AP® Physics C Mechanics Syllabus

1 Prerequisites and Purposes of AP® C Mechanics

AP® Physics C Mechanics is the first course in a two-course sequence. It is offered in the first semester to students who have completed Physics 163 or Physics 173 and who have completed or are enrolled concurrently in an AP® Calculus course. AP® Physics C Mechanics assumes students have understood the content of Physics 163 or Physics 173. Differential and integral calculus are freely used throughout AP® Physics C Mechanics. Completing the AP® Physics C sequence, AP® Physics C Electricity and Magnetism follows AP® Physics C Mechanics and is offered in the second semester. Together, AP® Physics C Mechanics and AP® Physics C Electricity and Magnetism correspond roughly to a year of University Physics.

AP® Physics C Mechanics affords students an opportunity to increase their ability to use fundamental models in classical mechanics to describe and explain nature and also to earn university credit. In practice, many prospective science and engineering students use AP® Physics C Mechanics to gain excellent preparation for their required introductory physics courses in university while students who aspire to non-science majors often apply any credit earned toward fulfillment of the science requirement of their undergraduate degree.

2 Textbook

Fundamentals of Physics, 7th edition, by Halliday, Resnick, and Walker (Wiley, 2005), is the textbook for both AP® C Mechanics and AP® C Electricity and Magnetism. It is a standard textbook for University Physics courses for science and engineering majors and meets all requirements for AP® Physics C Mechanics.

3 Course Design

The goal of AP® Physics C is to provide students with an outstanding education in introductory physics at the university level. The content of the course is defined by a small set of core models, some of which were developed and used in Physics 163 and 173. The method of instruction is described by a modeling cycle. In general, a modeling cycle begins with the introduction of a model basic to the course, by way of experiment when possible. Subsequently, students refine their understanding of this model as they use it to solve problems and to conduct experiments in which they use the model to describe, explain, predict, and design various phenomena and apparatus. Class periods alternate between 90 minute periods one day and 45 minutes the next day. Quizzes are used routinely for formative assessment.

3.1 Experiments

Laboratory experiments are essential to physics and to learning physics. They are therefore components of AP® Physics C Mechanics. Out of the 87 class periods in a semester, we will spend about 20 of them doing experimental work. Each student will keep a laboratory journal including a neat record of actions, equipment, and observations during experiments as well as final, formal lab reports. In this course there are three basic kinds of experiments. First, there are experiments in which a model fundamental to the phenomena targeted by this course is developed. Second, there are experiments in which a familiar model is used to make a prediction or to calculate some desired value. Third, there are experiments in which important laboratory equipment or skills are introduced.

Typically the goal of an experiment will be framed through class discussion focused on some phenomenon presented to them. Students will identify the salient variables that characterize the phenomenon from which related variables are selected for experimental investigation. Then they will be introduced to equipment that is available that may be of use in determining the relationships of interest. Following student discussion about experimental methods that may be considered, students will be assigned to groups of two or three to design and conduct their experiments. Upon completion of their experimental work and preliminary analysis, students will reconvene for whiteboard presentations and discussion of their findings. Once difficulties and questions are addressed and a valid consensus is reached, students will generally write a formal report.

3.2 Using Models in Problem-Solving and in Programming

Questions to answer and problems to solve will be provided by the instructor and assigned from the textbook. These are intended to refine and deepen students' understanding of their models, of how these models account for a wide variety of phenomena, and of the Newtonian theory governing the models. These questions and problems also develop students' mathematical skill. On the day assigned problems are due, they will be checked in by the instructor and returned to students. Students will be assigned to groups of two or three to present their solutions to the class on whiteboards. Students may make comments and corrections on their assignments as needed during presentations. After presentations are completed for an assignment, students will turn in the final version of their solutions for grading. When appropriate, students will also solve and present solutions to released Free Response problems from previous AP® exams.

In addition, students will be introduced to simple computer programming in Python using the visual module (VPython) in order to acquaint them with very basic ideas of programming and to explore the implications of familiar models in a new way.

4 Assessment

Grades will be determined from an assortment of assignments including homework problems, quizzes, lab notebook, formal lab reports, projects, and exams. Daily quizzes based on reading assignments will be given. These quizzes are intended to determine if you have read the text with understanding. Grades are calculated as the percentage of points earned out of the total possible. Typically about 30% of points are from exams, 15% from quizzes, 35% from homework, and 20% from lab reports and projects.

5 Course Outline

1. **Introduction** (Week 1)
   (a) **Experiment:** Upon what does the period of a pendulum depend? (2 days + postlab, hands on)
   (b) Reading
      i. Keeping a good lab notebook
      ii. Writing a formal lab report
2. **Particles having constant v and constant a in 1 dimension** (Week 2)
   (a) Chapter 2 Assignments
      i. 2a p. 29: 1, 2, 3, 62
      ii. 2b pp. 30 ff: 5, 60
      iii. 2c pp. 30ff: 37, 53, 55, 58
   (b) Motion in 1 dimension
   (c) Reading: Calculus for AP® Physics C: the derivative
3. **Particles having constant v and constant a in 2 dimensions** (Week 3)
   (a) Chapters 4, 23, and 28 Assignments
      i. 4a pp. 75-76: 4, 9
      ii. 4b pp. 78ff: 30, 34, 39, 80
      iii. 4c pp. 78ff: 53, 82, 88
      iv. 23a p. 600: 35, 46
      v. 28a pp. 756-757: 1, 3, 5, 7
      vi. 28b pp. 758-759: 6, 7, 8, 24
   (b) Motion in 2 dimensions
   (c) Vector arithmetic
   (d) Relative velocity
   (e) **Experiment:** Hit a target with a projectile fired from a launcher at a specified angle and location. (1 day, hands on)
   (f) Projectile motion
      i. Components: $\Delta x = v_{0x}\Delta t + \frac{1}{2}a_x\Delta t^2$
      ii. Vectors: $\Delta \mathbf{r} = \mathbf{v}_0\Delta t + \frac{1}{2}\mathbf{a}\Delta t^2$
   (g) Simple computer modeling with VPython: Projectiles

4. **Particles subject to zero net force; Particles subject to constant net force** (Week 4)

   (a) Chapter 5 Assignments

      i. 5a p. 107: 8, 11, 12

      ii. 5b pp. 107-115: 42, 45, 51, 54, 64, 88

   (b) **Experiment:** Predict electron beam deflection in CRT from CRT tube dimensions and applied potentials (Explicitly depends on understanding from first-year physics) (2 days, hands on)

   (c) Newtonian Interaction Laws

      i. Newton's First Law

      ii. Newton's Second Law: $\sum \mathbf{F} = m\mathbf{a}$

      iii. Newton's Third Law

      iv. Gravitational force law: $\mathbf{F} = m\mathbf{g}$

      v. Electrical force law: $\mathbf{F} = q\mathbf{E}$

      vi. String forces: Unconstrained, light strings pull inward at each end with essentially the same force

      vii. Surface support forces: Surfaces exert supporting forces normal to the surfaces due to their inherent "springiness."

   (d) **Lab Practicum:** Predicting the force scale reading on a block on a ramp (0.5 day, hands on)

5. **Particles subject to zero net force; Particles subject to constant net force; Particles subject to central net force** (Weeks 5 and 6)

   (a) Chapter 6 Assignments

      i. 6a pp. 131-139: 20, 21, 25, 28, 41, 49, 51, 52, 58

      ii. 28c pp. 758-761: 9, 59

   (b) More Newtonian Interaction Laws

      i. Kinetic friction force: $F_{friction} \approx \mu_k F_{support}$

      ii. Static friction force: $0 \leq F_{friction} \lessapprox \mu_s F_{support}$

      iii. Magnetic force law: $\mathbf{F} = q\mathbf{v} \times \mathbf{B}$

   (c) **Lab Practicum:** Predicting which objects will remain on a turntable after it is spinning at 45 rpm (0.5 day, hands on)

   (d) Reading: Fields in Physics

   (e) **Experiment:** Interactive VPython computer simulation: Mass spectrometer determination of KE of alpha particles from several polonium isotopes. Contrived scenario yields KE for each alpha. KE's correlate with mass loss yielding $KE = \Delta mc^2$. Thus, energy in a system at rest has mass. (2 days, interactive simulation)

6. **All preceding particle models; Object having thermal energy system** (to account for dissipated mechanical energy) (Week 7)

   (a) Chapter 7 Assignments

      i. 7a pp. 158-159: 5, 6, 10

   ii. 7b pp. 159-164: 33, 36, 43, 46, 50, 71

(b) Identifying useful systems

(c) Energy as a state variable of systems

(d) Work as a particular, specially named mode of energy transfer

(e) More Newtonian Interaction Laws

   i. Energy transfer by working $W = \int \mathbf{F} \cdot d\mathbf{l}$

   ii. Work-energy theorem for particles

   iii. Rate of energy transfer between systems: Power

(f) Reading: Making Work Work

7. Conservative systems and conservative fields (Weeks 8 and 9)

(a) Chapter 8 Assignments

   i. 8a p. 187: 5

   ii. 8b pp. 188-200: 4, 7, 11, 22, 28, 29, 36, 37, 38, 62

(b) **Experiment:** Forces and energy in a vertical, oscillating spring-mass-gravitational field system (2 days, hands on)

(c) Potential energy as field energy

(d) Mechanical energy

(e) Potential energy functions and curves

(f) Force as derivative of $U(r)$: $\mathbf{F} = -(\frac{\partial U}{\partial x}\hat{\mathbf{i}} + \frac{\partial U}{\partial y}\hat{\mathbf{j}} + \frac{\partial U}{\partial z}\hat{\mathbf{k}})$

(g) Conservative and non-conservative fields; $\oint \mathbf{F} \cdot d\mathbf{l} = 0$

(h) **Experiment:** Magnetic field energy for Pasco collision carts and bumpers. In this experiment students plot magnetic force vs position for magnetic Pasco collision cart pushed against repulsive magnetic bumper. KE of cart when released is compared to $\int F dx$. (2 days, hands on)

8. Particles subject to impulsive net forces (Week 10)

(a) Chapter 9 Assignments

   i. 9a pp. 227-240: 1, 8, 9, 15, 16,

   ii. 9b pp. 227-240: 20, 44, 73, 96, 110

   iii. 9c pp. 227-240: 5, 63

   iv. 9d pp. 227-240: 32, 33, 49, 113, 130

(b) Momentum

(c) Impulse $\mathbf{J} = \int \mathbf{F} dt$

(d) Center of mass

(e) **Experiment:** Finding elasticity coefficient in collisions (1 day, hands on)

(f) More Newtonian interaction laws

   i. Rate of momentum transfer between systems: Force

   ii. Momentum conservation in 1- and 2-dimensional interactions

(g) **Experiment:** Finding the velocity of object through collisions (2 days, hands on)

9. **Extended, rigid bodies having constant ω and constant α** (Week 11)
   (a) Chapter 10 Assignments
      i. 10a p. 264: 1, 2, 7, 10
      ii. 10b pp. 267-274: 4, 6, 11, 22, 27, 33, 36, 39
      iii. 10c pp. 267-274: 47, 53, 55, 84, 67, 108
   (b) Describing rotating bodies: rotational kinematics
   (c) Rotational KE
   (d) Parallel axis theorem

10. **Extended, rigid bodies subject to zero torque, constant net torque, and impulsive net torque** (Weeks 12 and 13)
   (a) Chapter 11 Assignments
      i. 11a p. 296: 4, 5, 6
      ii. 11b pp. 297-304: 1, 4, 7, 15, 37, 39, 46, 51, 56, 59
   (b) Torque defined
   (c) More Newtonian interaction laws
      i. Rate of angular momentum transfer between systems: Torque
      ii. Conservation of angular momentum
   (d) **Experiment:** Finding the rotational inertia of a large mailing tube (2 days + postlab, hands on)

11. **Extended, rigid body subject to both zero net force and zero net torque** (Week 14)
   (a) Chapter 12 Assignments
      i. 12a p. 320: 5
      ii. 12b pp. 321-329: 7, 10, 11, 15, 23, 27, 31, 81
   (b) Forces on stationary structures
   (c) Optional project: Chicago Bridge Building Contest

12. **Particle subject to central force; Keplerian particle** (Weeks 15 and 16)
   (a) Chapter 13 Assignments
      i. 13a pp. 351-358: 11, 28, 32, 33,
      ii. 13b pp. 351-358: 56, 58, 84, 92, 98
   (b) Universal gravitation
   (c) Activity: Writing a VPython script for orbiting particles
   (d) Energy in gravitational systems
      i. Bound systems: circular orbits
      ii. Unbound systems: escape velocity
      iii. Relation to physical and chemical binding
   (e) Particles in elliptical orbits

(f) **Experiment:** Using orbital data for central stars in Milky Way and Kepler's Third Law to find the mass of the Milky Way's central black hole (1 day, students use data provided at Cosmus, courtesy of Andrea Ghez and Jessica Lu.)

(g) NOVA video about Milky Way's central black hole: *Monster of the Milky Way*

13. **Simple harmonic oscillator (SHO)** (Week 17)

    (a) Chapter 15 Assignments

    i. 15a pp. 403-404: 1, 2, 5, 6, 7, 9, 11

    ii. 15b pp. 405-412: 9, 12, 16, 30, 31, 37, 49, 51, 96

    (b) **Experiment:** Finding how T depends on k and m for a spring-mass system (2 days, hands on)

    (c) Mass-spring system

    (d) Energy in SHO

    (e) Solution to differential equation for undamped SHO

    (f) **Experiment:** Finding how T depends on properties of embroidery hoops used as physical pendulums (2 days, hands on)

    (g) Systems modeled in accordance with SHO

    i. Simple pendulum

    ii. torsional pendulum

    iii. physical pendulum