General Physics 40 A B C D E - Syllabus Addendum for Prospective Teachers Young H. D. & Freedman, R. A. (2004). *University Physics*, 11th Edition		
Chapter	**Subject Matter Requirements for Prospective Teachers General Science**	**Academic content standards for kindergarten through grade twelve, adopted by the California State Board of Education**
Ch 1-Units, Physical Quantities, and Vectors	9.1c Describe the relationships among position, distance, displacement, speed, velocity, acceleration, and time, and perform simple calculations using these variables for both linear and circular motion	Science Content Standards for California Public Schools, Grade 8: 1c Students solve problems involving distance, time, and average speed.
Ch 2-Motion along a Straight Line	9.1c Describe the relationships among position, distance, displacement, speed, velocity, acceleration, and time, and perform simple calculations using these variables for both linear and circular motion	Science Content Standards for California Public Schools, Grade 8: 1c Students solve problems involving distance, time, and average speed.
	9.1e Construct and analyze simple vector and graphical representations of motion and forces (e.g., distance, speed, time)	Science Content Standards for California Public Schools, Grade 8: 1a Students know position is defined in relation to some choice of a standard reference point and a set of reference directions; 1b Students know that average speed is the total distance traveled divided by the total time elapsed and that speed of an object of an object along the path travels can vary; 1c Students know how

		to solve problems involving distance; time, and average speed; 1d Students know the velocity of an object must be described by specifying both the direction and the speed of the object; 1e Students know changes in velocity may be due to changes in speed, direction, or both; 1g Students know how to interpret graphs of position versus time and graphs of speed versus time for motion in a single direction
Ch 3-Motion in Two or Three Dimensions	9.1c Describe the relationships among position, distance, displacement, speed, velocity, acceleration, and time, and perform simple calculations using these variables for both linear and circular motion	Science Content Standards for California Public Schools, Grade 8: 1c Students solve problems involving distance, time, and average speed.
	9.1e Construct and analyze simple vector and graphical representations of motion and forces (e.g., distance, speed, time)	Science Content Standards for California Public Schools, Grade 8: 1a Students know position is defined in relation to some choice of a standard reference point and a set of reference directions; 1b Students know that average speed is the total distance traveled divided by the total time elapsed and that speed of an object of an object along the path travels can vary; 1c Students know how to solve problems involving distance; time, and average speed; 1d Students know the velocity of an object

		must be described by specifying both the direction and the speed of the object; 1e Students know changes in velocity may be due to changes in speed, direction, or both; 1g Students know how to interpret graphs of position versus time and graphs of speed versus time for motion in a single direction
Ch 4-Newton's Laws of Motion	9.1a Discuss and apply Newton's laws (i.e., first, second, third, and law of universal gravitation)	Science Content Standards for California Public Schools, Grade 8: 1a Students know position is defined in relation to some choice of a standard reference point and a set of reference directions; 1b Students know that average speed is the total distance traveled divided by the total time elapsed and that the speed of an object along the path traveled can vary; 1c Students know how to solve problems involving distance, time, and average speed; 1d Students know the velocity of an object must be described by specifying both the direction and the speed of the object; 1e Students know changes in velocity my be due to changes in speed, direction or both
	9.1d Identify the separate forces that act on a body (e.g., gravity, pressure, tension/compression, normal force, friction) and describe the net force on the body	Science Content Standards for California Public Schools, Grade 8: 2b Students know when an object is subject to two or more forces at once, the result is the cumulative

		effect of all the forces.
	9.1e Construct and analyze simple vector and graphical representations of motion and forces (e.g., distance, speed, time)	Science Content Standards for California Public Schools, Grade 8: 1a Students know position is defined in relation to some choice of a standard reference point and a set of reference directions; 1b Students know that average speed is the total distance traveled divided by the total time elapsed and that speed of an object of an object along the path travels can vary; 1c Students know how to solve problems involving distance; time, and average speed; 1d Students know the velocity of an object must be described by specifying both the direction and the speed of the object; 1e Students know changes in velocity may be due to changes in speed, direction, or both; 1g Students know how to interpret graphs of position versus time and graphs of speed versus time for motion in a single direction
	9.1f Identify fundamental forces, including gravity, nuclear forces, and electromagnetic forces (magnetic and electric), and explain their roles in nature, such as the role of gravity in maintaining the structure of the universe	Science Content Standards for California Public Schools, Grade 8: 2a Students know a force has both direction and magnitude; 2b Students know when an object is subject to two or more forces at once the result is the cumulative effect of all the forces; 2c Students know when the forces of an object are balanced the

		motion of the object does not change; Students know to identify separately the two or more forces that are acting on a single static object including gravity , elastic forces due to tension or compression in matter and friction; 2e Students know that when the forces on a object are unbalanced, the object will change its velocity; 2f Students know the greater the mass of an object, the more force is needed to achieve the same rate of change in motion; 2g Students know the role of gravity in forming and maintaining the shapes of planets, stars, and solar system
	9.1g Explain and calculate mechanical advantages for levers, pulleys, and inclined planes	Science Content Standards for California Public Schools, Grade 7: 6h Students know how to compare joints in the body with structures used in machines and simple devices; 6i Students know how levers confer mechanical advantage and how the application of this principle applies to the musculoskeletal system
Ch 5-Applying Newton's Laws	9.1a Discuss and apply Newton's laws (i.e., first, second, third, and law of universal gravitation)	Science Content Standards for California Public Schools, Grade 8: 1a Students know position is defined in relation to some choice of a standard reference point and a set of reference directions; 1b Students know that average speed is the total distance traveled divided by the total

		time elapsed and that the speed of an object along the path traveled can vary; 1c Students know how to solve problems involving distance, time, and average speed; 1d Students know the velocity of an object must be described by specifying both the direction and the speed of the object; 1e Students know changes in velocity my be due to changes in speed, direction or both
	9.1e Construct and analyze simple vector and graphical representations of motion and forces (e.g., distance, speed, time)	Science Content Standards for California Public Schools, Grade 8: 1a Students know position is defined in relation to some choice of a standard reference point and a set of reference directions; 1b Students know that average speed is the total distance traveled divided by the total time elapsed and that speed of an object of an object along the path travels can vary; 1c Students know how to solve problems involving distance; time, and average speed; 1d Students know the velocity of an object must be described by specifying both the direction and the speed of the object; 1e Students know changes in velocity may be due to changes in speed, direction, or both; 1g Students know how to interpret graphs of position versus time and graphs of speed versus time for motion in a single direction

	9.1f Identify fundamental forces, including gravity, nuclear forces, and electromagnetic forces (magnetic and electric), and explain their roles in nature, such as the role of gravity in maintaining the structure of the universe	Science Content Standards for California Public Schools, Grade 8: 2a Students know a force has both direction and magnitude; 2b Students know when an object is subject to two or more forces at once the result is the cumulative effect of all the forces; 2c Students know when the forces of an object are balanced the motion of the object does not change; Students know to identify separately the two or more forces that are acting on a single static object including gravity , elastic forces due to tension or compression in matter and friction; 2e Students know that when the forces on a object are unbalanced, the object will change its velocity; 2f Students know the greater the mass of an object, the more force is needed to achieve the same rate of change in motion; 2g Students know the role of gravity in forming and maintaining the shapes of planets, stars, and solar system
	9.1g Explain and calculate mechanical advantages for levers, pulleys, and inclined planes	Science Content Standards for California Public Schools, Grade 7: 6h Students know how to compare joints in the body with structures used in machines and simple devices; 6i Students know how levers confer mechanical advantage and how the application of this

		principle applies to the musculoskeletal system
Ch 7-Potential Energy and Energy Conservation	9.1g Explain and calculate mechanical advantages for levers, pulleys, and inclined planes	Science Content Standards for California Public Schools, Grade 7: 6h Students know how to compare joints in the body with structures used in machines and simple devices; 6i Students know how levers confer mechanical advantage and how the application of this principle applies to the musculoskeletal system
Ch 12-Gravitation	9.1a Discuss and apply Newton's laws (i.e., first, second, third, and law of universal gravitation)	Science Content Standards for California Public Schools, Grade 8: 1a Students know position is defined in relation to some choice of a standard reference point and a set of reference directions; 1b Students know that average speed is the total distance traveled divided by the total time elapsed and that the speed of an object along the path traveled can vary; 1c Students know how to solve problems involving distance, time, and average speed; 1d Students know the velocity of an object must be described by specifying both the direction and the speed of the object; 1e Students know changes in velocity my be due to changes in speed, direction or both
	9.1f Identify fundamental forces, including gravity, nuclear forces, and electromagnetic forces (magnetic and electric), and	Science Content Standards for California Public Schools, Grade 8: 2a Students know a force has both direction and

	explain their roles in nature, such as the role of gravity in maintaining the structure of the universe	magnitude; 2b Students know when an object is subject to two or more forces at once the result is the cumulative effect of all the forces; 2c Students know when the forces of an object are balanced the motion of the object does not change; Students know to identify separately the two or more forces that are acting on a single static object including gravity , elastic forces due to tension or compression in matter and friction; 2e Students know that when the forces on a object are unbalanced, the object will change its velocity; 2f Students know the greater the mass of an object, the more force is needed to achieve the same rate of change in motion; 2g Students know the role of gravity in forming and maintaining the shapes of planets, stars, and solar system
Ch 14-Fluid Mechanics	9.1b Define pressure and relate it to fluid flow and buoyancy (e.g., heart valves, atmospheric pressure)	Science Content Standards for California Public Schools, Grade 7: 6j Students know that contractions of the heart generate blood pressure and that the heart valves prevent backflow of blood in the circulatory system
Ch 15- Mechanical waves	8.1a Compare the characteristics of sound, light, and seismic waves (e.g., transverse/longitudinal, travel through various media, relative speed)	Science Content Standards for California Public Schools, Grade 3: 1d Students know energy can be carried from one place to another by waves, such as water waves and sound waves by electric current and by moving objects; Grade 6: 3a Students know energy can be carried from

		one place to another by heat flow or by waves including water, light and sound waves, or by moving objects; Grades 9-12: Physics 4a Students know waves carry energy from one place to another; 4f Students know how to identify the characteristic properties of waves: Interference (beats), diffraction, reaction, Dopler effect, and polarization
	8.1b Explain that energy is transferred by waves without mass transfer and provide examples	Science Content Standards for California Public Schools, Grades 9-12: Physics 4b Students know how to identify transverse and longitudinal waves in mechanical media such as springs and ropes and on the earth (seismic waves); 4d Students know sound is a longitudinal wave whose speed depends on the properties of the medium in which it propagates
Ch 16-Sound and Hearing	8.1a Compare the characteristics of sound, light, and seismic waves (e.g., transverse/longitudinal, travel through various media, relative speed)	Science Content Standards for California Public Schools, Grade 3: 1d Students know energy can be carried from one place to another by waves, such as water waves and sound waves by electric current and by moving objects; Grade 6: 3a Students know energy can be carried from one place to another by heat flow or by waves including water, light and sound waves, or by moving objects; Grades 9-12: Physics 4a Students know waves carry energy from one place to another; 4f Students know how to identify the characteristic properties of waves: Interference (beats), diffraction, reaction, Dopler effect, and polarization
Ch 21-Electrical Charge and Electric Field	9.1f Identify fundamental forces, including gravity, nuclear forces, and electromagnetic forces (magnetic and electric), and explain their roles in nature, such as the role of gravity in maintaining the structure of the universe	Science Content Standards for California Public Schools, Grade 8: 2a Students know a force has both direction and magnitude; 2b Students know when an object is subject to two or more forces at once the result is the cumulative effect of all the forces; 2c Students

		know when the forces of an object are balanced the motion of the object does not change; Students know to identify separately the two or more forces that are acting on a single static object including gravity , elastic forces due to tension or compression in matter and friction; 2e Students know that when the forces on a object are unbalanced, the object will change its velocity; 2f Students know the greater the mass of an object, the more force is needed to achieve the same rate of change in motion; 2g Students know the role of gravity in forming and maintaining the shapes of planets, stars, and solar system
	10.1a Describe and provide examples of electrostatic and magnetostatic phenomena	Science Content Standards for California Public Schools, Grade 4: 1e Students know electrically charged objects attract or repel each other; 1f Students know that magnets have two poles and that like poles repel each other and unlike poles attract each other
	10.1b Predict charges or poles based on attraction/repulsion observations	Science Content Standards for California Public Schools, Grade 4: 1e Students know electrically charged objects attract or repel each other; 1f Students know that magnets have two poles and that like poles repel each other and unlike poles attract each other

Ch 22-Guass's Law	10.1a Describe and provide examples of electrostatic and magnetostatic phenomena	Science Content Standards for California Public Schools, Grade 4: 1e Students know electrically charged objects attract or repel each other; 1f Students know that magnets have two poles and that like poles repel each other and unlike poles attract each other
Ch 23-Electric Potential	10.1a Describe and provide examples of electrostatic and magnetostatic phenomena	Science Content Standards for California Public Schools, Grade 4: 1e Students know electrically charged objects attract or repel each other; 1f Students know that magnets have two poles and that like poles repel each other and unlike poles attract each other
Ch 24-Capacitance and Dielectrics	10.1a Describe and provide examples of electrostatic and magnetostatic phenomena	Science Content Standards for California Public Schools, Grade 4: 1e Students know electrically charged objects attract or repel each other; 1f Students know that magnets have two poles and that like poles repel each other and unlike poles attract each other
Ch 26-Direct-Current Circuits	10.1f Define and calculate power, voltage differences, current, and resistance in simple circuits	Science Content Standards for California Public Schools, Grade 8: 1g Students know electrical energy can be converted to heat, light, and motion; Grades 9-12: Physics 5a Students know how to predict the voltage or current in simple direct current electric circuits constructed from batteries, wires, resistors and

		capacitors; 5b Students know to solve problems involving Ohm's law; 5c Students know any resistive element in a DC circuit dissipates energy, which heats the resistor. Students can calculate the power (rate of energy dissipation) in any resistive circuit element by using the formula Power = IR (potential difference) x I (current) = I^2R
Ch 27-Magnetic Filed and Magnetic Forces	9.1f Identify fundamental forces, including gravity, nuclear forces, and electromagnetic forces (magnetic and electric), and explain their roles in nature, such as the role of gravity in maintaining the structure of the universe	Science Content Standards for California Public Schools, Grade 8: 2a Students know a force has both direction and magnitude; 2b Students know when an object is subject to two or more forces at once the result is the cumulative effect of all the forces; 2c Students know when the forces of an object are balanced the motion of the object does not change; Students know to identify separately the two or more forces that are acting on a single static object including gravity , elastic forces due to tension or compression in matter and friction; 2e Students know that when the forces on a object are unbalanced, the object will change its velocity; 2f Students know the greater the mass of an object, the more force is needed to achieve the same rate of change in motion; 2g Students know the role of gravity in forming and

		maintaining the shapes of planets, stars, and solar system
	10.1a Describe and provide examples of electrostatic and magnetostatic phenomena	Science Content Standards for California Public Schools, Grade 4: 1e Students know electrically charged objects attract or repel each other; 1f Students know that magnets have two poles and that like poles repel each other and unlike poles attract each other
	10.1b Predict charges or poles based on attraction/repulsion observations	Science Content Standards for California Public Schools, Grade 4: 1e Students know electrically charged objects attract or repel each other; 1f Students know that magnets have two poles and that like poles repel each other and unlike poles attract each other
	10.1c Build a simple compass and use it to determine direction of magnetic fields, including the Earth's magnetic field	Science Content Standards for California Public Schools, Grade 4: 1b Students know how to build a simple compass and use it to detect magnetic effects including Earth's magnetic field
Ch 28-Sources of Magnetic Field	10.1a Describe and provide examples of electrostatic and magnetostatic phenomena	Science Content Standards for California Public Schools, Grade 4: 1e Students know electrically charged objects attract or repel each other; 1f Students know that magnets have two poles and that like poles repel each other and unlike poles attract each other
	10.1d Relate electric currents to magnetic fields	Science Content Standards for California Public

	and describe the application of these relationships, such as in electromagnets, electric current generators, motors, and transformers	Schools, Grade 4: 1C Students know electric currents produce magnetic fields and know how to build a simple electro magnet; 1d Students know the role of electromagnets in the construction of electric motors electric generators and simple devices such as doorbells and earphones
Ch 29-Electomagnetic Induction	10.1d Relate electric currents to magnetic fields and describe the application of these relationships, such as in electromagnets, electric current generators, motors, and transformers	Science Content Standards for California Public Schools, Grade 4: 1C Students know electric currents produce magnetic fields and know how to build a simple electro magnet; 1d Students know the role of electromagnets in the construction of electric motors electric generators and simple devices such as doorbells and earphones
Ch 30-Inductance	10.1d Relate electric currents to magnetic fields and describe the application of these relationships, such as in electromagnets, electric current generators, motors, and transformers	Science Content Standards for California Public Schools, Grade 4: 1C Students know electric currents produce magnetic fields and know how to build a simple electro magnet; 1d Students know the role of electromagnets in the construction of electric motors electric generators and simple devices such as doorbells and earphones
Ch 31-Alternating Current	10.1d Relate electric currents to magnetic fields and describe the application of these relationships, such as in electromagnets, electric current generators,	Science Content Standards for California Public Schools, Grade 4: 1C Students know electric currents produce magnetic fields and know how to

	motors, and transformers	build a simple electro magnet; 1d Students know the role of electromagnets in the construction of electric motors electric generators and simple devices such as doorbells and earphones
	10.1f Define and calculate power, voltage differences, current, and resistance in simple circuits	Science Content Standards for California Public Schools, Grade 8: 1g Students know electrical energy can be converted to heat, light, and motion; Grades 9-12: Physics 5a Students know how to predict the voltage or current in simple direct current electric circuits constructed from batteries, wires, resistors and capacitors; 5b Students know to solve problems involving Ohm's law; 5c Students know any resistive element in a DC circuit dissipates energy, which heats the resistor. Students can calculate the power (rate of energy dissipation) in any resistive circuit element by using the formula Power = IR (potential difference) x I (current) = I^2R
Ch 32-Electromagnetic Waves	8.1a Compare the characteristics of sound, light, and seismic waves (e.g., transverse/longitudinal, travel through various media, relative speed)	Science Content Standards for California Public Schools, Grade 3: 1d Students know energy can be carried from one place to another by waves, such as water waves and sound waves by electric current and by moving objects; Grade 6: 3a Students know energy can be carried from one place to another by heat flow or by waves including water, light and sound waves, or by moving objects; Grades 9-12: Physics 4a Students know waves carry

		energy from one place to another; 4f Students know how to identify the characteristic properties of waves: Interference (beats), diffraction, reaction, Dopler effect, and polarization
Ch 33-The Nature and Propagation of Light	8.1e Compare transmission, reflection, and absorption of light in matter	Science Content Standards for California Public Schools, Grade 3: 2a Students know sunlight can be locked to create shadows; 2b Students know light is reflected from mirrors and other surfaces; 2c Students know the color of light striking an object affects the way the object is seen; 2d Students know an object is seen when light traveling from the object enters the eye; Grade 7: 6a Students know visible light is a small band within a very broad electromagnetic spectrum; 6c Students know that light travels in straight lines if the medium it travels through does not change
Ch 34-Geometric Optics and Optical Instruments	8.1c Explain how lenses are used in simple optical systems, including the camera, telescope, microscope, and the eye	Science Content Standards for California Public Schools, Grade 3: 4c Students know telescopes magnify the appearance of some distant objects in the sky including the moon and the planets. The number of stars that can be seen through telescopes is dramatically greater than the number that can be seen by the unaided eye; Grade 7: 6d Students know how simple lenses are used in a magnifying glass, the eye, a cameral, a telescope, and a microscope
	8.1d Explain and apply the laws of reflection and refraction	Science Content Standards for California Public Schools, Grade 7: 6e Students know white light is a mixture of many wavelengths and that retinal cells react differently to different wavelengths; 6g Students know the angle of reflection of a light beam is equal to the angle of incidence
	8.1e Compare transmission, reflection, and absorption of light in matter	Science Content Standards for California Public Schools, Grade 3: 2a Students know sunlight can be locked to create shadows; 2b Students know light is reflected from mirrors and other surfaces; 2c Students know the color of

		light striking an object affects the way the object is seen; 2d Students know an object is seen when light traveling from the object enters the eye; Grade 7: 6a Students know visible light is a small band within a very broad electromagnetic spectrum; 6c Students know that light travels in straight lines if the medium it travels through does not change
Chapter	**Physics Subject Matter Requirements**	**Academic content standards for kindergarten through grade twelve, adopted by the California State Board of Education**
Ch 2- Motion along a straight line	1.1b Construct appropriate free-body diagrams of many-body problems (e.g., two or more coupled masses)	Science Content Standards for California Public Schools, Grades 9-12, Physics: 1d Students know that when one object exerts a force on a second object, the second object always exerts a force of equal magnitude and in the opposite direction (Newton's third law)
	1.1e Generate and understand functional relationships of graphs showing distance, velocity, and acceleration versus time	Science Content Standards for California Public Schools, Grades 9-12, Physics: 1a Students know how to solve problems that involve constant speed and average speed; 1b*Students know* that when forces are balanced, no acceleration occurs; thus an object continues to move at a constant speed or stays at rest (Newton's first law); 1c Students know how to apply the law F=ma to solve one-dimensional motion problems that involve constant forces (Newton's second law); 1d Students know that when one object exerts a force on a second object, the second object always exerts a force of equal magnitude and in the opposite direction (Newton's third law); 1e Students know the relationship between the universal law of gravitation and the effect of gravity on an object at the surface of Earth; 1f Students know applying a force to an object perpendicular to the direction of its motion causes the object to change direction but not speed (e.g., Earth's gravitational force causes a satellite in a circular orbit to change direction but not speed); 1g Students know circular motion requires the application of a constant force

		directed toward the center of the circle.
	1.1f Recognize relationships among variables for linear motion and rotational motion	Science Content Standards for California Public Schools, Grades 9-12, Physics: 1h* Students know Newton's laws are not exact but provide very good approximations unless an object is moving close to the speed of light or is small enough that quantum effects are important; 1i* Students know how to solve two-dimensional trajectory problems; 1j* Students know how to resolve two-dimensional vectors into their components and calculate the magnitude and direction of a vector from its components; 1k* Students know how to solve two-dimensional problems involving balanced forces (statics); 1l* Students know how to solve problems in circular motion by using the formula for centripetal acceleration in the following form: $a=v^2/r$; 1m* Students know how to solve problems involving the forces between two electric charges at a distance (Coulomb's law) or the forces between two masses at a distance (universal gravitation).
Ch 3-Motion in two or three dimensions	1.1b Construct appropriate free-body diagrams of many-body problems (e.g., two or more coupled masses)	Science Content Standards for California Public Schools, Grades 9-12, Physics: 1d Students know that when one object exerts a force on a second object, the second object always exerts a force of equal magnitude and in the opposite direction (Newton's third law)
	1.1d Solve 2-dimensional problems involving vector analysis of motion and forces, including projectile motion, uniform circular motion, and statics	Science Content Standards for California Public Schools, Grades 9-12, Physics: 1 f *Students know* applying a force to an object perpendicular to the direction of its motion causes the object to change direction but not speed (e.g., Earth's gravitational force causes a satellite in a circular orbit to change direction but not speed); g *Students know* circular motion requires the application of a constant force directed toward the center of the circle; j * *Students know* how to resolve two-dimensional vectors into their components and calculate the magnitude and direction of a vector from its components; k *

		Students know how to solve two-dimensional problems involving balanced forces (statics)
	1.1e Generate and understand functional relationships of graphs showing distance, velocity, and acceleration versus time	Science Content Standards for California Public Schools, Grades 9-12, Physics: 1a Students know how to solve problems that involve constant speed and average speed; 1b*Students know* that when forces are balanced, no acceleration occurs; thus an object continues to move at a constant speed or stays at rest (Newton's first law); 1c Students know how to apply the law F=ma to solve one-dimensional motion problems that involve constant forces (Newton's second law); 1d Students know that when one object exerts a force on a second object, the second object always exerts a force of equal magnitude and in the opposite direction (Newton's third law); 1e Students know the relationship between the universal law of gravitation and the effect of gravity on an object at the surface of Earth; 1f Students know applying a force to an object perpendicular to the direction of its motion causes the object to change direction but not speed (e.g., Earth's gravitational force causes a satellite in a circular orbit to change direction but not speed); 1g Students know circular motion requires the application of a constant force directed toward the center of the circle.
	2.1f Interpret force-versus-time and force-versus-distance graphs to find, for example, work done or impulse on a system	Science Content Standards for California Public Schools, Grades 9-12, Physics: 2a Students know how to calculate kinetic energy by using the formula $E=(1/2)mv^2$; 2c Students know how to solve problems involving conservation of energy in simple systems, such as falling objects
Ch 4- Newton's laws of motion	1.1a Solve problems using Newton's Second Law (e.g., problems involving time, velocity, and space-dependent forces)	Science Content Standards for California Public Schools, Grades 9-12, Physics: 1 a Students know how to solve problems that involve constant speed and average speed, 1b *Students know* that when forces are balanced, no acceleration occurs; thus an object continues to move at a constant speed or stays at rest (Newton's first law); 1c *Students know* how to apply the law F=ma to solve one-dimensional motion

		problems that involve constant forces (Newton's second law) 1h * *Students know* Newton's laws are not exact but provide very good approximations unless an object is moving close to the speed of light or is small enough that quantum effects are important
	1.1b Construct appropriate free-body diagrams of many-body problems (e.g., two or more coupled masses)	Science Content Standards for California Public Schools, Grades 9-12, Physics: 1d Students know that when one object exerts a force on a second object, the second object always exerts a force of equal magnitude and in the opposite direction (Newton's third law)
	1.1g Solve problems involving linear and rotational motion in term of forces and torques	Science Content Standards for California Public Schools, Grades 9-12, Physics: 1j* Students know how to resolve two-dimensional vectors into their components and calculate the magnitude and direction of a vector from its components; 1k* Students know how to solve two-dimensional problems involving balanced forces (statics); 1l* Students know how to solve problems in circular motion by using the formula for centripetal acceleration in the following form: $a=v^2/r$
	6.1b Evaluate the assumptions and relevance of the Bohr model of the atom	Science Content Standards for California Public Schools, Grades 9-12, Chemistry: 1i Students know the experimental basis for the development of the quantum theory of atomic structure and the historical importance of the Bohr model of the atom
Ch 5- Applying Newton's laws	1.1a Solve problems using Newton's Second Law (e.g., problems involving time, velocity, and space-dependent forces)	Science Content Standards for California Public Schools, Grades 9-12, Physics: 1 a Students know how to solve problems that involve constant speed and average speed, 1b *Students know* that when forces are balanced, no acceleration occurs; thus an object continues to move at a constant speed or stays at rest (Newton's first law); 1c *Students know* how to apply the law F=ma to solve one-dimensional motion problems that involve constant forces (Newton's second law) 1h * *Students know* Newton's laws are not exact but provide very good approximations unless an object is moving close to the speed of light or is small enough that quantum effects are important
	1.1c Solve periodic motion problems	Science Content Standards for California Public Schools, Grades 9-12, Physics: 1eStudents know

		the relationship between the universal law of gravitation and the effect of gravity on an object at the surface of Earth; f *Students know* applying a force to an object perpendicular to the direction of its motion causes the object to change direction but not speed (e.g., Earth's gravitational force causes a satellite in a circular orbit to change direction but not speed); 1g *Students know* circular motion requires the application of a constant force directed toward the center of the circle; l*Students know* how to solve problems in circular motion by using the formula for centripetal acceleration in the following form: $a=v^2/r$.
	1.1d Solve 2-dimensional problems involving vector analysis of motion and forces, including projectile motion, uniform circular motion, and statics	Science Content Standards for California Public Schools, Grades 9-12, Physics: 1 f *Students know* applying a force to an object perpendicular to the direction of its motion causes the object to change direction but not speed (e.g., Earth's gravitational force causes a satellite in a circular orbit to change direction but not speed); g *Students know* circular motion requires the application of a constant force directed toward the center of the circle; j * *Students know* how to resolve two-dimensional vectors into their components and calculate the magnitude and direction of a vector from its components; k * *Students know* how to solve two-dimensional problems involving balanced forces (statics)
	1.1g Solve problems involving linear and rotational motion in term of forces and torques	Science Content Standards for California Public Schools, Grades 9-12, Physics: 1j* Students know how to resolve two-dimensional vectors into their components and calculate the magnitude and direction of a vector from its components; 1k* Students know how to solve two-dimensional problems involving balanced forces (statics); 1l* Students know how to solve problems in circular motion by using the formula for centripetal acceleration in the following form: $a=v^2/r$
Ch 6-Work and kinetic energy	2.1a Use conservation of energy to characterize kinetic-potential energy	Science Content Standards for California Public Schools, Grades 9-12, Physics: 2a Students know how to calculate kinetic energy by using the formula $E=(1/2)mv^2$; 2b

	systems such as oscillating systems (pendula and springs), projectile motion, and roller coasters	Students know how to calculate changes in gravitational potential energy near Earth by using the formula (change in potential energy) =mgh (h is the change in the elevation); 2c Students know how to solve problems involving conservation of energy in simple systems, such as falling objects; 2h * Students know how to solve problems involving conservation of energy in simple systems with various sources of potential energy, such as capacitors and springs
	2.1c Solve problems involving linear and rotational motion in terms of conservation of momentum and energy	Science Content Standards for California Public Schools, Grades 9-12, Physics: 2b Students know how to calculate changes in gravitational potential energy near Earth by using the formula (change in potential energy) =mgh (h is the change in the elevation); 2e Students know momentum is a separately conserved quantity different from energy; 2h Students know how to solve problems involving conservation of energy in simple systems with various sources of potential energy, such as capacitors and springs
	2.1d Recognize relationships between energy/momentum conservation principles and Newton's Laws	Science Content Standards for California Public Schools, Grades 9-12, Physics: 2b Students know how to calculate changes in gravitational potential energy near Earth by using the formula (change in potential energy) =mgh (h is the change in the elevation); 2c Students know how to solve problems involving conservation of energy in simple systems, such as falling objects; 2d Students know how to calculate momentum as the product mv; 2e Students know momentum is a separately conserved quantity different from energy; 2f Students know an unbalanced force on an object produces a change in its momentum
	2.1e Examine the impact of friction on conservation principles	Science Content Standards for California Public Schools, Grades 9-12, Physics: 2b Students know how to calculate changes in gravitational potential energy near Earth by using the formula (change in potential energy) =mgh (h is the change in the

		elevation); 2c Students know how to solve problems involving conservation of energy in simple systems, such as falling objects; 2f Students know an unbalanced force on an object produces a change in its momentum
	2.1f Interpret force-versus-time and force-versus-distance graphs to find, for example, work done or impulse on a system	Science Content Standards for California Public Schools, Grades 9-12, Physics: 2a Students know how to calculate kinetic energy by using the formula $E=(1/2)mv^2$; 2c Students know how to solve problems involving conservation of energy in simple systems, such as falling objects
Ch 7-Potential Energy and Energy Conservation	1.1g Solve problems involving linear and rotational motion in term of forces and torques	Science Content Standards for California Public Schools, Grades 9-12, Physics: 1j* Students know how to resolve two-dimensional vectors into their components and calculate the magnitude and direction of a vector from its components; 1k* Students know how to solve two-dimensional problems involving balanced forces (statics); 1l* Students know how to solve problems in circular motion by using the formula for centripetal acceleration in the following form: $a=v^2/r$
	2.1a Use conservation of energy to characterize kinetic-potential energy systems such as oscillating systems (pendula and springs), projectile motion, and roller coasters	Science Content Standards for California Public Schools, Grades 9-12, Physics: 2a Students know how to calculate kinetic energy by using the formula $E=(1/2)mv^2$; 2b Students know how to calculate changes in gravitational potential energy near Earth by using the formula (change in potential energy) =mgh (h is the change in the elevation); 2c Students know how to solve problems involving conservation of energy in simple systems, such as falling objects; 2h * Students know how to solve problems involving conservation of energy in simple systems with various sources of potential energy, such as capacitors and springs
	2.1c Solve problems involving linear and rotational motion in terms of conservation of momentum and energy	Science Content Standards for California Public Schools, Grades 9-12, Physics: 2b Students know how to calculate changes in gravitational potential energy near Earth by using the formula (change in potential energy) =mgh (h is the change in the elevation); 2e Students know momentum is a separately

		conserved quantity different from energy; 2h Students know how to solve problems involving conservation of energy in simple systems with various sources of potential energy, such as capacitors and springs
	2.1d Recognize relationships between energy/momentum conservation principles and Newton's Laws	Science Content Standards for California Public Schools, Grades 9-12, Physics: 2b Students know how to calculate changes in gravitational potential energy near Earth by using the formula (change in potential energy) =mgh (h is the change in the elevation); 2c Students know how to solve problems involving conservation of energy in simple systems, such as falling objects; 2d Students know how to calculate momentum as the product mv; 2e Students know momentum is a separately conserved quantity different from energy; 2f Students know an unbalanced force on an object produces a change in its momentum
	2.1e Examine the impact of friction on conservation principles	Science Content Standards for California Public Schools, Grades 9-12, Physics: 2b Students know how to calculate changes in gravitational potential energy near Earth by using the formula (change in potential energy) =mgh (h is the change in the elevation); 2c Students know how to solve problems involving conservation of energy in simple systems, such as falling objects; 2f Students know an unbalanced force on an object produces a change in its momentum
	2.1f Interpret force-versus-time and force-versus-distance graphs to find, for example, work done or impulse on a system	Science Content Standards for California Public Schools, Grades 9-12, Physics: 2a Students know how to calculate kinetic energy by using the formula $E=(1/2)mv^2$; 2c Students know how to solve problems involving conservation of energy in simple systems, such as falling objects
Ch 8-Momentum, impulse, and collisions	2.1b Analyze elastic and inelastic collisions and solve for unknown values	Science Content Standards for California Public Schools, Grades 9-12, Physics: 2g Students know how to solve problems involving elastic and inelastic collisions in one dimension by using the principles of conservation of momentum and energy

	2.1c Solve problems involving linear and rotational motion in terms of conservation of momentum and energy	Science Content Standards for California Public Schools, Grades 9-12, Physics: 2b Students know how to calculate changes in gravitational potential energy near Earth by using the formula (change in potential energy) =mgh (h is the change in the elevation); 2e Students know momentum is a separately conserved quantity different from energy; 2h Students know how to solve problems involving conservation of energy in simple systems with various sources of potential energy, such as capacitors and springs
	2.1f Interpret force-versus-time and force-versus-distance graphs to find, for example, work done or impulse on a system	Science Content Standards for California Public Schools, Grades 9-12, Physics: 2a Students know how to calculate kinetic energy by using the formula $E=(1/2)mv^2$; 2c Students know how to solve problems involving conservation of energy in simple systems, such as falling objects
Ch 9-Rotation of rigid bodies	1.1f Recognize relationships among variables for linear motion and rotational motion	Science Content Standards for California Public Schools, Grades 9-12, Physics: 1h* Students know Newton's laws are not exact but provide very good approximations unless an object is moving close to the speed of light or is small enough that quantum effects are important; 1i* Students know how to solve two-dimensional trajectory problems; 1j* Students know how to resolve two-dimensional vectors into their components and calculate the magnitude and direction of a vector from its components; 1k* Students know how to solve two-dimensional problems involving balanced forces (statics); 1l* Students know how to solve problems in circular motion by using the formula for centripetal acceleration in the following form: $a=v^2/r$; 1m* Students know how to solve problems involving the forces between two electric charges at a distance (Coulomb's law) or the forces between two masses at a distance (universal gravitation).
	1.1g Solve problems involving linear and rotational motion in term of	Science Content Standards for California Public Schools, Grades 9-12, Physics: 1j* Students know how to resolve two-dimensional vectors into their components and

	forces and torques	calculate the magnitude and direction of a vector from its components; 1k* Students know how to solve two-dimensional problems involving balanced forces (statics); 1l* Students know how to solve problems in circular motion by using the formula for centripetal acceleration in the following form: $a=v^2/r$
	2.1c Solve problems involving linear and rotational motion in terms of conservation of momentum and energy	Science Content Standards for California Public Schools, Grades 9-12, Physics: 2b Students know how to calculate changes in gravitational potential energy near Earth by using the formula (change in potential energy) =mgh (h is the change in the elevation); 2e Students know momentum is a separately conserved quantity different from energy; 2h Students know how to solve problems involving conservation of energy in simple systems with various sources of potential energy, such as capacitors and springs
Ch 10-Dynamics of rotational motion	1.1f Recognize relationships among variables for linear motion and rotational motion	Science Content Standards for California Public Schools, Grades 9-12, Physics: 1h* Students know Newton's laws are not exact but provide very good approximations unless an object is moving close to the speed of light or is small enough that quantum effects are important; 1i* Students know how to solve two-dimensional trajectory problems; 1j* Students know how to resolve two-dimensional vectors into their components and calculate the magnitude and direction of a vector from its components; 1k* Students know how to solve two-dimensional problems involving balanced forces (statics); 1l* Students know how to solve problems in circular motion by using the formula for centripetal acceleration in the following form: $a=v^2/r$; 1m* Students know how to solve problems involving the forces between two electric charges at a distance (Coulomb's law) or the forces between two masses at a distance (universal gravitation).
	1.1g Solve problems involving linear and rotational motion in term of	Science Content Standards for California Public Schools, Grades 9-12, Physics: 1j* Students know how to resolve two-dimensional

	forces and torques	vectors into their components and calculate the magnitude and direction of a vector from its components; 1k* Students know how to solve two-dimensional problems involving balanced forces (statics); 1l* Students know how to solve problems in circular motion by using the formula for centripetal acceleration in the following form: $a=v^2/r$
	2.1c Solve problems involving linear and rotational motion in terms of conservation of momentum and energy	Science Content Standards for California Public Schools, Grades 9-12, Physics: 2b Students know how to calculate changes in gravitational potential energy near Earth by using the formula (change in potential energy) =mgh (h is the change in the elevation); 2e Students know momentum is a separately conserved quantity different from energy; 2h Students know how to solve problems involving conservation of energy in simple systems with various sources of potential energy, such as capacitors and springs
	5.1f Explain properties of transistors, diodes, and semiconductors	Science Content Standards for California Public Schools, Grades 9-12, Physics: 5a Students know how to predict the voltage or current in simple direct current (DC) electric circuits constructed from batteries, wires, resistors, and capacitors; 5d Students know the properties of transistors and the role of transistors in electric circuits
Ch 12-Nuclear Reactions and Applications	3.1f Describe a plasma, state its characteristic properties, and contrast it with an ideal gas	Science Content Standards for California Public Schools, Grades 9-12, Physics: 3b Students know that the work done by a heat engine that is working in a cycle is the difference between the heat flow into the engine at high temperature and the heat flow out at a lower temperature (first law of thermodynamics) and that this is an example of the law of conservation of energy; 3d Students know that most processes tend to decrease the order of a system over time and that energy levels are eventually distributed uniformly
Ch 13-Periodic Motion	1.1c Solve periodic motion problems	Science Content Standards for California Public Schools, Grades 9-12, Physics: 1eStudents know the relationship between the universal law of gravitation and the effect of gravity on an object

		at the surface of Earth; f *Students know* applying a force to an object perpendicular to the direction of its motion causes the object to change direction but not speed (e.g., Earth's gravitational force causes a satellite in a circular orbit to change direction but not speed); 1g *Students know* circular motion requires the application of a constant force directed toward the center of the circle; l*Students know* how to solve problems in circular motion by using the formula for centripetal acceleration in the following form: $a=v^2/r$.
	6.1a Distinguish the four fundamental forces of nature, describe their ranges, and identify their force carriers	Science Content Standards for California Public Schools, Grades 9-12, Chemistry: 1i Students know the experimental basis for the development of the quantum theory of atomic structure and the historical importance of the Bohr model of the atom
Ch 15-Mechanical waves	1.1c Solve periodic motion problems	Science Content Standards for California Public Schools, Grades 9-12, Physics: 1eStudents know the relationship between the universal law of gravitation and the effect of gravity on an object at the surface of Earth; f *Students know* applying a force to an object perpendicular to the direction of its motion causes the object to change direction but not speed (e.g., Earth's gravitational force causes a satellite in a circular orbit to change direction but not speed); 1g *Students know* circular motion requires the application of a constant force directed toward the center of the circle; l*Students know* how to solve problems in circular motion by using the formula for centripetal acceleration in the following form: $a=v^2/r$.
	4.1a Relate wave propagation to properties of materials (e.g., predict wave speed from density and tension)	Science Content Standards for California Public Schools, Grades 9-12, Physics: 4a Students kn*ow* waves carry energy from one place to another; 4b Students know how to identify transverse and longitudinal waves in mechanical media, such as springs and ropes, and on the earth (seismic waves); 4d Students know sound is a longitudinal wave whose speed depends on the properties of the

		medium in which it propagates
	4.1b Describe, distinguish, and solve both conceptual and numerical problems involving interference, diffraction, refraction, reflection, Doppler effect, polarization, dispersion, and scattering	Science Content Standards for California Public Schools, Grades 9-12, Physics: 4c Students know how to solve problems involving wavelength, frequency, and wave speed; 4e Students know radio waves, light, and X-rays are different wavelength bands in the spectrum of electromagnetic waves whose speed in a vacuum is approximately 3×10^8 m/s (186,000 miles/second); 4f Students know how to identify the characteristic properties of waves: interference (beats), diffraction, refraction, Doppler effect, and polarization
Ch 16-Sound and hearing	1.1c Solve periodic motion problems	Science Content Standards for California Public Schools, Grades 9-12, Physics: 1eStudents know the relationship between the universal law of gravitation and the effect of gravity on an object at the surface of Earth; f *Students know* applying a force to an object perpendicular to the direction of its motion causes the object to change direction but not speed (e.g., Earth's gravitational force causes a satellite in a circular orbit to change direction but not speed); 1g *Students know* circular motion requires the application of a constant force directed toward the center of the circle; l*Students know* how to solve problems in circular motion by using the formula for centripetal acceleration in the following form: $a=v^2/r$.
	4.1b Describe, distinguish, and solve both conceptual and numerical problems involving interference, diffraction, refraction, reflection, Doppler effect, polarization, dispersion, and scattering	Science Content Standards for California Public Schools, Grades 9-12, Physics: 4c Students know how to solve problems involving wavelength, frequency, and wave speed; 4e Students know radio waves, light, and X-rays are different wavelength bands in the spectrum of electromagnetic waves whose speed in a vacuum is approximately 3×10^8 m/s (186,000 miles/second); 4f Students know how to identify the characteristic properties of waves: interference (beats), diffraction, refraction, Doppler effect, and polarization
Ch 17-Temperature and heat	3.1a Solve problems involving the laws of	Science Content Standards for California Public Schools, Grades 9-12, Physics: 3a Students know

	thermodynamics using the relationships among work, heat flow, energy, and entropy	heat flow and work are two forms of energy transfer between systems; 3b Students know that the work done by a heat engine that is working in a cycle is the difference between the heat flow into the engine at high temperature and the heat flow out at a lower temperature (first law of thermodynamics) and that this is an example of the law of conservation of energy; 3e Students know that entropy is a quantity that measures the order or disorder of a system and that this quantity is larger for a more disordered system; 3g * Students know how to solve problems involving heat flow, work, and efficiency in a heat engine and know that all real engines lose some heat to their surroundings
	3.1b Define and correctly apply thermodynamic properties of materials such as specific heat (heat capacity), heats of fusion, heat of vaporization, thermal conductivity, and thermal expansion to solve problems	Science Content Standards for California Public Schools, Grades 9-12, Physics: 3b Students know that the work done by a heat engine that is working in a cycle is the difference between the heat flow into the engine at high temperature and the heat flow out at a lower temperature (first law of thermodynamics) and that this is an example of the law of conservation of energy; 3c Students know the internal energy of an object includes the energy of random motion of the object's atoms and molecules, often referred to as thermal energy. The greater the temperature of the object, the greater the energy of motion of the atoms and molecules that make up the object
	3.1e Interpret graphs showing phase changes and graphs of cyclic processes	Science Content Standards for California Public Schools, Grades 9-12, Physics: 3b Students know that the work done by a heat engine that is working in a cycle is the difference between the heat flow into the engine at high temperature and the heat flow out at a lower temperature (first law of thermodynamics) and that this is an example of the law of conservation of energy; 3e Students know that entropy is a quantity that measures the order or disorder of a system and that this quantity is larger for a more disordered system; 3f* Students know the statement "Entropy tends to increase" is a law of

		statistical probability that governs all closed systems (second law of thermodynamics).
Ch 18-Termal Properties of matter	3.1a Solve problems involving the laws of thermodynamics using the relationships among work, heat flow, energy, and entropy	Science Content Standards for California Public Schools, Grades 9-12, Physics: 3a Students know heat flow and work are two forms of energy transfer between systems; 3b Students know that the work done by a heat engine that is working in a cycle is the difference between the heat flow into the engine at high temperature and the heat flow out at a lower temperature (first law of thermodynamics) and that this is an example of the law of conservation of energy; 3e Students know that entropy is a quantity that measures the order or disorder of a system and that this quantity is larger for a more disordered system; 3g * Students know how to solve problems involving heat flow, work, and efficiency in a heat engine and know that all real engines lose some heat to their surroundings
	3.1b Define and correctly apply thermodynamic properties of materials such as specific heat (heat capacity), heats of fusion, heat of vaporization, thermal conductivity, and thermal expansion to solve problems	Science Content Standards for California Public Schools, Grades 9-12, Physics: 3b Students know that the work done by a heat engine that is working in a cycle is the difference between the heat flow into the engine at high temperature and the heat flow out at a lower temperature (first law of thermodynamics) and that this is an example of the law of conservation of energy; 3c Students know the internal energy of an object includes the energy of random motion of the object's atoms and molecules, often referred to as thermal energy. The greater the temperature of the object, the greater the energy of motion of the atoms and molecules that make up the object
	3.1c Solve problems for ideal gas systems	Science Content Standards for California Public Schools, Grades 9-12, Physics: 3b Students know that the work done by a heat engine that is working in a cycle is the difference between the heat flow into the engine at high temperature and the heat flow out at a lower temperature (first law of thermodynamics) and that this is an example of the law of conservation of energy; 3d Students know that most

		processes tend to decrease the order of a system over time and that energy levels are eventually distributed uniformly
	3.1e Interpret graphs showing phase changes and graphs of cyclic processes	Science Content Standards for California Public Schools, Grades 9-12, Physics: 3b Students know that the work done by a heat engine that is working in a cycle is the difference between the heat flow into the engine at high temperature and the heat flow out at a lower temperature (first law of thermodynamics) and that this is an example of the law of conservation of energy; 3e Students know that entropy is a quantity that measures the order or disorder of a system and that this quantity is larger for a more disordered system; 3f* Students know the statement "Entropy tends to increase" is a law of statistical probability that governs all closed systems (second law of thermodynamics).
Ch 19-The first law of thermodynamics	3.1a Solve problems involving the laws of thermodynamics using the relationships among work, heat flow, energy, and entropy	Science Content Standards for California Public Schools, Grades 9-12, Physics: 3a Students know heat flow and work are two forms of energy transfer between systems; 3b Students know that the work done by a heat engine that is working in a cycle is the difference between the heat flow into the engine at high temperature and the heat flow out at a lower temperature (first law of thermodynamics) and that this is an example of the law of conservation of energy; 3e Students know that entropy is a quantity that measures the order or disorder of a system and that this quantity is larger for a more disordered system; 3g * Students know how to solve problems involving heat flow, work, and efficiency in a heat engine and know that all real engines lose some heat to their surroundings
	3.1b Define and correctly apply thermodynamic properties of materials such as specific heat (heat capacity), heats of fusion, heat of vaporization, thermal conductivity, and thermal expansion to solve	Science Content Standards for California Public Schools, Grades 9-12, Physics: 3b Students know that the work done by a heat engine that is working in a cycle is the difference between the heat flow into the engine at high temperature and the heat flow out at a lower temperature (first law of thermodynamics) and that this is an example of the law of

	problems	conservation of energy; 3c Students know the internal energy of an object includes the energy of random motion of the object's atoms and molecules, often referred to as thermal energy. The greater the temperature of the object, the greater the energy of motion of the atoms and molecules that make up the object
	3.1c Solve problems for ideal gas systems	Science Content Standards for California Public Schools, Grades 9-12, Physics: 3b Students know that the work done by a heat engine that is working in a cycle is the difference between the heat flow into the engine at high temperature and the heat flow out at a lower temperature (first law of thermodynamics) and that this is an example of the law of conservation of energy; 3d Students know that most processes tend to decrease the order of a system over time and that energy levels are eventually distributed uniformly
Ch 20-The second law of thermodynamics	3.1a Solve problems involving the laws of thermodynamics using the relationships among work, heat flow, energy, and entropy	Science Content Standards for California Public Schools, Grades 9-12, Physics: 3a Students know heat flow and work are two forms of energy transfer between systems; 3b Students know that the work done by a heat engine that is working in a cycle is the difference between the heat flow into the engine at high temperature and the heat flow out at a lower temperature (first law of thermodynamics) and that this is an example of the law of conservation of energy; 3e Students know that entropy is a quantity that measures the order or disorder of a system and that this quantity is larger for a more disordered system; 3g * Students know how to solve problems involving heat flow, work, and efficiency in a heat engine and know that all real engines lose some heat to their surroundings
	3.1b Define and correctly apply thermodynamic properties of materials such as specific heat (heat capacity), heats of fusion, heat of vaporization, thermal conductivity, and	Science Content Standards for California Public Schools, Grades 9-12, Physics: 3b Students know that the work done by a heat engine that is working in a cycle is the difference between the heat flow into the engine at high temperature and the heat flow out at a lower temperature (first law of thermodynamics) and that this is

	thermal expansion to solve problems	an example of the law of conservation of energy; 3c Students know the internal energy of an object includes the energy of random motion of the object's atoms and molecules, often referred to as thermal energy. The greater the temperature of the object, the greater the energy of motion of the atoms and molecules that make up the object
	3.1c Solve problems for ideal gas systems	Science Content Standards for California Public Schools, Grades 9-12, Physics: 3b Students know that the work done by a heat engine that is working in a cycle is the difference between the heat flow into the engine at high temperature and the heat flow out at a lower temperature (first law of thermodynamics) and that this is an example of the law of conservation of energy; 3d Students know that most processes tend to decrease the order of a system over time and that energy levels are eventually distributed uniformly
	3.1d Solve problems involving cyclic processes, including calculations of work done, heat gain/loss, , and entropy change	Science Content Standards for California Public Schools, Grades 9-12, Physics: 3d Students know that most processes tend to decrease the order of a system over time and that energy levels are eventually distributed uniformly; 3e Students know that entropy is a quantity that measures the order or disorder of a system and that this quantity is larger for a more disordered system; 3f* Students know the statement "Entropy tends to increase" is a law of statistical probability that governs all closed systems (second law of thermodynamics).
	3.1e Interpret graphs showing phase changes and graphs of cyclic processes	Science Content Standards for California Public Schools, Grades 9-12, Physics: 3b Students know that the work done by a heat engine that is working in a cycle is the difference between the heat flow into the engine at high temperature and the heat flow out at a lower temperature (first law of thermodynamics) and that this is an example of the law of conservation of energy; 3e Students know that entropy is a quantity that measures the order or disorder of a system and that this quantity is larger for a more

		disordered system; 3f* Students know the statement "Entropy tends to increase" is a law of statistical probability that governs all closed systems (second law of thermodynamics).
Ch 21-Electric charge and electric field	3.1b Define and correctly apply thermodynamic properties of materials such as specific heat (heat capacity), heats of fusion, heat of vaporization, thermal conductivity, and thermal expansion to solve problems	Science Content Standards for California Public Schools, Grades 9-12, Physics: 3b Students know that the work done by a heat engine that is working in a cycle is the difference between the heat flow into the engine at high temperature and the heat flow out at a lower temperature (first law of thermodynamics) and that this is an example of the law of conservation of energy; 3c Students know the internal energy of an object includes the energy of random motion of the object's atoms and molecules, often referred to as thermal energy. The greater the temperature of the object, the greater the energy of motion of the atoms and molecules that make up the object
Ch 21-Electric charge and electric field	5.1a Analyze electric and magnetic forces, charges, and fields using Coulomb's law, the Lorentz force, and the right-hand rule	Science Content Standards for California Public Schools, Grades 9-12, Physics: 5e Students know charged particles are sources of electric fields and are subject to the forces of the electric fields from other charges; 5f Students know magnetic materials and electric currents (moving electric charges) are sources of magnetic fields and are subject to forces arising from the magnetic fields of other sources; 5k * Students know the force on a charged particle in an electric field is qE, where E is the electric field at the position of the particle and q is the charge of the particle; 5m Students know static electric fields have as their source some arrangement of electric charges; 5n * Students know the magnitude of the force on a moving particle (with charge q) in a magnetic field is qvB sin(a), where a is the angle between v and B (v and B are the magnitudes of vectors v and B, respectively), and students use the right-hand rule to find the direction of this force
Ch 22-Guass's laws	5.1a Analyze electric and magnetic forces, charges, and fields using Coulomb's	Science Content Standards for California Public Schools, Grades 9-12, Physics: 5e Students know charged particles are sources of

	law, the Lorentz force, and the right-hand rule	electric fields and are subject to the forces of the electric fields from other charges; 5f Students know magnetic materials and electric currents (moving electric charges) are sources of magnetic fields and are subject to forces arising from the magnetic fields of other sources; 5k * Students know the force on a charged particle in an electric field is qE, where E is the electric field at the position of the particle and q is the charge of the particle; 5m Students know static electric fields have as their source some arrangement of electric charges; 5n * Students know the magnitude of the force on a moving particle (with charge q) in a magnetic field is qvB sin(a), where a is the angle between v and B (v and B are the magnitudes of vectors v and B, respectively), and students use the right-hand rule to find the direction of this force
Ch 23-Electrical potential	5.1b Apply energy principles to analyze problems in electricity, magnetism, and circuit theory involving capacitors, resistors, and inductors	Science Content Standards for California Public Schools, Grades 9-12, Physics: 5c Students know any resistive element in a DC circuit dissipates energy, which heats the resistor. Students can calculate the power (rate of energy dissipation) in any resistive circuit element by using the formula Power = IR (potential difference) × I (current) = I^2R; 5d Students know the properties of transistors and the role of transistors in electric circuits; 5i Students know plasmas, the fourth state of matter, contain ions or free electrons or both and conduct electricity
	5.1c Calculate power, voltage changes, current, and resistance in multiloop circuits involving capacitors, resistors, and inductors	Science Content Standards for California Public Schools, Grades 9-12, Physics: 5a Students know how to predict the voltage or current in simple direct current (DC) electric circuits constructed from batteries, wires, resistors, and capacitors; 5b Students know how to solve problems involving Ohm's law; 5g *Students know* how to determine the direction of a magnetic field produced by a current flowing in a straight wire or in a coil; 5i Students know plasmas, the fourth state of matter, contain ions or free electrons or both and conduct

		electricity
Ch 24-Capacitance and dielectrics	5.1b Apply energy principles to analyze problems in electricity, magnetism, and circuit theory involving capacitors, resistors, and inductors	Science Content Standards for California Public Schools, Grades 9-12, Physics: 5c Students know any resistive element in a DC circuit dissipates energy, which heats the resistor. Students can calculate the power (rate of energy dissipation) in any resistive circuit element by using the formula Power = IR (potential difference) × I (current) = I^2R; 5d Students know the properties of transistors and the role of transistors in electric circuits; 5i Students know plasmas, the fourth state of matter, contain ions or free electrons or both and conduct electricity
	5.1c Calculate power, voltage changes, current, and resistance in multiloop circuits involving capacitors, resistors, and inductors	Science Content Standards for California Public Schools, Grades 9-12, Physics: 5a Students know how to predict the voltage or current in simple direct current (DC) electric circuits constructed from batteries, wires, resistors, and capacitors; 5b Students know how to solve problems involving Ohm's law; 5g *Students know* how to determine the direction of a magnetic field produced by a current flowing in a straight wire or in a coil; 5i Students know plasmas, the fourth state of matter, contain ions or free electrons or both and conduct electricity
	5.1d Interpret and design mixed series and parallel circuits involving capacitors, resistors, and inductors	Science Content Standards for California Public Schools, Grades 9-12, Physics: 5a Students know how to predict the voltage or current in simple direct current (DC) electric circuits constructed from batteries, wires, resistors, and capacitors; 5c Students know any resistive element in a DC circuit dissipates energy, which heats the resistor. Students can calculate the power (rate of energy dissipation) in any resistive circuit element by using the formula Power = IR (potential difference) × I (current) = I^2R
Ch 25-Current, resistance, and electromotive force	5.1c Calculate power, voltage changes, current, and resistance in multiloop circuits involving capacitors, resistors, and inductors	Science Content Standards for California Public Schools, Grades 9-12, Physics: 5a Students know how to predict the voltage or current in simple direct current (DC) electric circuits constructed from batteries, wires, resistors, and capacitors; 5b Students know how to solve problems involving

		Ohm's law; 5g *Students know* how to determine the direction of a magnetic field produced by a current flowing in a straight wire or in a coil; 5i Students know plasmas, the fourth state of matter, contain ions or free electrons or both and conduct electricity
	5.1d Interpret and design mixed series and parallel circuits involving capacitors, resistors, and inductors	Science Content Standards for California Public Schools, Grades 9-12, Physics: 5a Students know how to predict the voltage or current in simple direct current (DC) electric circuits constructed from batteries, wires, resistors, and capacitors; 5c Students know any resistive element in a DC circuit dissipates energy, which heats the resistor. Students can calculate the power (rate of energy dissipation) in any resistive circuit element by using the formula Power = IR (potential difference) × I (current) = I^2R
Ch 26-Direct-current circuits	5.1c Calculate power, voltage changes, current, and resistance in multiloop circuits involving capacitors, resistors, and inductors	Science Content Standards for California Public Schools, Grades 9-12, Physics: 5a Students know how to predict the voltage or current in simple direct current (DC) electric circuits constructed from batteries, wires, resistors, and capacitors; 5b Students know how to solve problems involving Ohm's law; 5g *Students know* how to determine the direction of a magnetic field produced by a current flowing in a straight wire or in a coil; 5i Students know plasmas, the fourth state of matter, contain ions or free electrons or both and conduct electricity
	5.1d Interpret and design mixed series and parallel circuits involving capacitors, resistors, and inductors	Science Content Standards for California Public Schools, Grades 9-12, Physics: 5a Students know how to predict the voltage or current in simple direct current (DC) electric circuits constructed from batteries, wires, resistors, and capacitors; 5c Students know any resistive element in a DC circuit dissipates energy, which heats the resistor. Students can calculate the power (rate of energy dissipation) in any resistive circuit element by using the formula Power = IR (potential difference) × I (current) = I^2R
Ch 27-Magnetic field and magnetic forces	5.1a Analyze electric and magnetic forces, charges,	Science Content Standards for California Public Schools, Grades 9-12, Physics: 5e Students know

	and fields using Coulomb's law, the Lorentz force, and the right-hand rule	charged particles are sources of electric fields and are subject to the forces of the electric fields from other charges; 5f Students know magnetic materials and electric currents (moving electric charges) are sources of magnetic fields and are subject to forces arising from the magnetic fields of other sources; 5k * Students know the force on a charged particle in an electric field is qE, where E is the electric field at the position of the particle and q is the charge of the particle; 5m Students know static electric fields have as their source some arrangement of electric charges; 5n * Students know the magnitude of the force on a moving particle (with charge q) in a magnetic field is qvB sin(a), where a is the angle between v and B (v and B are the magnitudes of vectors v and B, respectively), and students use the right-hand rule to find the direction of this force
Ch 28-Sources of magnetic field	5.1a Analyze electric and magnetic forces, charges, and fields using Coulomb's law, the Lorentz force, and the right-hand rule	Science Content Standards for California Public Schools, Grades 9-12, Physics: 5e Students kno*w* charged particles are sources of electric fields and are subject to the forces of the electric fields from other charges; 5f Students know magnetic materials and electric currents (moving electric charges) are sources of magnetic fields and are subject to forces arising from the magnetic fields of other sources; 5k * Students know the force on a charged particle in an electric field is qE, where E is the electric field at the position of the particle and q is the charge of the particle; 5m Students know static electric fields have as their source some arrangement of electric charges; 5n * Students know the magnitude of the force on a moving particle (with charge q) in a magnetic field is qvB sin(a), where a is the angle between v and B (v and B are the magnitudes of vectors v and B, respectively), and students use the right-hand rule to find the direction of this force
Ch 29-Electromagnetic induction	5.1c Calculate power, voltage changes, current,	Science Content Standards for California Public Schools, Grades 9-12, Physics: 5a Students know

	and resistance in multiloop circuits involving capacitors, resistors, and inductors	how to predict the voltage or current in simple direct current (DC) electric circuits constructed from batteries, wires, resistors, and capacitors; 5b Students know how to solve problems involving Ohm's law; 5g *Students know* how to determine the direction of a magnetic field produced by a current flowing in a straight wire or in a coil; 5i Students know plasmas, the fourth state of matter, contain ions or free electrons or both and conduct electricity
	5.1d Interpret and design mixed series and parallel circuits involving capacitors, resistors, and inductors	Science Content Standards for California Public Schools, Grades 9-12, Physics: 5a Students know how to predict the voltage or current in simple direct current (DC) electric circuits constructed from batteries, wires, resistors, and capacitors; 5c Students know any resistive element in a DC circuit dissipates energy, which heats the resistor. Students can calculate the power (rate of energy dissipation) in any resistive circuit element by using the formula Power = IR (potential difference) × I (current) = I^2R
	5.1e Solve problems involving the relationships between electric and magnetic phenomena	Science Content Standards for California Public Schools, Grades 9-12, Physics: 5f Students know magnetic materials and electric currents (moving electric charges) are sources of magnetic fields and are subject to forces arising from the magnetic fields of other sources; 5h *Students know* changing magnetic fields produce electric fields, thereby inducing currents in nearby conductors; 5j * Students know electric and magnetic fields contain energy and act as vector force fields; 5l * Students know how to calculate the electric field resulting from a point charge; 5o * Students know how to apply the concepts of electrical and gravitational potential energy to solve problems involving conservation of energy
Ch 30-Inductance	1.1c Solve periodic motion problems	Science Content Standards for California Public Schools, Grades 9-12, Physics: 1eStudents know the relationship between the universal law of gravitation and the effect of gravity on an object at the surface of Earth; f *Students know* applying a force to an object

		perpendicular to the direction of its motion causes the object to change direction but not speed (e.g., Earth's gravitational force causes a satellite in a circular orbit to change direction but not speed); 1g *Students know* circular motion requires the application of a constant force directed toward the center of the circle; l*Students know* how to solve problems in circular motion by using the formula for centripetal acceleration in the following form: $a=v^2/r$.
	5.1b Apply energy principles to analyze problems in electricity, magnetism, and circuit theory involving capacitors, resistors, and inductors	Science Content Standards for California Public Schools, Grades 9-12, Physics: 5c Students know any resistive element in a DC circuit dissipates energy, which heats the resistor. Students can calculate the power (rate of energy dissipation) in any resistive circuit element by using the formula Power = IR (potential difference) × I (current) = I^2R; 5d Students know the properties of transistors and the role of transistors in electric circuits; 5i Students know plasmas, the fourth state of matter, contain ions or free electrons or both and conduct electricity
	5.1c Calculate power, voltage changes, current, and resistance in multiloop circuits involving capacitors, resistors, and inductors	Science Content Standards for California Public Schools, Grades 9-12, Physics: 5a Students know how to predict the voltage or current in simple direct current (DC) electric circuits constructed from batteries, wires, resistors, and capacitors; 5b Students know how to solve problems involving Ohm's law; 5g *Students know* how to determine the direction of a magnetic field produced by a current flowing in a straight wire or in a coil; 5i Students know plasmas, the fourth state of matter, contain ions or free electrons or both and conduct electricity
	5.1d Interpret and design mixed series and parallel circuits involving capacitors, resistors, and inductors	Science Content Standards for California Public Schools, Grades 9-12, Physics: 5a Students know how to predict the voltage or current in simple direct current (DC) electric circuits constructed from batteries, wires, resistors, and capacitors; 5c Students know any resistive element in a DC circuit dissipates energy, which heats the resistor. Students can

		calculate the power (rate of energy dissipation) in any resistive circuit element by using the formula Power = IR (potential difference) × I (current) = I^2R
	5.1e Solve problems involving the relationships between electric and magnetic phenomena	Science Content Standards for California Public Schools, Grades 9-12, Physics: 5f Students know magnetic materials and electric currents (moving electric charges) are sources of magnetic fields and are subject to forces arising from the magnetic fields of other sources; 5h *Students know* changing magnetic fields produce electric fields, thereby inducing currents in nearby conductors; 5j * Students know electric and magnetic fields contain energy and act as vector force fields; 5l * Students know how to calculate the electric field resulting from a point charge; 5o * Students know how to apply the concepts of electrical and gravitational potential energy to solve problems involving conservation of energy
Ch 31-Alternating current	1.1c Solve periodic motion problems	Science Content Standards for California Public Schools, Grades 9-12, Physics: 1eStudents know the relationship between the universal law of gravitation and the effect of gravity on an object at the surface of Earth; f *Students know* applying a force to an object perpendicular to the direction of its motion causes the object to change direction but not speed (e.g., Earth's gravitational force causes a satellite in a circular orbit to change direction but not speed); 1g *Students know* circular motion requires the application of a constant force directed toward the center of the circle; l*Students know* how to solve problems in circular motion by using the formula for centripetal acceleration in the following form: $a=v^2/r$.
	5.1c Calculate power, voltage changes, current, and resistance in multiloop circuits involving capacitors, resistors, and inductors	Science Content Standards for California Public Schools, Grades 9-12, Physics: 5a Students know how to predict the voltage or current in simple direct current (DC) electric circuits constructed from batteries, wires, resistors, and capacitors; 5b Students know how to solve problems involving Ohm's law; 5g *Students know* how to determine the direction of

		a magnetic field produced by a current flowing in a straight wire or in a coil; 5i Students know plasmas, the fourth state of matter, contain ions or free electrons or both and conduct electricity
	5.1d Interpret and design mixed series and parallel circuits involving capacitors, resistors, and inductors	Science Content Standards for California Public Schools, Grades 9-12, Physics: 5a Students know how to predict the voltage or current in simple direct current (DC) electric circuits constructed from batteries, wires, resistors, and capacitors; 5c Students know any resistive element in a DC circuit dissipates energy, which heats the resistor. Students can calculate the power (rate of energy dissipation) in any resistive circuit element by using the formula Power = IR (potential difference) × I (current) = I^2R
	5.1e Solve problems involving the relationships between electric and magnetic phenomena	Science Content Standards for California Public Schools, Grades 9-12, Physics: 5f Students know magnetic materials and electric currents (moving electric charges) are sources of magnetic fields and are subject to forces arising from the magnetic fields of other sources; 5h *Students know* changing magnetic fields produce electric fields, thereby inducing currents in nearby conductors; 5j * Students know electric and magnetic fields contain energy and act as vector force fields; 5l * Students know how to calculate the electric field resulting from a point charge; 5o * Students know how to apply the concepts of electrical and gravitational potential energy to solve problems involving conservation of energy
Ch 32-Electromagnetic waves	1.1c Solve periodic motion problems	Science Content Standards for California Public Schools, Grades 9-12, Physics: 1eStudents know the relationship between the universal law of gravitation and the effect of gravity on an object at the surface of Earth; f *Students know* applying a force to an object perpendicular to the direction of its motion causes the object to change direction but not speed (e.g., Earth's gravitational force causes a satellite in a circular orbit to change direction but not speed); 1g *Students know* circular motion requires the application of

		a constant force directed toward the center of the circle; l*Students know* how to solve problems in circular motion by using the formula for centripetal acceleration in the following form: $a=v^2/r$.
	4.1b Describe, distinguish, and solve both conceptual and numerical problems involving interference, diffraction, refraction, reflection, Doppler effect, polarization, dispersion, and scattering	Science Content Standards for California Public Schools, Grades 9-12, Physics: 4c Students know how to solve problems involving wavelength, frequency, and wave speed; 4e Students know radio waves, light, and X-rays are different wavelength bands in the spectrum of electromagnetic waves whose speed in a vacuum is approximately 3×10^8 m/s (186,000 miles/second); 4f Students know how to identify the characteristic properties of waves: interference (beats), diffraction, refraction, Doppler effect, and polarization
	5.1e Solve problems involving the relationships between electric and magnetic phenomena	Science Content Standards for California Public Schools, Grades 9-12, Physics: 5f Students know magnetic materials and electric currents (moving electric charges) are sources of magnetic fields and are subject to forces arising from the magnetic fields of other sources; 5h *Students know* changing magnetic fields produce electric fields, thereby inducing currents in nearby conductors; 5j * Students know electric and magnetic fields contain energy and act as vector force fields; 5l * Students know how to calculate the electric field resulting from a point charge; 5o * Students know how to apply the concepts of electrical and gravitational potential energy to solve problems involving conservation of energy
Ch 33-The nature and propagation of light	4.1b Describe, distinguish, and solve both conceptual and numerical problems involving interference, diffraction, refraction, reflection, Doppler effect, polarization, dispersion, and scattering	Science Content Standards for California Public Schools, Grades 9-12, Physics: 4c Students know how to solve problems involving wavelength, frequency, and wave speed; 4e Students know radio waves, light, and X-rays are different wavelength bands in the spectrum of electromagnetic waves whose speed in a vacuum is approximately 3×10^8 m/s (186,000 miles/second); 4f Students know how to identify the characteristic properties of waves: interference (beats), diffraction,

		refraction, Doppler effect, and polarization
Ch 34-Geometrical optics and optical instruments	4.1b Describe, distinguish, and solve both conceptual and numerical problems involving interference, diffraction, refraction, reflection, Doppler effect, polarization, dispersion, and scattering	Science Content Standards for California Public Schools, Grades 9-12, Physics: 4c Students know how to solve problems involving wavelength, frequency, and wave speed; 4e Students know radio waves, light, and X-rays are different wavelength bands in the spectrum of electromagnetic waves whose speed in a vacuum is approximately 3×10^8 m/s (186,000 miles/second); 4f Students know how to identify the characteristic properties of waves: interference (beats), diffraction, refraction, Doppler effect, and polarization
Ch 35-Intererence	4.1b Describe, distinguish, and solve both conceptual and numerical problems involving interference, diffraction, refraction, reflection, Doppler effect, polarization, dispersion, and scattering	Science Content Standards for California Public Schools, Grades 9-12, Physics: 4c Students know how to solve problems involving wavelength, frequency, and wave speed; 4e Students know radio waves, light, and X-rays are different wavelength bands in the spectrum of electromagnetic waves whose speed in a vacuum is approximately 3×10^8 m/s (186,000 miles/second); 4f Students know how to identify the characteristic properties of waves: interference (beats), diffraction, refraction, Doppler effect, and polarization
Ch 36-Diffraction	4.1b Describe, distinguish, and solve both conceptual and numerical problems involving interference, diffraction, refraction, reflection, Doppler effect, polarization, dispersion, and scattering	Science Content Standards for California Public Schools, Grades 9-12, Physics: 4c Students know how to solve problems involving wavelength, frequency, and wave speed; 4e Students know radio waves, light, and X-rays are different wavelength bands in the spectrum of electromagnetic waves whose speed in a vacuum is approximately 3×10^8 m/s (186,000 miles/second); 4f Students know how to identify the characteristic properties of waves: interference (beats), diffraction, refraction, Doppler effect, and polarization