

## Calculus/Physics Schedule, Second Semester

Note to instructors: There are two key places where the calculus and physics are very intertwined and the scheduling is difficult: Gauss' Law and the differential equation for RC circuits. It seems essential that the concepts are introduced first in physics and then the mathematics is carried out in detail in calculus. In the schedule below, this means that there is some juggling of Friday class time to make this possible.

<b>Monday Calculus</b>	<b>Tuesday Physics</b>	<b>Wednesday Calculus</b>	<b>Thursday Physics</b>	<b>Friday Combined</b>
	<p><u>First Day of Class</u> <u>Equilibrium problems</u> (review torque, model a problem on the board, then let students do several other problems in groups) SWBAT</p> <ul style="list-style-type: none"> <li>• Understand that hinges, pins, etc can provide forces in all directions, but pedestals only push up/down</li> <li>• Solve standard equilibrium problems, but nothing too fancy</li> </ul>	<p><u>Imaginary Numbers</u> SWBAT<sup>1</sup></p> <ul style="list-style-type: none"> <li>• Feel comfortable with the notation</li> <li>• Add, subtract, multiply and divide complex numbers</li> <li>• Represent complex numbers on the plane and think of complex numbers as vectors</li> <li>• Take a complex conjugate</li> <li>• Use <math>j</math> to stand for the square root of negative one</li> </ul>	<p><u>Describing oscillations</u> (UNH worksheets on <i>description of motion and investigating parameters</i>) SWBAT</p> <ul style="list-style-type: none"> <li>• Pick off amplitude, period, phase, frequency given <math>x(t)</math></li> <li>• Recall relations between period, frequency, and angular frequency</li> <li>• Understand qualitatively the effect of the mass and the spring constant on the motion</li> </ul>	<p><u>Imaginary Numbers</u> (Calculus only class) SWBAT</p> <ul style="list-style-type: none"> <li>• Express complex numbers in terms of angle and magnitude</li> <li>• Use Taylor's series to derive Euler's Formula that links exponentials to sines and cosines</li> <li>• Begin to do operations on complex numbers that are in exponential form</li> </ul>

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<sup>1</sup> SWBAT = Students will be able to

<p><u>WEEK TWO</u>  <u>Imaginary Numbers</u>  SWBAT</p> <ul style="list-style-type: none"> <li>• Take roots of complex numbers</li> <li>• Begin to be able to solve linear differential equation with constant coefficients using the guess <math>x=Re^{nt}</math>. This is used in the next physics class. They will use this same idea in the combined class on damped motion in a few weeks.</li> </ul>	<p><u>Dynamics of oscillations</u>  (UNH Worksheet <i>Forces for on object on a spring and Physical Pendulum</i>)  SWBAT</p> <ul style="list-style-type: none"> <li>• Find the differential equation knowing the forces</li> <li>• Solve the differential equation using <math>x=Re^{nt}</math> which was covered yesterday in math</li> <li>• Go between exponential and trigonometric functions</li> <li>• See the role of initial conditions in the solution</li> </ul>	<p><u>Differential Equations and Taylor Series</u>  Here students see the differential equation for simple harmonic motion solved using Taylor series. Also students see that the solution does not always converge.</p>	<p><u>Introductions to Waves</u>  (Lots of discussion, plus UNH worksheet <i>wave velocity/particle velocity</i>)  In this introductory class students are introduced to waves in general, the different types, begin to distinguish between wave and particle motion.</p>	<p><u>Fourier Series</u>  (UNH Sheet on Fourier Series)  Students will be introduced to the idea of Fourier series and get a bit of experience in calculating Fourier coefficients. This will be followed up with integration of trig functions in the next calc class.</p>
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<b>Monday Calculus</b>	<b>Tuesday Physics</b>	<b>Wednesday Calculus</b>	<b>Thursday Physics</b>	<b>Friday Combined</b>
<p><u>WEEK THREE</u> <u>Integration of Trig functions</u> SWBAT</p> <ul style="list-style-type: none"> <li>Integrate products of two sine or cosine functions as is needed for calculation of Fourier coefficients</li> </ul>	<p><u>Mathematical Formalism for Waves</u> (Do a book problem that has student translate between words, plots and/or equations description of waves; UNH sheet of phase; Maryland tutorial on superposition)</p>	<p><u>Introduction to Sequences and Series</u> Students are introduced to sequences of numbers and the question of convergence. They look at a few sequences and try to determine convergence.</p>	<p><u>Wave/Oscillation Experiments</u> (UNH sheets on <i>Resonance on a String</i> and <i>Oscillations on a Spring</i>) SWBAT</p> <ul style="list-style-type: none"> <li>Calculate resonance frequencies for a string</li> <li>Understand that sometimes our simplifications (e.g. a massless spring) gives us incorrect predictions</li> </ul>	<p><u>Problem: Damped Oscillators</u> (UNH Sheet on Damped Motion) Students try to find the value of smallest value of magnetic damping that meets certain design specification. This is a chance to solve a slightly more difficult differential equation; knowledge of the details of magnetic damping are not needed.</p>
<p><u>Geometric Series</u> SWBAT</p> <ul style="list-style-type: none"> <li>Recognize geometric series</li> <li>Be able to determine if a geometric series converges or diverges</li> </ul>	<p><u>Kinetic Theory of Gases</u> (UNH sheet on <i>What is temperature, really?</i>) SWBAT</p> <ul style="list-style-type: none"> <li>Make the connection between temperature and average kinetic energy</li> </ul>	<p><u>Review</u></p>	<p><u>Review</u></p>	<p><u>Test</u></p>

<p><u>WEEK FIVE</u> <u>Integral Test and U-substitution</u> SWBAT</p> <ul style="list-style-type: none"> <li>• Use the integral test to show convergence or divergence</li> <li>• Understand the value of u-substitution in integration</li> </ul>	<p><u>Specific Heat and Heat Transfer</u> (Standard book problems on specific heat) Students get another chance to look at conservation of energy through the lens of heat transfer and phase change.</p>	<p><u>Direct and Limit Comparison Tests</u> SWBAT</p> <ul style="list-style-type: none"> <li>• Use these two tests to check for series convergence</li> </ul>	<p><u>Introduction to electrostatics</u> (<i>Tutorial on Electric Charge</i>, standard book equilibrium problem) SWBAT</p> <ul style="list-style-type: none"> <li>• Define "same charges"</li> <li>• Explain and give evidence for the principle of superposition</li> <li>• Understand induced charge and its effects</li> <li>• Solve a three body equilibrium problem</li> </ul>	<p><u>Comet Problem - Part I</u> (Start project groups; UNH sheet on <i>How fast is the comet going?</i>) Students get a chance to put together gravitational force and work-energy theorem to solve a problem.</p>
<p><u>WEEK SIX</u> <u>More on u-substitution</u> SWBAT</p> <ul style="list-style-type: none"> <li>• Use this techniques to integrate</li> </ul>	<p><u>Coulomb Force, Gravitational Force</u> (Finish <i>Tutorial on Charge</i>, standard and UNH sheet on <i>Net Force</i>) SWBAT</p> <ul style="list-style-type: none"> <li>• Apply Newton's laws to situations that include Coulomb and/or Gravitational Forces</li> <li>• Student know how to find the net force on a charged particle/ planet using vector addition</li> </ul>	<p>Day to catch up or get ahead. (There is one more math day at this point in the semester, than last year.)</p>	<p><u>Introduction to the E field</u> (UNH sheet on <i>Electric Field</i> and <i>Tutorial on Electric Field and Flux</i>) This conceptual introduction to flux should be done before the mathematical calculations of flux. SWBAT</p> <ul style="list-style-type: none"> <li>• Define the electric field</li> <li>• interpret electric field lines</li> <li>• point out incorrectly drawn field lines</li> </ul> <p>estimate flux through a surface</p>	<p><u>Motion in an electric field and Comet Problem - Part II</u> (UNH sheets <i>Motion in an electric field</i> and <i>When will the comet hit?</i>) Students will get a chance to see again that the motion is not necessarily in the direction of the force, and see how to solve a differential equation numerically and check the answers for reasonableness.</p>

<p><u>WEEK SEVEN</u>  <u>Trigonometric substitution</u>  SWBAT</p> <ul style="list-style-type: none"> <li>Use this techniques to integrate</li> </ul>	<p><u>Gauss' Law- Part I<sup>2</sup></u>  (Tutorial on <i>Gauss' law</i>, finish up comet problem or start <i>E field due to bar of charge</i>)  SWBAT</p> <ul style="list-style-type: none"> <li>Estimate flux through a surface using <i>Gauss Law</i></li> <li>See why <i>Gauss law</i> still holds even if the charge is outside the surface.</li> </ul>	<p><u>Flux through a surface of revolution</u>  SWBAT</p> <ul style="list-style-type: none"> <li>Calculate the flux through a surface of revolution due to a point charge</li> </ul>	<p><u>Electric Field due to a bar of charge</u>  (UNH sheet on <i>E field due to a bar of charge</i>)  SWBAT</p> <ul style="list-style-type: none"> <li>Use superposition and knowledge of Reimann sums and integrals to calculate the <i>E field due to a uniform charge distribution</i></li> </ul>	<p><u>Satellite Problem</u>  Students use their understanding of Newton's Law of Gravity, circular motion, and problem solving to find the period of a satellite.  There might be extra time today to have students "discover" Kepler's Laws by putting together ideas they have been using all year.</p>
<p><u>Flux through a plane due to a point charge</u>  SWBAT</p> <ul style="list-style-type: none"> <li>Calculate the electric flux through an infinite plane</li> <li>Calculate the electric field due to an infinite uniform plane of charge</li> </ul>	<p><u>Gauss' Law - Part II</u>  (UNH sheets on <i>Gauss' Law and Symmetry</i> and <i>E field calculations Using Gauss Law</i>)  SWBAT</p> <ul style="list-style-type: none"> <li>Explain why symmetry plus <i>Gauss Law</i> can help us calculate <i>E</i> in a few special cases</li> <li>Understand why it is useful in <i>ONLY</i> these three cases for finding <i>E</i></li> </ul>	<p><u>Review</u></p>	<p><u>Review</u></p>	<p><u>Test</u></p>

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<sup>2</sup> The *Gauss' Law* is a bit out of standard order (that is, before calculation of *E* using integration) so that the calculations of flux can be done in the Calculus classes after a conceptual introduction in the physics class.

<b>Monday Calculus</b>	<b>Tuesday Physics</b>	<b>Wednesday Calculus</b>	<b>Thursday Physics</b>	<b>Friday Combined</b>
<p>WEEK NINE <u>Partial Fractions</u> SWBAT</p> <ul style="list-style-type: none"> <li>• Decompose a ratio into partial fractions</li> <li>• Use partial fractions to integrate</li> </ul>	<p><u>Potential Energy- Part I</u> (UNH sheets on <i>Motion in a gravitational/electric field, Calculating V due to point charges, Calculating V due to charge distributions</i>) SWBAT</p> <ul style="list-style-type: none"> <li>• Calculate the electric potential for groups of point charges, simple charge distributions and symmetric charge distributions</li> </ul>	<p><u>Integration by parts- Part I</u> SWBAT</p> <ul style="list-style-type: none"> <li>• Use integration by parts to calculate center of mass</li> <li>• Use integration by parts to find Fourier coefficients</li> </ul>	<p><u>Potential Energy - Part II</u> (UNH sheets on <i>Visualizing V and V due to a cylinder</i>) SWBAT</p> <ul style="list-style-type: none"> <li>• Interpret equipotential curves</li> <li>• Calculate V for an infinite cylinder</li> <li>• Verify V between two concentric hoops</li> </ul>	<p><u>Neon Light problem</u> (UNH sheet on <i>Neon Lights</i>) Students use their understanding of energy and the electric potential to understand energy transitions in a neon atom.</p>

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<p>WEEK TEN</p> <p><u>Integration by Parts - Part II</u></p> <p>Students continue to practice with integration by parts, using it twice to solve an integral.</p>	<p><u>Capacitance - Part I</u> (UNH sheet on <i>Infinite Sheets of Charge</i> and <i>Tutorial on Capacitance</i>)</p> <p>SWBAT</p> <ul style="list-style-type: none"> <li>Understand the role of a capacitor in a circuit</li> <li>Explain why capacitance depends only on geometry and not on charge or voltage</li> </ul>	<p><u>Root and Ratio Test</u></p> <p>SWBAT</p> <ul style="list-style-type: none"> <li>Prove convergence or divergence of a series using root, ratio, and previously discussed convergence tests</li> </ul>	<p><u>Capacitance - Part II</u> (Standard book problems on equivalent capacitance, UNH sheet on <i>Messy capacitors</i> and <i>More complicated capacitors</i>)</p> <p>SWBAT</p> <ul style="list-style-type: none"> <li>Recognize capacitors in series and in parallel, even if the circuit is drawn in a messy way</li> <li>Find the equivalent capacitance for a complicated circuit</li> <li>Understand the role of a dielectric material in a capacitor</li> </ul>	<p><u>Physics Class</u><sup>3</sup></p> <p><u>Introduction to Resistors and Kirchhoff's Laws</u> (<i>Tutorial on Current and Resistance</i> and an introductory discussion of Kirchhoff's Laws)</p> <p>SWBAT</p> <ul style="list-style-type: none"> <li>Understand the basics of resistors in series and parallel</li> <li>Understand that current is not used up</li> <li>Understand that Kirchhoff's Laws are really conservation of energy and charge</li> </ul>
<p>WEEK ELEVEN</p> <p><u>Power Series and Alternating Series</u></p> <p>SWBAT</p> <ul style="list-style-type: none"> <li>Be able to check the interval of convergence of a power series, including checking the endpoints</li> </ul>	<p><u>Resistors - Part II</u> (<i>Tutorial on Current and Resistance, part II</i> and standard book problems on equivalent resistance, UNH sheet on <i>Ammeters and Voltmeters</i>)</p> <p>SWBAT</p> <ul style="list-style-type: none"> <li>Conceptually use the loop rule to predict circuit behavior</li> <li>Find the equivalent resistance</li> </ul>	<p><u>Differential Equations for RC circuits- Part I</u></p> <p>SWBAT</p> <ul style="list-style-type: none"> <li>Write down the differential equation for a single loop RC circuit</li> </ul> <p>Solve the inhomogeneous differential equation using integrating factors.</p>	<p><u>Kirchhoff's Laws</u> (Standard book problems on Kirchhoff's Laws)</p> <p>SWBAT</p> <p>Analyze a moderately complicated circuit (two to three loops) using Kirchhoff's Laws</p>	<p><u>Charging and Discharging RC circuits -Day 1</u> (UNH sheets on <i>Charging RC Circuits</i> and <i>Discharging RC Circuits</i>)</p> <p>SWBAT</p> <ul style="list-style-type: none"> <li>Understand an RC circuit conceptually, mathematically and experimentally</li> </ul>

<sup>3</sup> This is out of order to introduce Kirchhoff's laws before students solve circuits in calculus class

<b>Monday Calculus</b>	<b>Tuesday Physics</b>	<b>Wednesday Calculus</b>	<b>Thursday Physics</b>	<b>Friday Combined</b>
<p>WEEK TWELVE <u>Differential Equations for RC circuits- Part II</u> SWBAT</p> <ul style="list-style-type: none"> <li>• Write down the differential equation for multiloop RC circuit</li> </ul> <p>Find qualitative solutions only for such systems of equations</p>	<p><u>Charging and Discharging RC circuits -Day 2</u> (UNH sheets on <i>Charging RC Circuits</i> and <i>Discharging RC Circuits</i>) SWBAT</p> <ul style="list-style-type: none"> <li>• Understand an RC circuit conceptually, mathematically and experimentally</li> </ul>	<p>Review</p>	<p>Review</p>	<p>test</p>
<p>WEEK THIRTEEN <u>Polar coordinates - Part I</u> SWBAT</p> <ul style="list-style-type: none"> <li>• Convert a function from Cartesian to polar coordinates</li> <li>• Use their calculator to plot a function of polar coordinates</li> </ul>	<p><u>Introduction to Magnetism</u> (UNH sheet on <i>Investigating Magnets</i>) SWBAT</p> <ul style="list-style-type: none"> <li>• Draw distinctions between electrostatics and magnetism</li> <li>• Sketch the lines of magnetic force</li> <li>• See the effect of a magnet on the motion of a beam of electrons</li> </ul>	<p><u>Polar Coordinates - part II</u> SWBAT</p> <ul style="list-style-type: none"> <li>• Calculate arc length and work in polar coordinates</li> </ul>	<p><u>Motion in a Magnetic Field</u> (UNH sheet on <i>Motion in a constant B field</i> and standard book problems) SWBAT</p> <ul style="list-style-type: none"> <li>• Explain why a charged particle will move in a circle in a constant B field</li> <li>• Explain how we know from the Hall effect that electrons are carry current, not protons</li> </ul>	<p><u>LRC Circuit</u> (UNH sheet on <i>A new circuit element</i>) Students use their knowledge of circuits and differential equations to solve for the time evolution of an LC and an LRC circuit. At this point the inductor is a black box, since inductors are the last thing they learn about this year.</p>

<b>Monday Calculus</b>	<b>Tuesday Physics</b>	<b>Wednesday Calculus</b>	<b>Thursday Physics</b>	<b>Friday Combined</b>
<p>WEEK FOURTEEN <u>Limits Redux - Part I</u> Students revisit the idea of limits in a more rigorous way than before, using the electric potential due to a bar of charge as the specific example</p>	<p><u>Current Loop as a Magnetic Dipole</u> (<i>Tutorial on Magnetic Interactions</i>) SWBAT</p> <ul style="list-style-type: none"> <li>• See that current loops create magnetic fields similar to bar magnets</li> <li>• See that current loops behave like bar magnets when placed near another magnet</li> <li>• Understand that there are current loops inside all materials</li> </ul>	<p><u>Limits Redux - Part II</u> Students are introduced to the <math>\epsilon</math>-<math>\delta</math> definition of limits, using graphs as an aid to understanding. They see some pathological examples seen in dealing with limits.</p>	<p><u>Magnetic Fields and Current-carrying wires</u> (UNH sheets on <i>torque on a current loop</i> and <i>B field due to a wire</i> and standard book problems) SWBAT</p> <ul style="list-style-type: none"> <li>• Calculate the torque on a current loop</li> <li>• Calculate the B field due to a straight piece of wire or an arc of wire</li> <li>• Calculate the force between two straight current-carrying wires</li> </ul>	<p><u>Martian Gas Gauge</u> The students bring together many ideas (circuits, series and differential equations) to help some Martian visitors solve a difficult design problem. This is a long and difficult problem, and should only be done if all else is going well. Otherwise, use this day to catch up.</p>
<p>WEEK FIFTEEN <u>L'Hopital's Rule - Part I</u> Students are introduced to this rule and practice using it to determine the limit of a function <math>h(t)/g(t)</math> when both <math>h</math> and <math>g</math> go to zero.</p>	<p><u>Ampere's Law and Faraday's law</u> (UNH sheet on <i>Applying Ampere's law</i>, and standard book problems on Lenz law) SWBAT</p> <ul style="list-style-type: none"> <li>• Use Ampere's law in situations of high symmetry to calculate the B field</li> <li>• See that changing magnetic flux induces a current</li> <li>• Calculate how much current is induced in a given situation.</li> </ul>	<p><u>L'Hopital's Rule - Part II</u> Students are introduced to using this rule with composite functions.</p>	<p><u>Lenz's Law</u> (<i>Tutorial on Lenz's Law</i>) SWBAT</p> <ul style="list-style-type: none"> <li>• Predict the direction of induced current in a given situation</li> <li>• Understand the role of inductors in a circuit</li> </ul>	<p><u>Project Presentations</u></p>

