DUBLIN
CITY SCHOOLS

K-12 SCIENCE
Graded Course of Study
2025

A K-12 Dublin City Schools science education aims to create lifelong learners who are curious, critical thinkers, and effective collaborators, equipped with the scientific knowledge and skills necessary to navigate and shape a complex and ever-changing world.

Our vision is to inspire students to develop a deep appreciation for science and its applications, empowering them to:

- Ask questions, seek answers, and explore the natural world with a sense of wonder and curiosity.
- Think critically and creatively to solve problems and make informed decisions as a scientifically literate citizen.
- Communicate and collaborate effectively in our diverse community and beyond to address common challenges and create innovative solutions.
- Build their own identity as a scientist in order to apply scientific concepts and methods to understand and address real-world issues competently and confidently.
- Develop the resilience, adaptability, and perseverance needed to succeed in a rapidly evolving world.

Instructional Agreements for Science Learning within the Dublin City Schools

- Teachers will provide opportunities for students to engage in hands-on experiences, projects, and real-world simulations to provide context and relevance to science concepts.
- Teachers will create an environment that emphasizes the importance of effort, perseverance, and reflection in order to learn and grow from both success and failure.
- Content standards will be learned in conjunction with best practices regarding science education.

Together, we will cultivate resourceful, adaptable, and collaborative individuals with the ability to tackle real-world challenges with resilience and innovation.

Nature of Science	
One goal of science education is to help students become scientifically literate citizens able to use science as a way of knowing about the natural and material world. All students should have sufficient understanding of scientific knowledge and scientific processes to enable them to distinguish what is science from what is not science and to make informed decisions about career choices, health maintenance, quality of life, community and other decisions that impact both themselves and others.	
Scientific Inquiry, Practice and Applications	All students must use these scientific processes with appropriate laboratory safety techniques to construct their knowledge and understanding in all science content areas.
Science is a Way of Knowing	Science assumes the universe is a vast single system in which basic laws are consistent. Natural laws operate today as they did in the past and they will continue to do so in the future. Science is both a body of knowledge that represents a current understanding of natural systems and the processes used to refine, elaborate, revise and extend this knowledge.
Science is a Human Endeavor	Science has been, and continues to be, advanced by individuals of various races, genders, ethnicities, languages, abilities, family backgrounds and incomes.
Scientific Knowledge is Open to Revision in Light of New Evidence	Science is not static. Science is constantly changing as we acquire more knowledge.

Scientific and Engineering Practices:
1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Ohio's Cognitive Demands for Science	
Educators will refer to "Ohio's Cognitive Demands for Science" to create experiences for students to engage in science content and demonstrate understanding of scientific concepts in ways that align with current research about how people learn.	
DESIGNING TECHNOLOGICAL/ ENGINEERING SOLUTIONS USING SCIENCE CONCEPTS	Requires students to solve science-based engineering or technological problems through application of scientific inquiry. Within given scientific constraints, propose or critique solutions, analyze and interpret technological and engineering problems, use science principles to anticipate effects of technological or engineering design, find solutions using science and engineering or technology, consider consequences and alternatives, and/or integrate and synthesize scientific information.
DEMONSTRATING SCIENCE KNOWLEDGE	Requires students to use scientific practices and develop the ability to think and act in ways associated with inquiry, including asking questions, planning and conducting investigations, using appropriate tools and techniques to gather and organize data, thinking critically and logically about relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific arguments. (Slightly altered from National Science Education Standards)
INTERPRETING AND COMMUNICATING SCIENCE CONCEPTS	Requires students to use subject-specific conceptual knowledge to interpret and explain events, phenomena, concepts and experiences using grade-appropriate scientific terminology, technological knowledge and mathematical knowledge. Communicate with clarity, focus and organization using rich, investigative scenarios, real-world data and valid scientific information.
RECALLING ACCURATE SCIENCE	Requires students to provide accurate statements about scientifically valid facts, concepts and relationships. Recall only requires students to provide a rote response, declarative knowledge or perform routine mathematical tasks. This cognitive demand refers to students' knowledge of science fact, information, concepts, tools, procedures (being able to describe how) and basic principles.

	◦ Respiration mechanics is the process by which humans breathe and includes the movement of the diaphragm and pressure-volume relationships. ◦ Gas exchange refers to the diffusion of gas across the alveolar epithelium in the respiratory system and capillary endothelium of the cardiovascular system. • Lung volumes and capacities can be measured using spirometry. • Homeostatic imbalances are explored. ◦ These include, but are not limited to, asthma, chronic obstructive pulmonary disease (COPD), tuberculosis, cystic fibrosis and the effects of smoking and pollution. • Investigations are used to understand and explain the respiratory system in a variety of inquiry and design scenarios that can incorporate evolutionary concepts, scientific reasoning, comparative analysis, communication skills and real-world applications.

REPRODUCTION	
Content Statement	**Content Elaboration**
AP.R.1: Reproductive system	• The reproductive system consists of internal and external organs and hormones. • The ovaries and testes produce gametes that fuse to form a zygote, a single cell that develops into an embryo and eventually an adult. • A comparison of male and female anatomy should be explored. The female body has the function of providing protection and nourishment for the developing fetus until birth. If all is successful, a new generation of offspring will occur. • The processes of the reproductive system include oogenesis, spermatogenesis and fertilization. Additional processes can include birth, lactation and menstruation. • Homeostatic imbalances are explored. ◦ These include, but are not limited to, infertility, chromosomal disorders, endometriosis, cancer, Human Papillomavirus (HPV), and sexually transmitted diseases (STD's). • Investigations are used to understand and explain the reproductive system in a variety of inquiry and design scenarios that can incorporate evolutionary concepts, scientific reasoning, comparative analysis, communication skills and real-world applications.

Physics

Course Goals

Physics elaborates on the study of the key concepts of motion, forces and energy as they relate to increasingly complex systems and applications that will provide a foundation for further study in science and scientific literacy. Students engage in investigations to understand and explain motion, forces and energy in a variety of inquiry and design scenarios that incorporate scientific reasoning, analysis, communication skills and real-world applications.

MOTION	
In physical science, the concepts of position, displacement, velocity and acceleration were introduced and straight-line motion involving either uniform velocity or uniform acceleration was investigated and represented in position vs. time graphs, velocity vs. time graphs, motion diagrams and data tables. In this course, acceleration vs. time graphs are introduced and more complex graphs are considered that have both positive and negative displacement values and involve motion that occurs in stages (e.g., an object accelerates then moves with constant velocity). Symbols representing acceleration are added to motion diagrams and mathematical analysis of motion becomes increasingly more complex. Motion is explored through investigation and experimentation. Motion detectors and computer graphing applications can be used to collect and organize data. Computer simulations and video analysis can be used to analyze motion with greater precision.	
Content Statement	**Content Elaboration**
P.M.1: Motion graphs	Position vs. time ● Average velocity is determined as the linear slope of a position time graph for an object that is not accelerating. ● Instantaneous velocity is determined by calculating the slope of the tangent line formed from a position time graph at a specific time denotation. Velocity vs. time ● Velocity time graphs reveal an increase in speed with slopes that increase in value from the x-axis and decrease in speed with a slope that approaches the x axis. ● Constant velocity Is demonstrated by a nonzero plot that has no slope. ● Acceleration can be derived from a velocity time graph by calculating a non zero slope. Acceleration is positive for objects speeding up in a positive direction or slowing

	down in a negative direction. Conversely , Acceleration is negative for objects speeding up in a negative direction or slowing down in a positive direction. ● The area under the curve of a velocity time graph will yield the change in the object's position. However, the origin of the object's initial position or absolute position cannot be inferred from the area under that curve. Acceleration vs. time ● Graphs comparing a non-constant rate of acceleration vs time are introduced.
P.M.2: Problem Solving	Using graphs (average velocity, instantaneous velocity, acceleration, displacement, change in velocity) ● Problems can be solved with graphs ○ Displacement = area under velocity graph curve ○ Acceleration = slope of velocity graph Uniform acceleration including free fall (initial velocity, final velocity, time, displacement, acceleration, average velocity) ● When acceleration is constant, kinematics equations can be used. ● Problems involving freefall (objects only influenced by Earth's gravity) should be included.
P.M.3: Projectile Motion	Independence of horizontal and vertical motion ● Objects have both horizontal and vertical components that act independent of each other. ● The horizontal velocity does not change if air resistance is not considered. ● The vertical component is controlled by the acceleration due to Earth's gravity. Problem-solving involving horizontally launched projectiles ● Problem solving shall be limited to finding range, time in the air, initial height, initial velocity, and final velocity of horizontally launched projectiles only (cliff problems). ○ Problems including objects launched at angles are beyond the scope of this course.

FORCES, MOMENTUM AND MOTION	
In earlier grades, Newton's laws of motion were introduced, gravitational forces and fields were described conceptually, the gravitational force (weight) acting on objects near Earth's surface was calculated, and friction forces and drag were addressed conceptually and quantified from force diagrams. The forces required for circular motion were introduced conceptually. In this course, Newton's laws of motion are applied to mathematically describe and predict the effects of forces on more complex systems of objects and to analyze falling objects that experience significant air resistance. Gravitational forces are studied as a universal phenomenon and gravitational field strength is quantified. Elastic forces and a more detailed look at friction are included. At the atomic level, contact forces are actually due to the forces between the charged particles of the objects that appear to be touching. These electric forces are responsible for friction forces, normal forces and other contact forces. Air resistance and drag are explained using the particle nature of matter. Projectile motion is introduced and circular motion is quantified. The vector properties of momentum and impulse are introduced and used to analyze elastic and inelastic collisions between objects. Analysis of experimental data collected in laboratory investigations is used to study forces and momentum. This can include the use of force probes and computer software to collect and analyze data.	
Content Statement	**Content Elaboration**
P.F.1: Newton's laws applied to complex problems	Newton's Laws of Motion • Objects experiencing balanced forces (F_{net} = 0) have a constant velocity. • Objects experiencing unbalanced forces will accelerate. • The acceleration of an object is determined by **$a = F_{net} / m$**. • Interacting objects exert forces on each other that are equal in strength and opposite in direction. The laws of motion can be used to solve problems involving single objects and systems of objects. • Problem solving should include forces that must be quantified (e.g. gravitational, friction, elastic, tension).
P.F.2: Gravitational force and fields	Gravitational force • Gravitational interactions are weak and are difficult to observe unless one object is massive. • The attractive force between objects can be found with $F_G = G\ (m_1\ m_2)\ /\ r^2$ • Calculate the F_{net} on an object placed between two massive objects. • Calculating the position of an object between two larger objects of the F_{net} on the object is known.

	Gravitational field strength ● Gravitational field strength, "g" (acceleration due to gravity), at a certain location is defined as the gravitational force felt on the object depending on its mass ($g = F_g / m$). It is always directed toward the center of the larger object. ○ Distinguish between G and g ● A person's "apparent" weight is the Normal Force on the object. "Apparent" weight changes if the object is accelerated. ● Weight is in Newtons and Mass is in Kg.
P.F.3: Elastic forces	The mathematical model for the force that a linearly elastic object exerts on another object is $F_{elastic} = -k\Delta x$ where Δx is the displacement from the original position. ● The direction of the elastic force is always directed opposite the displacement from equilibrium. ● The constant of proportionality, k ,is the same for compression and extension and depends on the "stiffness" of the elastic object.
P.F.4: Friction force	Kinetic frictional force ● The amount of kinetic frictional force between two objects depends on the Normal force between the two objects and the nature of the two materials. ● The mathematical relationship for finding kinetic frictional force is $F_k = u_k F_N$. Static frictional force ● Static forces between two objects can prevent from being able to slide past each other. ● The maximum static frictional force depends on the nature of the two objects and the magnitude of the Normal force. ○ This is taught conceptually. ● The objects will not slide past each other until the applied force surpasses this maximum static frictional force. ● When the object is in motion the static friction force is no longer present - the kinetic frictional force comes into play. Solve problems involving finding kinetic frictional force, objects moving at a constant velocity or accelerating (due to friction only or an additional force.) ● Kinematics equations will be used to determine stopping distances. ● Free body diagrams should be drawn and used in conjunction with problem solving.

P.F.5: Air resistance and drag	● When an object pushes on the particles in a fluid, the fluid particles can push back on the object according to Newton's third law and cause a change in motion of the object. ● Forces from fluids are quantified using Newton's second law and force diagrams.
P.F.6: Forces in two dimensions	Adding vector forces ● Forces can be broken into horizontal and vertical components using trigonometric functions. ● Vector addition can be done with trigonometry or scaled diagrams. Motion down inclines ● Net force, final velocity, time, displacement, and acceleration can be calculated. ○ Calculations involving parallel vs perpendicular forces ● Inclines are either frictionless or the force of friction will already be quantified. Circular motion and centripetal forces ● Objects moving at constant speeds along curves are accelerating due to continuous direction change. ● A net force directed towards the center of the curve (centripetal) is necessary to cause an object to move along a curved path. Without this force, the object would move on a straight line path. ● "Centripetal" describes the direction of net force needed for circular motion. It is not a type of force such as gravity or friction. ● Centripetal acceleration can be calculated by $a_c = v^2/r$ which can be used with Newton's 2nd law to determine net centripetal force.
P.F.7: Momentum, impulse and conservation of momentum	Momentum ● Momentum, p , is a vector quantity that is directly proportional to the mass, m, and the velocity, v, of the object. Conservation of momentum ● In a closed system,the total linear momentum is always conserved for elastic, inelastic, and totally elastic collisions in both the x-axes and y-axes. ● While total energy is always conserved in any collision, in a perfectly elastic collision, kinetic energy is specifically conserved. ● However, in an inelastic collision kinetic energy is not conserved.

	Impulse • Impulse , Δp, is the total momentum transfer into or out of a system. • The change in momentum is always precipitated by the application of an average external force acting on the system over a specific time period. • This is a restatement of Newton's second law and is typically written as Ft = mΔv.

ENERGY	
In Physical Science, the role of strong nuclear forces in radioactive decay, half-lives, fission and fusion, and mathematical problem solving involving kinetic energy, gravitational potential energy, energy conservation and work (when the force and displacement were in the same direction) were introduced. In this course, the concept of gravitational potential energy is understood from the perspective of a field, elastic potential energy is introduced and quantified, nuclear processes are explored further, and the concept of mass-energy equivalence is introduced. The concept of work is expanded, power is introduced and the principle of conservation of energy is applied to increasingly complex situations. Energy is explored by analyzing data gathered in scientific investigations. Computers and probes can be used to collect and analyze data.	
Content Statement	**Content Elaboration**
P.E.1: Gravitational potential energy	Gravitational potential energy exists between a system of attracting masses based on their masses and the distance between them. • Energy is transferred into the gravitational field as the masses are moved farther apart and out of the field as they are moved closer together. Solve problems that involve objects near the Earth's surface and those far away (like satellites).
P.E.2: Energy in springs	• The change in potential energy stored in a spring is related to the distance the spring (or elastic object) is stretched or compressed from its relaxed length. The formula for finding this is $\Delta Eelastic \;=\; 1/2\; k\Delta x^{\,2}$
P.E.3: Work and power	Work • Mechanical work can be calculated for situations where a net force displaces an object in the same plane of motion (x axis or y axis). • If the force is directed at an angle the component of the force in that dimension is used yielding the equation W = F$\Delta x\;(cos\;\theta)$. ○ Can also use d instead of x.

	◦ Less emphasis on angles and more on positive/negative work based on relative direction of force and displacement vectors. ◦ Force and motion in the same direction. • Work is a scalar quantity that can alter the energy in a closed system. ◦ Positive work will increase the energy in a system. ◦ Negative work will take energy out of a system. Power • The rate that work/energy change is called power (P) and can be calculated as $P = \Delta E/t$ or $P = W/\Delta t$. • Power is a scalar property. • The unit of power is the watt (J/s).
P.E.4: Conservation of energy	The principle of energy conservation • Total initial energy of a system + energy entering a system = final energy of the system + energy leaving the system. • System energy transformations can be represented with verbal or written descriptions, energy diagrams and mathematical equations or a combination of these. Solve problems using the principle of energy conservation - these should require the use of free body diagrams and Newton's Laws. • Friction should be included. • Draw diagrams or graphs to represent energy flow into or out of the system.

ELECTRICITY AND MAGNETISM	
In earlier grades, electric and magnetic potential energy were treated conceptually. The relative number of subatomic particles present in charged and neutral objects, attraction and repulsion between electric charges and attraction and repulsion between magnetic poles were explored. The concept of fields to conceptually explain forces at a distance was introduced and the concepts of current, potential difference (voltage) and resistance were used to explain circuits. Additionally, connections between electricity and magnetism were made as observed in electromagnets, motors and generators. In this course, the details of electrical and magnetic forces and energy are further explored and can be used as additional examples of energy and forces affecting motion.	
Content Statement	**Content Elaboration**

P.EM.1: Charging objects	For all methods of charging, charge is conserved and the overall net charge between objects doesn't change. ● Charging by friction involves rubbing two neutral objects, causing electrons to transfer from one to the other. ● Charging by contact involves bringing a charged object into contact with a neutral object causing electrons to evenly distribute between the two objects. ● Charging by induction involves bringing a charged object near a neutral object and then grounding the neutral object. ● Charge separation can occur in conductors and insulators. ○ In conductors, free electrons are attracted toward or repelled away from a charged object. ○ In insulators, the electron cloud of each atom shifts slightly.
P.EM.2: Coulomb's law	Two charged objects can be modeled as point charges. ● The forces between point charges are proportional to the product of the charges and inversely proportional to the square of the distance between the point charges [$F = k_e q_1 q_2/r^2$]. ● The Coulombic forces can also be seen as forces that super impose themselves on a chosen particle where the net force can be calculated as a vectorial sum.
P.EM.3: Electric fields and electric potential energy	The strength of a charged object at a certain location is given by the force per unit charge experienced by another small, charged object. ● Creating electric field diagrams allows for a qualitative understanding of electric field strength. ● The electric field exists around a charged object even if a small charged object is not present. A single charged particle produces an electric field, regardless of the mass of the particle, following the inertia principle. ● The direction of the electric field is the direction a small positive charge would move. **Note:** $E = F_e/q$ is a more advanced calculation than needed for this course.
P.EM.4: DC circuits	Circuits ● Once a circuit is connected, current (I) flows instantaneously in all parts of the circuit with electrons moving at just a few centimeters per second. ● The electric field travels instantaneously through the circuit moving the electrons already present in the wire. ● Potential difference or voltage (ΔV) across an energy source is the potential energy

	difference (ΔE) supplied by the energy source per unit charge (q).
	
	Ohm's law
	• Resistance is the ratio of potential difference to current. $R = \Delta V/I$
	• Resistance is measured in Ohms and impacts the current caused by a certain voltage.
	• Resistance is constant when temperature is constant.
	  ○ An Ohmic resistor is one that has constant resistance.
	
	Series, parallel, and mixed circuits
	• Resistances have different cumulative effects when added in series and parallel.
	
	Applying conservation of charge and energy (junction and loop rules)
	• Both energy and charge are conserved in circuits.
	  ○ Potential difference around any loop of resistors in a circuit must add to the potential difference supplied by the energy source.
	  ○ Current flowing into any junction must equal the current flowing out of any junction.
	• The rate of energy transfer (power) for any circuit element is equal to the product of current through and potential difference across that element.

P.EM.5: Magnetic fields	The direction of the magnetic field at any point in space is the equilibrium direction of the north end of a compass placed at that point. • Magnetic Fields can be represented by field diagrams obtained by plotting field arrows at a series of locations. • Greater magnetic fields result in larger magnetic forces on magnetic objects or moving charges placed in the field. **Note:** This topic will not be treated mathematically in this course.
P.EM.6: Electromagnetic interactions	A moving charged particle interacts with a magnetic field. • The magnetic force that acts on a moving charged particle in a magnetic field is perpendicular to both the magnetic field and to the direction of motion for that particle. • There is no force applied to a particle that moves parallel to a magnetic field. • There is no force applied to an uncharged particle moving in a magnetic field. • **Note:** Calculations of the magnetic field are not required at this grade level.

	A changing magnetic field creates an electric field. ● If the path is closed, such as in a wire, a current may flow and create amperage. ○ This is the theory behind which electric motors operate. The interaction between electricity and magnetism should be explored in a laboratory setting (inner workings of motors, generators and electromagnets).

WAVES	
In earlier grades, the electromagnetic spectrum and basic properties (wavelength, frequency, amplitude) and behaviors of waves (absorption, reflection, transmission, refraction, interference, diffraction) were introduced. In this course, conservation of energy is applied to waves and the measurable properties of waves (wavelength, frequency, amplitude) are used to mathematically describe the behavior of waves (index of refraction, law of reflection, single- and double-slit diffraction). The wavelet model of wave propagation and interactions is not addressed in this course. Waves are explored experimentally in the laboratory. This may include, but is not limited to, water waves, waves in springs, the interaction of light with mirrors, lenses, barriers with one or two slits and diffraction gratings.	
Content Statement	**Content Elaboration**
P.W.1: Wave properties	Wave properties can be explored with springs, water, interaction of light with mirrors, lenses, barriers with one or two slits and diffraction gratings. Conservation of energy ● When a wave strikes a new medium or barrier, a part of the wave's energy is reflected and a portion is passed into the new medium (refracted). ○ When a wave approaches a barrier, the angle of incidence = the angle of reflection. ● Some of this transferred energy can be converted into thermal energy. The speed and wavelength of waves change as the wave travels from one medium into another (including 2D waves (surface water, seismic waves) or 3D waves (sound, electromagnetic waves). ● Depending on the angle of incidence, the direction of the wave in the new medium will change (refraction). Waves encountering slits or diffraction gratings ● The amount of bending around a barrier or small opening increases with decreasing

	wavelength (diffraction).
	• As light passes through single and double slits diffraction patterns are created (areas of constructive and destructive interference).
	  ○ These patterns are related to width of slits, spacing between the slits, and wavelength of the light.
	  ○ Standing waves and interference patterns between two sources are included.

P.W.2: Light phenomena	Ray diagrams (propagation of light)
	• Investigate the image formed by a lens by experimentally determining the focal length.
	• Draw ray diagrams for light refracting through thin lenses to determine the location of a formed image.
	• Draw ray diagrams for light reflecting off of plane, concave, and convex mirrors to determine the location of a formed image.
	• Compare images for converging vs diverging lenses.
	
	Law of reflection (equal angles)
	• Since light is a wave that sometimes behaves as a particle, the law of reflection applies.
	• The angle of incidence as measured normal (perpendicular) to a surface will equal the angle of reflection (also measured normal to a surface).
	
	Snell's law
	• As light enters a different medium, it will refract towards the normal or away from the normal depending on the density of the medium.
	  ○ This value *n* is called the index of refraction and is a ratio between the constant velocity of light (*c*) and the current velocity of the light ray (*v*).
	• Snell's law quantifies the refraction experience entering and leaving mediums with the equation $n_1 \sin\theta = n_2 \sin\theta$.
	
	Diffraction patterns
	• The amount of bending around a barrier or small opening increases with decreasing wavelength (diffraction).
	• As light passes through single and double slits diffraction patterns are created (areas of constructive and destructive interference).
	  ○ These patterns are related to width of slits, spacing between the slits, and wavelength of the light.

	Wave-particle duality of light ● Young's Law discusses the idea that light will behave as a particle (momentum) and as a wave (pure energy). There are multiple examples of each category. Visible spectrum of color ● Humans can only perceive the visible portion of the electromagnetic spectrum. Different colors correspond to radiant energies. ● When white light strikes an object the pigments in the object reflect one or more colors and absorb the other colors.