. **[SP 6.4, 7.2]**

Textual Readings

- **Knight**: Chapter 9 (9.1 through 9.7) **[19 pages]**

BIG IDEA 3: The interactions of an object with other objects can be described by forces.
3.D.1.1: I can justify the selection of data needed to determine the relationship between the direction of the force acting on an object and the change in momentum caused by that force. **[SP 4.1]**
3.D.2.1: I can justify the selection of routines for the calculation of the relationships between changes in momentum of an object, average force, impulse, and time of interaction. **[SP 2.1]**
3.D.2.2: I can predict the change in momentum of an object from the average force exerted on the object and the interval of time during which the force is exerted. **[SP 6.4]**
3.D.2.3: I can analyze data to characterize the change in momentum of an object from the average force exerted on the object and the interval of time during which the force is exerted. **[SP 5.1]**
3.D.2.4: I can design a plan for collecting data to investigate the relationship between changes in momentum and the average force exerted on an object over time. **[SP 4.2]**

BIG IDEA 4: Interactions between systems can result in changes in those systems.
4.B.1.1: I can calculate the change in linear momentum of a two-object system with constant mass in linear motion from a representation of the system (data, graphs, etc.). **[SP 1.4, 2.2]**
4.B.1.2: I can analyze data to find the change in linear momentum for a constant-mass system using the product of the mass and the change in velocity of the center of mass. **[SP 5.1]**
4.B.2.1: I can apply mathematical routines to calculate the change in momentum of a system by analyzing the average force exerted over a certain time on the system. **[SP 2.2]**
4.B.2.2: I can perform analysis on data presented as a force-time graph and predict the change in momentum of a system. **[SP 5.1]**

BIG IDEA 5: Changes that occur as a result of interactions are constrained by conservation laws.
5.A.2.1: I can define open and closed systems for everyday situations and apply conservation concepts for energy, charge, and linear momentum to those situations. **[SP 6.4, 7.2]**
5.D.1.1: I can make qualitative predictions about natural phenomena based on conservation of linear momentum and restoration of kinetic energy in elastic collisions. **[SP 6.4, 7.2]**
5.D.1.2: I can apply the principles of conservation of momentum and restoration of kinetic energy to reconcile a situation that appears to be isolated and elastic, but in which data indicate that linear momentum and kinetic energy are not the same after the interaction, by refining a scientific question to identify interactions that have not been considered. Students will be expected to solve qualitatively and/or quantitatively for one-dimensional situations and only qualitatively in two-dimensional situations. **[SP 2.2, 3.2, 5.1, 5.3]**
5.D.1.3: I can apply mathematical routines appropriately to problems involving elastic collisions in one dimension and justify the selection of those mathematical routines based on conservation of momentum and restoration of kinetic energy. **[SP 2.1, 2.2]**
5.D.1.4: I can design an experimental test of an application of the principle of the conservation of linear momentum, predict an outcome of the experiment using the principle, analyze data generated by that experiment whose uncertainties are expressed numerically, and evaluate the match between the prediction and the outcome. **[SP 4.2, 5.1, 5.3, 6.4]**
5.D.1.5: I can classify a given collision situation as elastic or inelastic, justify the selection of conservation of linear momentum and restoration of kinetic energy as the appropriate principles for analyzing an elastic collision, solve for missing variables, and calculate their values. **[SP 2.1, 2.2]**
5.D.2.1: I can qualitatively predict, in terms of linear momentum and kinetic energy, how the outcome of a collision between two objects changes depending on whether the collision is elastic or inelastic. **[SP 6.4, 7.2]**

5.D.2.2: I can plan data collection strategies to test the law of conservation of momentum in a two-object collision that is elastic or inelastic and analyze the resulting data graphically. **[SP 4.1, 4.2, 5.1]**
5.D.2.3: I can apply the conservation of linear momentum to a closed system of objects involved in an inelastic collision to predict the change in kinetic energy. **[SP 6.4, 7.2]**
5.D.2.4: I can analyze data that verify conservation of momentum in collisions with and without an external friction force. **[SP 4.1, 4.2, 4.4, 5.1, 5.3]**
5.D.2.5: I can classify a given collision situation as elastic or inelastic, justify the selection of conservation of linear momentum as the appropriate solution method for an inelastic collision, recognize that there is a common final velocity for the colliding objects in the totally inelastic case, solve for missing variables, and calculate their values. **[SP 2.1, 2.2]**
5.D.3.1: I can predict the velocity of the center of mass of a system when there is no interaction outside of the system but there is an interaction within the system (i.e., the student simply recognizes that interactions within a system do not affect the center of mass motion of the system and is able to determine that there is no external force). **[SP 6.4]**

Unit 7: Unit Simple Harmonic Motion

- Simple Harmonic Motion
- SHM Graphs: position, velocity, acceleration, energy
- Energy in SHM
- Mass-Spring Systems
- Simple Pendulum

Textual Readings

- **Knight**: Chapter 14 (14-1 through 14-5) **[16 pages]**

BIG IDEA 3: The interactions of an object with other objects can be described by forces.
3.B.3.1: I can predict which properties determine the motion of a simple harmonic oscillator and what the dependence of the motion is on those properties. **[SP 6.4, 7.2]**
3.B.3.2: I can design a plan and collect data in order to ascertain the characteristics of the motion of a system undergoing oscillatory motion caused by a restoring force. **[SP 4.2]**
3.B.3.3: The student can analyze data to identify qualitative or quantitative relationships between given values and variables (i.e., force, displacement, acceleration, velocity, period of motion, frequency, spring constant, string length, mass) associated with objects in oscillatory motion to use that data to determine the value of an unknown. **[SP 2.2, 5.1]**
3.B.3.4: I can construct a qualitative and/or a quantitative explanation of oscillatory behavior given evidence of a restoring force. **[SP 2.2, 6.2]**

BIG IDEA 5: Changes that occur as a result of interactions are constrained by conservation laws.
5.B.2.1: I can calculate the expected behavior of a system using the object model (i.e., by ignoring changes in internal structure) to analyze a situation. Then, when the model fails, the student can justify the use of conservation of energy principles to calculate the change in internal energy due to changes in internal structure because the object is actually a system. **[SP 1.4, 2.1]**
5.B.3.1: I can describe and make qualitative and/or quantitative predictions about everyday examples of systems with internal potential energy. **[SP 2.2, 6.4, 7.2]**
5.B.3.2: I can make quantitative calculations of the internal potential energy of a system from a description or diagram of that system. **[SP 1.4, 2.2]**
5.B.3.3: I can apply mathematical reasoning to create a description of the internal potential energy of a system from a description or diagram of the objects and interactions in that system. **[SP 1.4, 2.2]**
5.B.4.1: I can describe and make predictions about the internal energy of systems. **[SP 6.4, 7.2]**
5.B.4.2: I can calculate changes in kinetic energy and potential energy of a system, using information from representations of that system. **[SP 1.4, 2.1, 2.2]**

Unit 8: Torque & Rotational Motion

- Torque
- Center of Mass (qualitative)
- Rotational Kinematics
- Rotational Dynamics and Rotational Inertia
- Rolling Motion (without slipping)
- Rotational Kinetic Energy
- Angular Momentum and its Conservation

Textual Readings

- **Knight**: Chapter 7 (7-1 through 7-7) **[26 pages]**

Unit 9: Mechanical Waves & Sound

- Wave Motion
- Types of Waves: Transverse and Longitudinal
- Energy Transmitted by Waves: relationship of energy and wave amplitude
- Reflection and Interference of Waves

BIG IDEA 3: The interactions of an object with other objects can be described by forces.
3.F.1.1: I can use representations of the relationship between force and torque. **[SP 1.4]**
3.F.1.2: I can compare the torques on an object caused by various forces. **[SP 1.4]**
3.F.1.3: I can estimate the torque on an object caused by various forces in comparison to other situations. **[SP 2.3]**
3.F.1.4: I can 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: I can 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: I can 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: I can 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: I can 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: I can 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 I can use representations of the center of mass of an isolated two-object system to analyze the motion of the system qualitatively and semi-quantitatively. **[SP 1.2, 1.4, 2.3, 6.4]**
4.D.1.1: I can 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: I can 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: I can 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: I can 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: I can 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: I can 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: I can 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: I can 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: I can 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]**

- Standing Waves
- Sources of Sound:
  - Standing waves for stringed instruments
  - Standing waves for a tube open at both ends and for a tube closed at one end

- Beats
- Doppler Effect (qualitative)

Textual Readings

- **Knight**: Chapter 15 (15-1, 15-2, 15-7); Chapter 16 (16-1 through 16-4 and 16-7) **[26 pages]**

BIG IDEA 6: Waves can transfer energy and momentum from one location to another without the permanent transfer of mass and serve as a mathematical model for the description of other phenomena.
6.A.1.1: I can use a visual representation to construct an explanation of the distinction between transverse and longitudinal waves by focusing on the vibration that generates the wave. **[SP 6.2]**
6.A.1.2: I can describe representations of transverse and longitudinal waves. **[SP 1.2]**
6.A.2.1: I can describe sound in terms of transfer of energy and momentum in a medium and relate the concepts to everyday examples. **[SP 6.4, 7.2]**
6.A.3.1: I can use graphical representation of a periodic mechanical wave to determine the amplitude of the wave. **[SP 1.4]**
6.A.4.1: I can explain and/or predict qualitatively how the energy carried by a sound wave relates to the amplitude of the wave, and/or apply this concept to a real-world example. **[SP 6.4]**
6.B.1.1: I can use a graphical representation of a periodic mechanical wave (position versus time) to determine the period and frequency of the wave and describe how a change in the frequency would modify features of the representation. **[SP 1.4, 2.2]**
6.B.2.1: I can use a visual representation of a periodic mechanical wave to determine wavelength of the wave. **[SP 1.4]**
6.B.4.1: I can design an experiment to determine the relationship between periodic wave speed, wavelength, and frequency and relate these concepts to everyday examples. **[SP 4.2, 5.1, 7.2]**
6.B.5.1: I can create or use a wave front diagram to demonstrate or interpret qualitatively the observed frequency of a wave, dependent upon relative motions of source and observer. **[SP 1.4]**
6.D.1.1: I can use representations of individual pulses and construct representations to model the interaction of two wave pulses to analyze the superposition of two pulses. **[SP 1.1, 1.4]**
6.D.1.2: I can design a suitable experiment and analyze data illustrating the superposition of mechanical waves (only for wave pulses or standing waves). **[SP 4.2, 5.1]**
6.D.1.3: I can design a plan for collecting data to quantify the amplitude variations when two or more traveling waves or wave pulses interact in a given medium. **[SP 4.2]**
6.D.2.1: I can analyze data or observations or evaluate evidence of the interaction of two or more traveling waves in one or two dimensions (i.e., circular wave fronts) to evaluate the variations in resultant amplitudes. **[SP 5.1]**
6.D.3.1: I can refine a scientific question related to standing waves and design a detailed plan for the experiment that can be conducted to examine the phenomenon qualitatively or quantitatively. **[SP 2.1, 3.2, 4.2]**
6.D.3.2: I can predict properties of standing waves that result from the addition of incident and reflected waves that are confined to a region and have nodes and antinodes. **[SP 6.4]**
6.D.3.3: I can plan data collection strategies, predict the outcome based on the relationship under test, perform data analysis, evaluate evidence compared to the prediction, explain any discrepancy and, if necessary, revise the relationship among variables responsible for establishing standing waves on a string or in a column of air. **[SP 3.2, 4.1, 5.1, 5.2, 5.3]**
6.D.3.4: I can describe representations and models of situations in which standing waves result from the addition of incident and reflected waves confined to a region. **[SP 1.2]**
6.D.4.1: I can challenge with evidence the claim that the wavelengths of standing waves are determined by the frequency of the source regardless of the size of the region. **[SP 1.5, 6.1]**
6.D.4.2: I can calculate wavelengths and frequencies (if given wave speed) of standing waves based on boundary conditions and length of region within which the wave is confined, and calculate numerical values of wavelengths and frequencies. Examples should include musical instruments. **[SP 2.2]**
6.D.5.1: I can use a visual representation to explain how waves of slightly different frequency give rise to the phenomenon of beats. **[SP 1.2]**

Unit 10: Electric Charge & Electric Force

- Static Electricity; Electric Charge and its Conservation

- Electric Charge in the Atom
- Charging Processes
- Coulomb's Law

Textual Readings

- **Knight**: Chapter 20 (20-1 through 20-3) **[11 pages]**

BIG IDEA 1: Objects and systems have properties such as mass and charge. Systems may have internal structure.
1.B.1.1: I can make claims about natural phenomena based on conservation of electric charge. **[SP 6.4]**
1.B.1.2: I can make predictions, using the conservation of electric charge, about the sign and relative quantity of net charge of objects or systems after various charging processes, including conservation of charge in simple circuits. **[SP 6.4, 7.2]**
1.B.2.1 I can construct an explanation of the two-charge model of electric charge based on evidence produced through scientific practices. **[SP 6.2]**
1.B.3.1: I can challenge the claim that an electric charge smaller than the elementary charge has been isolated. **[SP 1.5, 6.1, 7.2]**

BIG IDEA 3: The interactions of an object with other objects can be described by forces.
3.C.2.1: I can use Coulomb's law qualitatively and quantitatively to make predictions about the interaction between two electric point charges. **[SP 2.2, 6.4]**
3.C.2.2: I can connect the concepts of gravitational force and electric force to compare similarities and differences between the forces. **[See SP 7.2]**

BIG IDEA 5: Changes that occur as a result of interactions are constrained by conservation laws.
5.A.2.1: I can define open and closed systems for everyday situations and apply conservation concepts for energy, charge and linear momentum to those situations. **[SP 6.4, 7.2]**

Unit 11: DC Circuits

- Electric Current
- Ohms Law: Resistance and Resistors
- Resistivity
- Electric Power
- DC Circuits
- Resistors in Series and Parallel
- Kirchhoff's Rules (circuits with one battery only)
- Internal Resistance is NOT covered in AP Physics 1

Textual Readings

- **Knight**: Chapter 22 (22-1 through 22-6); Chapter 23 (23-1 through 23-5) **[30 pages]**

BIG IDEA 1: Objects and systems have properties such as mass and charge. Systems may have internal structure.
1.B.1.1: I can make claims about natural phenomena based on conservation of electric charge. **[SP 6.4]**
1.B.1.2: I can make predictions, using the conservation of electric charge, about the sign and relative quantity of net charge of objects or systems after various charging processes, including conservation of charge in simple circuits. **[SP 6.4, 7.2]**
1.E.2.1 I can choose and justify the selection of data needed to determine resistivity for a given material. **[SP 4.1]**

BIG IDEA 5: Changes that occur as a result of interactions are constrained by conservation laws.
5.B.9.1: I can construct or interpret a graph of the energy changes within an electrical circuit with only a single battery and resistors in series and/or in, at most, one parallel branch as an application of the conservation of energy (Kirchhoff's loop rule). **[SP 1.1, 1.4]**
5.B.9.2: I can apply conservation of energy concepts to the design of an experiment that will demonstrate the validity of Kirchhoff's loop rule (∑□V=0) in a circuit with only a battery and resistors either in series or in, at most, one pair of parallel branches. **[SP 4.2, 6.4, 7.2]**
5.B.9.3: I can apply conservation of energy (Kirchhoff's loop rule) in calculations involving the total electric potential difference for complete circuit loops with only a single battery and resistors in series and/or in, at most, one parallel branch. **[SP 2.2, 6.4, 7.2]**
5.C.3.1: I can apply conservation of electric charge (Kirchhoff's junction rule) to the comparison of electric current in various segments of an electrical circuit with a single battery and resistors in series and in, at most, one parallel branch and predict how those values would change if configurations of the circuit are changed. **[SP 6.4, 7.2]:**
5.C.3.2: I can design an investigation of an electrical circuit with one or more resistors in which evidence of conservation of electric charge can be collected and analyzed. **[SP 4.1, 4.2, 5.1]**
5.C.3.3: I can use a description or schematic diagram of an electrical circuit to calculate unknown values of current in various segments or branches of the circuit. **[SP 1.4, 2.2]**

Laboratory Investigations & The Science Practices

The AP Physics 1 course devotes over 25% of the time to laboratory investigations [CR5]. The laboratory component of the course allows the students to demonstrate the seven science practices through a variety of investigations in all of the foundational principles.

The students use guided inquiry (GI) or open inquiry (OI) in the design of their laboratory investigations. Some labs focus on investigating a physical phenomenon without having expectations of its outcomes. In other experiments, the student has an expectation of its outcome based on concepts constructed from prior experiences. In application experiments, the students use acquired physics principles to address practical problems.

All investigations are reported in a laboratory journal. Students are expected to record their observations, data, and data analyses. Data analyses include identification of the sources and effects of experimental uncertainty, calculations, results and conclusions, and suggestions for further refinement of the experiment as appropriate. [CR7]

UNIT	**LAB INVESTIGATION OBJECTIVE(S) CR6a** (Investigation identifier: Guided Inquiry: **GI** Open Inquiry: **OI**) **[CR6b]**	**SCIENCE PRACTICES [CR6b]**
UNIT 1. KINEMATICS	**1. Meeting Point (OI)** To predict where two battery-powered cars will collide if they are released from opposite ends of the lab table at different times.	1.1, 1.2, 1.4, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.2, 5.3, 6.1, 6.2, 6.4, 7.2
	2. Match the Graph (GI) To determine the proper placement of an air track, a glider, and a motion detector to produce a motion that matches a set of given graphs: position, velocity and acceleration versus time.	1.2, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.4, 7.2
	3. Free-Fall Investigation (OI) To determine and compare the acceleration of two objects dropped simultaneously.	1.4, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.4, 7.2
	4. Vector Addition (GI) To determine the value of a resultant of several vectors, and then compare that value to the values obtained through graphical and analytical methods.	1.1, 1.2, 1.4, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.3, 6.1, 6.4, 7.2
	5. Shoot the Target (OI) To determine the initial velocity of a projectile, the angle at which the maximum range can be attained and predict where the projectile will land.	1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.3, 6.1, 6.4, 7.2
	6. Chase Scenario (OI) *Lab Practicum:* Students use a battery- cart and a fan cart to recreate a chase scenario (police-thief) to predict the position where the "'thief"' will be caught and the final speeds of both cars.	1.1, 1.2, 1.4, 1.5, 2.1, 2.2, 3.1, 3.2, 3.3, 4.1, 4.2, 4.3, 5.1, 5.2, 5.3, 6.1, 6.2, 6.4, 7.2

UNIT 2. DYNAMICS	**7. Inertial and Gravitational Mass (GI)** To determine the difference (if any) between inertial mass and gravitational mass.	1.4, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.3, 6.1, 6.4, 7.2
	8. Forces Inventory (GI) Qualitative and quantitative investigation on a variety of interactions between objects.	1,1, 1.4, 1.5, 2.1, 2.2, 3.3, 4.1, 4.2, 4.3, 5.1, 6.1, 6.2, 6.4, 7.2
	9. Static Equilibrium Challenge (OI) To determine the mass of a hanging object in a setup with three strings at various angles.	1.1, 1.4, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.4, 7.2
	10. Newton's Second Law (OI) To determine the variation of the acceleration of a dynamics cart in two scenarios: (1) the total mass of the system is kept constant while the net force varies, and (2) the net force is kept constant while the total mass of the system varies.	1.1, 1.4, 1.5, 2.1, 2.2, 3.1, 3.2, 3.3, 4.1, 4.2, 4.3, 5.1, 5.2, 5.3, 6.1, 6.2, 6.4, 7.2
	11. Coefficient of Friction (OI) To determine the maximum coefficient of static friction between a shoe and a wooden plank.	1.1, 1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.3, 6.1, 6.4, 7.2
	12. Atwood's Machine (GI) To determine the acceleration of a hanging mass and the tension in the string.	1.1, 1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.3, 6.1, 6.4, 7.2

UNIT 3. CIRCULAR MOTION AND GRAVITATION	**13. Flying Toy (GI)** To determine the tension in the string and the centripetal acceleration of the flying toy.	1.1, 1.2, 1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.3, 6.1, 6.4, 7.2

UNIT 4. ENERGY	**14. Roller Coaster Investigation (OI)** To design a simple roller coaster using provided materials to test whether the total energy of the system is conserved if there are no external forces exerted on it by other objects.	1.1, 1.2, 1.3, 1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.3, 6.1, 6.2, 6.4, 7.2
	15. Work Done in Stretching a Spring (GI) To determine the work done on the spring from force-versus-distance graph of the collected data.	1.1, 1.2, 1.3, 1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.3, 6.1, 6.4, 7.2
	16. Energy and Non-Conservative Forces (GI) To determine the energy dissipated by friction of a system consisting of a modified Atwood's machine.	1.1, 1.2, 1.3, 1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.3, 6.1, 6.4, 6.5, 7.2

UNIT 5. MOMENTUM	**17. Bumper Design (OI)** To design a paper bumper that will soften the impact of the collision between a cart and a fixed block of wood. Their designs are evaluated by the shape of an acceleration-versus-time graph of the collision.	1.4, 2.1, 2.2, 3.1, 3.2, 4.1, 4.2, 4.3, 5.1, 5.2, 5.3, 6.1, 6.2, 6.4, 7.2
	18. Impulse and Change in Momentum (GI) To measure the change in momentum of a dynamics cart and compare it to the impulse received.	1.1, 1.2, 1.3, 1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.4, 7.2
	19. Elastic and Inelastic Collisions (OI) To investigate conservation of momentum and conservation of energy using a ballistic pendulum to determine the type of collision.	1.1, 1.2, 1.3, 1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.2, 5.3, 6.1, 6.2, 6.4, 7.2
	20. Forensic Investigation (OI) *Lab Practicum:* Apply principles of conservation of energy, conservation of momentum, the work-energy theorem, and a linear model of friction to find the coefficient of kinetic friction.	1.1, 1.2, 1.4, 1.5, 2.1, 2.2, 3.1, 3.2, 3.3, 4.1, 4.2, 4.3, 5.1, 5.2, 5.3, 6.1, 6.2, 6.4, 7.2

UNIT 6. SIMPLE HARMONIC MOTION	**21. Finding the Spring Constant (OI)** To design two independent experiments to determine the spring constants of various springs of equal length.	1.1, 1.4, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.3, 6.1, 6.4, 7.2
	22. Graphs of an Oscillating System (GI) To analyze graphs of position, velocity, and acceleration versus time for an oscillating system to determine how velocity and acceleration vary at the equilibrium position and at the endpoints.	1.1, 1.2, 1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.4, 7.2
	23. Simple Pendulum Investigation (OI) To investigate the factors that affect the period of a simple pendulum and test whether the period is proportional to the pendulum's length, the square of its length, or the square root of its length.	1.2, 1.4, 2.1, 2.2, 2.3, 3.1, 3.2, 3.3, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.4, 7.2

UNIT 7. TORQUE & ROTATIONAL MOTION	**24. Torque and the Human Arm (OI)** To design and build an apparatus that replicates the forearm and biceps muscle system to determine the biceps tension when holding an object in a lifted position.	1.1, 1.2, 1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.2, 5.3, 6.1, 6.2, 6.4, 7.1, 7.2
	25. Rotational Inertia (GI) To determine the rotational inertia of a cylinder from the slope of a graph of an applied torque versus angular acceleration.	1.1, 1.2, 1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.4, 7.2
	26. Conservation of Angular Momentum (GI) To investigate how the angular momentum of a rotating system responds to changes in the rotational inertia.	1.1, 1.2, 1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.4, 7.2

UNIT 8. MECHANICAL WAVES & SOUND	**27. Mechanical Waves (OI)** To model the two types of mechanical waves with a spring toy to test whether or not these characteristics affect the speed of a pulse: frequency, wavelength and amplitude.	1.2, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.2, 6.4, 7.2
	28. Speed of Sound (OI) Design two different procedures to determine the speed of sound in air.	1.1, 1.2, 1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.3, 6.1, 6.4, 7.2
	29. Wave Boundary Behavior (GI) To compare what happens to the phase of a transverse wave on a spring toy when a pulse is reflected from a boundary and when it is reflected and transmitted from various boundaries (spring to string).	1.4, 3.1, 4.1, 4.2, 4.3, 5.1, 6.1, 6.4, 7.2
	30. Standing Waves (GI) Given a specified tension, students predict the length of the string necessary to generate the first two harmonics of a standing wave on the string. Then they perform the experiment and compare the outcome with their prediction.	1.1, 1.2, 1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.4, 7.2

UNIT 9. ELECTRIC CHARGE & ELECTRIC FORCE	**31. Static Electricity Interactions (GI)** Students use sticky tape and a variety of objects to make qualitative observations of the interactions when objects are charged, discharged, and recharged.	1.2, 3.1, 4.1, 4.2, 5.1, 6.2, 7.2
	32. Coulomb's Law (OI) To estimate the charge on two identical, equally charged spherical pith balls of known mass.	1.1, 1.2, 1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.4, 7.2

UNIT 10. DC CIRCUITS	**33. Brightness Investigation (GI)** To make predictions about the brightness of light bulbs in a variety of series and parallel circuits when some of the bulbs are removed.	1.2, 3.1, 4.1, 4.2, 4.3, 5.3, 6.1, 6.4, 7.2
	34. Voltage and Current (GI) To determine the relationship between the current through a resistor and the voltage across the resistor.	1.1, 1.2, 1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.4, 7.2
	35. Resistance and Resistivity (OI) To investigate the effects of cross-sectional area and length on the flow of current through a roll of Play-Doh.	1.4, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1,5.3, 6.1, 6.4, 7.2
	36. Series and Parallel Circuits (OI) To investigate the behavior of resistors in series, parallel, and series-parallel circuits. The lab should include measurements of voltage and current.	1.1, 1.2, 1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.2, 5.3, 6.1, 6.4, 7.2