**AP Physics C: Mechanics, Electricity & Magnetism  
Delve, MIT ESP  
September 16, 2012 – May 12, 2013**

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**Description:** This course covers all of the material in the AP Physics C curriculum as published by the College Board and serves to prepare students for the AP Physics C exams in Mechanics and Electricity and Magnetism.

First-semester topics include kinematics, Newton’s laws, conservation of momentum and energy, gravitation and Kepler’s laws, rotational motion, and simple harmonic motion. Second-semester topics include Coulomb’s law, Gauss’s law, electric potential, capacitance, direct-current circuits and Kirchhoff’s rules, Ampère’s law, the Biot-Savart law, and electromagnetic induction.

**Prerequisites:** Students should be familiar with single-variable differentiation and integration, which are used widely in AP Physics C. It is also strongly recommended that students have previously taken a physics course in high school.

**Meeting times:** Classes meet from 10 a.m. to 3 p.m., including a one-hour lunch break at noon, each Sunday in room 2-146, MIT; a map can be found online at whereis.mit.edu. As noted in the schedule below, there are a total of twenty-seven classes from September 16 through May 12, as well as two in-class, full-length practice exams.

**Course website:** Supplemental readings and problem sets will be posted regularly on hcs.harvard.edu/newton.

**Readings:** Readings will be assigned from the course textbook, Young and Freedman’s *University Physics* (12th edition), a standard college-level physics textbook with calculus which will be distributed during the first class. An AP exam review book is also helpful (we recommend the most recent edition by the Princeton Review) but should not be used as a primary text.

**Problem sets:** Doing problems is an integral component of learning physics. Care has been taken to ensure that the weekly problem sets are not just tedious busy work and involve more sophistication than “plugging and chugging.” Problem sets will be posted online and handed out at the beginning of each week and to be turned in at the beginning of the following week. Though no grades are given for this course, we will provide feedback on each problem set.

Though self-contained, this course has fewer class hours than most traditional AP classes offered by high schools. Therefore, self-review and study outside of class is necessary for success. In particular, students will need to complete all problem sets to do well on the AP exam.

**Course Schedule**

* **Week 1: Kinematics 9/16**
  + **What is AP Physics C? Some problems, examples, a (brief) history**  
    *A preview of what’s to come; some interesting examples and teasers*
  + **Vectors and trigonometry**

*Vector algebra, trigonometry, other miscellaneous mathematics review*

* + **Units and dimensional analysis: when knowing no physics solves physics problems**  
    *Determine the period of a pendulum using dimensional analysis, checking units, SI system*
  + **Kinematics: describing motion**  
    *Differentiate and integrate to find position, velocity, and acceleration; motion in one dimension*
  + **Kinematics in multiple dimensions**

*Resolving motion in multiple dimensions*

* **Week 2: Projectile motion and Newton’s laws** **9/23**
  + **Projectile motion: shooting a (Gauss) cannon**   
    *Several interesting projectile motion examples; cart on an incline*
  + **Newton’s (three but really two) laws of motion**  
    *“Every particle continues in its state of rest of uniform motion in a straight line except insofar that it doesn’t.”*
  + **Some types of practical forces**  
    *Gravity, normal, friction, springs, tension*
  + **Free-body diagrams: some basic examples**

*Blocks, ramps, strings*

* **Week 3: Applying Newton’s laws 9/30**
  + **A few classic examples**

*Compound Atwood’s machine, free sliding block and plane*

* + **More with kinematic constraints: circular motion dynamics**
  + **Lab:** Conical Pendulum

*Determine the angle created by a vertical pendulum; check later with the analytic solution*

* **Week 4: More on applying Newton’s laws 10/7**
  + **Some not-so-easy problems**
  + **Variable forces**

*Solving differential equations to understand drag forces and fluid resistance*

* **Week 5: Work and energy 10/14**
  + **Can’t learn mechanics without *work***

*Definition of work, work in two dimensions*

* + **Work-energy theorem**

*Derivation of kinetic energy, proof of work-energy theorem*

* + **Potential energy, law of conservation of energy**  
    *Derive law of conservation of energy, introduce concept of potential energy*
  + **Non-conservative forces**  
    *Accounting for non-conservative forces, friction, (non-) conservation in multiple dimensions*
* **Week 6: More on potential energy 10/21**
  + **Finding potential functions**

*Analyzing potential energy curves, finding minima and maxima*

* + **Some example potential functions**

*Gravity, spring, non-Hooke’s law spring*

* + **Power**

*Differentiate to find power*

* + **Spicy Delve**
* **Week 7: Momentum 10/28**
  + **Conservation of momentum (aka Newton’s third law), collisions in one dimension***Derivation of 1D elastic and inelastic collisions and limiting behavior, “basketball-tennis ball” demo*
  + **Relative motion**

*Frames of reference and relative speeds*

* + **Center of mass**  
    *Develop concept of center of mass, center of mass problems, center of mass for continuous objects*
* **Week 8: More on momentum 11/4**
  + **Collisions in two dimensions***Billiard ball examples*
  + **Impulse**

*Definition of impulse, impulse-momentum theorem*

* + **Variable-mass systems**  
    *Sand in a cart, falling chain, rocket propulsion*
* **Week 9: Rotational motion 11/11**
  + **Angular kinematics**  
    *Give, by analogy, equations for angular kinematics*
  + **Moment of inertia, rotational energy**  
    *Motivate moment of inertia from rotational kinetic energy*; *calculations, parallel-axis theorem*
  + **Lab**: Roller derby  
    *Roll objects down an inclined plane with different moments of inertia to gain intuition with rotational concepts*
* **MIT Splash 11/18**

***Thanksgiving break (no class on 11/25)***

* **Week 10: Rotational dynamics 12/2**
  + **Newton’s second law for rotational motion**

*Torque as the rotational analogy to (translational) force*

* + **Conservation of angular momentum**  
    *Conservation of angular momentum, spinning block on table, conical pendulum revisited*
* **Week 11: Applications of rotational dynamics 12/9**
  + **Collisions with rotational motion**  
    *Colliding stick example, center of percussion*
  + **Statics: keeping things in equilibrium**
  + **The law of gravitation, gravity of continuous bodies**  
    *Newton’s law of universal gravitation, gravitational potential energy and potential, gravity of a spherical shell*
  + **Kepler’s laws**  
    *Kepler’s second and third laws, calculating the period of earth’s orbit*
* **Week 12: Simple harmonic motion and parting shots** **12/16**
  + **Simple harmonic motion: solving the spring equation**

*Simple harmonic motion, solving second-order differential equations*

* + **Pendulums**

*Simple harmonic motion for the pendulum, simple and physical pendulums*

* + **Other harmonic oscillators**

*Hole through the earth, LC circuit*

* + **Parting shots for mechanics**  
    *A few challenging problems to keep students on their toes*

***Winter break (no class on 12/23, 12/30)***

* **Practice AP Exam 1** **1/6**
* **Week 13: Electrostatics 1/13**
  + **A (very brief) history of electromagnetism**
  + **Coulomb’s law**

*Apply Coulomb’s law to determine forces on point charges; superposition to calculate force on multiple charges*

* + **Electric fields**

*Draw electric fields from point charges; calculate forces on test charges placed in field; integrate to calculate field from a wire, thin ring of charge, and uniformly charged disk*

* **Week 14: Gauss’s law 1/20**
  + **Electric flux**

*Surface integrals of electric fields that vary in one dimension over rectangular surfaces*

* + **Gaussian surfaces: a faster method**

*Choosing symmetric surfaces to derive field from a point, line, plane, sphere, cylinder and slab*

* **Week 15: Electric potential 1/27**
  + **Finding charge distributions from electric fields**

*Applying Gauss’s law to determine charge*

* + **Can’t learn electromagnetism without *work***

*Energy stored in an electric field, electric fields are conservative*

* + **Potential**

*Sketching equipotential surfaces; calculating potential from electric fields and charge distributions*

* **Week 16: Conductors and Insulators 2/3**
  + **Potentials from charge distributions**

*Calculate potentials from sphere, wire, ring of charge, disk, infinite planes, and two planes*

* + **Conductors are equipotential surfaces**

*Implications; sketching charge distribution, field lines, and equipotential surfaces around conductors*

* + **Properties of insulators**
* **Week 17: Capacitance and dielectrics 2/10**
  + **Electric field and potential of two opposite-charged parallel plates**
  + **Capacitance**

*Relation between stored charge and voltage in a capacitor; deriving capacitance of plates, cylinder, and sphere*

* + **Energy of capacitor**

*Determine energy stored in a capacitor and work done when moving objects around capacitors*

* + **Dielectrics and their effects on capacitance**
* **Week 18: Circuits I – Resistors 2/17**
  + **Current and electric fields**

*Derive Ohm’s Law from our knowledge of moving charges through electric fields*

* + **Ohm’s law**
  + **Direct current circuits with batteries and resistors**

*Simplifying resistors in circuits; Kirchhoff’s rules to determine unknowns in circuits*

* + **Energy usage in circuits**

*Determine power and total energy dissipated by resistors or supplied by batteries*

* + **Voltmeters and ammeters as useful tools in circuits**
* **Week 19: Circuits II – Capacitors 2/24**
  + **Capacitors in circuits**

*Calculating equivalent capacitance of multiple capacitors; calculating charge and voltage of many capacitors*

* + **RC circuits**

*Solve differential equation to derive charge on a capacitor in an RC circuit; analyzing energy and power*

* + **Spicy Delve**
* **Week 20: Circuits III and review of electricity 3/3**
  + **Some not-so-easy circuit problems**
  + **Review and brush up on any remaining topics from electricity**
* **MIT Spark 3/10**
* **Week 21: Review of classical mechanics 3/17**
  + **Mechanics? What was that again?**
  + **Fun problems**
* **Week 22: Magnetism 3/24**
  + **Magnetic forces**

*Lorenz force equation; force on charge traveling through both electric and magnetic fields; force on wires*

* + **Magnetic fields**

*Magnetic field from a current in a straight wire*

* + **Magnets**

*Drawing magnetic field lines from a magnet*

***Spring break (no class on 3/31)***

* **Week 23: Ampère’s law and Biot-Savart law 4/7**
  + **Using Biot-Savart law to calculate magnetic fields**

*Integrating to calculate magnitude and direction of field due to current-carrying wire, loop, and solenoid*

* + **Amperian loops: a faster method**

*Choosing symmetric loops to derive field from a plane and cylinder; using superposition*

* **Practice AP Exam 2 4/14**
* **Week 24: Induction 4/21**
  + **Magnetic flux**

*Surface integrals of magnetic fields that vary in one dimension over rectangular surfaces*

* + **Faraday’s law**

*Determining induced EMF due to changing magnetic flux, Lenz’s law*

* + **Mutual and self-inductance**

*Calculate the mutual inductance of two rings and the self-inductance of a solenoid*

* **Week 25: Circuits IV – Inductors and Maxwell’s equations 4/28**
  + **LR circuits**

*Solve differential equation to derive current through the battery in an LR circuit; analyzing energy and power*

* + **Electromagnetism summarized by Maxwell’s equations**

*Differential form of Maxwell’s equations and their implications*

* + **Electromagnetic waves**
* **Week 26: Review and practice problems 5/5**
* **Week 27: Review and practice problems 5/12**

***AP Exam: Monday, May 13***

***Mechanics (12–2 pm) and Electricity & Magnetism (2–4 pm)***