HORRY GEORGETOWN
TECHNICAL COLLEGE

INSTRUCTIONAL PACKAGE

PHY 222
University Physics II

Effective Term
Fall 2023/Spring 2024/Summer 2024

INSTRUCTIONAL PACKAGE

Part I: Course Information

Effective Term: Fall 2023/Spring 2024/Summer 2024

COURSE PREFIX: PHY 222 COURSE TITLE: University Physics II

CONTACT HOURS: 3-3 CREDIT HOURS: 4

RATIONALE FOR THE COURSE:

Completion of PHY 222 enables the student to gain an appreciation and working knowledge of fundamental principles in the area of physics and build on the concepts introduced in PHY 221. These concepts are approached through the development of problem-solving skills, which helps prepare students for future careers in science fields. Additionally, this course applies concepts learned in calculus to topics in physics, therefore enhancing cross-curriculum instruction.

COURSE DESCRIPTION:

This course is a continuation of calculus-based treatment of the following topics: thermodynamics, kinetic theory of gases, electricity and magnetism, including electrostatics, dielectrics, electric circuits, magnetic fields, and induction phenomena. This course is transferable to public senior institutions as part of the South Carolina Higher Education Statewide Articulation Agreement.

PREREQUISITES/CO-REQUISITES:

Credit level PHY 221 Minimum Grade of C or Credit level PHY 221 Minimum Grade of TC

***Online/Hybrid** courses require students to complete the DLi Orientation Video prior to enrolling in an online course.

REQUIRED MATERIALS:

Please visit the BOOKSTORE online site for most current textbook information.

Enter the semester, course prefix, number and section when prompted and you will be linked to the correct textbook.

ADDITIONAL REQUIREMENTS:

A scientific calculator and graph paper.

For Hybrid/Online Students Only: Each student will be required to view an orientation PowerPoint presentation during the first week of class. This presentation can be found on the course homepage in D2L under News. After viewing the presentation, all online students must complete the orientation quiz, which can be found under the dropdown assignment menu. A student will not be considered officially enrolled in the course until the presentation has been viewed and the quiz completed with a 100% score. Any submitted work from the student including discussion posts, assignments, etc. will not be given a grade until the presentation has been viewed and the quiz has been submitted. Failure to view the presentation and take the quiz before midnight on the last day to add/drop classes will result in the student being automatically dropped from the course.

TECHNICAL REQUIREMENTS:

Access to Desire2Learn (D2L), HGTC's learning management system (LMS) used for course materials.
Access to myHGTC portal for student self-services.
College email access – this is the college's primary official form of communication.

STUDENT IDENTIFICATION VERIFICATION:

Students enrolled in online courses will be required to participate in a minimum of one (1) proctored assignment and/or one (1) virtual event to support student identification verification. Please refer to your Instructor Information Sheet for information regarding this requirement.

CLASSROOM ETIQUETTE:

As a matter of courtesy to other students and your professor, please turn off cell phones and other communication/entertainment devices before class begins. If you are monitoring for an emergency, please notify your professor prior to class and switch cell phone ringers to vibrate.

NETIQUETTE: is the term commonly used to refer to conventions adopted by Internet users on the web, mailing lists, public forums, and in live chat focused on online communications etiquette. For more information regarding Netiquette expectations for distance learning courses, please visit Online Netiquette.

ACADEMIC DISHONESTY:

All forms of academic dishonesty, as outlined in the Student Code in the HGTC catalog, will NOT be tolerated and will result in disciplinary action. Anyone caught cheating or committing plagiarism (Defined in the code as: "The appropriation of any other person's work and the unacknowledged incorporation of that work in one's own work offered for credit") will be given a grade of a zero for that assignment and reported to the Senior VP of Academic Affairs, in accordance with the student handbook. A second offense will result in the student being withdrawn from the course with a "WF" and charges being filed with the Chief Student Services Officer.

Part II: Student Learning Outcomes

COURSE LEARNING OUTCOMES and ASSESSMENTS*:

A student will demonstrate an understanding of temperature, heat, and the first law of thermodynamics by:

Identifying the lowest temperature as zero on the Kelvin scale (absolute zero)
Explaining the zeroth law of thermodynamics
Explaining the conditions for the triple-point temperature
Explaining the conditions for measuring a temperature with a constant-volume gas thermometer.
For a constant-volume gas thermometer, relating the pressure and temperature of the gas in some given state to the pressure and temperature at the triple point.
Converting a temperature between any two (linear) temperature scales, including he Celsius, Fahrenheit, and kelvin scales.
Identifying that a change of one degree is the same on the Celsius and Kelvin scales.
For one-dimensional thermal expansion, applying the relationship between the temperature change ΔT, the length change ΔL, the initial length L, and the coefficient of linear expansion α.
For two-dimensional thermal expansion, use one-dimensional thermal expansion to find the change in area.
For three-dimensional thermal expansion, apply the relationship between the temperature change ΔT, the volume change ΔV, the initial volume V, and the coefficient of volume expansion β.
Identifying that thermal energy is associated with the random motions of the microscopic bodies in an object.
Identifying that heat Q is the amount of transferred energy (either to or from an object's thermal energy) due to a temperature difference between the object and its environment.
Converting energy units between various measurement systems.
Converting between mechanical or electrical energy and thermal energy.
For a temperature change ΔT of a substance, relating the change to the heat transfer Q and the substance's specific heat c and mass m.
Identifying the three phases of matter.
For a phase change of a substance, relating the heat transfer Q, the heat of transformation L, and the amount of mass m transformed.
Identifying that if a heat transfer Q takes a substance across a phase-change temperature, the transfer must be calculated in steps: (a) a temperature change to reach the phase-change temperature,
(b) the phase change, and then (c) any temperature change that moves the substance away from the phase-change temperature.
If an enclosed gas expands or contracts, calculating the work W done by the gas by integrating the gas pressure with respect to the volume of the enclosure.
Identifying the algebraic sign of work W associated with expansion and contraction of a gas.
Given a p-V graph of pressure versus volume for a process, identifying the starting point (the initial state) and the final point (the final state) and calculate the work by using graphical integration.
On a p-V graph of pressure versus volume for a gas, identifying the algebraic sign of the work associated sign of the work associated with a right-going process and a left-going process.

Applying the first law of thermodynamics to relate the change in the internal energy ΔE_{int} of a gas, the energy Q transferred as heat to or from the gas, and the work W done on or by the gas.
Identifying that the internal energy ΔE_{int} of a gas tends to increase if the heat transfer is to the gas, and it tends to decrease if the gas does work on its environment.
Identify that in an adiabatic process with a gas, there is no heat transfer Q with the environment.
Identify that in a constant-volume process with a gas, there is no work W done by the gas.
Identify that in a cyclical process with a gas, there is no net change in the internal energy ΔEint.
Identify that in a free expansion with a gas, the heat transfer Q, work done W, and change in internal energy ΔEint are each zero.

<u>A student will demonstrate an understanding of the kinetic theory of gases by:</u>

Identify Avogadro's number NA.
Apply the relationship between the number of moles n, the number of molecules N, and Avogadro's number NA.
Apply the relationships between the mass m of a sample, the molar mass M of the molecules in the sample, the number of moles n in the sample, and Avogadro's number NA.
Identify why an ideal gas is said to be ideal.
Apply either of the two forms of the ideal gas law, written in terms of the number of moles n or the number of molecules N.
Relate the ideal gas constant R and the Boltzmann constant k.
Identify that the temperature in the ideal gas law must be in kelvins.
Sketch p-V diagrams for a constant-temperature expansion of a gas and a constant-temperature contraction.
Identify the term isotherm.
Calculate the work done by a gas, including the algebraic sign, for an expansion and a contraction along an isotherm.
For an isothermal process, identify that the change in internal energy ΔE is zero and that the energy Q transferred as heat is equal to the work W done.
On a p-V diagram, sketch a constant-volume process and identify the amount of work done in terms of area on the diagram.
On a p-V diagram, sketch a constant-pressure process and determine the work done in terms of area on the diagram.
Identify that the pressure on the interior walls of a gas container is due to the molecular collisions with the walls.
Relate the pressure on a container wall to the momentum of the gas molecules and the time intervals between their collisions with the wall.
For the molecules of an ideal gas, relate the root-mean-square speed vrms and the average speed Vavg.
Relate the pressure of an ideal gas to the rms speed vrms of the molecules.
For an ideal gas, apply the relationship between the gas temperature T and the rms speed vrms and molar mass M of the molecules.
For an ideal gas, relate the average kinetic energy of the molecules to their rms speed.
Apply the relationship between the average kinetic energy and the temperature of the gas.
Identify that a measurement of a gas temperature is effectively a measurement of the average kinetic energy of the gas molecules.

Identify what is meant by mean free path.
Apply the relationship between the mean free path, the diameter of the molecules, and the number of molecules per unit volume.
Explain how Maxwell's speed distribution law is used to find the fraction of molecules with speeds in a certain speed range.
Sketch a graph of Maxwell's speed distribution, showing the probability distribution versus speed and indicating the relative positions of the average speed vavg, the most probable speed vP, and the rms speed vrms.
Explain how Maxwell's speed distribution is used to find the average speed, the rms speed, and the most probable speed.
For a given temperature T and molar mass M, calculate the average speed vavg, the most probable speed vP, and the rms speed vrms.
Identify that the internal energy of an ideal monatomic gas is the sum of the translational kinetic energies of its atoms.
Apply the relationship between the internal energy Eint of a monatomic ideal gas, the number of moles n, and the gas temperature T.
Distinguish between monatomic, diatomic, and polyatomic ideal gases.
For monatomic, diatomic, and polyatomic ideal gases, evaluate the molar specific heats for a constant-volume process and a constant-pressure process.
Calculate a molar specific heat at constant pressure Cp by adding R to the molar specific heat at constant volume CV and explain why (physically) Cp is greater.
Identify that the energy transferred to an ideal gas as heat in a constant-volume process goes entirely into the internal energy (the random translational motion) but that in a constant-pressure process energy also goes into the work done to expand the gas.
Identify that for a given change in temperature, the change in the internal energy of an ideal gas is the same for any process and is most easily calculated by assuming a constant-volume process.
For an ideal gas, apply the relationship between heat Q, number of moles n, and temperature change ΔT, using the appropriate molar specific heat.
Between two isotherms on a p-V diagram, sketch a constant-volume process and a constant-pressure process, and for each identify the work done in terms of area on the graph.
Calculate the work done by an ideal gas for a constant-pressure process.
Identify that work is zero for constant volume.
Identify that a degree of freedom is associated with each way a gas can store energy (translation, rotation, and oscillation).
Identify that a monatomic gas can have an internal energy consisting of only translational motion.
Identify that at low temperatures a diatomic gas has energy in only translational motion, at higher temperatures it also has energy in molecular rotation, and at even higher temperatures it can also have energy in molecular oscillations.
Calculate the molar specific heat for monatomic and diatomic ideal gases in a constant-volume process and a constant-pressure process.
On a p-V diagram, sketch an adiabatic expansion (or contraction) and identify that there is no heat exchange Q with the environment.
Identify that in an adiabatic expansion, the gas does work on the environment, decreasing the gas's internal energy, and that in an adiabatic contraction, work is done on the gas, increasing the internal energy.
In an adiabatic expansion or contraction, relate the initial pressure and volume to the final pressure and

volume.
In an adiabatic expansion or contraction, relate the initial temperature and volume to the final temperature and volume.
Calculate the work done in an adiabatic process by integrating the pressure with respect to volume.
Identify that a free expansion of a gas into a vacuum is adiabatic but no work is done and thus, by the first law of thermodynamics, the internal energy and temperature of the gas do not change.

<u>A student will demonstrate an understanding of entropy and the Second Law of Thermodynamics by:</u>

Identify the second law of thermodynamics: If a process occurs in a closed system, the entropy of the system increases for irreversible processes and remains constant for reversible processes; it never decreases.
Identify that entropy is a state function (the value for a particular state of the system does not depend on how that state is reached).
Calculate the change in entropy for a process by integrating the inverse of the temperature (in kelvins) with respect to the heat Q transferred during the process.
For a phase change with a constant-temperature process, apply the relationship between the entropy change ΔS, the total transferred heat Q, and the temperature T (in kelvins).
For a temperature change ΔT that is small relative to the temperature T, apply the relationship between the entropy change ΔS, the transferred heat Q, and the average temperature Tavg (in kelvins).
For an ideal gas, apply the relationship between the entropy change ΔS and the initial and final values of the pressure and volume.
Identify that if a process is an irreversible one, the integration for the entropy change must be done for a reversible process that takes the system between the same initial and final states as the irreversible process.
For stretched rubber, relate the elastic force to the rate at which the rubber's entropy changes with the change in the stretching distance.
Identify that a heat engine is a device that extracts energy from its environment in the form of heat and does useful work and that in an ideal heat engine, all processes are reversible, with no wasteful energy transfers.
Sketch a p-V diagram for the cycle of a Carnot engine, indicating the direction of cycling, the nature of the processes involved, the work done during each process (including algebraic sign), the net work done in the cycle, and the heat transferred during each process (including algebraic sign).
Sketch a Carnot cycle on a temperature–entropy diagram, indicating the heat transfers.
Determine the net entropy change around a Carnot cycle.
Calculate the efficiency ϵC of a Carnot engine in terms of the heat transfers and in terms of the temperatures of the reservoirs.
Identify that there are no perfect engines in which the energy transferred as heat Q from a high-temperature reservoir goes entirely into the work W done by the engine.
Sketch a p-V diagram for the cycle of a Stirling engine, indicating the direction of cycling, the nature of the processes involved, the work done during each process (including algebraic sign), the net work done in the cycle, and the heat transfers during each process.
Identify that a refrigerator is a device that uses work to transfer energy from a low-temperature reservoir to a high-temperature reservoir, and that an ideal refrigerator is one that does this with reversible processes and no wasteful losses.

Sketch a p-V diagram for the cycle of a Carnot refrigerator, indicating the direction of cycling, the nature of the processes involved, the work done during each process (including algebraic sign), the net work done in the cycle, and the heat transferred during each process (including algebraic sign).
Apply the relationship between the coefficient of performance K and the heat exchanges with the reservoirs and the temperatures of the reservoirs.
Identify that there is no ideal refrigerator in which all the energy extracted from the low-temperature reservoir is transferred to the high-temperature reservoir.
Identify that the efficiency of a real engine is less than that of the ideal Carnot engine.
Explain what is meant by the configurations of a system of molecules.
Calculate the multiplicity of a given configuration.
Identify that all microstates are equally probable but the configurations with more microstates are more probable than the other configurations.
Apply Boltzmann's entropy equation to calculate the entropy associated with a multiplicity.

<u>A student will demonstrate an understanding of Coulomb's Law by:</u>

Distinguish between being electrically neutral, negatively charged, and positively charged and identify excess charge.
Distinguish between conductors, nonconductors (insulators), semiconductors, and superconductors.
Describe the electrical properties of the particles inside an atom.
Identify conduction electrons and explain their role in making a conducting object negatively or positively charged.
Identify what is meant by "electrically isolated" and by "grounding."
Explain how a charged object can set up induced charge in a second object.
Identify that charges with the same electrical sign repel each other and those with opposite electrical signs attract each other.
For either of the particles in a pair of charged particles, draw a free-body diagram, showing the electrostatic force (Coulomb force) on it and anchoring the tail of the force vector on that particle.
For either of the particles in a pair of charged particles, apply Coulomb's law to relate the magnitude of the electrostatic force, the charge magnitudes of the particles, and the separation between the particles.
Identify that Coulomb's law applies only to (point-like) particles and objects that can be treated as particles.
If more than one force acts on a particle, find the net force by adding all the forces as vectors, not scalars.
Identify that a shell of uniform charge attracts or repels a charged particle that is outside the shell as if all the shell's charge were concentrated as a particle at the shell's center.
Identify that if a charged particle is located inside a shell of uniform charge, there is no net electrostatic force on the particle from the shell.
Identify that if excess charge is put on a spherical conductor, it spreads out uniformly over the external surface area.
Identify that if two identical spherical conductors touch or are connected by conducting wire, any excess charge will be shared equally.
Identify that a nonconducting object can have any given distribution of charge, including charge at interior points.
Identify current as the rate at which charge moves through a point.

For current through a point, apply the relationship between the current, a time interval, and the amount of charge that moves through the point in that time interval.
Identify the elementary charge.
Identify that the charge of a particle or object must be a positive or negative integer times the elementary charge.
Identify that in any isolated physical process, the net charge cannot change (the net charge is always conserved).
Identify an annihilation process of particles and a pair production of particles.
Identify mass number and atomic number in terms of the number of protons, neutrons, and electrons.

<u>A student will demonstrate an understanding of electric fields by:</u>

Identify that at every point in the space surrounding a charged particle, the particle sets up an electric field, which is a vector quantity and thus has both magnitude and direction.
Identify how an electric field can be used to explain how a charged particle can exert an electrostatic force on a second charged particle even though there is no contact between the particles.
Explain how a small positive test charge is used (in principle) to measure the electric field at any given point.
Explain electric field lines, including where they originate and terminate and what their spacing represents.
In a sketch, draw a charged particle, indicate its sign, pick a nearby point, and then draw the electric field vector at that point, with its tail anchored on the point.
For a given point in the electric field of a charged particle, identify the direction of the field vector when the particle is positively charged and when it is negatively charged.
For a given point in the electric field of a charged particle, apply the relationship between the field magnitude E, the charge magnitude, and the distance r between the point and the particle.
Identify that the equation given here for the magnitude of an electric field applies only to a particle, not an extended object.
If more than one electric field is set up at a point, draw each electric field vector and then find the net electric field by adding the individual electric fields as vectors (not as scalars).
Draw an electric dipole, identifying the charges (sizes and signs), dipole axis, and direction of the electric dipole moment.
Identify the direction of the electric field at any given point along the dipole axis, including between the charges.
Outline how the equation for the electric field due to an electric dipole is derived from the equations for the electric field due to the individual charged particles that form the dipole.
For a single charged particle and an electric dipole, compare the rate at which the electric field magnitude decreases with increase in distance. That is, identify which drops off faster.
For an electric dipole, apply the relationship between the magnitude p of the dipole moment, the separation d between the charges, and the magnitude q of either of the charges.
For any distant point along a dipole axis, apply the relationship between the electric field magnitude E, the distance z from the center of the dipole, and either the dipole moment magnitude p or the product of charge magnitude q and charge separation d.
For a uniform distribution of charge, find the linear charge density λ for charge along a line, the surface charge density σ for charge on a surface, and the volume charge density ρ for charge in a volume.
For charge that is distributed uniformly along a line, find the net electric field at a given point near the

line by splitting the distribution up into charge elements dq and then summing (by integration) the electric field vectors set up at the point by each element.
Explain how symmetry can be used to simplify the calculation of the electric field at a point near a line of uniformly distributed charge.
Sketch a disk with uniform charge and indicate the direction of the electric field at a point on the central axis if the charge is positive and if it is negative.
Explain how the equation for the electric field on the central axis of a uniformly charged ring can be used to find the equation for the electric field on the central axis of a uniformly charged disk.
For a point on the central axis of a uniformly charged disk, apply the relationship between the surface charge density σ, the disk radius R, and the distance z to that point.
For a charged particle placed in an external electric field (a field due to other charged objects), apply the relationship between the electric field at that point, the particle's charge q, and the electrostatic force that acts on the particle, and identify the relative directions of the force and the field when the particle is positively charged and negatively charged.
Explain Millikan's procedure of measuring the elementary charge.
Explain the general mechanism of ink-jet printing.
On a sketch of an electric dipole in an external electric field, indicate the direction of the field, the direction of the dipole moment, the direction of the electrostatic forces on the two ends of the dipole, and the direction in which those forces tend to rotate the dipole, and identify the value of the net force on the dipole.
Calculate the torque on an electric dipole in an external electric field by evaluating a cross product of the dipole moment vector and the electric field vector, in magnitude-angle notation and unit-vector notation.
For an electric dipole in an external electric field, relate the potential energy of the dipole to the work done by a torque as the dipole rotates in the electric field.
For an electric dipole in an external electric field, calculate the potential energy by taking a dot product of the dipole moment vector and the electric field vector, in magnitude-angle notation and unit-vector notation.
For an electric dipole in an external electric field, identify the angles for the minimum and maximum potential energies and the angles for the minimum and maximum torque magnitudes.

<u>A student will demonstrate an understanding of Gauss's Law by:</u>

Identify that Gauss' law relates the electric field at points on a closed surface (real or imaginary, said to be a Gaussian surface) to the net charge enclosed by that surface.
Identify that the amount of electric field piercing a surface (not skimming along the surface) is the electric flux Φ through the surface.
Identify that an area vector for a flat surface is a vector that is perpendicular to the surface and that has a magnitude equal to the area of the surface.
Identify that any surface can be divided into area elements (patch elements) that are each small enough and flat enough for an area vector to be assigned to it, with the vector perpendicular to the element and having a magnitude equal to the area of the element.
Calculate the flux Φ through a surface by integrating the dot product of the electric field vector and the area vector (for patch elements) over the surface, in magnitude-angle notation and unit-vector notation.
For a closed surface, explain the algebraic signs associated with inward flux and outward flux.

Calculate the net flux Φ through a closed surface, algebraic sign included, by integrating the dot product of the electric field vector and the area vector (for patch elements) over the full surface.
Determine whether a closed surface can be broken up into parts (such as the sides of a cube) to simplify the integration that yields the net flux through the surface.
Apply Gauss' law to relate the net flux Φ through a closed surface to the net enclosed charge qenc.
Identify how the algebraic sign of the net enclosed charge corresponds to the direction (inward or outward) of the net flux through a Gaussian surface.
Identify that charge outside a Gaussian surface makes no contribution to the net flux through the closed surface.
Derive the expression for the magnitude of the electric field of a charged particle by using Gauss' law.
Identify that for a charged particle or uniformly charged sphere, Gauss' law is applied with a Gaussian surface that is a concentric sphere.
Apply the relationship between surface charge density σ and the area over which the charge is uniformly spread.
Identify that if excess charge (positive or negative) is placed on an isolated conductor, that charge moves to the surface, and none is in the interior.
Identify the value of the electric field inside an isolated conductor.
For a conductor with a cavity that contains a charged object, determine the charge on the cavity wall and on the external surface.
Explain how Gauss' law is used to find the electric field magnitude E near an isolated conducting surface with a uniform surface charge density σ.
For a uniformly charged conducting surface, apply the relationship between the charge density σ and the electric field magnitude E at points near the conductor, and identify the direction of the field vectors.
Explain how Gauss' law is used to derive the electric field magnitude outside a line of charge or a cylindrical surface (such as a plastic rod) with a uniform linear charge density λ.
Apply the relationship between linear charge density λ on a cylindrical surface and the electric field magnitude E at radial distance r from the central axis.
Explain how Gauss' law can be used to find the electric field magnitude inside a cylindrical nonconducting surface (such as a plastic rod) with a uniform volume charge density ρ.
Apply Gauss' law to derive the electric field magnitude E near a large, flat, nonconducting surface with a uniform surface charge density σ.
For points near a large, flat nonconducting surface with a uniform charge density σ, apply the relationship between the charge density and the electric field magnitude E and also specify the direction of the field.
For points near two large, flat, parallel, conducting surfaces with a uniform charge density σ, apply the relationship between the charge density and the electric field magnitude E and also specify the direction of the field.
Identify that a shell of uniform charge attracts or repels a charged particle that is outside the shell as if all the shell's charge is concentrated at the center of the shell.
Identify that if a charged particle is enclosed by a shell of uniform charge, there is no electrostatic force on the particle from the shell.
For a point outside a spherical shell with uniform charge, apply the relationship between the electric field magnitude E, the charge q on the shell, and the distance r from the shell's center.
Identify the magnitude of the electric field for points enclosed by a spherical shell with uniform charge.
For a uniform spherical charge distribution (a uniform ball of charge), determine the magnitude and direction of the electric field at interior and exterior points.

<u>A student will demonstrate an understanding of electric potentials by:</u>

Identify that the electric force is conservative and thus has an associated potential energy.
Identify that at every point in a charged object's electric field, the object sets up an electric potential V, which is a scalar quantity that can be positive or negative depending on the sign of the object's charge.
For a charged particle placed at a point in an object's electric field, apply the relationship between the object's electric potential V at that point, the particle's charge q, and the potential energy U of the particle–object system.
Convert energies between units of joules and electron-volts.
If a charged particle moves from an initial point to a final point in an electric field, apply the relationships between the change ΔV in the potential, the particle's charge q, the change ΔU in the potential energy, and the work W done by the electric force.
If a charged particle moves between two given points in the electric field of a charged object, identify that the amount of work done by the electric force is path independent.
If a charged particle moves through a change ΔV in electric potential without an applied force acting on it, relate ΔV and the change ΔK in the particle's kinetic energy.
If a charged particle moves through a change ΔV in electric potential while an applied force acts on it, relate ΔV, the change ΔK in the particle's kinetic energy, and the work Wapp done by the applied force.
Identify an equipotential surface and describe how it is related to the direction of the associated electric field.
Given an electric field as a function of position, calculate the change in potential ΔV from an initial point to a final point by choosing a path between the points and integrating the dot product of the field and a length element along the path.
For a uniform electric field, relate the field magnitude E and the separation Δx and potential difference ΔV between adjacent equipotential lines.
Given a graph of electric field E versus position along an axis, calculate the change in potential ΔV from an initial point to a final point by graphical integration.
Explain the use of a zero-potential location.
For a given point in the electric field of a charged particle, apply the relationship between the electric potential V, the charge of the particle q, and the distance r from the particle.
Identify the correlation between the algebraic signs of the potential set up by a particle and the charge of the particle.
For points outside or on the surface of a spherically symmetric charge distribution, calculate the electric potential as if all the charge is concentrated as a particle at the center of the sphere.
Calculate the net potential at any given point due to several charged particles, identifying that algebraic addition is used, not vector addition.
Draw equipotential lines for a charged particle.
Calculate the potential V at any given point due to an electric dipole, in terms of the magnitude p of the dipole moment or the product of the charge separation d and the magnitude q of either charge.
For an electric dipole, identify the locations of positive potential, negative potential, and zero potential.
Compare the decrease in potential with increasing distance for a single charged particle and an electric dipole.

For charge that is distributed uniformly along a line or over a surface, find the net potential at a given point by splitting the distribution up into charge elements and summing (by integration) the potential due to each one.
Given an electric potential as a function of position along an axis, find the electric field along that axis.
Given a graph of electric potential versus position along an axis, determine the electric field along the axis.
For a uniform electric field, relate the field magnitude E and the separation Δx and potential difference ΔV between adjacent equipotential lines.
Relate the direction of the electric field and the directions in which the potential decreases and increases.
Identify that the total potential energy of a system of charged particles is equal to the work an applied force must do to assemble the system, starting with the particles infinitely far apart.
Calculate the potential energy of a pair of charged particles.
Identify that if a system has more than two charged particles, then the system's total potential energy is equal to the sum of the potential energies of every pair of the particles.
Apply the principle of the conservation of mechanical energy to a system of charged particles.
Calculate the escape speed of a charged particle from a system of charged particles (the minimum initial speed required to move infinitely far from the system).
Identify that an excess charge placed on an isolated conductor (or connected isolated conductors) will distribute itself on the surface of the conductor so that all points of the conductor come to the same potential.
For an isolated spherical conducting shell, sketch graphs of the potential and the electric field magnitude versus distance from the center, both inside and outside the shell.
For an isolated spherical conducting shell, identify that internally the electric field is zero and the electric potential has the same value as the surface and that externally the electric field and the electric potential have values as though all of the shell's charge is concentrated as a particle at its center.
For an isolated cylindrical conducting shell, identify that internally the electric field is zero and the electric potential has the same value as the surface and that externally the electric field and the electric potential have values as though all of the cylinder's charge is concentrated as a line of charge on the central axis.

<u>A student will demonstrate an understanding of capacitance by:</u>

Sketch a schematic diagram of a circuit with a parallel-plate capacitor, a battery, and an open or closed switch.
In a circuit with a battery, an open switch, and an uncharged capacitor, explain what happens to the conduction electrons when the switch is closed.
For a capacitor, apply the relationship between the magnitude of charge q on either plate (“the charge on the capacitor”), the potential difference V between the plates (“the potential across the capacitor”), and the capacitance C of the capacitor.
Explain how Gauss’ law is used to find the capacitance of a parallel-plate capacitor.
For a parallel-plate capacitor, a cylindrical capacitor, a spherical capacitor, and an isolated sphere, calculate the capacitance.

Sketch schematic diagrams for a battery and (a) three capacitors in parallel and (b) three capacitors in series.
Identify that capacitors in parallel have the same potential difference, which is the same value that their equivalent capacitor has.
Calculate the equivalent of parallel capacitors.
Identify that the total charge stored on parallel capacitors is the sum of the charges stored on the individual capacitors.
Identify that capacitors in series have the same charge, which is the same value that their equivalent capacitor has.
Calculate the equivalent of series capacitors.
Identify that the potential applied to capacitors in series is equal to the sum of the potentials across the individual capacitors.
For a circuit with a battery and some capacitors in parallel and some in series, simplify the circuit in steps by finding equivalent capacitors, until the charge and potential on the final equivalent capacitor can be determined, and then reverse the steps to find the charge and potential on the individual capacitors.
For a circuit with a battery, an open switch, and one or more uncharged capacitors, determine the amount of charge that moves through a point in the circuit when the switch is closed.
When a charged capacitor is connected in parallel to one or more uncharged capacitors, determine the charge and potential difference on each capacitor when equilibrium is reached.
Explain how the work required to charge a capacitor results in the potential energy of the capacitor.
For a capacitor, apply the relationship between the potential energy U, the capacitance C, and the potential difference V.
For a capacitor, apply the relationship between the potential energy, the internal volume, and the internal energy density.
For any electric field, apply the relationship between the potential energy density u in the field and the field's magnitude E.
Explain the danger of sparks in airborne dust.
Identify that capacitance is increased if the space between the plates is filled with a dielectric material.
For a capacitor, calculate the capacitance with and without a dielectric.
Name some of the common dielectrics.
In adding a dielectric to a charged capacitor, distinguish the results for a capacitor (a) connected to a battery and (b) not connected to a battery.
Distinguish polar dielectrics from nonpolar dielectrics.
In adding a dielectric to a charged capacitor, explain what happens to the electric field between the plates in terms of what happens to the atoms in the dielectric.
In a capacitor with a dielectric, distinguish free charge from induced charge.
When a dielectric partially or fully fills the space in a capacitor, find the free charge, the induced charge, the electric field between the plates (if there is a gap, there is more than one field value), and the potential between the plates.

<u>A student will demonstrate an understanding of current and resistance by:</u>

Apply the definition of current as the rate at which charge moves through a point, including solving for the amount of charge that passes the point in a given time interval.

Identify that current is normally due to the motion of conduction electrons that are driven by electric fields (such as those set up in a wire by a battery).
Identify a junction in a circuit and apply the fact that (due to conservation of charge) the total current into a junction must equal the total current out of the junction.
Explain how current arrows are drawn in a schematic diagram of a circuit and identify that the arrows are not vectors.
Identify a current density and a current density vector.
For current through an area element on a cross section through a conductor (such as a wire), identify the element's area vector.
Find the current through a cross section of a conductor by integrating the dot product of the current density vector and the element area vector over the full cross section.
For the case where current is uniformly spread over a cross section in a conductor, apply the relationship between the current i, the current density magnitude J, and the area A.
Identify streamlines.
Explain the motion of conduction electrons in terms of their drift speed.
Distinguish the drift speeds of conduction electrons from their random-motion speeds, including relative magnitudes.
Identify charge carrier density n.
Apply the relationship between current density J, charge carrier density n, and charge carrier drift speed vd.
Apply the relationship between the potential difference V applied across an object, the object's resistance R, and the resulting current i through the object, between the application points.
Identify a resistor.
Apply the relationship between the electric field magnitude E set up at a point in a given material, the material's resistivity ρ, and the resulting current density magnitude J at that point.
For a uniform electric field set up in a wire, apply the relationship between the electric field magnitude E, the potential difference V between the two ends, and the wire's length L.
Apply the relationship between resistivity ρ and conductivity σ.
Apply the relationship between an object's resistance R, the resistivity of its material ρ, its length L, and its cross-sectional area A.
Apply the equation that approximately gives a conductor's resistivity ρ as a function of temperature T.
Sketch a graph of resistivity ρ versus temperature T for a metal.
Distinguish between an object that obeys Ohm's law and one that does not.
Distinguish between a material that obeys Ohm's law and one that does not.
Describe the general motion of a conduction electron in a current.
For the conduction electrons in a conductor, explain the relationship between the mean free time τ, the effective speed, and the thermal (random) motion.
Apply the relationship between resistivity ρ, number density n of conduction electrons, and the mean free time τ of the electrons.
Explain how conduction electrons in a circuit lose energy in a resistive device.
Identify that power is the rate at which energy is transferred from one type to another.
For a resistive device, apply the relationships between power P, current i, voltage V, and resistance R.
For a battery, apply the relationship between power P, current i, and potential difference V.
Apply the conservation of energy to a circuit with a battery and a resistive device to relate the energy transfers in the circuit.
Distinguish conductors, semiconductors, and superconductors.

<u>A student will demonstrate an understanding of circuits by:</u>

Identify the action of an emf source in terms of the work it does.
For an ideal battery, apply the relationship between the emf, the current, and the power (rate of energy transfer).
Draw a schematic diagram for a single-loop circuit containing a battery and three resistors.
Apply the loop rule to write a loop equation that relates the potential differences of the circuit elements around a (complete) loop.
Apply the resistance rule in crossing through a resistor.
Apply the emf rule in crossing through an emf.
Identify that resistors in series have the same current, which is the same value that their equivalent resistor has.
Calculate the equivalent of series resistors.
Identify that a potential applied to resistors wired in series is equal to the sum of the potentials across the individual resistors.
Calculate the potential difference between any two points in a circuit.
Distinguish a real battery from an ideal battery and, in a circuit diagram, replace a real battery with an ideal battery and an explicitly shown resistance.
With a real battery in a circuit, calculate the potential difference between its terminals for current in the direction of the emf and in the opposite direction.
Identify what is meant by grounding a circuit and draw a schematic diagram for such a connection.
Identify that grounding a circuit does not affect the current in a circuit.
Calculate the dissipation rate of energy in a real battery.
Calculate the net rate of energy transfer in a real battery for current in the direction of the emf and in the opposite direction.
Apply the junction rule.
Draw a schematic diagram for a battery and three parallel resistors and distinguish it from a diagram with a battery and three series resistors.
Identify that resistors in parallel have the same potential difference, which is the same value that their equivalent resistor has.
Calculate the resistance of the equivalent resistor of several resistors in parallel.
Identify that the total current through parallel resistors is the sum of the currents through the individual resistors.
For a circuit with a battery and some resistors in parallel and some in series, simplify the circuit in steps by finding equivalent resistors, until the current through the battery can be determined, and then reverse the steps to find the currents and potential differences of the individual resistors.
If a circuit cannot be simplified by using equivalent resistors, identify the several loops in the circuit, choose names and directions for the currents in the branches, set up loop equations for the various loops, and solve these simultaneous equations for the unknown currents.
In a circuit with identical real batteries in series, replace them with a single ideal battery and a single resistor.
In a circuit with identical real batteries in parallel, replace them with a single ideal battery and a single resistor.
Explain the use of an ammeter and a voltmeter, including the resistance required of each in order not to

affect the measured quantities.
Draw schematic diagrams of charging and discharging RC circuits.
Write the loop equation (a differential equation) for a charging RC circuit.
Write the loop equation (a differential equation) for a discharging RC circuit.
For a capacitor in a charging or discharging RC circuit, apply the relationship giving the charge as a function of time.
From the function giving the charge as a function of time in a charging or discharging RC circuit, find the capacitor's potential difference as a function of time.
In a charging or discharging RC circuit, find the resistor's current and potential difference as functions of time.
Calculate the capacitive time constant τ.
For a charging RC circuit and a discharging RC circuit, determine the capacitor's charge and potential difference at the start of the process and then a long time later.

<u>A student will demonstrate an understanding of magnetic fields by:</u>

Distinguish an electromagnet from a permanent magnet.
Identify that a magnetic field is a vector quantity and thus has both magnitude and direction.
Explain how a magnetic field can be defined in terms of what happens to a charged particle moving through the field.
For a charged particle moving through a uniform magnetic field, apply the relationship between force magnitude charge q, speed v, field magnitude B, and the angle φ between the directions of the velocity vector and the magnetic field vector.
For a charged particle sent through a uniform magnetic field, find the direction of the magnetic force by (1) applying the right-hand rule to find the direction of the cross product and (2) determining what effect the charge q has on the direction.
Find the magnetic force acting on a moving charged particle by evaluating the cross product in unit-vector notation and magnitude-angle notation.
Identify that the magnetic force vector must always be perpendicular to both the velocity vector and the magnetic field vector.
Identify the effect of the magnetic force on the particle's speed and kinetic energy.
Identify a magnet as being a magnetic dipole.
Identify that opposite magnetic poles attract each other and like magnetic poles repel each other.
Explain magnetic field lines, including where they originate and terminate and what their spacing represents.
Describe the experiment of J. J. Thomson.
For a charged particle moving through a magnetic field and an electric field, determine the net force on the particle in both magnitude-angle notation and unit-vector notation.
In situations where the magnetic force and electric force on a particle are in opposite directions, determine the speeds at which the forces cancel, the magnetic force dominates, and the electric force dominates.
Describe the Hall effect for a metal strip carrying current, explaining how the electric field is set up and what limits its magnitude.
For a conducting strip in a Hall-effect situation, draw the vectors for the magnetic field and electric field. For the conduction electrons, draw the vectors for the velocity, magnetic force, and electric force.
Apply the relationship between the Hall potential difference V, the electric field magnitude E, and the

width of the strip d.
Apply the relationship between charge-carrier number density n, magnetic field magnitude B, current i, and Hall-effect potential difference V.
Apply the Hall-effect results to a conducting object moving through a uniform magnetic field, identifying the width across which a Hall-effect potential difference V is set up and calculating V.
For a charged particle moving through a uniform magnetic field, identify under what conditions it will travel in a straight line, in a circular path, and in a helical path.
For a charged particle in uniform circular motion due to a magnetic force, start with Newton's second law and derive an expression for the orbital radius r in terms of the field magnitude B and the particle's mass m, charge magnitude q, and speed v.
For a charged particle moving along a circular path in a uniform magnetic field, calculate and relate speed, centripetal force, centripetal acceleration, radius, period, frequency, and angular frequency, and identify which of the quantities do not depend on speed.
For a positive particle and a negative particle moving along a circular path in a uniform magnetic field, sketch the path and indicate the magnetic field vector, the velocity vector, the result of the cross product of the velocity and field vectors, and the magnetic force vector.
For a charged particle moving in a helical path in a magnetic field, sketch the path and indicate the magnetic field, the pitch, the radius of curvature, the velocity component parallel to the field, and the velocity component perpendicular to the field.
For helical motion in a magnetic field, apply the relationship between the radius of curvature and one of the velocity components.
For helical motion in a magnetic field, identify pitch p and relate it to one of the velocity components.
Describe how a cyclotron works, and in a sketch indicate a particle's path and the regions where the kinetic energy is increased.
Identify the resonance condition.
For a cyclotron, apply the relationship between the particle's mass and charge, the magnetic field, and the frequency of circling.
Distinguish between a cyclotron and a synchrotron.
For the situation where a current is perpendicular to a magnetic field, sketch the current, the direction of the magnetic field, and the direction of the magnetic force on the current (or wire carrying the current).
For a current in a magnetic field, apply the relationship between the magnetic force magnitude FB, the current i, the length of the wire L, and the angle φ between the length vector and the field vector.
Apply the right-hand rule for cross products to find the direction of the magnetic force on a current in a magnetic field.
For a current in a magnetic field, calculate the magnetic force with a cross product of the length vector and the field vector, in magnitude-angle and unit-vector notations.
Describe the procedure for calculating the force on a current-carrying wire in a magnetic field if the wire is not straight or if the field is not uniform.
Sketch a rectangular loop of current in a magnetic field, indicating the magnetic forces on the four sides, the direction of the current, the normal vector, and the direction in which a torque from the forces tends to rotate the loop.
For a current-carrying coil in a magnetic field, apply the relationship between the torque magnitude τ, the number of turns N, the area of each turn A, the current i, the magnetic field magnitude B, and the angle θ between the normal vector and the magnetic field vector B.
Identify that a current-carrying coil is a magnetic dipole with a magnetic dipole moment that has the direction of the normal vector, as given by a right-hand rule.

For a current-carrying coil, apply the relationship between the magnitude μ of the magnetic dipole moment, the number of turns N, the area A of each turn, and the current i.
On a sketch of a current-carrying coil, draw the direction of the current, and then use a right-hand rule to determine the direction of the magnetic dipole moment vector.
For a magnetic dipole in an external magnetic field, apply the relationship between the torque magnitude τ, the dipole moment magnitude μ, the magnetic field magnitude B, and the angle θ between the dipole moment vector and the magnetic field vector.
Identify the convention of assigning a plus or minus sign to a torque according to the direction of rotation.
Calculate the torque on a magnetic dipole by evaluating a cross product of the dipole moment vector and the external magnetic field vector, in magnitude-angle notation and unit-vector notation.
For a magnetic dipole in an external magnetic field, identify the dipole orientations at which the torque magnitude is minimum and maximum.
For a magnetic dipole in an external magnetic field, apply the relationship between the orientation energy U, the dipole moment magnitude μ, the external magnetic field magnitude B, and the angle θ between the dipole moment vector and the magnetic field vector.
Calculate the orientation energy U by taking a dot product of the dipole moment vector and the external magnetic field vector, in magnitude-angle and unit-vector notations.
Identify the orientations of a magnetic dipole in an external magnetic field that give the minimum and maximum orientation energies.
For a magnetic dipole in a magnetic field, relate the orientation energy U to the work Wa done by an external torque as the dipole rotates in the magnetic field.

<u>A student will demonstrate an understanding of magnetic fields due to currents by:</u>

Sketch a current-length element in a wire and indicate the direction of the magnetic field that it sets up at a given point near the wire.
For a given point near a wire and a given current-length element in the wire, determine the magnitude and direction of the magnetic field due to that element.
29.1.3 Identify the magnitude of the magnetic field set up by a current-length element at a point in line with the direction of that element.
29.1.4 For a point to one side of a long straight wire carrying current, apply the relationship between the magnetic field magnitude, the current, and the distance to the point.
29.1.5 For a point to one side of a long straight wire carrying current, use a right-hand rule to determine the direction of the field vector.
29.1.6 Identify that around a long straight wire carrying current, the magnetic field lines form circles.
29.1.7 For a point to one side of the end of a semi-infinite wire carrying current, apply the relationship between the magnetic field magnitude, the current, and the distance to the point.
For the center of curvature of a circular arc of wire carrying current, apply the relationship between the magnetic field magnitude, the current, the radius of curvature, and the angle subtended by the arc (in radians).
For a point to one side of a short straight wire carrying current, integrate the Biot–Savart law to find the magnetic field set up at the point by the current.
Given two parallel or antiparallel currents, find the magnetic field of the first current at the location of the second current and then find the force acting on that second current.
Identify that parallel currents attract each other, and antiparallel currents repel each other.

Describe how a rail gun works.
Apply Ampere's law to a loop that encircles current.
With Ampere's law, use a right-hand rule for determining the algebraic sign of an encircled current.
For more than one current within an Amperian loop, determine the net current to be used in Ampere's law.
Apply Ampere's law to a long straight wire with current, to find the magnetic field magnitude inside and outside the wire, identifying that only the current encircled by the Amperian loop matters.
Describe a solenoid and a toroid and sketch their magnetic field lines.
Explain how Ampere's law is used to find the magnetic field inside a solenoid.
Apply the relationship between a solenoid's internal magnetic field B, the current i, and the number of turns per unit length n of the solenoid.
Explain how Ampere's law is used to find the magnetic field inside a toroid.
Apply the relationship between a toroid's internal magnetic field B, the current i, the radius r, and the total number of turns N.
Sketch the magnetic field lines of a flat coil that is carrying current.
For a current-carrying coil, apply the relationship between the dipole moment magnitude μ and the coil's current i, number of turns N, and area per turn A.
For a point along the central axis, apply the relationship between the magnetic field magnitude B, the magnetic moment μ, and the distance z from the center of the coil.

<u>A student will demonstrate an understanding of induction and inductance by:</u>

Identify that the amount of magnetic field piercing a surface (not skimming along the surface) is the magnetic flux ΦB through the surface.
Identify that an area vector for a flat surface is a vector that is perpendicular to the surface and that has a magnitude equal to the area of the surface.
Identify that any surface can be divided into area elements (patch elements) that are each small enough and flat enough for an area vector to be assigned to it, with the vector perpendicular to the element and having a magnitude equal to the area of the element.
Calculate the magnetic flux ΦB through a surface by integrating the dot product of the magnetic field vector and the area vector (for patch elements) over the surface, in magnitude-angle notation and unit-vector notation.
Identify that a current is induced in a conducting loop while the number of magnetic field lines intercepted by the loop is changing.
Identify that an induced current in a conducting loop is driven by an induced emf.
Apply Faraday’s law, which is the relationship between an induced emf in a conducting loop and the rate at which magnetic flux through the loop changes.
Extend Faraday’s law from a loop to a coil with multiple loops.
Identify the three general ways in which the magnetic flux through a coil can change.
Use a right-hand rule for Lenz’s law to determine the direction of induced emf and induced current in a conducting loop.
Identify that when a magnetic flux through a loop changes, the induced current in the loop sets up a magnetic field to oppose that change.
If an emf is induced in a conducting loop containing a battery, determine the net emf and calculate the corresponding current in the loop.
For a conducting loop pulled into or out of a magnetic field, calculate the rate at which energy is

transferred to thermal energy.
Apply the relationship between an induced current and the rate at which it produces thermal energy.
Describe eddy currents.
Identify that a changing magnetic field induces an electric field, regardless of whether there is a conducting loop.
Apply Faraday's law to relate the electric field induced along a closed path (whether it has conducting material or not) to the rate of change $d\Phi/dt$ of the magnetic flux encircled by the path.
Identify that an electric potential cannot be associated with an induced electric field.
Identify an inductor.
For an inductor, apply the relationship between inductance L, total flux $N\Phi$, and current i.
For a solenoid, apply the relationship between the inductance per unit length L /l, the area A of each turn, and the number of turns per unit length n.
Identify that an induced emf appears in a coil when the current through the coil is changing.
Apply the relationship between the induced emf in a coil, the coil's inductance L, and the rate di/dt at which the current is changing.
When an emf is induced in a coil because the current in the coil is changing, determine the direction of the emf by using Lenz's law to show that the emf always opposes the change in the current, attempting to maintain the initial current.
Sketch a schematic diagram of an RL circuit in which the current is rising.
Write a loop equation (a differential equation) for an RL circuit in which the current is rising.
For an RL circuit in which the current is rising, apply the equation i(t) for the current as a function of time.
For an RL circuit in which the current is rising, find equations for the potential difference V across the resistor, the rate di/dt at which the current changes, and the emf of the inductor, as functions of time.
Calculate an inductive time constant τ_L.
Sketch a schematic diagram of an RL circuit in which the current is decaying.
Write a loop equation (a differential equation) for an RL circuit in which the current is decaying.
For an RL circuit in which the current is decaying, apply the equation i(t) for the current as a function of time.
From an equation for decaying current in an RL circuit, find equations for the potential difference V across the resistor, the rate di/dt at which current is changing, and the emf of the inductor, as functions of time.
For an RL circuit, identify the current through the inductor and the emf across it just as current in the circuit begins to change (the initial condition) and a long time later when equilibrium is reached (the final condition).
Describe the derivation of the equation for the magnetic field energy of an inductor in an RL circuit with a constant emf source.
For an inductor in an RL circuit, apply the relationship between the magnetic field energy U, the inductance L, and the current i.
Identify that energy is associated with any magnetic field.
Apply the relationship between energy density u_B of a magnetic field and the magnetic field magnitude B.
Describe the mutual induction of two coils and sketch the arrangement.
Calculate the mutual inductance of one coil with respect to a second coil (or some second current that is changing).
Calculate the emf induced in one coil by a second coil in terms of the mutual inductance and the rate of

change of the current in the second coil.

<u>A student will demonstrate an understanding of electromagnetic oscillations and alternating current by:</u>

Sketch an LC oscillator and explain which quantities oscillate and what constitutes one period of the oscillation.
For an LC oscillator, sketch graphs of the potential difference across the capacitor and the current through the inductor as functions of time and indicate the period T on each graph.
Explain the analogy between a block–spring oscillator and an LC oscillator.
For an LC oscillator, apply the relationships between the angular frequency ω (and the related frequency f and period T) and the values of the inductance and capacitance.
Starting with the energy of a block–spring system, explain the derivation of the differential equation for charge q in an LC oscillator and then identify the solution for q(t).
For an LC oscillator, calculate the charge q on the capacitor for any given time and identify the amplitude Q of the charge oscillations.
Starting from the equation giving the charge q(t) on the capacitor in an LC oscillator, find the current i(t) in the inductor as a function of time.
For an LC oscillator, calculate the current i in the inductor for any given time and identify the amplitude I of the current oscillations.
For an LC oscillator, apply the relationship between the charge amplitude Q, the current amplitude I, and the angular frequency ω.
From the expressions for the charge q and the current i in an LC oscillator, find the magnetic field energy UB(t) and the electric field energy UE(t) and the total energy.
For an LC oscillator, sketch graphs of the magnetic field energy UB(t), the electric field energy UE(t), and the total energy, all as functions of time.
Calculate the maximum values of the magnetic field energy UB and the electric field energy UE and also calculate the total energy.
Draw the schematic of a damped RLC circuit and explain why the oscillations are damped.
Starting with the expressions for the field energies and the rate of energy loss in a damped RLC circuit, write the differential equation for the charge q on the capacitor.
For a damped RLC circuit, apply the expression for charge q(t).
Identify that in a damped RLC circuit, the charge amplitude and the amplitude of the electric field energy decrease exponentially with time.
Apply the relationship between the angular frequency ω′ of a given damped RLC oscillator and the angular frequency ω of the circuit if R is removed.
For a damped RLC circuit, apply the expression for the electric field energy UE as a function of time.
Distinguish alternating current from direct current.
For an ac generator, write the emf as a function of time, identifying the emf amplitude and driving angular frequency.
For an ac generator, write the current as a function of time, identifying its amplitude and its phase constant with respect to the emf.
Draw a schematic diagram of a (series) RLC circuit that is driven by a generator.
Distinguish driving angular frequency ωd from natural angular frequency ω.
In a driven (series) RLC circuit, identify the conditions for resonance and the effect of resonance on the current amplitude.
For each of the three basic circuits (purely resistive load, purely capacitive load, and purely inductive

load), draw the circuit and sketch graphs and phasor diagrams for voltage v(t) and current i(t).
For the three basic circuits, apply equations for voltage v(t) and current i(t).
On a phasor diagram for each of the basic circuits, identify angular speed, amplitude, projection on the vertical axis, and rotation angle.
For each basic circuit, identify the phase constant, and interpret it in terms of the relative orientations of the current phasor and voltage phasor and also in terms of leading and lagging.
Apply the mnemonic "ELI positively is the ICE man."
For each basic circuit, apply the relationships between the voltage amplitude V and the current amplitude I.
Calculate capacitive reactance XC and inductive reactance XL.
Draw the schematic diagram of a series RLC circuit.
Identify the conditions for a mainly inductive circuit, a mainly capacitive circuit, and a resonant circuit.
For a mainly inductive circuit, a mainly capacitive circuit, and a resonant circuit, sketch graphs for voltage v(t) and current i(t) and sketch phasor diagrams, indicating leading, lagging, or resonance.
Calculate impedance Z.
Apply the relationship between current amplitude I, impedance Z, and emf amplitude $\mathcal{E}$m.
Apply the relationships between phase constant ϕ and voltage amplitudes VL and VC and also between phase constant ϕ, resistance R, and reactances XL and XC.
Identify the values of the phase constant ϕ corresponding to a mainly inductive circuit, a mainly capacitive circuit, and a resonant circuit.
For resonance, apply the relationship between the driving angular frequency ωd, the natural angular frequency ω, the inductance L, and the capacitance C.
Sketch a graph of current amplitude versus the ratio ωd/ω, identifying the portions corresponding to a mainly inductive circuit, a mainly capacitive circuit, and a resonant circuit and indicating what happens to the curve for an increase in the resistance.
For the current, voltage, and emf in an ac circuit, apply the relationship between the rms values and the amplitudes.
For an alternating emf connected across a capacitor, an inductor, or a resistor, sketch graphs of the sinusoidal variation of the current and voltage and indicate the peak and rms values.
Apply the relationship between average power Pavg, rms current Irms, and resistance R.
In a driven RLC circuit, calculate the power of each element.
For a driven RLC circuit in steady state, explain what happens to (a) the value of the average stored energy with time and (b) the energy that the generator puts into the circuit.
Apply the relationship between the power factor cos ϕ, the resistance R, and the impedance Z.
Apply the relationship between the average power Pavg, the rms emf $\mathcal{E}$rms, the rms current Irms, and the power factor cos ϕ.
Identify what power factor is required in order to maximize the rate at which energy is supplied to a resistive load.
For power transmission lines, identify why the transmission should be at low current and high voltage.
Identify the role of transformers at the two ends of a transmission line.
Calculate the energy dissipation in a transmission line.
Identify a transformer's primary and secondary.
Apply the relationship between the voltage and number of turns on the two sides of a transformer.
Distinguish between a step-down transformer and a step-up transformer.
Apply the relationship between the current and number of turns on the two sides of a transformer.
Apply the relationship between the power into and out of an ideal transformer.

Identify the equivalent resistance as seen from the primary side of a transformer.
Apply the relationship between the equivalent resistance and the actual resistance.
Explain the role of a transformer in impedance matching.

<u>A student will demonstrate an understanding of Maxwell's equations and magnetism of matter by:</u>

Identify that the simplest magnetic structure is a magnetic dipole.
Calculate the magnetic flux Φ through a surface by integrating the dot product of the magnetic field vector and the area vector (for patch elements) over the surface.
Identify that the net magnetic flux through a Gaussian surface (which is a closed surface) is zero.
Identify that a changing electric flux induces a magnetic field.
Apply Maxwell's law of induction to relate the magnetic field induced around a closed loop to the rate of change of electric flux encircled by the loop.
Draw the field lines for an induced magnetic field inside a capacitor with parallel circular plates that are being charged, indicating the orientations of the vectors for the electric field and the magnetic field.
For the general situation in which magnetic fields can be induced, apply the Ampere–Maxwell (combined) law.
Identify that in the Ampere–Maxwell law, the contribution to the induced magnetic field by the changing electric flux can be attributed to a fictitious current ("displacement current") to simplify the expression.
Identify that in a capacitor that is being charged or discharged, a displacement current is said to be spread uniformly over the plate area, from one plate to the other.
Apply the relationship between the rate of change of an electric flux and the associated displacement current.
For a charging or discharging capacitor, relate the amount of displacement current to the amount of actual current and identify that the displacement current exists only when the electric field within the capacitor is changing.
Mimic the equations for the magnetic field inside and outside a wire with real current to write (and apply) the equations for the magnetic field inside and outside a region of displacement current.
Apply the Ampere–Maxwell law to calculate the magnetic field of a real current and a displacement current.
For a charging or discharging capacitor with parallel circular plates, draw the magnetic field lines due to the displacement current.
List Maxwell's equations and the purpose of each.
Identify lodestones.
In Earth's magnetic field, identify that the field is approximately that of a dipole and also identify in which hemisphere the north geomagnetic pole is located.
Identify field declination and field inclination.
Identify that a spin angular momentum (usually simply called spin) and a spin magnetic dipole moment are intrinsic properties of electrons (and also protons and neutrons).
Apply the relationship between the spin vector and the spin magnetic dipole moment vector.
Identify that the observed components Sz and μs,z are quantized and explain what that means.
Apply the relationship between the component Sz and the spin magnetic quantum number ms, specifying the allowed values of ms.
Distinguish spin up from spin down for the spin orientation of an electron.
Determine the z components μs,z of the spin magnetic dipole moment, both as a value and in terms of

the Bohr magneton μB.
If an electron is in an external magnetic field, determine the orientation energy U of its spin magnetic dipole moment.
Identify that an electron in an atom has an orbital angular momentum and an orbital magnetic dipole moment.
Apply the relationship between the component of the orbital angular momentum and the orbital magnetic quantum number mℓ, specifying the allowed values of mℓ.
Determine the z components of the orbital magnetic dipole moment, both as a value and in terms of the Bohr magneton.
If an atom is in an external magnetic field, determine the orientation energy U of the orbital magnetic dipole moment.
Calculate the magnitude of the magnetic moment of a charged particle moving in a circle or a ring of uniform charge rotating like a merry-go-round at a constant angular speed around a central axis.
Explain the classical loop model for an orbiting electron and the forces on such a loop in a nonuniform magnetic field.
Distinguish diamagnetism, paramagnetism, and ferromagnetism.
For a diamagnetic sample placed in an external magnetic field, identify that the field produces a magnetic dipole moment in the sample, and identify the relative orientations of that moment and the field.
For a diamagnetic sample in a nonuniform magnetic field, describe the force on the sample and the resulting motion.
For a paramagnetic sample placed in an external magnetic field, identify the relative orientations of the field and the sample's magnetic dipole moment.
For a paramagnetic sample in a nonuniform magnetic field, describe the force on the sample and the resulting motion.
Apply the relationship between a sample's magnetization M, its measured magnetic moment, and its volume.
Apply Curie's law to relate a sample's magnetization M to its temperature T, its Curie constant C, and the magnitude B of the external field.
Given a magnetization curve for a paramagnetic sample, relate the extent of the magnetization for a given magnetic field and temperature.
For a paramagnetic sample at a given temperature and in a given magnetic field, compare the energy associated with the dipole orientations and the thermal motion.
Identify that ferromagnetism is due to a quantum mechanical interaction called exchange coupling.
Explain why ferromagnetism disappears when the temperature exceeds the material's Curie temperature.
Apply the relationship between the magnetization of a ferromagnetic sample and the magnetic moment of its atoms.
For a ferromagnetic sample at a given temperature and in a given magnetic field, compare the energy associated with the dipole orientations and the thermal motion.
Describe and sketch a Rowland ring.
Identify magnetic domains.
For a ferromagnetic sample placed in an external magnetic field, identify the relative orientations of the field and the magnetic dipole moment.
Identify the motion of a ferromagnetic sample in a nonuniform field.
For a ferromagnetic object placed in a uniform magnetic field, calculate the torque and orientation

energy.
Explain hysteresis and a hysteresis loop.
Identify the origin of lodestones.

Students – please refer to the Instructor's Course Information sheet for specific information on assessments and due dates.

Part III: Grading and Assessment

EVALUATION OF REQUIRED COURSE MEASURES/ARTIFACTS*

Students' performance will be assessed and the weight associated with the various measures/artifacts are listed below.

EVALUATION*

Lecture	75%
Lab	25%
Total	100%

Students, for the specific number and type of evaluations, please refer to the Instructor's Course Information Sheet.

GRADING SYSTEM:

Please note the College adheres to a 10-point grading scale A = 100 – 90, B = 89- 80, C = 79 – 70, D = 69 – 60, F = 59 and below.

Grades earned in courses impact academic progression and financial aid status. Before withdrawing from a course, be sure to talk with your instructor and financial aid counselor about the implications of that course of action. Ds, Fs, Ws, WFs and Is also negatively impact academic progression and financial aid status.

The Add/Drop Period is the first 5 days of the semester for **full term** classes. Add/Drop periods are shorter for accelerated format courses. Please refer to the academic calendar for deadlines for add/drop. You must attend at least one meeting of all of your classes during that period. If you do not, you will be dropped from the course(s) and your Financial Aid will be reduced accordingly.

Part IV: Attendance

Horry-Georgetown Technical College maintains a general attendance policy requiring students to be present for a minimum of 80 percent (80%) of their classes in order to receive credit for any course. Due to the varied nature of courses taught at the college, some faculty may require up to 90 percent (90%) attendance. Pursuant to 34 Code of Federal Regulations 228.22 - Return to Title IV Funds, once a student has missed over 20% of the course or has missed two (2) consecutive weeks, the faculty is obligated to withdraw the student and a student may not be permitted to reenroll. **Instructors define absentee limits for their class at the beginning of each term; please refer to the Instructor Course Information Sheet.**

For online and hybrid courses, check your Instructor's Course Information Sheet for any required on-site meeting times. Please note, instructors may require tests to be taken at approved testing sites, and if you use a testing center other than those provided by HGTC, the center may charge a fee for its services.

Science Department Attendance Policies
For a 15-week course (fall and spring) or a 10-week course (summer), the allowed number of absences for a MW or TR class is as follows: 4 absences are allowed for lecture and 2 are allowed for lab, regardless of reason. For a lecture class that meets once a week, the allowed number of absences is 2.

For a 7-week fast-paced course (fall and spring) or a 5-week fast-paced course (summer), the allowed number of absences is as follows: 1 absence is allowed for lecture and 1 for lab, regardless of reason.

When a student surpasses the allowed number of absences, the student will be dropped automatically from the course with a W or a WF. Remember, an absence is an absence, no matter if it is excused or not!

Online/Hybrid Attendance:
Students enrolled in distance learning courses (hybrid and online) are required to maintain contact with the instructor on a regular basis to be counted as "in attendance" for the course. All distance learning students must participate weekly in an Attendance activity in order to demonstrate course participation. Students showing no activity in the course for two weeks (these weeks do not need to be consecutive) will be withdrawn due to lack of attendance.

Lab Attendance for Hybrid Courses:
Students in hybrid classes in which labs meet weekly, are allowed two (2) lab absences. Students in hybrid labs that only meet 5 or 6 times during the semester, must attend all lab sessions for its entirety. When a student surpasses the allowed number of absences, the student will be dropped automatically from the course with a W or a WF.

Part V: Student Resources

SSTC
STUDENT SUCCESS AND TUTORING CENTER

THE STUDENT SUCCESS AND TUTORING CENTER (SSTC):

The SSTC offers to all students the following **free** resources:

1. **Academic tutors** for most subject areas, **Writing Center support**, and **college success skills**.
2. Online **tutoring** and academic support resources.

3. Professional and interpersonal communication **coaching** in the EPIC Labs.

Visit the Student Success & Tutoring Center website for more information. To schedule tutoring, contact the SSTC at sstc@hgtc.edu or self-schedule in the Penji iOS/Android app or at www.penjiapp.com. Email sstc@hgtc.edu or call SSTC Conway, 349-7872; SSTC Grand Strand, 477-2113; and SSTC Georgetown, 520-1455, or go to the Online Resource Center to access on-demand resources.

STUDENT INFORMATION CENTER: TECH Central

TECH Central offers to all students the following free resources:

1. **Getting around HGTC**: General information and guidance for enrollment, financial aid, registration, and payment plan support!
2. Use the Online Resource Center (ORC) including Office 365 support, password resets, and username information.
3. **In-person workshops, online tutorials and more services** are available in Desire2Learn, Student Portal, Degree Works, and Office 365.
4. **Chat with our staff on TECH Talk**, our live chat service. TECH Talk can be accessed on the student portal and on TECH Central's website, or by texting questions to (843) 375-8552.

Visit the Tech Central website for more information. Live Chat and Center locations are posted on the website. Or please call (843) 349 – TECH (8324), Option #1.

HGTC LIBRARY:

Each campus location has a library where HGTC students, faculty, and staff may check out materials with their HGTC ID. All three HGTC campus libraries are equipped with computers to support academic research and related schoolwork; printing is available as well. Visit the Library website for more information or call (843) 349-5268.

STUDENT TESTING:

Testing in an **online/hybrid** course and in **make-up exam** situations may be accomplished in a variety of ways:

- Test administered within D2L
- Test administered in writing on paper
- Test administered through Publisher Platforms (which may have a fee associated with the usage)

Furthermore, tests may have time limits and/or require a proctor.

Proctoring can be accomplished either face-to-face at an approved site or online through our online proctoring service. To find out more about proctoring services, please visit the Online Testing section of the HGTC's Testing Center webpage.

The **Instructor Information Sheet** will have more details on test requirements for your course.

DISABILITY SERVICES:

HGTC is committed to providing an accessible environment for students with disabilities. Inquiries may be directed to HGTC's Accessibility and Disability Service webpage. The Accessibility and Disability staff will review documentation of the student's disability and, in a confidential setting with the student, develop an educational accommodation plan.

Note: It is the student's responsibility to self-identify as needing accommodations and to provide acceptable documentation. After a student has self-identified and submitted documentation of a disability, accommodations may be determined, accepted, and provided.

STATEMENT OF EQUAL OPPORTUNITY/NON-DISCRIMINATION STATEMENT:

Horry-Georgetown Technical College prohibits discrimination and harassment, including sexual harassment and abuse, on the basis of race, color, sex, national or ethnic origin, age, religion, disability, marital or family status, veteran status, political ideas, sexual orientation, gender identity, or pregnancy, childbirth, or related medical conditions, including, but not limited to, lactation in educational programs and/or activities.

TITLE IX REQUIREMENTS:

All students (as well as other persons) at Horry-Georgetown Technical College are protected by Title IX—regardless of their sex, sexual orientation, gender identity, part- or full-time status, disability, race, or national origin—in all aspects of educational programs and activities. Any student, or other member of the college community, who believes that he/she is or has been a victim of sexual harassment or sexual violence may file a report with the college's Chief Student Services Officer, campus law enforcement, or with the college's Title IX Coordinator or designee.

> *Faculty and Staff are required to report incidents to the Title IX Coordinators when involving students. The only HGTC employees exempt from mandatory reporting are licensed mental health professionals (only as part of their job description such as counseling services).

INQUIRIES REGARDING THE NON-DISCRIMINATION/TITLE IX POLICIES:

Student and prospective student inquiries concerning Section 504, Title II, Title VII, and Title IX and their application to the College or any student decision may be directed to the Vice President for Student Affairs.

Dr. Melissa Batten, VP Student Affairs
Title IX, Section 504, and Title II Coordinator
Building 1100, Room 107A, Conway Campus
PO Box 261966, Conway, SC 29528-6066

843-349-5228
Melissa.Batten@hgtc.edu

Employee and applicant inquiries concerning Section 504, Title II, and Title IX and their application to the College may be directed to the Vice President for Human Resources.

Jacquelyne Snyder, VP Human Resources
Affirmative Action/Equal Opportunity Officer and Title IX Coordinator
Building 200, Room 205B, Conway Campus
PO Box 261966, Conway, SC 29528-6066
843-349-5212
Jacquelyne.Snyder@hgtc.edu