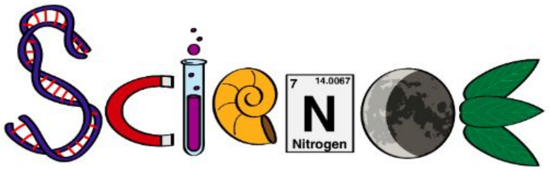

## K-12 SCIENCE EDUCATION VISION

A K-12 Dublin City Schools science education engages *all students* in critical thinking and problem solving as they experience science and engineering. We believe that students can become scientifically literate citizens equipped with the knowledge and skills demanded by the ever-changing future, whether in the workforce or higher education.

We believe in developing our learners through high quality experiences that include:

- A challenging, collaborative and inquiry based environment.
- Opportunities to solve and investigate real-world problems that require critical and global thinking.
- Opportunities for students to build an identity as a scientist, able to interpret the natural world, participate productively in scientific practices and contribute to society in meaningful ways.
- Opportunities to research, generate and evaluate evidence and explanations that uphold or refute scientific data.

We believe these learning experiences will grow independent, confident students who will become creative, innovative adults that are capable of using informed scientific judgement to improve their world.

## Instructional Agreements for Science Learning within the Dublin City Schools

1. Learning goals will be communicated to guide students through the expectations of science learning using a variety of instructional techniques and technology integration.
2. Teachers will ensure a safe, challenging learning environment focused on inquiry and science exploration.
3. Teachers will provide support to students as they learn to frame questions, assess and analyze data, and create and critique explanations – all important components of scientific and engineering practices.
4. Content standards will be learned in partnership with Ohio’s Cognitive Demands for Science, Science and Engineering Practices and Nature of Science practices.

| Nature of Science | |
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| 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 | |
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| **Cognitive Demand** | **Description** |
| **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. |

# PHYSICS

## Physics

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.

<table>
<tr><th colspan="2">MOTION</th></tr>
<tr><td colspan="2">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.</td></tr>
<tr><th>Content Statement</th><th>Content Elaboration</th></tr>
<tr><td><b>P.M.1: Motion graphs</b><br>• Position vs. time<br>• Velocity vs. time<br>• Acceleration vs. time</td><td>● Average velocity is determined as the linear slope of a position time graph for an object that is not accelerating.<br>● Instantaneous velocity is determined by calculating the slope of the tangent line formed from a position time graph at a specific time denotation.<br>● 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.<br>● 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.<br>● 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.</td></tr>
<tr><td><b>P.M.2: Problem Solving</b></td><td>● Problems can be solved with graphs</td></tr>
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| • Using graphs (average velocity, instantaneous velocity, acceleration, displacement, change in velocity)<br>• Uniform acceleration including free fall (initial velocity, final velocity, time, displacement, acceleration, average velocity) | ○ Displacement = area under velocity graph curve<br>○ Acceleration = slope of velocity graph<br>● When acceleration is constant, kinematics equations can be used.<br>● Problems involving freefall (objects only influenced by Earth's gravity) should be included. |
| **P.M.3: Projectile Motion**<br>• Independence of horizontal and vertical motion<br>• Problem-solving involving horizontally launched projectiles | ● Objects have both horizontal and vertical components that act independent of each other<br>● The horizontal velocity does not change if air resistance is not considered<br>● The vertical component is controlled by the acceleration due to Earth's gravity<br>● Problem solving shall be limited to finding range, time in the air, initial height, initial velocity, final velocity of horizontally launched projectiles only. |

## 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 |
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| **P.F.1: Newton's laws applied to complex problems** | ● Objects experiencing balanced forces ($F_{net} = 0$) have a constant velocity.<br>● Objects experiencing unbalanced forces will accelerate.<br>● The acceleration of an object is determined by $\mathbf{a = F_{net} / m}$.<br>● Interacting objects exert forces on each other that are equal in strength and opposite in direction.<br>● The laws of motion can be used to solve problems involving single objects and systems |

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| | of objects.<br>● Problem solving should include forces that must be quantified (e.g. gravitational, friction, elastic). |
| **P.F.2: Gravitational force and fields** | ● Gravitational interactions are weak and are difficult to observe unless one object is massive.<br>● The attractive force between objects can be found with $F_G = m_1\ m_2/r^2$<br>● Calculate the Fnet on an object placed between two massive objects.<br>● Calculate the position of an object between two larger objects of the Fnet on the object is known.<br>● Gravitational field strength, “g”, 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.<br>● A person’s “apparent” weight is the Normal Force on the object. “Apparent” weight changes if the object is accelerated. |
| **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 $\Delta x$ is the displacement from the original position.<br>● The direction of the elastic force is always directed away from the applied force in an opposite yet equal magnitude.<br>● 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** (static and kinetic) | ● 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.<br>● The mathematical relationship for finding kinetic frictional force is $F_k = u_k\ F_N$.<br>● Static forces between two objects can prevent form being able to slide past each other.<br>● The maximum static frictional force depends on the nature of the two objects and the magnitude of the Normal force. $Fs <= u_sF_N$<br>● The objects will not slide past each other until the applied force surpasses this maximum static frictional force.<br>● When the object is in motion the static friction force is no longer present - the kinetic frictional force comes into play.<br>● Solve problems involving/finding kinetic frictional force, objects moving at a constant velocity or accelerating (due to friction only or an additional force.)<br>● Kinematics equations will be used to determine stopping distances.<br>● Free body diagrams should be drawn and used in conjunction with problem solving. |

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| **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.<br>● Forces from fluids are quantified using Newton's second law and force diagrams. |
| **P.F.6: Forces in two dimensions**<br>• Adding vector forces<br>• Motion down inclines<br>• Centripetal forces and circular motion | ● Forces can be broken into horizontal and vertical components using sine and cosine.<br>● Vector addition can be done with trigonometry or scaled diagrams<br>● Motion down inclines<br>○ Net force, final velocity, time, displacement, and acceleration can be calculated.<br>○ Inclines are either frictionless or the force of friction will already be quantified.<br>● Circular motion and centripetal forces<br>○ Objects moving at constant speeds along curves are accelerating due to continuous direction change.<br>○ 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.<br>○ "Centripetal" describes the direction of net force needed for circular motion. It is not a type of force such as gravity or friction.<br>○ 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, $p$, is a vector quantity that is directly proportional to the mass, m, and the velocity, v, of the object.<br>● 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.<br>● 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.<br>● Impulse , $\Delta p$, 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 $Ft = m\Delta v$. |

## 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 |
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| **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.<br>● 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..<br>● 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** | ● 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 $\Delta x\, (cos\, \theta)$ .<br>● Work is a scalar quantity that can alter the energy in a closed system. Positive work will increase the energy in a system and negative work will take energy out of a system.<br>● 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** | ● Total initial energy of a system + energy entering a system = final energy of the system + energy leaving the system.<br>● System energy transformations can be represented with verbal or written descriptions, energy diagrams and mathematical equations or a combination of these.<br>● 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 |

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| | diagrams or graphs to represent energy flow into or out of the system. |

| **ELECTRICITY AND MAGNETISM** | |
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| 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** (friction, contact and induction) | ● For all methods of charging, charge is conserved and the overall net charge between objects doesn't change.<br>● Charging by friction involves rubbing two neutral objects, causing electrons to transfer from one to the other.<br>● Charging by contact involves bringing a charged object into contact with a neutral object causing electrons to evenly distribute between the two objects.<br>● Charging by induction involves bringing a charged object near a neutral object and then grounding the neutral object.<br>● 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 [ $F = k_e q_1 q_2/r^2$] .<br>● 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. E = Fe/q.<br>● The electric field exists around a charged object even if a small charged object is not present.<br>● The direction of the electric field is the direction a small positive charge would move. |

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| | Electric field line diagrams do not need to be included. |
| **P.EM.4: DC circuits**<br>• Ohm's law<br>• Series circuits<br>• Parallel circuits<br>• Mixed circuits<br>• Applying conservation of charge and energy (junction and loop rules) | ● 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.<br>● Potential difference or voltage (ΔV) across an energy source is the potential energy difference (ΔE) supplied by the energy source per unit charge (q) ($\Delta V = \Delta E/q$).<br>● Resistance is measured in Ohms and impacts the current caused by a certain voltage. Resistances have different cumulative effects when added in series and parallel.<br>● Resistance is the ratio of potential difference to current. $R = \Delta V/I$<br>● Resistance is constant when temperature is constant. An Ohmic resistor is one that has constant resistance.<br>● Both energy and charge are conserved in circuits.<br>○ Potential difference around any loop of resistors in a circuit must add to the potential difference supplied by the energy source.<br>○ Current flowing into any junction must equal the current flowing out of any junction.<br>● 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.<br>● Magnetic Fields can be represented by field diagrams obtained by plotting field arrows at a series of locations.<br>● 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.<br>● There is no force applied to a particle that moves parallel to a magnetic field. Calculations of the magnetic field are not required at this grade level.<br>● 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<br>● The interaction between electricity and magnetism should be explored in a laboratory setting (inner workings of motors, generators and electromagnets ). |

<table>
<tr><th colspan="2">WAVES</th></tr>
<tr><td colspan="2">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.</td></tr>
<tr><td><b>Content Statement</b></td><td><b>Content Elaboration</b></td></tr>
<tr><td><b>P.W.1: Wave properties</b><br>• Conservation of energy<br>• Reflection<br>• Refraction<br>• Interference<br>• Diffraction</td><td>● Wave properties can be explored with springs, water, interaction of light with mirrors, lenses, barriers with one or two slits and diffraction gratings.<br>● 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). Some of this transferred energy can be converted into thermal energy.<br>● Reflection - when a wave approaches a barrier the angle of incidence = the angle of reflection.<br>● Speed and wavelength of wave 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).<br>● The amount of bending around a barrier or small opening increases with decreasing wavelength (diffraction).<br>● Standing waves and interference patterns between two sources are included.<br>● 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.</td></tr>
<tr><td><b>P.W.2: Light phenomena</b><br>• Ray diagrams (propagation of light)<br>• Law of reflection (equal angles)<br>• Snell's law<br>• Diffraction patterns<br>• Wave—particle duality of light<br>• Visible spectrum of color</td><td>● Investigate the image formed by a lens by experimentally determining the focal length<br>● Draw ray diagrams for light refracting through thin lenses to determine the location of a formed image.<br>● Draw ray diagrams for light reflecting off of plane, concave, and convex mirrors to determine the location of a formed image.<br>● Compare images for converging vs diverging lenses.<br>● Since light is a wave that sometimes behaves as a particle, the law of reflection applies.<br>● The angle of incidence as measured normal (perpendicular) to a surface will equal the</td></tr>
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| | angle of refraction ( also measured normal to a surface ).<br>● 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*).<br>● Snell's law quantifies the refraction experience entering and leaving mediums with the equation $n_1\sin\theta=n_2\sin\theta$.<br>● The amount of bending around a barrier or small opening increases with decreasing wavelength (diffraction).<br>● 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.<br>● 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.<br>● Humans can only perceive the visible portion of the electromagnetic spectrum. Different colors correspond to radiant energies.<br>● When white light strikes an object the pigments in the object reflect one or more colors and absorb the other colors. |